AVIATION IN THE XXI-ST CENTURY

INTERNATIONAL CIVIL AVIATION ORGANIZATION
NATIONAL ACADEMY OF SCIENCES OF UKRAINE
MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY

PROCEEDINGS

THE SIXTH WORLD CONGRESS "AVIATION IN THE XXI-st CENTURY"

"Safety in Aviation and Space Technologies"

Volume 1

September 23-25, 2014
Kyiv, Ukraine

INTERNATIONAL CIVIL AVIATION ORGANIZATION
NATIONAL ACADEMY OF SCIENCES OF UKRAINE
MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY

PROCEEDINGS

THE SIXTH WORLD CONGRESS
"AVIATION IN THE XXI-st CENTURY"

"Safety in Aviation
and Space Technologies"

September 23-25, 2014

Volume 1

KYIV 2014

COFOUNDER

- ✈ National Aviation Academy State "Azerbaijan Hava Yollari" Closed Join-Stock Company, Azerbaijan
- ✈ Georgian Aviation University, Georgia
- ✈ JSC "Civil Aviation Academy", Kazakhstan
- ✈ Nanchang Hangkong University, China
- ✈ Vilnius Gediminas Technical University, Lithuania
- ✈ The State School of Higher Education in Chelm, Poland
- ✈ The International University of Logistics and Transport in Wroclaw, Poland
- ✈ Polish – Ukrainian Research Institute, Poland-Ukraine

SYMPOSIA

Volume 1

SYMPOSIUM 1. MODERN SPACE AND AVIATION TECHNOLOGIES
1.1. Latest technologies for maintaining aircraft airworthiness
1.2. Aerodynamics and flight safety
1.3. Fatigue and fracture of aircraft structures
1.4. Problems of recovery controllability of the aircrafts
1.5. Engines and Power Installations
1.6. Latest technologies for maintaining aircraft airworthiness
1.7. Methods and tools for technical and medical diagnostics
1.8. Automated process control systems
1.9. Specialized Computer Systems and CALS – Technology in Aviation
1.10. The intellectual robot-technical measuring complexes and systems
1.11. Information security in aviation
1.12. Computer systems
1.13. Advanced information technologies in aviation
1.14. Mathematical modeling and numerical methods

Volume 2

SYMPOSIUM 2. UNMANNED AIRCRAFT SYSTEMS (UAS)

SYMPOSIUM 3. AIR NAVIGATION AND ATM SYSTEMS
3.1 Air traffic management
3.2 Communication, navigation, surveillance
3.3 Aviation English and safety of flight
3.4 Avionics
3.5 Complex systems control

SYMPOSIUM 5. ENVIRONMENT PROTECTION
5.1. Chemical technology and engineering
5.2. Environmental protection
5.3. Land management, cadastre and land monitoring
5.4. Biotechnology in aviation

SYMPOSIUM 6. AVIATION CHEMMOTOLOGY

SYMPOSIUM 7. COMMUNICATION FACTOR IN MODERN INTERNATIONAL RELATIONS
7.1. Information and legal principles of international relations
7.2. The transformation of journalism in the context of technologizing the world and the processes of globalization
7.3. The international scientific and technical cooperation of Ukraine in aerospace industry

Volume 3

SYMPOSIUM 8. ECONOMY AND MANAGEMENT IN AVIATION

SYMPOSIUM 9. HUMAN FACTOR IN AVIATION
9.1. Language modelling of aviation information systems
9.2. Social, political, moral and psychological components of aviation safety
9.3. Psychology of aircraft safe operation and modern ergatic systems

SYMPOSIUM 10. SPATIAL ORGANIZATION OF AIR COMPLEXES

SYMPOSIUM 11. AIR AND SPACE LAW: INTERNATIONAL AND NATIONAL ISSUES OF SECURITY

SYMPOSIUM 12. INNOVATIVE TECHNOLOGY OF PROFESSIONAL TRAINING ON THE BASIS OF HIGHER EDUCATION

13. ROUND TABLE DISCUSSION "ICAO: Aviation Safety Challenges"

CONTENTS

1.10. The intellectual robot-technical measuring complexes and systems

UDC 620. 178. 16 (045)

V. Marchuk, Ph.D., Associate Professor (NAU, Kiev)

SYSTEM ANALYSIS OF DISCRETE-ORIENTED STRUCTURE SURFACE PROPERTIES

In the result of research is complex study of the properties and characteristics of the discrete oriented structure surfaces in the form of recesses formed mechanically. It is shown that the combination of friction and wear processes research in different scientific and technological areas such as mathematical statics, contact mechanics, physics of surfaces, magnetic phenomena, fluid dynamics have allowed deeper explain the processes that occur at discrete surfaces contacting parts.

Today, systems analysis serves as one of the main factors solutions to global problems in various industries, involving the efforts of many specialists from different research areas. Introduction of friction units of machines and mechanisms as the system allows to organize the results of physico-mechanical and tribological studies for different friction and wear, which more fully into account all the properties of elements and nodes of all the relationships between the properties of these elements.

In recent years, the study of friction and wear is in order to fully take into account various factors that can influence this process. This is especially important for the development of the theoretical foundations of tribology, because it combines the various scientific and technical disciplines. We know that friction is considered as elastic-oscillatory process heat generation in the surface layer and the formation of secondary structures [1, 2]. Along with the generation of heat by friction, there are other energy conversion, including the case of excitation of electric and magnetic fields, creating termostrums, trybochemicals reactions and so on. Moreover, most friction units of machines and mechanisms operating under lubrication of contacting surfaces. The mechanism of wear in such a complex and different for most of the friction units.

The special interest is the application of a systematic approach for the study of surfaces with discrete-oriented structure. Discrete surface (in foreign literature they are called textured surface, spotty coverage) as a means of improving the tribological characteristics of machine parts and assemblies, having many years ago, but widespread over the last decade as the most promising area of sustainable engineering surfaces [3-5]. The introduction of this technology is to expand the range of parts in extreme conditions (for allowable load, wear, friction, physical, mechanical, magnetic, electrical, hydrodynamic properties, etc.).

The basis of the system approach studies the properties of surfaces with discrete-oriented structure is a hierarchical structure of methodological levels of analysis: problem-conceptual, operational and detailed. At the level of problem-conceptual analysis determined purpose of the study and the main problem to solve, analyzes system environment is allocated and justified the selection process that creates the basis for operational analysis. At the operational level determined by physical, mechanical and tribotechnical indicators is the best choice of fitness regimes for making structural and functional basis of systematic research process at a detailed level and the development of its mathematical models. At the detailed level research formed a basis of operations choosing optimal design solutions, study and evaluation of the optimal process parameters that will solve the problem.

Systematic and comprehensive research-oriented discrete surface structure in the form of holes with a given texture [3, 6] can logically organize complex processes of research on common methodological information base system approach, which is based on known principles of commitment, modeling , physicality, which defines the procedures for systematic studies.

To determine the optimal parameters of the process forming holes textured surfaces commonly used method for multivariate experimental design and mathematical processing of statistical data that can provide technological process in the form of functional dependence of input and output parameters. That technology of hole surfaces are considered as a way to control the properties of the surface layer. When conducting complex investigations related to the experimental determination of the main characteristics tribotechnical details of hole surfaces, the problem of optimization of the process of forming multiparameter seen as taking into account the design, technological and operational factors. Objective and complete assessment of the working conditions of parts assemblies and mechanisms for different types of friction and wear allowed to choose certain criteria optimization of the process of formation of hole surfaces (technological residual stresses, the intensity of wear, friction, temperature trybocontacts etc.). When choosing a managed factors used by expert assessments on which defined the group of factors that affect the value of optimization criteria and the level of variation.

Numerical simulation of the stress-strain state in discrete areas of finite element analysis allowed to establish and reveal patterns and mechanisms of phenomena and processes occurring in thin surface layers, using and combining science and knowledge of physics of deformable solids, hydrodynamics, materials engineering, electromagnetic fields and others. Yes simulation of temperature and power load by finite element analysis in fretting revealed a picture of the distribution of the stress-strain state and temperature textured surface hole. Major tensions arise between holes space allocated in the form of islands. Due to the lack of high residual stresses this type of surface modification in the form of holes has advantages in comparison with coatings, which are characterized by different coefficients of thermal expansion of the material base and cover. This is supported by studies of the temperature distribution on the surface trybocontacts. No significant temperature drop in between holes space in the hole and on the surface of the base material reduces the thermal stress (Fig. 1). Taken together, these processes provide high tribotechnical characteristics hole textured surface [7].

In discrete areas in the form of depressions or holes formed complex fluid motion, depending on the mode of flow and geometric parameters of the surface. Circulating fluid motion generates both large-and small-scale vortex structures, whose number increases with increasing flow velocity. Vortex structure periodically may occupy the entire volume of discrete areas, and then, under appropriate conditions, are thrown into the stream, acting as a "vortex bearings" to prevent the destruction of the points of contact surfaces under extreme operating conditions [8].

High-durability textured surface holes caused by high capacity wells to prevent the occurrence of unacceptable damage to the surface layer processes in the space between the holes in areas of actual contact by the ability to attract paramagnetic particle degradation and lubricant products ferromagnetic wear particles. Products will concentrate wear (contact) initially with great performances on the surface (hole edges), which are the largest hub of magnetic field lines, compared to the surface roughness in the space between the holes (Fig. 2). Each share of food deterioration in the magnetic field is directed to the top edge of the hole bigger axle. Depending on the load of the friction pair, sliding speed and other factors is wearing hole edges and vertices blunt peaks of wear particles and their shift so that the newly created most major axis directed along the magnetic field lines. That is mechanical wear (smoothing) Career edges of holes and particles of food deterioration in the submicroscopic level. At the edges of the holes wear magnetic field lines are reduced to the value of the magnetic field in the space between the hole and the further deterioration of products withdrawn from the hole. These processes can eliminate the likelihood of friction in the area of critical loads and temperatures and prevent the occurrence of unacceptable damage to the processes of the surface layer in the space between the holes in areas of actual contact and improve technical characteristics of friction pairs [9].

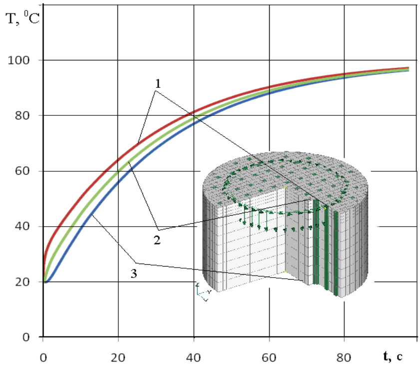


Fig. 1. Temperature distribution on the surface of the sample discrete function of time: 1 - change the temperature on the surface between holes 2 - change of temperature in the hole 3 - change in temperature at the base of the sample

Significant contribution to improving tribotechnical properties of friction pairs provide lubricants. The hole will be stored lubricants that provide continuous regeneration of lubricant film in trybocontacts places. The effectiveness of the protective film of lubricant for couples with surfaces approximate discrete structures confirmed by the lowest coefficient of friction between working and stability period after working that lets you manage processes in fretting by choosing the optimal discrete surface texture, leading to a decrease in the coefficient of friction by 57-62% compared with the original surface without holes [7].

Forming holes textured surface reduces the endurance limit of specimens of steel 30KhGSA in a "pure" fatigue at ~ 1.84 times in comparison with the starting material without holes. At the same time, in fretting fatigue is reduced slightly - 1.17 times. Fraktohrafics research breaks surfaces of samples with holes revealed that in the origin of fretting fatigue cracks occurs in one, two or three cells on the surface of a dangerous intersection and is not connected with a hole. Only one case of fatigue cracks initiated on the contours of holes, as in this case, edge support contrbody coincided with the line placement holes (Fig. 3). It also shows that the stress-strain state in the area of fretting determines the durability of steel in fretting fatigue and stress concentration and residual stress in the holes affect the ultimate state of the material in these conditions. Significant positive effect on the fatigue resistance characteristics provides ion nitriding surface samples from holes. During tests on fretting fatigue of three samples of the party none of them destroyed by fretting. That was the destruction of the "pure" fatigue in the area of maximum stress location through holes.

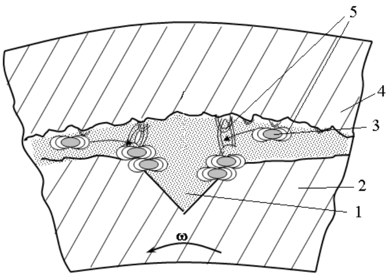


Fig. 2. Physical model wear a separate discrete areas under marginal lubrication: 1 – hole, 2 – contrbody, 3 - wear products, 4 – sample, 5 - magnetic fields

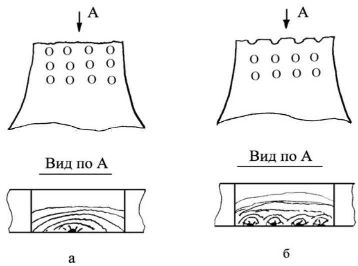


Fig. 3. Scheme and fracture surface of samples with holes destroyed by fretting fatigue: a - the destruction outside holes, b - destruction by hole

Textured surface holes provide a reduction in abrasive wear of the surface layer of steel 30KhGSA to 37-38% due to acquisitions (removal) of abrasive particles and product deterioration of surface friction in the hole. The destruction of the surface layers of abrasive particles due to their frequent exposure and accumulation of damage in the surface layers and inner sides trybocontacts holes. The biggest wear surface is exposed to a distant hole relative to the direction of motion of abrasive particles. Countering the introduction of abrasive particles in the far surface will determine the level of abrasive wear of discrete sites and hole surface as a whole [10].

Conclusions. A complex approach to scientific research of discrete-oriented structure surfaces has allowed to discover and analyze the complicated processes that occur in thin surface layers. High tribotechnical characteristics of discrete surfaces with recesses for different friction and wear conditions are connected with the fact that the recesses are reservoirs for getting of wear products, which provide stimulation of tribotechnical processes by continuously removing them from the surface friction. Furthermore recesses are the reservoirs for holding lubricant materials that is used to regenerate lubricant layer in case of it absence between contacting surfaces. High-durability textured surface recesses is also associated with the magnetic field, which occurs at the edges of discrete areas, and their ability to exclude paramagnetic particles (products of degradation of lubricants) and ferromagnetic particles (products of wear).

References

1. Lubrication, friction, and wear. National aeronautics and space administration. – Langley, 1971.

2. Dmitriyev S., Koudrin A., Labunets A., Kindrachuk M. Functional coatings application for strengthening and restoration of aviation / /Aviation, Vol IX, No 4, 2005, 39-45.

3. Saka N., Tian H., Suh N. P. Boundary lubrication of undulated metal surface at elevated temperatures // Tribology Transactions. – 1989. – N32. – P. 385-389.

4. Suh N.P., Mosleh M., Howard P.S. Control of friction. // Wear. – 1994. – 175. – P. 151-158.

5. Wang X., Kato K. Improving The anti-seizure ability of SiC seal in water with RIE texturing //Tribology Letters. – 2003. – N14. – P. 275-280.

6. Чихос Х. Системный анализ в трибонике / Х. Чихос. – М.: Мир, 1982. – 352 с.

7. Цыбанев Г. В., Марчук В. Е., Калиниченко В. И. Управление свойствами поверхностей трения при приработке дискретных покрытий в условиях фреттинга // Проблемы трибологии. – 2011. - №1. – С. 52–57.

8. Цибаньов Г. В., Марчук В. Є., Кураш Ю. П., Градиський Ю. О. Вихрові потоки рідини у дискретних ділянках трибо сполучень // Вісник Харківського НТУСГ ім. Петра Василенка. – Вип. 109. /Проблеми технічної експлуатації машин. – Х: «Апостроф», 2011. – С. 55–64.

9. Марчук В.Є., Морозов В.І., Духота О.І., Морозова І.В. Процеси тертя та зношування у трибосистемах з дискретно-орієнтованою структурою. Повідомлення 1. Магнітні явища при терті поверхонь з дискретно-орієнтованою структурою // Проблеми трибології. – 2012. - №4. – С. 53–57.

10. Марчук В. Є. Механізм зношування дискретних поверхонь в умовах абразивного зношування // Проблеми тертя та зношування: наук.-техн. зб. – К.: Вид-во нац. авіац. ун-ту “НАУ-друк”, 2010. – Вип. 52. – С. 112–119.

UDC 620:619.1

O.V.Bashta, PhD. (NAU, Kyiv)

FACTORS OF CRACK INITIATION AND MICROCRACK PROPAGATION IN ALUMINUM

Effects of microstructure and grain size on fatigue behaviors such as fatigue strength, crack initiation and propagation behaviors were discussed. Data about lengths of microcracks (MC) which appear during a loading before revealing of a macrocrack, growth rates of cracks and a kinetics of growth MC are obtained.

Essence of a problem. Accumulation and association of dissipated short cracks concerns one of leading mechanisms of damageability and realisation of a limiting condition of it designs, it is necessary to consider at forecasting of their resource.

For metals micron-sized microcracks formation and coalescence occur in the plastic zone as a result of dislocation-activity and stress concentration.

To understand such fracture behaviors, it is necessary to establish a method to detect microcracks which are undetectable by the existing technologies. Microscopically, fracture can be classified into shear and tensile separation. When a macrocrack propagates, microcracks coalesce three-dimensionally in front of the macrocrack, and fracture resistance (toughness) varies depending on whether the coalescence process is of shear type or tensile type. In e□ect, it is necessary to classify both microscopic and macroscopic fractures into shear and tensile types, and the formation speed of microcracks can serve as an evaluation parameter of ductility and brittleness.

For macroscopic understanding of fractures, it is necessary to define the propagation of the main crack associated with the material structure. As the main crack often propagates non-uniformly, it is necessary to define the length corresponding to the non-uniform propagation of the crack.

It is known, that process of fatigue of metals is localised in a blanket [1]. With increase in quantity of cycles in all materials the characteristic strip structure - strips of the steady localised shift develops. The substructure in sliding strips can be different depending on material type. Borders of strips and especially their joints often become places of fatigue cracks origin. Transformations in dislocation arrangement which are realised in the course of fatigue tests, have character of "phase transition" in a defective subsystem and occur, as a rule, at achievement of certain ("critical") density of dispositions.

Thus microcracks in plastic materials arise in steady strips of sliding. Therefore the surface is a data carrier about dynamics of exhaustion of carrying ability of constructional elements. Estimation of the blanket condition is considered as a way of fatigue damage diagnostics.

One of fundamental features of multiple destruction of materials is the multystage. Each stage of the destruction process is characterised by separate dimensional level. At each stage there is an origin and growth of the dispersed defects (cracks, pores). Thus transition from a stage of destruction with lower dimensional level of damages on following on which damages have the big sizes, occurs by accumulation of defects in limiting concentration. Such scheme of destruction is inherent practically in all constructional materials and arises at various kinds of power interaction [2].

Stages of damageability at fatigue failure can be write down, as [1-3].: the Stage 1 - accumulation of separate micropores and microcracks statically distributed in volume of metal; stage 2 - development of cracks on borders of grains, twinnings and sliding strips; stage 3 - development of the main crack in a material, with existing system of microcracks.

One of displays of the machine details damage at a cyclic loading is presence of disseminated on the limited surface area the short cracks. Destruction of materials, is caused by the continuous in time processes of cracks origin, growth and association, it is considered universal [4], is called as plural and is characteristic for many damaging factors, for example, for fatigue [5-7], cyclic creep and corrosion.

The quantity of experimental data on plural destruction is very limited. It is connected with labour of input identification and complexity of supervision at the behaviour of a considerable quantity of small defects on a surface of samples.

At presence on the limited area of a surface or in material volume even a small amount of microcracks (MC) which sizes is in an interval 0,1... 10^3 the micron [1-7], always exists final probability of their association. Association of MC carries danger of sudden occurrence of macroscopical defect. Therefore the initial estimation of a limiting condition at a stage of development MC should be made taking into account the factor of association of dissipated defects.

Technique and essence of experiment. Nondestructive evaluation comprises the steps of (1) detecting the presence of defects in materials, (2) locating the position, (3) classifying the type, (4) determining the size and shape of each defect, (5) clarifying the mode of cracking and other characteristics, (6) determining the mode of fracture by considering external load and environmental conditions, and judging the degree of the severity of the defects by using an analysis based on fracture mechanics, (7) making an ultimate judgment on acceptability or, in other words, implementing material screening, and then, (8) for materials that have proved acceptable, evaluating its safety factor and service life. Here, the steps (1) to (5) for detecting defects are in the category of nondestructive test and inspection, while nondestructive evaluation includes the steps (6) to (8) as well. In applying such nondestructive evaluation, therefore, it is necessary not only to enhance the accuracy of nondestructive inspection techniques for detecting defects but also to consider (1) undetectable defects, (2) correspondence between the size of the detected defects and the size of defects leading to fracture, (3) fracture models (representing formation, growth and coalescence processes of micro defects).

The detection of microcracks is indispensable to non-destructive evaluation. Although various microcrack-detection methods, including X-ray, ultrasonic, microfocus X-ray based on electromagnetic equipments, high-frequency ultrasonic and ultrasonic microscope are being developed, it is still impossible to detect internal defects finer than several tens of microns, and there is no method to evaluate the mode of fracture. Although electric resistance, ultrasonic and acoustic emission analyses are used for the detection of microcracks.

Standard corset specimens cut out from sheet aluminum alloy Д-16АТ with the thickness of 1,3 mm with a plating layer, the average grain size on the plating layer is 47 μm. They were loaded on hydro-pulsating machine MUP - 20. The maximum loading in the minimum section was equaled to 250 MPa at frequency of a loading of 11 Hz. A loading cycle - sinusoidal, zero. The base of tests was not less 10^5 cycles. In the present study the fatigue tests were carried out in laboratory air (temperature 16–25 ^{0}C, humidity 40–70%).

After the next stage of a loading the specimen tacked away from loading machine and parameters of microcracks were measured, further the specimen passed the next loading.

The program of tests of specimens on a low-cycle fatigue included research of accumulation processes and development of short cracks before occurrence of a macrocrack, their association and definitive destruction of the specimen.

Identification of cracks, definition of their co-ordinates on the specimen surface sand measurement of it sizes was carried out visually by means of microscope MMP-4 ЛОМО and with application an eyepiece of a micrometer with which it is completed microhardnessmeter ПМТ-3.

After the control of a surface of the specimen the gain of quantity and length of cracks for a stage of tests, density of cracks on the surface area, growth rate of cracks was estimated.

For each microcrack was defined it growth speed $\Delta h = {\Delta l}/{\Delta N}$, where Δl - a gain of length of a crack for ΔN loading cycles.

Experimental data and their discussion. Figure 1 shows the relation between the crack length 2a of main cracks and the relative number of cycles to fracture cycles $N=N_f$ for two specimens in both alloys. From the figures, the crack propagation curves showed almost similar tendency in both alloys. Plural number of cracks occurred at each specimen, but crack didn’t coalesce each other during the fatigue process and each main crack propagated individually. The cracks initiated at very early stage from inclusions near surface, but they propagated very slowly during the early stage.

Process of accumulation of multiple damage can be characterised as formation at first a considerable quantity of small cracks, their gradual growth, and already then their gradual, and subsequently avalanche merges in cracks with much big sizes. The size of the microcracks arising in superficial plated layer of aluminum alloy Д-16АТ proportional to size of structural elements of a material.

Thus microcracks which arise on steady strips of sliding in the middle of grain, extend within grain with certain speed then meeting structural barriers in the form of border of grain they stop or become such that do not extend. Thus a share of cracks which do not grow, or have very small growth rate - considerable (fig. 3). After the crack will overcome border of grain speed of its growth increases, except own growth also at the expense of association with the next cracks. On the basis of the examined laws it is possible to draw a conclusion on casual character of MC growth rate (fig. 2).

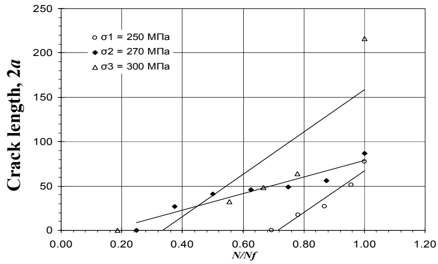


Fig. 1 Relation between crack length $2a$ and ratio of number of cycles to failure $N=N_f$.

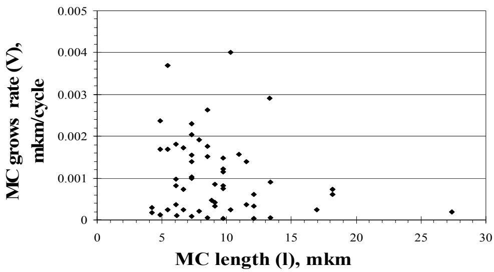


Fig.2. Dependence of the MC grows rate to their length

The quantity of new MC arising for surfaces of the specimen decreases up to a stage before destruction. It confirms the fact of prevalence of process of association MT on the big operating time.

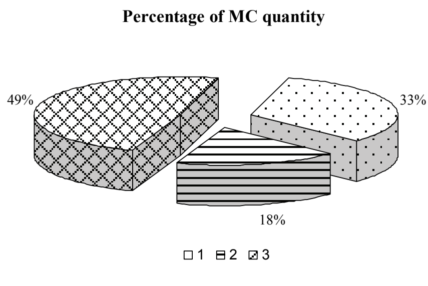


Fig.3. Percentage of MC quantity: 1 – $\Delta h=0$;
2 – which are disappeared; 3 – which are growing nonstop

At a cyclic loading dependence of dissipated microcracks quantity from quantity of cycles of a loading as a rule is linear. Thus the final stage of the damage connected with formation of cracks of higher dimensional level, is characterized by reduction of quantity of dissipated defects because of their intensive association. In some cases it leads to reduction of speed of accumulation of cracks and a deviation of corresponding dependence on the linear.

Conclusions

The question of MC growing is investigated. Namely growth rate of cracks and a kinetics of MC growth. Thus received, that on a surface of the specimen the part of cracks grows with constant speed, a part - in steps, the part does not extend, and the part from them disappears, i.e. so-called "healing" MC is observed.

At statistical processing of empirical histograms of crack quantity to their speeds distribution it has been received, that the given distributions are approximated by the indicative law (fig. 3).

The major factor defining destruction at multiple damaging, is association of dispersed cracks, especially at a finishing stage which makes, approximately, 30 % from the general durability. At this stage of growth of the largest crack it is carried out exclusively at the expense of its association with other cracks along a distribution trajectory.

References

1. *Немец Я.* Развитие усталостных трещин // Проблемы прочности. – 1988. – № 7. – С. 9–18.
2. *Ботвина Л.Р.* Кинетика разрушения конструкционных материалов. - М.: Наука, 1989. - 232 с.
3. Механика разрушения и прочность материалов. Справочное пособие в 4-х томах. / Под общей ред. В.В. Панасюка. – К.: Наукова думка, – 1988 – 1990. –Т. 4: Усталость и циклическая трещиностойкость конструкционных материалов. / *О.Н. Романив, С.Я Ярема и др.*, – 1990, – 680с.
4. *Школьник Л.М.* Скорость роста трещин и живучесть металла. - М.: Металлургия, 1973.-216 с.
5. *Suh C. M., Kitagawa H. (1986)* Crack growth behaviour of fatigue microcracks in low carbon steels. Fatigue Fract. Eng. Mater. Structures. - 9, № 6. - P. 409-424.
6. *Игнатович С.Р., Кучер А.Г., Якушенко А.С., Башта А.В.* Моделирование объединения рассеянных поверхностных трещин. Сообщение 1. Вероятностная модель объединения трещин // Пробл. прочности. – 2004. –№2. – С. 21–32.
7. *Gao N, Brown M.W., Miller K.J.* Crack growth morphology and microstructural changes in 316 stainless steel under creep-fatigue cycling // Fatigue Fract. Eng. Mater. Structur. - 1995. - 18, № 12. - P. 1407-1422.

UDC: 621.891

M. Kindrachuk, d.t.s., (NAU, Kyiv), O.Radionenko, PhD (Pryazovskyi State Technical University, Ukraine, Mariupol), A. Kryzhanovskyi, PhD, V. Marchuk, PhD (NAU, Kyiv),

THE MECHANISM OF FRICTION BETWEEN SURFACES WITH REGULAR MICRO GROOVES UNDER BOUNDARY LUBRICATION

The results of researches related to the influence of partially regular microrelief parameters on the adhesion component of the friction factor under boundary lubrication have been given. It has been shown that under boundary friction micro grooves are effective on precision surfaces with low roughness when lack of film and probability of seizure appear.

According to Molecular Mechanics Theory of Friction the total friction force under boundary lubrication can be resolved into an adhesion component and a deformation component. The measurement of these components can be done with some difficulties. This paper has investigated the adhesion and deformation components of friction under boundary lubrication of surfaces with regular micro grooves.

There are many technological methods to improve the tribological characteristics of sliding friction pairs. One of these methods is the formation of sinusoidal micro grooves regularly spaced on friction surfaces that are called "surfaces with a partially regular microrelief" according to GOST 24773-81 [1]. The grooves are formed by means of surface plastic deformation performed by the spherical indenters (Fig. 1). The depth of these grooves can be taken from 5 to 50 μm.

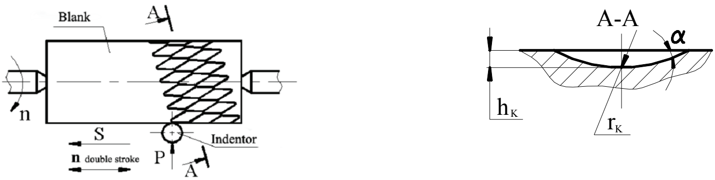


Fig. 1. Model of a partially regular microrelief formation by surface plastic deformation

To research the influence of surfaces with a partially regular microrelief on the tribological characteristics of samples, it is necessary to eliminate the influence of shape errors as well as the influence of friction surface position errors. It is not possible to eliminate the influence of these errors when applying the tribometer used in mechanical engineering. In order to eliminate the mentioned errors, macro running-in of the samples to equalize the nominal contact area and contour contact area is required. During this process micro running-in takes place and uniform roughness is formed.

To conduct tribological researches without using macro running-in, the new tribometer has been developed on the basis of friction between shaft and metal tape [3]. The metal tape can be used as a mating sample and due to its small thickness -

0.06 mm, it is flexible, which allows it to locate itself on the sample without shape errors and surface position errors. Thus the nominal contact area and contour contact area are equalized. The tribometer is equipped with an air damper to reduce self-oscillations and with an inductive friction torque transmitter (Fig. 2). The drive of a tribometer has the ability to provide stepless speed control of the sample. Different loading can be obtained by means of two tension springs and application of mating samples of different lengths. This tribometer allows one to perform testing at pressure up to 2 MPa on a sample and at loading to 470 N. Due to small thickness of the tape it is possible to control the temperature in the friction area with high precision. This is achieved by soldering the chromel-copel thermocouple of Ø 0,2 mm directly to tape of a mating sample over the friction area. The tribometer and its instrumentation allow one to control lubrication modes (boundary lubrication, mixed lubrication, liquid lubrication) according to the electrical resistance of lubricant film. While studying surfaces with a partially regular microrelief friction torque is monitored and friction factor is calculated by a formula obtained on the basis of the Euler equation derived for the case of wrapping the shaft with a flexible cable.

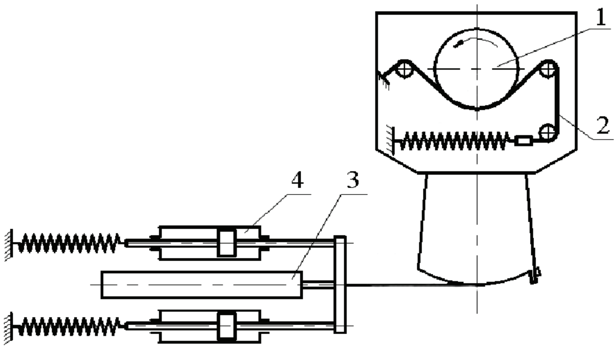


Fig. 2. Diagram of a tribometer (1 – sample; 2 – steel tape as a mating sample; 3 –friction torque transmitter; 4 – air dampers)

The purpose of the research of surfaces with a partially regular microrelief is to study the influence of micro grooves on adhesion and deformation components of the friction factor, and identification of the lubricant removal mechanism from the micro grooves.

All the studies were conducted with oil ‘Industrial 20’ and steel C45 of 30 ... 32 HRC. Micro grooves of different depth h_K, the radius of the bottom r_K and the relative area F_K are formed parallel to a cylinder element on the samples of 30 mm diameter by means of plastic deformation.

The adhesion component was studied using the method of exclusion of the deformation component of friction, for which the roughness of samples and the roughness of mating samples were taken as R_Z = 0,08 ... 0,1 mm. The surface of the sample was fed with a strictly dosed small drop of oil on, carefully distributed over the entire surface. The measurement of friction torque is performed with 3 ... 5 friction cycles at maximum friction. From the start of friction a small number of cycles did not change the initial roughness, and provided self-location of a mating sample (tape) on the sample and a reliable contact of the friction surfaces. After 3 ... 5 cycles there was a decrease of friction force due to the beginning of formation of the uniform roughness and improvement of lubrication conditions. All experiments related to the adhesion component were performed under boundary lubrication at sliding velocity of $3{,}14 \times 10^{-2}$ m/s. The temperature was kept constant at $(33 \pm 2)\ ^0$C.

It was necessary to research surfaces with different areas of micro grooves F_K and consequently surfaces with different contour areas of contact. The preliminary experiment was carried out to identify the influence of contour pressure p_C on the friction factor for samples without micro pits. The experiment confirmed the total independence of the friction factor f after micro running-in and the adhesion component of the friction factor f_a from contour pressure p_C in the range to 2 MPa for both surfaces without micro grooves and surfaces with micro grooves.During the studies, the possible location of a mating sample along the chord (effect of a chord) above a micro groove has been verified. In this case the thin steel tape is used as a mating sample. Besides, the influence of the above mentioned effect on the readings of the tribometer has been determined. The test results have shown that "the effect of a chord" does not appear.

In this experiment the friction factor f_a depends on the relative area of micro grooves F_K due to lubrication mechanisms only, in other words, due to the ability of friction surfaces to absorb lubricant from micro grooves and to form reliable boundary lubrication.

The depth of micro grooves h_K and their radius r_K affect f_a value and consequently the ability to absorb lubricant from micro grooves. When the depth of micro grooves decreases and their radius increases the absorption of lubricant from micro grooves improves and the adhesion component of the friction factor decreases.To determine the role of deformation component, running-in of surfaces with micro grooves has been studied

For this purpose, the duration of micro running-in of the samples with micro grooves and mating samples has been studied. During research a flexible steel tape with surface roughness ranged from 5 to 7 μm (Ra≈ 0,8μm) was used as a mating sample. The roughness of the tape was provided by means of grit paper, and the direction to the roughness traces was made perpendicular to the tape axis.

Research was conducted with the help of the tribometer (Fig. 2) using samples from steel C45 of hardness 28 ... 32 HRC and mating samples in the form steel tape of grade C80W2 with thickness 0.06 mm.

Micro grooves on samples were formed as a result of pressing with a spherical indenter with radius r = 1,5 mm. Micro grooves were located parallel to a cylinder element. Cold laps and metal swellings on the edges of micro pits were carefully removed in order to provide the minimum obstruction of the edges of micro grooves. Carrying surface roughness was ranged from Rz= 0,8 to 1,0μm (Ra≈ 0,15 μm). The researches were conducted in the boundary lubrication mode using oil 'Industrial 20' at the sliding velocity $V = 3{,}14 \cdot 10^{-2}$ m/s. In all experiments contour pressure was calculated for the surfaces excluding the area of micro grooves and was equal to $p_0 = 0{,}61$ MPa.

Duration of micro running-in was determined depending upon the time taken before the friction factor was stabilized. During the process of micro running-in the excess of lubricant was provided, as evidenced, by its appearance in the inlet area of friction.

Boundary lubrication mode was controlled by the electric resistance in the contact area and by the oscilloscope displays.

The experiment has confirmed the dependence of micro running-in duration on the relative area of micro grooves F_k, which allows making conclusion about an engagement of micro asperity projections with the edges of micro grooves.

The rate of micro running-in is affected by the loading cyclicity of micro asperity projections, which causes their fatigue failure. The greater the relative area of micro grooves F_k at the constant width b_k is, the faster micro running-in is finished. Under sliding friction in the boundary lubrication mode the loading cyclicity of micro asperity projections can lead to more extensive wear of a friction surface mated with the surface where micro grooves are formed. But this is compensated by the decrease of wear which occurs due to the formation and destruction of adhesive welding bridges, and the most important thing is that the probability of seizure is eliminated.

Fatigue wear can be considered a growth of a wear value under normal friction in the mode of boundary or mixed lubrication when the relative area of micro grooves F_k increases and its value exceeds the optimum value F_k= 25...45%.

The value of the deformation component of friction force should increase in case of micro seizure, because the break of adhesive welding bridges is accompanied by the removal of metal micro particles welded to the mating surface projections from the friction surface. This leads to the formation of higher projections with high hardness, which engage with the edges of micro grooves and significantly deform them.

Decrease in the deformation component of friction force reduces the energy cost for friction during the steady state mode of friction as well as improves the smoothness of movement. The latter is indicated by decrease in the variations of friction force when tape surface roughness is reduced from Rz= 5...7 μm to Rz= 2...3 μm. At the same time, in order to accelerate the process of running-in it is necessary to increase the deformation component of friction.

The necessary depth of micro grooves should be made in order to ensure good running-in of the friction surfaces, which results in light surface wear and reduction of groove depth. Profile of grooves is also changed, so one of the edges gets more rounded. Upon completion of running-in the grooves with less depth and rounded edges of micro grooves provide a reduction of adhesion and deformation components of friction and decrease wear on the friction surfaces in comparison with the period of running-in.

Conclusions

1. The formation of micro grooves of 3-20 μm on the friction surface reduces the adhesion component of friction force under boundary lubrication, if the friction surfaces do not have micro cavities to reserve lubricant. This friction pair ought to

have minimum clearance, high accuracy in shape (round surface, longitudinal section profile) and with minimum surface roughness less than Rz = 0,8 ... 1,0 μm).

2. Micro grooves increase the deformation component of friction force under boundary lubrication, especially when surface roughness on the mating friction surface.

Thus, the formation of micro grooves on friction surfaces under boundary lubrication is highly applicable for precision friction units, for example, in the boxes of theodolites, in the friction units of telescopes and other precision devices.

The effect of micro grooves under boundary lubrication appears in cases when the friction surfaces are unable to provide normal modes of friction and lubrication. If a friction pair is run in and operates without deviations, it will be inappropriate to form micro grooves on contacting surfaces in order to improve the mechanism of lubrication and increase their wear resistance, except cases when structural errors were made during the process of a new friction pair design.

References

1. Schneider, Yu. Operational properties of details with regular microrelief. Leningrad: Mashinostroyeniye, 1982.- 248 p.
2. Kragelskyi, I., Gitis, N. Probability of ‘lack of film’ in plastic lubricants.‘Friction and Wear’.- 1983.-Vol. 4, №1, 12-17 p.
3. Radionenko, A. The tribometer to study the influence of surface quality on the condition of lubricant film.‘Mashinovedeniye’.-1987.- 93-97 p.
4. Radionenko, A. 2005.Lubricant mechanism of surfaces with a partially regular microrelief. Kyiv: Press of National Aviation University. ‘Problems of Tribology’ №4, 203-206 p.
5. Radionenko, A., Kindrachuk M. 2005. Friction model and technological support of surfaces with a partially regular microrelief.Kyiv: Press of National Aviation University. ‘Problems of Tribology’ №1, 59-68 p.

UDC: 621.891

A.O. Kornienko, Ph.D., S.V. Fedorchuk (NAU, Kiev)

NICKEL-BASED EUTECTIC ALLOY FOR COMPOSITE ELECTROLYTIC COATINGS

The investigations of structure, elements distribution and microhardness of areas: matrix-transition zone-particle of composite nickel-based electrolytic coatings are carried out. As a composite coating filler the wear-resistant eutectic alloy powder designed for operation at elevated temperatures is used. Hight wear resistance of designed coatings due to surface wear-inhibiting films formation it is established by tribotechnical investigations.

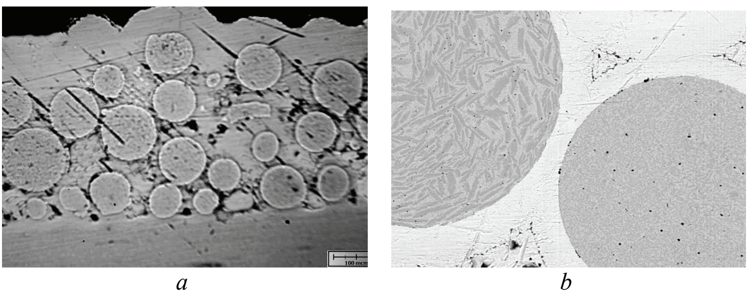
Problem statement. One of perspective methods of the machine elements superficial strengthening is applying of composite electrolytic coating (CEC) [1]. However, existing today CEC cannot satisfy constantly growing requirements to exploitation of corresponding friction units of mechanisms in the conditions of the dynamic loading, active influence of corrosive environments and especially increase temperatures. One of effective ways of reception of materials with high thermal stability and wear resistance are creation of compositions on the metal basis strengthened by refractory borides and carbides with use of eutectic reaction between them as high heat resistance and thermal stability is defined by their structurally-phase structure. In work [2] it is shown, that the phases of penetration TiB_2, CrB_2 and VC are characterized by chemical compatibility, a strong binding and are in stable equilibrium at the raised temperatures (to $0{,}9T_{\text{melt}}$) with the metal basis close on structure to a steel 12X18H9T. Such alloys are capable to work in the loaded units of a friction at simultaneous influence of the chemically-active environment, heats in the absence of greasing. On the other hand the creation of eutectic coatings by a welding method results in non-uniform heating across detail section with a coating and heats on a surface with their sharp reduction to a core that leads to possible change of geometry of a detail and a surface. Besides the given method allows to put a covering only on external surfaces which should be well accessible to processing, and does not allow to put on internal surfaces, especially if details have length greater than diameter. To avoid above mentioned shortcomings is possible by using the electrolytic method. In-process [2] it is shown that such phases of penetration, as TiB2, CrB2 and VC is characterized by chemical compatibility, strong connection and are in a stable equilibrium at increase temperatures (to 0,9Тпл) with metallic basis near after composition to steel of 12X18H9T. Such alloys are able to work in the loaded knots of friction. Therefore the task was to develop composite electrolytic coating with eutectic alloy powders as filler to increase the endurance at elevated temperatures and to investigate a structural condition and wear resistance of the received coatings.

Experiment technique. Composite electrolytic coatings are received by settling of electrolytic nickel with eutectic alloy powder specially developed for work at the raised temperatures [3] on the horizontal cathode at pulse moving of electrolyte and density of a current from 5 to 10 А/дм^2, PH 3-3, at electrolyte temperature 25-40^o. Thermal processing of samples with a coating was carried out by vacuum annealing at temperatures 950 ºC and 1250 ºC. Microstructure researches are carried out by means of optical microscope NEOPHOT 21 and electronic raster microscope with energy dispersive microanalysis system PEM-106I. Test a material for microhardness are done on device PMT-3. The element structure was analyzed with the help energy dispersive spectrometer «Link 860/500» firm "Link". Tribological tests are carried out on installation M 22-M.

Results of researches. Physic mechanical and tribological properties of composite coatings are defined by the intense-deformed state of a coating and its structure. One of the basic conditions of creation of coatings with the set structure is possibility of introduction of certain quantity filler in a matrix. The nature of filler particles, their chemical compound, quantity and the size, character of interaction with a matrix define the future complex of physic mechanical and tribological properties of a composite coating. Technological parameters of processes of galvanic powder coatings sedimentation are chosen to receive a coating with necessary contents of eutectic alloy powder according to recommendations [4] as content of the second phase particles have essential influence on a coating wear resistance.

As CEC filler is used different dispersion eutectic alloy powders developed to work under the raised temperatures. Investigated coatings contain 30-40 vol.% of eutectic alloy powders in a nickel matrix. According to the recommendations of the works [1, 4, 5] such content of filler in the composition allow to achieve the optimum of the intense-deformed conditions, physic mechanical and tribological properties of coatings. As the basic influence of solid particles in a coating is matrix strengthening the presence of rigid impurities strengthens, or reinforces, a matrix by restriction of its plastic current. Thus the zone of the raised pressure tangents which are results of interaction between stress fields of the next particles, goes deep into a material below the particles. As a result a loading on the matrix in area between particles is reduced and provides a positive gradient of pressure from a friction surface to core. At the lower filler content and, accordingly, bigger center distances between particles the durability of a composition decreases due to formation of cracks on the weakened borders the particle-particle. Above mentioned shows that a coating with filler 30-40 vol.% should work effectively in the conditions of a friction and wear process.

The structure of CEC nickel-eutectic alloy is shown on fig. 1.



a *b*

Fig. 1. Structure of CEC nickel-eutectic alloy: *a* – × 100; *b* – × 600

The coating is a nickel matrix with eutectic powder particles. As eutectic alloy powder particles are electroconductive the received coatings are characterized by insignificant porosity up to 5 %. Initial eutectic powders contain fine-dispersed crystals of penetration phases, and the sizes of these crystals depend on a particle diameter because a speed of powder cooling depends on the size of a particle while manufacturing (table 1).

Table 1

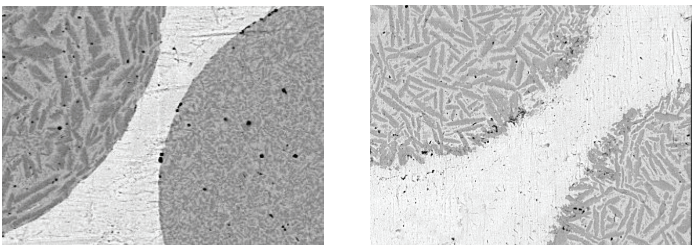
Dependence of crystallization speed of eutectic alloy powders and the sizes of eutectic crystals on powder grain diameter [2]

Diameter powder grain, micron	Crystal thickness, micron	Speed of crystallization V, K/sec	Note
-	3,5	20	Cast alloy
240	2,0	$5 \cdot 10^4$	-
150	1,2	$8 \cdot 10^4$	-
58	0,3	$3 \cdot 10^5$	-
35	-	$6 \cdot 10^5$	Crystals are not present

Preliminary researches have shown not high enough wear resistance of the given coatings as the given coatings in an initial state have low adhesion to a backing and low cohesion in a coating because of a interstices (fig. 1, *a*) and absence of interaction between a matrix and a filler (fig. 1, *b*), that causes chipping filler particles under tests. That's why a heat treatment (HT) of CEC by means of annealing is recommended.

It has been selected two temperature modes of heat treatment: 1 - in a mode without melting at temperatures about 950 ºC, that is $0{,}8T_{\mathrm{melt}}$ for eutectic powders (30 minutes soaking and cooling with the furnace); 2 - in a mode with melting at temperatures about 1250 ºC (30 minutes soaking and cooling with the furnace).

After heat treatment (HT) by vacuum annealing at temperatures 950 ºC on border a particle - the matrix disappears neat border of phases division (fig. 2), occurs eutectic recrystallization and as a result eutectic crystals of different grains of powder have the identical size (fig. 2, *b*).



a *b*

Fig. 2. Structure of CEC nickel-eutectic alloy, × 1000: *a* – without heat treatment; *b* - after heat treatment in a mode without melting at temperatures 950º C

Results of investigation of the chemical element coating compound (table 2) by X-ray method have shown that in the result of heat treatment the change of a chemical compound of coating components takes place due to a mutual diffusion between filler particles and a matrix as far as structurally-phase transformations. So, between filler particles and a matrix is formed a transitive zone with high contents of Ti, Cr and Fe in comparison with a chemical compound of a coating part on the border a matrix - filler particle without heat treatment, while essential changes in a filler particle chemical compound is not observed.

Table 2

CEC chemical compound of coating areas

Element, %	Ti	Cr	Fe	Ni
Matrix				
without heat treatment	0,08	0,03	0,44	99,45
heat treatment 950°C	0,09	2,9	8,37	88,64
heat treatment 1250°C	0,14	12,1	35,05	52,71
Transitive zone				
without heat treatment	0,10	0,67	1,72	97,51
heat treatment 950°C	0,17	8,3	33,68	57,85
heat treatment 1250°C	0,19	22,11	47,02	30,68
Filler particle				
without heat treatment	0,24	26,91	63,03	9,82
heat treatment 950°C	0,23	28,63	61,71	9,43
heat treatment 1250°C	0,21	23,09	51,01	25,69

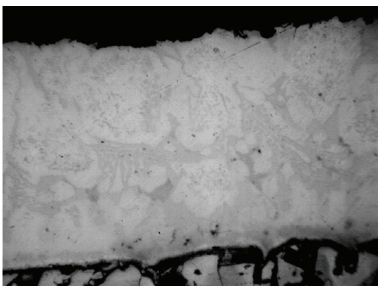


Fig. 3. Structure of melted CEC nickel-eutectic alloy after heat treatment at 1250°C, × 200

The heat treatment results in a matrix strengthen. Microhardness measurements in different coatings areas before and after heat treatment have shown (table 3), that as a result of heat treatment the transitive zone with microhardness $H\mu$=4,5–5,5 GPa between a matrix and filler is arisen. The filler microhardness after heat treatment decreases, as already at temperature 950 °C there is a recrystallization of eutectic alloy filler (fig. 2, *a, b*), and at temperature 1250 °C occurs complete melting of the coatings with eutectic formation (fig. 3).

Table 3

CEC microhardness, GPa

Heat treatment mode	Without heat treatment	Heat treatment at 950°C	Heat treatment at 1250°C
Matrix	3,0-3,2	3,3-4,0	4,0-4,7
Filler particle	8,1-8,9	6,7-7,5	6,0-6,5

Conclusions

Heat treatment in modes without melting and with melting of composite coatings of system nickel - eutectic alloy essentially changes the structure and element content of coating areas: matrix - transitive zone – particle filler. Necessity of heat treatment is validated by need of increase the mechanical properties of a matrix, increase the adhesion and cohesion. Besides, as the coatings were developed for operation at the raised temperatures the applying of heat treatment at temperatures above than friction units operational temperatures promotes avoidance of uncontrollable structural transformations in a coating at action of operational temperatures.

References

1. Кіндрачук М.В. Експерементально-аналітичні дослідження триботехнічних характеристик покриттів матрично-наповненого типу / М.В.Кіндрачук, М.В.Лучка, А.О. Корнієнко // Проблеми трибології. – 2005, № 2, – С. 74–80.

2. Структуроутворення та формування триботехнічних власти-востей евтектичних покриттів / М.В. Кіндрачук, Ю.А. Куницький, О.І. Дудка, Ю.Г. Сухенко, В.М. Коржик. – К.: Вища шк., 1997.– 120 с.

3. Пат. 65018 України МПК (2011.01) C25D 15/00 / Склад для одержання зносостійких композиційних електролітичних покриттів на основі нікелю для роботи при підвищених температурах / Кіндрачук М.В., Корнієнко А.О., Федорчук С.В., Лучка М.В., Перро Д.М., Подлєсний В.В. № u 2011 05006; Заявл. 20.04.2011; опубл. 25.11.2011, Бюл. № 22. – 4с.

4. Корнієнко А.О. Формування триботехнічних властивостей композиційних електролітичних покриттів на основі нікелю створенням градієнтних структур: Дис. ...канд. техн. наук.: 05.02.04. – К., 2007. – 167 с.

5. Эволюция структуры и свойств эвтектических покрытий при трении // М.В. Киндрачук, Ю.Я. Душек, М.В.Лучка, В.Н. Гладченко // Порошковая металлургия. – 1995. – №5/6. – С. 104–110.

UDC: 621.891 (045)

M.V. Kindrachuk, d.t.s., O. Tisov, PhD. (NAU, Kyiv)

GRADIENT COMPOSITE COATINGS FOR WORKING SURFACES OF BRAKING DEVICES

In this paper a study to develop a composite wear-resistant coatings for application to the working surface of linings of brake devices, which is based on a rule of a positive gradient of mechanical properties was carried out. It was created and tested eutectic composites based on alloy steel 12H18N9T based on thermal characteristics of all components.

Introduction and formulation of research problems. Friction materials used in dynamic friction devices, which include brake pads, special support slipping, clutches, variators. These devices are designed to break up (clutch) and stop (brakes, sliding slip resistance) transport machines and drives for process equipment (different friction clutches and regulators) and the transmission and to change the direction of motion.

To achieve high and stable friction coefficient the intermediate layer should have specific heterogeneous structure and properties would provide a large coefficient of internal friction at high temperatures and prevent damage to the friction surface of the material.

However, there are theoretical and experimental study of the effect of temperature and temperature gradients on the friction and wear of friction pairs for various purposes [1-4]. In addition to direct effects of temperature on the wear, friction factor, theoretically and experimentally, it was found that the coefficient of friction increases with increasing temperature gradient and a decrease in overall temperature in friction.

In this regard, there is scientific and applied interest in creating composite friction materials and coatings that would allow strong thermal control. Eutectic composite alloy as the matrix use a 12H18N9T austenitic steel. As the reinforcing phase are the most heat-resistant and wear-resistant carbides and borides were used.

The objects of the study were composites based on alloys steel 12H18N9T, which include borides of titanium and chromium (HTN), borides of titanium and vanadium carbide (VTN). The chemical and phase composition of the alloys are given in Table. 1., Thermal properties in the table. 2 [5].

Table 1.

Chemical and phase composition of eutectic alloys

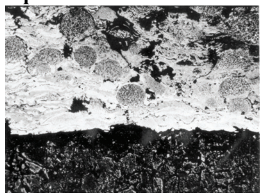
Alloy	Chemical composition, %							Phase composition		Hardness, HB	Melting point, K
	Cr	*Ni*	*Ti*	*V*	*B*	*C*	*Fe*	Матриця	Harde-ning elements		
BTH	15,4	7,7	3,2	8,1	1,4	1,9	62,3	12X18H9T	*TiB_2+ VC*	470	1460
XTH	20,5	8,6	2,5	—	2,6	—	65,8		*(Ti, Cr)B_2*	370	1490

Structure and properties of plasma coatings. For coating powders of eutectic alloy of two systems: VTN and HTN [6] were used. In sputtered eutectic coatings 'white' areas were observed, white layers, partially melted or unmelted powder and a small amount of pores (Fig. 1).

Table 2

Thermal properties of the alloy components

Material	Thermal Conductivity λ, W (m. deg)	Heat capacity C, kJ (kg deg)
12X18H9T	15,9	0,505
VC	25	0,531
TiB_2	21	0,636
CvB_2	22	0,695



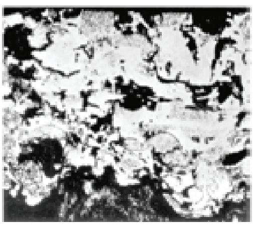
Fog. 1. Microstructure of plasma coating VTN; x 500

Experimental procedure. Tests on the friction and wear were performed on a friction machine M22-M, which allows in the process the experiment to automatically record basic characteristics of friction and wear (linear wear of friction pair) without notables model of it. As counter body the rollers of diameter 40mm, made of cast iron MF-15-32 were used. At a distance of 0.5 mm from the surface of friction of the sample introduced chromyl - koppel thermocouple, which allows to control temperature change in the friction zone and to fox the stabilization of friction and wear. Test specimens with coatings was carried out in terms of friction without lubrication by the scheme 'shaft-plane' and the load was P = 20; 40; 60; 150 N, sliding speed V = 0,1-2m / s. Friction distance L = 1km.

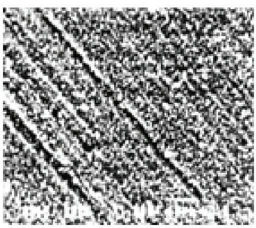
The chemical composition and structure of the components of the surface layer formed as a result of tribological interactions were determined by X-ray analysis.

Results and discussion. The cross-section micrographs of tested friction samples shows that the friction surface coating VTN have areas with eutectic structure (Fig. 2a). They determine the amount of wear and wear rate dependence on the specific load. Lots of white layers placed between the eutectic areas, due to the low ductility and lack of cohesion spall out from the surface.

Battered solid white layer, getting in the zone of friction, act as an abrasive (Fig. 2b) with this enhancing wear. Brittle fracture at the surface friction explicit plasma coating HTN. Specific loads of 8 MPa bursting of the coating are typical phenomena. Tribological properties of plasma sputtered UC depend on load and



a



b

Fig. 2. Microstructures plasma coating (*a*), x200 and the friction surface (*b*), x500 of eutectic powder VTN

temperature determined by the degree of non-equilibrium condition, porosity and adhesive-cohesive strength. Normal plasma friction coating operation is observed in a narrow range of loads and temperatures. If the load P> 5 MPa, there is an intensification of wear due to brittle fracture, accompanied by chipping of elements that have abrasive properties. By elevated temperatures (T> 600 ° C) low durability is predetermined by decrease in hardness of the coating due to the collapse of supersaturated solid solutions and coating wears through withdrawal from the zone of friction due to loose of porous oxide films, that rapidly form on the surface of friction.

In the diffractograms of the friction surface of HTN coating reflexes of oxides Fe_3O_4, Fe_2O_3, Cr_2O_3, TiO_2, B_2O_3 were detected. In the coating of HTN compared with VTN coating formed larger number of oxides B_2O_3 and Cr_2O_3. Perhaps this factor, and high heat resistance is explained by the higher wear resistance of coating HTN at elevated temperatures than at lower ones. Thus, plasma coating can not realize their potential high tribotechnical properties. There is only a limited range of external factors in which coating workable, fair running in and form secondary structures.

Structure, mechanical properties and tribotechnical gradient of plasma coatings obtained by laser melting. Laser treatment due to its specificity (rapid heating and subsequent accelerated cooling) gives fine - dispersed structures supersaturated solid solutions and, therefore, high wear resistance of coating. Because of practical interest it is the consideration of the structural features and properties of plasma coating after processing them using laser melting.

In this mode of exposure was chosen such that the depth of penetration equal to the thickness of the applied coating or exceed it. Fig. 3 presents the microstructure of plasma coating on steel 40X, melted by the laser beam. Coating has a columnar structure - dendritic structure. Compared with the initial microstructure it can be noted that the metal as a result of the concentrated radiation energy was in the liquid state. Under the influence of a large temperature gradient and the resulting high speed crystallization, the growth of dendrites principal axes held parallel to the heat sink. Note that near the surface area heat sink is less pronounced, and is parallel to the displacement of the laser beam on the surface. Thus, the orientation of dendrites in the melting zone is determined by the direction of heat. Melting of the coating are almost bezporystymy (porosity of 0.5 - 1.0%), adhesion strength is increased to 400 - 450 MPa.

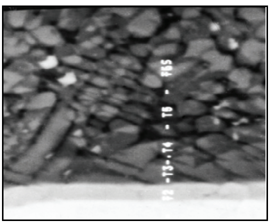


Fig. 3. Microstructure fused plasma coating VTN, x 500

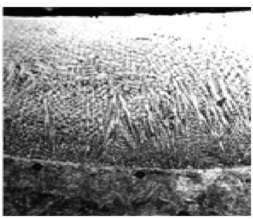


Fig. 4. Microstructure gradient plasma coating system VTN, x 500

The process of formation of gradient coatings obtained a patent [7]. The micrograph if the coating is shown in fig. 4. Tribological tests found increasing resistance of melted surfaces to wear compared to the original without processing more than in 2 times. Thus, if the reduced wear of sprayed coating VTN at 293 K is 51.1 mg/cm^2·km, and of melted - 27.9 mg/cm^2·km.

The task was to provide a method of drawing plasma coating with high wear resistance and working in by forming its gradient structure: a thin surface layer of dispersed structure with low shear resistance and depth of the columnar structure oriented normal to the friction surface.

To draw such a coating an alloy VTN of the system 12H18N9T - TiB2 – VC was chosen, because it is more durable than the alloy HTN. Previously the optimal structure of hardening phases (TiB2, VC) on the wear resistance coatings, based on their thermal properties was investigated.

It should be noted that the decrease in wear and friction coefficient in the temperature range 300 - 500 ° C with increasing content of vanadium carbide probably due to its ability to oxidation. Unlike the diboride of titanium, vanadium carbide under these temperature begins to oxidize. The resulting oxide film containing FeO, TiO2, V2O3, B2O3 serves as a solid lubricant and protect the surface from wear.

Therefore, for further research, given optimal tribotechnical properties of the coating (I, *f*, Θ), we selected an alloy with eutectic composition with 10 vol.% TiB2 and 15 vol.% VC.

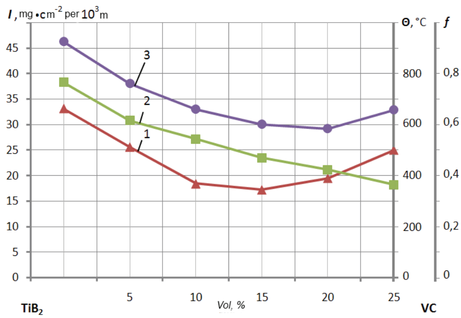
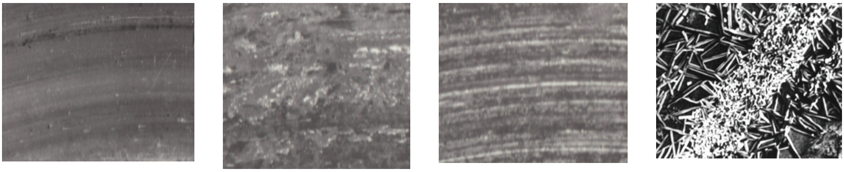


Fig. 5. Dependence tribotechnical properties melted coating VTN plasma volume content of TiB2 and VC at P = 2 MPa, V = 0,5 m / s 1 - f; 2 - Θ; 3 - I

Research has established that such properties as wear, the maximum surface temperature and the coefficient of friction depends on the ratio of the content of TiB2 inclusions and VC (Fig. 5). This is probably not only due to their different physico - mechanical properties, but also thermophysical.

In Fig. 6 the microstructure of their friction surfaces are given. By sliding speed of 0.2 - 0.8 m / s (surface temperature 300 ° C) the formed secondary structure has smooth surface (Fig. 6 *a*). With increasing sliding speed to 1.2 m / s (temperature 400 ° C) and up to 1.6 m / s (temperature 550 ° C) processes of friction and wear are determined by the formation of oxide films (as in Fig. 6 *b* and 6 *c*,). In the sliding speed range 1.8-2 m / s (temperature 800 - 850 ° C) occurs contact friction. Wear scars on the samples - are flows and solidified eutectic crystals (Fig. 6, d). Thus there is a sharp decrease in the coefficient of friction to values characteristic to boundary friction (0.05 - 0.10).



a *b* *c* *d*

Fig. 6. Microstructure surface friction gradient coating, P = 2 MPa, *a* - V - 0,4 m / s, t - 250 ° C; *b* - V -1,2 m / s, t - 400 ° C; *c* - V-1,6 m / s, t - 560 ° C; *d* - V - 2m / s, t - 850 ° C.

Conclusions

1. It was proved and experimentally confirmed the composition of the eutectic composite alloy gradient coating based on thermo physical properties of the binder and fillers (thermal conductivity, heat capacity): steel binder 12H18N9T - 75%; fillers TiB2 - 10%, Vc - 15%.

2. We improved the durability of doubly fused plasma coating due to its gradient structure, where the surface layer of elastic - plastic fine-grained structure contributes to running in of secondary structures and self-organization, and is located below the layer with columnar structure efficiently damps external normal and shear loading. This increases the contact strength of the coating and reduces the friction and temperature gradient.

3. Designed coating for braking devices can be attributed to friction materials for medium friction conditions (short-term temperature up to 400 ° C, long - up to 250 ° C, pressures up to 1.5 MPa).

References

1. *Крагельський І.В.* Тертя та зношування / І.В. Крагельський – М.: Машиностроение, 1986. – 480с.
2. *Чичинадзе А.В.* Материалы в триботехнике нестационарных процессов / А.В. Чичинадзе, Р.М. Матвеевский, Э.Д. Браун. – М.: Наука, 1986. – 248с.
3. *Чичинадзе А. В.* Расчёт, испытание и подбор фрикционных пар / А.В. Чичинадзе, Э.Д. Браун, А.Г. Гинзбург, З.В. Игнатьев. М.: Наука, 1989. – 267с.
4. *Chichinadze A.V.* Evaluation method of the carton friction composite materials used in multiple disk aviation brakes / Chichinadze A.V. //Tribologia. Warszawa. №1 (2000). Part 1. P. 7-22; № 2 (2000) Part 2. P 133-154; №1 (2001). Part 3. P. 23-38.
5. *Киндрачук М.В.* Износостойкость нержавеющих эвтектических сплавов с фазами внедрения / М.В. Киндрачук, А.К. Шурин, В.Е. Панарин // Проблемы трения и изнашивания. – К.: Техника. – 1981. - № 19. – С. 17 – 28.
6. А.с. № 1050179 СССР. Порошковый материал для износостойких покрытий / Киндрачук М.В., Корнеев В.Г., Мелентев О.П., Панарин В.Е (СССР)- № 3411077/27; Заявл. 05.03.1982; Опубл. в БИ 1983.
7. Пат. 84998 України МПК C21D1/78 (2006.01) Спосіб отримання градієнтних зносостійких плазмових покриттів з високою припрацьовуваністю / Кіндрачук М.В., Корбут Є.В., Стебелецька Н.М. та ін., № u 201304817; Заявл. 16.04.2013; Опубл. 11.11.2013, Бюл. № 21. – 4с.

UDC: 621.795; 669.255

T. Cherepova, PhD., G. Dmitrieva, PhD, (Institute for Metal Physics NASU, Kiev)
A.Duhota, PhD., M. Kindrachuk, d.t.s, O. Tisov, PhD. (NAU, Kiev)

WEAR RESISTANT PROTECTIVE MATERIALS FOR ROTOR BLADES OF AIRCRAFT GAS TURBINE ENGINES

The analysis of alloying materials that are promising for special wear-resistant materials for reinforce edge banding shelves of turbine engine rotor blades was carried out. Evaluation was carried out on indicators of performance properties of the alloys of the same application

The service life of aircraft gas turbine engine (GTE) is determined by the reliability and durability of its most critical components of the hot part, such as turbine and nozzle vanes contacting surfaces, which are worn when working in hostile environments at high temperatures and variable loads. In modern aircraft gas turbine engine to the turbine rotor blades are widely used with bandage shelves (Fig. 1), with their ends special contact pads for greater stiffness of all blades after assembling the turbine wheels. This connection of blades improves their vibration strength and prevents fatigue fracture, but has a drawback - wear of contacting surfaces. An effective way to increase the operating time of rotor blades is applying bandage on their shelves more wear-resistant material than the material of the blades

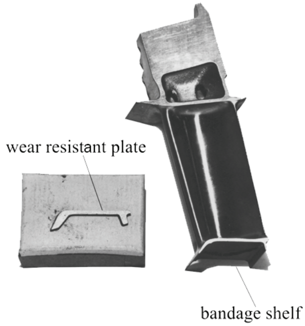


Fig 1 - Turbine blade wear-resistant pad

Heat resistant alloys of metals in modern engineering are created using refractory phases of implementation - carbides, borides, nitrides and oxides. Eutectic alloys of metals (Co, Ni, Fe) monocarbides of refractory metals (NbC, TiC), which are formed from the melt during crystallization, are natural composites with high performance durability.

Powder and cast alloys based on cobalt and nickel alloys are already used in industrial manufacturing of various parts for gas turbines [1]. The main ways to strengthen them – solution strengthening, carbides, particles of γ'-phase (for Co-Ni alloy), mainly aimed at increasing strength at elevated temperatures. Best of all they are represented in the encyclopaedia on metallurgy and materials [2], which also considers the possibility of raising the resistance of material to oxidation and hot corrosion at temperatures up to 900°C.

In Russia (JSC "Perm motors") it was established a new durable material to enhance the contact surfaces of the blades of GTE by modifying the chemical composition of serial high-temperature nickel alloys ЖС30-ВИ and ЖС-32ВИ [3,4], which are made in the form of specialized plates and are used as welding material at argon-arc welding. The advantage of these alloys is the high initial hardness, although data on the hot hardness are not available.

To strengthen shelves used as bandage material В3К in cobalt-based and ВЖЛ-2 based on nickel intermetallic strengthening compounds, developed by VIAM, with operating temperature which does not exceed 900°C. Heat resistance of stellite В3К significantly reduces starting from 850°C, and application to turbine blades new alloys that require soldering operations at ≈ 1270 ° C preclude the use of alloy ВЖЛ-2 with a melting point of 1220 ° C [5].

At the Institute of Metal Physics of the NAS of Ukraine on the initiative and in collaboration with the State Enterprise "Zaporozhye Machine-Building Design Bureau" Progress "(SE" ZMKB "PROGRESS") there were carried out researches in order to create a new alloy to protect against wear the bandage shelves of rotor blades of aircraft gas turbine engines. The basic requirements to develop new alloys have been expanding the range of working temperatures up to 1000 ° C, stable durability with increased loading on the shelf (≥ 20 MPa), the melting point of not lower than 1300 ° C, the thermal stability of the structure and phase composition. Alloys must be technological - have good casting properties, satisfactorily treated, be sufficiently heat resistant, have high strength of soldered joints of plates with edge banding shelf blades and thermal expansion close to the blade alloys.

As the basis of eutectic alloys developed in we selected cobalt, which has significant advantages over nickel - higher melting point, which allows the use the alloys at temperatures higher than nickel-based ones, the best thermal fatigue resistance, lower thermal expansion, better weldability and others. Volume fraction of reinforcement carbide (Ti, Nb)C reaches 16-18%. Doping tungsten and molybdenum for solution strengthening and chromium and aluminum – for increased heat resistance. Based on the results of tests for durability in operation at 20, 500, 800 and 1000°C and specific loads that match the pressure in the structures of blades of different capacity engines, alloy brand ХТН-37 at a pressure of 19.6 MPa for wear resistance is 15 times higher than that of alloy ВЖЛ-2 and 8-10 times ЖС6У alloy blade that runs on low-power engines without soldering and at a pressure of 49.0 MPa than alloy ВЖЛ 2 to 4 times.

Chemical activity of titanium in the alloy ХТН-37 and its interaction with the ceramic forms for melting pledged to reduce its content in the alloy to a complete replacement for niobium, as a result an alloy ХТН-61 was created. It is based on cobalt eutectic system - niobium carbide. Poster and full-scale tests on the engine of alloy grade ХТН-61 found it a great advantage to the alloy ВЖЛ-2, which at the time allowed to increase the service life of gas turbine engine from 1000 hours (without protection shelves) to 2000 hours (soldering alloy plates with ВЖЛ- 2). Durability of alloy ХТН-61 is 5-10 times higher than that of alloy ВЖЛ-2, and the melting point of nearly 100 degrees higher (1320^{o}C of ХТН-61 alloy to 1220 of ВЖЛ-2). Alloy ХТН-61 also has the advantage of corrosion resistance in injection molding qualities, the ability to grinding and brazing high-temperature solder. Serial fusion of brand XTH-61 is used on engines produced at JSC "Motor Sich" and SE "ZMKB" Progress "[6]. In the fusion received a patent of Ukraine [7] and developed Technical conditions 88.061.001-92 "cast rods of alloys XTH and XTH-37-61 ', which were approved by the State Committee of Ukraine for Standardization, Metrology and Certification. Subsequently, the specifications have been replaced by TU 88.061.007-98 improvements to the alloy. Alloy XTH-61 is also used for the repair of rotor blades in the engines that have exhausted service life, and to eliminate defects by deposition on other engine parts [8]. The use of this alloy has made it possible to increase the life of aircraft engines from 2000 to 9000 hours. More than 15 years of the alloy is used in engines that are installed on the aircraft AN-124 "Ruslan", AN-225 "Mriya", AN-70, AN-148.

In connection with the further development of aviation equipment it was necessitated increasing the operating temperature of the blades, and, consequently, increased heat resistance characteristics of protective alloys. As a result of the research it was designed a durable cobalt based alloy of high heat resistance marked XTH-62 [9]. The basis is the eutectic alloy Co-NbC (NbC ≤ 17,5 wt.%) and doping complex was narrowed to chromium, tungsten, aluminum and iron. The advantage of XTH-62 alloy is 10-20 times higher heat resistance (Table 1), while retaining all the positive characteristics of the alloy XTH-61.

Table 1

Properties of alloy development by IMP compared to ВЖЛ-2

Alloy	Wear intensity I_v x 10^6 mm^3 /cycle at T, °C				Melting temperature, °C	Heat-resistance Δ m, g/m^2 ear at T, °C	
	500	850	1000	1100		1000	1100
ВЖЛ–2	1,35	0,95	4,5	–	1220	–	0,9
XTH–37	0,54	0,33	1,19	–	1330	–	4,1
XTH–53	0,58	0,27	1,57	–	1355	–	1,2
XTH–61	0,28	0,25	0,4	15,1	1350	1,2	7,8
XTH–62	–	–	0,3	15,0	1320	0,6	0,4

Good performance of wear resistance showed XTH-53 nickel-based alloy [10], also several times the wear resistant of alloy ВЖЛ 2.

High performance alloys XTH-37, XTH-61 and XTH-62 is due to their eutectic structure. High wear resistance is achieved by increased volume fraction of carbide phase in alloys and heat resistance by a complex of alloying elements, forming substitution solid solution with cobalt (Cr, Fe, Al, Mo, W).

Cast eutectic composites such as XTH contain no more than 19% vol. carbide phase. Niobium carbides - the main strengtheners in the developed eutectic alloy, have low heat resistance, resulting in oxidation of carbides and erosion chipping. To further strengthen the alloy must increase it number of carbide phase and niobium carbide replaced by any more resistant.

Given the fact that titanium carbide is 2-3 times higher than chromium carbides in hardness and 1.5 - 2 times the melting point [11], it was decided to use titanium carbide powder to strengthen alloys.

Increase the carbide phase by melting when carbide forming element and carbon are introduced separately can not be used due to a significant increase in the liquidus temperature and the inability to complete melting of the alloy and the formation of undesirable too large carbide crystals. Number of crystals of dispersed carbide phase may be increased by powder metallurgy methods - carbide sintering or hot pressing. In this case, there is an opportunity to achieve the required dispersion strengthening, without changing the temperature of the beginning of melting of the alloy.

The development of new wear-resistant powder alloy is made from the of Co-TiC composition, despite the fact that the eutectic temperature of the corresponding binary system is 1380°C. Based on the results of tests conducted by the Kyiv National Aviation University, the performance of the investigated alloys - linear wear in the temperature range from 20 to 1050°C higher than for alloy XTH–62 in 4 - 10 times (Fig. 2)

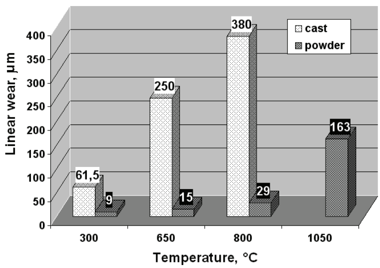


Fig 2 - Linear wear of alloys in high temperature fretting conditions: (Light - cast alloy type XTH, dark-sintered cobalt based alloy)

Optimal structure and properties, which prevent damage to the development of surface friction and highest wear resistance characteristic of alloys based on cobalt alloyed with titanium carbide in its content at 50% vol. [12].

A promising direction of finding of wear-resistant, high-temperature powder alloy can be dispersion strengthening of alloy by particles of another phase - carbides, borides, nitrides, oxides. The creation of such composites require studying the properties of their components and mechanisms of adhesion, interaction of components. Chemical interaction of metallic solid basis should be minimized to preserve both the hardening of crystals and their strength characteristics, especially at high temperatures. Required strong coupling of material with the base alloy can be achieved by applying modern methods.

There is an interest to powder alloy doped by oxides dispersed and strengthened by mechanical alloying without melting. Introduction to powder alloys of small (20-40 nm) particles of chemically inert oxide (usually Y_2O_3 - Al_2O_3) creates conditions for further strengthening of variance consolidated alloy presence of dispersed oxides ensures high durability of these materials at temperatures up to 1100°C due to the mechanism of jamming dislocations (strengthening by Orovan) [13]. Oxide content – is about 1% to the volume of the alloy.

New powder materials, which are created for the needs of the aviation engine, has great potential, expanding its scope. However, with the development of materials such as ceramics and ceramic composites, great importance is the factor of economic efficiency.

Conclusions

1. The main characteristics of the eutectic composite materials such as XTH on cobalt and nickel based, developed at the Kurdyumov Institute of Metal Physics. VG NAS Ukraine that protect against wear high-end bandage shelves rotor blades of gas turbine engines were presented. An analysis of domestic and Russian developments in the field of materials science of special wear-resistant materials to enhance the contact surfaces of aircraft turbine engine blades was carried out.

2. The highest durability of pressed powder-based alloys doped with cobalt and titanium carbide can be predictive of high tribological properties under operating conditions.

References

1. Contsouradis D., Davin A., Lamberigts M. Cobaltbased superalloys for application in gas turbines. //Mater. Sci and Eng. –1987. – v.88. – P.11–19.
2. An Encyclopedia of Metallurgy and Materials. C.R. Tottle. –1985. –Table 9.
3. Патент РФ RU 2112069. Литейный жаропрочный сплав на основе никеля Копылов А.Г.; Дубровский В.А.–Опубл. 27.05.1998.
4. Патент РФ RU 2081931. Литейный жаропрочный сплав на основе никеля Копылов А.Г.; Дубровский В.А.; Батуев В.Н. –Опубл. 20.06.1997.
5. Сорокин Л.И. Аргонодуговая наплавка бандажных полок рабочих лопаток из высокожаропрочных никелевых сплавов //Сварочное производство. – 2004. –№7. – С. 36–39.
6. Пейчев Г.И., Шурин А.К., Замковой В.Е., Калашников Г.П., Андрейченко Н.В. Разработка и внедрение высокотемпературного износостойкого сплава для упрочнения бандажных полок лопаток двигателей. //Технологические системы. – 2000. № 3(5). –С. 58–60.
7. Патент України № 8240А. Сплав на основі кобальту. Шурін А.К., Дмитрієва Г.П., Черепова Т.С., Андрійченко Н.В., Івщенко Л.Й. –Опубл. 29.03.1996; Бюл. № 1.
8. Петрик И.А., Перемиловский И.А. Дальнейшее развитие технологии упрочнения бандажных полок лопаток турбины из жаропрочных сплавов //Технологические системы – 2001. №3 – С. 90–92.
9. Пат. № 39450 України. Сплав на основі кобальту. Шурін А.К., Черепова Т.С. та ін. – Опубл. 25.02.2009.
10. Патент України № 102213. Ливарний сплав на основі нікелю. Дмитрієва Г.П., Черепова Т.С. – Опубл. 10.06.2013; Бюл. № 8.
11. Войтович Р.Ф. Окисление карбидов и нитридов. – Киев. – Наукова думка. – 1981.
12. Патент України № 92883. Сплав на основі кобальту. Черепова Т.С., Дмитрієва Г.П., Андрійченко Н.В.– Опубл. 10.12.2010; Бюл. № 17.
13. Суперсплавы. – Москва. – Металлургия. – 1995.

UDC 539.538 (045)

M.S. Khimko, postgraduate (NAU, Kiev)

WEAR RESISTANCE OF VACUUM-ARC AND ELECTROPLATED COATINGS IN THE CONDITION OF FRETTIN-CORROSION

Compared experiments on the wear resistance of vacuum-arc and electroplated coatings of chromium and molybdenum were carried out. The experiments were conducted in the medium of hydraulic liquid АМГ-10. It was determined that the most wear resistant coating is vacuum-arc coating of chromium.

Introduction

Vacuum arc coating is a physical method of coating (thin film) in a vacuum, by condensation on the substrate (product detail) material of plasma flows that are generated at the cathode target in the cathode spot of high-current vacuum arc of low-voltage discharge that is exclusively developing in material parts of the electrode.

The method is used for the application of metal, ceramic and composite films for various products.

Vacuum arc evaporation process begins with ignition of vacuum arc (characterized by high current and low voltage) that forms on the cathode surface (target) one or more point (ranging in size from several microns to tens of microns) emission zones (so-called "cathode spots") in which all power of discharge is concentrated. Local temperature of the cathode spot is extremely high (about 15,000°C), which causes intense evaporation and ionization of cathode material and appearance of high-speed (up to 10 km / s) plasma flows propagating from the cathode spots in the surrounding area. Separate cathode spot exists only for a very short time (microseconds), leaving on the cathode surface the characteristic microcraters, then it happens self-extinction and self-initiation of a new cathode spot in the new field at the cathode, close to the previous crater. Visually, this is perceived as a moving arc over the surface of the cathode.

In the vacuum arc cathode spots it is focused extremely high density power, resulting in a high level of ionization (30-100 %) which results in generated plasma flows, consisting of multiply charged ions, neutral particles, clusters (particulate drops). When during the evaporation process the vacuum chamber is introduced with reactive gas by reaction with the plasma stream it can be its dissociation, ionization and excitation, followed by passage of the plasma-chemical reactions with the formation of new chemical compounds and their deposition in the form of a film (coating).

The purpose is to determine the ability to resist the wear of chromium and molybdenum vacuum arc coatings with the aim to replace electroplating in engineering and aviation industries.

Methodology of performing tests. Tests on fretting corrosion were carried out on the installation which simulates vibration МФК-1 according to the contact scheme plane-plane. The essence of the method is that the movable cylindrical sample (contra-sample) in contact with the fixed end of a cylindrical sample at a given pressure, driven by reciprocating rotary motion with specified amplitude and frequency.

Studies were performed at a load of 20 and 30 MPa. The oscillation amplitude was 130 microns. The oscillation frequency remained constant at 30Hz. Tests base corresponded to 500 thousand cycles. Temperature of the samples at the beginning of the experiment was equal to 293K. Research in the studying of changes in linear wear and wear rate of the coatings were carried out in air at dry friction and also in the hydraulic fluid АМГ-10.

The sample is a cylindrical roller with a diameter of 20 mm, made of titanium alloy BT-22 with the coating of chromium and molybdenum. Contra samples for tests were made of steel 95X18.

Wear was measured by the fixed linear pattern, using a vertical type optimeter ИКВ for a predetermined number of cycles, the value of which is determined by the wear resistance of the material tested. Number of experiments was three for each experiment.

Results of experiment

The test results of vacuum-arc and electrolytic coatings fretting resistance are shown in Table 1.

Table 1

Linear wear of coatings in terms of fretting corrosion in hydraulic liquid АМГ-10

Coatings / P, MPa	BT-22	Cr solid	Cr soft	Mo	Cr gal
20	15,10	0,1	2,5	4,8	0,3
30	22,9	1,4	6,7	6,5	4,1

Durability histograms of vacuum-arc and galvanic coatings in the condition of АМГ-10 is represented in Fig. 1.

Analyzing histograms we can say that durability of all tested materials on pure titanium alloy BT-22 in АМГ-10 conditions differs.

Durability data of vacuum-arc and galvanic coatings are proportional to durability of titanium alloy BT-22 during testing in АМГ-10 conditions. It can be possible to make the conclusion that for coating durability determination the researches are ought to be done in АМГ-10 conditions.

It is necessary to mention that durability of all tested materials in the condition of АМГ-10 is high. But such coatings as soft chromium and galvanic chromium during the testing with lubricant АМГ-10 at loads of 30MPa showed great durability than in comparison with loads of 20 MPa. That is because of fretting-corrosion testing in soft chromium we can observe the layer oxidation and also oxidation of the sample 95X18 with appearance of fine-dispersed oxides from black to red colors (Fe_2O_3) that appeared like roller bearings for the friction pair.

All in all it is necessary to say that during testing the greatest value of durability showed such materials as solid vacuum-arc chromium and galvanic coatings of chromium. Vacuum-arc soft chromium and molybdenum showed the worst results in АМГ-10. Also we can mention that durability of galvanic chromium during testing in АМГ-10 condition at loads of 30 MPa is worse in comparison with loads of 20 MPa. Its durability increased in 12 times. It can be connected with the fact that the lubricant condition does not undergo the sample pressure and the gripe appearance. As a result of which it can be seen the dug on the chromium surface of the sample.

The most acceptable from all coatings are the vacuum-arc chromium and solid chromium. Its durability is commensurate with galvanic chromium durability and in some cases it is even greater. So, during testing of vacuum-arc solid chromium in the condition of АМГ-10 at loads of 20 MPa practically had not got the wear.

Titanium alloy BT-22 during testing in the conditions of АМГ-10 showed the classical durability results. Usage of the АМГ-10 condition decreases the durability of titanium alloy in 3 times. It is connected with the fact that titanium alloy BT-22 is very inclined to grip. In the process of testing the condition of АМГ-10 didn't not allow the surface to oxide. Thereby there is the lubrication of titanium alloy specimen surface and the friction titanium to titanium appeared. So, the effect of selective transfer appeared.

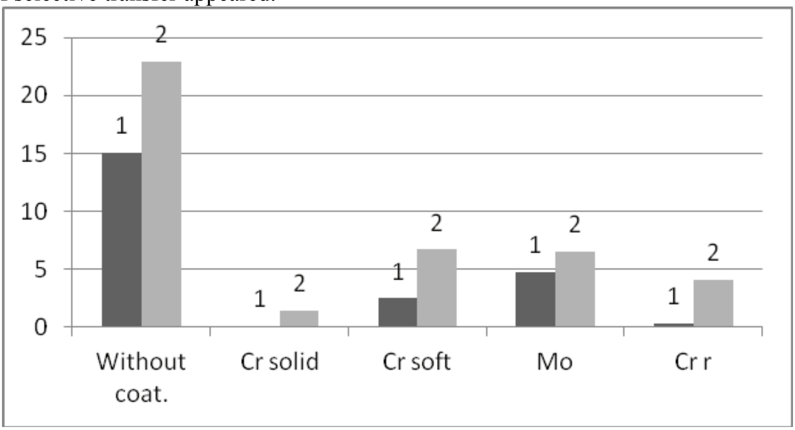


Fig. 1. Dependence of linear wear of the vacuum-arc coatings in hydraulic fluid АМГ-10: 1.-Under load of 20 MPa. 2.-Under load of 30 MPa.

Analyzing the durability of material BT-22 and coatings in fretting condition in surrounding of the hydraulic liquid АМГ-10, we can say that galvanic chromium coating with a thickness of 12-24 microns has shown the most wear resistant characteristics as in the tests at 20 MPa and 30 MPa. Friction tracks of this coating remained practically smooth along all the control sample contact. Only just at loads of 30 MPa tears of electroplated chromium coating appeared in some places of the contact as a result of seizure with counter-specimen 95X18.

When wear of galvanized chromium coating on titanium alloy BT-22 takes place, and then intensity of wear sharply increases due to increased influence of titanium alloy to seizure with control sample.

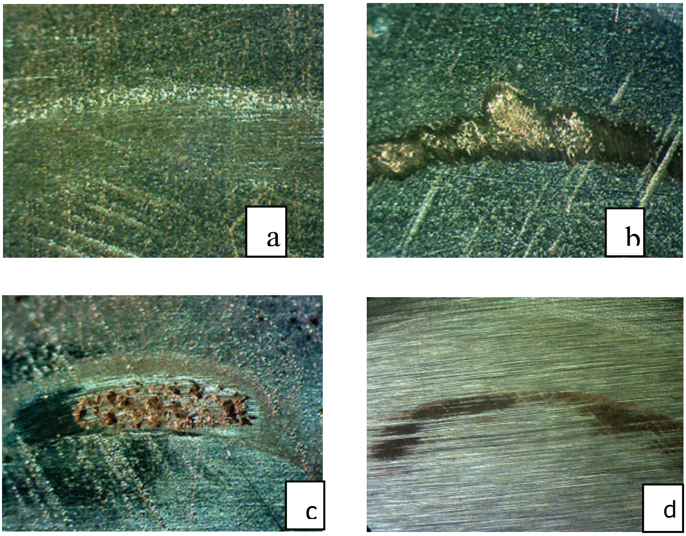


Fig. 3. Friction tracks of coatings with steel 95X18 in the condition of AMГ-10, load-20 MPa: a-solid vacuum-arc coating of chromium, b-a soft vacuum-arc coating of chromium, c- molybdenum coating, d- galvanic coating of chromium.

Conclusions. 1. Wear resistance of vacuum-arc coating and electroplated coatings on the titanium alloy BT-22 is high enough with the clause on the fretting-corrosion in the hydraulic liquid AMГ-10. The same effect can be observed both with the loading of 20 MPa and 30 MPa. More soft and viscose base of the titanium alloy BT-22 is able to absorb (damp) more micro impacts, which distribute under the friction.

The surfaces of the testing experience impulsive (vibrating) loadings, due to which on the surface layers the calmed down waves of deformation are spread. Mechanical energy, which is submitted by the external friction, is transferred to the material of the coating with a help of mentioned above waves, and is explained by the inelastic phenomena and characterized ability of BT-22 alloy irreversibly dissipate the energy of mechanical fluctuations and transform it on the heat.

2. The most wear resisted coating among tested is electroplated coating of chromium. In some cases wear resistance of solid vacuum-arc coating of chromium (under loading of 20 MPa) is even more than electroplated, but low strength of adhesion of the solid chromium leads to the sharp destruction of the surface with the increasing of loading.

3. The vacuum-arc coatings of the soft chromium and molybdenum showed practically the same bad wear resistance results in the condition of fretting-corrosion. It is recommended to decrease the usage of these types of coating for the details that work in the hydraulic liquid AMГ-10, in the condition of fretting-corrosion and friction-sliding.

UDC 621.793:62-5:686.4

N. Miedviedieva, Ph.D, O. Radko, Ph.D (NAU, Kyiv)

FORMATION OF WEAR RESISTANT SURFACE LAYERS QUALITY BY ELECTRIC-STRENGTHENING OF SPRAYED COATINGS

The quality criteria of wear-resistant coatings are considered. The algorithm of consistent actions to obtain high quality coatings made by the complex technological method ECSSC (electrocontact strengthening of sprayed coatings) is proposed. Ishikawa diagram is plotted which allows to identify the causes of the quality criteria impairment of wear-resistant coatings obtained by the combined technology.

Introduction. The quality of the product can be considered as a major motivation for its purchase undercompetitive conditionsas well as one ofthe factorsof its competitiveness.Market requires competitive technologies that would provide appreciable effectprovided their own low cost and complexity.Development of new manufacturing methods to improve wear resistance and durability of machine parts is a priority of modernmechanical engineering.Among resource-saving technologies coatings play a very important role, becausein many cases it is not necessary to harden the whole machine part and is enough to make acoating layer with required properties. Coatings made by electrocontact strengthening of sprayed coatings method (*ECSSC*) allow to increase wear resistance, heat resistance, corrosion resistance, fatigue strength,etc.,due to changing the material conditiononthe surface.However, the problem of quality assessing is not sufficiently studied, because currently there is no complex quality assessing of the coatings obtained by the combined technology and the quality of coatings is determined by single properties.

Problem statement. The objective of this paper is to obtain qualitycoatings made by combined technology.

Discussion of results. Making coatings that ensureserviceability of machines and equipment undercritical conditionsof operation provides prerequisites for significant advance in the development of many branches of national economy. Among various coating technologies nowadaysthe gas-thermal spraying methods have found the widest application.

It is known that among various gas-thermal spraying methods the electric arc metallization (EAM) one is the cheapest and simple method of making coatings requiring no expensive equipment.In addition, EAM method is characterizedby high productivity, insignificant thermal influence on a machine part, technological flexibility of using parts of various sizes.

Using traditional methods of implementing schemes of gas-thermal spraying allows to forma coating that meets the needs of many repair industries [1]. However, the quality parameters of these coatings are not always adequate to the increased requirements of the operating characteristics of machine parts engaged in intensive manufacturing processes.

Under these conditions possible ways of improving the quality of coatings made by electric arc metallization and expansion of its rational use are search for new methods that allow us to make a qualitative breakthrough in the properties of wear-resistant coatings.

High wear resistance, hardness (microhardness) and other properties of coatings can be providedby the methods such as thermo- or thermomechanical strengthening. Using a combination of spraying technologies followed by thermomechanical strengthening opens great opportunities to create high quality protective coatings [2].

Realization of electrocontact strengthening after electric arc metallization allows to geta hardened layer composite structure of relatively large thickness on the surfaces of the "shaft"- type parts.

The combined technology results in an increase in physical and mechanical properties, operating characteristics of restored surfaces and simultaneous reduction of modes parameters both of spraying and electrocontactstrengthening. This increases the adhesion of the coating to 200 MPa, the porosity is reduced to 5...3%,operating characteristics, wear resistance, durability and reliability of machine parts are improved. Large thickness of the hardened layer up to 3 mm allows to use the method of maintenance size during further repairs of these parts [3].

The strengthening process of sprayed coatings is provided by the combined action of temperature that does not exceed 0.8 ... 0.9 melting temperature, pressure and high heating rates. The main advantage of electrocontact strengthening process is the maximum reproducibility of mechanical properties of coatings.

Depending on the purpose, operation conditions, reliability and durability of using machine parts quality requirements are determined.It is necessary to have understanding ofbasic properties of the wear-resistant coatings, such as mechanical, physical, safety, fatigue characteristics, etc.

The criteria of wear-resistant coatings quality are low porosity of the coating, high hardness (microhardness), adhesion and cohesion strength of coating, as well as the elastic modulus and Poison's ratio.

The quality control of coating envisages control in preparation of surfaces before coating as well as during application and after coating obtaining.

To provide coatings quality made by the combined technology the algorithm of consistent actions has been developed and proposed (Fig. 1).

The statistical method is one of the most effective components of the integrated system of products quality control. Statistical methods for products quality control are now becoming increasingly popular and are commonly accepted in the industry.

These methods of quality management are based on a systematic approach that consists inconsideration of all events, phenomena and processes interconnection in their interrelationship, setting priority, work on causes rather than effects, regularity, getting any case to its logical conclusion.

The solution of the problem of quality assessment should begin with finding the key cause, i.e. identifying the main causes of defects and their appearance.It is therefore proposed to build up cause-effect diagram that allows to identify the most significant factors affecting the coating quality.

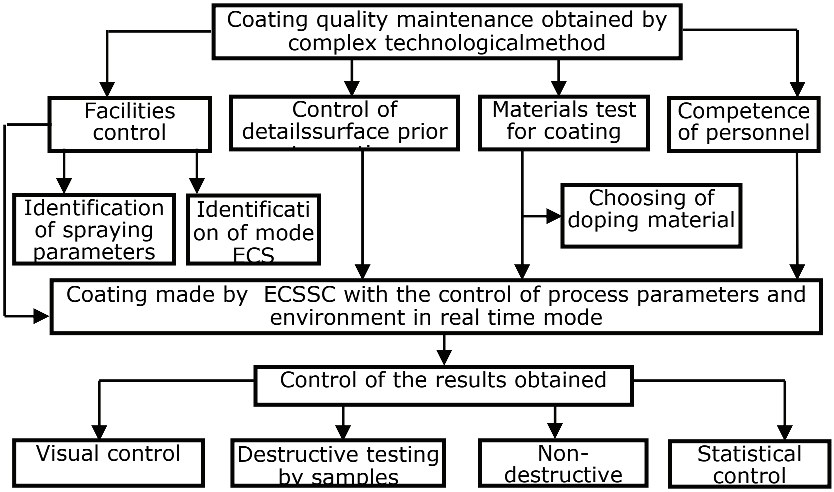


Fig. 1. Algorithm of consistent actions to ensure quality of coating made by complex technological method

If during the manufacturing process of coating application the quality of the modified surface layer proved to be unsatisfactory, then at some point there had happened deviation from the given conditions. For creation of quality wear-resistant coatings it is necessary to make the most important quality parameter comply with various cause factors.

In plotting Ishikawa diagram the most important external factors from technical perspective have been chosen (Fig. 2).

On the basis of developed Ishikawa diagram we can analyze and identify the causes that lead to the deterioration in the quality particularly of physical, mechanical and operational properties of the coating obtained by the complex method of technology ECSSC. Of all the possible causes we need to identify the most significant one and decide what action should be taken to prevent it in the future.

The restoration process of worn machine parts is a complex multifaceted problem whose initial solution requires consideration of a great number of different data, interrelationships, interaction laws which requires the use of modern information technology, one element of which is statistical processing of information. This will significantly improve the quality of the coating along with economic efficiency.

Conclusion.

The proposed algorithm of a sequence of control measures allows to provide the necessary quality of coatings made by the complex method of technology ECSSC. The use of the developed Ishikawa diagram makes it possible to determine the most important causes that lead to the deterioration of values of quality criteria of wear-resistant coatings and to timely propose measures for their elimination.

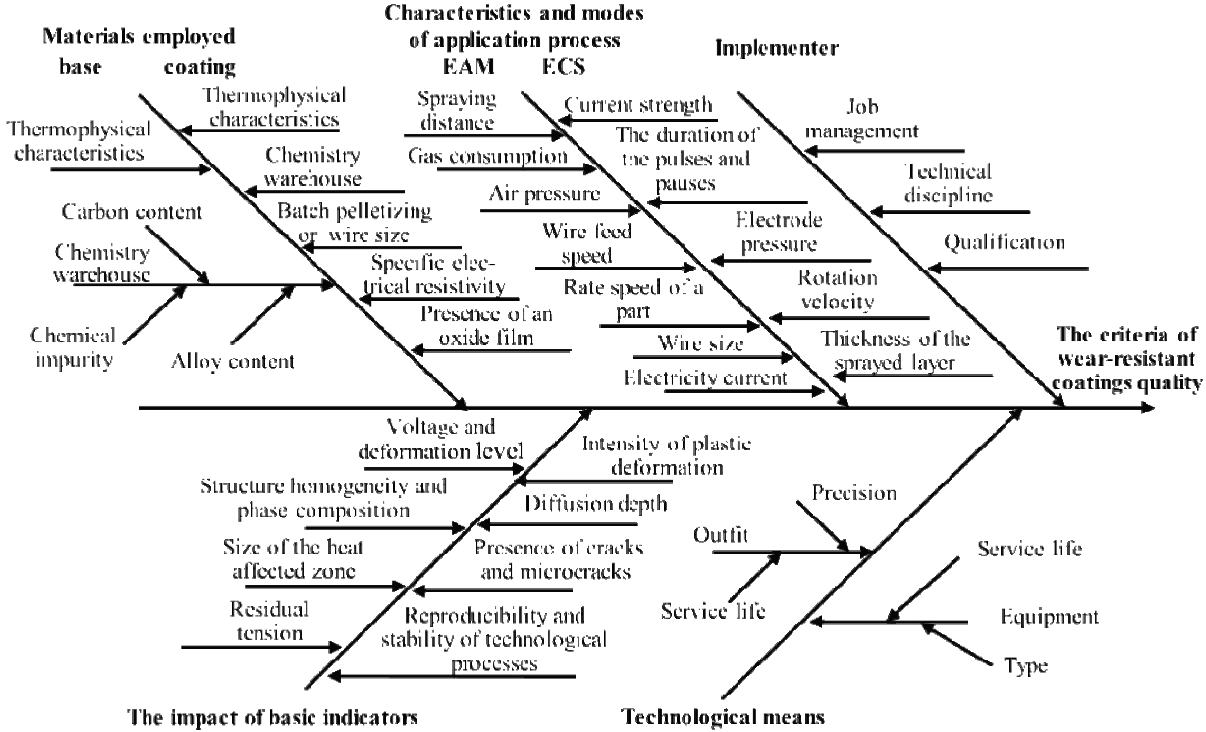


Fig. 2 Ishikawa diagram

References

1. *Посвятенко Е. К.* Електродугова металізація як спосіб ремонту та інженерії поверхні автомобільних деталей, вузлів та агрегатів / Е. К. Посвятенко, І. К. Римаренко, Л. А. Лопата, Н. А. Савченко // Системні методи керування, технологія та організація виробництва, ремонту і експлуатації автомобілів: зб. наук. прац. – К.: НТУ, 2002. – Вип. 15. – С. 186-190.
2. *Лопата Л. А.*Основные направления получения качественных износостойких покрытий методом электродуговой металлизации / Л. А. Лопата, Н. А. Савченко // Инженерия поверхности и реновация изделий: межд. научно-техн. конф., 28 – 30 мая 2002г. Крым, Украина : тезисы докл. – К., 2002. – С. 98-100.
3. *Лопата Л. А.* Влияние технологических факторов электроконтактногоприпекания на формирование напыленного порошкового слоя / Л. А. Лопата, Н. А. Медведева, В. Н. Кулижский // Конструювання, виробництво та експлуатаціясільськогосподарських машин: зб. наук.праць. – Кіровоград: КНТУ, 2005. – №35. – С.417-420.

UDC: 620.168 (045)

V.M. Shmarov, d.t.s.,. V.F. Labunets PhD, O.V. Samkov d.t.s., (NAU, Kiev)
I.A. Kozlova, d.b.s.
(Zabolotny Institute of Microbiology and Virology, NAS Ukraine, Kyiv, Ukraine)
R.Y. Belevtsev, d.g-m.s
(Institute of Geochemistry earth environment NAS Ukraine, Kyiv, Ukraine)

BIOGEOCHEMICAL ASPECTS OF TRIBOLOGY

A study of tribotechnical properties of materials covered by the layer of bio-induced material was studied. The new direction of tribological material science is proposed – tribobiomineralization

The capacity of knots of friction of modern technique is provided by development of new wearproof materials and coverages, which own high antifriction properties, and also modification of workings surfaces of details of tribosystem.

We will mark, that in modern tribology, as in the area of knowledges and its use, it is possible to select six major perspective scientific directions which develop intensively, like as : 1) tribo analysis; 2) tribomonitoring; 3) tribotekhnology; 4) (trybological material science); 5) tribotechnology; 6) triboinformatics [1]. Inspite of a large value of each of these directions, for technologists the most scientific and practical interest is presented by directions of tribotechhnology and trybological material science. Scientists, which work in these directions engaged in the study of tribotechnical materials and management of them physical-technological by properties, and also development of new technological methods of the superficial strengthening and overcoating, on the workings surfaces of details of triboknots and toolpieces. Perspective direction of increase of tribological properties of contacting surfaces of tribosystems is their biomineralization.

General term biomineralization belongs to biologically induced mineralization at which an organism is modified by the local microenvironment, forming terms for the chemical besieging of mineral phase out of cages. Most it appears the result of oxidization or proceeding in the components of nourishing environment which is carried out some types of microbes formative biomineralizative product [2]. Creation of biofilms on the workings surfaces, which contain sulfides, nitrids, phosphides, selenides and other allows to promote antifriction properties of friction knot. Because of it to lubricating materials add additives which contain the indicated compounds. However such methods of modification of lubricating materials not always have a positive effect Up-to-date development of biotechnologies perspective is the use of biofilms, different materials formed on surfaces. Biofilms – high-well-organized, and at organization biological structures which optimize the vital functions. Biofilms, which are formed the bacteria of cycle of sulphur, nitrogen and iron, on the surfaces of construction materials, capable to modify their workings surfaces due to biological minerals, such as element sulphur, sulfides, phosphides and other

The analysis of literary sources rotined that the offered technology of tribomineralization of the surfaces of elements of tribosystem appeared the newest and the analogues of which do not exist for today.

Essence of this technology consists in that, that biofilms which are formed on-the-spot construction materials appear the place of co-operation of bacteria with metals and their alloys that by the place of flowing of biological processes.

One of displays of activity of biofilms on-the-spot metals is microbal corrosion [3]. It is accompanied by the processes of biomineraliztion, that by formation of products of corrosion, which depending on ecological terms can be oxides or picked up thread connections, for example, by sulfides

Research in industry of biomineralization, being on the nature widely interdisciplinary, instrumental in rapprochement of many heterogeneous areas, for example such, Colloid and biochemistry, physical chemistry of surface, biophysics, tribology, clusters and aerosols, powder nanotechnology, computers.

Connections of microorganisms, which are able to register, metabolize and form associative colonies with other organisms it is accepted to name "biofilms". Using the modern methods of researches, scientists came to the conclusion, that biofilms show by itself a complex well-organized union which forms the so called micro-colonies. Colonies in the mid permeated by canals and channels designed to circulate nutrients, metabolites, gases, signaling molecules, etc. [6].

Biofilms are complex microbial compounds whose cells as microcolonies growing in ekzo polymeric matrix associated with the surface.

In the thickness of matrix the products of co-operation of bacteria accumulate with metals as biominerals of such as selenides, molybdenites, sulfides, element sulphur but other So, for example, the last biominerals appear in the process of microbal transformation of sulphur of sulfat-recovery (SR) and carbothionic (CT) bacteria. Characteristically, that sulfides can appear both crystalline and amorphous, that it is very important for the decision of tribological problems.

A necessary condition for tribological studies is the selection of crops sulphate bacteria (SRB), which are characterized by minimal aggressiveness. In Table. 1 shows the characteristics of CSR, which indicate the possibility of their use in trybosystems.

Table 1.

The aggressiveness of sulfate-reducing bacteria

Object of research	The production of hydrogen sulfide, mg / l	Corrosion rate, h/m2/hod
Desulfovibrio desulfaricans Kyiv-45	325 ± 5,1	$9{,}0?10^{-2}$
Desulfovibrio indonensis Indonesia	-	$2{,}9?10^{-1}$
Desulfovibrio desulfaricans Alaska	-	$2{,}7?10^{-1}$
Desulfovibrio sp.10	291 ± 4,4	$2{,}5?10^{-1}$

By researches conducted in Institute of geochemistry of earth and environment of NAN of Ukraine and in Institute of microbiology and virology of NAN of Ukraine at the study of microbal corrosion of steel in the process of development of biofilm of SVB found out formation of thin tape of pirotyn (FES), which densely adjoins to the surface of steel and can be examined as a reliable factor of its modification.

Will mark that pirotyn can carry out a double role, namely: protector or corrosive aggressor. Thin, densely adjoining, freely located tape appears in first case. In the second is thick uneven, freely located, tape which becomes an anode

The thermodynamic parameters of chemical reactions in the formation of biofilms varies widely and depends on the physico-chemical properties of materials on the surface of which biofilms are inflicted.

The analysis of the getting results testifies that in the structure of biofilm at certain terms is possible to get molybdenite which is used in the knots of friction in quality of hard butter. Researches [7,8] are conducted by us rotined that biogenic forming of nanoparticles (MoS_2) and other matters (connections of sulphur, chlorine, phosphorus) executing ability the function of hard butter, to form the second structures, hinder development of processes of fight and provide high antifriction properties of tribological joints.

In addition, biofilms can improve Tribotechnical characteristics of protective coatings that are used to enhance the durability of parts and components of friction.

Conclusion. Tribebiomineralization – is a promising direction of increasing the tribological properties of friction units of parts and tooling.

References

1. Tribology: [Tutorial] / M. Kindrachuk, V. Labunets, M. Pashechko, E. Korbut. Publisher NAU "NAU - print" 2009-392p;
2. Labunets V. Trends Protective structures Tribological / V. Labunets / / Problems of friction and wear. - K.: NAU, 2006. - Issue .45. - P. 107-118;
3. Microbial corrosion and its activators / E. Andreyuk, V. Bilai, E. Koval, I. Kozlova.-K. Scientific Thought, 1980.-288s;
4. Belevtsev R. About new technologies modification tribosystems reduced friction on the surface of aircraft alloys at biomineralization / R. Belevtsev, S. Spivak, V. Labunets etc. / / Environmental Security: Problems and Solutions. Scientific-Technical Collection. , Kharkiv, 2012.-T.2.-p212-216;
5. Labunets V. Formation of secondary structures of friction in terms of microbial corrosion / V. Labunets V. Lazarev, I. Kozlov, R. Belevtseva / / Problems of friction and wear. - K.: NAU, 2010. - P. 116-119;
6. Kudrin A. Microbial surface modification of materials / A. Kudrin, V. Labunets, V. Lazarev, etc. / / East European Journal of advanced tehnologiy.- Kharkov, 2005. - № 5/1 (17)., P.68-75;
7. Labunets V. Bacteriogenic products using for increasing performance capabilities of the detonation coatings / V. Labunets, V. Lazarev, E. Korbut, T. Klimova, I. Kozlova // The Fourth World Congress “Aviation in the XX–st century“: “Safety in Aviation and Space Technologies“, September 21-23-K.: NAU, 2010.-P. 1355-1358;
8. Synthesis of biological materials for tribological Materials / V. Labunets, T. Klimova, V. Lazarev / AVIA-2006: International Scientific Conference abstracts ext. - K., 2006. - T2. - P. 388-390.

UDC: 621.793:62-5:686.4

O. Radko, Ph.D, V. Labunets, Ph.D, L. Bratitsa, V. Zagrebelnyi (NAU, Kyiv,)
O.V. Andreev, Ph.D (SE «Antonov», Kyiv, Ukraine

TRIBOLOGICAL PROPERTIES OF POLYMER COMPOSITE MATERIALS

A study of tribotechnical properties of materials covered by the layer of bio-induced material was studied. The new direction of tribological material science is proposed – tribobiomineralization.polymer composites. It was established that under sliding friction without lubricant best resistance to wear demonstrated Sustadur PET GLD 130, and abrasion wear the most durable material in the way of friction is 50 m PET, and for 200 m - Sustamid 6G and Sustapeek natural.

Introduction. The constant increasing of demands for reliability and durability of structural elements of modern aviation technology stimulates the development of new materials with enhanced physical, mechanical and performance properties. One of the most promising are considered polymeric composite materials (PCM), due to their properties such as low weight compared to metals; good strength; high durability in a pair of metal; resistance to vibration; high corrosion resistance, etc. [1].

Due to the wide range of possibilities for varying compositions bases and fillers is created many new PCM, but their widespread adoption in aircraft production constrained by the lack of experimental data on the performance properties of newly created PCM. Therefore, studies of the determination of the properties of the particular durability is an actual problem.

Problem statement. The aim of the study is to determine tribotechnical properties of polymer composites.

Discussion of results. PTP test was performed under conditions of sliding friction without lubricant and abrasive wear.

Tribological characteristics in the first case were determined on a friction machine [2]. Studies conducted in the following conditions: force pinning - 100 ... 400 N; sliding speed - 0.4 m / s; way of friction - 1000 m

Sample size 5h10h10 mm with different PCM (Zellamid 900 (POM - polioksymetylen); Zellamid 202 MO (PA6 + MoS2 - Polyamide (Nylon) 6 modified by molybdenum disulfide), PE-1000 Polystone M (superhighmolecular polyethylene); Sustadur PET GLD 130 (polyethylene terephthalate)) snuggled up roller-counterbody diameter of 40 mm steel 45 (GOST 1050-74), heat treated to a hardness of 50 ... 52 HRC. Worktop counterbody after grinding roughness was Ra = 0,25 ... 0,35 mm. Contact the friction pair occurred in a "drive-block." To this end, the working surfaces of samples were carried out in the form of concave cylinder with a diameter of 40 mm.

While research continuously measured and recorded friction force Ftr. The coefficient of friction was calculated as the quotient of the friction force Ftr efforts by pressing R.

For comparative assessment of durability PTP was calculated by weight in the intensity of wear kg/cm2 at 1,000 m path of friction. Weighing was carried out on laboratory analytical balance VLR 200.

Abrasive wear tests were carried out at the facility [3], which is used for the comparative evaluation of durability of materials and coatings in friction under conditions of non-rigid fixed abrasive particles (GOST 23.20879) [4] in the medium quartz sand ($SiO2$) grain size of 120-160 microns. Wear was determined gravimetrically on electronic scales to the nearest 0.0001 g, and the width of the track, which was formed during wear.

Admitted to the research method for determining the wear resistance coincides with the American method of standard ASTM S6585.

The results of the research in terms of friction without lubricant are shown in Fig. 1-3

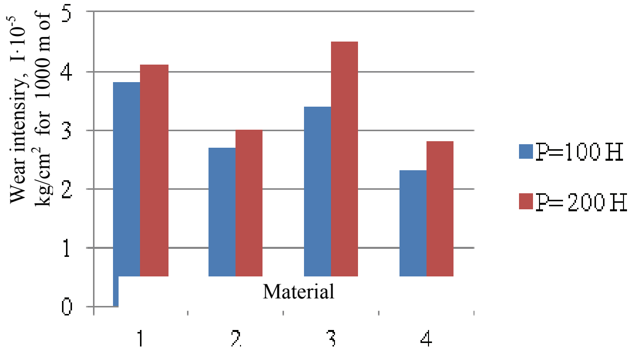


Fig. 1. results of testing of PCM with no lubrication at sliding friction. The load P = 100 N and P = 200 N, friction speed V = 0,4 m/sec, path of friction *L*=1000 m: 1 - Zellamid 900; 2 - Zellamid 202 MO; 3 - PET-1000 Polystone M; 4 - Sustadur PET.

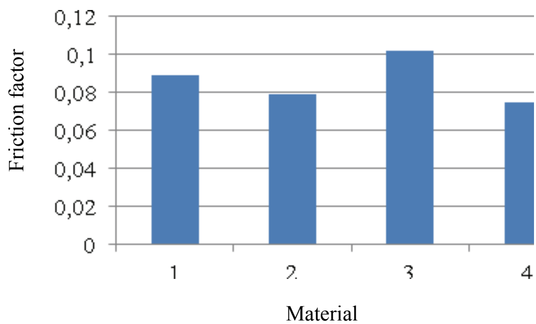


Figure 2 - coefficient of friction for materials when tested under conditions of sliding friction without lubricant in an effort to clamp P = 200 N and sliding velocity V = 0,4 m / s in the way of friction L = 1,000 m: 1 - Zellamid 900; 2 - Zellamid 202 MO; 3 - PE-1000 Polystone M; 4 - Sustadur PET.

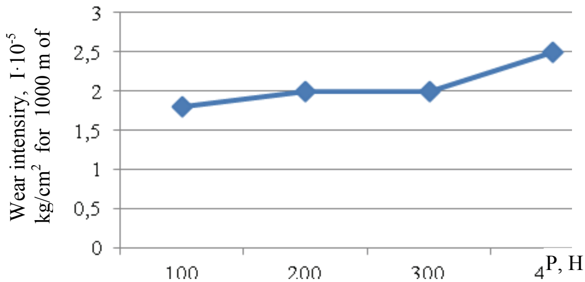


Figure 3 - Dependence of friction in the track width with the force P of test material Zellamid 202 MO in terms of friction without lubricant at the sliding speed V = 0,4 m / s in the way of friction L = 1000 m

Analysis of the results leads to the following conclusions:

1. The best resistance to wear demonstrated Sustadur PET GLD 130. Wear intensity amounted 2,3 • 10-5 kg/cm2 at 1,000 m of path of friction. Then (in descending order of durability) materials are located as follows: Zellamid 202 MO, PE-1000 Polystone M, Zellamid 900, the difference between the best and worst of 1.7 times.

2. Values of the coefficients of friction studied PCM in an effort to clamp P = 200 N and sliding velocity V = 0,4 m / s lie in the range 0.079 ... 0.102, and the difference between best and worst is slightly smaller than the width of the tracks when determining friction - 1 4 times. The order of the material on the criterion of an increase in friction coefficient is similar to their order by increasing the wear rate.

3. During the same speed sliding with increasing load from 100 N to 200 N resistance to wear material Zellamid 202 MO at first slightly increases (10%), followed by the 200 N to 300 N is constant, but after 300 H and 400 H increases more intensity (20%). This behavior of the material can indicate the presence of certain optimal for him given the maximum wear resistance range of operating loads and sliding speeds for different materials and these ranges may vary.

Analysis of the results of the tests on the abrasive wear of medium quartz sand (SiO2) 0.5 grain (Fig. 4) showed that the PET material is characterized by the gradual increase in minor wear to the friction value by 150 m, and then - a sharp increase in depreciation of 2 5 times on the way friction 200m reason for this tribological behavior Pat processes can be mechanical and thermal degradation, which occur in the surface layer of the material with increasing time trials and lead to seizure.

For the material Sustamid 6G amount of wear on the friction path of 50 m is somewhat larger than in PET, an increase of 100 m is more intense and the larger values (0.0067 g Sustamid 6G against 0.0044 g PET), but on the way friction 200m wear increases less rapidly and to lower values (0.0131 g Sustamid 6G against 0.0153 g PET).

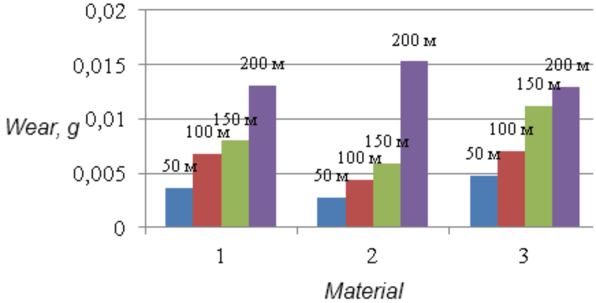


Figure 4 - Results of tests on the abrasive wear of medium quartz sand (SiO2) granularity of 0.5: 1 - Sustamid 6G; 2 - PET; 3 - Sustapeek natural.

Tribological behavior of materials Sustapeek natural for these test conditions a more uniform and smooth growth path with increasing wear of friction compared to the first two materials.

In general, we note that most durable material for these test conditions on the path of friction is 50 m PET, and for 200 m - Sustamid 6G and Sustapeek natural. Uneven growth amount of wear at the same time increase testing for a variety of composite materials shows the influence of structural and phase composition of the surface layers in friction and wear.

Test results on abrasive wear among alumina (Al_2O_3) (Fig. 5) revealed similar trends:

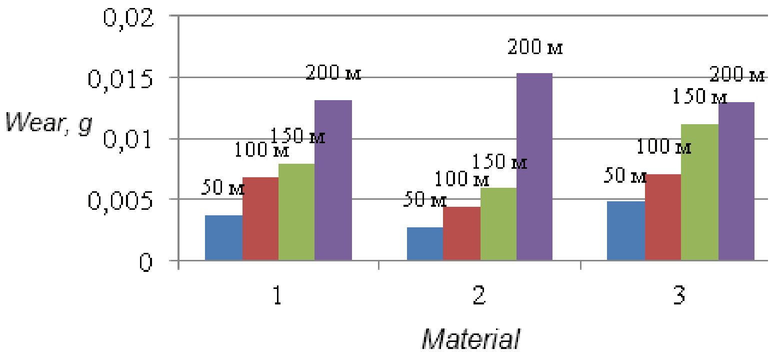


Figure 5 - Results of tests on abrasive wear: 1 - Sustamid 6G; 2 - PET; 3 - Sustapeek natural.

slight gradual increase of wear of PET material to the value of the friction path of 150 m, and then - a sharp increase in wear 2.6 times on the path of friction 200m; greater than the value of PET material wear Sustamid 6G friction on the path of 50 meters, more intense and significant growth in its na100 m, but less intense and less significant - in the way of friction 200m;

The most uniform increase in size with increasing wear of time trials for the material Sustapeek natural;

The most durable material for these test conditions on the path of friction 50 m is PET, and for 200 m - Sustamid 6G and Sustapeek natural.

Conclusion.

Past studies of tribotechnical properties of polymer composites showed that under sliding friction without lubricant best resistance to wear is demonstrated by Sustadur PET GLD 130, the intensity of wear which amounted 2,3 • 10-5 kg/cm^2 at 1,000 m path of friction. Then (in descending order of durability) materials are located as follows: Zellamid 202 MO, PE-1000 Polystone M, Zellamid 900, the difference between the best and worst of 1.7 times.

In conditions of abrasive wear the most durable material in the path of friction 50 m is PET, and for 200 m - Sustamid 6G and Sustapeek natural.

Further studies of tribotechnical features of a wide range of PCM to determine the optimum operating speeds and loads for specific materials allow technologists and designers at the design stage to select preset conditions such PCM that allow increase the reliability and durability of structural elements of aviation equipment while reducing material costs.

References

1. *Дерек Иренеуш*. Применение полимерных трибологических материалов в авиации / Иренеуш Дерек, В.Ф. Лабунец // Проблеми тертя та зношування. – К.: НАУ, 2012. – Вип.58. – С. 119-127.
2. *Пат. 2*4695 Україна МПК (2206) G01N3/56. Машина тертя / Скуратовський А. К. ; заявник та патентовласник Національний технічний університет України "Київський політехнічний інститут". − № u 2007 02330 ; заявл. 03.03.2007 ; опубл. 10.07.2007, бюл. № 10.
3. *Кудрин А.П.* Исследование износостойкости упрочненной углеродистой стали в условиях абразивного изнашивания / А.П. Кудрин, В.Ф. Лабунец, О.А. Вишневский. – К.: Вісник НАУ, 2003. – № 2. – С. 111 – 114.
4. *ГОСТ* 23.208 – 79 “Обеспечение износостойкости изделей. Метод испытания материалов на износостойкость при трении о нежестко закрепленные абразивные частицы“.

UDC 621.891

M. Kindrachuk d.t.s., J. Khlevna, PhD. (NAU, Kiev)

THE INFLUENCE OF EXTERNAL FACTORS ON THE LAWS OF INITIAL RUNNING IN OF ANTIFRICTIONAL SYSTEMS

This paper presents patterns of changes in the characteristics of the process of running in and the influence of external factors. It is shown that the stepwise increase in load and constant sliding speed augments the running in process, thus decreasing the time and wear as a result of mechanical destruction of oil, accompanied by enrichment of friction surfaces with carbon.

One of the areas of service life increase of friction units is not only the use of materials with high wear resistance, but also to optimize operating modes of tribosystems. Most research works covering the phenomenon on stage of stationary operation, although nearly 70% of depreciations accounts for the phase of running in of tribological systems (TS) at the initial operation [1,2].

During the friction and wear of solids under the influence of external factors and of the friction occurring numerous physical and mechanical processes [3 – 5]. The main factors that determine the physical and chemical phenomena of running in include friction regime, in particular the impact of specific load - P (MPa) and sliding velocity ν - (m / s). It should be noted that the current process of running in surfaces in the presence of the lubricant under regimes that have reduced both the time and the wear of this stage is a matter which is the least studied. The relevance of the research process of running in and the impact of the mode of friction due to the fact that the optimization of this process enhances durability friction units.

The aim of this work is the choice of optimum modes running in phase and investigation of mechanochemical transformation of the microstructure of friction surfaces of steel and bronze in the conditions of the original work - running in of the classical tribological system "БрАЖМц 10-3-1, 5 - АМГ-10 – 30ХГСА."

Tribological investigations under conditions of one-side directional sliding at hydraulic fluid АМГ–10 with kinematic scheme "plane – plane" by an overlap factor of 0.25. The operational parameters are established by the coefficient of variation of the friction force (V). Modes in which the coefficient of variation of the friction force exceeds 40% were not taken into account because it shows the process taken by jamming and bounce on stage of running in.

The surface friction of bronze and steel studied by optical microscopy, scanning electron microscopy and X-ray microanalysis energodispersive, Auger - spectroscopy.

Based on an analytical model of friction and wear characteristics of running in were identified: time and wear and tear on the initial stage [6].

It was established that running in of tribological system 30ХГСА – АМГ-10 - БрАЖМц 10-3-1,5 with a coefficient of variation of the friction force of 10 – 30% is under load P=2,2 MPa. Running in process for a given load is characterised by three periods of the initial work of tribological systems, namely:

- In the first period there is optimization of surface quality, ie. there is mikrogeometrical running in, accompanied by smoothing the surface and which corresponds to the coefficient of variation of 30%. The stage has high wear rate, a strong discontinuity in the gap of oil film in trybocouple. This can prove that the initial stage is dominated by the conditions of intensive wear protective films mild structural component, while the conditions for the release of their surface.

- During the second stage of stabilization it is observed since the friction coefficient of variation is 15%, which helps to strengthen and stabilize the geometrical parameters of the surface. During this period, minor wear, and the friction coefficient reached a minimum value of 0,015 – 0,022, which corresponds to the normal friction operation of bronze – steel pairs.

- Third stage runs up to complete formation of stable quality characteristics related to both surfaces, with a coefficient of variation of 10%. Stabilization of variation coefficient of friction is considered as the end of running in. Speed as the load was chosen for handling the coefficient of variation of the friction force and load P = 2,2 MPa, was ν = 2m / s.

Depreciation of running in determined in accordance with the method of [6]. The contribution of running-in process to the wear under load P = 2,2 MPa have reached 52mkm. At the same time running in was 4 hours.

In order to reduce the time of running in, expanding the range of load limiting values, we selected the method of stepwise increasing load (Table 1).

Table 1

Tribological characteristics of running in of БрАЖМц -10-3-1,5 - АМГ-10 - 30ХГСА at speed ν = 2m / s

№	Load, MPa	Running in time, min	Wear, mkm		Path of friction, m	Coefficient of friction
			Bronze	Steel		
1	2,2	240	52	12	28800	0,02 ±0,003
2	2,2+2,8	220	47	9	26400	
3	2,2+2,8+3,1	210	44	7,2	25200	
4	2,2+2,8+3,1+3,7	180	40	6,8	21600	

The initial load was 2.2 MPa and speed of 2m / s. Because of the time (t = 45 min), which tracked according to the coefficient of variation of the friction load pidvyschuvalos one place. For tribological system 30ХГСА – АМГ-10 – БрАЖМц10-3-1, 5, in the first stage of running in V = 30% after 45 minutes of operation when V = 24% of the load was increased to the maximum permissible 2,8 MPa, and the coefficient of variation was 28%, after a time t, the coefficient of variation of the friction force was equal to 21% and then the load was increased to 3,1 *MPa*, respectively, an increase in the coefficient of variation to 25%, and the subsequent decline to 19% and then had a partial load of P = 3,7*MPa*, with a coefficient of variation of the friction force was 24%, a 45-minute experiment, it has stabilized to 14%, indicating the end of the process running in. The final level of stress was 3,7 MPa, since the next stage of 4,5 MPa, the coefficient of variation exceeded 40%, which was accompanied by the appearance of smoke due heating and destruction of tribological structures.

Comparative analysis of the results are given in table. 1 revealed that the efficiency of running in at a constant sliding speed of 2 m / s and stepwise increasing of specific load has a better effect than studies at constant load. Each step of external influence of all cases examined load, reduces the coefficient of variation of the friction force as a result of increasing the actual contact area, the formation of tribological structures at each stage of loading.

Careful study of various areas of friction surface of the pairs bronze-steel, made using Auger microprobing revealed new features formed by surface microstructures generally significantly different from the expected. Suddenly became a conclusion about the absence of a sufficient concentration of copper on the steel friction surfaces in the areas of visual "copper" colour. In all investigated cases, on the friction pair, the concentration of copper in the surface layers of microstructures of steel surface was less than 4,7 at. %. However, the concentration of iron and oxygen in these surface layers reaches values of 36 – 44 and 46 – 54 at. %, Respectively. Even with prolonged spraying of friction the surfaces by argon ions, which contributed significantly to research the surface remote from the interior surface of the metal layers, the oxygen concentration remained relatively high. It was found that "copper" shade on the steel friction surfaces formed in the studied pair of bronze-steel is due to the colour of the surface film of iron oxides layer of submicron thicknesses.

Compared with steel friction surfaces to corresponding mikroareas the bronze in all cases is much less oxidized. Instead, they are areas saturated with carbon, whose concentration remains high within the surface layer of micron thickness and several times higher than the concentration of oxygen.

The second unexpected result was obtained after the analysis of changes in the composition of the surface layers of bronze. Availability in all subjects in micron thickness of the surface layers of bronze along with carbon ions also ions of carbide forming elements: chromium and titanium defunded from steel. However, these surface layers were found with significantly reduced concentrations of "native" bronze БрАЖМц additives such as aluminum and manganese. In contrast, the concentration of these additives in iron was significantly increased. The reasons for the presence of elements of carbide forming elements of steel and high concentration of iron in the "depth" of the surface layers of bronze require more detailed analysis.

Accordingly, on the mikroareas of steel friction surfaces, we observe depletion in chromium and, to some extent, carbon (relative volume concentration of 4,3 – 4,7 atm.%). Within mikroareas which were recorded the presence of chromium, manganese segregation was observed, which, however, can be transferred to the surface layer of steel as well as traces of bronze. The possibility of the latter indicates the presence of some points on the friction surface of steel characteristic to the traces of tin bronze.

According to the results of the Auger analysis of elemental composition of friction surface of pair bronze-steel we observed the carbonization of bronze surface layer under conditions of friction and enrichment by carbide forming elements of steel (Cr, Ti, and Fe) and their traces depleted in bronze (Al, Mn), and oxidized surface layer of steel, however, albeit to a lesser extent, on their own depleted by Cr, C, but enriched by Al, Sn, Mn, and Cu.

Instead of this, there is a mutual transfer of elements to the conjugate surface from one contact area to another without the formation on each of these films the film of the base metal. It should be argued on the formation of friction in the contact zone of relatively thick (micron and submicron thickness) and high concentration of carbon in the surface films dissolving other elements.

Conclusions

Effectiveness of the process of running in is largely determined by the mode of loading. Running in proceeds is more effective at constant sliding speed and step increase in load.

Stepwise loading and simultaneous regulation of frictional heat of friction pair leads to expansion of the maximum permissible load, reducing time and wear from running in.

We found that the resulting tribological structures formed during running in are saturated by carbon, products of mechanical destruction of oils and transfer of positively charged elements from surface to surface.

References

1.Кузьменко, А. Г. Износ узлов трения двигателей при граничной смазке (обзор) [Текст] / А.Г. Кузьменко, О.П. Бабак. // Проблеми трибології. – 2007. – №3. – С. 61 – 93.

2.Кульгавий, Э. А. Триботехнические характеристики и их применение [Текст] Э. А.Кульгавий //Проблеми трибології. – 2003. – № 3. – С. 51 – 61.

3.Дроздов, Ю.Н. Трение и износ в экстремальных условиях [Текст] / Ю.Н. Дроздов, В.Г. Павлов, В.Н Пучков. – М.: Машиностроение, 1986. – 224с.

4.Буяновский, И.А. Развитие трибологии в России [Текст] / И.А. Буяновский // Трение и смазка в машинах и механизмах. Приложение к журналу «Сборка в машиностроении, приборостроении». – 2005. – № 2 (8). – С. 12-18.

5.Мищук, О.А. Легирование поверхности металлов при трении под влиянием органических поверхностно-активных веществ:[Текст]: дис. канд. физ.-мат. наук: 01.04.18/ Олег Александрович Мищук. – К., 1996. – 194с.

6.Кіндрачук М.В. Вплив зовнішніх факторів на закономірності припрацювання антифрикційних систем /М. В. Кіндрачук, Ю. Л. Хлевна, Е.А. Кульгавий, О.І. Духота// Восточно-европейский журнал передових технологий. – 2013. – № 5. – С. 54 – 63.

UDC 678.01

Prof. Dr. Eng. A.I. Burya
Gr. St. O.A. Naberezhnaya
(Dneprodzerzhynsk State Technology University, Ukraine)

SELF-REINFORCED HEAT-RESISTANT ORGANOPLASTICS: ADVANCED MATERIALS OF TRIBOLOGICAL PURPOSE

The properties of self-reinforced organic plastics based on aromatic polyamides have been developed and investigated. It is shown that the optimum fiber content is determined by the proximity of its polymer structure to the structure of the binder. It has been established that in case of the optimal content of reinforced fibers, organoplastics exceed the base polymer by 1.2-1.6 times. An example of using the developed material in the steel industry has been given.

Introduction

Creation, study and use of polymeric composite materials are extremely promising and rapidly developing area of materials science. Modern aircraft, rocket and space technology, shipbuilding, engineering are unthinkable without polymer composites. The more developed this branch of technology is, the more the composites are applied, the higher the quality of these materials is. Many of them are lighter and stronger than the best metal (aluminum and titanium) alloys and their use can reduce the weight of the product (aircraft, missiles, and spacecraft) and, accordingly, reduce fuel consumption. Organoplastics (so-called reinforced plastics based on organic polymer fibers) are used in aeronautical engineering and rocket building for the manufacture of components operating in tension, for example, the internal pressure vessels, high-speed flywheels [1]. The aim of this work has been to develop and study the properties of promising new heat-resistant self-reinforced organoplastic materials.

Methods and subjects of investigation

Phenylone aromatic polyamide C-1 (TS 6-05-221-101-71) was used as a binder; this represents finely divided pink powder with a bulk density of 0.2 - 0.3 g / cm^3 and a specific viscosity of 0.5 % in dimethylformamide solution with 5 % of lithium chloride not less than 0.75, characterized by the following properties: density of 1.35 g / cm ^{3}, toughness of 20 kJ / m^2, hardness of 18 HRB, the tensile breaking stress of 100 MPa.

For the reinforcement of phenylon C-1 heat resistant organic fibers were selected from aromatic polyamides sulfone-T (fiber length of 3 mm, strength of 51-58 kg c/ mm 2, the relative strength of 85%, elongation of 16-18%, modulus of 600kgs / mm^2, resistance bending of 12,000 cycles, density of 1.45-146 g / cm^3, is operational in the temperature range 573-623K) phenylone fiber (2-3 mm long, the strength of 69 kgf / mm ^{2}, an elongation of 15-20%, the elastic modulus of 900 - 1200 kgf / mm ^{2}, density of 1.37-1.38 g / cm ^{3}).

To obtain composite materials the container was charged with a powdery sample of phenylon and crushed fibers, ferromagnetic particles were added produced in the form of cylinders with a diameter of 2 mm and a length of 15mm. The volume was placed into a rotary electromagnetic field (0.12-0.15 T). The resulting mixture was tableted at a room temperature and a pressure of 30 MPa. The tablets were charged in a mold preheated to 523K, heated to 593-598K and maintained at this temperature for 10min, 10min without pressure and under pressure of 30 MPa. To fix the shape of a product, the goods were cooled under pressure to a temperature of 523 K and pushed out of the mold later.

The study of tribological properties under dry friction was carried out at room temperature in a disc drive friction. The wear of the sample was evaluated by the disk layout (steel 45 HRC 50, Ra 0.08) - Thumb composite (Ø 10mm, 10mm height) at the specific load of 0.4-1MPa, sliding speed of 1-2.5 m / s, with the path of 1000 m. Before loading the same processing and pre-burnishing samples was carried out. The wear of the samples was determined by means of an analytical balance VLR-200 with an accuracy of 0.0002 g. The investigation of wear of the reinforced plastic in case of industrial lubrication oil (GOST 1767-51) and distilled water (GOST 6769-72) was performed on a friction machine MI-1M scheme clip-board (video - 45 steel, HRC 45-48, block - reinforced plastic) at a speed of 0.5-1 m / s.

The wear was calculated in three or more test pieces of the same material. Way friction in case of lubrication with water made 400 m, in case of lubrication with oil – 3000 m. Brinell hardness was measured by indentation under a given load on the hardness tester BTSHPSP GOST 46-70-77 and specific toughness, which is a dynamic test of polymers, a single blow bending according to GOST 4647-69. Compressive yield point was determined on a test machine with the mechanical loading of the sample and mechanical force measure, IM-4P.

Electron microscopic studies were carried out with samples of materials that can withstand 3 minutes in liquid nitrogen and then were subjected to brittle fracture. On freshly prepared fracture in vacuum (10-4mm.merc.st.) the carbon film of 500-700 A thick was deposited by thermal evaporation on a VUP-2K at 24. Then, a carbon film was deposited into a 20% solution of gelatin in water. After drying gelatin carbon film was frustrated with the sample surface. Carbon film was washed in hot distilled water from the gelatin, washed in alcohol and placed on a copper grid. To enhance the image contrast carbon film by thermal evaporation in vacuum. Shielding platinum at an angle 250 thus prepared film was seen in the electron microscope UEMV-100K at an accelerating voltage in the range of 75 kWt increase from 3.000 to 30.000 times.

The results and their discussion

Analyzing the tests, the samples with an optimal fiber content were determined: phenylone - 5 mass % and sulfone-T – 10 mass %. Comparing the results shows that the fiber-reinforced organoplastics phenylone has the best physico-mechanical properties and tribological characteristics, namely: a yield strength in compression of 1.2 times; hardness of 1.6 times; toughness of 1.3 times; coefficient of friction and wear in the 1.4 and 1.2-fold, respectively (Table 1).

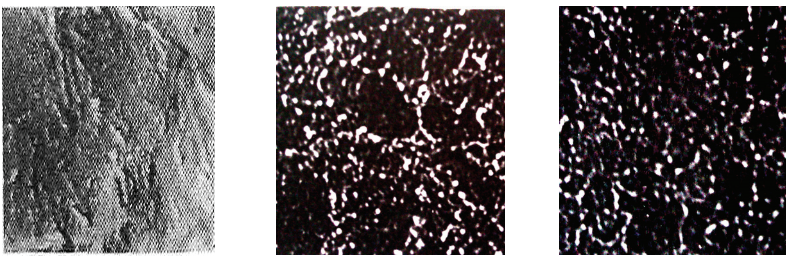
Table 1

Properties of composites based on phenylone

Filler fiber wt.%	Physical and mechanical properties			The relative change in the properties	
	Tensile strength at compression, MPa	Brinell hardness, HRB	Toughness, kJ / m ^{2}	I, mg	f
-	236	328	32	1,0	1,0
phenylone - 5	271	406	43	0,42	0,67
Sulfone-T - 10	230	260	33	0,5	0,95

** The process of friction without lubrication was carried out on disk friction machine. Counterbody was that of the steel wheel / steel 45, heat-treated to a hardness of 45-48 HRC, the surface roughness of Ra = 0.32 m, sliding speed of 0.3 m / sec; specific load of 0.6 MPa. The absolute value of wear (I) and the coefficient of friction (f), phenylon equal to the corresponding 34 m / km and 0.4 was conditionally accepted as the mesurement unit.*

The lower viscosity of the solution of the wear particles in comparison with the solution of the original block of phenylon indicates the molecular mechanism of destruction of aromatic polyamide and is direct evidence that in case of the action of stresses arising in the process of friction the chemical bonds are broken.



a b c

Figure 1 Submicrostructure of phenylon friction surface (a), amorphous disordered (b) amorphously ordered (c).

Macromolecules of phenylon degrade less intensively than in aliphatic polyamides [2]. No significant changes at the molecular level are confirmed by the results of infrared spectroscopy. Spectrogram of base phenylon and that of wear particles are identical, except for a slight displacement of the absorption band in the frequency range 1500-1550 cm^{-1}, which is proof of the rupture of hydrogen bonds.

We can assume that the destruction of aromatic polyamides in case of wear mainly occurs due to break ties on the boundaries of the molecular structures.

The combined effect of normal and tangential forces form submicrostructure of the friction surface of aromatic polyamides (see Fig. 1a). For phenylon globular strucure with traces of intense destruction is characteristic. The mutual arrangement of the globular structures is different from the original one, which is characterized by denser packing.

Comparing wear-resistance of the self-reinforced organoplastic materials with bronze of antifriction application OCS 5-5-5 (Table 2), we can conclude that the developed of the reinforced plastics are promising anti-friction materials.

Table 2

Depreciation reinforced composite material and bronze lubrication oil and water

The material	Specific load 5MPa	
	Depreciation, m / km · cm^2	
	When lubricating oil	When lubricating water
phenylone	6	-
phenylone +10%fiber	0,6	35
bronze OCS 5-5-5	does not work	

Positive laboratory results allowed to begin production testing of the self-reinforced phenylon in friction pilger rolling mills. The tested bearings were put on roller conveyors pin grooves in the most severe conditions at ambient temperature of 180-2000 C and insufficient lubrication. During 120 days of operation of the bearing wear phenylon copolymer made 0.233 mm per diameter. Bronze bearings under these conditions get completely out of order in 40-50 days, thus their wear makes up to 5mm or more.

Conclusions

Thus the studies found the optimal content of reinforcing fibers phenylon - 5, sulfone-T – 10 mass %, the smaller it is, the closer it is to the nature of the matrix fibers.

It has been shown that fiber organoplastics reinforced with phenylone possess superior properties compared to their analogues containing sulfone fiber-T by 1.2-1.6 times.

It has been established that organoplastics can be successfully used for the manufacture of metallurgical equipment, providing greater durability compared to standard bronze OCS 5-5-5 is more than an order of magnitude.

References

1. Berlin Al.Al. Sovremennye polimernye kompozitsionnye materialy (PKM) // Sorosovskii obrazovatel'nyi zhurnal, 1995, №1, s. 57-65
2. N.G.Cherkasova, A.I. Buria. Reaktoplasty, khaotichno armirovannye khimicheskimi voloknami.- Dnepropetrovsk: «IMA-pres», 2011. -234s.

UDC 620.178: 621.793 (045)

E.V. Kharchenko (NAU, Kiev)

REGULARITIES OF FRICTION AND WEAR AMORPHOUS-CRYSTALLINE COATING ON THE BASIS OF ZIRCONIUM

Has been reviewed the durability of amorphous coatings developed under loading friction in a wide range of sliding speeds. It is found that the amorphous-crystalline composition at an optimal volume fraction, structure and morphology of its components has a high surface strength and wear resistance in sliding

Processes of friction, wear and lubricating action continue to be one of the most important areas of research in tribology because they theoretical and applied methods studied something with which had to meet in the daily operation of units and aircraft components. Phenomena accompanying problems of friction and wear are closely related to the surface properties of materials.

Effective way to increase the surface strength of materials, working in conditions of friction is the application of protective wear-resistant coatings.

One of the universal technological methods of surface hardening of new and restoration of worn parts is detonation-gas spraying [1]. Detonation coatings are preferred in service parts components and assemblies of aircraft at high loads and temperatures, intense wear and corrosive environments.

In the present work we investigated the tribological properties of amorphous coatings based on zirconium doped aluminum and boron. In [2] experimentally established technological parameters, which determine the possibility of obtaining amorphous coatings.

Shown on the basis of the state diagram, the components of the test composition are melts congruently and have a narrow range of homogeneity, while stressed that detonation-gas spraying not only creates the optimal conditions for obtaining eutectic compositions in a metastable state, but also has a number of advantages over the traditional methods of high-speed cooling. Justified the component structure of composite coatings of Zr-Al-B, investigated their structural and phase characteristics.

The purpose of the work. Study of the wear resistance of amorphous coatings developed by friction under load over a broad range of sliding velocities.

The results of research. Fig. 1 presents data they determine the functional dependence of the wear rate of speed at a constant load of 5.0 MPa.

To investigate the character and patterns of structural changes that determine the high wear resistance of coatings systems Zr-Al-B (curve 3) on the micro analyzer has been studied the distribution of elements through the thickness of the sprayed layer.

The analysis is carried with a diameter of probe 2 and 10 microns, results showed the presence of the transition of the diffusion zone about 20-25 microns variable concentrations of the elements that are part of the coating. When matching prints taken in absorbed electrons and X-rays, it was not possible to identify the data structures, indicating that the heterogeneity of its composition.

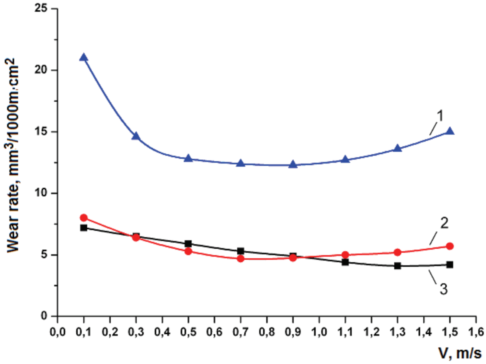


Fig.1 Dependence wear intensity from the sliding velocity coatings: 1-based on the Ni (Ni-Cr-Al-B); 2- type BK15; 3- amorphous-crystalline system Zr-Al-B

The resulting discrepancies in the chemical composition, confirm the presence of uneven dispersion structure, which coincides with modern ideas about the nature of amorphous and amorphous-crystalline composites [4].

Radiographic studies of phase showed that the coating comprises a α-solid solution on the basis of Zr, finely dispersed borides ZrB_2 and AlB_2, aluminides and Zr_2Al, also been detected in the surface layer Al_2O_3 and a complex oxide of the type of ZnAlO.

Wear resistance of Zr-Al-B practically across the speed range with the present load as seen from the experimental curves exceeds that for types of coatings VK15 and nickel-based that is caused by the creation of optimal heterogeneous durable thin film structures with a high level of self-organization and structural adaptability. Quantity of the amorphous phase is from 75 to 82%. Photomicrographs of cross sections of coatings systems Zr-Al-B are shown in Fig. 2.

In Table 1 presents the results of research into the mechanical properties of detonation coatings based on zirconium-containing fine particles of crystalline refractory borides and aluminides.

Table 1

The mechanical properties of the coatings Zr-Al-B

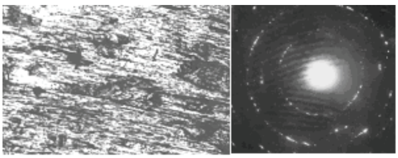
The content of the components, %			E, H/mm	σ_T, H/mm^2	m	HV, MPa
Zr	Al	B				
80	10	5	173900	4070	2,21	1350
70	15	8	181800	4250	2,27	1410
60	20	10	195300	4950	3,10	1620

Studies be carried out , the methodology of which is described in [5],were determined yield strength (σ_T) by angle of residual bending flat samples with coating thus established the existence of the strain hardening. The degree of hardening (m) defined according to [6]. In the case of linear dependence for amorphous materials m<2,5, that is increase of σT must not exceed 2.5% by increasing the degree of plastic deformation of 1%. Table 1 shows the values of m, calculated for the test coatings. Analysis of the data presented in the table shows that the hardness of coatings with decreasing content of Zr increases and aluminum (simultaneously with B) - increases dramatically. Thus the introduction up to 20% Al and 10% increase in the value YS, and the Young's modulus the strain hardening coefficient also increases and exceeds the limit values for the amorphous alloys ($E=180000$ H/mm^2 and $m=2,5$), which confirms the presence in the structure crystalline phase [7].

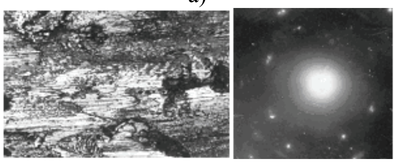
Figure 2 shows the microstructure of the electron diffraction patterns which are present as diffuse rings and the point reflections of crystalline phases. Researches in dark and light fields have established that the test the coating system Zr-Al-B consists of an amorphous matrix with crystalline inclusions of a size of 0.10-0.25 microns, and generally have a globular shape.

From the viewpoint of structural energy hypotheses are presented microstructure and electron diffraction patterns, reflecting kinetics of decay of structures on the surface friction of detonation coatings based on zirconium, fever activates the coagulation and recrystallization processes developing at different levels of scale, as evidenced by the gradual disappearance of the rings and the appearance of electron-point reflections.

Thus, this transformation of secondary structures can be regarded as adequate basic mechanisms of adaptation of the surface layers in the structural adaptability of friction. Thus, on one hand, due to the statistical laws phase formation and fragmentation of secondary structures in various portions of the contact surfaces are not identical, but their distribution is additive structurally stable temporary state, on the other - the formation of the surface layer structure is not indetermine and controlled by minimum principles dissipative processes [9]. In other words, it can be argued that if the structure can be adapted to the given conditions of friction, it is necessarily will happen, or rather, if there is any distribution of secondary structures, corresponding to the state of adaptability, the system will adapt, and friction parameters will be minimal.



a)



b)

Fig. 2 Microstructures and electron diffraction patterns of the friction surfaces coatings Zr-Al-B tested at speeds: a) V = 0,5 m/s; b) V = 1,5 m/s.

The stability of the coating with increasing sliding speed, shows the high efficiency of the test detonation coatings, both on the basis of nichrome, hard alloy type VC-15 and the amorphous-crystalline based on the Zr. The wear resistance of coatings based on nichrome is somewhat lower than in the well-known VC wear resistant coating, and according to the analysis of phase is a solid solution of fcc lattice based on nickel and finely dispersed mixture of hardening phases, mainly in the form of chromium borides and nickel aluminides.

The conclusions. Analysis of the results of studies of coatings which contain in the structure of amorphous and crystalline phases can be concluded that amorphous-crystalline composition with optimum volume fraction, structure and morphology of its constituent has higher surface strength and frictional wear resistance.

Thus, simultaneous introduction a sprayed material based on the optimal amounts of Zr and Al and B cause the formation of an amorphous matrix dispersed particles, that essentially increases the mechanical properties without decreases the plasticity and thermal stability.

Therefore, alloying elements forming refractory dispersion compound allows to affect the structure of the coatings, their chemical composition and mechanical properties in the right direction, i.e. is one of the principal ways to control friction and wear of amorphous-crystalline detonation coatings.

References

1. Ющенко К.А. Інженерія поверхні / К.А. Ющенко, Ю.С. Борисов, В.Д. Кузнецов, В.М. Корж. – К.: Наукова думка, 2007-557с.

2. Харченко Е.В. Аморфные покрытия системы Zr-Al-B // МНТК «Авиа-2009» - К.: НАУ, 2010 – с.15.41-15.44.

3. Носовский И.Г., Щепетов В.В., Марчик В.Е. Детонационные покрытия для защиты узлов трения от изнашивания // Наука і оборона. К.: Варта. – 1999.-с.126-135.

4. Feller H.. Klinger R. Zum tribologischen verhalten von metallischen glasern // Metall. – 2007.-39, №7-p. 627-631.

5. Kimura H., Masumoto T., Fabrication applications – oriented properties of amorphous metal matrix composittes//Sci. repts. Res.Inst. – Tohoku Univ. 2001.№2.-p.248-266.

6. Утиевская О.Л., Молотилов В.Б. Механические свойства аморфных сплавов// Металлофизика.-1993,№3.-с.28-45.

7. Общетехнический справ очник /Под ред. Е.А. Скороходова – 2е изд.-М.: Машиностроение, 1990.-415с.

8. Белоцкий А.В., Куницкий Ю.А. Структура и свойства быстрозакалённых сплавов.-К.: КПИ, 2002.-130с.

9. Костецкий Б.И. Поверхностная прочность материалов при трении/ Б.И. Костецкий, И.Г. Носовский, А.К. Караулов, Л.И. Бершадский, В.А. Ляшко, М.Ф.Сачак.К.: Техника.-1986.-296с.

UDC 621.793 (045)

S.D. Nedayborshch (SE «PLANT 410CA», Kiev)
E.V. Kharchenko (NAU, Kiev)

RESISTANCE TO WEAR OF DETONATION COATINGS Cr-Si-B IN A VACUUM WHICH CONTAINS MOLYBDENUM DISULFIDE

There are the results of the test work in conditions of vacuum characteristics of friction and wear developed detonation coating Cr-Si-B, which additionally as an anti-friction component contains solid lubricant additive. Established that the wear resistance of coatings ensured by the creation of the object of the thin film that separates the juvenile surface representing the product of oxygen-free structures based on intermetallic phases of the chemical elements included in the coating composition.

The level of quality and reliability of the aircraft is largely determined by the surface hardness and wear resistance of the materials used in its units and mechanisms. The problem of surface strength of materials in friction remains one of the most complex scientific and engineering areas of knowledge, as it is theoretical and applied methods of studying the questions that have to solve in everyday engineering practice, operation, repair and rehabilitation units and aircraft components. Despite the results achieved, its application solution falls short of modern requirements. It is particularly important questions remain wear resistance and surface strength in extreme operating conditions, which include not only an extremely high load and speed of movement, but also influence of the environment, in particular vacuum, where the use of the traditional lubricants are restricted [1].

In the scientific literature there is not enough reasonable information about the impact of individual structural components of composite powder materials on the strength properties of detonation coatings. And almost no data, showing the impact of the wear resistance of molybdenum disulfide detonation coating in the vacuum. To date, the main way to develop coatings remains an empirical search for dependences of structure-properties.

In aircraft to the details, flexible interface which in operation under loading friction exposed to wear and tear, leading to the defectiveness due to jamming and gripes relate working in a rarefied atmosphere bearings tooth flanks and friction gearing, slideways, end support, movements pairs of constant amplitude, the hinge-bolt coupling, parts of control systems [2]. Service and maintenance of operational availability is one of the most important engineering tasks systems of service and repairs aviation equipment [3]. To perform these tasks, need use modern materials, of high performance work in extreme conditions and under vacuum.

The purpose of the work. Study wear resistance under vacuum conditions elaborated detonation coating system Cr-Si-B, which additionally contain as the component of antifriction additives solid lubricant in dispersed form of molybdenum disulfide.

The results of research. Investigation of regularities of friction and wear processes in the absence of oxygen from the air, are relevant because they allow create a theoretical prerequisites to practical problems on exploring the creation of wear-resistant materials and coatings, and the most efficient combinations in the pairs of friction of units and aggregates aircrafts working in the under vacuum conditions. Test results are presented in Figure 1. in the form of dependence of the intensity of wear as functions of the values of the sliding speed under load of 2.5 MPa that allows to approximate the processes of physical and chemical mechanics of friction to the actual operating conditions.

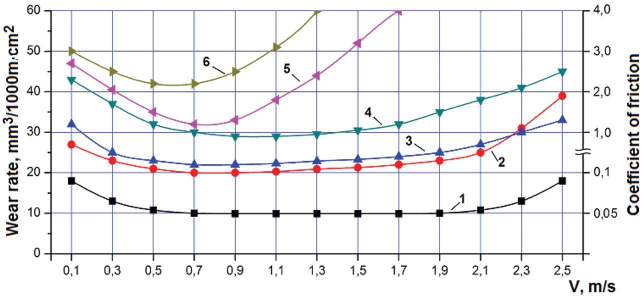


Fig. 1 Dependence wear intensity and friction coefficient on the sliding velocity (P=2.5 MPa): 1-covering Cr-Si-B-MoS_2, 2-covering hard alloy VK15, 3-richness vanadium specimens, 4-chrome-plated specimens, 5-coating Cr-Si-B, 6-borated specimens.

High durability under these conditions of friction coatings Cr-Si-B-MoS_2, (Figure 1, curve 1) is caused structural adaptability, which is implemented as a universal phenomenon is, firstly, due to structurally free molybdenum disulfide, which provides in the process friction to create a protective film (Fig. 2).

The data of metallographic analyze and study of the friction surfaces confirm the presence of a passivating solid-lubricating film of molybdenum disulfide, which prevents adhesion of juvenile surfaces while isolated pockets of destruction are localized in the thin surface layers and annihilated in the process of grain boundary sliding, excluding any kind defectiveness.

Secondly, the tendency of the coating to passivation provided by the occurrence in the conditions of friction diffusion and solid-phase components of tribochemical reactions with the formation of ultra fine nanophase. In studying the character and principles of formation a surface layer, causes resistance to wear, it was found it is finely dispersed quasi layered composite structure based on MoS_2, fiber reinforced intermetallic compounds Cr_5Si, CrSi, Cr_3Si, $CrSi_2$, besides molybdenum chalcogenide resulting tribochemical reaction with the deformed surface layer forms the sulfides CrS, which creates favorable conditions to significantly improve wear resistance and, as stated, to increase the bearing capacity.

Changing the solid phase surface structure of the films determines the value of the coefficient of friction, which during the entire range of test (Fig. 1, curve 1) is 0.05-0.07. In these conditions the coefficient of friction is not so much a function of the normal load, as dependence of the tribo physical processes occurring as a result of the additive combination of load, sliding speed, temperature and generalized vector friction parameters (materials, environment conditions, etc.). Thus, the solid lubricating surface film or active oversurface layer, except of antifriction and antiwear action has properties that, in these conditions of friction ensures high durability coatings Cr-Si-B-MoS_2 a thicker wearing coat in a vacuum.

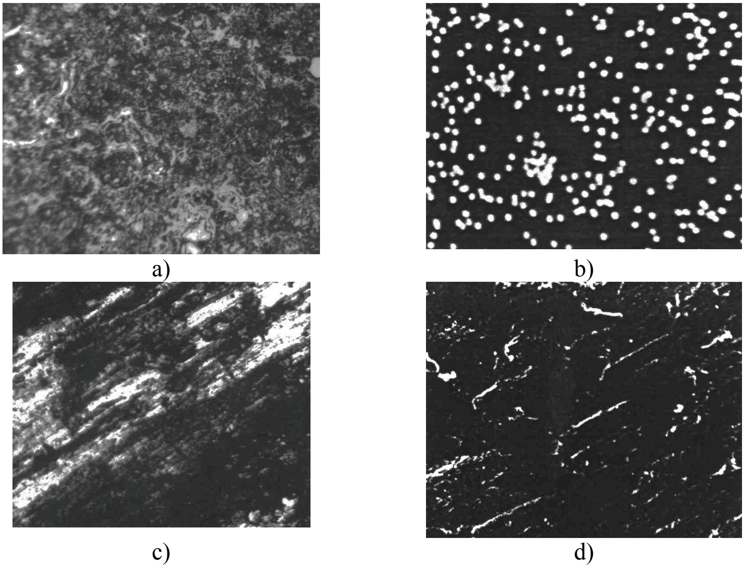


Fig. 2 friction surface coating Cr-Si-B-MoS_2: a) the initial state; b) the distribution of the electron microprobe MoS2, x650; c) after the rubbing test at V = 0,3 m/s, x320, g) after testing for friction when V = 2,3 m/s, x320.

Coating Cr-Si-B, in which there is no part of molybdenum disulfide (Fig. 1, curve 5), the variation of the wear rate and the dependence of the coefficient of friction on the rate essentially changes. It should be noted that the coating Cr-Si-B at sliding speeds of about 0.7 m/s have the minimum friction parameters. At speeds of tests more 1.0 m/s is broken thermodynamic balance of friction, under the given conditions leading type of wear coatings not containing MoS_2, is becoming a developing of the setting process.

High wear resistance of the coated, powder coating hard alloy type VK15 (Fig. 1, curve 2). As it is known, coating VK15 represent the classical structure of antifriction material, [7]. The increased wear resistance of carbide coatings caused both the nature included in them components and structure. However, at sliding speeds more than 1.0 m/s for stability coating are starting to influence the temperature as the main potent operating parameter [8].

From the samples subjected to diffusion alloyed corresponds to richness vanadium friction surfaces (Fig. 1, curve 3), which is associated with the formation of the working layer saturated with vanadium carbide, which is characterized by high mechanical properties, in particular hardness and high melting point [9].

Character of wearing out of steel samples hardened by thermal diffusion of chromium plating (Fig. 1, curve 4), similar to the general regularities of wear the surface richness of the vanadium. Higher values of the samples are due to wear chrome tendency to seizing caused by the comparatively low surface strength by friction in a vacuum [10].

The conclusions. Installed legitimacy methodologies and algorithms used in the conducting under vacuum conditions experimental studies of heterogeneous coatings based on Cr-Si-B, which composition additionally contains as the antifrictional component structurally free molybdenum disulphide, as modifying additive, performs the role of a solid lubricant.

Established high wear resistance of coatings investigated Cr-Si-B-MoS_2 by creating a passivating solid-lubricating film of molybdenum disulfide, which prevents the interaction of juvenile surfaces. It was noticed that the separate centers of destruction, localized in the surface layers, are annihilated in the process of grain boundary sliding, blocking in this range test any kind defectiveness.

In studying the character and the regularities which determine tendency to passivation coatings noted that its implementation is also caused by solid phase tribochemical and diffusion processes of formation of quasi layered surface structures based on the MoS2 and particulates intermetallic compounds of the components in the coating composition.

Determined that the protective thin film surface structure helps to reduce adhesion component of friction force, and its plastic deformation not associated with considerable thermal input and contributes to the minimum degree of power loss. In this case, the dependence of the coefficient of friction and agreement with regularity of wear, determined by the properties of the surface structures, and its stability evidence of high working capacity coatings.

References

1. *Nosovsksj I.G.* Vliyanie gazovoi sredy na iznos metsllov / I.G. Nosovskij. // K. : Technika. – 1988. – 165p.

2. *Garcunov D.N.* Povyshenie iznosostoykosti detalej samoletov / D.N. Garcunov, A.A. Poljkov // M. Mashinostroenie, 1989 – 200p.

3. *Pugachev A.I.* Technichescaj ekspluatacija letatelnich apparatov / Pod. Red. A.I. Pugachev. // M.: Transport, 1989 – 374p.

4. *Nosovsksj I.G.* Aviacionnye materyaly I pokrij / I. G. Nosovskij, V.V. Shchepetov // K.: KI VVS – 1999 -165 p.

5. *Polotaj V.V.* Mashina treniya M – 22GD. – K.: Znanie, 1988. – 20 p.

6. *Nedayborshch S.D.* Zakonomernosty I mechanism iznashivanij detonacionnyh pokrytij Cr-Si-B pri trenij v otsutstvij smazky / S.D. Nedayborshch // Problemy trenij I iznashivania. 2010. – Vyp. 54 – p. 163-171.

7. Bowden F., Hickam W. Friction and Wear Characteristics of Dry Lubricants . Machine Design. 2009. Vol. 35. №16. p. 195-199.

8. *Hinsley G., Male A.* Frictional properties of Metall Oxides at High Temperatures Wear. 2011. Vol. 11, №2. P. 233-238.

9. *Clauss F.* Materials of Lubricated Systems Materials. Wesley Publishing Company Inc. 2005. p. 209-215.

10. *Zeman K., Coffin I.* Friction and Wear of Refractory Compounds. ASLE Trans. 2012. Vol.3, №5 / p. 191-199.

UDC 681.26: 629.735.018

S.A. Ischenko, Dr.sc. eng., A.V. Bondar
(National Aviation University, Ukraine)

THE EXPERIMENTAL EQUIPMENT FOR WIND TUNNEL TAD - 2 NAU

Experimental equipment, which consists of six-component combined weights of strain-gauge sting balance type, calibration device, information collecting and processing system, coordinate device for determination of air stream parameters, additional equipment for study of propellers.

A lot of attention recently is given to unsteady characteristics of objects of research and for that purpose new measurement tools are needed. This is due to an increase in flight speed, reduction of drag and introduction of new methods, which would allow to create and increase the lift force.

The majority of modern aircrafts create lift force due to steady flow around the lifting surfaces and due to depression, which occurs as a result of a flow around lifting surfaces. But the air flow around vehicles, which have propeller or windmilling propeller as lifting surface and objects with complex geometric shape is unsteady and with separation. That is why the necessity of special experimental equipment usage for studies of such phenomena occurs. In wind tunnels for such purposes multi-strain balances are used.

To date, multi-component system for measuring aerodynamic loads is created, which gives possibility to carry out independent measurements of six components of the total aerodynamic force during aerodynamic experiment. These strain-gauge balances will allow to carry out experimental studies not only of static but also dynamic loads, which act on the object of study. This approach will make it possible to investigate aerodynamic characteristics of such objects as lifting system of windmilling propeller type, propeller of helicopter and vortex structures around objects of complex geometric form or behind parts of the aircraft.

Fig. 1 shows the general view of multicomponent system for measuring aerodynamic loads of strain-gauge sting balance type.

Fig. 2 shows elastic elements of this balance. Fig. 3 shows adopted coordinate system with respect to strain-gauge balance, and provides limits of measured loads for each component of the total aerodynamic force.

One of the main tasks, for obtaining high accuracy of aerodynamic research results, is metrological certification of measuring instrument – strain gauge balance.

For this purpose the calibration test rig for six-component strain-gauge balance was developed. This rig is designed to assess metrological characteristics of aerodynamic strain-gauge type balance.

The construction of this rig requires maximum accuracy and also must meet the following requirements: while applying partial forces at the origin the moments, calculated by calibrating formulas must be equal to zero; a rig and calibrating equipment should be rigid; the calibrating equipment should allow simultaneous application of all forces and moments at one point, which is the origin of balance, for initial position before calibration.

Fig.1 General view of six-component combined strain-gauge balance.

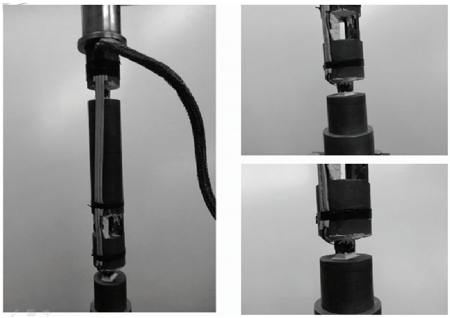
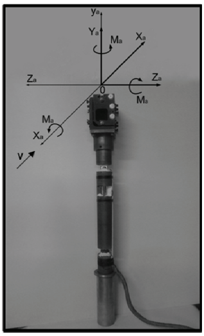


Fig. 2 Elastic devices of strain-gauge balance.



Forces and the moments which act on scales	Limiting value
Уa	±1000 Н
Xa	± 730 Н
Za	± 325 Н
Mx	± 25 Н·м
My	± 60 Н·м
Mz	± 240 Н·м

Fig. 3 Accepted axes of strain-gauge balances and the limiting values of measured loads for each balance component.

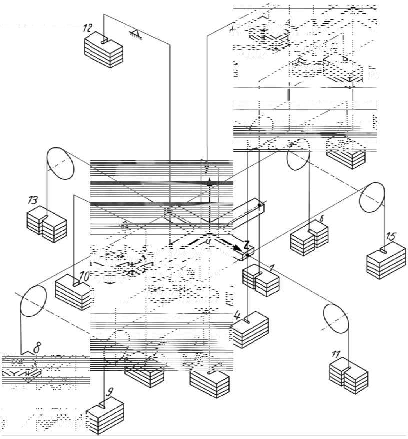
Calibration is the process of determining metrological characteristics of measuring equipment complex from balance to equipment, which records random and systematic errors.

Fig. 4 shows the kinematic scheme of calibration rig and positions for creation of necessary loads by components.

By means of a designed calibration test rig the assessment of metrological characteristics of this strain-gauge balance, as well as in the future of balance of other type will be carried out. Fig. 5 shows the general view of the calibration test rig.

Also a coordinate device for air flow parameters research was developed. It allows assessment of vortex structures characteristics, namely to investigate unsteady and vortex characteristics of the flow. The construction is based on Cartesian coordinate system with two degrees of freedom: 0.5m vertically and 1m horizontally.

As the flow parameters measurement sensor the Pitot tube with six components is used



Forces and moments which necessary to create	№ load position
X+	8;9
X-	6;15
Y+	5
Y-	16
Z+	11
Z-	13
Mx+	3;7
Mx-	4;12
My+	8;15
My-	9;6
Mz+	2;14
Mz-	10;1

Fig. 4 The kinematic scheme of calibration test rig.

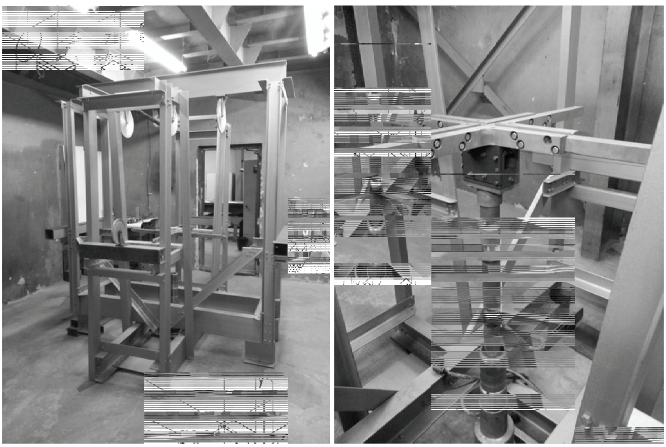


Fig. 5 General view of calibration test rig.

Sensor design provides an opportunity to get the velocity vector angle position in horizontal and vertical planes and the velocity vector itself. Thus, it is possible to investigate vortex structures in the flow. Fig. 6 shows general view of coordinate device elements: moving components, information and measurement equipment, Pitot tube.

Fig. 6 General view of coordinate device components.

Conclusions

Six-component combined balance of strain-gauge sting balance type, which would extend researches in the field of experimental aerodynamics with the possibility to evaluate unsteady characteristics of research objects. Calibration test rig, which design allows conducting both static and dynamic calibration of balance, was developed for determination of metrological characteristics In addition, it is possible to calibrate other devices in this rig. Coordinate device will allow to measure vortex structure parameters during experiment with possibility to evaluate velocity vector taking into account angular position with respect to set plane and initial point. Also system for collection and processing data was developed. As auxiliary equipment for studying of lifting propellers the special mounting system was designed, propeller hub with sensor to determine rotor speed and set angle.

References

1.*Горлин С.М., Слезингер И.И.* Аэромеханические измерения. – М.: Наука, 1964. – 720 с.

2.*Дубов Б.С.* Основы обеспечения качества испытаний в аэродинамических трубах. – М.: Бумажная Галерея, 2003. – 320 с.

3.*Лавров М.Г., Левицкий Н.П., Постнов А.И.* Автоматизированное конструирование внутримодельных аэродинамических тенхометрических весов. –М.: Издательский отдел ЦАГИ, 1983. – 30 с.

UDC 533.6.04

Gurkan Ortamevzi, Ph.D student (KPI, Ukraine)
D.N. Zinchenko, Ph.D (KPI, Ukraine)
V.V. Zilinka, Ph.D student (NAU, Ukraine)

THE ASSESSMENT OF THE EFFECTIVENESS WING WITH SOFT SKIN

It is shown that in article analysis is performed design aircraft carrier with a soft surface, considered especially their aerodynamics, defined scientific novelty research, the goals and objectives of the work. Based on the analysis of deformable wing aerodynamics, performed the assessment method applicability computational aerodynamics to the task.

ACTUALITY

The research is a substantial increase in operating capacity aircraft, that is confirmed by the fact development experimental aircraft with the soft wings as shown in the fig. 1.

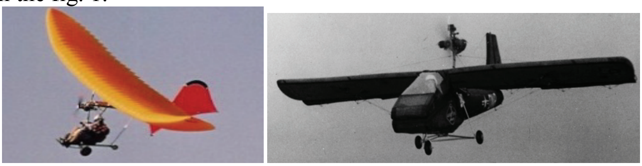


Fig. 1 Aircraft with inflatable wings

An objective feature of the layout all inflatable wings before the aircraft is a small extension value, that is, in the first instance, availability durability material upholstery. This fact allows you to assume that the options cantilever wings with a soft lining, which inflated by thruster flow, will not have the values lengthen, exceeding 7 units. Compare the features flying units with soft side curtain air bag wings presented below in the table comparing and unit parameters (Table 1).

Table 1

Compares the features and unit parameters aircraft wing with soft inflatable wings

Type	**λ**	$\chi_{1/4}$	**η**	$G_{kg/м^2}$	$N_{hp/kg}$	V_{min}	V_{max}
GA-468 Inflatoplane	2.8	0	1	3.3	0.8	60	116
Woopy Fly	1.4	0	1.6	4.75	0.2	45	70
Stingray	1.8	0	3	6.5	1.5	65	130
I2000 (Dryden)	2	0	1.2	3	1.2	45	100
Arup S-2	2.2	15	2	5	0.5	70	155

SCIENTIFIC NOVELTY

The scientific novelty research aerodynamics soft wing is defined:

1. Lack of a single methodology aerodynamic design bearing surface, which supports its form with the ram, the need to aggregate and organize results of the study.
2. The incompleteness possible constructive solutions soft wings, insufficient data on the impact of the various types of surface deformation on its aerodynamic characteristics, stability and handling.
3. The need to assess effects deformation methods computational aerodynamics, the definition of core principles suggested new model design model soft deformable wing depending on the method applied mathematical modeling.
4. Opportunity to study in situ conditions on the number without pilot laboratory, the need for an appropriate scientific methodology to ensure accuracy of the results of the trial.

THE GOALS AND OBJECTIVES

The main goal of our research is the formation of the common methodology aerodynamic design aircraft with a soft applied mathematics wing. To accomplish this, you must address the following tasks.

1. Analysis and synthesis of aerodynamics aircraft carriers with the soft surfaces. The aerodynamic characteristics of an aircraft with a soft wing. Selection and justification for study layout options, limits of the applicability of criteria of applicability constructive decision-making an aircraft with a soft wing that is deformed.
2. The development evaluation algorithm aerodynamic performance aircraft with a soft wing, takes into account the influence deformable wing using numerical methods. Selection and justification for methods applied computational aerodynamics. Planning computing experiment, development of imputation models. Analysis and synthesis of results.
3. Assessment of changes frequent flyer aerodynamic characteristics apparatus with a soft applied mathematics wing in real experiment on the model number. Selection and justification for a prototype apparatus for frequent flyer frequent flyer stand. Design and manufacture of an experimental model number. Determination of the composition of the measuring equipment, methodology of the flight testing and processing of the results of the trial.
4. The development of a common algorithm aerodynamic layout an aircraft with a soft applied mathematics wing based on the results of computing and physical experiment.

FEATURES OF AERODYNAMICS DEFORMABLE WING

To achieve the objectives set in the scientific research tasks it is advisable to consider particular deformable wing aerodynamics. The most characteristic type aircraft with applied mathematics wing is hang-glider. Analysis of research performance disembarkation f*rom wing, held in aerodynamic tubes and presented in [1], will make it possible to* determine a range of possible event factor values of forces and moments, caused by deformation surface.

Because of the lack of an open information on the aerodynamics aircraft with a soft applied mathematics wing, we have the results of the testing [1,3] as a first approximation.

Below (Fig. 2) are especially geometry and aerodynamics wing small lengthening (data [3]).

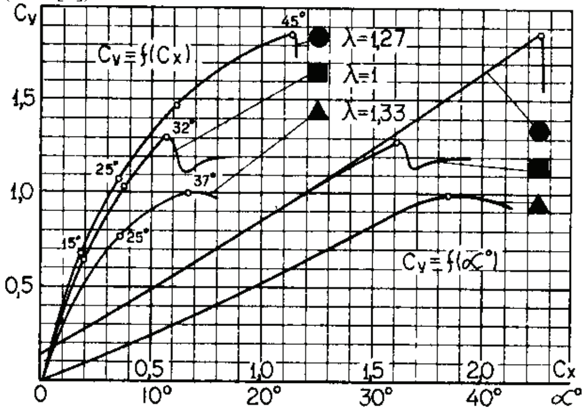


Fig. 2. Wing aerodynamic characteristics small elongation varying forms in the plan [3]

Aerodynamics wing depends on the deformation, but the change does not take place runaround, i.e. wing deformed from ram does not cause the ruination flow, strong distortions geometry wing, and distribution of aerodynamic characteristics along the swing wing for various deformation predictably and can be determined.

THE APPLICABILITY OF THE METHODS CALCULATED AERODYNAMICS

The runaround wing with soft lining on the basis of computational aerodynamics is one of the priority areas of research, conducted by leading academic aviation institutes. Methodological Framework for the study was proposed in [2] and developed in [4]. The results and possible ways of addressing the task clearly shows in the works [5-10] and others.

The analysis publications show that, for the two and three-dimensional pc profile runaround the authors largely apply method FEM - Finite element method (FEM - Finite element method).

Inflatable wing is multivariable system, in which aerodynamic characteristics are defined by many interrelated factors - high-speed pressure washing, surface deformation, the pressure inside fender and other. Just take into account the relationship these parameters methods mathematical modeling is virtually impossible. This is confirmed by the lack of a in the cases reviewed work tasks flow around cylindrical wing with variable calculated net, as their decision requires substantial computing resources and time.

In general it can be concluded on the feasibility of methods development aerodynamics for the study of soft inflatable cushion wing aerodynamics.

CHOICE OF PARAMETERS MODELING SOFT WING RUNAROUND

As can be seen from materials analysis, presented in [5-10], that aerodynamic characteristics any objects have clearly defined form of its surface, and the movement parameters. Form the surface soft inflatable cushion wing is determined by the value an external ram and internal excess pressure. This fact determines, as at least two parameter - flight speed and interior boost pressure. This fact determines, as at least two parameter - flight speed and interior boost pressure. Rigid wing determines its deformation, in the first instance this will effect the distribution of angles wing cross-section along the magnitude, which in turn is able to influence the changing aerodynamic performance.

Therefore, to obtain reliable information on the distribution of yarn along the magnitude is highly desirable for the qualitative relationship between the aerodynamics and deformation. To determine the actual distribution of angles wing cross-section variation in magnitude during the experiments it is advisable to use video footage.

Change the shape of the surface, of course, would have an impact on the nature of the currents at the boundary layer wing, you may have a local or large continuously flow from the surface, join-up vortices. To identify the presence of these factors can be seen using the method runaround imaging surface with the wool tuft, video their runaround.

In the present work it is also proposed to introduce another parameter - the width лобика rigid inflatable cushion part of the wing. The rationale for such a proposal is the fact that over 70% aerodynamic load wing-the overwhelming majority of classical scheme picks up 30% of the area (or the chord wing) frontal part of it. Creating a multi-wing design will allow, without significant restrictions on portability, to achieve a higher aerodynamic characteristics, because 80% resistance wing is defined form and the quality of the surface frontal profile. The use of multi-design also will significantly reduce ground design, because cloth trim, selected by the value actual aerodynamic load may be more thin and lightweight.

As the prototype for the design a pilot model layout is selected light aircraft Aeroprakt A-20, because in the open sources [4] presented the results of an experiment model A-20 with the hard wing, held in a wind tunnel mocking TAD-2 NAU. The use of these data will enable reliable verification of the results obtained.

CONCLUSION

In our study determined the feasibility assessment of the impact on the aerodynamic characteristics the following parameters:
- stream speed V;
- pressure inside wing P_w;
- the act distribution yarn on sweep φ (z);
- the nature of the flow surface runaround;
- Width rigid part front profile $X_{solid\ part}$

Measured parameters are presented below in the fig.

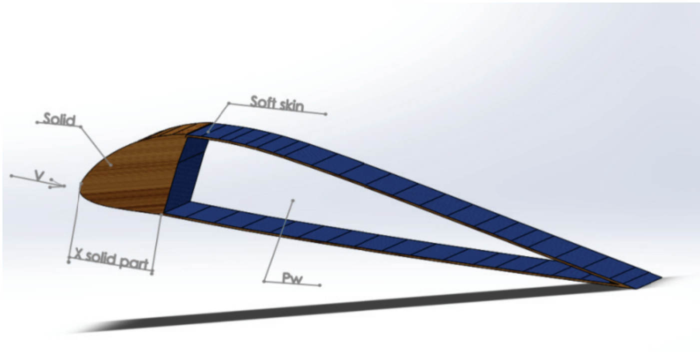


Fig. 3. Figure of the experimental wing

References

1. *Азарьев И.А., Горшенин Д.С., Силков В.И.* Практическая аэродинамика дельтаплана.

2. Исследование парашютов и дельтапаланов на ЭВМ. Под ред. д.т.н. *С.М. Белоцерковского*. М. Машиностроение. 1987 г.

3. *Козьмин В. В., Кротов И. В.* Дельтапланы. М.: ДОСААФ, 1989. 271 с.

4.*Кондратьев В.П. Яснопольский Л.Ф.* Самолет своими руками. М. Патриот. 1993 г.

5. *Щербонос О.Г.* Аеродинамічні характеристики крила з генераторами вихрів в умовах нестаціонарного обтікання. Дисертація на здобуття к.т.н. УДК 533.694.73. НАУ. Київ 2011р.

6. *Branden James Rademacher*. In-flight trajectory planning and guidance for autonomous parafoils. A dissertation submitted to the graduate faculty in partial fulfillment of the requirements for the degree of Doctor of philosophy. Iowa State University. Ames, Iowa. 2009.

7. *S. Mittal, P. Saxena and A. Singh.* Computation of two-dimensional flows past ram-air parachutes. Department of Aerospace Engineering, Indian Institute of Technology. Int. J. Numer. Meth. Fluids 2001: 35: 643-667. Kanpur, India.

8. *Yogesh Babbar*. Computational analysis of ram air parachute canopy using panel methods. B.E. 5th semester, Department of Aeronautical Engineering, Punjab Engineering College, Chandigarh 160012. 2004.

9. *Michael Forostoski, Justin Riley, Virgil Vaillancourt, Jeffrey Wilfong*. Investigation of Variable-Glide Parafoils. Worcester Polytechnic Institute. In partial fulfillment of the requirements for the Degree of Bachelor of Science. May 2, 2006.

10. *John R. Chambers*. Longitudinal dynamic modeling and control of powered parachute aircraft. Rochester Institute of Technology Rochester, New York 14623. April 2007.

11. *Nathan J. Slegers*. Dynamic Modeling, Control Aspects and Model Predictive Control of a Parafoil and Payload System. Dissertation. June 2005.

UDC 533.6.04

Rahmati Ahmad, D.N. Zinchenko,
(National Technical University of Ukraine "KPI", Ukraine)
V.V. Zilinka (National Aviation University, Ukraine)

CALCULATION RESEARCH OF AERODYNAMIC CHARACTERISTICS OF THE WINGS SMALL ELONGATION FOR LAYOUT THE AIRCRAFT WITH HIGH BEARINGS PROPERTIES

Considered the characteristics features of definition the aerodynamic characteristics unmanned aerial vehicle with short take off and landing, wing small elongation. Proposed the method of determination the coefficients of lift and drag with the annular wing UAV based on panel-vortex method. Completed an analysis of the influence of parameters on the layout calculated aerodynamic characteristics.

INTRODUCTION:

UAVs with short takeoff and landing - the aircraft which has the ability to take off and land without the use of prepared runway, almost vertically.

Significant increase in the operational capabilities of the aircraft is achieved in the implementation of the opportunities of vertical take-off. The complexity of the task is confirmed by the fact that aircraft with vertical takeoff exist in single copies, their payload is substantially below conventional aircraft.

Possibility of vertical take-off can only be realized with the help of aerodynamic layout features that deliver a substantial increase in bearing properties, and it requires serious calculation researches aerodynamic layout bearings properties.

Completed the calculated simulation influence of the carrier scheme - the elongation, the thickness profile, form wing in the plan on the aerodynamic characteristics carrier scheme, including the with the jet running screw. Proposed scheme Empennage, allowing to provide stability and manageability the aircraft in a wide range of flight speeds, angles of attack and slip, using the panel-vortex method method performed an evaluation of its effectiveness.

Based on the analysis results of the modeling various layout options UAV with high lifting properties, That allows us to realize the UAV start virtually from their seats place without complex control systems, while maintaining a performances and technical specifications - aerodynamic quality, maximum coefficient lifting force.

The practical significance of completed studies is formed methodical recommendations on the development of UAV with short takeoff and landing.

Relevance of my work is determined by the need to expand operational capacity through the implementation of the possible UAV short take off and landing provided ensure a high level of aerodynamic efficiency of the layout on the cruise phase.

The objective of the work. Develop methodology to layout UAV with high bearing properties, taking into account the influence of the parameters on its aerodynamic performance.

Scientific novelty. Scientific novelty of the work is determined by the need to improve performance characteristics designed UAV at the modes take-off and landing;

- The need for improving the existing scientific and methodological apparatus designed to calculate the aerodynamic characteristics of the UAV taking into account working screws.
- The need to obtain the calculated and experimental data on the interactions attached vortex wing small elongation, working with power plant.

Task. To create a theoretical model for the assessment of impact layout options, using the selected method computational aerodynamics.

Perform the calculation of aerodynamic characteristics of different layouts UAV with high bearing properties, to determine the most appropriate version of the layout.

The Plan experimental and computational model

as a starting layout for the project made the search parameters disc-shaped wing tested in studies MAI gliders "Diskoplan" [1] . For the operational evaluation of layout solutions used panel-vortex method [2].

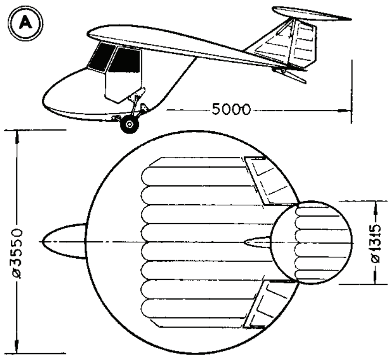


Fig.1 Experimental Glider "Diskoplan"

The results tube tests, performed for the wings of small elongation in TSAGI demonstrate a very characteristic feature of wing small elongation circular shape - saving almost unseparated flow to large angles of attack simultaneously with an acceptable level of maximum aerodynamic quality – about 6units

To determine the acceptable layout options was formed a number calculated models layouts bearing surfaces with elongation, equal to elongation range $\lambda = 1.27$ units. Consistently were investigated the effect of shape of the front edge of the wing in the frontal projection (straight line, circle, ellipse), , the thickness of the wing profile shape of the contour of the wing in the planned projection, location and intensity of jet propulsion. Examples of calculation models are shown in fig. 2.

In the course of the study were taken such basic criteria as the maximum aerodynamic quality K_{MAX} and the degree of static stability. Characteristic comparison of results from different calculation models are presented in the form of a dependencies СУ(α), К(СУ) mZ(CY)

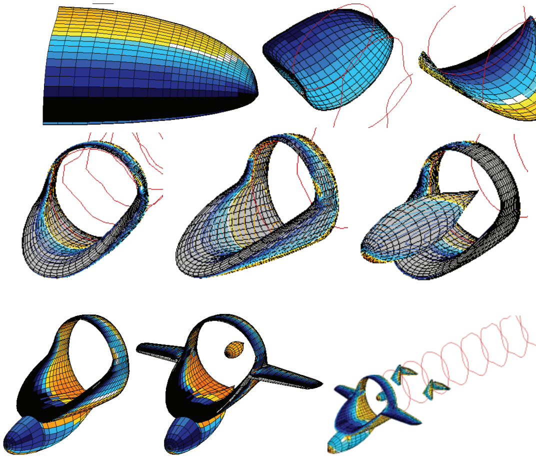


Fig. 2 Genesis calculated models

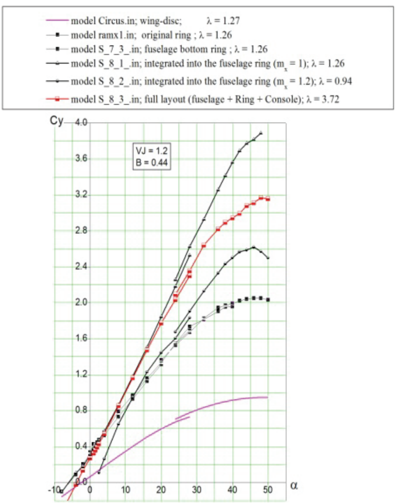


Fig. 3 dependencies Cyv(α) vj=1.2

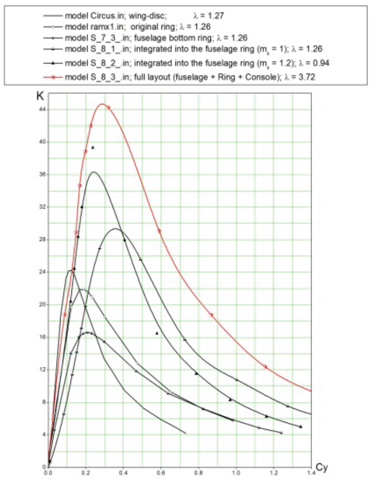


Fig. 4 dependencies K(Cy)

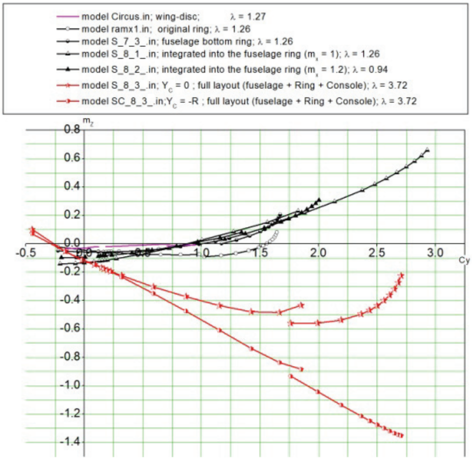


Fig. 5 graph experimental dependencies Mza(Cya)

Conclusions

1. The change of law front edge in the frontal plane increases Kмах, but ΔK = +10 and bearing properties of a wing with all models are unstable and require stabilization т.к.. $\left(m_Z^{C_{Y0}} > 0\right)$

2. Increasing the relative thickness Cmax Image quality significantly reduces Kmax models for $\chi^{1/4}$ =0, and χ = 0 nk) but $c_{\text{мах}}$ = 12% this decrease slightly, which can be used in calculating the strength of the structure.

3. Formation carrier sweep pattern with zero axial chord ¾ significantly increases load-bearing properties as compared with the arrangement of the disc-shaped wing;

4. Most advantageous arrangement is the zero sweep axis ¾ chord and form a circle when viewed from the front - this provides the maximum lift of growth in comparison with the disc-shaped unit by more than a factor of 2. Virtually no loss of aerodynamic control.

5. Most tech is the airfoil shape model with a straight trailing edge, straight edge parabolic formed under the law circle in the plane Y0Z. The change in aerodynamic characteristics in comparison with the results of model minor that allows to continue to prepare the layout of the disk around the propeller;

6. All models sweep angle 0 to the axis of the chords are resistant because $\left(m_Z^{C_{Y0}} < 0\right)$

7. Location jet propeller position on ¼ chord with appropriate zero sweep and form a circle in the front view is impractical because influence on the aerodynamic characteristics of blasting layout negative - virtually unchanged lift increases resistance and instability support surface.

8. Most convenient is the location of the screw at the rear of the wing layout. When this screw is located closer to the trailing edge, the more effective the jet affects the aerodynamic characteristics of the rotor arrangement.
9. Maximum lift coefficient at blasting layout can be more than 3 units, which corresponds to Cy max for transport aircraft IL-76 advanced 3-slotted wing mechanization in the landing configuration. 10. In all cases the settlement calculation model is stable.
11. Zoom model the X-axis leads to a reduction of its load-bearing properties and a decrease in the stability, while "stretching" geometry chordal 1.5 times equivalent to a reduction of maximum lift coefficient at - 0.45 units.
12. With this change to the properties of the carrier mX = 1.2 slightly, which can be used to form a common support arrangement, since "Stretching" of geometry chord provides additional wing area.
13. The most optimal in terms of maintaining maximum carrying properties and maximum aerodynamic efficiency is to assemble the fuselage, the dual integral with the lower surface of the wing. In the comparison with the original layout of the carrier ring lift virtually unchanged, and the loss of maximum aerodynamic efficiency compared to other options the minimum possible;
14. Location fuselage axis of the ring from the aerodynamic point of view is impractical because is 2 times the maximum value reduces layout;
15. For detailed design is advisable to perform computational studies model with optimized position relative to the wing fuselage, wings and the presence of consoles motor channel ring.
16. Application in the aerodynamic configuration of the fuselage, oriented with respect to the linear current and associated wing ring allows for a significant increase in lift force even without the influence of the jet propeller. Sumax increment ΔCy_{max} = 1,75 compared to the original layout of the disc-shaped wing.
17. The original layout of calculation model also provides maximum aerodynamic efficiency over 2 times the value of K_{max} for disc-shaped wing.
18. Application end of wings for the carrier ring makes a sustainable model that allows to use small size and mass of feathers.
19. Determined on the basis of previous studies in the presence of an arrangement of feathers with the above parameters is able to provide stability and control the UAV in the whole range of angles of attack and flight speeds.

References

1. *Sobolev DA* Planes special schemes / DA Sobolev. - M. Engineering in 1985. - 134.

2. *Kuhemann D. F.R.S.*. The aerodynamic design of aircraft. Pergamon Press Inc. Oxford OX3 0BW, England. 1985.- 175 c.

3. *Fletcher D.* Computational methods in dynamics / D. Fletcher. - M. Engineering, 1988. - 98.

4. *Byushgens GS, "*aerodynamics, stability and control of supersonic aircraft." Fizmatlit, Moscow, 1998 799 p.

5. *Mkhitaryan AM*, "Aerodynamics" M. Mechanical Engineering, 1976. - 448.

UDC 532.526

S.V. Kopylov (National Aviation University, Ukraine)

RESEARCH OF TECHNOLOGICAL PARAMETRES OF MANUFACTURE OF POLYMERIC PIPELINES OF AIRCRAFTS FOR INCREASE OF SAFETY OF FLIGHTS

The question of calculation of technological parametres of manufacture of polymeric pipelines for the aviation technics is considered. Speed characteristics are received at a polymer current on an initial site. Such characteristics are important for definition of time of heating of polymer and other technical characteristics by manufacture of pipelines. Definition of the above-stated characteristics is necessary for avoidance of the subsequent sudden destruction of the pipeline during operation and increase of safety of flights.

Calculation of technological parametres of manufacture of polymeric pipelines becomes complicated that high-speed characteristics of a stream non-Newtonian liquids on an initial site in a backlash between cylindrical surfaces cannot be defined in the regular way. Complexity of definition is connected with influence convection accelerations. Safety of flights depends on accuracy of calculation of technological parametres of manufacture of pipelines. Now such characteristics are defined experimentally.

The liquid current is described by the equations [1]:

$$u\frac{\partial u}{\partial z}+v\frac{\partial u}{\partial y}=-\frac{1}{\rho}\frac{dP}{dz}+\frac{1}{y\rho}\frac{\partial}{\partial y}(y,\tau),$$

$$\tau=-K(\frac{\partial u}{\partial y})^n \qquad (1)$$

$$\frac{\partial yu}{\partial z}+\frac{\partial yv}{\partial y}=0, \qquad u=v=0 \text{ At } y=1 \text{ and } z\succ 0.$$

$$v_x=uv_{zcc};\ v_y=vv_{zcc};\ P=\overline{p}0{,}5\rho v_{xcc}^2;\ \tau=Kv_{xcc}^nR_2^{-n}\tau_{y,z};$$

$$y=\frac{h}{h_2}$$

In the equations to - consistency a constant, $\tau-$ tangent tension, n - a current index, $\rho-$ liquid density, u and v speeds of polymer in the channel on axes, h_1 and h_2 distance from an axis to an external and internal surface of the channel accordingly, h – value of co-ordinate y.

Boundary conditions on a liquid input in the channel:

$u = v = 0$ at y=1, 0;

$u = v = 0$ at $y = \varepsilon$, 0;

$v = 0$ at $\tau = 0, y = \lambda\varepsilon,$

Where $\varepsilon = \dfrac{h_1}{h_2}, \chi$ - factor (an integration constant at $\tau = 0$).

All sizes in system of the equations the dimensionless.

We believe that the profile of speeds asymmetrically rather from a back-lash, and in a laminar stream a maximum of speed depends only from $\varepsilon_1 = \dfrac{h_1}{h_2}$,

$v(z, \lambda\varepsilon) = 0$ and $\tau(z, \lambda\varepsilon) = 0$

We multiply the equation on at and having integrated it on an interval $[\lambda\varepsilon_1, 1]$

Let's receive:

$$\int_{\lambda\varepsilon_1}^{1} yu \frac{\partial u}{\partial z} dy + \int_{\lambda\varepsilon_1}^{1} yv \frac{\partial u}{\partial y} dy = -\frac{1}{\rho}\frac{dP}{dz}\int_{\lambda\varepsilon_1}^{1} ydy + \int_{\lambda\varepsilon_1}^{1} \frac{\partial}{\partial y}(y, \tau) dy$$

We have:

$$\int_{\lambda\varepsilon_1}^{1} yu \frac{\partial u}{\partial z} dy = \frac{d}{dz}\int_{\lambda\varepsilon_1}^{1} y \frac{u^2}{2} dy$$

$$\int_{\lambda\varepsilon_1}^{1} yv \frac{\partial u}{\partial z} dy = \left\{ \begin{aligned} & dQ = \frac{\partial u}{\partial y} dy, Q = u \\ & P = yv, dP = \frac{\partial yv}{\partial y} dy = -\frac{\partial yu}{\partial z} dy \end{aligned} \right\} =$$

$$= yvu \Big|_{\lambda\varepsilon_1}^{1} + \int_{\lambda\varepsilon_1}^{1} yu \frac{\partial u}{\partial z} dy = \frac{1}{2}\frac{d}{dz}\int_{\lambda\varepsilon_1}^{1} yu^2 dy.$$

$$\int_{\lambda\varepsilon_1}^{1} \frac{\partial}{\partial y}(y,\tau)dy = y\tau \Big|_{\lambda\varepsilon_1}^{1} = \tau_{z=R_2},$$ Having accepted $\rho = 1$

$$\frac{dP}{dz}\int_{\lambda\varepsilon_1}^{1} ydy = \frac{1}{2}(1-\lambda^2\varepsilon_1^2)\frac{dP}{dz}.$$

Thus the equation gets

$$\frac{d}{dz}\int_{\lambda\varepsilon_1}^{1} yu^2 dy = -\frac{1}{2}(1-\lambda^2\varepsilon_1^2)\frac{dP}{dz} + \tau_{z=R_2}.$$

As $\frac{dP}{dz}$ does not depend from at believing b (1), y=1, we will receive

$$-\frac{dP}{dz} + \tau(1) + \tau_y^1(1) = 0$$

Or $$\frac{dP}{dz} = \left(\tau_{z=R_2} + \frac{\partial \tau_{z=R_2}}{\partial y}\right),$$

$\tau_{z=R_2}$ - tangent tension at a wall of the big pipe

Therefore

$$\frac{d}{dz}\int_{\lambda\varepsilon_1}^{1} yu^2 dy = -(1-\lambda^2\varepsilon_1^2)(\tau_{z=R_2} + \tau^1{}_{z=R_2}) + \tau_{z=R_2} =$$
$$= (1+\lambda^2\varepsilon_1^2)\tau_{z=R_2} - (1-\lambda^2\varepsilon_1^2)\tau^1{}_{z=R_2}.$$

In the field of $z \geq 0 \;\; \lambda\varepsilon_1 \leq y \leq 1$ function U (z, y) we will accept the equation in a kind:

$$U(z,y) = \frac{b(z)+2}{b(z)}\left[1-\left(\frac{y-\lambda\varepsilon_1}{1-\lambda\varepsilon_1}\right)^{b(z)}\right]$$

Also we will integrate the left member of equation

$$\int_{\lambda\varepsilon_1}^{1} yu^2 dy = \left[\frac{b(z)+2}{b(z)}\right]^2 \int_{\lambda\varepsilon_1}^{1} y\left[1+\left(\frac{y-\lambda\varepsilon_1}{1-\lambda\varepsilon_1}\right)^{2b(z)} - 2\left(\frac{y-\lambda\varepsilon_1}{1-\lambda\varepsilon_1}\right)^{b(z)}\right]dz$$

Having designated integral we will receive

$$I_t = \int_{\lambda\varepsilon_1}^{1} y(y-\lambda\varepsilon_1)^t dy = \begin{cases} z = y-\lambda\varepsilon_1 \\ dz = dy \\ \bar{z} = 1-\lambda\varepsilon_1 \\ z = 0 \end{cases} = \int_0^{1-\lambda\varepsilon_1} (z+\lambda\varepsilon_1) z^t dz =$$

$$= \frac{z^{t+2}}{t+2}\bigg|_0^{1-\lambda\varepsilon_1} + \lambda\varepsilon_1 \frac{z^{t+1}}{t+1}\bigg|_0^{1-\lambda\varepsilon_1} = \frac{(1-\lambda\varepsilon_1)^{t+2}}{t+2} + \lambda\varepsilon_1 \frac{(1-\lambda\varepsilon_1)^{t+1}}{t+1}.$$

$$I_t = (1-\lambda\varepsilon_1)^{t+1} \cdot \left(\frac{1-\lambda\varepsilon_1}{t+2} + \frac{\lambda\varepsilon_1}{t+1}\right) = (1-\lambda\varepsilon_1)^{t+1} \frac{t+1+\lambda\varepsilon_1}{(t+1)(t+2)}.$$

Hence

$$\int_{\lambda\varepsilon_1}^{1} yu^2 dy = \left[\frac{b(z)+2}{b(z)}\right]^2 \left\{ \frac{1-\lambda^2\varepsilon_1^2}{2} + \frac{(1-\lambda\varepsilon_1)^{2b(z)+1}[2b(z)+1+\lambda\varepsilon_1]}{(1-\lambda\varepsilon_1)^{2b(z)}[2b(z)+1][2b(z)+2]} - \right.$$

$$\left. - 2\frac{(1-\lambda\varepsilon_1)^{b(z)+1}[b(z)+1+\lambda\varepsilon_1]}{(1-\lambda\varepsilon_1)^{b(z)}[b(z)+1][b(z)+2]} \right\} = \left[\frac{b(z)+2}{b(z)}\right]^2 \left\{ \frac{1-\lambda^2\varepsilon_1^2}{2} + \right.$$

$$\left. + \frac{(1-\lambda\varepsilon_1)[2b(z)+1+\lambda\varepsilon_1]}{2[b(z)+1][2b(z)+1]} - 2\frac{(1-\lambda\varepsilon_1)[b(z)+1+\lambda\varepsilon_1]}{[b(z)+1][b(z)+2]} \right\}.$$

We differentiate the received expression on Z and substituting in the equation we will receive the differential equation for size b (z). It is necessary to notice that the decision of this problem at $\varepsilon_1 \to 0$ leads to the decision of a problem for a single pipe. For area $z \ge 0, \varepsilon_1 \le y \le \lambda\varepsilon_1$ for U (z, y) it is possible to prevent the equation in a kind:

$$U(z,y) = \frac{b(z)+2}{b(z)}\left\{1-\left[\frac{\lambda\varepsilon_1 - y}{\varepsilon_1(\lambda-1)}\right]^{b(z)}\right\}$$

For construction of a profile of speeds it is necessary to construct the function schedule first of all:

$$U(0,y)=\left|\begin{array}{ll}\dfrac{b_0(z)+2}{b_0(z)}\left\{1-\left[\dfrac{\lambda\varepsilon_1-y}{\varepsilon_1(\lambda-1)}\right]^{b_0(z)}\right\} & \qquad\qquad \varepsilon_1\le y\le\lambda\varepsilon_1\\ \dfrac{b_0(z)+2}{b_0(z)}\left\{1-\left[\dfrac{y-\lambda\varepsilon_1}{1-\varepsilon_1\lambda}\right]^{b_0(z)}\right\} & \end{array}\right.$$

The received dependences of speed of a stream in a backlash between cylindrical surfaces allow to calculate technological parametres of manufacture of pipelines including time of heating of polymer. The decision of the equations is spent taking into account different curvature of a surface of an external and internal pipe of the channel on which polymer flows. Comparison of the received analytical dependences with experimental data allow to draw a conclusion on convergence of results of experiment and the analytical decision.

References

1. *Повх И.Л.* Теоретическая гидромеханика Л Машиностроение 1969 с.520
2. *Копилов С.В. Яхно Б.О.* Математическое моделирование течения аномально-вязких жидкостей в цилиндрических зазорах. Международная научно-техническая конференция КПИ Киев 1998 с.464.

UDC 532.526

S.V. Kopylov (National Aviation University, Ukraine)

FEATURES OF EXPERIMENTAL RESEARCH OF PRODUCTION OF AVIATION POLYMERIC PIPELINES ARE FOR THE INCREASE OF RELIABILITY OF EXPLOITATION OF AIR SHIPS

In article features of physical modeling and measurement kinematics and dynamics characteristics of a current of stream non-Newtonian liquids in a backlash between cylindrical surfaces are described.

At processing production of aviation polymeric pipelines of determination of kinematics and dynamic descriptions of technological processes and deformation descriptions of fusions are got as experimentally so in theory have a large practical value.

To research of flow of non-Newtonian liquids in a double pipes area the devoted row of researches in particular Leybenzon, Mak-Kelvi of Fridrikson and Bird et al.

If for non-Newtonian liquids flow in two-bin an area full enough studied, for non-Newtonian liquids analytical decisions carry more frequent close character. In the resulted researches absent information is about influence of terms of entrance on the parameters of stream in the area of initial area about distributing of speeds into account the difference of area of surface of external and internal pipe separate information about length of initial area which results in leading to of . The feature of such equipment is that the workings areas of such equipment are short and flows there not stability according to a flow on a hydrodynamic initial area. For the calculation of equipment it is necessary to know kinematics and dynamic descriptions of stream, and also sliding which arises up. For example, kinematics and dynamic descriptions are needed for timing stay of polymer in a working area, to shut out his overheat and in some cases of burning which can result in the break of pipe during exploitation of air ship. It is also necessary to know the tangents of tension, exceeding of which conduces to large superficial heterogeneity, which results in the greater vibrations of stream, which in same queue leads to that polymer it goes out as the involutes stream which also results in large superficial heterogeneity distorted, which result in the pulsations of stream which also can result in the break of pipe during exploitation of air ship. If for a non-Newtonian liquid these tasks are decided, for the non-Newtonian liquid of decision carry close character, absent or incomplete information about length of hydrodynamic initial area distributing of pressure and tangents of tangents of tension.

In this time, for that, to start a machine in series it is necessary to make a model to conduct a physical design and only after this equipment started in a mass production that result in the high cost of products.

In actual work the physical design of flow of non-Newtonian liquid was conducted in a between too pipes area.

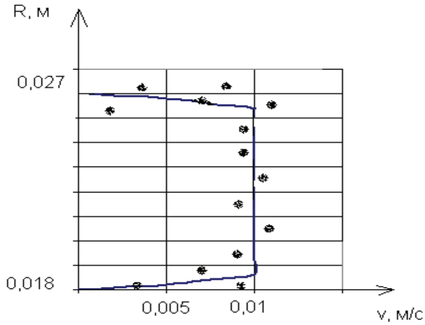
A mathematical design was before done it was based on the decision of the system of equalizations of boundary layer which takes into account practically everything really possible variety of terms of entrance of stream in a channel at next maximum and initial terms. This system is universal. The chart of decision was specified at an analytical decision.

The physical design of flow was conducted on the specially collected stand which researches of kinematics were simultaneously conducted on, dynamic and reologic descriptions of stream of non-Newtonian liquid at its flow in a between too pipes area. As designing liquids were used aquatic solutions of PVS of brand 72 GOST 10779-69 and by part of sodium salt and KMC THAT 15-692-72. As designing liquids were used aquatic solutions of PVS of brand 72 GOST 10779-69 and by part of sodium salt and KMC THAT 15-692-72. Choice them based on that them reologic properties are such, as well as at fusions of polymers. The concentrations of races of work in connection with the wide range of the set indexes of flow hesitated from 0,5 to 1,5. Liquids long enough kept the structure and did not appear inflammable and toxic. The range of serves had an experimental stand from that answers speeds of change from 0,32 - 192 S^{-1}. Hydraulic part of stand is executed as reserved a contour and consisted of centrifugal the pump of Calpeda MGH with vector CU HITAHI Sg-200 and reverse connection on pressure and ventilator for cooling of electric motor of working area calming and downlow a tank and flowing a tank and induction flowmeter of RKE-29. The use of scalar CU to the pump appeared impossible in connection with that scalar CU does not provide a high circulating moment which necessary for the pumping-over of polymers. Use flowing a tank it is necessary for doing of pulsations of stream impossible which arise up in connection the features of non-Newtonian conduct of liquid.

Vector CU HITAHI Sg-200 tailed to PC for the change of fixing and control of parameters of electric motor of pump and ventilator. A working area is executed as glass twin-tubes of different diameter with the thickness of wall 0,5 mm and long a 1,5 meter. Distributing of pressure was measured by gauges. Reological of description was measured on the viscometer-stirrer of "Reotest 2". Kinematics descriptions were measured on the specially collected laser doppler measuring device [4] of speed on the basis of differential chart theoretical development of which resulted in . However much the use of such chart in practice for research of non-Newtonian liquid appeared not impossible. Therefore such chart was done and complemented.

A chart consisted of helium - neon emitter of LG-79-1, which generates a ray, 0.63 mkm with the index of TEM (0, 0) by power to 24 mW. Power of laser radiation was regulated by CU. A ray from an emitter go on light divisible block, where divided into two rays for 50 percents of power. These two rays by specially constructed for such researches of lenses with a candle-power 1.2 and 50 mm. and 15 mm. focused focal distance in the probed point of stream of liquid.

Two lens was used for that, to measure local speed in the wide range of speeds in connection with that frequency of signal depends on a corner under which rays intersect and at the exceeded frequencies of signal higher 100 kHz frequency of signal will be is in the area of noises of radio frequencies and noises from a laser radiation in connection with the considerable not focusing of laser rays after their crossing in the stream of non-Newtonian liquid. As noises of radio frequencies on amplitude higher, than amplitude of signal it would be impossible to measure a signal. To use a lens for focusing of rays at the liquid probed a point at measuring of epure of speeds in between pipe space it appeared impossible in connection with extraordinarily large aberration of rays on the edges of lens which increased due to heterogeneities which are present on-the-spot be what pipe and lens effect of pipe that led that the closeness of power of laser radiation in the point of measuring diminished so that measuring of epure of speeds appeared impossible. On that reason the use of prism appeared impossible for unlinking of laser ray. For diminishing of influence of surface of pipes on aberration in this work pipes were used with the thickness of wall 0,5 mm. In a lens which was created specially for such researches corrected aberration and the form of ray changed thus, that a cut of ray in the point of measuring was cylinder and also for doing of origin of effects of non-Newtonian optics impossible. A lens consisted of six lenses. As known every lens removes 5 percents of laser radiation. That the losses of power of laser radiation were made by the more than half of power that would bring a leadthrough over of experience to impossibility. In connection with foregoing it was done coverage on every lens which consisted of 16 layers. Such coverage allowed to decrease the losses of radiation which in all chart made not more than 3 percents. There was interference at crossing of rays. When parts which were in a liquid passed through this point from them a signal, proportional speed of part, was reflected. This signal through a lens with focal distance 50 mm and by a candle-power 1.4 focused on a diaphragm with the diameter of opening $2*10^{-6}$ mm. Diaphragm opening determined size an experimental way. Diaphragm was used for that in order to avoid the hit of superfluous laser radiation and other light in photoelectronic for a multiplier so as such light has amplitude higher, than amplitude of signal and frequency the same as frequency of signal. For the increase of exactness measuring was conducted diaphragming of laser rays in a lens. Diaphragming it is in this case necessary for that, to increase the depth sharpnesses of image of intersection laser rays and avoid influence on measuring of local speed of nearby layers of liquid. Farther a signal was caught photo multiplier. In which on electrodes a signal increased and there was the first transformation of Fur'e. The place of location of photo multiplier got out on the basis of research of diagram of dispersion pseudo plastic liquid which investigational the author of the article first in-process. After a photo multiplier signal go on a switch, then on the specially developed rejector filter, for that, to select necessary frequency and then on a selective strengthener. The use of ordinary filters for such researches appeared impossible because as known every radio signal consists of spectrum of signals which have different frequency. Each of signals of this spectrum is responsible for the form of signal. The constituents of spectrum of signals at such researches coincide on frequency with frequency of noise. That ordinary filtration of signal resulted in filtration and constituents of spectrum of signal that and signal. It brought a lead through over of such experiments to impossibility. For development of filter for such researches it is necessary it was to consider every constituent of spectrum of signal. The lead through of such researches became possible at the use digital spectrum of analyzer in which the foreseen function of memorizing of all constituents of spectrum of signal. As known amplitude of spectrum constituents sharply diminishes at the changed frequencies from bearing to endlessness. Therefore on this go there was the developed filter which simultaneously conducted filtration on amplitude and frequency of signal with such calculation, to skip fully bearing frequency and spectrum constituents and to filter noise only. Development of filters became complicated yet and those that frequency of signal changed depending on speed of particles. In accordance with it changed frequency and all constituents of spectrum of signal. Therefore filter members are neat thus, that fix changes of frequency of signal and his constituents of spectrum and accordingly to filter noise only. After a selective strengthener a signal was given on the digital of "Rigol". From "Rigol" an on a processor for that, to support the necessary level of signal when particles are not in the area of crossing of laser rays and then on the analyzer of spectrum of "Agilend". On the analyzer of spectrum measuring of frequency of signal was conducted. From the analyzer of spectrum a signal is given on PC where registered and due to the developed software transferred in speed and the epure of speeds is built.



Picture 1. Local speeds.

The results of experimental researches were confronted with analytical, that allowed to draw conclusion about convergence of results experimental and analytical. An error makes no more one percent.

As a result of work the made method of calculation of technological equipment. On the basis of method the created program of calculation is on PC. The results of researches were inculcated on the row of enterprises of Ukraine.

References

1. Proceedings of the International Workshops on the Physics of Turbulent Compressible Mixing: v. 1 - Prinston, USA, v. 3 - Abbey of Royaumont, France, v. 4 - Cambridge, England, v. 5 - Stony Brook, USA, v. 6 - Marseilles, France.

2. *K.I. Read*. Experimental Investigation of Turbulent Mixing by Rayleigh-Taylor Instability. Physica 12D, p. 45, 1984.

3. *Ю.А. Кучеренко, С.И. Балабин, и др.* Экспериментальное исследование развития возмущений в гравитационно-неустойчивой системе с непрерывным распределением плотности. ВАНТ, серия: теоретическая и прикладная физика, вып. 1, стр. 20,1988.

4. *Ю. Н. Дубнищев, Б. С. Ринкевичюс.* Методы лазерной доплеровской анемометрии. Москва, Наука, 1982.

UDC 620.197.6(045)

V.N. Shmarov, Dr.of Sc. (NAU, Ukraine, Kyiv)
S.R. Ignatovich, Dr.of Sc. (NAU, Ukraine, Kyiv)
M.V. Karuskevich, Dr.of Sc. (NAU, Ukraine, Kyiv)

NEGATIVE SIDE EFFECTS CAUSED BY CORROSION PREVENTIVE COMPOUNDS

The possibility of negative side effects caused by the application of corrosion preventive compounds is discussed. It is shown that the corrosion preventive compounds being surfactants can influence on initial stage of fatigue crack nucleation, on the stage of fatigue crack propagation as well as they influence on the mechanical properties of riveted joints of aircraft structure. The necessity of the special tests directed on the revealing the side effect is grounded. Some methods for the side effects investigation are presented.

Introduction

Despite the development of new constructional materials and variety of methods and technologies against corrosion of aircraft components the problem remains actual.

Protection by the petroleum based corrosion preventive compounds (CPCs) or Corrosion Inhibiting Compounds (CICs) widely used due to the proved by years their efficiency. CPCs are applied to painted and bare metal surfaces, they act by spreading across surfaces and into crevices, displacing any water which may be present. The carrier solvent evaporates and leaves the film with hydrophobic additive and the inhibitors.

CPCs may include an oil, grease or resin based film former, a volatile, low surface tension carrier solvent, a non volatile hydrophobic additive and various corrosion inhibitors or surface active agents.

Thus, some CPCs may be considered as surfactants with expecting negative consequences.

The negative influence on the metal fatigue may be expected on the stage of the crack nucleation and on the stage of the fatigue crack propagation.

Some researchers have found the influence of preventive compounds on the fatigue of riveted joints.

Unfortunately, all related information has uncoordinated character and necessity of the systematic investigation is evident.

1. Influence of corrosion preventive compounds on the stage of fatigue crack nucleation

Taking into account the chemical composition of many types of CPCs there are enough arguments to consider these substances as surfactants. Thus the Rebinder effect [1] is expected. The Rebinder effect is the drop in mechanical strength and deformation and decomposition of solids through the reversible physicochemical action of a particular medium. The effect was discovered in 1928 by P. A. Rebinder in an investigation of the mechanical properties of the crystals of calcite and rock salt.

If the metal fatigue is considered, the Rebinder effect manifests change of correspondent dislocation structure of the surface layer as well as acceleration or deceleration of the damage accumulation process.

At National Aviation University the methodology of fatigue damage assessment based on quantitative analysis of the surface deformation relief has been developed [2]. The deformation relief have been observed and analysed on the surface of alcalad aluminium alloys D16AT, V95, 2024T3, 7075T6. The methodology relies on the possibility to measure intensity of the deformation relief by the computer aided light microscopy technique.

The evolution of the relief intensity presented in the fig.1.

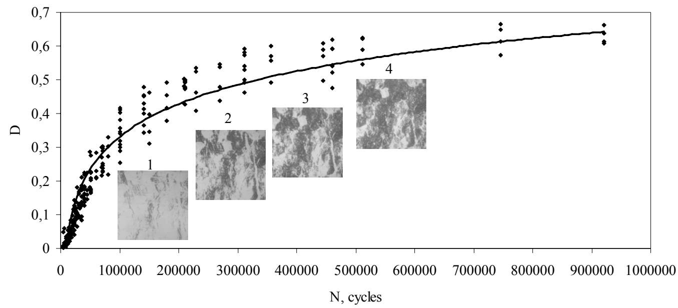


Fig.1 Evolution of the deformation relief under fatigue

Some more sophisticated methods of nondestructive inspection of the metal surface can be used also, for example atomic force microscopy, scan microscopy, non-contact interference profilometry. All mentioned methods have been used in the researches conducted at National Aviation University.

It can be presumed that deformation relief being good indicators of accumulated fatigue can be used to reveal Rebinder effect produced by the CPCs and to assess associated loss of bearing capacity [3].

2. Influence of corrosion preventive compounds on the stage of fatigue crack propagation

Damage tolerance concept assumes the appearance and propagation of fatigue cracks. That’s why there is strong necessity to know all factors that affect cracks.

Analysis of researches in which aviation materials and components, treated by CPCs were tested, proves the possible of the harmful effect on fatigue crack propagation rate.

For example, the paper [4] presents the results of crack growth measurements conducted on aluminum alloy 2024-T351 samples, in normal laboratory air, distilled water and an oily film CPCs commonly used in the aerospace industry. Samples subjected to medium to high stress fatigue in the CPCs environment exhibit an increase in crack growth rate of the order of 20%, compared to about 7% increase in distilled water. The influence of the environment is mainly seen as a change in the Paris coefficient C, with negligible change in the Paris exponent "n". Authors of the paper consider some mechanisms by which the presence of CPCs increases crack propagation rates and recognize as necessary the further researches covering a wider spectrum of load levels, stress ratios, frequencies and materials.

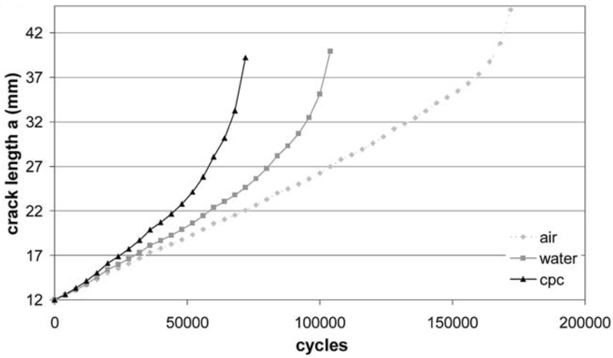


Fig.2. Acceleration of the crack rate caused by the environment [4]

3. Influence of corrosion preventive compounds on the fatigue of riveted joints

Some tests performed in different countries have shown the negative effect of the CPCs on the fatigue of the riveted structural components. Similar tests have been carried out at the National Aviation University in Kiev in the 1980th and in the Great Britain [5], Holland [6], Australia [7].

In one research [8] the specimens were subjected to constant amplitude fatigue testing, at different load levels. Two CPCs used to prevent aircraft corrosion were applied. The results showed that the application of CPCs reduced the fatigue life of single lap joints. The greatest reduction occurred when the joints were tested at intermediate load levels and at the upper bound of the low load levels; a reduction factor of two or more was found. At high and low load levels, a lesser reduction in fatigue life was observed.

Some possible mechanisms of the phenomena are still under discussions. A major factor in this drop of fatigue life could be the reduction of friction due to the lubricating properties of the compounds. The reduction in friction between connected sheets would cause more load to be transferred through the rivets. Such a change in load transfer mechanism would explain the changes observed in the fatigue of the joints.

4. Key points of the test strategy directed on the reveal of side effects caused by the corrosion preventive compounds

As the corrosion remains to be one of the most probable and dangerous damage of the aircraft the new generations of CPCs will be under inventions and implementations. The necessity of the tests of their functional properties test is obvious. Not only protective efficiency is actual, as it is shown above.

The methodology of the test have to include three main branches:

1. Investigation of the side effects on the initial stage of the fatigue.
2. Investigation of the side effects on the stage of fatigue crack propagation stage.
3. Investigation of the side effects for the samples modeling structural components, especially riveted joints.

For covered by the aluminium layer alclad alloys the first point can be performed with the use of deformation relief parameters as quantitative indicators of the fatigue damage.

For the second point of the test methodology the crack must be monitored and correspondent parameters of the Paris equation to be calculated.

For the third point of the test program it is necessary to test specimens reflecting main particularities of the design, taking into account possible penetration of the compounds into the gaps between the bonded parts.

Conclusions

Application of the corrosion preventive compounds can lead to the drop of fatigue life of the constructional aluminium alloys. This effect may be revealed on the initial stage of fatigue and during the crack propagation stage for the simple standard specimens of materials. The negative effect can be observed also while the components of aircraft skin with riveted joints are tested. There is a set of different mechanisms for the harmful effects.

To prevent bad influence on aircraft service life the tests of the compounds intended for the implementation are mandatory. At the initial stage of fatigue the surface deformation relief can be considered as an indicator of the CPCs influence; on the stage of crack propagation correspondent influence can be revealed as a crack acceleration or deceleration. Special attention must be drown to the CPCs influence on the structural components, Here the effect may be more complicated and to include two mentioned above points as well as to be a result of the load redistribution between joined parts.

References

1. Malkin, A. I. (2012). "Regularities and mechanisms of the Rehbinder's effect". *Colloid Journal* 74 (2): 223–238.

2. Karuskevich M. Extrusion/intrusion structures as quantitative indicators of accumulated fatigue damage / O. Karuskevich, T. Maslak, S. Schepak. // International Journal of Fatigue. – 2012. – № 39. – P. 116–121.

3. Karuskevich M., Maslak T., Seidametova G. Deformation relief as an indicator of Rebinder effect. Procedings of the National Aviation University. - 2013.№1 (54), P.82-86

4. Craig Purry, Alan Fien, Krishnakumar Shankar. The effect of corrosion preventative compound on fatigue crack growth properties of 2024-T351 aluminium alloys International Journal of Fatigue 25 (2003) 1175–1180

5. O'Neill PH, Smith RJ. A short study of the effect of a penetrant oil on the fatigue life of a riveted joint. Farnborough, UK: Royal Aircraft Establishment, pp. 1305, 1973.

6. Schijve J, Jacobs FA, Tromp PJ. Effect on anticorrosion penetrant on the fatigue life in flight simulation tests of various riveted joints. NLR TR 77103. Amsterdam: National Aerospace Laboratory, 1977.

7. Dhamari RDA. The effects of water displacing corrosion preventatives on the fatigue behaviour of mechanically fastened aluminium joints. PhD thesis: Aerospace, Civil & Mechanical Engineering, Australian Defence Force Academy, UNSW, 2005.

8. Aditya Jaya, Ung Hing Tiong, Reza Mohammed, Cees Bil, Graham Clark. The influence of corrosion treatments on fatigue of aircraft structural joints, 27th international congress of the aeronautical sciences, 19-24 September 2010, Nice, France, pp.1-8.

UDC 621.921

S.S. Yutskevych, PhD. (NAU, Kyiv, Ukraine)
G.G. Pisarenko, Dr.of Sc. (Institute of Problems of Strength NASU, Kyiv, Ukraine)
A.M. Maylo PhD. (Institute of Problems of Strength NASU, Kyiv, Ukraine)
Rao De (NAU, Kyiv, Ukraine)
Liu Yong(NAU, Kyiv, Ukraine)

STUDYING OF STEEL 12H18N10T PHYSICAL-MECHANICAL PROPERTIES CHANGES BY RESONANCE METHOD OF INELASTICITY CONTROLING

It's shown the comparative results of values, that are describing of generalized damage parameter of steel 12H18N10T obtained by resonance method of inelasticity controlling for polished and not polished surfaces.

For an aircraft structure is most important next requirements: high static and fatigue strength in one hand and low weight of structure on the other. This conflicting demands are performed necessary safety level aircraft structure and make to develop methods of prediction of boundary level, connected with sudden bearing capacity decreasing. This methods should based on the understanding of the processes that take place in metals and alloys in different scale levels under fatigue. A lot of works describe material structural changes on nano-, micro-, meso- and macro levels, leading to the crack initiation that could be taken as a boundary condition [1].

The evolution of metal and alloys structure under fatigue change physical- mechanical properties of materials and applying of proper nondestructive methods in this case could give information about decreasing of bearing capacity.

There are carried out the fundamental researches in aircraft structure fatigue test laboratory showing that fatigue process has no any liner dependence and has complicated self-organized form with bifurcations points, cause of which is lying in different scale levels [2].

It's known that under cycling loading the damages accumulated with high intensive in the surface layer of material that is connected with the presence of free surface and dividing of material on two environment. According to this controlling of physical-mechanical properties changes in surface layer allows to estimate current level of material damage. For this purpose it was used local-sensitive method of statistics measurements of generalized damage parameter, developed in the Institute for Problems of Strength [3].

Fatigue test was performed as cantilever bending with constant amplitude allowing to obtain 490 MPa stress in control area and 25 Hz frequency. This tests were conducted on flat specimen from steel 12H18N10T. One side of the specimen was polished and the others side stayed unpolished. The measurement is carried out by the scanner device, schematic circuit of which is represented on Fig.1.

A generator generates signal with 19.64 kHz frequency for lines A and B. The value of this frequency entering into resonance the sensor and allows to obtain the feedback signal of the testing specimen in line C. According to this feedback, signal in line C has phase-shift angle in comparison with line A that is registered by means of dual input sound card and interpret and recorded by software program. The results of scanning is describing by angle of phase shifting ($\Delta\varphi$) of lines A and C signals.

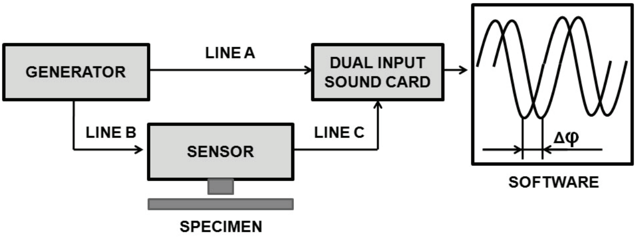
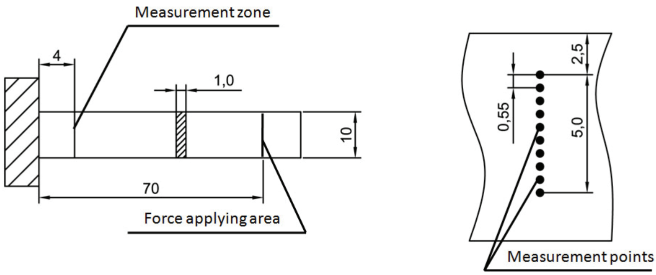


Fig.1. Schematic circuit of scanner device

For the statistic analyzes of the scanning results there are carrying out 10 measurements of the surface. The drawing of the specimen and principle of measurement area estimation is shown in fig.2a and fig. 2b correspondingly.



a) b)

Fig.2. Drawing of the specimen (a) and measurement zone (b)

Basing on this 10 measurements:

- the mean value of phase-shift angle:

$$\overline{\Delta\varphi} = \frac{\sum_{10}^{i} \Delta\varphi_i}{10};$$

- the root mean square deviation (RMSD):

$$\sigma_{\Delta\varphi} = \sqrt{\frac{1}{10}\sum_{10}^{i}\left(\Delta\varphi_i - \overline{\Delta\varphi}\right)};$$

were determined and used as material properties changes control parameters.

For the researching of the surface roughness influence on the measurement data polished and unpolished sides were controlled and RMSD founded. For polished side the value of RMSD was $\sigma_{\Delta\varphi\, P}$ = 13,74 degrees, for unpolished side the value of

RMSD was $\sigma_{\Delta\varphi\, UnP}$ =12,57 degrees. It is no significant difference between this two values.

Next part of test was implemented for cycling loading researches. Studying of control parameters changes of polished and unpolished sides was made by periodically with 1000 loading cycles fatigue test interruption for specimen surface scanning. Results of this measurements are represented on fig 3 a and fig.3 b.

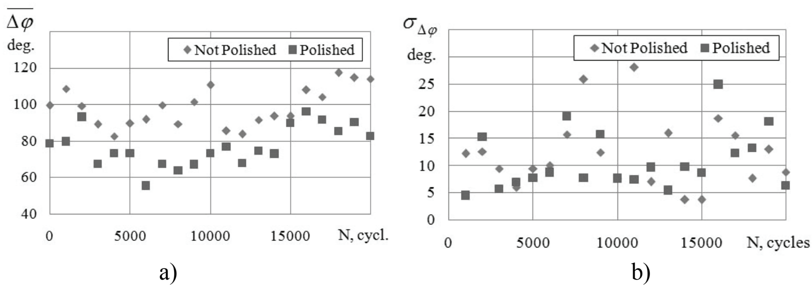


Fig. 3. Mean value of phase-shift angle vs. cycling loads (a) and root mean square deviation of phase-shift angle vs. cycling loads (b)

Conclusion

The dependences in Fig.3 have complicate form with wave shape tendency that may be explained by material structure evolution under fatigue process. Such behavior were described at works [2, 4] that makes method of material inelasticity controlling promising for nondestructive methods of material physical-mechanical properties studying.

References

1. Panin V.E. Overview on mesomechanics of plastic deformation and fracture of solids / Theoretical and Applied Fracture Mechanics 30 (1998) P. 1-11.

2. Radchenko A.I. Yutskevych S.S., Panteleev V.M. Synergetic Discretely-Likelihood Fatigue Model Based Structure Lifetime Prediction Methods Improvement: materials of 19th ECF «Fracture Mechanics for Durability, Reliability and Safety» (26 - 31 August, 2012). – Kazan, 2012 – P. 148-154.

3. Patent 17348 of Ukraine, МПК (2006) G 01 N 3/00 Method of structural element material level degradation estimation / Pisarenko G.G., Kopchevskiy P.M., Maylo A.M. – № u200603858; alleged. 07.04.2006; published. 15.09.2006, bulletin.№ 9 (in Ukrainian).

4. Radchenko A.I. Yutskevych S.S., Panteleev V.M. Aspects of metal fatigue process under two-block loading tests / Aviation in the XXI-st century. Safety in Aviation and Space Technologies: the V world congress, 25–27 September 2012: abstracts. – K., 2012. – P. 1.2.15–1.2.19.

UDC 620.179.1

S.V. Shchepak, PhD. (NAU, Ukraine, Kyiv)
O.P. Linnik (NAU, Ukraine, Kyiv)
V.M. Oleksiuk (NAU, Ukraine, Kyiv)

INFLUENCE OF LOCAL FATIGUE DAMAGE ON THE CRACK PROPAGATION RATE

Application of damage tolerance principle at operation of aircrafts assumes ability to predict propagation of fatigue cracks. Conducted experiments have proved that local metal damage accumulated due to cyclic loadings has influence on fatigue crack propagation, especially on the initial stages of crack development. Density of deformation relief at the stress concentrator is being used as damage indicator. It has been proved, that there exists correlation between time of crack propagation and saturation of deformation relief at the stress concentrator.

Introduction

Ensuring of effective and safe operation of aircrafts is based on the three principles of their design: Safe-Life, Fail-Safe and Damage Tolerance. The above-mentioned methods do not contradict each other, but instead complement each other because of the fact that they are being applied to different aggregates, assemblies and parts of the structure. For thin-walled aircraft structures like fuselage, application of damage tolerance approach is most appropriate. In this case a clear need to develop a technique for reliable monitoring of fatigue cracks and prediction of their further propagation arises.

Linear fracture mechanics makes it possible to forecast fatigue crack kinetics by the means of empirical relationships developed by Paris and Erdogan [1], bounding speed of crack propagation *dl/dn* with range of the stress concentration coefficient ΔK as

$$\frac{dl}{dn} = C(\Delta K)^q$$

Such approach does not take into account damage accumulated at the incubatory stage and possible differences of physical and mechanical characteristics of material at the moment of crack initiation.

In this article results of research, which has proved the possibility of fatigue crack propagation prediction based on correlation between deformational relief at the stress concentrator and rate of crack propagation, are being considered.

1. Deformational relief as an indicator of accumulated fatigue damage

Initial stage of alclad aluminum alloys fatigue is accompanied by formation and development of surface deformational relief, which consists of a set of extrusions, intrusions and slip.

It is possible to observe deformational relief by application of light microscope while assessing it quantitatively by means of digital pictures obtained at 200^x-

400^x scale. In order to assess intensity of deformational relief a set of parameters have been introduced: damage parameter D, which characterizes its saturation, fractal dimensionality of clusters $D_{p/s}$, representing the shape of deformational relief clusters [2-4].

Damage parameter D is determined as ratio of area with signs of microplastic deformation to the total area of the controlled area. Special computer aided optical equipment and software for automatic determination of damage parameter has been developed. Existence of correlation between value of the introduced parameter and amount of damage accumulated at the incubatory stage of fatigue has been proved.

2. Results of the experiments

The performed experiments were aimed at obtaining data about development of fatigue cracks in specimens of sheet alclad alloy D16AT and establishment of correlation relationship between duration of crack propagation and accumulated damage at the incubatory stage.

Specimens with side notch have been tested. Fatigue testing has been performed on a standard testing machine by axial tension with maximum cycle stress equal to 60.0; 70.0; 80.0 MPa with stress ratio R=0. Loading mode choice has been made taking into account real conditions of aircraft structures loading.

During the testing following parameters were recorded: value of damage parameter at the stress concentrator and corresponding number of cycles at the incubatory stage, number of cycles to 1,0 mm long fatigue crack formation, crack length and corresponding number of cycles at the crack propagation stage; time of specimen failure.

The amount of performed tests allowed to obtain kinetic diagram of fatigue crack growth (fig. 1), which leads to solution on the base of linear fracture mechanics.

Initial data for construction of diagram of fatigue crack growth includes fatigue crack length l and corresponding number of loading cycles n, obtained from tests performed at maximum cycle stress σ_{max}=60,0; 70,0; 80,0 MPa with stress ratio $R=0$. Coefficients of Paris equation C=9*10^{-15} and q=4,367 have been obtained by approximation of experimental data shown at the fig. 1.

Paris equation satisfactorily describes experimental data corresponding to double logarithmic scale of linear interval II of kinetic fatigue failure and does not correspond to the non-linear intervals (I and III). It is assumed that the crack is propagating through undamaged material which does not differ from its initial state.

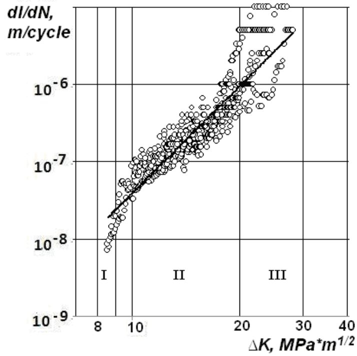


Fig. 1. Kinetic diagram of fatigue crack growth for alclad alloy *D16AT*, *R*=0 (○-experimental data, ▬ experimental data approximation)

3. Prediction of fatigue crack propagation process based on parameters of deformational relief at the stress concentrators

Earlier numerous researches have proved the possibility of number of cycles till crack initiation prediction based on the deformation relief parameters – its saturation and fractal dimensionality [2-4].

In the presented research monitoring of the damage parameter D at the stress concentrator during the incubatory stage of fatigue has been carried out. The limit value of the D parameter has been determined, i.e. the value which corresponds to complete saturation of relief and fatigue crack initiation. It has been assumed that after the crack initiation deformation relief density at the stress concentrator does not change, which has been proven experimentally. Value of the damage parameter D at the moment of crack initiation is referred to as critical damage parameter $D_{cr.}$

Critical damage parameter characterizes the material state at the crack initiation area, Regarding the fact that area of damage localization and deformation relief formation at the set loading parameters is equal to several millimeters, we can assume that there exists a close correlation relationship between the damage parameter $D_{crit.}$ and the crack propagation process characteristics.

At the fig.2 as an example, dependence of propagation stage duration of the fatigue crack $N_{dur.}$, measured in thousands of cycles on the critical damage parameter $D_{crit.}$, obtained by testing with maximum loading 70,0 MPa with asymmetry coefficient $R=0$ is shown.

Given curve may be approximated by equation

$$N=4{,}9318-11{,}55\mathrm{Ln}(D_{cr.}),$$

which makes it possible to predict the crack propagation stage duration with help of critical damage parameter $D_{crit.}$ at the stress concentrator. Accuracy of the approximation is represented by the determination coefficient R^2 = 0,8139.

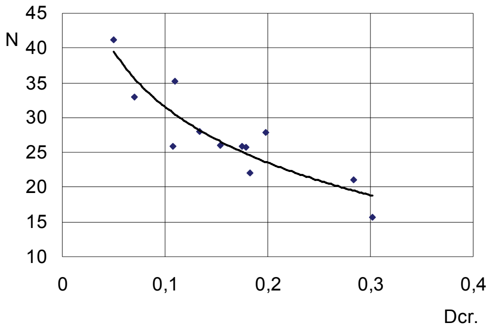


Fig.2. Diagram of dependence of crack propagation stage duration on the critical damage parameter.

It's worth mentioning that influence of the deformation relief on the crack propagation rate persists after its propagation beyond the borders of the specified area, though closeness of the connection between the critical damage parameter and the growth rate decreases. Determination coefficients values R^2 for dependences of crack propagation rate on the critical damage parameter are shown in the table 1.

Table 1

Determination coefficients R^2 values for dependence of the crack propagation rate on the critical damage coefficient D_{crit}, for various crack lengths

Crack length, L, $_{mm}$	0-4	4-8	8-12	12-16
Determination coefficient, R^2	0,915	0,8627	0,7339	0,5995

4. Results of crack propagation duration prediction

Results of fatigue crack propagation time prediction for 10 specimens at the maximum loading of 70.0 MPa and the asymmetry coefficient $R=0$ are given in the table 2.

Results of calculation performed by the two abovementioned approaches are represented by means of following notations:

$N_{act.}$ – actual duration of the crack propagation stage (10^3 cycles);

$N_{Dcrit.}$ – duration of the crack propagation stage determined by the critical damage parameter(10^3 cycles);

$N_{fract.\ mech.}$ - duration of the crack propagation stage determined by the fracture mechanics technique (10^3 cycles);

$N_{act.} - N_{Dcrit.}$ – crack propagation stage duration prediction error when determining with the help of critical damage parameter (10^3 cycles);

$N_{act.}$-$N_{fract.mech.}$ – crack propagation stage duration prediction error when determining with the help of fracture mechanics technique (10^3 cycles).

Durability estimation results have been obtained by the known classic fracture mechanics approach.

Table 2

Results of alloy D16AT specimens endurance prediction

Spec.	1	2	3	4	5	6	7	8	9	10
$N_{act.}$	41,2	22,1	25,7	25,8	25	25,8	24,6	15,6	21	35,2
$N_{Dcrit.}$	38,4	23,2	24,9	31,1	27,0	25,0	23,5	18,7	19,8	31,1
$N_{.fract.\ mech.}$	27,1	24,3	24,3	24,3	24,3	25,9	24,3	24,3	24,3	25,9
$N_{act.}$ - $N_{Dcrit.}$	2,8	-1,1	0,8	-5,3	-2	0,8	1,1	-3,1	1,2	4,1
$N_{act.}$- $N_{act.mech.}$	14,1	-2,2	1,4	1.5	0,7	-0,1	0,3	-8,7	-3,3	9,3

As it is shown in the table above, absolute error of crack propagation stage duration prediction does not exceed $4.1 \cdot 10^3$ cycles, while the conventional approach only provides accuracy of $14.1 \cdot 10^3$ cycles.

Conclusions

Assessment of sheet alclad aluminum alloys may be performed by surface damage parameters at the stress concentrator. The predicted crack rate is the most correct at the initial stage of crack propagation, i.e. for the crack of the length till 4 mm. Comparison with the fracture mechanics approaches shows the advantages of the proposed method.

References

1. Paris P.S., Erdogan F. A critical analysis of crack propagation laws /Journal of Basic Engineering. Trans.Asme. – 1963.-Vol. d-85, N4.- P.528-534.

2. Karuskevich M.V., Korchuk E.Yu., Yakushenko A.S., Maslak T.P. Estimation of the accumulated fatigue damage by saturation and fractal dimension of the deformation relief // Strength of materials - Vol. 40. - № 6. – P. 693-698.

3. Karuskevich M., Karuskevich O., Maslak T., Schepak S. Extrusion/intrusion structures as quantitative indicators of accumulated fatigue damage // International Journal of Fatigue. – 2012. – № 39. – P. 116–121.

4. Karuskevich M.V. Fatigue life prediction by the structurally sensitive damage indicator // Proceeding of NAU. – 2012. – № 1. – P. 139–143.

UDC 621.179

T.P. Maslak, PhD. (NAU, Kyiv, Ukraine)
D.N. Kosteniuk, PhD. of NAU (NAU, Kyiv, Ukraine)

ANALYSIS OF THE PLASTIC ZONE SIZE AND SHAPE FOR THE ALUMINIUM ALLOYS

The paper presents the results of the plastic zones size and shape investigation by the deformation relief on the surface of alluminum alloy. Fatigue tests of the specimens of the D16AT were conducted under the loading conditions close to the operational. It has been shown the possibility of plastic zone size and shape calculation for cladded and not cladded materials.

Introduction

The instrumentals methods for the analysis of the shape and size of the plastic zones are used for the control, implementation and creation for the new models of fatigue damage accumulation and failure process. The size of plastic zone or radius (normal distance from the crack edge to the boundary of plastic zone) [1] gives the possibility to find the following parameters, which take place at crack growth: the maximum of stress intensity factor K_{max} and maximum stress σ_{max} of loading cycle, fatigue crack growth rate.

The determination of these parameters is used for the investigation of fatigue failures of aviation and other structures under the full-scale fatigue tests. Full-scale fatigue tests are needed because there are no unique methods of stress intensity factor calculation for any structure with damages in operation, there are a lot of factors which influence on the fatigue failure process and it is difficult to take them into account in analytical calculations. Aircraft fuselage structure is a good example of structure that is based largely on a slow crack growth rate design. The presence of large stress concentrators like holes for the rivets complicates the calculation of multi-site damage of fuselage skin, complicates the loads distribution, the distribution of stress, deformation and so it makes difficult to calculate analytically the stress intensity factor.

Experimental method

The plastic deformation of pollycrystals is the deformation of grains (the changes in size and shape), their rotation and displacement relatively to each other. The presented optical method is used for the determination of zones where the grain rotation is occurs. It has been shown the comparison of experimental data with analytical data related to the plastic zone calculation. This method establishes the correspondence between the size and shape of grain rotation zones with the size and shape of plastic zone.

The fig. 1 shows the specimen of D16AT (the thickness of specimen is 1,2 mm) for the plastic zones experimental analysis. The specimen without initial crack was tested under the maximum stress 89.2 MP with stress ratio R=0 at frequency of loading 11 Hz.

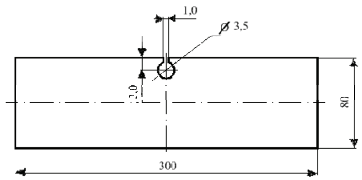


Fig.1 Fatigue test specimen

The analytical form for the plastic zone calculations by Rice has the view [2]:

$$R_{pc} = C(\Delta K / \sigma_{0,2})^2$$

where R_{pc} – radius of plastic zone, C – coefficient (for current analytical calculation C=0,09), ΔK – amplitude of stress intensity factor, under R=0, ΔK=K_{max}, $\sigma_{0.2}$=270 MPa.

The maximum value of stress intensity factor K_{max} is determined as [3]:

$$K_{\max} = \sigma_{\max}\sqrt{l}\cdot Y(\lambda)$$

where σ_{max} - maximum stress of loading cycle, l - effective length of crack (crack together with the stress concentrator), $\lambda = l/b$, b – specimen width, $Y(\lambda)=1{,}99-0{,}41\,\lambda+18{,}7\,\lambda^2-38{,}48\,\lambda^3+53{,}85\,\lambda^4$.

The results of analytical calculation and experimental definition of plastic zone are shown in fig.2.

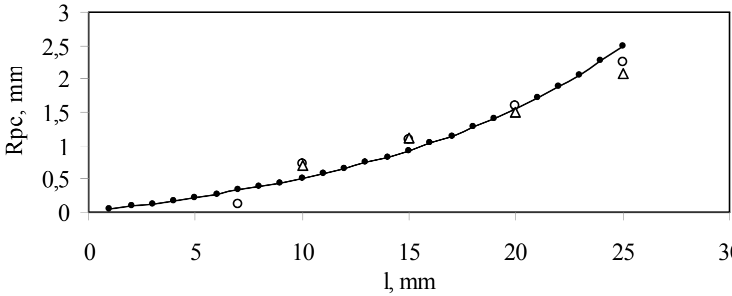


Fig. 2. Relationship between the radius of plastic zone and the length of crack: ○ - experimental data for plastic zone on the surface of D16AT without clad layer, Δ - experimental data for plastic zone on the surface of D16AT with clad layer, ● - analytical data.

The specimens of D16AT have layer of pure aluminum for the corrosion resistance. But for the mentioned above analytical analyses the influence of layer on plastic zone was not taking into account that is why the layer was removed from the surface of some tested specimen in a crack propagation area. The results of experimental investigation show that the layer does not influence on the size of plastic zones.

So it confirms the ability of method implementation to the analyses for alloys without cladding.

The data presented in the fig. 2 manifests close correlation between experimental data and analytical data. The maximum deviation of plastic zone size obtained experimentally in comparing with the analytical one is equal to the 0,4 mm. Thus this method is well grounded for the determination of plastic zones size and shape.

Algorithm of plastic zone determination in structural element includes the following procedure.

Before loading:

1. Determination of controlling area. The radius of plastic zone can reach approximately 8 mm under overloads.

2. Control area preparing by mechanical polishing with diamond paste for the elimination of any signs of roughness.

After loading:

3. Cleaning of the surface preventing any damages of deformation relief.

4. Tuning of light microscope for necessary scale (approximate magnification can be 50-80^x).

5. The determination of a plastic zone boundary by the light microscope. During the changing of focusing we can see the changing of deformation relief signs. When observed area or a part of it is evenly diffused it means that there are no grain rotations in these observed area or its part.

The main features of relief images transformation where the grain rotation takes place are the following:

- during focusing within 2,5 μm from maximum sharp you can see disappearance of one slip lines and the appearance of another slip lines,

- during focusing within 10 μm from maximum sharp the images are saturated by details which keep their sharpness (hollows or tops of deformation relief).

- during the next focusing the images look like black and white signs. This feature can be taking into account for the definition of plastic zone boundaries only after previous two features.

Mentioned above features of deformation relief images under focusing one can see in the fig.3. At images of the same place at different focusing (the magnification is 80^x) from the left side one can see the crack and deformation relief near the plastic zone, from the right side there are no any grain rotations. The boundary between area with the grain rotation and without grain rotation is corresponded to the boundary of plastic zone.

6. The determination of plastic zone size. It can be made with the distance measurement from the tip or edge of crack to the boundary of plastic zone.

7. The definition of plastic zone shape. It can be made directly during the observation of plastic zone in microscope ocular or by marking their boundary on panorama image of control area.

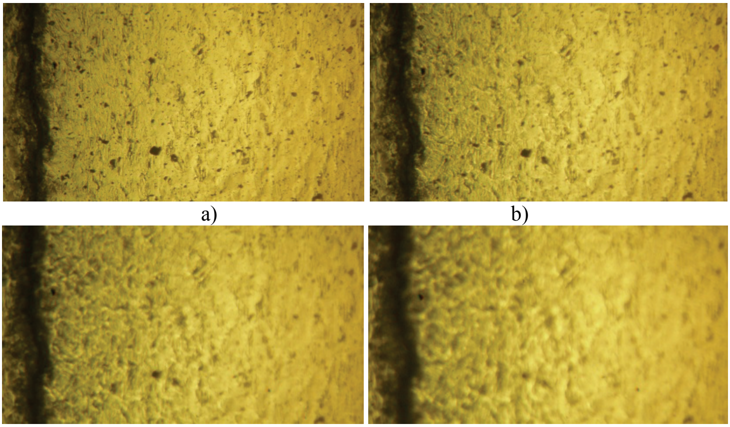


Fig.3. Deformation relief images near the crack under focusing: a – with maximum sharpness; b – focusing is displaced to 2,5 µm; c – focusing is displaced to 7,5 µm; d – focusing is displaced to 12,5 µm.

Conclusions

The plastic zone of cracks and others stress concentrators is characterized by the rotation of grain on the surface of metals. This feature allows identifying the shape and size of plastic zone.

The next investigation will be devoted to the determination of size and shape of plastic zone with the light profilometer and the implementation of the method to the other aviation alloys.

References

1. Klevtsov G.V., Botvina L.R., Klevtsova N.A. Plastic zone formation under different types of loading conditions // ISIJ International, 1996. – Vol. 36. - № 2. – P. 215-221.

2. Kocanda S. Fatigue failure of metals // Sijthoff noordhoff, Netherlands. – 1978. – 380 p.

3. Nott J.F. Fundamentals of fracture mechanics / Butterworth and Co., Ltd. – London, 1973. – 328 p.

UDC 539.3

A.V. Plashchynska, PhD., V.P. Golub, Dr.of Sc.
(Institute of mechanics S.P. Timoshenko NASU, Ukraine),
M.V. Karuskevich, Dr.of Sc. (NAU, Ukraine),

FATIGUE CRACK GROWTH MODELING IN THIN ALUMINUM PLATE UNDER ASYMMETRICAL CYCLIC LOADING ALLOWING FOR DAMAGE ACCUMULATION

The theoretical approach to the modeling of fatigue fracture based on the joint consideration of concepts of fracture mechanics and concepts of the continuum damage theory is presented. Using the equivalent stresses criterion allows to reduce asymmetrical loading cycle to the equivalent symmetrical cyclic loading on rupture time.

Introduction

Many structural elements in the aircraft are subjected to complex of static and cyclic loads with different stress ratio of asymmetrical cyclic loading. As is known, the main cause of failure of such structures is fatigue fracture. Experimental data was confirmed that the effect of mean stresses of asymmetry cycle has significant influence on the fatigue crack growth rate. The problem of the prediction of the term of the safe operation of aircraft - is a very important and actual. Mainly its solution related to the definition of the kinetics of fatigue crack growth based on building model of fatigue fracture. Recently, models based on accounting damage accumulation in the material of the structure take a special place.

Experimental approach to building models of fatigue fracture is connected with the conduct of complex tests and obtains on their basis of empirical relationships. The experimental identification of the damage parameter is offers difficulty. For example, the density of deformation relief at the stress concentrator is used as damage indicator [1].

The present work is the development of a theoretical approach [2,3], based on the joint consideration of the concepts of fracture mechanics and mechanics of continuous damage. The fatigue fracture process is described by scalar function of damage. The criteria of continuum damage mechanics are used as the fatigue crack extension force. The two-stage model of fatigue crack growth is build and the kinetic ratio to estimate the rate of fatigue crack growth are obtained from the solution of the non-linear integral equation for fatigue crack front movement. The model was tested on the solution of the problem of central crack growth in thin rectangular plate under uniaxial asymmetrical cyclic tension-compression.

Formulation of the problem and background

Let's consider a normal tensile crack with initial half-length ℓ_0 in a thin finite isotropic plate with width W and height H in plane stress state. The crack is growing along the x – axis and the center of the crack is at $x = 0$. The plate is subjected to uniform uniaxial asymmetrical loading $\tilde{\sigma}$ applied to the ends of the plate along the y – axis and can be represented in the form

$$\tilde{\sigma} = \sigma_m + \sigma_a g(n) \,, \tag{1}$$

where σ_m and σ_a – is mean stress and stress amplitude values according, $g(\cdot)$ – is a known alternating function of a number of cycles n of a change in stresses $(n = ft)$, t – is the physical time, and f – is the loading frequency.

The problem is to derive a two-stage model of the fatigue crack growth in a thin finite plate/ In fact the problem can be reduce to specify the relation

$$\frac{d\ell}{dn} = F_1\left(\sigma_a, \sigma_m, \ell, H, W, C_i\right) \tag{2}$$

where $\tilde{N}_i$ – are material constants $\left(i = 1, k\right)$.

Fatigue crack growth model is based on joint solving of the problem of determination of the local stress field at the moving crack tip and the problem of formulation of criterion of fatigue crack propagation using the concepts of damage mechanics.

Suppose that any asymmetric loading cycle can be reduced to the equivalent symmetrical cyclic loading on rupture time using the equivalent stresses criterion can be represented in the form

$$\tilde{\sigma}_{eqv} = \tilde{\sigma}_a = \sigma_a \left[1 - \frac{1}{2}\left(\frac{\pi\sigma_m}{2\sigma_B}\right)^2\right]^{-\eta}, \tag{3}$$

where $\tilde{\sigma}_a$ - stress amplitude of equivalent symmetric cycle, η - sensitivity coefficient of asymmetrical cyclic loading.

The fatigue crack is considered as a narrow, sharp-tipped slot. The modified Dagdale model [4] is used to describe two different plastic zones formed at the crack tip. One of which $\lambda_m(\ell)$ – is a monotonic plastic zone which occurs in the half-cycle of tension and stress in the zone is limited by the yield stress σ_Y. Another one $\lambda(\ell)$ – is cyclic plastic zone formed in the half-cycle of unloading. Its length in the plane stress state is determined by the scale of stress $\Delta\sigma = \sigma_{max} - \sigma_{min}$ and stress along its length changed from $-\sigma_Y$ to σ_Y. Outside of the plastic zone the material of a plate is deformed linear-elastically.

The stress distribution in the vicinity of the fatigue crack tip at any time moment is determined by solving the boundary value problem of elasticity theory with a moving boundary. The set of corresponding simultaneous equations includes: equilibrium equations:

$$\frac{\sigma_{xx}(n)}{\partial x} + \frac{\partial\tau_{xy}(n)}{\partial y} = 0, \quad \frac{\partial\tau_{xy}(n)}{\partial x} + \frac{\partial\sigma_{yy}(n)}{\partial y}, \tag{4}$$

compatibility equations in the terms of stress:

$$\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\left(\sigma_{xx}(n)+\sigma_{yy}(n)\right)=0\,; \tag{5}$$

boundary values for plate in form:

$$\sigma_{xx}(n)=0, \quad x=\pm\frac{W}{2} \quad -\frac{H}{2}\le y\le\frac{H}{2}$$

$$\sigma_{yy}(n)=\begin{cases}\pm\tilde{\sigma}, & y=\pm\frac{H}{2}; \quad -\frac{W}{2}\le x\le\frac{W}{2} \\ 0 \quad y=0 & \begin{cases}-\ell_0\le x\le\ell_0 & 0\le n\le n_* \\ -\ell(n)\le x\le\ell(n) & n\succ n_*\end{cases}\end{cases} . \tag{6}$$

The process of the fatigue macrodamage accumulation takes place on the plate and crack front and its extension. The damage level is specified by a scalar damage function $\omega(x,n)$ which accumulation kinetics is given by the differential evolution equation:

$$\frac{\partial\omega(x,n)}{\partial n}=D\left[\frac{\Delta\sigma_{yy}(x,n)}{1-\omega}\right]^q, \tag{7}$$

here D and q are material constants to be determined experimentally. The initial and boundary values:

$$\begin{cases}\omega(x,0)=0 \\ \omega(x,n_R)=1\end{cases} . \tag{8}$$

According to presented model the fatigue crack increases step by step on the length of cyclic plastic zone when damage function equal 1 along its length. The lengths of plastic zones near crack tip are defined on base modified Dugdale model:

$$\lambda(\ell(n))=\frac{1}{8}\left(\frac{\pi\tilde{\sigma}_a\cdot f\left(\frac{H}{W},\frac{\ell(n)}{W}\right)}{2\sigma_Y}\right)^2\ell(n), \tag{9}$$

where $f\left(\frac{H}{W},\frac{\ell(n)}{W}\right)$ - correction function for central cracking finite plate.

Model of fatigue crack growth

As a result, the joint solution of equations (3) - (9) we obtain the fundamental relations model for the fatigue crack growth [3]:

$$\begin{cases} \dfrac{d\ell}{dn} = \left(1+\dfrac{1}{q}\right) D \dfrac{1}{\left[2\lambda(\ell(n))\right]^{\frac{q}{2}-1}} \cdot \left(\tilde{\sigma}_a \sqrt{\ell} \cdot f\left(\dfrac{H}{W}, \dfrac{\ell(n)}{W}\right)\right)^q \\ n_* = \dfrac{1}{(1+q)D} \left[\dfrac{1}{\tilde{\sigma}_a}\right]^q \left[\dfrac{2\lambda(\ell_0)}{\ell_0}\right]^{\frac{q}{2}} \cdot f\left(\dfrac{H}{W}, \dfrac{\ell_0}{W}\right)^{-q} \end{cases} \tag{10}$$

Models of the fatigue crack growth (10) involve material constants σ_Y , σ_B , and coefficients D , q , η .

The first group σ_Y , σ_B are determined from stress-strain diagrams in uniaxial tension tests.

The second group involves q and D coefficients and characterizes the material resistance to the accumulation of scattered fatigue macrodamage. The values of q and D are calculated by results of standard fatigue tests of plain cylindrical specimens under uniaxial reversed tension-compression presented in a form of the Wöchler curve.

The coefficient η - is determined from experiments on fatigue of smooth cylindrical specimens under tension-compression at different degrees of asymmetry cycle by minimizing the functional

$$\Phi\left(\psi\left(\frac{\sigma_m}{\sigma_B}\right), \eta\right) = \sum_{i=1}^{k} \left[\psi\left(\frac{\sigma_{m_i}}{\sigma_B}\right) - \left(\frac{\sigma_{a_i}}{\sigma_n}\right)\right]^2 = \min \tag{11}$$

Where in - $i = \overline{1,k}$ the number of experiments with different kinds of asymmetry cycle, σ_n - fatigue limit symmetrical loading cycle corresponding to the same durability.

Example

Thus, in what follows the study of some features of fatigue crack growth in thin finite plates made of materials with different stress range values may be of interest. The calculations are carried out for original crack length of $\ell_0 = 2{,}54\text{mm}$ in the plate with width $W = 305\text{mm}$ and height $H = 889\text{mm}$ under asymmetrical high-cycle loading. The material investigated is aluminum alloys 7075-T6 ($\sigma_Y = 523\text{MPa}$, $\sigma_B = 571\text{MPa}$, $q = 9{,}23$, $\eta = 3{,}57$, $D = 3{,}33 \cdot 10^{-29} (\text{MPa}^q \cdot \text{cycl})^{-1}$).

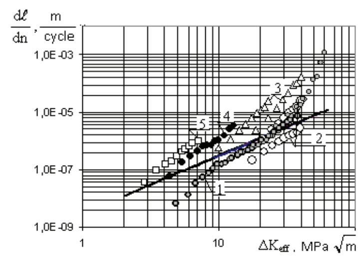


Fig. 1. Kinetic diagram fatigue crack growth at different stress ratio of asymmetrical cyclic loading
(R =-1 (1); -0,8 (2); -0,33 (3); 0 (4); 0,5 (5), ▬ - the model calculation)

Kinetic diagram fatigue crack growth

at different stress ratio of asymmetrical cyclic loading is on fig.1, where:

$$\frac{d\ell}{dn} = \left(1 + \frac{1}{q}\right) D \frac{2^{q-2}}{\pi^{q-1}} \cdot (2\sigma_Y)^{\frac{q}{2}-1} \cdot \Delta K_{eff}^2 \left(\frac{H}{W}, \frac{\ell_{(n)}}{W}\right)^{-q} \quad (12)$$

$$\Delta Keff = \sigma_a \left[1 - \frac{1}{2}\left(\frac{\pi\sigma_m}{2\sigma_B}\right)^2\right]^{-\eta} \sqrt{\pi\ell} * f\left(\frac{H}{W}, \frac{\ell(n)}{W}\right) \quad (13)$$

The satisfactory agreement between the calculated results and experimental data [5] allows us to insist on the adequacy of the constructed model.

Conclusion

The paper presents the theoretical approach to construct a phenomenological two-stage model of the fatigue crack growth at asymmetrical loading, based on joint consideration of concepts of fracture mechanics and continuum damage mechanics.

The material constants and coefficients used in constitutive set of model equations determined also the properties of materials and independent on crack geometry because they are calculated by the results of standard tests of plain cylindrical specimens. Using the equivalent stresses criterion allows to reduce asymmetrical loading cycle to the equivalent symmetrical cyclic loading on rupture time. The calculation results within the framework of the model for 7075-T6 agree well with experimental data.

References

1. Karuskevich M.V. Influence of accumulated fatigue damage on crack propagation in clad aluminum alloy // M.V. Karuskevich, A.V. Plashchynska, S.V. Shchepak, O.I. Shchur / Наукоємні технології. – Том 17, №1, 2013, pp. 14 – 17.

2.Golub V.P. A phenomenological model of fatigue crack growth in perfectly plastic infinite plates under completely reversed uni-axial loading / V.P., Golub, A.V Plashchynska // Int. Appl. Mech. – 2005. – 41(3). – P. 1426–1436.

3. Plashchynska A.V. Fatigue fracture of thin rectangular plates with central crack under uniaxial high-cyclic symmetrical loading / A.V. Plashchynska, P.N. Baranova // Pr. of XLI Summer School Conference APM 2013. – 2013 – pp. 163–171.

4. Newman J.C.Jr. A crack-closure model for predicting fatigue crack growth under aircraft spectrum loading // NASA. – TM 81941. – 1981. – P.63.

5. Hudson C.M. Effect of stress ratio on fatigue-crack growth in 7075-T6 aluminum-alloy sheet / C.M. Hudson, J.T. Scardina // NASA. – TMX 60125, 1967. – P.24.

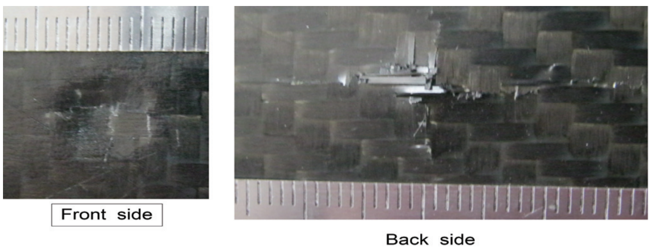
UDC 620.22-419.8

O.A. Schevchenko, PhD, O.I. Olefir, PhD, O.E. Skrypnikov,
(NAU, Ukraine, Kyiv)

DAMAGE OF FIBER REINFORCED POLYMER MATRIX COMPOSITES FROM A DROP-WEIGHT IMPACT EVENT

Damages of different fiber-reinforced polymer matrix composites namely carbon fiber reinforced plastics (CFRP), glass fiber reinforced plastics (GFRP) and TWINTEX thermoplastics from a low - velocity drop-weight impact event have been investigated. Investigation results are presented in form of graphs. Conclusion about resistance of these materials to impact loading was made, the most resistant are TWINTEX.

Composite materials (CM) successfully replace traditional metals in structures of modern aircraft of both military and civil purposes that allowed a significant increase in their efficiency. Speaking about military aircraft structures, CM have practically replaced traditional metals [1], while the most modern B.787 has 50% of mass made of CM and the A350 has up to 53%. In structures of modern aircraft they usually use polymer composite materials (PCM) which are much more technologically advanced than analogical metals and have by 40% less weight, but they are significantly more expensive. The most widespread PCM in aircraft structures are CFRP due to high rigidity but they, like most of PCM, are susceptible to impact loadings that occur during operation. Taking this into account, there is a significant problem to investigate PCM resistance to impact loading. Especially relevant investigation is that of the damage of CM from a low - velocity and low-energy impact at which the front side has barely visible damage while the back side has a significant one. A typical fashion of a Barely Visible Impact Damage (BVID) of a CFRP is presented on Fig. 1.



a *b*

Fig. 1. CFRP damage fashion front side (*a*) and back side (*b*)

Work [2] presents results of different CFRP specimens investigation damaged by impact events of different energy ranged from 4 J up to 40 J. Damages dimensions were determined with the help of computed tomography, ultrasonic C-scan method and optical locking thermography.

Particular investigation is devoted to testing of specimens made of CFRP and GFRP with epoxy bonding agent and thermoplastic CM TWINTEX with polypropylene base with the aim to compare damages at similar energy and after-damage strength estimation.

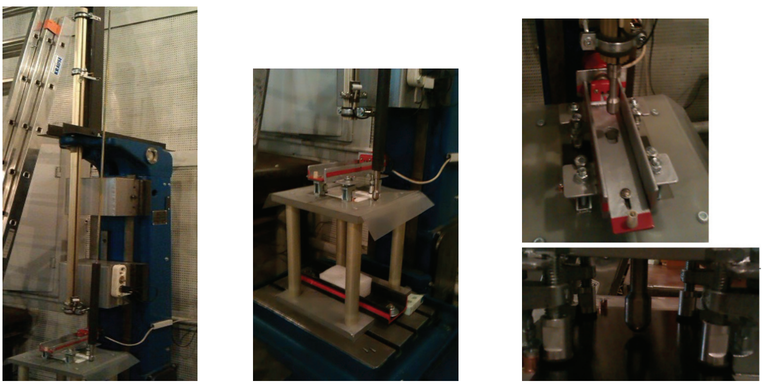
Up to date there are different standards concerning CM testing with a low - velocity impact event. Primary are the following ones: ISO18352, ASTM D7136 та ASTM D7137, DIN 65561, prEN 6038, NASA RP 1092 ST-1, Airbus AITM 1.0010, Boeing BSS 7260 – type II, SACMA SRM 2R-94, CRAG method 403. Methods, installations and specimens detailed analysis according to the given standards is given in the presentation [3]. Tested specimens have 100×150 mm^2 sizes and are fixed on impact support fixture base with a rectangular cut-out with sizes of 75×125 mm^2 while the only CRAG method 403 standard specifies the opening diameter to be 140 mm. Particular standards are practically identical concerning methodology of testing conducting. Impact event is caused by falling weight of mass m [kg] from height h [m], the weight has a spherical shape of 16 mm size, the falling weight mass differs from standard to standard according to the range of $1 \div 6.8$ kg, while the impact energy is calculated by the following formula

$$E = mgh,$$

where g is gravity acceleration [m/sec^2].

Low Velocity Impact (LVI) resistance depending on composite material based on epoxy matrices Fiber Volume Content (FVC) is considered in work [4]. Work [5] is devoted to complex investigation of damage resistance of CFRP with different matrices and FVC.

Particular testing requires a special installation which has been designed and built in National Aviation University Mechanical department research laboratory. General view of the installation is presented on Fig. 2a.



a *b* *c*

Fig. 2. Impact testing installation (*a)* and its basic components (*b)* and (*c)*.

A specimen for testing with sizes of 100×150 mm^2 is fixed on impact support fixture base with a rectangular cut-out with sizes of 75×125 mm^2 of the whole rigid base (see Fig. 2b) with the help of special stiff rubber-ended clamps (see Fig. 2c).

ASTM D7136/D7136M – 05 standard was chosen for experimental investigation of specimens damage resistance. According to this standard, specimens testing is provided by a drop-weight impact event with specified energy and further determination of damage parameters. To compare low-speed impact event resistance three different composites were chosen: CFRP, GFRP and TWINTEX thermoplastic. Particular materials were used to produce three series of specimens for testing.

The first series was made of CFRP with epoxy-base bonding agent with average material thickness of 1.8 mm. The second series of specimens was made of GFRP phenol-epoxy glass-fabric-reinforced laminate which is a sandwich material obtained by method of hot pressing of glass-fabrics soaked with thermoreactive bonding agent based on superposed epoxy and phenol resins with average thickness of 1.62 mm. The third series of specimens is made of modern TWINTEX material, the base of which is fiberglass connected by polypropylene matrix. This material is produced by lining layers of a special fabric which is webbed from twisted beams of glass and polypropylene fibers with further thermopressing at temperature of about 200° C.

The particular series of specimens were tested with the following range of impact energies: 2,07 J, 4,01 J, 6,06 J, 12,4 J and 24,8 J. Fig. 3 presents after-damage energy-corresponding fashion of specimens front side, while energy of 24,8 J was used for TWINTEX composite only.

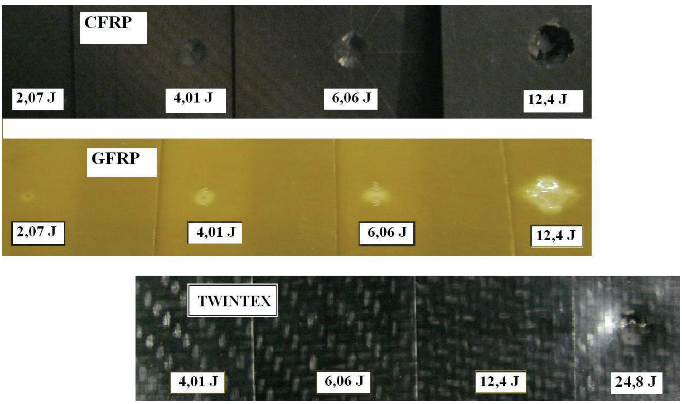
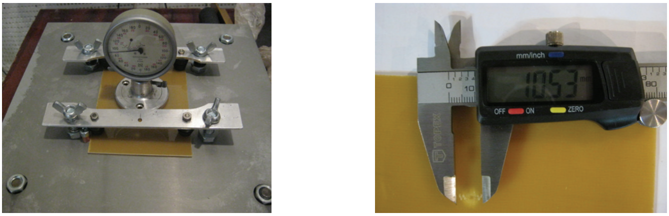


Fig. 3. Front side specimens damage fashion

Back sides of chosen CM are quite more damaged than the front ones. Fig. 4 presents after-damage energy-corresponding fashion of specimens back side.

With the help of special device equipped with high-precision clock-type indicator (Fig. 5*a*) all specimens damage depths were measured. Diameters of damage as the biggest its dimension were measured with the help of digital caliper (Fig. 5*b*).



a *b*

Fig. 5. Instruments to measure the damage depth (*a)* and damage diameter (*b)*

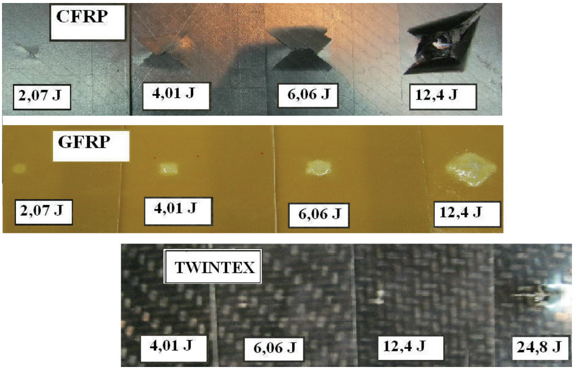
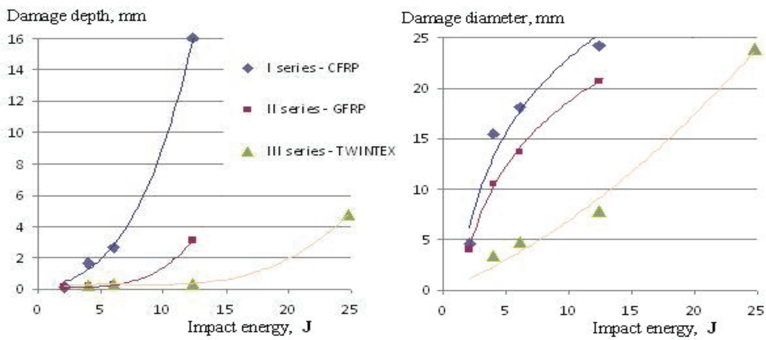


Fig. 4. Back side specimens damage fashion

Damage depth and diameter measuring results are presented in form of graphs (Fig. 6*a* and Fig. 6*b*, respectively) that illustrate the dependence of these values on impact energy.



a *b*

Fig. 6. Graphs of the damage depth (*a)* and damage diameter (*b)* variation

Conclusions

CFRP specimens turned out to be much less resistant as compare to that of GFRP and, especially, TWINTEX. This is explained by the fact that CM with stiffer fibers are less resistant to low - velocity impact event action.

Damage sizes of CFRP quite exceed that of GFRP and TWINTEX. Namely, at equal impact energy CFRP damage depth is 10 times more than that of the GFRP and TWINTEX. Damage diameter of CFRP is 1.5 times and 4 times more than that of GFRP and TWINTEX correspondingly. Damage depth variation is quite well approximated by polynomial function (Fig. 6*a*), while damage diameter - by log function (Fig. 6*b*). This statement holds true for materials chosen for the particular testing.

The chosen CFRP has shown quite high impact sensitivity. Ballistic limit for that material hardly exceeds 6.7 J impact energy per 1 mm of thickness, which is typical in ASTM D7136/D7136 M – 05 standard.

References

1. Астанін В.В., Хоменко А.В., Шевченко О.А. Композиційні матеріали у конструкціях сучасних літальних апаратів. – К. – Вісник НАУ. - №3. - 2004. – С. 46-52.

2. Wagner H., Bansemir H., Drechsler K., Weimer C. Impact Behavior and Residual Strength of Carbon Fiber Textile Based Materials. SAMPE Europe, SETEC 2007. – P.15 – 25.

3. Zwick / Roell Intelligent Testing. Corporate Presentation \ Composites. XIX International Forum "testXpo". 10 / 2010.

4. Ruhala L.A., Engel R.S. An Investigation of the Effect of Fiber Volume Fraction on the Impact Properties of Fiber Reinforced Composite Laminated Plates. Journal of Reinforced Plastics and Composites. 2000. V.19. N 06.

5. Erber A., Gittel D., Geiger O., Chandhari R., Henning F., Drechsler K. Edvanced Damage tolerance of CFRP Laminates Using in-SITU Polymerised Thermoplastics. SAMPE Europe, SETEC 2009. – P. 15 – 25.

UDC 629.7.017

I.O. Golovchenko, postgraduate student (NAU «KhAI», Kharkov, Ukraine)

TO THE QUESTION OF THE AIRPLANE CONSTRUCTION DAMAGE BY THE SOIL SOLID PARTICLES IN THE OPERATION

The analysis of the airplane aggregates damage reasons in case of maintenance on soil runways was carried out. The damage process of the airplane skin from impacts with flying soil particles was considered in detail. For development of protection measures, the approach for determination of the intense deformed skin status after impacts was offered.

In the case of takeoff and landing on soil and unprepared airfields, of flying at small heights and in the dust air conditions impacts of various on mass, form and hardness soil particles with an airplane covering take place.

As a result the following consequences are watched:

- aero abrasive wear by the dust-like particles of the airplane aggregates (bottom face of a fuselage covering, wing front edges and plumage, air screw, etc.);
- fatigue failure of a covering as a result of the oscillatory intense deformed status (IDS) arising because of impacts by particles;
- combination of aero abrasive wear and fatigue failure.

If from aero abrasive wear effective protect paint and covers exist and are applied, from fatigue failure the only way of protection is a lowering of level of tension to values, below an endurance limit.

Lowering of friction and wear in technique is the major economic task therefore it is very much published and is published scientific and technical literature on this subject, for example, [1-2]. Scientific bases of prediction of wear by particles in an air flow (aero abrasive wear) are created in scientific researches of the Kharkov aviation institute [3-5] which main results is determination of the boundary separating corrupting by micro cutting from accumulation of fatigue exhaustion of bearing capacity.

The analysis of operating conditions, for example, of Antonov Company airplanes which can fly up and sit down on the soil runways, including pebble and gravel, shows that a pacing factor of damageability of a covering are rather large solid particles of soil which are taking off from under wheels of the chassis. It leads, on the one hand, to appearance of the scratches and dents reducing fatigue longevity, and with another – to accumulation of classical fatigue because of cyclic loading as a result of impact. For construction protection, special impact proof paint and various special polymeric coverings are applied, but their stiffness characteristics are incomparable less, than the covering reinforced by stringers or with filler. Questions of abrasive wear of polymeric materials are rather deeply studied, for example, [1, 2, 6, 7], but generally at the level of micro cutting and wear of material. Thus, in the literature practically there are no data on research of the airplane construction behavior as a result of intensive "bombing" by solid macroscopic particles. It is caused by that it is necessary to consider the intense deformed state of a real covering, which differs for each plane.

The covering of the airplane aggregates always consists of the thin leaf reinforced in two directions by stringers and frames or ribs, and flexural rigidness of a reinforcement is much more, than coverings. This circumstance allows putting experiments on the plane samples from a leaf imitating a covering section between the adjacent strengthening elements. Similar arguments are fair and for panels with filler. Thus, the pilot studies of solid particles impacts on a covering can be realized on plane samples of covering material with a covering or without it, clamped on a circuit between rigid sponges that provides in physical and mathematical sense bearing conditions between the hinge and seal and corresponds to a covering bearing on stringers or frames (ribs).

The pacing faulting factors of chassis of solid particles scattering from under wheels are the speed of their concussion with a covering and their mass. Appearance of scratches depends on speed, being a consequence of micro cutting, and the mass through kinetic energy defines quasistatic intense deformed state and accumulation of fatigue damages. Covering concussion with rather big particles at speeds smaller, than is necessary for micro cutting, leads to origin of the flexural intense deformed state, as a result of which probably static corrupting in the form of holes, initialization of oscillations and covering vibration with tension causing accumulation of fatigue damages, and to longevity lowering owing to cyclic loading by periodically striking particles.

For the quantitative assessment of these phenomena, it is necessary to synthesize the estimated diagram for the intense deformed state determination. The most suitable models are built based on the plate bend theory by the concentrated forces or the efforts distributed within the given section for which in literature there are appropriate equations and finite formulas.

Thus, in view of impossibility of the pilot study of solid particles with a covering of the real airplane, it is expedient to put experiences on model samples for which there are ready or requiring insignificant modification formulas and dependences. This approach is justified as well by that there is a real research of different protecting and paint covers behavior, and airplane coverings with a covering in all interval of operational temperatures and taking into account other climatic factors. The most complete information in case of insufficient resources of the test equipment and data-acquisition equipment can be received as a result of static loading with observance of equality condition of scattering particles kinematics energy, loading indenter operations and potential energy of airplane covering deformation. Considering complexity of the phenomenon of interaction of the flying solid particle with rather flexible covering for creation of required model, it is expedient to use phenomenological approaches among which laws of conservation of energy and movement pulse are effective. In the linear setting the covering deflection from point loading is directly proportional to operating force and then the operation made by a particle on covering deformation is equal (fig. 1).

$$A = \frac{1}{2} R_y \omega \qquad (1)$$

where R_y – a normal component of force value at the time of a particle full braking, ω – covering displacement under the influence of particle impact.

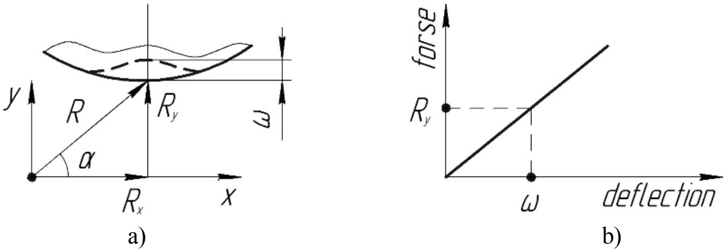


Fig. 1. The flying solid particle and the airplane covering interaction diagram

Operation of a solid particle on covering deformation is equal to the particle kinetic energy and to the construction elastic deformation energy U, i.e.

$$A = \frac{1}{2} m (v \sin \alpha)^2 = U \tag{2}$$

where m – particle mass, v – full speed of a particle at the time of concussion, α – angle between a velocity vector and an axis x (see fig. 1).

For computation of elastic deformation energy U classical expression, which is related to an orthotropic plate and has an appearance [8], is used

$$U = \frac{1}{2} \iint \left[D_1 (\frac{\partial^2 \omega}{\partial x^2})^2 + 2 D_1 \mu_{yx} \frac{\partial^2 \omega}{\partial x^2} \frac{\partial^2 \omega}{\partial y^2} + D_2 (\frac{\partial^2 \omega}{\partial y^2}) + 4 D_k (\frac{\partial^2 \omega}{\partial x \partial y})^2 \right] dxdy \tag{3}$$

where integration is made on all surface of a plate. In this formula, it is designated:

$$D_1 = \frac{E_x \partial^2}{12(1 - \mu_{xy} \mu_{yx})}; D_2 = \frac{E_y \partial^2}{12(1 - \mu_{xy} \mu_{yx})}; D_3 = D_1 \mu_{yx} + 2 D_k; \; D_k = \frac{G_{xy} \partial^2}{12}, \tag{4}$$

where E_x, E_y, G_{xy}, μ_{xy}, μ_{yx} – covering material elastic constants in the coordinate system matching orthotropic axes.

Thus, knowing the form of a covering curved surface as a result of interaction with a solid particle $\omega\ (x,y)$ from the second member of equation (2) it is possible to find value of the maximum deflection, and then from equality (1) value of force is defined, knowing which it is possible to model the intense deformed state in a contact zone, i.e. to solve the problem of the local intense deformed state. Considering the covering intense deformed state from influence of particles separately, i.e. without tension from loadings aboard the plane as a whole (it is justified by the superposition principle for linearly deformable systems), we will accept that membrane efforts in a covering are absent (tension from the force R_x (see fig. 1) are rather small for the case of micro cutting absence). Then normal σ_x, σ_y and shearing stresses τ_{xy} can be computed on formulas:

$$\sigma_x = -z\frac{12D_1}{\partial^3}(\frac{\partial^2\omega}{\partial x^2} + \mu_{yx}\frac{\partial^2\omega}{\partial y^2}) = -z\frac{E_x}{1-\mu_{xy}\mu_{yx}}(\frac{\partial^2\omega}{\partial x^2} + \mu_{yx}\frac{\partial^2\omega}{\partial y^2}), \tag{5}$$

$$\sigma_y = -z\frac{12D_2}{\partial^3}(\frac{\partial^2\omega}{\partial y^2} + \mu_{xy}\frac{\partial^2\omega}{\partial x^2}) = -z\frac{E_y}{1-\mu_{xy}\mu_{yx}}(\frac{\partial^2\omega}{\partial y^2} + \mu_{xy}\frac{\partial^2\omega}{\partial x^2}), \tag{6}$$

$$\tau_{xy} = -z\frac{24D_k}{\partial^3}\frac{\partial^2\omega}{\partial x\partial y} = -2zG_{xy}(\frac{\partial^2\omega}{\partial x\partial y}). \tag{7}$$

In these formulas z is a coordinate on a normal to a curved surface that is digitized from the covering middle thickness. The classical dependences given above completely define the covering panel intense deformed state in the presence of the surface curved form equation.

Thus, the careful analysis of the reasons and nature of the airplane construction damages in the case of maintenance on soil runways is carried out. The approach for the determination of the covering intense deformed state after concussion with soil solid particles that is important for development of possible protection methods of the fuselage bottom surface is offered.

References

1. Kragelskiy I.V. Trenie i iznos. M.: Mashinostroenie, 1968. – 480 s.

2. Bartenev G.M., Lavrentev V.V. Trenie i iznos polimerov. L.: Himiya, 1972. – 240 s.

3. Pilnik A.F., Rassoha A.A. Teoriya iznosa poverhnostey v potoke abrazivnyih chastits / Sb. HAI «Prochnost konstruktivnyih elementov letatelnyih apparatov». Harkov, 1973. Vyip. 1. – S. 152-158.

4. Gaydachuk V.E., Pilnik A.F.,Rassoha A.A. K teorii iznosa poverhnostey abrazivnyimi chastitsami // Samoletostroenie. Tehnika vozdushnogo flota: resp. mezhved. temat. nauch.-tehn. sb. – H., 1975. – Vyip. 36. – S. 56-58.

5. Gaydachuk V.E., Pilnik A.F. Modelirovanie aeroabrazivnoy erozii elementov konstruktsiy letatelnyih apparatov na eksperimentalnyih ustanovkah // Voprosyi mehaniki deformiruemogo tverdogo tela: temat. sb. nauch. tr. / M-vo vyissh. i srednego spets. obrazovaniya SSSR, Hark. aviats. in-t. im. N.E. Zhukovskogo – H., 1981. – Vyip. 2. – S. 84-86.

6. Bezborodko M.D. Trenie i iznos plastikov pri vyisokih kontaktnyih napryazheniyah / Plasticheskie massyi. 1962, №5. – S. 53-57.

7. Tadolder Yu.A. Vliyanie geometrii abrazivnogo zerna na intensivnost iznashivaniya metallov v potoke abrazivnyih chastits / Trudyi Tallinnskogo politehnicheskogo instituta. Seriya A. Tallinn, 1966, №237. S. 15-22.

8. Lehnitskiy S.G. Anizotropnyie plastinki. M., Gos. izd. tehn.-teor. lit., 1957. – 463 s.

UDC 629,735,051:511.6(043.2)

Prof. Kozak V.M. (National Aviation University, Ukraine)
Pgd.student Zharin I.S. (National Aviation University, Ukraine)

PERSPECTIVE OF ION-MARKER METHODS IN WING DIAGNOSIS

This report provides a comparative analysis of the possibility of methods based on ion-marker theory inexternal contour airckraft wing diagnosis. Considered foreign and ukrainian methods of diagnosing the external contour of the wing in flight. Proposed a method based on ion-marker theory as a perspective.

Well known that aircraft wing is a complex system exposed to external mechanical, biological and electrical influences, which significantly reduce the airplane safety. According to the analysis of statistical data, 21.1% of bird strikes occurs in the wing. In the United States in the period from 1990 to 2011 ware 25,847 cases of collisions with birds that fell on the wing[1]. The current trend growth air traffic intensity, and collisions with foreign bodies, put these factors on the third leading cause of aircraft incendent. Existence of a diagnosing system of the state of the external contour of the wing in flight, allows timely spot time, place and degree of damage, and makes it possible significantly reduce number of aircraft incendent.

At the moment, questions of diagnosing the external contour of the wing in flight are developed both in Ukraine and abroad. Method of diagnosis based on the registration of changes of the aerodynamic forces and moments is reliesed on fact that damage of the external contour lead to a change in distribution of the aerodynamic forces and moments, and as a result, a change in the total resultant forces, and plane centering. Dimensionless aerodynamic coefficients of forces and moments in the case of sudden damage to the surface of the airframe has features not only the angles of attack and sideslip, Mach number, altitude, centering, ground proximity, deviations of the controls and configuration of aircraft, but also features the time location and extent of damage. However, these methods require special power sources, additional internal volume to accommodate the sensor, moreover changing the weighting characteristics of the wing.

The fiber-optic method is based on the integration of ultrathin fiber sensors embedded in composite construction material aviation, which give an opportunity of real time diagnoses of the time, place of emergence, the nature and extent of the damage in flight. In particular, the type of sensor, known as Bregs fiber grating (VRB). The sensor has shown its effectiveness in measuring voltage and temperature.. The principle of operation of the VRB based on Fresnel reflection. The light flux which passes through the fiber with different refractive indices can be as repulsed and refracted on the boundary of the zones with different refractive indices.

The essence of the capacitive method, developed by "Boeing" is to change the registration of the capacitor charging in the event of damage or deformation. Outer contour of the airplane glued over the capacitor film and externally. Capacitor film is a multilayer capacitor array of capacitive sensors. If the damage is external contour capacitor charge at the deformation site changes, which enables us to determine the time, place and degree of damage. A feature of this method is that it ignores the multiple minor deformations 0.1-0.5% of the area of the capacitor. While their total aerodynamic destabilizing moment can significantly affect the safety of flight.

First publications of the development and use of ion-marker measuring devices appeared in the early 50s. Development were carried out both in our country and abroad. Ion marker transducers are a class of devices that implement a method for measuring the kinematic parameters of the flow, in particular the angle of attack and flow velocity. This method of measurement is one of the first people started to use when determining wind direction by orientation of plume. The article substantiates the possibility of ion-based sensors to solve the problem of diagnosis moment of time, place, nature and extent of damage to the wing of the aircraft. Ion marker method applies to kinematic. Movement tags can be considered fully coincident with the movement of the environment if its size is much smaller than the spatial scale of turbulence, and its density is the density of the controlled environment. The first indicated associated requirements affect the degree of spatial averaging of pulsating flow component and for the majority of the practice is easily achieved. Most types of labels used have a finite lifetime, which is a decrease in the concentration inhomogeneities homogeneity forming label. Therefore, time, time in which the label must reach the reception area is limited, which separates the definition requirements on the choice of workers (base) distances, taking into account the fact minimum flow rate in the range of measurement. Analysis of the properties of different types of labels flows and transducers based on them shows that in relation to the problems of measurement in various operating conditions, typical of many objects (including aircraft), the most promising transducers are based on unipolar ion tags. They represent the local area air flow with a high concentration of unipolar ions formed by certain energy impact on ambient air molecules. Such a mark can be formed in a small volume of flow, and its gas-dynamic properties practically do not differ from the properties of air, which ensures complete compliance motion parameters tags flow characteristics of the air flow. Modern civilian aircraft have wing with laminar and supercritical profiles. One of the peculiarities of these profiles is laminar flow on the upper edge down to 50-60%. Fact that the damaged leading edge, where 90% of encounters with various kinds of formations, the upper edge of the laminar flow is disturbed. Using ion-marker method can obtain qualitative and quantitative data describing the state of the external contour. Qualitative indicators are the lack of a signal at the receiving electrode in turbulence breakouts and breakdowns contours in clashes. The amplitude of the output signal U preamplifier ion marker probe is proportional to the current induced by the mark on the electrode and defined by the relationship [5]:

$$U = q_M(t) V k_{ny} S F(\alpha),$$

Where $q_M(t)$ - the amount of charge ion tags at the time of registration (function $q_M(t)$ shows the recombination of ions and change (decrease) in charge tags over time); V - speed tags; k_{ny} - conversion factor "current-voltage" preamp; S - area of the receiving electrode; $F(\alpha)$,- angular characteristic of the receiving electrode, which characterizes the dependence of the amplitude given to him by current deflection angle relative to the center electrode tags. Placement of sensors for linear 45-50% CAX provide high accuracy quantitative characteristics of the formation of informative signals *U* by summing the charges q_i, listed on the receiving electrodes in near turbulent zone caused by seal labels ion trajectories due to increased pressure in the zone of turbulence. (Fig. 1)

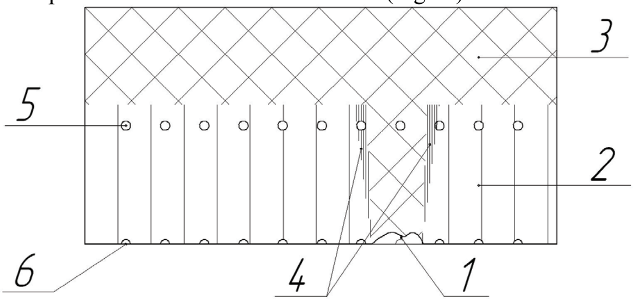


Fig.1 Character flow in boundary layer on the upper edge of the wing with a laminar profile whit damaged leading edge. (1 damage, 2-zone of laminar flow, 3-zone turbulent flow, 4-zone near *turbulent loop for damage 5 - receivers ion labels; 6 emitters ion labels)*

The main characteristic features of ion-marker sensors are acting in the absence of flow elements contributing uncertainty due to flow distortion, absolute measurement - speed is defined as the distance traveled by the ion label for some time, a negligible dependence on environmental parameters: humidity, temperature, pressure. Thus, the method allows to obtain information from the primary transmitter directly to the time-frequency band of the moment, place the nature and extent of damage the external contour of wing. Furthermore ion marker method allows to minimize the transmission loss and treatment of the primary information signal.

References

1. Wildlife Strikes to Civil Aircraft in the United States 1990-2004 / E. Cleary et. Al. // Federal Aviation Administration National Strike Database. – 2005.– No 11. – 77 p.
2. Діагностування аеродинамічної поверхні літальних апаратів /Казак В.М., Гальченко С.М. // Вісн. НАУ. – 2002. – №4. –46–49 С
3. Патент на корисну модель: спосіб діагностики зовнішнього обводу літального апарата на основі температурного поля площини літального апарата в польоті. – №73709; заявл. 14.02.12; опубл. 10.10.2012; бюл. №19 – 4с.Бабенко А.Є., Казак В.А
4. Основи контролю та технічної діагностики К.:НАУ, 2013. - 300 с ISBN 978–966–598–800–7 Казак В.А.
5. Ионно-меточные измерители воздушной скорости летательного аппарата ТанеевФ.А Издательство КГТУ., Казань, 1996, - 257с.

UDC 621.391

O. Lysenko, Doctor of Engineering Science (National Aviation University, Ukraine)
V. Novikov (National Technical University «KPI», Ukraine)

PROBLEM OF INCREASING THE LIFETIME OF WIRELESS SENSOR NETWORKS

The analysis methods and algorithms increase the lifetime of wireless sensor networks, in particular of energy balancing.

Sensor network is a distributed self-configuring wireless network of small intelligent sensor devices [1]. Each device is equipped with a microcontroller, transceiver, battery and a set of sensors for measuring certain parameters of the environment, such as temperature, light, vibration, pressure, noise level and other. Sensor networks are traditionally used in various monitoring and controlling systems, such as burglar and fire monitoring, climate control, remote collection of readings from domestic and industrial sensors, environmental monitoring. The concept of sensor networks implies that any unit running on a standalone power source. If this source is a conventional battery recharged during operation of energy, then at some point in time it is discharged and standalone device stops working. Since every network element performs a set of tasks originally assigned to it, the failure of a network node can mean the following:

- If a set of tasks performed by the host is not critical, then we can talk about the fall of the quality of network service.
- If the node is a key element of the system, for example, performing the tasks of routing large number of threads, its failure and the inability to dynamically replace means the entire failure of network.

Since, in general, all the elements of the wireless sensor network (WSN) are autonomous, certainly there comes a time when the network is no longer able to solve its tasks. Time from the beginning of the network up to this point is called the network lifetime.

In solving practical problems based on autonomous WSN, there are two main tasks associated with an access time of life:

1. Assessment suggest network lifetime for given characteristics of the hardware and algorithms of its work.
2. Increase of the lifetime due to the use of a number of methods and algorithms.

The hardware methods for increasing battery life of WSN refers improved hardware device characteristics: reduction of power consumption of individual components, optimization of their placement on a chip or printed circuit board, and increasing the capacity of batteries.

From the perspective of software algorithms for data processing at the nodes of the system, the following options:

- Data reduction.
- Accumulation of data and their subsequent transfer as large blocks.

Great practical interest is the group of energy balancing techniques. As noted above, the sensor networks are primarily intended for the collection of data. This means that there are one or more dedicated nodes that drained the information from the whole network. These nodes (sinks), tend to have a constant power supply interfaces for interfacing with local networks, global networks or with more powerful computing devices. Thus, the sensor network has a preferential direction of movement of payload traffic, which leads to the fact that the routing through nodes that are adjacent to the drain (s) takes place a greater volume of traffic.

Modern technological advances have led to microprocessors with very low power consumption, capable of performing a wide range of tasks. However, in order to transmit data wirelessly, you need to spend greater amount of energy (table. 1.1).

Table 1.1.

Modes of wireless modules WSN

Mode	**Designation of power**	**Typical value, mWt**
Reception	P_{rx}	52
Transmission	P_{tx}	45
Procession	P_a	20
Sleep mode	P_s	0,03

The table shows that the more data passes through the node of the wireless network, the much bigger its power consumption. As a consequence, there is a problem of energy imbalance in the network [2] (Fig. 1.1), leading to the fact that the autonomous elements, which are located next to the central node (nodes) data collection, before the others fail due to the discharge of their own batteries, and as a consequence, decreases the battery life of the sensor network.

To equalize the power consumption of all the nodes in the network we can use the following energy balancing methods

The construction of a heterogeneous network is to use a range of possibilities :

1. Individual selection of battery capacity, depending on the position of the devices in the network structure and the functions they perform. [3] In this case, the main repeating unit can be supplied by large capacity batteries. This approach is one of the most simple, but it also leads to low network scalability and poor adaptation to the conditions of operation. The need to develop different solutions for different structural elements leads to an increase in the cost of finite systems.

2. The density of network nodes location depending on the anticipated traffic load in a particular zone [4]. This solution aims to provide redundancy in the network structure and duplication of functions of individual nodes. So in case of failure of the next router its functions will be shifted to the adjacent element, up to this point can not be used.

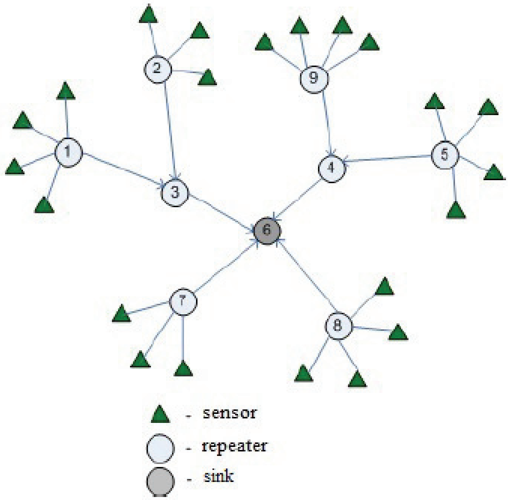


Fig. 1.1. Typical structure of the sensor network

Program methods includes using of routing protocols based on the metric of the residual energy of nodes [5] or virtual coordinates [6], the alternation of the distal and proximal transmission [7], the positioning of nodes [8], and clustering [9].Thus, if the sensor networks are often used metric of the residual energy of nodes on the path to the sink, in this case of a plurality of alternative routes is selected the one in which the nodes are either greater residual energy.

A promising method is to use mobility balancing individual network components. Several studies have shown that mobility can potentially provide the greatest benefit in terms of increasing battery life network.

Conclusions

The analysis of open sources showed that wireless sensor networks are a promising technology in the field of domestic and industrial data acquisition and control. A key indicator of the FSU, determining their applicability in practice is a time of their life, a larger problem is still relevant and prioritize this issue continuously increases with the use of OSS in practice.

References

1. Vyshnevskyy V.M. Liakhov A.I., Portnoy S.L., Shakhnovich I.V. Широкополосные беспроводные сети передачи информации.. Moscow: Technosphere, 2005. 592 p.

2. Zhang H., Shen H. Balancing Energy Consumption to Maximize Network Lifetime in Data-Gathering Sensor Networks / / IEEE Trans. Parallel Distrib. Syst. In 2009. Vol. 20, no. 10. P. 1526-1539.

UDC 615.6:621.7 (043.2)

Y. Zaharchenko (National Aviation University, Ukraine, Kyiv)

AUTOMATION OF PROJECT MANAGEMENT OF MODERNIZATION AVIATION EQUIPMENT

In this paper, the solution search problem of the optimal allocation of resources between projects considered. Model building a project plan developed aviation equipment modernization. The method of solving the problem, suggested based on immune algorithm allows display to achieve the required accuracy of the results for planning of modernization and feasibility of practical recommendations.

Modern aviation market sets strict requirements to continuous aircraft upgrade. First of all, it is the result of growing requirements to flight safety, efficiency and economic feasibility of aircraft operation. Realization of these requirements is based on the implementation of the results of next-generation scientific research either in the process of new aircraft types development or during existing types of upgrade. Aircraft upgrade urgency in modern environment is caused by abrupt increase in aircraft cost, global economic crisis and the continuous process of aircraft fleet ageing. Aircraft upgrade means upgrading of obsolescent and aged aircraft types by means of design, components, materials and manufacturing technology development aiming to enhance performances and to increase operation efficiency. Numerous passenger and cargo aircraft continuously undergo upgrade to meet growing ICAO requirements.

The problem of resources distribution at modernization can dare in different conditions of its security: at sufficient and insufficient maintenance with resources, and also in the conditions of their uncertainty.

Findings of optimum variants of AC modernization, the necessary terms, volumes of financing and industrial resources of the enterprises, and also indicators of performance of the plan and their parity (Fig. 1) are the important results of its decision at a planning stage.

A number of methodical approaches is developed for the decision of a problem of modernization AC in the conditions of sufficient and insufficient maintenance with resources [3], which will not consider factors of uncertainty and allows them to use only in partial cases.

Decision a task becomes complicated because modernization AC and parks on their basis is accompanied by delays in supply of the wide resources nomenclature and generates conditions of their uncertainty and insufficiency [3]. However, methods and algorithms which would allow to solve such problems does not exist. Therefore it is required workings out of the methodical device which will allow to carry out support of decision-making in the conditions of uncertain and insufficient maintenance with different types of resources, for processes of AT modernization during planning and management.

The purpose of this article is working out a method and model the decision of a management projects problem for AT modernization on the basis of new methodical device - immune algorithms. Application of this method will allow to lower errors at AT modernization planning and validity of practical recommendations in the conditions of uncertainty of maintenance with resources.

For the decision a task, it is offered to consider modernization from a position of the system approach at AT park level and as object of researches to allocate AC which, except aircraft, includes means of land service, technical maintenance, communication and management.

Set of characteristics AC, capacities and requirements to them is the entrance data of the research problem that include:

- Problem and the possibilities which decisions should provide AC after modernization;
- Type AC that modernizations are subject;
- Capacities of the enterprises on which modernization will be spent;
- Possible variants of modernization behind AC types;
- Volumes of different resources types for modernization, including financial;
- Terms of receipt resources, etc.

The factors with uncertainty are volumes and terms of delivery resources (for example, financial).

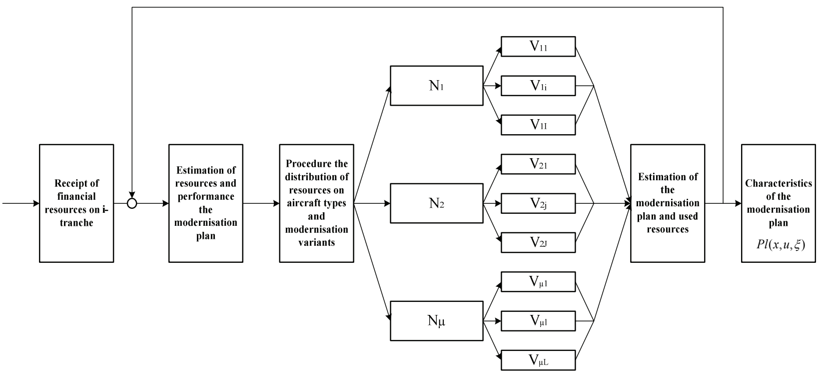


Fig. 1. The scheme of management of formation of the plan of modernization of park of joint-stock company

In connection with uncertainty in a management projects problem for AC modernization consider statement of the scientific research problem. It is necessary to find for certain type AC such “i” optimum variant of modernization, which will provide a maximum of a population mean of criterion function and increases of possibilities factor for AC park after modernization in the presence of uncertainty volumes financing taking into account restrictions on the set terms and the modernization budget.

The are a wide nomenclature of resources and works for maintenance of modernization process. It is defined by financing volumes, types and variants of AC modernization. The basic types of resources are: spare parts, materials, human, financial and time resources. Change of some resource, or a delay of works lead to a deviation from the plan and to growth expenses for carrying out of modernization.

The plan of AC park modernization is defined by set of characteristics (1):

$$Pl(x,u,\xi)\,, \tag{1}$$

where {x} - certain characteristics which consist of final elementary sets and are characterised by a vector of parametres: $\{A\} \neq \varnothing$ –Set of μ-types AC; $\{B\} \neq \varnothing$ –set of characteristics j-variants of μ-types AC modernization; $\{D\} \neq \varnothing$ –set of characteristics of capacities of the enterprise; $\{E\} \neq \varnothing$ – set of characteristics the modernization plan; $\{u\}$ – the distribution law of financial resources $u(t)$; $\{\xi\}$ – characteristics of modernization uncertainty.

The problem is reduced to a finding such plan $Pl(x,u,\xi)$ for optimum distribution of resources $u = \varphi(u_1,u_2,...,u_j,)$, $u_{onm} \in u$ behind μ -types AC taking into account all variants of modernization which would provide the maximum gain of potential possibilities of all AC park and would satisfy with restriction (2):

$$\begin{cases} \sum\limits_{i=1}^{n} s_i \leq S_{giv} \\ T_{gen} \leq T_{giv} \end{cases}, \tag{2}$$

where S_{giv} - volume of financial resources which is allocated for all modernization program; T_{gen}, T_{giv}- terms carrying out of modernization (the general and provided by the modernization program accordingly).

The plan of park AC modernization can be formalized under the following scheme (where Ni – AC types, Vij - variants of certain type AC modernization) that describes receipt of financial resources (volumes and terms), their estimation of sufficiency, distribution procedure, an estimation results of the modernization plan, the analysis of a deviation from the plan and entering of corrective amendments (Fig. 1). In an end result the optimum (rational) plan of carrying out for AC park modernization is formed.

Distribution of resources between different capacities of the enterprises is one of the important planning problems in process of AC modernization. Result of planning is the planned schedule of all process. It moves in the form of jobs behind AC types taking into account terms of performance of all modernization programs. Thus it is necessary to develop calendar specifications to provide uniform AC modernization in the set term.

For problems of planning of processes and management of designs following lines are characteristic:

– The wide range of sizes of problems, and range upper bound can attain significances in ten thousand and more works.

– Multicriterion, the basic criteria - a time and cost of fulfillment of the plot. In the capacity of criterion function often choose cost, in number of restrictions switch on times of closing-up and, was possibly, a number of use conditions of resources.

– A variety of types of controlled variables among which there can be magnitudes real, integer, non-numerical[1, 2].

If to transfer statements of a problem of the scheduling theory on a problem of formulation of the scheduling in management of designs, that, it is obvious, that design work is "operation" from the time schedule theory, a project phase, i.e. logically gated out chain of works of the design - "work" from a problem of the theory of the scheduling, and resources - "machines" and "details" from the theory of scheduling. As the quantity of resources of the design, as a rule, is not restricted, or measured by tens or hundreds it is is univocal possible to draw a leading-out, that classical methods of the theory of the scheduling will not approach for an optimisation problem solving in management of designs. Besides, in problems of the scheduling theory the same relations between cars and operations are observed, in problems of management of designs - these relations can be diverse.

Thus, it is possible to draw a leading-out, that the problem of formulation of the scheduling and optimisation at management of designs is a NP-difficult problem of discrete optimisation, therefore for its solution it is better to take advantage of crude methods. One of possible alternatives of the solution is the heuristic method on the basis of immune algorithm[2].

For construction of immune algorithm it is necessary to define: a way of representation a problem in the form of antibodies (individuals), and procedure of a reproduction, which includes operators of selection, cloning and mutations of antibodies. The three-dimensional matrix is one of the most convenient representations problem. Matrix axes are: AC types, on which modernization is carried out; variants of each AC type modernization; works on performance of modernization process. This antibody structure can be represented in the form of table 1.

Tab. 1 Distribution of works (W) concerning performance of AC modernization taking into account their variants (μ)

W1			***W2***			**…**	***Wi***		
μ_1	…	μ_i	μ_1	…	μ_i	…	μ_1	…	μ_i
0	…	1	1	…	1	…	1	…	0

For realisation an algorithm of clonal selection and decision of modernization plan all list of works and their resource restrictions is formalized in the form of antibodies. Project planned schedule is defined by a method of search on the basis of sequence of numbers. Necessity about maintenance of all genes uniqueness is featured such formalisation.

For this work, two simple ideas are employed from the immune system. The first is that the gene segments to be used in the construction of antibody molecules evolve, so as to capture information about genes that occur with higher frequencies in the antigenic universe. The second idea employed is that the bone marrow combines these gene segments together in order to generate final antibody molecules.

An antigen is represented as an integer string of length j in an integer shape-space, where j is the number of jobs to be scheduled on the machine, with each element of the string corresponding to the identity of a given job to be scheduled [2].

The work of clonal selection algorithm:

1. Create an initial pool of m antibodies (candidate solutions).

2. Compute the makespan value of each antibody.

3. Select n best (fittest) individuals from the m original antibodies, where n < m, based on their makespan values. These antibodies will be referred to as the elites.

4. Place each of the n selected elites in n separate and distinct pools. They will be referred to as the elite pools.

5. Clone the elites in each elite pool with a rate proportional to its fitness. The fitter the antibody (the lower the makespan), the more clones it will have.

6. Subject the clones in each pool through a hyper-mutation process. Half of the clones will undergo operation order mutation while the other half will undergo machine order mutation. The mutation rate for both cases is inversely proportional to the fitness of the parent antibody.

7. Determine the fittest individual in each elite pool from amongst its mutated clones to become the elite for the next generation. All other clones are discarded.

8. Replace each elite in the worst l elite pools with a new antibody (cell renewal) once every k generations to introduce diversity and prevent the search from being trapped in local optima.

9. Determine if the number of generations to evolve is reached. If it has, terminate and return the best antibody; if it has not, return to Step 4.

Conclusion

In this work there was a task in view of working out of methodology of control of projects of aviation technics modernization. During research the planned schedule of activities on carrying out of modernization of an AT by means of several methodical approaches has been constructed. The expediency of application of the modified immune algorithm offered in activity is shown. The model of modernization plans and methods the decision of a problem allow to receive well-founded modernization plans in the conditions of uncertainty and to discharge errors at planning.

References

1. *Mori K., Tsukiyama* M, *Fukuda T.* Immine algorithm and its application to factory load dispatching planning// 1993 JAPAN - USA Symp. On flexible Automation, 1994. P. 1343-1346.
2. *Yl.Ong Z.X., Tay J.C., Kwoh C.K.* Applying the clonal selection principle to find flexible job-shop schedules // Artificial Immune Systems 4th International Conference, ICARIS 2005 Banff, Alberta, Canada, August 14-17, 2005 Proceedings, P. 442-455.
3. *Самков О.В., Захарченко Ю.А.* Застосування алгоритму клонального відбору для побудови планів модернізації авіаційної техніки// Автоматика. Автоматизація. Електротехнічні комплекси та системи. - №1(23), Херсон, 2009. С. 110-114.
4. *Захарченко Ю.А., Качур С.Ю., Корнієнко О.В.* Методика вирішення завдань управління проектами модернізації авіаційної техніки// Вестник Херсонского національного технического университета, №1(34), 2009. С. 43-47.

UDC 004.032.2:629.735.036.34.5*7(042)

S.V. Enchev, PhD (National Aviation University, Ukraine)
S.S. Tovkach, postgraduate student (National Aviation University, Ukraine)

WAVELET TRANSFORM FOR ESTIMATING THE TECHNICAL STATE AVIATION GAS TURBINE ENGINE

A new approach of gear fault diagnosis based on continuous wavelet transform is presented. Continuous wavelet transform can provide a finer scale resolution than orthogonal wavelet transform. It is more suitable for extracting mechanical fault information in aviation gas turbine engine.

Introduction. In order to increase the availability of gas turbine engine, the technique of vibration diagnosis has been widely used for many years as a tool for the detection of element aviation engine faults and has shown its advantages in many aspects [1].

For example, with the help of the vibration analysis it is possible to detect a fault of gas turbine engine at an early stage before the fault develops to an eventual failure and interrupts the production process. Its application saves a large amount of time for aircraft maintenance and reduces the production losses greatly.

In order to obtain useful information from vibration measurements and provide aid in early detection and diagnosis of faults there are many signal analysis techniques like Fourier Transform (FT), Short Time Fourier Transform (STFT) [2,3]-[5], Wigner-Ville Distribution (WVD), Envelope Detection (ED) [2], and Wavelet Transform (WT) [2,4]. The most of these methods use spectral analysis based on FT, therefore, these methods present some limitations; it is the inability of FT to detect non-stationary signals [4]. This inability makes wavelet transform an alternative for engine fault diagnosis.

The method of wavelet transform. The WT can be continuous or discrete. The Continuous Wavelet Transform (CWT) reveals more details about a signal but its computational time is enormous. For most applications, however, the goal of signal processing is to represent the signal efficiently with fewer parameters and less computation time.

The Discrete Wavelet Transform (DWT) often called multiresolution analysis can satisfy these requirements.

The selection of the appropriate wavelet is very important in signals analysis. There are many types of wavelets available can be used such as Haar, Daubechies, Meyer, and Morlet wavelet. Different wavelets serve different purposes.

WT is a time-frequency analysis technique. Due to its strong capability in time and frequency domain, it is applied recently by many researchers in rotating machinery. It decomposes a signal in both time and frequency in terms of a wavelet, called mother wavelet. Let s(t) is the signal; the CWT of s(t) is defined as

$$CWT(a,b) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{\infty} s(t)\psi\left(\frac{t-b}{a}\right)dt \qquad (1)$$

where $\psi(t)$ is the conjugate function of the mother wavelet $\psi^*(t)$ (2) a and b are the dilation (scaling) and translation (shift) parameters, respectively. The factor $\frac{1}{\sqrt{a}}$ is used to ensure energy preservation.

$$\psi^*(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right) \qquad (2)$$

The DWT is derived from the discretization of CWT. The most commondiscretization is dyadic. The DWT is given by

$$DWT(j,k) = \frac{1}{\sqrt{2^j}} \int_{-\infty}^{\infty} s(t)\psi\left(\frac{t-2^j k}{2^j}\right)dt \qquad (3)$$

where a and b are replaced by 2^j and $2^j k$, j is an integer.

A very useful implementation of DWT, called multiresolution analysis [], is demonstrated in fig. 1.

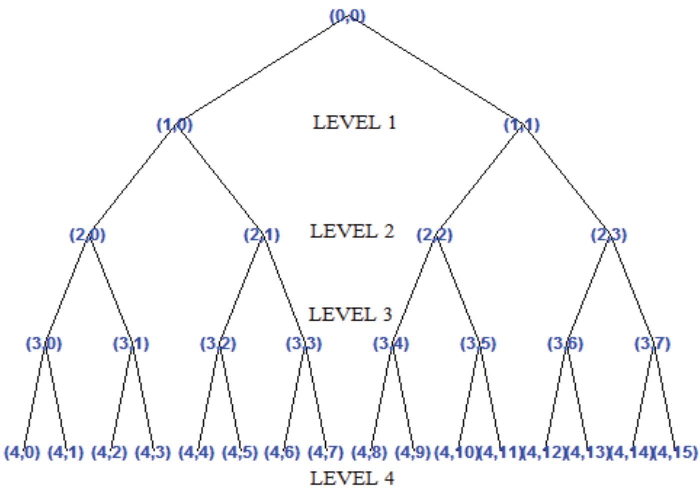


Figure 1: Principle of DWT decomposition

DWT analyzes the signal at different scales. It employs two sets of functions, called scaling functions and wavelet functions [], [], which are associated with low pass and high pass filters, respectively. The discrete signal is passed through a high pass filter (H) and a low pass filter (L), resulting in two vectors at the first level; approximation coefficient (A1) and detail coefficient (D1) [], []. Application of the same transform on the approximation (A1) causes it to be decomposed further into approximation (A2) and detail (D2) coefficients at the second level. Finally, the signal is decomposed at the expected level. The approximations are the high-scale, low-frequency components and the details are the low-scale, high-frequency components of the signal.

The wavelet decomposition for level 4 is illustrated in fig. 1. Each vector A_j includes approximately, $N/2^j$ coefficients, where N is the number of data points in the input signal s, and provides information about a frequency band $\left[0, Fs/2^{j+1}\right]$, where Fs is the sampling frequency.

These measurements were repeated for different states of the system at the frequencies; 17.5Hz and 25Hz in Vertical Directions (VD) and Horizontal Directions (HD), respectively. The number of data points or samples for each signal is 2048.

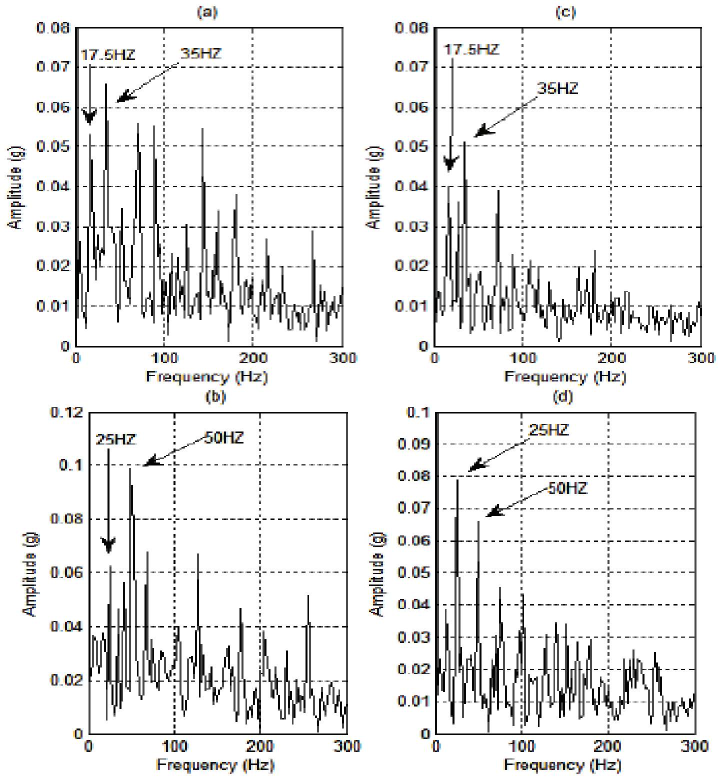


Fig 2: Spectrums of gear fault using Morlet wavelet at 17.5 Hz and 25 Hz speeds

From the Fig.2, it is clearly shown that the peaks at the rotation frequencies of the shaft1 17.5 and 25 Hz in HD (Fig.2a, Fig.2b) and VD (Fig.2c, Fig.2d) and their multiples are present in the frequency spectrum which confirms the presence of a gear fault.

For a better appreciation of the performance of the best method, we have presented in Fig.3 a comparison of the peaks of gear fault at the rotation frequencies of the shaft1 17.5 and 25 Hz in HD and VD for different methods ED and WT (Morlet).

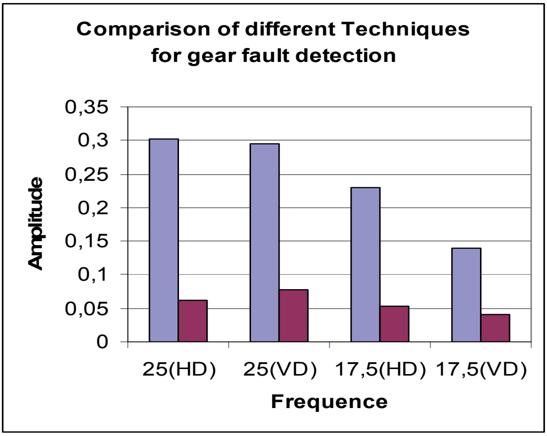


Fig. 3. Peaks comparison for different techniques (Envelop detection and Wavelet transform)

Conclusion. Signal analysis techniques play a key role for fault diagnosis of gas turbine engine. Traditional spectral analysis techniques provide a good description of stationary signals. However they can not give any information about the time dependency of the frequency contents of a signal. In addition these techniques are also unable to analyze non stationary signals. Thats why we used wavelet analysis.

It remains to test its feasibility on other types of faults in rotating machinery.

References

1. *Фалалеев С.В.* Современные проблемы создания двигателей летательных аппаратов /С.В. Фалалеев. – Самара, 2012. – С. 106.

2. *Djebala A., Ouelaa N., Benchaabane C., Laefer D.F.* Application of the Wavelet Multi-resolution Analysis and Hilbert transform for the prediction of gear defects// Journal of Mecanica. – 2012. – Vol. 47. – pp. 1601–1612.

3. *Амосов О.С.* Интеллектуальные информационные системы. О.С Амосов. – Комсомольск-на-Амуре: ГОУВПО «КнАГТУ», 2005. – 106 с.

4. *Пахомов Г.И., Пахомов Ю.Г.* Применение вейвлетов для обработки сигналов // Вестник ПГТУ. Электротехника, информационные технологии, системы управления / Г.И. Пахомов, Ю.Г. Пахомов. – Пермь: Изд-во Перм. гос. техн. ун-та, 2007. – 86 с.

UDC 621.311.68 (0432)

Krasnoshapka N. D., PhD (National Aviation University, Ukraine)
Tihonov V.V., PhD (National Aviation University, Ukraine)
Mazur T., PhD (National Aviation University, Ukraine)

DYNAMIC UNINTERRUPTIBLE POWER SUPPLY

Dynamic uninterruptible power supply can solve the problem of power supply in case of accidents in the power supply system and will improve the quality of electric power by the regime of «conditioning network»

The most important factor in ensuring safety at the airport is uninterrupted power supply with the required quality of all its systems. Most consumers in the airport belong to the first category of customers special group. Consequently, for their supply, we must use two independent input and an emergency source of electrical energy. The most promising of the emergency source today are the dynamic uninterruptible power supply (DUPS) [1]. The main modules of DUPS are the kinetic energy battery pack (flywheel) and the synchronous machine.

If consumers are powered by an external supply, the synchronous machine of DUPS operates in motor mode and supports rotation of the flywheel. If the network settings are outside the specified limits, the synchronous machine switches to generator mode and supports continuing sinusoidal voltage at the load. This mode is called «conditioning network». Source of energy in this mode is the flywheel. He maintains a steady speed of the rotor shaft of the synchronous machine. The kinetic energy of rotation of the flywheel can reach 16 MJ [2].

In the paper, we will offer a fundamentally new design of the dynamic uninterruptible power supply. It allows you to increase the amount of kinetic energy and time of working the source without running the diesel engine. In this construction combines the features of the kinetic energy battery pack (electrical energy storage device) and the generator [3].

Structural scheme of electrical energy storage device is shown in Figure 1. Energy accumulator consists of the outer rotor 1, the inner rotor 2, the generator (feeder machine) 3. Outer rotor 1 (flywheel) is made of ferromagnetic material with a broad hysteresis loop and has a short-circuit winding.

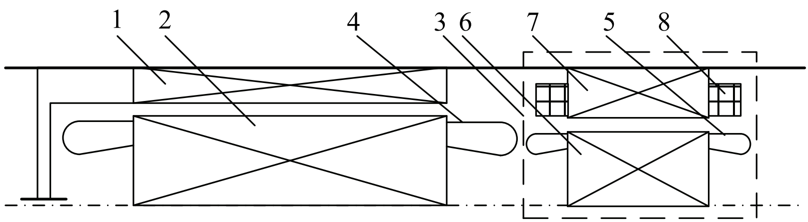


Fig. 1. Electrical energy storage device

The inner rotor (2) has a slots on the outer surface, containing polyphase winding (4) of the number of pole pairs p_{sd}. Winding (4) is connected to a multiphase winding (5) of rotor (6) of the generator (3), the rotor (6) of the generator (3) is located on the same axis of the rotor (2). The number of pole pairs of the rotor 6 of the generator 3 are p_g. On the stator (7) of the generator (3) are the poles with the field winding (8). Field winding (8) is connected to a DC current through the unit of regulation. Generator (3) works as synchronous generator.

The current flowing through the excitation winding (8) and creates a magnetic flux. If an internal rotor (2) energy storage and rotor (6) Generators (3) rotate at a certain speed n, then under the influence of the magnetic flux in multiphase winding 5 provides the electromotive force with a frequency $f_{\text{g}} = \frac{p_{\text{g}} n}{60}$.

The winding (5) of rotor of the generator (3) is connected to the winding (4) of inner rotor (2) of the storage device with a number of pole pairs p_{sd}. The current flowing through the winding (5), creates a rotating magnetic field in the direction of rotation of the rotor at a speed of $n_{\text{sd}} = \frac{60 f_{\text{g}}}{p_{\text{sd}}} = \frac{p_{\text{g}} n}{p_{sd}}$.

Relative to the outer rotor (1) the magnetic field rotates at a speed of $n + n_{sd} = n\left(1 + \frac{p_g}{p_{sd}}\right)$.

The magnetic field crosses the outer rotor (1) and leads it electromotive force. Under the action of the electromotive force in the rotor (1) current flows. The interaction of currents in the rotor (1) with inner magnetic field of the rotor (2) there is electromagnetic torque (asynchronous). This electromagnetic torque leads to the rotation of the rotor (1). Because outer rotor (1) is designed as a solid ferromagnetic rotor, its mechanical characteristics look like a dipper. It allows you to get large starting moment, and thus reduce the startup storage device. The outer rotor (1) in addition to the asynchronous moment affects a synchronous moment. It is the result of magnetization of the rotor (1) by magnetic flux of the inner rotor (2). The combination of these moments leads to the rotation of the outer rotor (1) at a speed of $n(1 + \frac{p_{\text{g}}}{p_{\text{sd}}})$.

For example, when the speed of rotation the inner rotor (2) $n = 1500$ r/min and the $p_g = 2$, $p_{sd} = 1$ speed the outer rotor (1) is about 4500 r/min.

Thus, changing the ratio of the p_g and p_{sd}, we can provide high-speed rotation of the outer rotor (1). This significantly increases the stockpile of kinetic energy:

$$W = \pi^2 M r^2 n^2 , \quad (1)$$

in the formula: M – mass of the outer rotor; r – radius of the outer rotor; n – speed of rotation of the outer rotor.

When the kinetic energy is converted into mechanical energy of rotation of the inner rotor (2), the speed of the outer rotor (1) is reduced. However, the speed of rotation of the inner rotor (2) remains constant. This is due to the presence of synchronizing moment acting on the inner rotor (2). The value of synchronizing moment maintained by changing the current in the multiphase winding (5) generator by regulating the current in the field winding (8).

Thus, by running outer rotor as solid rotor with a wide hysteresis loop and placed on the inner rotor multiphase winding with number of pole pairs less than the number of pole pairs of multiphase winding of generator (3) we can increase the magnitude of the angular momentum and thus provide more time to maintain a stable speed of inner rotor, and hence the motor - generator.

Kinetic energy storage device (kinetic energy battery pack) is an asynchronous machine with stator that rotates and fixed rotor. In three-phase windings of the inner rotor, which serves as a stator of asynchronous machine, current's flowed. These currents create a magnetic field. During the rotation of outer rotor and under the influence of the magnetic field in the outer rotor windings electromotive force is provided. Consequently, the equivalent circuit of kinetic energy storage device will be different from the equivalent circuit of the asynchronous machine.

The system of balance equations of voltage for the electrical circuit of inner and outer rotors and an equation for the magnetomotive force for energy storage device looks like asynchronous machine.

The value of the electromotive force (EMF) in short-circuited winding of outer rotor depends on frequency of the rotation of the inner rotor. Therefore, the conventionally present value of the EMF as follows:

$$\dot{E}_2 = \dot{E}_{2s} + \dot{E}_{2вр} , \quad (2)$$

in the formula: $\dot{E}_{2s} = 4.44 f_{2s} k_{об} W_2 \dot{\Phi}$ – transformer EMF in the winding of outer rotor; $\dot{E}_{2вр} = 4.44 f_{2вр} k_{об} W_2 \dot{\Phi}$ – electromotive force of the rotor.

Turn to the fixed outer and inner rotors and introduce the concept of equivalent sliding: $s' = \frac{n_1 - n_{вн}}{n_1}$. Thus, we obtain the equation of kinetic energy storage device:

$$\begin{aligned} &\dot{U}_1 = -\dot{E}_1 + \dot{I}_1 R_1 + j\dot{I} X_1 \\ &\dot{E}_{22} = \dot{I}_2 \frac{R_2}{1+s-s'} + j\dot{I}_2 X_{22} \frac{s}{1+s-s'} , \\ &\dot{I}_0 m_1 W_1 k_{об1} = \dot{I}_1 m_1 W_1 k_{об1} + \dot{I}_2 m_2 W_2 k_{об2} \end{aligned} \quad (3)$$

in the formula: $\dot{E}_{22}$ – EMF in the winding of outer rotor with magnitude of frequency f_1.

After bringing outer rotor winding parameters to the parameters of inner rotor windings receive energy storage equation in the above form:

$$\dot{U}_1 = -\dot{E}_1 + \dot{I}_1 R_1 + j\dot{I}X_1$$

$$\dot{E}'_{22} = I'_2 R'_2 + j\dot{I}'_2 X'_{22} + \dot{I}'_2 R'_2 \frac{1+\overline{S}}{\overline{S}+2n_r} - j\dot{I}'_2 X'_{22} \frac{n_r}{\overline{S}+2n_r}, \tag{4}$$

$$\dot{I}_0 = \dot{I}_1 + \dot{I}'_2$$

in the formula: $\overline{S} = \frac{n_1 - n_н}{n_1}$ – primary sliding, $n_r = \frac{n_{вн}}{n_1}$ – the relative speed of rotation of the outer rotor.

Equivalent circuit of energy storage device according to equation (3) is shown in Fig. 2.

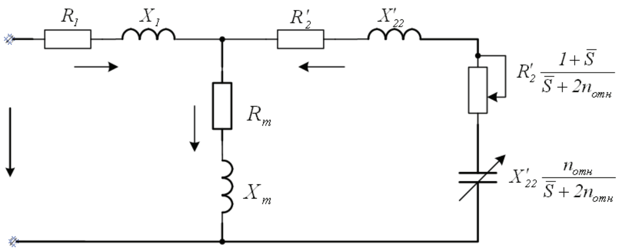


Fig. 2. Equivalent circuit of energy storage device

Analysis of the equivalent circuit shows that the accumulation of kinetic energy conventionally presented in the form of accumulation of electrical energy in the capacitor.

Conclusions

1. Using the dynamic uninterruptible power supply will provide power for consumers with zero power switching time and also will implement regime of «conditioning network» and provide power factor correction.

2. Transformation of the system equations of equilibrium and introduce the concept of equivalent sliding enable us to construct an equivalent circuit of the kinetic energy storage device. You can use this scheme when analyzing modes of DUPS.

References

1. Барсков А. Старые новые динамические ИБП/ А. Барсков// Журнал сетевых решений LAN – 2011. – №2. – С.59-67.

2. Бучинчик А.И. Динамические источники бесперебойного питания./ А.И. Бучинчик // Турбины и дизели. – 2007. – №6. – С.49-51.

3. Тихонов В.В., Николайчук Т.В. Накопичувач енергії. Заявка на патент

UDC 621.396.4

O. Lysenko, Doctor of Engineering Science (National Aviation University, Ukraine)
H. Tachinina, PhD (National Aviation University, Ukraine)
H. Panchenko (National Aviation University, Ukraine)

THE MATHEMATICAL FORMULATION OF MOVEMENT OPTIMIZATION OF FLYING ROBOTS GROUP BASED ON UNMANNED AERIAL VEHICLES

The method of converting the compound dynamic system to the branching dynamical system with transient size of state and control vectors at a moment of structural changes is proposed.

Introduction. The importance and complexity of the application of robotic systems, including unmanned aerial vehicles (UAVs) in many areas of science, technology and industry caused primarily by the fact that they can be used where human activity is difficult or impossible, for example, radioactive or chemical contamination zones, under battle conditions, during underwater or space research.

At the same time as the experience of the application in the designated areas, a single UAV, no matter how intelligent it may be, can be used only to solve some particular problems, or to perform relatively simple operations, because it usually has a relatively small capability to accomplish the problem.

The obvious solution for the problems mentioned above is deployment of multiple UAVs, i.e. UAV group to solve complex problems.

To use the group of UAVs decisive a single large task, they need a certain way to interact with each other so that as efficiently as possible to solve the problem in a complex environment when the situation can change suddenly. To achieve this goal, a group of UAVs will act as something whole, and the actions of each individual UAV should be aimed to achieve the largest group effect. For this purpose, it is proposed to consider the group of UAVs that perform a single task as a compound dynamic system [1-3].

The deployment effectiveness of these systems depends on the best and optimal choice of coordinates and the time of compound dynamic system (CDS) partition, as well as the optimal method of CDS movement to partition point and optimal movement of the subsystems to targets along paths after partition.

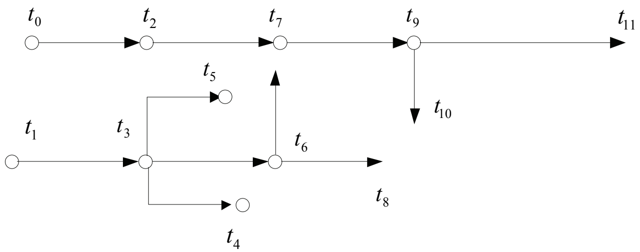


Fig. 1. Example of a branching path:

The CDS subsystems can be grouped and separated many times during its motion

t_i - moments of the CDS structural transformation;

The arrows indicate symbolically the movement direction of the CDS subsystems

Motion of the subsystems along the CDS path is described by the differential system [4]

$$\dot{x} = f(x, u; y, v; t), \; t \in [t_0, t_f], \qquad (1.1)$$

where $x \in E^n$, $u \in \cap \subset E^m$;

y – phase coordinates,

v -control of other subsystems from the CDS affecting the motion of the subsystem;

t_0, t_f – the moments of beginning and end of the motion subsystem on the path branches.

The scalar restrictions of the below form impose the subsystem path (1.1)

$$g_i(x(t_0), y(t_0),.t_0; x(t_f), y(t_f), t_f) \begin{cases} = 0, & i = \overline{1, k_g} \\ \leq 0, & i = \overline{k_g + 1, n_g} \end{cases} \qquad (1.2)$$

$$q_i(x(t), u(t),.t_0; y(t), v(t); t) \begin{cases} = 0, & i = \overline{1, k_q} \\ \leq 0, & i = \overline{k_q + 1, n_q} \end{cases} \qquad (1.3)$$

where $t \in [t_0, t_f]$.

Criterion for assessing the CDS performance is described by the expression

$$P = P(\cdot) + \rho_{\sum} \to min, \qquad (1.4)$$

where

– P (·) - criterion terminal component, depending on the subsystems phase coordinates in times of CDS structural transformation and its time points;

– $\rho_{\sum}$ – criterion integral component consisting of the sum of particular integral component of the form

$$\rho = \int_{t_0}^{t_f} h(x(t), u(t); y(t), v(t); t)\, dt, \qquad (1.5)$$

corresponding to the individual branches of the CDS path.

Thus, the problem (1.1) - (1.5) of the CDS path optimization is to find the optimal controls and paths of subsystems along branching path, minimizing the criterion (1.4), as well as finding the optimal time and phase coordinates, in which the CDS structural changes occur.

It is supposed to accomplish this task in three stages: first to make the transition from the state of a dynamical system to a discontinuous dynamical system with variable size of the control state vectors; then to optimize a discontinuous system, and finally back to the original task, expressing the result of a discontinuous system optimization through the notation of the task original formulation.

The transformation method of a compound dynamical system in a discontinuous dynamical system with changing state and control vectors at structural changes is as follows [4]:

- the branching diagram is plotted based on physical considerations of the CDS, the trajectory equations of motion subsystems along the path branches are formulated, the restrictions operating continuously for subsystem and at boundary points are recorded, the criterion is formulated;
- the chronological sequence of time structural changes of the CDS is set;
- the extended state X_i and control vectors U_i ($i=\overline{1,N}$) are introduced in the time intervals between the CDS structural changes, where $N+1$ = number of the CDS structural transformations taking into account structural transformation associated with the beginning of the CDS movement (i=0), consisting of state and control vectors of dynamic subsystems (blocks), which are moved along the path of branches in the time interval.

As a result of this method, the following formulation of optimization of the discontinuous system with variable size of state and control vectors [5-8] is achieved.

$$I = S(X_{1(}(t_0^+), t_0; X_{1(}(t_1\ ), X_{2(}(t_1^+), t_1; X_{2(}(t_2\ ), X_{3(}(t_2^+), t_2; \ldots$$

$$\ldots; X_{i(}(t_i\ ), X_{i+1(}(t_i^+), t_i; \ldots; \ldots; X_{N(}(t_N\ ), t_N) + \sum_{i=1}^{N} \int_{t_{i\ 1}^+}^{t_i} \hat{O}(X, U, t)dt \to \min, \quad (1.6)$$

$$G_i(X_{1(}(t_0^+), t_0; X_{1(}(t_1^-), X_{2(}(t_1^+), t_1; \ldots; X_{N(}(t_N^-), t_N) \begin{cases} = 0, & \overline{i = 1, K_G}; \\ \leq 0, & \overline{i = K_G + 1, N_G} \end{cases}; \quad (1.7)$$

$$Q_{ij}(X_{i(}(t), U_i(t), t) \begin{cases} = 0, & \overline{j = 1, K_{Qi}}; \\ \leq 0, & \overline{j = K_{Qi} + 1, N_{Qi}} \end{cases}; \quad (1.8)$$

$$\dot{X}_i = F_i(X_i, U_i, t), t \in \left[t_{i\ 1}^+, \quad t_i\ \right], i = \overline{1, N}; \quad (1.9)$$

$X_i \in E^{n\,\Sigma i\,i}$, $U \in \Omega_i \subset E^{m\,\Sigma i\quad i}$ $U_i(\cdot)$ - piecewise continuous. (1.10)

Here, X_i, U_i - advanced phase state and control vectors corresponding to the *i* time interval between the CDS structural transformations of dimension $n_{\Sigma i}$ and $m_{\Sigma i}$;

– $\cap_i$ - bounded set of space $E^{m\,\Sigma i}$;

– $S(\cdot)$, $G_j(\cdot)$ $\quad (j = \overline{1, N_G;})$ - smooth of $E^{2\sigma} \times E^{N+1} (\sigma = \sum_{i=1}^{N} n_{\Sigma i})$ scalar functions of variables for $X_1, \ldots X_{N,}\ t_0, \ldots t_N$;

– $Q_j(\cdot)\ (j = \overline{1, N_G})$ - continuous of $E^{n\,\Sigma i} \times E^{m\,\Sigma i} \times E^1$ together with the first derivatives with all arguments as scalar functions for which the correlations (1.8) satisfy the condition of community of position [64], i.e. the vectors $\mathrm{grad}_{U_i} Q_j(X_i(t), U_i(t), t) \quad (j = \overline{1, K_{G,i}})$ and $\mathrm{grad}_{U_i} Q_\gamma(X_\gamma(t), U_\gamma(t), t)$ $(\gamma \in I_\gamma; I_\gamma$ - the set of all indices from $j = \overline{K_{G,i} + 1, N_{Q,i}}$, for which $Q_j(\cdot) = 0$) are linearly independent;

– $F_i(\cdot)$ - continuous with mapping of matrix derivatives $E^{n\,\Sigma i} \times \Omega \times E^1 \rightarrow E^{n\,\Sigma i}$;

– K_G, N_G, K_Q, N_Q, N -given whole numbers, $0 \le K_G \le N_G$, $K_G \langle \sum_{i=1}^{N} (2n_{\sum i} + 1) + 1$; $0 \le K_{Q,i} \le N_{Q,i}$; $K_{Q,i} + K_\gamma \quad m_{\sum i}$, where $K\gamma$-number of γ indices.

It should be noted that only a reduction of the optimization problem of the CDS branching path to optimization of a discontinuous system path with variable size of the state control and vector (1.6) - (1.10) allows us to formulate the theorem on the base of which the CDS path optimization with arbitrary branch circuit is performed. Otherwise, each new branch circuit of the CDS path requires to perform all procedures of proof considering features of the path.

As discussed above, the third stage of solving the optimization problem of the CDS branching path is return to the terms of the original formulation of the task.

Bringing the conditions for optimal control and trajectory discontinuous dynamic system to optimality conditions CDS, which is the equivalent of a formal breaking system implemented by decomposition of extended state and control vectors, constraints and boundary conditions, support functions and variables used in the application of optimization method, in reverse sequence source transformations that led to the transition from the CDS to a discontinuous dynamic system by the rule of transition to the original terms.

For the most typical cases of this transition will be considered in subsequent publications in the form of the consequences of the main theorem, which formulates the result of solving the task (1.6) - (1.10).

Conclusions

In this paper we solve the task of the compound dynamical system path optimization consisting in finding the optimal controls and paths of the subsystems along branching paths that minimize the given criterion, as well as finding the optimal time and phase coordinates, in which the CDS structural transformation are performed.

The method of converting a compound dynamic system to a branching dynamical system with transient size of state and control vectors at a moment of structural changes is proposed also.

References

1. *Lysenko A.I.*. Метод синтеза оптимального по энергозатратам закона управления мобильной телекоммуникационной аэроплатформой. Науковий вісник академії муніципального управління, серія «Техніка». – 2010. – № 1. – С. 90–97.
2. *Oleksandr I. Lysenko, Inga V. Uryadnikova, Stanislav V. Valuiskyi, Sergej Chumachenko*. Increasing of manet throughput using quasi-optimal UAVs placement control.- Akademia ozbrojenyah sil. Gen. M.R. Stefanika. Slovakia Science&Military. №1, Volume 8, 2013, p. 52-61.
3. *Lysenko A.I.*. Моделирование оптимального движения составной динамической системы. Наукова думка, журнал "Електронне моделювання", т.11, № 4, 1989. – С. 71–76.
4. *A.I. Lysenko*. Необходимые условия оптимальности траектории составной динамической системы ВВИА им. проф. Жуковского, сб. "Авиационные приборы, навигационные системы обеспечения жизнедеятельности экипажей ЛА", 1988. – С. 11–18.
5. *Aschepkov LT.* Оптимальное управление разрывными система.- Новосибирск: Наука, 1987. –226 с.
6. *Ivanov V.A., N.V. Faldin.* Теория оптимальных систем автоматического управления. –М.: Наука, 1981. – 336 с.
7. *Лысенко А. И., Галкин И. Л.* Анализ возможности расширения информационного базиса адаптивной системы управления летательным аппаратом, окруженным газовой средой// Адаптив. системы автом. упр. – 1988. – Вып. – 16. – С. 20-24.
8. *Лысенко А.И. Лысенко А.И.* Условие скачка в задаче оптимального управления объектом// Адаптив. системы автом. упр.- 1988. – Вып. 16 - С. 136-141.

UDC 621.396.93

P. Lazarchuk (National Aviation University, Ukraine)
A. Zarutska (National Technical University «KPI», Ukraine)
T. Pryschepa (National Technical University«KPI», Ukraine)
I. Alekseeva (National Technical University«KPI», Ukraine)

MATHEMATICAL MODEL OF RELIABILITY WIRELESS SENSOR NETWORK NODE

General information and basic parameters of wireless sensor network nodes, their mathematical model.

The structure of the WSN, which is designed for topology may include five types of nodes – terminal device (TD; only transmit messages), PAN-coordinator (only accept messages), repeaters (both receive and transmit messages) and bridges. Regardless of the functional purpose nodes are characterized by the following parameters:

- A unique identification number (ID), required for the targeted delivery of messages;
- The geometric position in space, is the three-dimensional vector of coordinates: $X = (x_1, x_2, x_3)^T$. Determining the position of an anchor point node (in this case the center of symmetry of the antenna transceiver);
- The maximum information density that can be transmitted or received by nodes: $U_{f_c}^{max}$ bits per second in this frequency range based encoding method [1, 2];
- The average amount of load - the information density *U* baud transmitted and / or received by the node to solve the main problem WSN - delivering messages from TD to gateway.

$$U = \sum_S (U_i^{TX} + U_i^{RX})$$

Where *S* - set of TD generating information flows received and transmitted by the node;

U_i^{TX} and U_i^{RX} - the density of the transmitted and the received stream corresponding to the i-th TD (in special cases may be zero).

Each of N_{ED} TD as part of WSN characterized periodicity send informational messages (or rather, variable interval between the same two consecutive phases of similar posts), measured in seconds, and the message length L, measured in bytes. In this algorithm to account for the network load, these two parameters are replaced by an equivalent quantity - the density of the generated information flow in accordance with the following formula:

$$U_i^{ED} = \frac{L}{T_m} = 1 \ldots N_{ED},$$

generally unique for each of TD.
The characteristics of the transceivers placed on the nodes of the WSN are primarily working frequency range, a working channel within the range of the emitted signal power and maximum bandwidth, corresponding to the channel (density transmitted and received information stream bits / sec).
For modeling transceiver nodes tract these characteristics in accordance with [1] the following values:

- Reference frequency channel, MHz:

$f_c = 2405 + 5(k-11), k = 11,12,...,26$ channel width $df = 5MHz$

The working channel passed the channel 20 for which the reference frequency of the emitted signal is 2450 MHz.

- Power transmitters P_{TX} adopted the same for all nodes and is. 10^{-3} Wt ;
- Transmission and reception of information for the selected frequency range is 250 kbit / s.
- The gains of the transmitter-receiver path to simplification of the model are chosen the same. $G_{TX} = G_{TX} = 1$

In addition, the model of an autonomous node aggregates WSN model of its battery, which in the initial approximation can be represented as follows:

- battery charge proportional to the total duration of operation of the transceiver in reception mode and / or transmission.
- The probability of a node failure due to battery discharge unit is

considered as time passed $T = t_c \frac{U_{f_c}^{max}}{U}$ since the beginning of the site, where t_c - uptime node at the maximum allowable flux density, received and transmitted node: $U = U_{f_c}^{max}$;

In the simulation was made $t_c = 72h.$.
For modeling random output node failure was chosen exponential distribution probability of failure q_{md} [3]. Corresponding distribution function has the form:

$$F(t,\lambda) = 1 - e^{-\lambda f}$$

Where *t* - timeslot hours;
λ_f - average failure rate per hour. In the absence of real statistical data about the magnitude of its value in the simulation was modeled as follows:

$$\lambda_f = \lambda_{f_c} \frac{U}{U_{f_c}^{max}}$$

Where $\lambda_{f_c} = 1 \cdot 10^{-5}$ failues/hour - failure rate at maximum load node;
U - total density of the received and transmitted node information flow;
$U_{f_c}^{max}$ - maximum information density, capable of receiving or transmitting node.

With this notation for the probability of node performance for routine period can write the following relation:

$P_i'' = (1 - q_{bat})(1 - q_{rnd})$.

Thus, the reliability of the node model proposed WSN fundamental role played by the average information density, the node being processed.

Conclusions

Thus, the simulation results show that over time, the effectiveness of classic routing algorithm falls, whereas a probabilistic algorithm efficiency remains approximately constant. On a big time interval probabilistic algorithm shows average significantly better results. However, in the initial moments of the classical algorithm efficiency is quite high and exceeds the efficiency of the probabilistic algorithm.

References

1. *Mishagin, K.G.* Extending the lifetime of a sensor network using the methods of collective information transmission / K.G.Mishagin, V.A. Pastukhov, A.N. Sadkov / / Work. scientific. conf.in radio physics. Nizhny Novgorod, UNN, 2005. - P. 344 - 46.

2. *Arakelyan S.M.* The self-organizing information environment with decentralized control for interaction between educational institutions / S.M.Arakelyan, A.V.Duhanov, V.G.Prokoshev, S.V.Roschin.

3. *Bataev P.A.* Probabilistic approach in the creation of routing algorithms in networks with varying topology / P.A. Bataev / / Telecommunications and Information Systems: th. Intern. conf. - SPb., 2007. pp. 117 - 125. - ISBN 5-7422-1583-5.

4. *Oleksandr I. Lysenko, Inga V. Uryadnikova, Stanislav V. Valuiskyi, Sergej Chumachenko.* Increasing of manet throughput using quasi-optimal UAVs placement control.- Akademia ozbrojenyah sil. Gen. M.R. Stefanika. Slovakia Science&Military. №1, Volume 8, 2013, p. 52-61.

UDC 656.71.628.984

S. Ilienko, PhD (National Aviation University, Kyiv, Ukraine)

RELIABILITY AND OPERATION CHARACTERISTICS OF CIVIL AVIATION AIRFIELD AUTOMATED LIGHT SIGNAL SYSTEMS

Providing the necessary level of reliability lighting systems airfields in all stages of its life cycle: design, production, certification, and during the operation in the evaluation of technical condition. At all these stages for the elements airfield lighting systems to formulate the requirements for reliability, and to determine their compliance with these requirements.

Relevance. One of the main challenges facing civil aviation is a high level of security and regularity of aircraft operations. In reduced visibility airport lighting system is a crew of aircraft only source of visual information on the most crucial stage of the flight - the stage of visual piloting. In accordance with the State Standard of Ukraine DSTU 2860-94 "Reliability engineering. Terms and definitions ", airport lighting system reliability is defined as property, reflecting its ability to perform its required function for a specified period of time under specified conditions, operation, maintenance, storage and transportation. Reliability is a complex property that, depending on the purpose and the conditions of its application may include reliability, durability, maintainability, and the keeping or some combination of these properties. For questions airport lighting system operation are critical reliability and maintainability. Also the airport lighting system must have remote control of lighting equipment to obtain the required alarm system operation and its elements in accordance with the documentation on the type of equipment.

Research problem statement.

Objective of the study is the reliability and maintainability of the airport lighting system and lighting characteristics lighting equipment subsystems airport lighting system. Lighting equipment system is divided into:

- Systems of low-intensity lights intensity, composition, characteristics and wiring lights, designed for installation on a runway equipped for visual approaches and instrument approach;

- Systems with high-intensity lights, composition, characteristics and wiring designed for installation on a runway equipped for precision approach by Category I, II and III.

Reliability airport lighting system is completely determined by the reliability of its constituent elements - subsystems airport lighting system and control system lighting system airport. Reliability subsystems airport lighting system determined by the reliability of their elements - airfield lights and power supply subsystem airfield lights. Usable state airport lighting system (fully operational state) - is a condition in which all the elements are functional, or there is a failure does not preclude its use in weather conditions established for her category. Defined similarly usable state subsystem airport lighting system. It should be noted that the definitions given for the airport lighting system and its subsystems may be in working condition, even in the case where a certain part of their elements refused. Thus, airport lighting system and its subsystems are subject to redundancy. Since all elements of the airport lighting system and its subsystems are working in the same mode, the backup is loaded. Processes and refusal to restore the airport lighting system, its subsystems and elements are random processes, so the definition of reliability conducted by means of the theory of probability. During the comparative analysis of the results, it should be assumed that the subsystem airfield lights reliability indices which are determined, the required level of safety, if the probability of its failure during use less 10^{-3} - 10^{-4} [4].

Composition and circuit reliability of systems and components of the lighting system of the airport.

Consider subsystem airport lighting system. Each of them consists of two parts: a subsystem airfield lights and power supply subsystem airfield lights. Failure of the subsystem airfield lights can occur for two reasons:

- Failure airfield lights themselves with certain internal reasons (failure of the light source, an optical system or fittings fire and others.)
- Failure of power supply subsystem airfield lights.

Failure of power supply subsystem airfield lights seen as an independent event. Depending on the type of the airport lighting system, and the subsystem in its composition may comprise one or more cable systems. Cable network - is a serial electric circuit, consisting of the primary windings of transformers and insulating segments connecting cable for the transmission of electrical energy from the dimmer in the airfield lights. The composition also includes a cable network dimmer. With dimmer manages amperage cable network and the corresponding control light intensity airport lights. Isolating transformers carried conversion of voltage and current operating cable network to the values required for power supply light sources airfield fire and also provide non-repudiation cable network in case of failure of the relevant aerodrome fire. Segments connecting cable connected isolating transformers serial electrical circuit input terminals which are connected to the control brightness. Failure of brightness controller or any of the segments of the connecting cable leads to failure of the cable network in general. In the block diagram of reliability does not include such items as its isolation transformers, since the refusal of the primary winding of an isolation transformer is considered a rare event. If in the power supply subsystem airfield lights includes two or more cable networks, they can back each other up. If one of the cable networks refused and it did not lead to failure of power supply subsystem-airfield lights, then the state of this subsystem is defined as decreased performance status. During operation of the subsystem power supply airfield lights are renewable system. Information about the failure of any cable line goes directly to the manager and if it leads to failure of subsystems light signal of the airport and airport light signal system as a whole, the aircraft is given a command to stay in the air and begins the working condition of disaster recovery subsystem. After his conduct flight operations in progress. subsystem airport light signal system [4] is a set of elements - fire aerodrome situated in the territory of the airport for a specific pattern. Airfield fire consists of elements such as isolating transformer, light source, an optical system.

Disclaimer two cable networks in the subsystem power supply airfield lights with two or three cable networks always lead to the transition in disabled state. Failure of any of the elements of the airfield fire leads to his failure as a whole. Subsystem airfield lights is a complex system with many elements which reserve one another. When operating the airfield lights subsystem is considered non-renewable system. Thus, the subsystem airport light signal system in operation is a system that consists of two subsystems: subsystem renewable electricity airfield lights and not renewable subsystem airfield lights.

Automated remote control lighting system of the airport.

Light-airport system has a remote control equipment to obtain the required signaling system performance and its individual elements. The required amount of equipment remote control lighting equipment is determined for each airport, based on the structure of the controlled process equipment. According to the documentation Management of lighting equipment is formed as follows:

- hardware control points for lighting facilities managed by air traffic control and landing taxiing;
- hardware control points for lighting facilities managed by the controller;
- equipment controlled items;
- mnemonic diagrams – in view controllers landing, taxiing;
- operational control panel in panels controllers landing, taxiing, start.

When designing equipment transformer substations should include:

- remote control of autonomous units;
- signaling the next service personnel operating the presence of voltage on the external power supply;
- signaling the inclusion of diesel-electric units and emergency conditions.

Conclusions

The required light signal system reliability Airport is the main condition for the implementation of safe and regular flights to visual piloting stage in simple and adverse weather conditions on the ground of civil aviation. The level of equipment reliability, which is part of the airport light signal system, determines the timing and extent of operational measures to maintain it in working condition, routine maintenance and repair. From the airport light signal system reliability depends also necessary resources electro technical flight support services required number of staff service, the number of spare parts, tools and resources needed to quickly restore the working condition of light signal the airport.

References

1. ДСТУ 3589-97. Системи та комплекси авіаційного обладнання. Надійність та експлуатація. Терміни та визначення. К.: Київстандарт, 1997. – с. 28.
2. *В. Ю. Ломоносов, и др.* Электротехника. М.: Энергоатомиздат, 1990. – 400 с.
3. ДСТУ 2860-94. Надійність техніки. Терміни та визначення. К.: Київстандарт, 1996.
4. *Ю.В.Фрид, Ю.К. Величко, В.Д. Козлов.* Электро-светосигнальное оборудование аэродромов. М.: Воздушный транспорт, 1988. – 315 с.
5. ВСН 8-86. Пособие по проектированию объектов светосигнального и электрического оборудования систем посадки воздушных судов в аэропортах. М.: Аэропроект, 1987.

UDC 629.735.064.5: 621.316.722: 064.53

V. Zakharchenko, Ph. D. (NAU, Ukraine, Kyiv)
V. Kozub, P. G. (NAU, Ukraine, Kyiv)

INTEGRATION OF MODERN SMART CONTROL SYSTEMS IN AIRCRAFT POWER DISTRIBUTION SYSTEM

Development of the aircraft's power supply system is accompanied by the integration of modern smart control, monitoring and regulation systems to enhance the performance and numerous parameters of electric power

The development of new aircraft development and equipment leads to increased amounts of electric energy consumers. Currently, most of all aircraft avionics is an electrical energy. Also increases the power of the equipment and, therefore, increases overall system power consumption. At the same time stricter quality requirements of electrical energy. The electricity consumers power supply system shall provide efficient and safe functioning of a wide range of external influences in power quality, meeting the requirements of GOST 19705-89 [1].

On modern aircraft is widely used digital avionics, microprocessor computing equipment, digital transmission, processing and displays, these powerful avionics and electrical equipment operating in different modes, including a pulse mode. Pulse mode of the powerful onboard equipment negatively impacts on the quality of electrical energy: increasing transients. In this regard, it is more difficult to ensure the accuracy of voltage stabilization.

From the analysis of regulatory documents GOST 19705-81, GOST 19705-89, GOST R 54073-2010, which establishes requirements for the quality of electricity on board as designed as well as operated for 20 years aircrafts it's seen certain changes in the requirements that indicate a narrowing range parameter spread in certain modes of operation.

From the physical point of view [2] they are almost perfectly designed systems in which no serious technical changes are possible due to restructuring or revision of the concept of the whole system. Therefore, modernization of the power supply system is primarily possible in the implementation and integration of modern blocks or modules of monitoring, control and protection that are built on modern relatives to excellent smart systems.

The advantages of these systems is their high reliability, small dimensions and weight, ultra high performance, flexibility in setup and a very wide range of possible application of these decisions.

For example, such systems use expert systems, systems based on genetic algorithms, neural networks and fuzzy logic. Implementation of these approaches is possible with the available modern microprocessors and memory cards, analog-to-digital input and digital-to-analog converters at the output of these modules or blocks.

These technical devices have the ultra-high rate of speed that is a fraction of microelectronics thousandths of seconds.

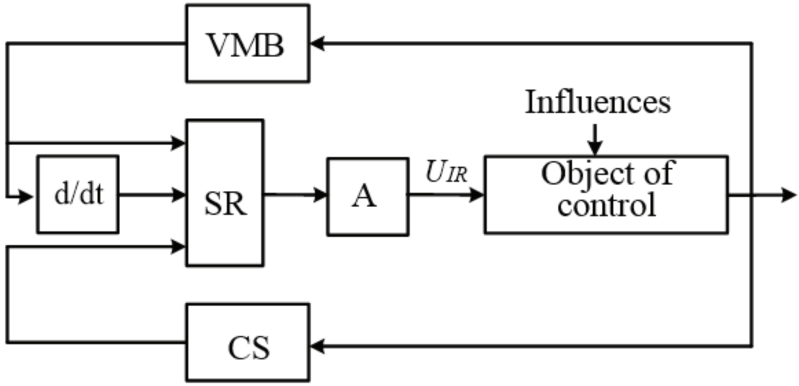
Introduction into electric power system of technical devices often occurs in integrating parallel channel control or regulation of certain parameters.

For more convenience, consider the particular case - control voltage AC power unit air using adaptive systems based on neural network controller.

Here we can distinguish a number of advantages:

- Narrowing the range of voltage variation of 1-2%;
- Reduction of the transient time;
- The ability to set leading influences;
- Respectively increase and decrease the life of the mass of the whole system in the subsequent design.

Combined control system [5] is shown in Pic. 1



Pic. 1. A combined system of regulation: VMB - measuring body voltage, CS - current sensor, A - amplifier, SR - smart regulator on the basis of neural network controller, d/dt - is the differentiator

This scheme uses two channels of control: the deviation (measuring body of power, the unit of calculation of the rate of voltage change (differentiator) and perturbation (sensor supply). On the basis of signals from these sensors, intelligent controller, built using the neural network outputs, which through the power leads output signal of the object of regulation to the nominal value.

Neural networks have a number of properties [5], which determine their effective application in a variety of systems, including PSS:

- ability to perform multivariate approximation;
- efficiency of work by AsParallel process of information processing;
- insensitive to the lack of a priori information about the dynamics of the object is achieved by compensation missing information from the table of precedents-the model of experimental data objects-analogues considered control object;
- processing of the data presented in various scales;
- ability to solve weakly formalized tasks;
- due to full connectivity and a large number of neurons of the national Assembly has the property of "holography" - the preservation of their properties at

destruction of randomly selected parts of the national Assembly. It shows high reliability of the national Assembly and tolerance of calculation results to distortion and interference in the input vectors, and the ability to learn and follow-up teaching for the same system.

The disadvantages of the introduction of intelligent systems is a long process of preparation of development data solutions for specific tasks. At the beginning of fully displayed mathematical model of the existing SES, then it is developed and supplemented intellectual links, then you can start to computer simulation of processes SES without integrated and integrated intellectual component to compare results. After receiving a positive performance on multiple computer studies, the system can be displayed as a ready block and apply it when modeling for real SES (poster laboratory tests).

Conclusions

Thus, improving the basic parameters and characteristics SES sun through the integration of modern intellectual control systems increases the reliability of the SES and the quality of electricity while minimizing mass-dimensional indicators, minimizing operating costs.

References

1.GOST 19705-89. Systems of power supply of aircraft and helicopters. General requirements and quality standards of electricity. - M: Isdland., 1989. – p. 45.

2.The sindeev I. M., Savelov A. A. power supply System of the aircraft. - M: Transport, 1990. - 296 C.

3.Allakov G.N., Asadullin V.M. ABOUT creation of intellectual systems of control and regulation of synchronous generators // Electrotechnical complexes and systems: meiwes. nauch. collection of Ufa: USATU, 2005. pp. 52-56.

4.Zakharchenko VA, Ilyenko S., Kozub V.V. Construction of mathematical models of voltage regulation SES aircraft for the study of statics and dynamics of processes. Transport problems. Issue 9. - Kyiv, 2012. - pp. 171-174.

5.*Park JW, Harley RG,* Venayagamoorthy GK, "Novel Optimal Neurocontrol for a Synchronous Generator Using RBF Neural Network", IF AC Symposium on Power Plants and PSC, Seoul, Korea, September 15-18, 2003, pp.41-46.

UDC 621.396.93

P. Lazarchuk (National Aviation University, Ukraine)
V.Novikov (National Aviation Universiyt, Ukraine)
V. Volovik (National Technical University«KPI», Ukraine)
I. Alekseeva (National Technical University «KPI», Ukraine)

PROBABILISTIC AND CLASSICAL APPROACHES TO ROUTING ALGORITHMS IN SENSOR NETWORKS

This paper examines and analyzes the decision of selecting approach to routing algorithms based on the components analysis of the sensor network. Showed comparison of the effectiveness between probabilistic and classical approaches.

Sensor network is built of a large number of simple information-gathering devices (motes), where each node is connected to more complex devices (base stations). Mote equipped with a sensor and transmitter. Mote transmitter has a very low power and therefore it can communicate with the base station only via neighboring motes, others - through chain of intermediate motes. Arising from this routing problem, which is complicated by the fact that the restrictions on the size, power consumption and price of motes, forced to equip them with low-power processor and small memory size.

As a operational model is proposed to use a stationary Markov process with two states: S0 - link doesn't work, S1 - link works. The intensities of the transitions from the S_0 to $S_1(\lambda_{01})$ and from the S_1 to $S_0(\lambda_{10})$ indicated as constants. The inversely proportional values $T_0 = 1/\lambda_{01}$ and $T_1 = 1/\lambda_{10}$ - is the mean residence time in the states S0 and S1, respectively.

Introduce p1(t) - the probability that link was in a state S1 and $\rho_0(t) = 1 - \rho_1(t)$ - the probability of finding a link in state S0 at the moment t. Under these conditions of Kolmogorov equations, obtained an expression (1), relating $\rho_0(t)$ and $\rho_1(t)$:

$$\rho_1(t) = (\rho_1(0) - \frac{T_1}{T_0 + T_1}) \cdot e^{\frac{T_0 + T_1}{T_0 \cdot T_1} \cdot t} + \frac{T_1}{T_0 + T_1} \qquad (1)$$

A probabilistic approach about values $\rho_1(t)$ and $\rho_0(t)$, which should be taken into account, while searching for routes between nodes. As opposed to classical routing algorithms, which assume that all links have the same length, in a probabilistic approach each link has some length. It depends on the statistical behavior of link, and it's actually $\rho_1(t)$ and $\rho_0(t)$. Distance between nodes (bond length) d(t) is calculated so that a larger value $\rho_1(t)$ corresponded minimal distance d(t). In particular, we can use a formula (2) or (3):

$$d(t) = -\ln(\rho_1(t)) \qquad (2)$$

$$d = \ln(1 + \frac{T_0}{T_1}) \tag{3}$$

(limiting transition d (t) with) $t \to \infty$. Shortest paths to all nodes are calculated in the metric d or d(t). Such paths are called probabilistic routes as they are built using probabilistic metrics.

Effectiveness of probabilistic or classical approach measured by the average number of correct routes in the routing table, in which all communication is currently working. This index compares the two routing tables built for the same network, but using different metrics.

The network topology is randomly generated with the given parameters *N, D, T1s* and *T0s,* where *N* - number of nodes in the network, *D* - the average number of neighbors nodes, *T1s* – average time *T1* for all network links, *T0s* – average time *T0* for all network links. If $T_0 < \infty$ for links, the nodes are considered neighbors. During generating a network topology, were selected nodes with possible direct connection, and so that the average number of neighbors of nodes is equal *D*. Next, select values *T0* and *T1* for each obtained links, suggesting that these values are random variables distributed exponentially with average *T0s* and *T1s*, respectively. Once the network topology is generated, the initial state of the network will be selected. For all links will be selected initial state: *S1* with probability $T_1/(T_1 + T_0)$ and *S0* with probability $T_0/(T_1 + T_0)$. Then, occurs the process of generating a routing table for classical and probabilistic approaches.

Both routing tables store the shortest path from a given node to all other nodes in the network, but they used different metrics to determine the length of the path. First routing table uses a simple metric in which the path length between two nodes is the sum of transit transitions in this way. In this case, only those links that worked (i.e., in a state *S1*) at the time of generation of the routing table. The second routing table uses a probabilistic metric d, which allows using links in routing tables,which are off at the moment of table generation. In fact, the state of the network at the time of generating the table does not affect the selection of the shortest routes, because considered only the statistical characteristics of the network.

After generating the routing tables begins modeling changes in the network topology. Due to switching links, some routes in the routing tables remains incorrect. The number of valid routes in the network Rc(t) is calculated as the sum of the correct routes in the routing tables for each node. Then there is the ratio of the number of correct routes at a given time to the maximum possible number of routes R, where. $R = N(N-1)$ Finally, the calculated value of the proportion of correct routes at a given time (4):

$$E(t) = \frac{R_c(t)}{R} \tag{4}$$

$$E_s(t) = \frac{\int_0^t E(x)dx}{t} \tag{5}$$

Value of the function Es(t) was calculated for both routing tables - classical and probabilistic (5). This function is to some extent characterizes the efficiency of the routing algorithm, because it shows the average time of the correct routes in the routing table.

Conclusions

Thus, the simulation results show that over time, the effectiveness of classic routing algorithm falls, whereas a probabilistic algorithm efficiency remains approximately constant. On a big time interval probabilistic algorithm shows average significantly better results. However, in the initial moments of the classical algorithm efficiency is quite high and exceeds the efficiency of the probabilistic algorithm. The more mobile network - more likely occurs changes in the network topology, the faster probabilistic algorithm passes classical.

Proposed to use a combination of classical and probabilistic approaches, where messages between nodes are first submitted via the normal route, and in case of failure - probabilistic.

References

1.*Mishagin, K.G.* Extending the lifetime of a sensor network using the methods of collective information transmission / K.G.Mishagin, V.A. Pastukhov, A.N. Sadkov / / Work. scientific. conf.in radio physics. Nizhny Novgorod, UNN, 2005. - P. 344 - 46.

2. *Arakelyan S.M.* The self-organizing information environment with decentralized control for interaction between educational institutions / S.M.Arakelyan, A.V.Duhanov, V.G.Prokoshev, S.V.Roschin.

3. *Bataev P.A.* Probabilistic approach in the creation of routing algorithms in networks with varying topology / P.A. Bataev / / Telecommunications and Information Systems: th. Intern. conf. - SPb., 2007. pp. 117 - 125. - ISBN 5-7422-1583-5.

4. *Oleksandr I. Lysenko, Inga V. Uryadnikova, Stanislav V. Valuiskyi, Sergej Chumachenko.* Increasing of manet throughput using quasi-optimal UAVs placement control.- Akademia ozbrojenyah sil. Gen. M.R. Stefanika. Slovakia Science&Military. №1, Volume 8, 2013, p. 52-61.

5. *Лысенко А.И. Лысенко А.И.* Условие скачка в задаче оптимального управления объектом// Адаптив. системы автом. упр.- 1988. – Вып. 16 - С. 136-141.

UDC 656.73

M.A. Vasilyev, postgraduate student (NAU, Kiev, Ukraine)

DECISIONS MAKING SUPPORT SYSTEM FOR PILOTS IN EXTRA SITUATION

Operators in high-risk domains such as aviation often need to make decisions under time pressure and uncertainty. One way to support them in this task is through the introduction of decision support systems.

Improved operational procedures system is associated with automation of the most complex processes operations of a pilot's work. At once one of the major problems of automation of an pilot's work during making decisions is to include him into the control loop of a computing device, that backup, but not a substitute pilot. So there are the development of device-adviser that helps pilot solves number of problems that are amenable to formalization. Assume that the work of the computing device can be considered as well as pilot's work.

Major place in scientific and theoretical problems that are related to the pilot's work automation takes a formulation of control goals, which mean definition of optimality criteria with limited conditions; creation a mathematical description of the control system; development control algorithm; development of structural-information schemes to implementing algorithm.

One of the possible approach for solving these problems is based on a system-wide principle of decomposition activity as a system structural analysis of functioning system. This approach allows select as independent series of typical decision making problems. Each of these tasks is characterized by its local goals, mathematical models, methods of formalizing and solutions.

The solution of the first goal, formulation of optimality ergatic functioning system criteria, based on the analysis of qualitative and quantitative characteristics of the process, that implemented with the typical problems. That analysis based on system characteristics which are sum of independent gains characteristics. Often pilots control rationality or optimality in a terms of specific problem can be defined only on a qualitative descriptive level. So formal description of optimal pilot's activity criteria as a gain of ergatic system is important question.

Achieving this goal is possible with the proposed theoretical and experimental approach. This approach based on principle of real activity final result evaluation, that considered as a reference. Assumed that the system pilot makes optimal control based on some optimal decision criteria. Which presented in the form of an pilot integral representation about goals and desired results in the real situation problems. In this case, the formalization of optimal criteria of control in extremum, needs the inverse optimal processes theory problem solution. The main goal of this problem is to determine the structure and optimal criteria parameters that basis of known system problem solution. That reflects extreme properties of pilot activities in specific situation. This assumption acceptable if problems solving keeping established order (defined list of the required goals and decision making rules), and content of pilot's instruction (recommendations) corresponds to best way that the process run.

However, it is clear that in the general case in a real situation possible optimal activity criteria instability, which appear as a consequence of various pilots work.

Considering these specialty appeared next important tasks: of evaluating estimation of degree reducing the quality of system functioning, and proofing adequacy and objectivity optimal activity criteria that was build. These problems could be solved by using inverse optimization techniques theory and expert evaluation together to build optimality activity criteria.

Wide range of mathematical models for solving typical problems significantly determine the specific application of these methods. However, proposed approach has elements of universality irrespective of the considering prolems class. That elements keep main content and characteristics of considering approach for processes decision making. This universality is primarily appeared in the fact that the formalization of optimal decision criteria is realized using the methods of expert evaluations for the analysis and selection those solutions of the inverse optimization problem, that implementation of the decision making process satisfies total quality requirements of all system, and activities of the pilot.

Some peculiarity of the implementation of these methods consider in example of landing aircraft in extra situation.

For each *i*-th realization, generalized control functions *u,* based on identification values from registration data and generalized phase coordinates vector *q* using for solving inverse problem of the theory of optimal processes. So generalized characteristic of the *i*-th process realization finds. That characteristic defines integral properties and qualities that system's technical and ergatic elements have in the *i*-th specific implementation. At constant technical system's characteristics (the same type of aircraft, uses the same means for display information) can be assumed that landing control in each implementation doing by pilot using his extreme abilities. That is determined by his professional and psychological qualities. So generalized characteristic J_i can be assumed as optimality pilot activity criteria but only under appropriate level of professional skills and if pilot ready for work under the i-th realization.

Each of the *i*-th process control landing realization passes expert assessment. After expert estimates results analysis and processing they can separates realizations and their corresponding criteria for a number of classes in accordance with the system of preferences that used in expert assessment. Parameters that form the optimal criteria core in each class averaged on one of the smoothing procedures. Classes are characterized by different functioning system quality levels. So they defines by different requirements to the pilots professional training and skills level. Ability of criation and classification criteria makes possible objective pilot's activities quality assessment on landing phase as in learning process and in real situation. Using the basic criteria J^S for assessing the system quality and for defining pilot's quality of work and professional skills, can be found by solving the inverse problem of optimization and classification optimal criteria results to one of the scheme classes that obtain the smallest distance *J* from the base $J^S \quad (s = \overline{1, n})$ in the space of their parameters.

Getting that way optimality criteria describe formed as a result of the experiments intuitive pilot's opinions about best control on the descent path. This criteria makes possible to synthesize control equivalent to pilot's control during normal functioning system with some accuracy. That defined by the increment optimal criteria value by averaging specific pilot results in creation optimal functioning system criteria.

From a qualitative point of view pilot's landing work optimization in this case is to determine the optimal contest of instruction for the final sequence of times. The optimal contest of instruction (advice or information about the relative position of the aircraft) is understood in the sense of providing mental and physical unloading pilot, as well as providing opportunities to implement stabilization position on the glide path without change established modes on landing phase. Unloading pilot from difficultness is possible to associate with quality stabilization aircraft on the final approach. The higher aircraft stabilization accuracy, then lower the possibility accumulation of large errors (deviations) for the remainder of the reduction and less necessity pilot intervention in the control process. It also reduces the time spent on the pilot's perception of information, decision making, production of motion act. Accuracy of stabilization on the glide path that is controlled by precision radar essentially depends not only on the quality of the maneuver to withdraw the aircraft on the glide path (which is mainly determined by the content and the time of issuance of appropriate instruction), but also from the moment of time of the dispatcher gives information "on the glide path."

Accounting for all of these requirements leads to a complex problem multicriteria system. So seems appropriate to use and develop theoretical and experimental methods of constructing the optimality criteria, based on the results of the theory of inverse optimization.

Should be noted that the theory of the inverse problem, which occupies a considered approach under consideration central location allows in easy way get constructive solutions in the case where the control functions can be represented as a linear combinations of generalized coordinates of the system, which describes the change in the system of linear differential equations. This fact largely determined the choice of the class of process models for the approach of the set of admissible. In general, the mathematic model system for the approach phase (after the decision on the landing) is a combination of number mathematical models describing aircraft dynamics; pilot pilot, performing the control functions in the circuit "crew-aircraft".

References

1. *Ashwin Kumar, M.; Goundan, P. R.; Srinathan, K. & Pandu Rangan, C.*, On perfectly secure communication over arbitrary networks, in ‘PODC ’02: Proceedings of the twenty-first annual symposium on Principles of distributed computing’, ACM, New York, NY, USA, pp. 193–202.

UDC 621.396.93

H. Tachinina, PhD (National Aviation University, Ukraine)
D. Harkavyi (National Technical University «KPI», Ukraine)
L. Afanaseva (National Technical University «KPI», Ukraine)

METHODS OF INTELLECTUALIZATION CONTROL OF SELF-ORGANIZING RADIO NETWORKS

This paper examines and analyzes methods of intellectualization control of self-organizing radio networks and shows reasons of involving artificial intelligence technology. At the end of the paper are given conclusions.

Emergence of a fundamentally new kind of management tasks associated with maintaining the required modes of operation of complex dynamic objects under uncertainty, required the development of specific methods for their solution involving artificial intelligence technology. Therefore, today management information systems are intensively developing in the direction of intellectualization, while the technology of management decisions is significantly changing. Intelligent Information Systems (IIS) combined capabilities of database management systems and artificial intelligence technology, and with a help of this storage management information in them is combined with handling and preparing it for use in making decision.

For a long time it was believed that IIS are effective and applicable only to solve the so-called non-formalizable and poorly formalized problems associated with the need of including an algorithm for the solution of the training data on real experimental data (eg, the problem of pattern recognition). Recently, however, IIS is increasingly used in solving problems in communication systems and telecommunications, such as switching control, routing, traffic management, distribution channels in mobile radio systems, etc.

Considering the self-organizing radio network (SON), referring to a class of complex dynamic systems operating in conditions of incomplete and unreliable control status information network, it is impossible to talk about the efficient operation of data networks without appropriate management system. Here are some reasons for that IIS should form an essential part of the control system of the SON:

- First, the main problem in the management of SON is the need to select a set of possible solutions of management decisions under uncertainty, and depending on the situation in the network, as well as requirements for the transfer of a certain type of traffic;
- Second, network management requires the collection and processing of a large amount of overhead on its condition, use management practices at various levels of the OSI model for decision-making. The problem of obtaining information from the objects (nodes) operating in real time, is now resolved (with using different methods sensing network). But this created another problem: how to reduce the proportion to the level of information that is really needed to make a decision by management system? At the same time it should be noted that the loss of information from the nodes of the network, working in real time, can significantly affect the final decision

taken by the management system;

- Third, the lack of time to make decisions and the problem of coordinating interaction management methods that perform various functions (routing management, topology, data flow, power consumption, security, etc.)

1. Control features of self-organizing radio networks. Self-organizing radio network characterized by a dynamic topology, limited energy opportunity nodes equipped with batteries, different dimensionality (tens, hundreds and thousands of nodes); heterogeneity of the transmission power and mobility of nodes, the security restrictions because the broadcast nature of the radio channel, etc. The nodes of this network must adapt quickly to frequent changes in the topology and efficient use of scarce network resources. In such conditions it is impossible to provide an information exchange with the specified quality without an effective control system (CS) of network.

Features of control system of SON:• multidimensionality due to the large number of subsystems, components and connections between them;• a lot of parameters defined diversity purposes of the individual subsystems, the diversity of their characteristics, requirements and performance indicators;• functionality and hierarchy, arising from the need to solve various problems of control at different levels and stages of the system;• strong dependence on the parameters of the functioning of the SON and external influences.

At the same time, the control system must meet the following SON basic requirements: ensuring the transfer of different types of traffic with the specified quality; providing adaptive and distributed network operation with the possibility of self-organization; decisions in real or near-real-time; minimum load network overhead; optimize network performance; maximum automation of network management.

The presence of many different and conflicting criteria for optimality of SON raises the problem of multiobjective (vector) process optimization of its functioning. The problem of optimizing the vector criterion is to find solutions that satisfy the extremum simultaneously all components of the vector of the optimality criterion. There are two basic ways to solve this problem: the search for compromise solutions that are optimal by Pareto and search for solutions that are optimal in the sense of generalized scalar criterion obtained by convolution (scalarization) all components of the vector criterion of optimality. Also one of the possible solutions to this problem is the search for compromise solutions by successive concessions, which consists in the ranking criteria according to their importance. In addition, taking into account the ranking of the proposed spending management purposes depending on the requirements for the transfer of ξ- type traffic and status information areas to ensure the specified quality of service of ξ- type traffic in various operating conditions of the SON.

2. Basic approaches to intellectualization of radio networks control. Importantly, the main architectural feature that distinguishes an intelligent control system constructed according to the "traditional" pattern, associated with connecting mechanisms of storage and processing of knowledge to realize their abilities for performing the required functions under uncertainty (incomplete information) at random nature of external perturbations.

Control system of SON has a rather complex architecture that includes a number of functional-subordinated subsystems. Hierarchy of subordination causes decomposition of initial management purposes and objectives on a sequence of nested components. Such separation involves multi-level organization of control system which has developed intellectual capabilities to analyze and recognize the situation, the formation of purposeful behavior strategy, planning, action sequences, as well as the synthesis of control actions designed to meet the service requirements of certain types of traffic.

Organization of each level of intellectual network control system involves the use of aggregate models of knowledge representation, information support, descriptions of the controlled object, etc. The main difference between the concept of constructing a hierarchical control systems is the use of SON methods and techniques of artificial intelligence as the primary means of struggle with the uncertainty of the environment. Practical realization of this concept involves the selective use of various technologies of knowledge processing depending on the specific tasks and features of the controlled object.

Thus, today happens intellectualization of information control systems and their transformation in the IIS. The are four techniques that are most promising for the development of intelligent control systems: technique of expert systems, associative memory, fuzzy logic, neural networks. The main idea in this case is to move from a strictly formalized algorithms prescribing the solution to problems, to logic programming with an indication of what needs to be solved on the basis of the knowledge accumulated by specialists in specific subject areas.

Conclusions

Thus, in the short term there is a need to talk about the creation of "smart radio network". Already in the node architecture there is provided data and knowledge bases, electronic map and training subsystem, application technology of distributed intelligent agents.Thus, the involving of IIS in the network control system will enable the radio network to:• optimize the control system of this network on the basis of analysis and consideration of the situation in the network (information direction), as well as requirements for the transfer of certain types of traffic;• minimize errors caused by human factor in the making the wrong decision in network control (especially during initialization of network);• reduce the time required to collect and analyze performance information on the state of the network, as well as significantly reduce the volume of this information.

References

1.*Bunin S.G., Voyter A.P., Ilchenko M.E., Romanuk V.A.* "Самоорганизующиеся радиосети со сверхширокополосными сигналами." – К.:НПП «Издательство «Наукова думка» НАН Украины». – 444р.

2. Minochkin A.I.., Romanuk V.A. "Інтелектуальний метод маршрутизації в мобільних радіомережах" // Зб. Наук. Праць ВІТІ НТУУ «КПІ». – 2009. - №1 – р. 88-97

UDC 621.396.93

S. Galchenko PhD (National Aviation University, Ukraine)
O. Kafidova (National Technical University «KPI», Ukraine)
V. Petrova (National Technical University «KPI», Ukraine)

METHOD OF IMPROVING THE EFFICIENCY OF WIRELESS SENSOR NETWORKS

The structure of the wireless sensor networks efficiency method, classification of those networks and their structural components and topologies, modes of operation and routing protocols were reviewed in this work. Also modern methods of WSN construction were analyzed.

Objective: To improve the efficiency of WSN.
This subject is relevant, because the scope of WSN is expanding and evolvingrapidly.

1. Analysis of the development of a wireless sensor network.

WSN are the new promising technology in the field of telecommunications. They are widely used in industry, agriculture, law enforcement, regulatory and law enforcement agencies. They provide strong tendency to expand their scope.

If you compare wireless sensor networks with conventional computing (wired and wireless) networks, the wireless sensor networks have the following advantages:

- absence of cables - electrical, communications, etc.;
- the possibility of compact accommodation, or even integration of sensors in the environment ;
- the reliability of individual elements and, more importantly, the entire system as a whole, in some cases, a network may operate in good condition only 10-20% of sensors;
- the staff do not need to install and to maintein.

2. Analysis of structural components and topologies.

In general telecommunication sensor networks are based on sensor and communication lines. Sensors are devices that consist of a sensor that provides measurement object monitoring, and the transceiver. WSN are built using two types of physical devices: a fully functional device (Full Function Device, FFD) and a device with a limited set of functions (Reduced Function Device, RFD)[1]. Device FFD can be communication with several FFD, and several RFD, while the device RFD is not a function to communicate with other RFD. Full-featured network devices operate in three modes (depending on the initial configuration): coordinator, router and end node and device RFD - only during the final node [2]. Functional separation of physical WSN allows you to build multiple topologies that on an organization can be decentralized, centralized, and hierarchical or hybrid [3].

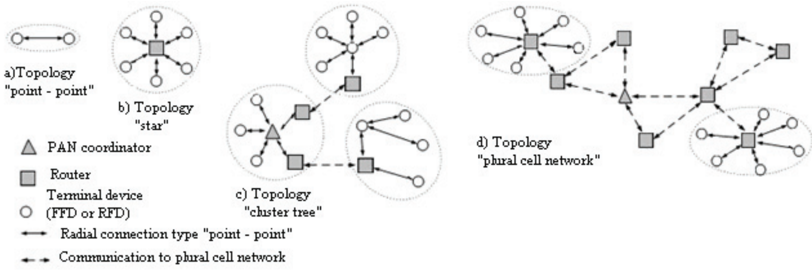


Figure 1.Topology of sensor networks.

In a decentralized network structure consisting of equal network nodes in such networks, each device connects to the adjacent nodes to transmit information using multiple relay (route) (network topology such as " point to point ", Fig. 1a). A centralized network structure implies that one network router that acts as a central station - a hub that decides routing of aggregated data to the next node. The topology construction of such networks for the type of "star" (Fig. 1b).

From a practical point of view among the hybrid network topology greatest interest of the " cluster tree." Topology " cluster tree" is the set of converged networks of the " star " in which the vertices are the nodes, routers, and there is a coordinator of the cluster (Fig. 1d). Networks of this type have a low resiliency to changes in the topology as routers provide selective routes and self-organization network.

Thus, the choice of structure WSN need to consider the communication range, the number of sensors on the served area, the required level of quality of service, the number of information flows and the amount of data transferred. Thus, for the same room constant climatic conditions sufficient to use the network of the " point to point " with one or two devices FFD.

3. Analysis of the consumption of resources and energy. Most sensors are mobile devices with built-in power sources. Therefore, one of the factors is the length of the operation unit energy consumption. Passive scanning channel leads to large energy losses. The solution of the problem is a periodic activity nodes, ie, a node can operate in three modes: Desktop, passive and off. In order to conserve electricity in WSN should implement two methods of network. The first of these methods assumes that the network coordinator is constantly active. It monitors your network and therefore is able to exchange data with the highest possible speed. For some parts of the signals coordinator periodically switching network is operating and exchanging messages. In the second method, the functioning of the entire network is in idle mode, including the coordinator. Data exchange is performed within individual network segments that run periodically. So can not only save energy, but also avoid the effect of individual network segments to each other. Illustration of the energy saving mode to an active coordinator and coordinator in working mode is shown in Figure 2.

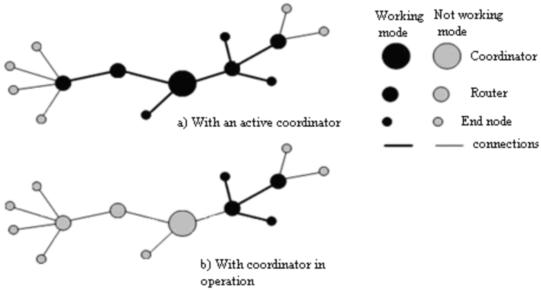


Figure. 2. Power saving modes: a) the active coordinator ; b) the coordinator in idle mode

In order to increase the effectiveness of WSN need to use different levels of the network hierarchy. It is also necessary to apply the method of saving. Deemed the construction of modern WSN is based wireless technology that provides reliable operation and mobility. Recommended standard 802.15.4 ZigBeefor WSN, and if necessary to provide high-speed data - standard 802.15.3a.

IEEE 802.11 is a set of media access control (MAC) and physical layer (PHY) specifications for implementing wireless local area network (WLAN) computer communication in the 2.4, 3.6, 5 and 60 GHz frequency bands. They are created and maintained by the IEEE LAN/MAN Standards Committee (IEEE 802).

The base version of the standard was released in 1997 and has had subsequent amendments. The standard and amendments provide the basis for wireless network products using the Wi-Fi brand. While each amendment is officially revoked when it is incorporated in the latest version of the standard, the corporate world tends to market to the revisions because they concisely denote capabilities of their products. As a result, in the market place, each revision tends to become its own standard. Within the IEEE 802.11 Working Group, the following IEEE Standards Association Standard and Amendments exist:

IEEE 802.11-1997: The WLAN standard was originally 1 Mbit/s and 2 Mbit/s, 2.4 GHz RF and infrared (IR) standard (1997), all the others listed below are Amendments to this standard, except for Recommended Practices 802.11F and 802.11T.

IEEE 802.11a: 54 Mbit/s, 5 GHz standard (1999, shipping products in 2001)

IEEE 802.11b: Enhancements to 802.11 to support 5.5 and 11 Mbit/s (1999)

IEEE 802.11g: 54 Mbit/s, 2.4 GHz standard (backwards compatible with b) (2003)

IEEE 802.11n: Higher throughput improvements using MIMO (multiple input, multiple output antennas) (September 2009)

Conclusions

Sensory systems now rapidly developing, improving and is an important part of the information society, providing monitoring of various industrial, natural, social and other processes.

Consider the appropriateness of building a modern WSN as multilevel hierarchical structure, where the hierarchy correspond to the magnitude of a part of the network, and the principle of self-organization is implemented at all levels.

The analysis of the important issues BSM - problems of power of individual elements. It is shown that the power is typically provided by independent sources that are set in different elements WSN. This method requires the use of energy efficiency, which is achieved through the use of modes of operation of units : working, passive off.

The expediency of building a modern WSN -based wireless technology that provides mobility and reliability of WSN. For personal wireless networks recommended standard 802.15.4 ZigBee.

References

1. *Kucheryavy E.A*. Principles of construction of sensors and wireless sensor networks / E.A.Kucheryavyy, S.A.Molchan, V.V.Kondratyev / / Telecommunication. - 2006. Number 6.

2. *Alguliev R.M., Fataliyev T.H., Agayev B.S., Aliyev T.S.* Sensor networks: state solution and prospects ISSN 1684-2588 Telecommunications. Monthly scientific and technical information and analytical and educational-methodical journal. - 2007. - № 4. - Pp. 27-32.

3. *Shcherbakov G.V., Melnikova L.I., Ruban I.V.,Sumtsov D.V.* Modern telecommunication networks in civil defense: Tutorial. - Kharkov: 2007. - 255 p.

4. *Mishagin, K.G.* Extending the lifetime of a sensor network using the methods of collective information transmission / K.G.Mishagin, V.A. Pastukhov, A.N. Sadkov / / Work. scientific. conf.in radio physics. Nizhny Novgorod, UNN, 2005. - P. 344 - 46.

5. Arakelyan S.M. The self-organizing information environment with decentralized control for interaction between educational institutions / S.M.Arakelyan, A.V.Duhanov, V.G.Prokoshev, S.V.Roschin.

6. *Bataev P.A.* Probabilistic approach in the creation of routing algorithms in networks with varying topology / P.A. Bataev / / Telecommunications and Information Systems: th. Intern. conf. - SPb., 2007. pp. 117 - 125. - ISBN 5-7422-1583-5.

7. *Oleksandr I. Lysenko, Inga V. Uryadnikova, Stanislav V. Valuiskyi, Sergej Chumachenko*. Increasing of manet throughput using quasi-optimal UAVs placement control.- Akademia ozbrojenyah sil. Gen. M.R. Stefanika. Slovakia Science&Military. №1, Volume 8, 2013, p. 52-61.

UDC 629.735.018.7.015.3.025.1

D.O. Shevchuk, PhD (National Aviation University, Ukraine)
M.H. Levchenko (National Aviation University, Ukraine)
O.M. Pavlenko (National Aviation University, Ukraine)

AUTOMATIC WING LEADING EDGE AIRPLANE AERODYNAMIC DIAGNOSTICS SYSTEM IN FLIGHT CONDITION

A new approach of leading edge diagnosis based on optic fiber injection into the composite materials is proposed. The result of semi-natural modeling the system components is provided.

Introduction. Having complete and accurate information about the time, place and degree of injury in a sudden flight accident gives an opportunity to assess the development of an emergency and perform the necessary actions to prevent its development.

Aerodynamic diagnostics system.

The use of composite materials is due to high strength and stiffness and low weight compared to metallic materials. However, a significant disadvantage of polymer composites is the possibility of hidden internal destructive micro shock due to various influences, which can cause accidents in the operation of the aircraft.

To diagnose internal progressive structural damage and injuries in flight that occur when a collision with biological electrical and mechanical facilities happens, using fiber optic sensors is proposed, the principle of which is based on the phenomenon of reflection of light in inhomogeneities in optical fibers.

Optical fibers embedded in the composite structure band during deformation, so the reflected light power that returns by optical fibers from the place of fiber destruction decreases. This power change is processed in signal processing unit (classifier). This fiber-optic diagnostic structure embedded in a composite material is used for identification of the time, place and the degree of damage.

Microcontrollers are an effective means of automating a variety of complex dynamic objects and processes.

Use of Atmel's AVR 8-bit RISC-microcontroller is proposed. They are a powerful tool an excellent basis for the creation of modern high-performance embedded controllers.

By the microcontroller there are LEDs and photoresistors (Fig. 1) connected which function assigned to the system.

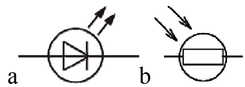


Fig. 1. Basic elements
a- LED, b- photoresistor

Custom LED resistance after saturation is very small, and without a resistor that limits the current through the LED, it blows, the order of inclusion "resistor before" or "resistor after" – is not important (Fig. 2).

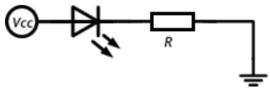


Fig. 2. Typical circuit of the LED

Calculate which resistor R in the above scheme should be used to obtain optimum power dissipation.

Initial data for calculation: the voltage drop across the LEDs V_F=2.3V, rated current I=20mA, Vcc=5V.

Calculate the voltage the resistor should take: $U_R = V_{CC} - V_F = 5 - 2.3 = 2.7\text{V}$.

According to Ohm's law we find the values of resistance that will provide a fall:

$$R = \frac{U_R}{I} = \frac{2.7}{0.02} = 135\text{Ом}$$

Find the power needed for resistor dissipating:

$$P_R = I^2 \cdot R = 0.02^2 \cdot 135 = 0.054 \text{ W}$$

Photoresistor acts as a resistive sensor in a diagnostic system.

Consistently connected resistors divide the voltage supplied to them in a certain proportion, thus forming a voltage divider (Fig. 3 a)., and replacing one of the resistors with resistive sensor, a resistive sensor is obtained (Fig. 3. b).

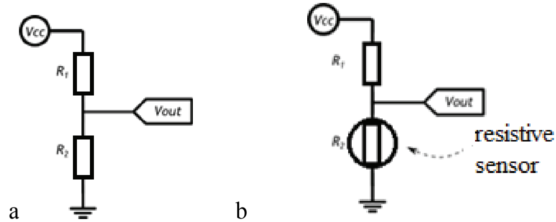


Fig. 3. Voltage divider a – plain, b- sensor

As LED brightness varies according to the supplied voltage to adjust the brightness we shall add resistive sensor based on the potentiometer. The result is a schematic diagram of reflectometer diagnosing system (Fig. 4).

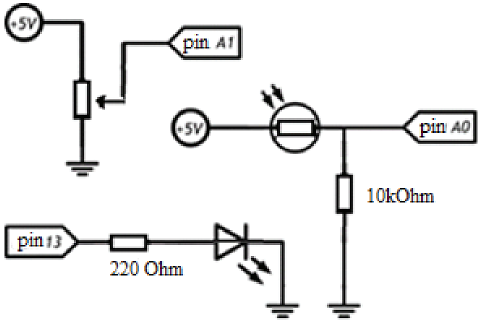


Fig. 4. Schematic diagram of the reflectometer diagnostic system

To test, draw on the breadboard circuit reflectometer (Fig.5).

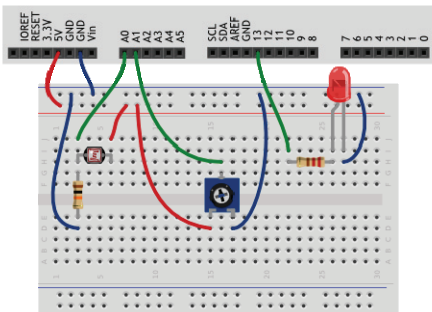


Fig 5. Test circuit diagnostic system

For performance testing, breadboard should be placed in a dark environment to simulate shell system diagnostics. As a result of semi natural experiment we obtain data on a scale 0-1023that corresponds to voltage 0 ... 5V. Based on the performance of experiments (Fig. 6), we obtain experimental values for the system.

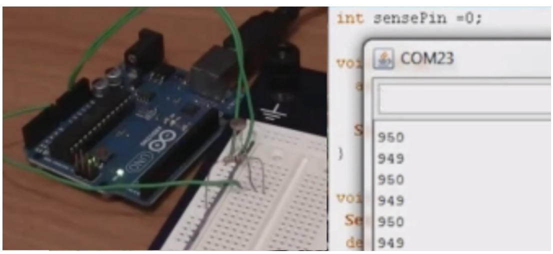


Fig. 6. The experiment on the reaction rate.

In table 1 there are results obtained within 10 seconds of the experiment.

Table 1.

Results of semi natural experiment

normal environment		dark environment without LED		dark environment with 50% of the voltage across the LED		full voltage for the LED	
950	949	188	190	220	214	549	549
949	949	190	190	221	221	550	550
950	950	187	189	220	219	549	550
949	949	189	188	219	219	549	549
950	950	190	191	219	221	549	550
949	949	188	190	220	219	549	550
950	950	190	191	222	220	550	549
950	950	189	190	220	220	549	549
949	950	190	190	222	220	548	548

While fiber fracture occurs subsidence signal, i.e. change in the amount of reflected light is 6-18%, so the error of the results obtained in different conditions should not exceed 75% of this value that should not be greater than 4% of the maximum value of the sample.

$$4\% \text{ of } 950 = 3{,}8 \approx 4$$

In a normal environment values vary from 949 to 950. 950-949 = 1 <4, in a dark environment without LED 191-188 = 3 <4, in a dark environment with 50% of the voltage across the LED is 221-219 = 2 <4, and at full voltage for the LED 550-548 = 2 <4. Thus, we can conclude that the proposed system provides the necessary accuracy.

References

1. *Lubin G.* Handbook of fiberglass and advanced plastics composites. Van Nostrand Reinhold. –New York, 1969. – 969 p.
2. *Hadcock R.N.* Joints in Composite Structures. Proc. Conf.Vehicle Design AFFDL-TR-72-13. – 1972. – P. 791–811.
3. *U.K. Patent GB* 2194062-A Detection of damage in materials/ Eastham John –1988.

UDC 621.396.93

S. Galchenko PhD (National Aviation University, Ukraine)
O.Velykyi (National Technical University «KPI», Ukraine)
T. Prischepa (National Technical University «KPI», Ukraine)

METHODS OF PEER REVIEW OF QUALITY INDICATORS OF ELECOMMUNICATION SYSTEMS THE DISASTER ZONE IN TERMS OF DESTRUCTIVE INFLUENCES

With the emergence of an emergency, information and telecommunication resources partially or completely lose their properties. Therefore, improving the process necessary peer review of quality indicators of telecommunication systems disaster are interims of destructive in fluencies.

AsinUkraineandallovertheworldeveryyeartherearseriousemergenciesofvariouskinds, of which the people are killed and property damageuptose veralbillion.

Itisknownthatalmostallemergenciesresultinlossofinformationandtelecommunicationsupporttherescueandrecoveryprocessworks , sotheproblemisalmostinstantaneousrecoveryofinformationandtelecommunicationsupportisveryimportant. [1]

The solution to this practical problem at the present time is carried out as follows:

There is a set of projects {T1, ...,Tk}. The decision to implement the project TKS disaster area attracted a group of experts who carry out an examination on the traditional model of expert evaluation. (Such as “Method scanning”,” method of morphological analysis”,” method Saaty”, “cross- impact method”, ” Delphi method”, ” method of brainstorming” etc.). [2]

But in practical application accepted for projects TCS disaster zone, they are not in full carry out their functions. It is therefore necessary to improve the methodological support peer review process of decision making for projects TCS disaster zone.

The main idea and principles of application.

Innovation is the improvement of the existing model assessment of projects TCS disaster area using systematic methodology of prediction. It allowed such as design for all types of TCS disaster zone hierarchical system of criteria for evaluating their effectiveness, improve the method of selecting the best option in the face of uncertainty, to develop expert modeling complex simulations to validate the decisions.

Figure 1 depicts a method for peer review of quality indicators of telecommunication systems the disaster zone in terms of destructive influences.

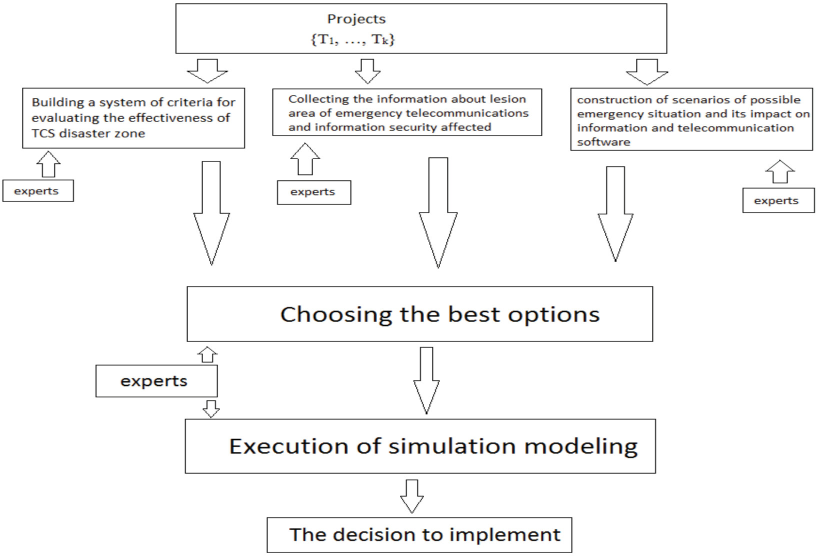


Figure 1 Improved model assessment of projects TCS disaster zone.

Building a system of criteria for evaluating the effectiveness of TCS disaster zone reflects estimates by experts on the effectiveness of TCS network, data link and physical level when collected and analyzed information on lesion area and information and telecommunication software affected. [3]

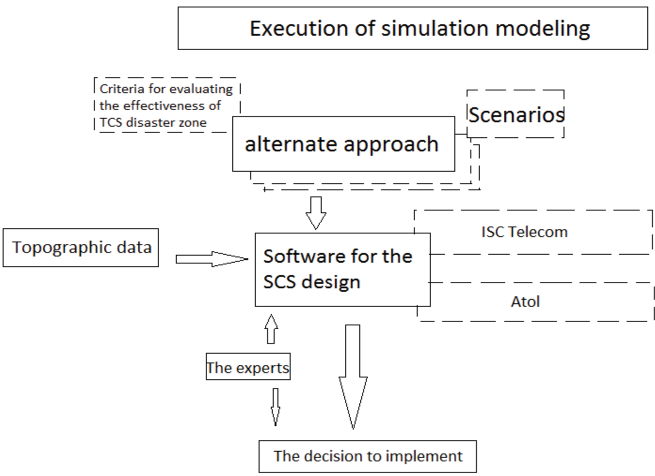


Figure 2 Performance of simulation modeling TCS disaster zone

Also constructed scenarios of the emergency calculated amount and scope, and impact on the TCS.

Once assembled variants, analysis of all the criteria is the choice of the best options offered. Filled matrix containing the script { C1 , ..., C n } and { T1 , ..., Tm } - TCS projects disaster zone. Each project contains all the scenarios for which experts exhibit conditional assessment of their feasibility and effectiveness. Options is carried out using the methods of game theory such as “Wald criterion”, “the criterion Savage” and “criterion Hurvytsya”.

For practical application selections, performed a simulation model, and estimates the efficiency of a system. (Figure 2)

Conclusions:

As a result it is concluded that the proposed system is better suited for this emergency, and a decision on the implementation of this method. [4]. Also, my methods are entered into the database, for revision and editing, when the emergency was repeated again.

This way increases the efficiency of telecom and information support of an emergency by using the improved model assessment of projects TCS disaster zone.

References

1. *D.A.Pospelov*, // Situation Management: Theory and Practice, - Moscow / Nauka, - 1986.

2. *A.D.Tsvirkun*, // Fundamentals structure synthesis of complex systems, - Moscow / Nauka, - 1982.

3. *I.V.Kuzmin,*// Basics of modeling of complex systems: studies /benefits for students: High School, - 1981.

4. *A.N.Voronin*, J.K.Ziatdinov, A.V.Kharchenko.// Complex technical and ergodic systems: a method of using, - 1997.

5. *Kucheryavy E.A*. Principles of construction of sensors and wireless sensor networks / E.A.Kucheryavyy, S.A.Molchan, V.V.Kondratyev // Telecommunication. - 2006. Number 6.

6. *Alguliev R.M., Fataliyev T.H., Agayev B.S., Aliyev T.S.* Sensor networks: state solution and prospects ISSN 1684-2588 Telecommunications. Monthly scientific and technical information and analytical and educational-methodical journal. - 2007. - № 4. - Pp. 27-32.

7. *Shcherbakov G.V., Melnikova L.I., Ruban I.V., Sumtsov D.V.* Modern telecommunication networks in civil defense: Tutorial. - Kharkov: 2007. - 255 p.

8. *Mishagin, K.G.* Extending the lifetime of a sensor network using the methods of collective information transmission / K.G.Mishagin, V.A. Pastukhov, A.N. Sadkov / / Work. scientific. conf.in radio physics. Nizhny Novgorod, UNN, 2005. - P. 344 - 46.

UDC 621.518.54:611.311(043.2)

A. Aslanyan, Dr. Sci. (Tech) (National Aviation University, Ukraine)
V. Zakharchenko, PhD (National Aviation University, Ukraine)
N. Sokolova (National Aviation University, Ukraine)

THE ORGANIZATIONAL STRUCTURE OF AIRPORT ELECTRICAL ENERGY CONSUMPTION EFFICIENCY MANAGEMENT

This article is proposed to solve the problem of effective management of electricity consumption airport. As results will ensure the efficient use of electric energy receivers airports contribute to the equalization of load demand energy systems that will ensure proper operation and minimize costs in the face of rising electricity prices.

Efficient use of electricity and airports reasonableness of costs is one of the most important and urgent issues.

One way of achieving the goal is to improve the management structure of its consumption [1]. Efficient power consumption mode control will ensure efficient electricity consumption receivers airports contribute to the equalization of load demand energy systems that will ensure proper operation and minimize costs in the face of rising electricity prices.

Airports - multipurpose transport company, which is the ground part of the air transport system. Receivers electricity airport is equipment that provides takeoff and landing transport ships and their ground handling, receiving and sending passengers, baggage, mail and cargo. To perform its functions airport using runway, terminal, Terminal area, ground facilities and equipment with the staff. Therefore, it is important and urgent implementation of energy saving policy for airports Ukraine, both for companies with annual growth of electricity consumption due to the increase in air traffic and the introduction of new facilities.

The aim of the study is to develop an effective management structure electricity consumption airport.

To achieve these goals it is necessary to solve the following problems:

- analysis of the existing management of electricity consumption;
- analysis of the current device to control consumption of electricity airports;
- development of an effective management structure consumption of electricity airports.

The effectiveness of management of electricity consumption is largely determined by the perfection of measures for sustainable consumption.

The main functions of Demand Side Management include [2]:

- planning;
- accounting and control;
- normalization;
- analysis;
- decision-making;
- corrective action.

Providing these areas of improvement is achieved through the development and implementation of a clear structuring of individual tasks, their interrelationships, algorithmic methods of solving, organizing and streamlining workflow.

One of the most important elements of the internal environment of the company is its organizational structure management. Organizational structure regulates the distribution of tasks to departments and divisions of the company; departments and units of competency in dealing with certain problems; overall interaction of departments and divisions. Organizational structure has a direct impact on the implementation of the business strategy, its interaction with the environment and efficient task.

For effective management system is necessary to establish it with information. This requires information that describes [3]:

- input and output parameters that indicate the volume, composition, properties and interactions towards material and energy flows;
- technical or design-composing options and patterns of interaction of individual objects (energy consumers) and sub-energy economies;
- functioning of organizational conditions (energy consumers) and sub-energy economies;
- regime-specific technological parameters of the processes taking place at the sites of energy economies;
- technical - economic parameters that reflect the results of the energy economies at different levels of hierarchical management structure.

Of the energy sector aimed at achieving high performance of the company. Achieving these goals requires increasing the effectiveness of energy management control systems, including:

- ensuring the company's management guidelines and practices for prospective and current planning energy management and operational management, which is essential for making economically sound decisions;
- improvement of the organizational structure of the energy sector through a clear division of functions and problems solved in some of its services;
- increase the reliability of the production units of the enterprise by improving the quality of power supply and ensure effective repair service power equipment;
-improving the logistics of all parts of the energy sector;
-strengthening coordination with other subsystems of the enterprise.

Providing these areas of improvement is achieved by a clear structuring of individual tasks, complete linking them together in time and in space, algorithmic methods of solution, streamlining workflow. The necessary step in power management on quality airport is the choice of the indicator of energy efficiency. An indicator of energy is - absolute or relative magnitude of the cost of energy resources that are set by national standards, and the introduction of the following standards - technical regulations nameplate equipment, standards and regulations specific consumption of energy resources.

Under the current regulatory laws are a number of indicators of efficiency. Given the specifics of airport performance may be specific consumption rate of energy resources and energy, and in some cases:

Organizational and methodological tools effective energy management [4] in power technology systems of airports based on the principles of consistency, regularity, documents, independence, credibility, transparency, validity and provides a consistent implementation of the following functions: planning, monitoring and control, normalization, analysis, decision making and corrective action.

To form the initial set of elements is used as the knowledge and experience of personnel, and various documentary information (energy passport enterprises and individual consumers of energy, financial and economic performance of the enterprise, forms of state statistical reporting regime typical daily schedule electric (heat) load and graphics consumption energy (per month, quarter, year), documentation of the repair, commissioning and testing works consuming equipment, energy efficiency programs and annual reports on their implementation, reports on preliminary energy audit, promising programs and projects of enterprise restructuring and modernization of its individual units, the survey and questioning of management and personnel).

Objectives and data collection necessary to put in an automated system control and energy metering. For most modern automated control and energy metering is implemented only accounting tasks and data visualization, reporting. Formation of an information management system software, especially with limited capital investment, equipment and labor costs, is essential for efficient operation. In this regard, proposed a closed system of effective electric power consumption airport, where management will be conducted for each facility and the airport in general. At the same time carried continuous, or periodic monitoring of indicators of effective consumer object (specific consumption of electric energy on core activities, etc.). As a result of the control decision is rational consumption until the next control, or to conduct energy-saving measures for the necessary facilities (maintenance work, replacement of equipment, modes of regulation, etc.).

Conclusions

1. Problem of performance management FER consumption is extremely important today for both individual companies and for certain industries, and the state as a whole.

2. Implementation of improved performance management system energy consumption for airports allowing for the equipment of the company, the specifics of its work will contribute to the energy consumption.

References

1. Воркут, А. І. Логістичне управління в полі зору ТАУ. [Текст] / А. І. Воркут // Вісник НТУ. – 1999. – №2. – С. 33–37.

2. Blok, K. 2005. Enhansed policies for the improvement of electricity efficiencies. Energy Policy 33: 1635-1641

3. Ямалов И.У. Моделирование процессов управления и принятия решений в условиях чрезвычайных ситуаций 2-е изд. (эл.) - М.: БИНОМ. Лаборатория знаний, 2012. - 289 с.

4. Рябинин И.А. Надежность и безопасность структурно-сложных систем. СПб.: Издательство Санкт-Петербургского университета, 2007 г., 278с.

UDC 517.9:681.5.017

A. Aslanyan, D.Sc., O. Belska, PhD (National Aviation University, Ukraine)

MATHEMATICAL MODEL OF ENERGETIC OBJECT

The article contains a nonlinear mathematical model for a wide class of energetic objects: gas turbine engines of aircraft and ships; gas compressor units; gas turbines and mobile power plants; steam-turbine plants; diesel power units; pumps, etc. On the basis of the Picard iteration method obtained an algorithm for calculation of the phase vector for a given input action.

Analytical description of processes in energy facilities is possible by a system of nonlinear differential and algebraic equations of the form [1]:

$$\begin{cases} \dot{\mathbf{y}} = \mathbf{F}(\mathbf{y}) + \mathbf{u}_F(t), \\ \mathbf{G}(\mathbf{y}) + \mathbf{u}_G(t) = 0. \end{cases} \tag{1}$$

In the system (1) $\mathbf{y}$ is a vector of condition variables; $\mathbf{F}$ and $\mathbf{G}$ are corresponding nonlinear vector-functions; $\mathbf{u}_F(t)$ and $\mathbf{u}_G(t)$ are vector-functions of external influences including control. Vector functions $\mathbf{F} = \begin{pmatrix} F_1 & F_2 & \ldots & F_q \end{pmatrix}^{\mathrm{T}}$ and $\mathbf{G} = \begin{pmatrix} G_{q+1} & G_{q+2} & \ldots & G_n \end{pmatrix}^{\mathrm{T}}$ are limited in space $\mathbf{Y}$, i.e. on the entire set of admissible condition parameters. Consider functions F_i and G_i as continuous and s times differentiable in this space.

Let's expand vector-functions $\mathbf{F}$ and $\mathbf{G}$ in the Taylor series up to the s member:

$$\begin{aligned} \mathbf{F}(\mathbf{y}) &= \mathbf{F}(\mathbf{y}_0) + \left(\frac{\partial \mathbf{F}}{\partial \mathbf{y}}\right)_0 (\mathbf{y} - \mathbf{y}_0) + \sum_{k=2}^{s} \frac{1}{k!} \left(\frac{\partial^k \mathbf{F}}{\partial \mathbf{y}^k}\right)_0 (\mathbf{y} - \mathbf{y}_0)^k + \mathbf{R}_{sF}(\mathbf{y}), \\ \mathbf{G}(\mathbf{y}) &= \mathbf{G}(\mathbf{y}_0) + \left(\frac{\partial \mathbf{G}}{\partial \mathbf{y}}\right)_0 (\mathbf{y} - \mathbf{y}_0) + \sum_{k=2}^{s} \frac{1}{k!} \left(\frac{\partial^k \mathbf{G}}{\partial \mathbf{y}^k}\right)_0 (\mathbf{y} - \mathbf{y}_0)^k + \mathbf{R}_{sG}(\mathbf{y}). \end{aligned} \tag{2}$$

In (2) $\mathbf{R}_{sF}$, $\mathbf{R}_{sG}$ are residual terms of the expansion, which as infinitesimal quantities of higher order with respect to $(\mathbf{y} - \mathbf{y}_0)^s$ are falling in further.

Let’s substitute (2) in the system of equations (1), as a result we obtain:

$$\begin{aligned} \dot{\mathbf{y}} &= \mathbf{F}(\mathbf{y}_0) + \left(\frac{\partial \mathbf{F}}{\partial \mathbf{y}}\right)_0 (\mathbf{y} - \mathbf{y}_0) + \sum_{k=2}^{s} \frac{1}{k!} \left(\frac{\partial^k \mathbf{F}}{\partial \mathbf{y}^k}\right)_0 (\mathbf{y} - \mathbf{y}_0)^k + \mathbf{u}_F(t), \\ \mathbf{0} &= \mathbf{G}(\mathbf{y}_0) + \left(\frac{\partial \mathbf{G}}{\partial \mathbf{y}}\right)_0 (\mathbf{y} - \mathbf{y}_0) + \sum_{k=2}^{s} \frac{1}{k!} \left(\frac{\partial^k \mathbf{G}}{\partial \mathbf{y}^k}\right)_0 (\mathbf{y} - \mathbf{y}_0)^k + \mathbf{u}_G(t). \end{aligned} \tag{3}$$

Assume that at the solution of equations (3) we have zero initial conditions. Otherwise, need to subtract from the vector-function $\mathbf{u}_F(t)$ the delta function with intensity equal to the initial value of the corresponding derivative. The free members expansions $\mathbf{F}(\mathbf{y}_0)$ and $\mathbf{G}(\mathbf{y}_0)$ are also relate to vector-functions $\mathbf{u}_F(t)$ and $\mathbf{u}_G(t)$.

As a result we obtained components of equivalent external influences

$$u_i(t)=\begin{cases}\varphi_{Fi}(t)+F_i(y_{01},y_{02},...,y_{0n})-\dot{y}_{0i}\delta(t),\ i=\overline{1,q};\\ \varphi_{Gi}(t)+G_i(y_{01},y_{02},...,y_{0n}),\ i=\overline{q+1,n}.\end{cases}$$

Denoting $x_1=\dfrac{y_1-y_{01}}{y_{01}}$ and $p=\dfrac{d}{dt}$ obtain the system of equations (3) in dimensionless operator notation in deviations:

$$\begin{aligned}
&(p-a_{11})x_1-a_{12}x_2-\cdots-a_{1n}x_n-f_1(x_1,x_2,...,x_n)=u_1(t),\\
&(p-a_{21})x_1-a_{22}x_2-\cdots-a_{2n}x_n-f_2(x_1,x_2,...,x_n)=u_2(t),\\
&\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\\
&(p-a_{q1})x_1-a_{q2}x_2-\cdots-a_{qn}x_n-f_q(x_1,x_2,...,x_n)=u_q(t),\\
&-a_{q+1,1}x_1-a_{q+1,2}x_2-\cdots-a_{q+1,n}x_n-f_{q+1}(x_1,x_2,...,x_n)=u_{q+1}(t),\\
&\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\\
&-a_{n,1}x_1-a_{n,2}x_2-\cdots-a_{n,n}x_n-f_n(x_1,x_2,...,x_n)=u_n(t).
\end{aligned}\tag{4}$$

In system of equations (4) are denoted:

$$a_{ij}=y_{0i}\left(\frac{\partial F_i}{\partial y_j}\right)_0,\ i=\overline{1,q},\ j=\overline{1,n}\ \text{and}\ a_{ij}=y_{0i}\left(\frac{\partial G_i}{\partial y_j}\right)_0,\ i=\overline{q+1,n},\ j=\overline{1,n};$$

$$f_i(x_1,x_2,...,x_n)=\sum_{k=2}^{s}\left(\sum_{j=1}^{n}y_{0j}\frac{\partial}{\partial y_j}x_i\right)_0^k F_i(y_1,y_2,...,y_n),\ i=\overline{1,q};$$

$$f_i(x_1,x_2,...,x_n)=\sum_{k=2}^{s}\left(\sum_{j=1}^{n}y_{0j}\frac{\partial}{\partial y_j}x_i\right)_0^k G_i(y_1,y_2,...,y_n),\ i=\overline{q+1,n}.$$

Equations (4) already prepared for solve with help of Picard iterations.

Let's write them in vector-matrix form and divide obtained system into two subsystems using block matrix $\mathbf{E}_q$ with total dimension $n\times n$:

$$\mathbf{E}_q=\begin{pmatrix}\mathbf{E} & \vdots & \mathbf{0}_q^{n-q}\\ \cdots & \cdots & \cdots\\ \mathbf{0}_{n-q}^q & \vdots & \mathbf{0}_{n-q}^{n-q}\end{pmatrix},$$

which consists of $\mathbf{E}$ - identity matrix with $q\times q$ dimension, and zero matrixes of corresponding dimensions.

For values $i=\overline{1,q}$ the subsystem shows a dynamic component of the object in general, and at $i=\overline{q+1,n}$ - inertialess.

Furthermore, the coefficients of the linear part are summarized in the matrix $\mathbf{A}=\left(a_{ij}\right)_n^n$, the nonlinear components and external actions - in corresponding vectors $\mathbf{f}(\mathbf{x})=\left(f_i(\mathbf{x})\right)_n^1$ and $\mathbf{u}(t)=\left(u_i(t)\right)_n^1$.

Thus, the system of equations (4) takes the form:

$$\left(p\mathbf{E}_q-\mathbf{A}\right)\mathbf{x}=\mathbf{f}(\mathbf{x})+\mathbf{u}(t).$$

Further we act in accordance with the recommendations [2].

Picard iterations are as follows:

$\mathbf{x}_r^{(1)}(t)=\left(p\mathbf{E}_q-\mathbf{A}\right)^{-1}\mathbf{u}(t)$ - first iteration;

$\mathbf{x}_r^{(k)}(t)=\left(p\mathbf{E}_q-\mathbf{A}\right)^{-1}\mathbf{u}(t)+\left(p\mathbf{E}_q-\mathbf{A}\right)^{-1}\mathbf{f}\left(\mathbf{x}_r^{(k-1)}\right),\ k\geq 2$ - k-th iteration.

Corresponding shortened Picard iterations can be written in the form:

$$\begin{aligned}&\mathbf{x}_r^{(1)}(t)=\left(p\mathbf{E}_q-\mathbf{A}\right)^{-1}\mathbf{u}(t),\\&\mathbf{x}_r^{(k)}(t)=\left(p\mathbf{E}_q-\mathbf{A}\right)^{-1}\mathbf{u}(t)+\left[\left(p\mathbf{E}_q-\mathbf{A}\right)^{-1}\mathbf{f}\left(\mathbf{x}_r^{(k-1)}\right)\right]_r,\ k\geq 2.\end{aligned}\tag{5}$$

Index "r" near square brackets means that the expanded notation vector-function in the square brackets, contains components, each of which consist of a non-linear operator with degree not higher s, and the rest of components are discarded.

The second relation of (5) is an approximate solution of the system (4).

Conclusions

Mathematical model of energetic object is the system of nonlinear differential and algebraic equations whose solution may be by the method of successive approximations Picard

Referenses

1. *Aslanyan A., Belskaya A.* / Singularities of mathematical modeling the dynamics of energy objects / Aviation in the XXI-st century. Safety in aviation and space technology. The V world congress.– K., 2012. – P.1.12.33 –1.12.36.

2. *Данилов Л.В.* Ряды Вольтерра-Пикара в теории нелинейных электрических цепей. –М.: «Радио и связь», 1987.

UDC 629.735.051.017.2

V.M. Kazak, Doctor of Engineering Science (National Aviation University, Ukraine)
N.A. Tymoshenko, postgraduate student (National Aviation University, Ukraine)

STABILIZATION OF HEIGHT HOVERING OF HELICOPTER IN CONDITIONS OF DISCRETE EXTERNAL PERTURBATIONS

The characteristics of the helicopter as an object hovering stabilization under the action of external discrete factors. That the model of acceleration change evaluation of the helicopter using an extended Kalman filter EKF.

According to the world's best practice the occasions of helicopter use for high-accuracy works become more and more frequent. For example cargo throw into the narrow pipe (as in fourth unit of Chernobyl NPP), or installation of telescopic mount for radio and television stations, etc. Mentioned work requires close and accurate stabilization of the helicopter with respect to a given point. However, these works are not only difficult, but also dangerous. It's impossible to forecast all dangerous factors but you can minimize the risk. Analysis of recent publications on the subject shows that the crew in conjunction with the stabilization system based on modern control technologies can reduce the risk significantly.

Installation work and spot landing in condition of difficult external influences requires special attention of the crew. Also it required high coherence and clarity of executing commands which creates additional physiological load different from the loads during the normal flight. Differential inclusion of automatic control system (ACS) in the main control wiring allows to reduce load on the crew and to release them from automatic stabilization functions. But hovering mode control during high-accuracy works is still very difficult according to latest analysis and research. Existing ACS's in hovering mode are not fully meet all necessary requirements for high-accuracy works. So, development of new technologies and new technical devices for automatization of hovering mode stabilization with respect to a given point is a priority task.

Helicopter is unstable laterally and longitudinally during hovering. To compensate these shortcomings, the helicopter must be equipped with some artificial stabilization. Hovering flight operations performed usually at a height of up to 10 m of a predetermined point, in the area of "air cushion" under normal summer conditions. Hovering height should be increased to 10-30 m during installation works or high-accuracy cargo throw. But safe vertical landing can not be provided in case of engine failure.

Authorization for hovering is allowed for visibility not less than 500 m and cloud height not lower than 50 m in the. That not depends of commander minimum. Height hovering in the zone of influence of the air cushion is determined visually on the ground and periodically monitored by the radio altimeter readings or SNS (satellite navigation system).

Rear wind and side wind significantly complicates single-rotor helicopter hovering [4]. Hovering become more complicated by the action of a discrete (gust) wind. Tangage angle should be increased, for the lowering of the tail boom and the growing body of the helicopter, which operates wind and the longitudinal aerodynamic force biasing helicopter while rear wind. That requires even greater deviations helicopter tangage to hold it over a given point. Equation of the longitudinal displacement of the helicopter in the starting coordinates OXgYgZg takes the following form:

$$\dot{X} = AX + BU - GW + F , \qquad (1)$$

where $X = \left[V_{kX_g} X_g V_{kY_g} H \omega_z \vartheta \right]^T$ - the state vector; $U = [\delta_в \varphi]^T$ - vector control; $W = \left[W_{X_g} W_{Y_g} \right]^T$ - wind velocity; $F = \left[f_{X_g} f_{Y_g} \right]^T$ - a discrete component of the wind. Coefficient matrix management system (1) have the form:

$$A = \begin{bmatrix} \overline{X}_g^{V_{X_g}} & 0 & \overline{X}_g^{V_{Y_g}} & \overline{X}_g^{H} & \overline{X}_g^{\omega_z} & \overline{X}_g^{\vartheta} \\ 1 & 0 & 0 & 0 & 0 & 0 \\ \overline{Y}_g^{V_{X_g}} & 0 & \overline{Y}_g^{V_{Y_g}} & \overline{Y}_g^{H} & \overline{Y}_g^{\omega_z} & \overline{Y}_g^{\vartheta} \\ 0 & 0 & 1 & 0 & 0 & 0 \\ \overline{M}_{Z_g}^{V_{X_g}} & 0 & \overline{M}_{Z_g}^{V_{Y_g}} & \overline{M}_{Z_g}^{H} & \overline{M}_{Z_g}^{\omega_z} & \overline{M}_{Z_g}^{\vartheta} \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}; B = \begin{bmatrix} \overline{X}_g^{\delta_в} & \mathrm{X}_g^{\varphi} \\ 0 & 0 \\ \overline{Y}_g^{\delta_в} & \overline{Y}_g^{\varphi} \\ 0 & 0 \\ \overline{M}_{Z_y}^{\delta_в} & \overline{M}_{Z_g}^{\varphi} \\ 0 & 0 \end{bmatrix};$$

$$G = \begin{bmatrix} \overline{X}_g^{V_{X_g}} & \overline{X}_g^{V_{Y_g}} \\ 0 & 0 \\ \overline{Y}_g^{V_{X_g}} & \overline{Y}_g^{V_{Y_g}} \\ 0 & 0 \\ \overline{M}_{Z_g}^{V_{X_g}} & \overline{M}_{Z_g}^{V_{Y_g}} \\ 0 & 0 \end{bmatrix}; \; F = \begin{bmatrix} \overline{X}_{ggust} \\ 0 \\ \overline{Y}_{ggust} \\ 0 \\ \overline{M}_{Zggust} \\ \end{bmatrix} \qquad (2)$$

Matrix A in the system (2) defines the characteristics of stability, and the matrix B - the handling characteristics of the helicopter under the action of external discrete perturbations. Matrix elements (2) are the product of forces and moments acting on the helicopter:

$$\begin{cases} \overline{X}_g^{V_{X_g}} = \dfrac{\partial X_g}{m \partial V_{X_g}}, \; \overline{Y}_g^{V_{Y_g}} = \dfrac{\partial Y_g}{m \partial V_{Y_g}}, \; \overline{X}_g^{\delta_в} = \dfrac{\partial \mathrm{X}_g}{m \partial \delta_в} \\ \overline{M}_{Z_g}^{V_{X_g}} = \dfrac{\partial M_{Z_g}}{J_{Z_g} \partial V_{X_g}}, \; \overline{M}_{Z_g}^{\delta_в} = \dfrac{\partial M_{Z_g}}{m \partial \delta_в}, \ldots, \end{cases}, \qquad (3)$$

where J_{Z_g} - the moment of inertia about the axis of the helicopter 0Zg earth coordinate system; $\delta_в, \varphi$ - deflection angles swash in the longitudinal plane and the collective pitch of the main rotor, respectively.

The angle of attack and tail rotor thrust and of the blades are decreasing during left side wind. Transverse aerodynamic force housing at discrete wind rocked the helicopter into the wind. If we consider only the case of the perturbed hovering, the aerodynamic torque, corresponding to a constant angle setting of the blade relative to the shaft axis, can not be taken into account and consider only the aerodynamic moments due indignant flapping. If we consider flapping blade is minimal, $\cos\beta = 1$, than we obtain that the flow velocity in the direction of the chord $\omega_H\left(r + \bar{l}_г\mathrm{R}\right)$, so that the local variation of the angle of attack due to blade flapping power [3]:

$$\Delta\alpha = \frac{-r\dot{\beta}_л}{r + \bar{l}_г\mathrm{R}} = \frac{-\bar{r}\dfrac{d\beta_л}{\mathrm{d}\psi_л}}{\bar{r} + \bar{l}_г}, \tag{4}$$

where $\bar{r} = \dfrac{r}{R}$.

The right pedal should be pressed ahead and drive the swash plate (SP) to the left, causing a decrease in rotor thrust (RT), balancing the force of gravity of the helicopter and the shaft power RT. All mentioned actions should eliminate turn left and right movement of the helicopter.

The inductive flow direction of tail rotor (TR) while wind is right-hand has anti-wind direction and after reaching the speed $\left|w_Z\right\rangle 4-6$ m/s causes the formation of a vortex ring mode, sophisticated inductive influence swirling flow RT keel and ground proximity [3]. When you offset the reduction in thrust TR challenge modes vortex ring with the wind right and prevent displacement and turning the helicopter left step necessary to increase TR, so that when $\left|w_Z\right\rangle 10-12$ m/s reserve the right pedal control can be settled.

Recent discoveries in estimation theory, as well as in computer technology enables very sophisticated algorithms helicopter under the action of discrete disturbances (1). Most common in the currently received estimation method based on the Kalman filter. In our case it's convenient to use the extended Kalman filter (EKF). The most important issue in the construction of EKF for stabilizing of the helicopter hovering under discrete perturbations, is the choice of the model of change of acceleration with respect to a given point. Propose a model that accurately describes it acceleration is impossible, since there is no possibility to predict the effect of discrete wind.

In this case selected model systems with zero acceleration helicopter hovering about a specified point. In the case of such a model number of state parameters EKF (2) is reduced to six: three components of the radius vector of a given point with respect to the position of the helicopter and the relative velocity vector displacement of the helicopter. Differential equation of state takes the form:

$$\begin{aligned} &\Delta\dot{D}(t) = \Delta V(t) \\ &\Delta\dot{V}(t) = -A_M(t) + W_M(t). \end{aligned} \tag{5}$$

Model system for EKF takes the form [3]

$$\begin{bmatrix} \Delta\dot{D}(t) \\ ---- \\ \Delta\dot{V}(t) \end{bmatrix}_{6\times1} = \begin{bmatrix} 0 & | & \dot{I} \\ - & - & - \\ 0 & | & 0 \end{bmatrix}_{6\times6} \begin{bmatrix} \Delta D(t) \\ ---- \\ \Delta V(t) \end{bmatrix}_{6\times1} + \begin{bmatrix} 0 & | & 0 \\ - & - & - \\ 0 & | & \dot{I} \end{bmatrix}_{6\times6} \begin{bmatrix} 0 \\ ---- \\ -A_M(t) \end{bmatrix}_{6\times1} + \begin{bmatrix} 0 \\ ---- \\ W_M(t) \end{bmatrix}_{6\times1} . \tag{6}$$

If the system model is given by equation (6), the state transition matrix can be written as

$$\Phi(t_k, t_{k-1}) = \begin{bmatrix} \dot{I} & | & \Delta t\dot{I} \\ - & - & - \\ 0 & | & \dot{I} \end{bmatrix} \tag{7}$$

Conclusion. Thus, by determining the behavior of the helicopter hovering under the action of external discrete perturbations and selecting main control parameters, and a model of change of acceleration of the helicopter when it is displaced by the action of these perturbations, we can significantly improve the accuracy of automatic stabilization of the helicopter.

References

1. Браверман А.С., Лаписова С.В. Балансировка одновинтового вертолета. – М.:Машиностроение, 1975. – 261с.
2. Брамвелл А.Р.С. Динамика вертолетов. Пер.с англ. – М.:Машиностроение, 1982. – 368с.
3. Вергес П.Л., Лайфер Р.К. Моделирование ускорения цели для наведения тактических ракет.М.:Аэрокосмическая техника №3, том 3, 1985. – С.100-107.
4. Володко А.М. Вертолет в особой ситуации. – М.:Транспорт, 1992. – 262с.
5. Кожевников В.А. Автоматическая стабилизация вертолета. – М.:ашиностроение, 1977. – 341с.
6. Saerens M., Soquet A. A neural controller based on back propagation algorithm//Proc.of First IEE Int.Conf. on Artificial Neural Networks, London, pp.211-215,1989.
7. Howard K., Itzhak B., Kenniths. Direct adaptive control algorithms:Theory and applications. Springer – Verlag, 1998.

UDC 629.735.018.4-03.03(045)

M. Kulyk, M. Koveshnikov,
L. Volyanska, Y. Petruk,B. Petruk
(National Aviation University, Ukraine)

EXPERIMENTAL DIAGRAM OF BOUNDARY STRESSES IN THERMOCYCLIC TESTING OF HEAT RESISTING MATERIALS AND ANALYTICAL ESTIMATION OF DURABILITY

It is shown experimental and calculated fatigue life of several high-temperature chrome-nickel alloys for gas turbine engine "hot part" components at critical points. It is assumed that the specimen materials are tested at the regimes maximum close to operating conditions of the components at the critical points which limit the useful life and specified life of gas turbine engines.

Introduction

Development of powerful engines requires new models and methods of calculation. The correctness of the models and methods of calculation is confirmed by the experimental data of thermocyclic durability available in the literature [1, 2]. This empirical model should more accurately represent effect of extreme value of temperature and thermomechanical stresses and allow determination the influence of thermomechanical stresses cycle asymmetry on the strength of materials and gas turbine engine components reduction. The main problem is to determine the optimal level and parameter of cycle asymmetry.

Analysis of research and publications

The analysis has showed that known thermocyclic durability characteristics are not enough to develop empirical models as for the well- known high-temperature materials so for the latest high-temperature alloy. It is known a lot of theoretical models using three-component approach to calculation of GTE parts, but they are not sufficiently confirmed by experimental characteristics. The model of three-component load is commonly used [3]. This model is based on approximation of hypothetical surfaces of boundary stresses by equation of elliptic paraboloid form:

$$\sigma_a = \alpha + \beta\sigma_m + \gamma\sigma_m^2 + \delta\Delta\sigma_{\text{ТМ}} + \lambda(\Delta\sigma_{\text{ТМ}})^2, \quad (1)$$

where: σ_a – amplitude of cyclic stress; σ_m – average stress of cycle; $\Delta\sigma_{\text{ТМ}}$ – thermomechanical stresses range; $\alpha, \beta, \gamma, \delta, \lambda$ – parameters determined by the experimental characteristics of high- temperature materials thermocyclic durability. These parameters were obtained under the following loading conditions (fig. 1): during vibration fatigue loading in terms of symmetric load cycle with an amplitude of stress σ_{-1}; with asymmetric fatigue loading $(\sigma_a + \sigma_m)$; sustained static thermal cyclic loading with the level of stress $\sigma_{\text{ст}}$; at (vibration) fatigue load imposed on the cyclic thermomechanical stress $(\sigma_a + \sigma_{\text{ТМ}})$; with a load of thermal fatigue in imposed on the cyclic thermomechanical stress $(\sigma_a + \sigma_{\text{ТМ}})$; with a load of thermal fatigue in symmetric load cycle with an amplitude of stress $\Delta\sigma_{\text{Т}}$.

Asymmetric vibration stresses were studied by A. N. Vetrov [4]. According his studies boundary curves (asymmetric vibration) of stresses $\sigma_a = f(\sigma_m)$ and $\sigma_a = \varphi(\Delta\sigma_{\text{ТМ}})$ can be described by the equations of the parabolas with sufficient accuracy. Coefficients α, β, γ can be defined by three experimental points. In the work [5] to provide accuracy of calculation it was proposed to approximate relation $\Delta\sigma_{\text{ТМ}} = \psi(\sigma_m)$ by equations of parabola:

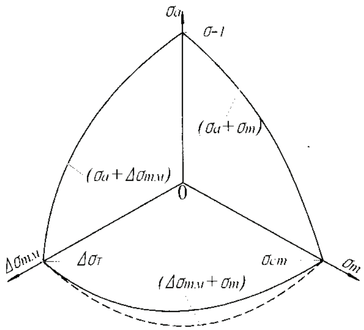


Fig.1. Scheme of surface of boundary stresses under three-component thermomechanical load

$$\Delta\sigma_{\text{TM}} = \alpha_1 + \beta_1\sigma_m + \gamma_1\sigma_m^2, \quad (2)$$

where $\alpha_1, \beta_1, \gamma_1$ – parameters determined from experimental characteristics of thermocyclic durability of materials. The experimental characteristics were obtained under the following loading conditions (see dashed line in fig.1):

- at long term static loads with the equal levels of stress $\sigma_{\text{СТ}}$;
- at thermal fatigue load in symmetric cycle of thermal stresses with divergence of parameter $\Delta\sigma_{\text{Т}}$;
- at asymmetric thermomechanical loading scheme.

Approximating parameters $\alpha_1, \beta_1, \gamma_1$ of equation (2) by linear functions of the logarithm of the number of thermal cycles ***N*** to fracture we get [5]:

$$N = \frac{a_{1T} + a_{2T}\left[\Delta\sigma_{\text{TM}} - \sigma_m\left(\beta_{11} + \gamma_{11}\sigma_m\right)\right]}{1 + \dfrac{a_{2T}}{\lg N_2}\left[\beta_{12} - \beta_{11} + \left(\gamma_{12} - \gamma_{11}\right)\sigma_m\right]}; \quad (3)$$

where $\alpha_{1T}, \alpha_{2T}, \beta_{11}, \beta_{12}, \gamma_{11}, \gamma_{12}$, lgN_2 – approximation constants of $\alpha_1, \beta_1, \gamma_1$.

The proposed approach provides a more accurate estimation of thermocyclic durability due to correlation of the relation $\Delta\sigma_{\text{ТМ}} = \psi(\sigma_m)$. But it requires additional experimental data. Therefore it is important to build an empirical model of thermocyclic durability based on a minimum of experimental data, and provide pinpoint accuracy of computational evaluation. It is primary purpose of this study.

Method and program of experimental research

Researches were performed on the improved experimental facility described in work [6]. This facility allows to i carry out asymmetric cyclic thermomechanical loading in a wide range of changes of cycle mean stress a_m.

The experimental facility allows researching of symmetric cycle loading $(\sigma_m = 0, \Delta\sigma_{\text{ТМ}} = \Delta\sigma_{\text{Т}})$ and performs testing in terms of only static stresses and cyclic temperatures $(\Delta\sigma_{\text{ТМ}} = 0; \sigma_m = \sigma_{\text{СТ}})$. Standard cylindrical samples of materials ЖС6К, ЖС6У, ЕІ437Б, ЕП99вд, Х18Н10Т having diameter of 5 mm, working length of 30 mm were studied on different modes. Each mode was tested at least 15 samples in three to five levels of stress.

Statistical analysis of the test results showed that the distribution of the number of cycles to fracture samples N corresponds to lognormal law, which is well illustrated by one of the modes of testing (fig.3). Lognormal density distribution of N can be displayed:

$$\varphi(N) = \frac{\lg e}{N\sqrt{2\pi D_{\lg N}}} \exp\left[-\frac{(\lg N - M_{\lg N})^2}{2D_{\lg N}}\right] \tag{4}$$

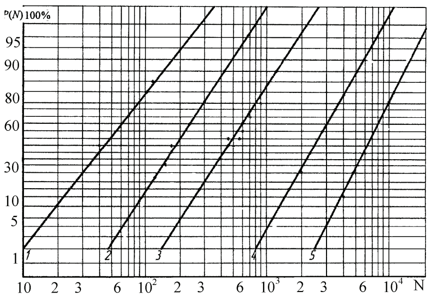


Fig. 3. Distribution of the number of cycles to fracture for alloy ЖС6К samples studied under thermocycling regime $T_{\min} \div T_{\max} = 250\div900$°C: 1 – $\sigma_{ст}$ =580MPa; 2 –$\sigma_{ст}$ =500MPa; 3 – $\sigma_{ст}$ =450MPa; 4 – $\sigma_{ст}$ =350MPa; 5 – $\sigma_{ст}$ =310M Pa

The parameters of this distribution: the mathematical expectation M_{lgN} and variance D_{lnN} dependent on the intensity of thermomechanical stresses $\sigma_{\text{ТМ}}$ and can be described by linear functions of stress σ :

$$M_{lg\,N} = a_1 + a_2\sigma; \quad D_{lg\,N} = a_3 + a_4\sigma \tag{5}$$

where $a_1, \ldots a_4$ parameters of distribution.

Usually dispersion of logarithm of the cycles number before fracture D_{lgN} is considered independent of the stress level σ, i. e. $D_{lgN} = a_3 = const$, but the results of this study show a monotonic decrease D_{lgN} at load reduction (see fig.3). Computer calculations allowed to indicate that $a_4 \approx 0$ especially at purely thermal loading $\Delta\sigma_{т}$ (when $\sigma_{ст} = \sigma_m = 0$); dispersion D_{tgN} according to a_3 and a_4, does not have large absolute values and changes slowly, the coefficient a_2 has a small negative values, and the most important is the statistical evaluation of mathematical expectation of parameters a_3 and a_2. This allows using expressions (5) to determine the mathematical expectation and variance of the cycle's number logarithm to fracture of models.

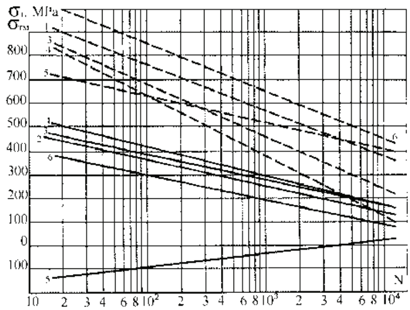


Fig.4. Characteristics of cycle durability of alloy ЖС6К studied for mode

The median curves of thermocyclic durability for models of alloy ЖС6К are shown in fig.4. The curves graphed using expression (5) as relations of thermomechanical stresses range $\Delta\sigma_{тм}$ (during thermal cycles T_{min}÷T_{max}= =350÷1000°C) and mean loading of cycle σ_m of the cycles number to fracture N. The diagrams of limit stresses under asymmetric cyclic of thermomechanical loading as $\sigma_m = f(\Delta\sigma_{тм})$ is shown in fig.5. This is also confirmed by the data of [7]. Presented in fig.5 experimental points of limit stresses can be approximated by the equation of inclined ellipse.

$$\frac{\sigma_m^2}{\sigma_{ст}^2} + \frac{\Delta\sigma_{тм}^2}{\Delta\sigma_{т}^2}\left(\frac{1}{\sigma_{ст}^2} - \frac{1}{\Delta\sigma_{т}^2}\right) tg2\alpha\sigma_m\Delta\sigma_{тм} = 1 ,$$

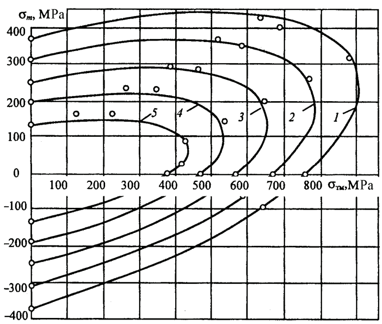


Fig.5. Curves of limit stresses of alloy ЖС6К at asymmetric cyclic thermomechanical loading at thermocycling regime $T_{min} \div T_{max}$ = 350÷1000^{0}C: 1. N=10^2; 2. N=3*10^2; 3. N=10^3; 4. N=3*10^3; 5. N=10^4

where $\sigma_{ст}$ - limit of prolonged static durability of the material at a thermocycling; $\Delta\sigma_{т}$ - range of thermocyclic stresses in symmetric cycle. To check the empirical model and the calculation method the experimental studies of thermocyclic durability of high- temperature alloys were carried out for different modes. This method was used to calculate the median durability according to the same data of asymmetric loadings. It showed that difference between calculated and experimental data is within the limits of accuracy of the experiment.

Conclusions:

1. Model of boundary stresses for the family of cyclic durability characteristics of high- temperature alloys ЖС6К can be approximated by the equation of an inclined ellipse with range of thermomechanical stresses and mean cycle stresses and described by the equation of 4-th power in durability logarithm lg*N*.
2. Relatively low levels of positive mean stresses of cycle increase limit value of thermomechanical stresses range and consequently lead to an increase of thermomechanical durability for thermocyclic and complex thermomechanical loading.
3. The positive effect of asymmetry cycle thermomechanical loading [1, 7] can be explained by static stress decreases negative thermomechanical stresses (absolute value) at the maximum temperature of the cycle.
4. The calculations by the proposed method and the additional experimental test showed good convergence of calculated and experimental thermocyclic durability with maximum accuracy up to 25%, this is within the limit of the experiment accuracy.
5. Experience shows that it makes sense to develop similar models and calculation methods, carry out experimental testing for all high - temperature alloys including the latest and give recommendation for practical using of alloys and materials of "hot parts" GTE components and other components operating in a cyclic asymmetric thermomechanical loading.

References

1. *Кулик М.С.* Вплив асиметрії циклу термомеханічного навантаження на довговічність жароміцних матеріалів при термоциклічних випробуваннях / М.С. Кулик, О.Г. Кучер, М.О. Ковешніков, С.С. Дубровський, Я.А. Петрук. // Наукоємні технології – К.: НАУ-друк –2009. – № 3. – С. 6 –18.
2. *Кулик М.С.* Локалізація критичних зон пошкодження жароміцних матеріалів та роторних деталей ГТД / М.С. Кулик, О.Г. Кучер, М.О. Ковешніков, С.С. Дубровський, Я.А. Петрук // Наукоємні технології – К.: НАУ-друк –2009. – № 2. – С. 64–72.
3. *Расчет* долговечности в условиях трехкомпонентного нагружения / Л.П. Лозицький.// Надежность и долговечность авиационных газотурбинных двигателей. – К.: КИИГА, вып. №1 – 1971. – С. 21–25.
4. *Ветров А.Н.* Исследование долговечности материалов деталей авиадвигателей при совместном действии вибрационных и термоциклических нагрузок. / А.Н. Ветров // автореф. Канд. Диссерт.–К.: КИИГА, 1972. – 25 с.
5. *Ковешников Н.А.* Методика исследования долговечности жаропрочных материалов в условиях циклического термомеханического нагружения. / Н.А. Ковешников. // Надежность и долговечность авиационных газотурбинных двигателей. – К.: КИИГА, 1973, №4. – С. 126–129.
6. А.С. 839022 (СССР). Установка для испытаний материалов на термомеханическую усталость. / Л.П. Лозицкий, А.Н. Ветров, Н.А. Ковешников // КИИГА: Заявл. 05.03.1979. №2732866/25 – 28; опубл. В Б.И., 1981, №38; М.К.З. 601№3/60. УДК 620.178.38(088.8)
7. *Дульнев Р.А.* Термическая усталость жаропрочных материалов при ассиметричном нагружении. / Р.А. Дульнев, Н.Г. Бычков // Проблемы прочности, 1975, №5. – С. 19 – 24.

UDC 621.452.3 – 6:519.22

V.V.Panin (Kyiv State Maritime Academy, Ukraine),
L.G.Volyanska, O.I.Chumak
(National Aviation University, Ukraine)

METHOD FOR DETERMINATION OF GAS TURBINE ENGINE MAIN PARAMETERS

The article presents a method of thrust and specific fuel consumption of air-breathing engines determination. The method is based on measuring of instantaneous fuel flow rate, compressor delivery total pressure, atmospheric pressure and using of the mathematical dependences among listed and main gas turbine engine parameters.

Introduction

Diagnosing of gas turbine engines by the parameters characterizing gas dynamic processes is one of the most common and effective methods of engine operational status estimation. These methods estimate engine's ability to create the required thrust.

Under reducing residual service life the change of such parameters like thrust, specific fuel consumption, gas temperature before the turbine and gasdynamic stability margin is regulated within limits defined by performance specification. The increase of engine operating time leads to divergence of engine basic parameters from values given in performance specification. It causes derating of performance characteristics of the aircraft. In addition thrust reduction reduces the level of flight safety. The increase of fuel consumption gives rise of operating costs. The development of methods of determination of the gas turbine engine main parameters in operation is an urgent task.

Review of existing methods of determination of the breathing engine main parameters in operation

Nowadays ensuring efficient operation on the status today of such complex functional systems like modern and advanced gas-turbine engines, an improvement of flight safety in the conditions of continuous design complexity and growing of thermal and mechanical loads is impossible without application of early detection methods and prediction of possible failures and their causes.

It is required measuring parameters of flow in all characteristic sections of engine for complete diagnostics of engine. The list of measuring parameters is limited in the practice.

Determination thrust and specific fuel consumption under operating conditions requires increase in the number of measuring parameters. For thrust determination it is necessary to use addition device (blast-meter).

The gas temperature before the turbine of modern gas turbine engines exceeds 1700 K. Direct measuring of this temperature requires using of a pyrometers having limited service life [1].

To determine the gas-dynamic stability margin it is necessary to measure the total pressure of air after compressor and use complex calculation methods to determine the position of the stability limit (surge line) [2].

Method of determination of the jet engine main parameters in the ground conditions

For developing a method of determination thrust and specific fuel consumption the basic problems were focused on using only authorized tools for measuring parameters and improving reading accurancy at the expense of a minimum number of measured parameters.

The thrust of jet engine in the aerodrome conditions can be determined with the formula given in the work [3]

$$R = D \cdot \frac{k}{k-1} \cdot F_C \cdot \beta_{кр} \left[\left(\frac{D\, p_к^*}{p_н} \right)^{\frac{k-1}{k}} - 1 \right] + F_C \left[D\, p_к^* \beta_{кр} - p_н \right] \qquad (1)$$

where $D = \sigma_{кс}\sigma_{см}\sigma_c \dfrac{1}{\pi_T^*}$; $\sigma_{кс}$, $\sigma_{см}$, σ_c – the total pressure loss coefficient in the combustion chambers, the mixing chamber and jet nozzle; π_T^* – expansion ratio in a turbine; k – the adiabatic exponent; $\beta_{кр} = \left[\dfrac{2}{(k+1)} \right]^{\frac{k}{k-1}}$ – critical pressure ratio; $p_к^*$ – total pressure at the compressor exit; $F_с$ – nozzle exit area; $p_н$ – atmospheric pressure.

In modern turbojet and turbofan engine turbines the expansion ratio is constant in wide range of engine operating modes and is determined by the results of gas-dynamic calculation of a specified type of engine. The total pressure loss coefficients in the elements of the gas turbine engines are also determined by the results of gas-dynamic calculation of a specified type engine.

The total pressure of air exiting the compressor of improved controllability engines is registered by the authorized tools. The atmospheric pressure at the airport of take-off can be defined using authorized devices installed on aircraft, and using data of the weather service. The area of the jet nozzle is determined by measuring or use log book data.

The thrust of turbojet engines and bypass exhaust mixing engines, as follows from equation (1), depends on the total compressor delivery pressure and atmospheric pressure. Using the methods of correlation and regression analysis of the results of bench tests of the engines НК-8-2У and Д-30КП-2, it was gotten that for this series of engines thrust is determined by the following equation:

$$R = A_1 p_{\text{К}}^{*} - A_2 p_{\text{Н}}, \tag{2}$$

where A_1 and A_2 – constants for this series of engines.

The formula (1) allows to determine thrust of turbojet engines and bypass exhaust mixing engines at the aerodrome conditions on the operating modes of the engine in which the expansion ratio in the turbine remains constant. The thrust definition at a derating modes for which the expansion ratio in the turbine changes, does not have practical significance, since these modes are used during taxiing and does not affect the level of flight safety.

The engines of low controllability do not have authorized tools for measuring the total compressor delivery pressure, but as a rule there are production holes past the compressor. They allow installing sensors for measuring the compressor delivery pressure during ground tests.

This allows determining thrust by using formula (1) for diagnostics of the engine operational status in service conditions.

$$\overline{R} = 1 - \frac{V}{R_{G0}}, \tag{3}$$

where $\overline{R} = \dfrac{R}{R_o}$ – relative thrust; R_o – a thrust developed by an engine at takeoff power when ground speed of 0; V – speed of aircraft; R_{G0} – specific thrust of engine at takeoff mode.

Formula (3) can be used for calculation of aircraft take off and landing performance. After determination of engine thrust the specific fuel consumption is determined by the following formulas

$$C_R = \frac{3600\,G_T}{R}, \tag{4}$$

$$C_R = \frac{G_{T.ч}}{R}, \tag{5}$$

where G_T – fuel flow rate; $G_{T.ч}$ – fuel flow per hour.

There are no difficulties in calculation of specific fuel consumption in operating conditions, record the readings of fuel flow rate or fuel flow per hour is carried out on all modern aircrafts with authorized devices.

Specific fuel consumption is a diagnostic character. The value of the specific fuel consumption increases with increase of engine operating time. The average increment of the specific fuel consumption $\frown{C}_R$ for processing in operation for gas turbine engines is determined with the regression equation [6]

$$\frown{C}_R = Be^{-\frac{b}{\tau}},$$

where B, b – constants specifying certain series of engines.

Actual increment of the specific fuel consumption for a concrete engine operating time τ_i is determined by the formula

$$\Delta C_R = C_R - C_{R_0} \ ,$$

where C_R – the value of specific fuel consumption, defined by the formula (5) subjected to the engine operating time; C_{R_0} – the value of specific fuel consumption at the beginning of operation according to official data.

If $\Delta C_R \rangle \Delta \widehat{C}_R$, it shows that it is necessary to carry out the adjuisment of fuel equipment. If the adjustment does not give a positive result, it is necessary to diagnose the engine and to decide on its further operation

Conclusions

The method of determination thrust and specific fuel consumption proposed in this paper is applicable for turbo jet engines and by-pass exhaust mixing engines of improved controllability. It allows determination parameters at aerodrome conditions. The engine thrust determination at take-off mode provides increase the level of flight safety, and the determination of specific fuel consumption enables to estimate the effectivity of the aircraft. Monitoring of these parameters in operation allows estimate changing of engine operational status.

References

1. *Пат. 12571 А. Украина, МПК5G01M15/00.* Спосіб визначення реактивної тяги/ *Дмитрієв С.О., Козлов В.В, Панін В.В., Моісеєв Б.М.;* КМУЦА-№94012422; Заявл. 04.01.94; Опубл. 28.02.97, Бюл №1.

2. *Пат. 13488 А. Україна, МПК^{7}G01N3/00.* Спосіб оцінки запасу газодинамічної стійкості компресора газотурбінних двигунів в умовах експлуатації /*В.В. Панін, Л.Г. Волянська, І.Ф. Кінащук, Ф.І. Кірчу*; НАУ - № 20020907245; Заявл. 03.09.2004; Опубл. 17.07.2006, Бюл. №7.

3. *Пат. 10000 А. Україна, МПК^{7}G01M15/00.* Спосіб визначення реактивної тяги ГТД/ В.*В. Панін, Ю.М. Терещенко, М.С. Кулик, Л.Г. Волянська;* НАУ - № 201002662; Заявл. 10.03.2010; Опубл. 17.08.2010, Бюл. №4.

4. *Терещенко Ю.М., Волянская Л.Г., Кулик Н.С., Панин В.В.* Теория авиационных газотурбинных двигателей. – К.: Книжное издательство НАУ. 2005. – 500с.

5. *Клячкин А.Л.* Теория воздушно-реактивных двигателей.- М.: Машиностроение 1969.-512с.

6. *Бутончиков А.П., Нестеров Е.Д., Акимов С.С., Симкин Э.Л.* О влиянии наработки в летной эксплуатации на ухудшение параметров двухконтурных двигателей.Труды ЦИАМ №731, 1976.-11 с.

UDC 621.7.036-226

Voznyuk A.P.
(National Aviation University, Ukraine)

RADIAL CLEARANCES INFLUENCE ON GAS TURBINE ENGINES OF AIR AND GROUND APPLICATION MAIN PARAMETERS.

The paper deals with gas turbine engine flow channel geometrical parameters changes due to radial clearance in the compressor and turbine during the long operation. The proposed method of assessing the impact of these changes on engines transit modes and practical measures to eliminate adverse effects.

Entry

During extended service live of gas turbine engine the process of geometric parameters changing result a shift of workflow characteristics.

Diagnosing and troubleshooting that arise due to these processes is very difficult duo to slow percolation, where gradational processes and the complexity of the altered characteristics. Despite the slow count and relative obscurity where degradation processes they take affect on almost all engine characteristics.

Problem

It is known that the most informative in terms of diagnosis, are transitional modes turbine engine.

To date, relatively little attention paid to modeling of transient gas-turbine engines. But we know that the signs of change in the workflow engine in the first place, there is in transition mode. This contradiction is explained by the fact that transiency transients prevented obtaining the necessary diagnostic information using on-board systems of accumulation and control.

The situation began to change after the emergence of digital control systems and storage media, which replaced the old on-board tools.

Get information in real time with high frequency and low poll period of processing options allows the use of dynamic models of aircraft gas turbine engines to meet the challenges of diagnosis. Improving the accuracy of the diagnosis requires consideration of factors such as changes in geometrical parameters of the flow during prolonged use.

Solution

Analysis of modified engines the same structural scheme, but with different absolute values of their parameters, shows that the relative deviation of key data on their values specifications are the same. The above enables use of statistics of different engines to establish general patterns of changes of parameters of operating time [2].

These geometric parameters as nozzle area turbine units are essential, those that directly affect the data base engine (thrust and specific fuel consumption). The value of radial clearance is not affected directly based data engine, and their impact is on defining parameters such as compressor efficiency and turbine stages.

Foreign companies and airlines, since GTE earlier generations, carefully study the impact of attrition on the performance and operational reliability of the engines. For example, the company "Pratt-Whitney" surveyed the effects of wear on the compressor motor JT3D characteristics and stability of supplies engine starting mode [3].

To determine the radial changes during operation we use exponential regression equation:

$$\Delta\delta(\tau) = Ae^{\frac{\alpha}{\tau}} \qquad (1)$$

where A and α - constant coefficient.

To find the constant coefficients A and α least-squares method to minimize the expression:

$$Q = \sum_{i=1}^{n} \left[\lg \Delta\delta(\tau) - \lg A + \alpha \frac{1}{\tau_i} \lg e \right]^2 \qquad (2)$$

After differentiation cut Equations (2) and the corresponding transformations we obtain relations for the determination of lg A and α .

$$\lg A = \frac{\sum_{i=1}^{n} \lg \Delta\Pi(\tau j)}{n - \frac{\sum_{i=1}^{n} \frac{1}{\tau j}^2}{\sum_{i=1}^{n} \frac{1}{\tau_i^2}}} \left[1 - \frac{\sum_{i=1}^{n} \frac{1}{\tau_i} \lg \Delta\Pi(\tau_i)}{\sum_{i=1}^{n} \lg \Delta\Pi(\tau_i)} \cdot \frac{\sum_{i=1}^{n} \frac{1}{\tau_i}}{\sum_{i=1}^{n} \frac{1}{\tau_i^1}} \right];$$

$$z = 2{,}302 \frac{1}{\sum_{i=1}^{n} \frac{1}{\tau_i}} \left[n \lg A - \sum_{i=1}^{n-1} \lg \Delta\Pi(\tau_i) \right], \qquad (3)$$

The calculation sums the values included in equations (3), carried out by the number of experimental points n.

It is necessary to establish a link between changes in the value of radial

clearance and defining parameters (efficiency compressor stages). .
To solve this problem use the dependence given in [1]

$$\delta\eta_K^* = -K_1 z_K \left(2{,}8 \frac{\left(\overline{\delta} - 0{,}01\right)}{\eta_{cn.o}^*} + \frac{\delta\varepsilon_{TP}}{K_2} \right) , \qquad (4)$$

where K_1 and K_2 - coefficients of influence $[6]$; $Z_K -$ number of stages in cascade; $\overline{\delta}$ - the relative value of radial clearance; $\delta\varepsilon_{TP}$ - relative deviation ratio of losses by increasing the degree of surface roughness of blades. Value of $\delta\varepsilon_{TP}$ associated with the relative roughness of blades the following relation:

$$\delta\varepsilon_{TP} = \frac{(0{,}05 - 0{,}08)\varepsilon^{0{,}25}\left(\frac{b}{A}\right)}{\varepsilon_{TP.0}} - 1 , \qquad (5)$$

Where b - blade chord; A – width between blade channel; $\delta\varepsilon_{TP}$ - Initial value of the coefficient of losses.

Using formulas (4) and (5), you can continue to evaluate how changing the basic parameters of the engine and workflow options for stationary and transient conditions of GTE.

Due to the properties of materials radial gaps between the shoulder blades and stator compressor and turbine are changed as a result of heating units running of the engine.

It is important to remember that largest thermal load acting on the turbine blades and nozzle apparatus. It is very important is the development and application of methods of cooling blades and stator parts of the compressor and turbine.

In most cases, the cooling air in the turbine selected from low pressure compressor. The following relation is important: larger selection of air from the internal circuit, the lower the efficiency of the engine. It is therefore necessary to try to select cooling air from an external circuit. This pre-compression cooling air can be made in some pinpoint drive compressors. Design and development of such systems, the selection is not yet complete. But raising fuel efficiency by reducing engine bleed air for cooling can be achieved by improving cooling turbine blades. In patent No US 2004/0151587A1. authors suggest instead of the traditional method of cooling and design of turbine blades, use “micro-circulation” cooling system.

In the traditional method of cooling air carts ARE through the holes in blade shank, served in the internal longitudinal profile of the Annals of k, and then goes partly to the holes in the final section, later in the tract for gas (convective cooling method).

However, the convective efficiency of the method is not enough high, as 90 of the last century began to use film cooling. This method of cooling air time margin is derived through the holes in the front and creates a film to avoid direct contact of hot gases from the surface of the blade.

Despite the high efficiency cooling, this method has a significant drawback: the effective thickness of the profile increases the thickness of film cooling. Consequently, the degree of efficiency decreases, which affects the fuel efficiency of the engine.

Therefore, there appropriateness of use of convective cooling method in, but at a new level: instead of 3.4 radial canals, as was the traditional method, using highly developed system of "micro-circulation" channels below the surface of the blade.

This method of cooling avoids shortcomings of traditional methods (convection and film), to provide reliable cooling blades without increasing the effective thickness profile and the resulting gain increasing efficiency of the turbine. Analytical expressions to describe the impact the efficiency of stages based on GTE working process parameters may be obtained by solving systems of equations describing the motion of the rotors and the conditions of operation elements engine transient conditions [6].

$$\frac{dn;}{dt} = \frac{N_{Tj} - N_{Kj} - \Delta N_j}{(\pi/30)^2 J_{zj} n_j};$$

$$G^{Kj} - G^{K}(j+1) - \Delta G^{Kj} = 0;$$

(6)

$$G^{\kappa.з.} + \sum_{i=j}^{N} \Delta G_{c.a.i} + \sum_{i=j+1}^{N} \Delta G_{pKi} - G^{rj}(\pi_{Tj}, \tau_{uj}) = 0;$$

$\Phi(F_C)=0$; $\Phi_1(g_n)=0$; $\}$ control laws in the transition process.

where n_j - rotational speed of the j-s rotor; N_T and N_{Kj} - power turbine and compressor rotor j- s rotor; ΔN_j - Power of the shaft shown in the j-s rotor; J_{zj} - Moment of inertia of the j-s rotor; G_{Kj} and $G_{Kз}$ - air losses in compressor j-s stage and in combustion chamber; $G_{rj}(\pi_{Tj}, \tau_{uj})$ - gas losses determined by the characteristics of each turbine stage; $\Delta G_{CA.j}$ and ΔG_{pKj} - amount of air flow for cooling blades of the machine nozzle and impeller j-s stage turbine; g_{Π} - relative fuel consumption; F_C - area of the nozzle.

Solutions of equations are carried out after setting the initial conditions, such as options on the idle power by using a standard program of integration of differential equations.

Changes in efficiency of stages directly affect the output value of these stages, which are a system of equations (6).

Conclusions

The suggested approach allows to take into account and numerically describe the effects of changes in radial clearance in the compressor and turbine GTE on flow where gradational processes. Integrated application of the proposed method and technical solutions allows you to create the conditions for significant improvement in engine parameters during continuous operation.

References

1. *Панин В.В., Чумак О.Ч., Ратынский В.В., Шевченко М.А.* Анализ корреляционных связей термодинамических и геометричиских параметров ГТД// Авиационно-космическая техника и технология
2. *Бутончников А.П.* О влиянии наработки в летной эксплуатации на ухудшение параметров двухконтурных турбореактивных двигателей /*А.П.,.Бутончиков, Е.Д.Нестеров, С.С. Акимов, Э.Л.Симкин*// Труды ЦИАМ №:731, 1976. – 11 с.
3. *Arnold B.R., Gast J.R.* A cooperative airline program to evaluate engine parts aging effect on a current turbofan engine model.SAE «Preprints»,s.a., №700329,10 pp.,ill. Экспресс-информация ВИНИТИ, Воздушный транспорт, 1971, №16
4. Инженерные расчеты газотурбинных двигателей методом малых отклонений /А.Я.Черкез -М.: Машиностроение, 1975.-380 с.
5. Динамика авиационных ГТД / *Г.В.Добрянский, Т.С.Марьянова* – М.: Машиностроение, 1989.-240 с.
6. Неустановившиеся режимы работы авиационных газотурбинных двигателей / *Сосунов В.А.,Литвинов Ю.А.* – М.: Машиностроение, 1975.-216 с.

UDC 621.694.2:629.3082.3(045)

K.I. Kapitanchuk., PhD. Sc. Science,
P.I. Grekov, PhD. Sc. Science,
N.M. Andriyishyn, M. Y. Bogdanov
(National Aviation University, Ukraine)

INTEGRAL METHOD OF GAS EJECTORS CALCULATING IN MIXING CHAMBER WITH UNEVEN FLOW BY SECTIONS

The possibility of using the integral method of calculating of the gas ejector considering uneven flow along the mixing chamber.

Increase in requirements to efficiency of power plants, the desire to get the most power and provide the least resistance to external integration of glider of aircraft have led to the need for deep research of gas dynamics flow in the output devices, which are the most important elements of power plants.

Use of ejector jet nozzle (output devices) of various applications creates additional problems relating to issues of optimal aerodynamic design to improve the efficiency of their use with minimal loss of energy and decreasing cost of the life cycle.

A variety in gas-dynamic and geometric parameters of turbulent three-dimensional flow that determine the type, scheme and the laws regulating jet ejector nozzle (output devices) do not allow, nowadays, theoretically solve all problems that arise in practice in development of array of nozzles for modern and future aircraft. [1]

In all sections of the mixing chamber of the finite ejector length there is uneven distribution of gas flow parameters. Therefore, the calculations of the ejector at input and output cross-sections, where flows are considered consistant are insificient.

Most unreasoned is an introduction of idialized model of the mixing chamber and the assumption of complete mixing of flows. Mixing chamber has a length comparable to its diameter.

Therefore, the velocity profile of the initial flow in output cross-section of mixing chamber is inconsistant. Strict length of mixing chamber leads to flow pressure rates decrease in ejector.

Moreover, the inconsistance of the flow due to incomplete mixing reduces efficiency of the diffuser and increase the pressure therein. In general, change among the parameters of the jet flow is faster than in the ideal case, and mixture of cold air appears to be less intense.

Calculation of the flow mixing process in the mixing chamber of the ejector is one of the applications to the theory of a free jet. Two streams of different initial speed, temperature, molecular weight and chemical composure will mix in ejector mixing chamber to gradualy reduce all uneveness of parameters to form a consistant flow.

Fig. 1 shows a diagram of the flow in the mixing chamber and the process of formation of the velocity field in the cross section of mixing chamber [2-4]. Universality of fields in different cross-sections allows the calculation of flow parameters in any cross-section point of mixing chamber via certain integral dependencies.

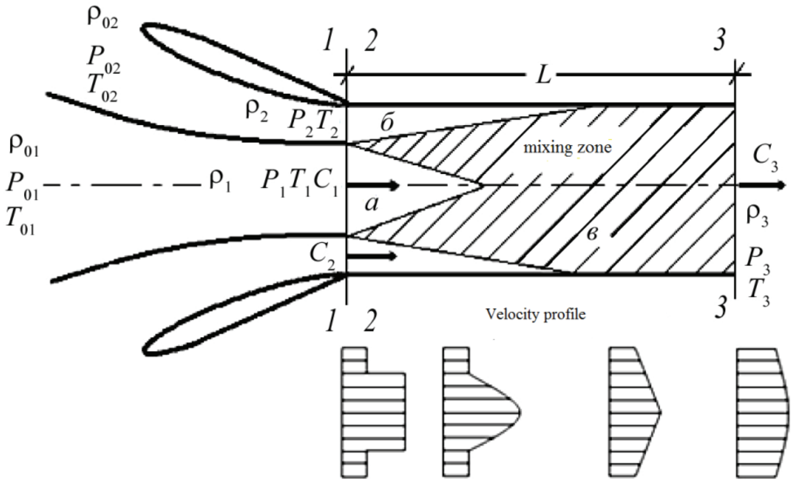


Fig. 1. Scheme of the flow in the mixing chamber of a gas ejector:
$\tilde{a}$ the potential core of active gas, $\tilde{b}$ a potential core passive gas;
$\tilde{c}$ mixing zone

To calculate the pressure in the short ejector one needs to know the total momentum in section *3-3*, that depends on the velocity profile.

Lets use the property of self-similarity profile in a turbulent mixing layer, as described in works of Abramovich [5] and Schlichting [6]:

$$c_1(x,r) = \frac{c_1(x)+c_2(x)}{2} + \frac{c_2(x)-c_1(x)}{2} f(z),$$

where $z = \dfrac{r - r_1(x)}{b(x)}$, $f(z)$ – universal function (at constant pressure of flow in cross-section).

To calculate the $f(z)$ formula $f(z) = (3z - z^2)/2$ can be used.

Other variables determined by the following algorithm:

– unperturbed velocity in the potential flow fields $c_1(x)$ and $c_2(x)$ defined by the values of static pressure from Bernoulli equation;

– half-width of the mixing layer $b(x)$ calculated with step-by-step integration of equation

$$db(x) = C' \frac{c_1(x) - c_2(x)}{c_1(x) + c_2(x)},$$ where – dimensionless constant [7];

– center of the mixing layer $r_1(x)$ calculated from the equation of conservation of mass in integral form;

– pressure $p(x)$ calculated with step by step integration of pulses equation

$$dp(x) = -\frac{dM}{A(x)}, \text{ where } M(x) = \int \rho C^2 dA .$$

Usually, integration of the equations to calculate $b(x)$ and $p(x)$ isn't difficult. Function $c_1(x)$ and $c_2(x)$ are the function of pressure (Bernoulli's law), and conversely, the pressure is a function of $c_1(x)$ and $c_2(x)$.

All variables in the right-hand side of equations must be defined from the previous step before iteration (Fig. 2). At the end of the jet potential Bernoulli equation is not applicable. Therefore, the value $c_1(x)$ calculated from the equation of conservation of mass and value of $r_1(x)$ considered equal to $b(x)$.

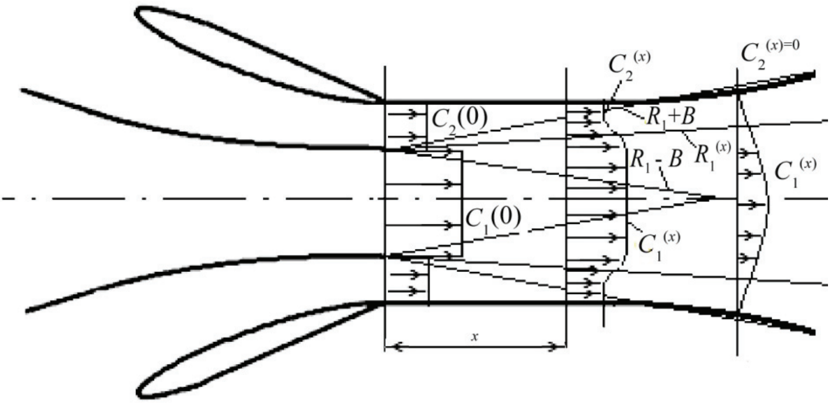


Fig. 2. Mixing chamber design model

The region of outer potential ends where the pressure is increased to value corresponding

$p(x) > p(0) + \rho c_2^2(0)/2$, in other words, at $c_2^2(x) < 0$.

This section describes cross-section, in which the mixing layer boundaries $(r_1 + b)$ does not reach the walls. If the mixing layer boundaries reaches the wall of the chamber, the Bernoulli equation must be replaced by another equation where $c_2(x) = 0$.

This based on an assumption of continuity $c_2(x)$. Its admission should be confirmed by comparing the calculation results with experimental data. In contrast to the approximate model of ideal mixing, used integral method can only be applied to axially symmetric ejectors. As the leafed nozzle significantly improves short ejectors output it's important to calculate the parameters for increasing ejection without using cumbersome three-dimensional applications.

Nozzle of arbitrary cross-sectional shape has axisymmetric equivalent of the same area, they differ from each other only by perimeter value.

Perimeter of leafed nozzle is greater than the perimeter of equivalent nozzle in K times [7], by value $K = P_r /(2\sqrt{\pi A_1})$.

It can be shown that axisymmetric approximation allows to simulate three-dimensional flow by changing dimensionless constant C' in the half-width mixing layer equation with $C' = KC'$.

In the case non-axisymmetric nozzle $K > 1$, corresponding thickness of the mixing layer grows faster than round nozzle case, mixing will be more intense and pressure grows at a short distance. However, in this case there is a problem determining static pressure at the mixing chamber inlet.

Conclusions

In all sections of the finite length ejector mixing chamber there is uneven distribution of gas flow parameters.

Therefore, the calculations of the ejector at input and output cross-sections, where flows are considered inconsistant, and in many cases are insufficient.

Thus, the idea of using the integral method for calculating the gas ejector considering uneven flow along the mixing chamber is put forward.

References

1. *Лаврухин Г.Н.* Аэрогазодинамика реактивных сопел // Внутренние характеристики сопел. — М.: Физматлит, 2003. — 376 с.
2. *Авиационные* эжекторные усилители тяги / В. Г. Ененков, А. Л. Клячкин, В. С. Коротков, В. М. Супрун; под ред. А. Л. Клячкина. – М. : Машиностроение, 1980. – 135 с.
3. *Дослідження* методів зменшення теплової помітності літальних апаратів / М. С. Кулик, П. І., Греков К. І. Капітанчук, О. Г. Ластівка // Промислова гідравліка і пневматика, 2008. – №1 (19). – С. 46–50.
4. *Греков П.І., Капітанчук К.І., Козлов В.В.* Pick up the question of definition gas-dynamic parameters of subsonic ejectors // The Fifth World Congress «Aviation in the XXI-st Century Safety in Aviation And Space Technologies». – Kyiv. : NAU, 2012. – V.1. – P. 1.13.15 –1.13.19.
5. *Абрамович Г. Н.* Теория турбулентных струй / Г. Н. Абрамович. – М. : ЭКОЛИТ, 1960. – 720 с.
6. *Шлихтинг Г.* Теория пограничного слоя / Г. Шлихтинг. – М. : Наука, 1974. – 711 с.
7. *Гогиш А.В.* Теория двумерных отрывных течений / А. В. Гогиш, В. Я. Нейланд, Г. Ю. Степанов // Итоги науки и техники. Гидромеханика. – М. : Наука, 1975. – С. 5–73.

UDC 629.735.083.02.06(045)

Yu. Yu. Tereshchenko, Phd, A. Tehrani, Post graduate student,
J. Abolhassanzade, Post graduate student,
(National Aviation University, Ukraine, Kyiv)

MODELING OF FLOW ON THE PLATE

Simulation results of flow on the plate in order to calculate the boundary layer thickness are presented in the work. Comparison results of numerical and physical experiments and analytical solution are given.

One way to explore the internal aerodynamics of aircraft engines is the use of numerical experiment.

Numerical experiment in the present time- it is one of the effective ways of theoretical research. It is based on the use of mathematical models of real processes. Numerical experiment is cheaper than the full-scale one, it can be easily and safely intervened, it can also be repeated and interrupted at any time. Numerical experiment is as a bridge between full-scale experiment and theoretical models.

Solving the problems of improving the internal aerodynamics in the air-gas channel of engine consists of several stages. One of them is the correct modeling of the boundary layer.

The purpose of this work is to make a computational analysis of the boundary layer on the plate by doing a numerical experiment, and then to compare the results of the computational analysis and the results of physical experiment.

We take a look the longitudinal flow along a flat surface boundless body by fluid flow. The temperature and speed of the incoming flow are constant. When the liquid particles in contact with the body surface, they "stick" into it. As a result, in the area near the plate due to the action of viscous forces, a thin layer of the inhibited liquid is formed, within which the speed changes from 0 at the surface of the body to the speed of the undisturbed flow away from the body. This inhibited layer is called hydrodynamic or simply dynamic boundary layer.

The greater the distance x from the front edge of the plate, the thicker boundary layer, because the effect of viscosity of the liquid as it moves further along the body enters into the undisturbed flow.

For fluid flow inside the boundary layer have the condition $\partial u/\partial y \neq 0$, outside the boundary layer and on its outer edge $\partial u/\partial y = 0$.

The concept of "boundary layer thickness" and "outer border of the boundary layer" is quite arbitrary, because there is no sharp transition from the boundary layer to flow outside the layer. Speed in the boundary layer with increasing coordinates in asymptotically approaches to the speed in the flow core.

We estimate the thickness of the boundary layer δ. The thickness of the boundary layer for a laminar flow is equal [1, 2]:

$$д = 5\sqrt{\frac{н \cdot l}{U}}\ ,\qquad (1)$$

ν - Kinematic viscosity, l - Length of the plate, U - Speed in the flow core (outside the boundary layer).

If we divide the boundary layer thickness δ to the length of the plate l, we will obtain the dimensionless boundary layer thickness, which can be determined by the formula [1]:

$$\frac{\delta}{l} = \frac{5}{\sqrt{\mathrm{Re}_l}}\ ,\qquad (2)$$

Re_l - The Reynolds number, composed for the length of the plate is equal

$$\mathrm{Re}_l = U \cdot l / \nu\ .\qquad (3)$$

Formula (1) shows that the thickness of the boundary layer δ is proportional to $\sqrt{\nu}$, and $\sqrt{l}$. Replacing the length l by the variable distance x from the front edge of the plate, we can see that the boundary layer thickness δ increases proportionally $\sqrt{x}$.

On the other hand, the equation (2) illustrates that the relative thickness of the boundary layer $\frac{\delta}{l}$ decreases with increasing Reynolds number Re_l proportionally $1/\sqrt{\mathrm{Re}_l}$, therefore the boundary layer disappears with the transition to the liquid, it means to $\mathrm{Re}_l \to \infty$.

The flow along the plate remains laminar as long as the number Re_l does not exceed $5 \cdot 10^5$ up to 10^6. When the Reynolds number Re_l is high, the boundary layer becomes turbulent.

Since the transfer speed of the boundary layer to the velocity of the outer flow occurs asymptotically, the determination of the thickness of the boundary layer to a certain extent arbitrary. However, for practical purposes, this arbitrariness is irrelevant, since the velocity in the boundary layer reaches the speed of the external flow is already at a very small distance from the wall. Under the boundary layer thickness is meant the distance from the wall at which the velocity in the boundary layer is characterized by a core flow rate by 1%.

Along with the boundary layer thickness is often used concept of displacement thickness δ^*.

This thickness is determined by the formula below:

$$U \cdot \delta^* = \int_0^{\delta} (U - u)dy\ .\qquad (4)$$

Displacement thickness - is the distance that the move away from the body of the external flow streamlines due to the formation of the boundary layer (the displacement effect of the boundary layer).

In the turbulent boundary layer flow is generally due to higher energy loss to be thicker than in the laminar flow. When longitudinal flow smooth flat plate boundary layer thickness increases downstream proportionally $x^{0.8}$, where x the distance from the front edge of the plate. For turbulent flow around a plate thickness of the boundary layer is determined by the formula (5):

$$\frac{\delta}{l} = 0.37(\mathrm{Re}_l)^{-1/5}\,. \tag{5}$$

In this work, as mentioned before, we have the task of comparing the results of numerical and physical experiments and analytical solutions. The object of study is the flow along the plate with length 50cm. Calculation of the gas flow is made by the numerical solution of the average Navier–Stokes equations (Reynolds equations). We used turbulent viscosity model SST Menter [3] to close the equations.

In the numerical experiment number Re_l was changed within $\mathrm{Re}_l = 1.08\cdot10^5 \div 7.28\cdot10^5$. Results of the numerical experiment are shown in the graph below, where they are compared with theoretical solutions and with the experimental data [1].

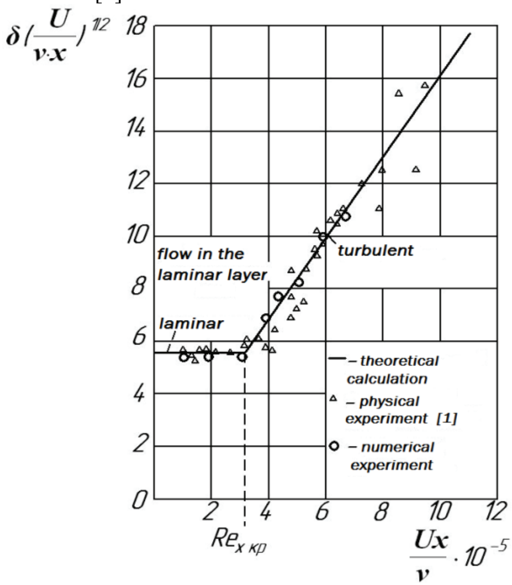


Fig. 1. The dependence of the thickness of the boundary layer on a flat plate streaming in a longitudinal direction from the Reynolds number

When the flow is along the plate the boundary layer remains laminar near its front edge and only becomes turbulent at a certain distance $x_{кр}$ from the front edge. The distance $x_{кр}$ determined by the critical Reynolds number $\mathrm{Re}_{lкр} = \left(\frac{\mathrm{U} \cdot \mathrm{x}}{\nu}\right)_{кр} = 3{,}2 \cdot 10^5 \div 3 \cdot 10^6$. Analysis graph (1) shows that the results of numerical and physical experiments have good convergence. When modeling the flow with a small error is obtained, the transition point of the laminar boundary layer in turbulent.

In the figure 2 for the example fragment pattern formation of the boundary layer on a plate $\mathrm{Re}_l = 7.28 \cdot 10^5$ is given:

Fig. 2. The fragment pattern of formation of the boundary layer on the plate

Conclusions

The numerical results are compared with experimental data [1]. This fact demonstrates a good convergence, approving the possibility of using this method of calculation for further researches.

References

1. Schlichting. Theory of the boundary layer/ Schlichting – M: «Science», 1969. – 742c.
2. Loitsyansky. Laminar boundary layer/ Loitsyansky – M: «Science», 1962. – 478c.
3. Menter F.R. Two-equation eddy viscosity turbulence models for engineering applications// AIAA J.- 1994. - 32, №11. - P.1299-1310

UDC 629.735.03:621.43.031.3(045)

*Yu.M. Tereschenko, Dr of Eng., K.V. Doroshenko, Ph.D.,
Yu.Yu. Tereschenko, Ph.D. (National Aviation University, Ukraine, Kiev)*

NUMERICAL SIMULATION OF FLOW AT COMPRESSOR STAGE

This paper presents the question about choise of mesh at modeling viscous gas flow at compressor stage. The results of numerical simulation and physical experiments must be compared.

Computational fluid dynamics (CFD) is concerned with numerical solution of differential equations governing transport of mass, momentum, and energy in moving fluids. Today, CFD finds extensive usage in basic and applied research, in design of gas turbine engine, airplanes ets.

For a long time, design of gas turbine engines depended on painstakingly generated empirical information. The empirical information is typically displayed in the form of correlations or tables and nomograms among the main influencing variables.

Today, numerical simulation has widespread using in turbomachinery.

Aerodynamic improvement of compressors is one of the leading research areas of gas turbine engines [1]. Numerical experiment allows at the design stage to improve the performance of engine components. However, one important question remains the validity of the numerical experiment. At decision this issue significant role played by the choice of computational mesh, model Turbulence viscosity, selection the method of calculation, etc [2-3].

The aim of this paper is to estimate the influence of the quality of the mesh for the simulation of axial-flow compressor cascade on validity the results. The results of numerical simulation and physical experiments must be compared.

CFD uses a series of cells (referred to as control volumes), elements and nodes that combined form the so called mesh. It is at each of these node locations, that CFD calculates the fundamental equations of fluid dynamics. The shape of the cells greatly impacts the accuracy of the solution due to discretisation errors, therefore the meshing stage is one of the most crucial stages in the problem simulation.

There are 2 types of meshing predominately used in CFD today, namely: 1. structured meshing; 2. unstructured meshing. Structured meshing uses hexagonal shaped elements (12 edges and 8 nodes) while unstructured meshing uses tetrahedron shaped elements (6 edges and 4 nodes). Both mesh types have their strengths and weakness and are listed in Table 1.

In the numerical solution of partial differential equations (PDE) a discrete domain is chosen where algebraic analogues of the PDEs are solved. One standard method is to introduce a grid and estimate the values of the unknowns at the grid points through the solutions of these algebraic equations. The spacing of the grid points determines the local error and hence the accuracy of the solution. The spacing also determines the number of calculations to be made to cover the domain of the problem and thus the cost of the computation.

Table 1

Name	Structured Mesh	Unstructured Mesh
Strengths	• Allows user high degree of control. Mesh can be accurately designed to user's requirements; • Hexahedral cells are very efficient at filling space, support a high amount of skewness and stretching before affecting solution; • Grid is flow aligned which helps the solver converge; • Post-processing is easier due to the logical grid spacing act as excellent reference points for examining the flow field.	• Automated grid generation allows much less effort by user to define mesh; • Well suited to inexperienced users; • Will generate a valid mesh for most geometries; • Users are able to get results for relatively large mesh size quickly.
Weakness	• Excessive time spent producing the mesh compared to unstructured mesh; • Some geometries don't allow structured topology due to the high skewness angles and stretch of cells that are required.	• Lack of user control - mesh may not be defined as well as the user may like in certain areas; • Tetrahedral elements do not twist or stretch well, which will severely impact accuracy of results; • Require excellent CAD surfaces. Small mistakes in the geometry can lead to large meshing problems; • Post processing software requires larger computer power to generate.

For well behaved problems a grid of uniform mesh spacing (in each of the coordinate directions) gives satisfactory results. However, there are classes of problems where the solution is more difficult to estimate in some regions (perhaps due to discontinuities, steep gradients, shocks, etc.) than in others. One could use a uniform grid having a spacing fine enough so that the local errors estimated in these difficult regions are acceptable. But this approach is computationally extremely costly. Besides for time dependent problems it is difficult to predict in advance a mesh spacing that will give acceptable results.

The aim of this study is to find the most optimum *unstructured mesh*.

Was performed a series of gas dynamic calculations in CFX for the axial-flow compressor cascade. Compressor cascade has the following characteristics: blade spacing t = 32mm, blade chord b = 52mm, angle of attack i = 2 ° (Fig. 1). The calculation was performed for three variants of unstructured mesh, variants № 2-3 are adaptive unstructured mesh. Mesh №1 has ≈200000 cells, mesh №2 has ≈500000 cells, mesh №3 has ≈1200000 cells.

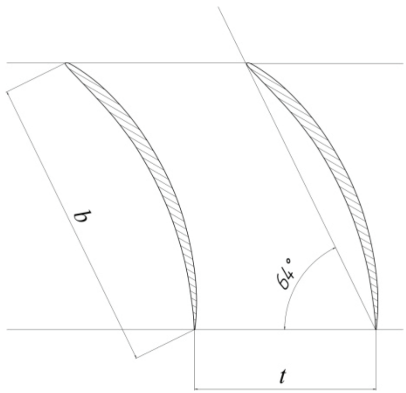


Fig.1 Scheme of axial-flow compressor cascade

The numerical solution of the Navier–Stokes equations for turbulent flow is extremely difficult, and due to the significantly different mixing-length scales that are involved in turbulent flow, the stable solution of this requires such a fine mesh resolution that the computational time becomes significantly infeasible for calculation or direct numerical simulation. Attempts to solve turbulent flow using a laminar solver typically result in a time-unsteady solution, which fails to converge appropriately. To counter this, time-averaged equations such as the Reynolds-averaged Navier–Stokes equations (RANS), supplemented with turbulence models, are used in practical computational fluid dynamics (CFD) applications when modeling turbulent flows. Some models include the Spalart-Allmaras, k-ω (k-omega), k-ε (k-epsilon), and SST models, which add a variety of additional equations to bring closure to the RANS equations. Large eddy simulation (LES) can also be used to solve these equations numerically. This approach is computationally more expensive-in time and in computer memory-than RANS, but produces better results because it explicitly resolves the larger turbulent scales. In this work, we used turbulence model SST. This model provides adequately calculation of the flow in the core of the flow and the boundary layer [4].

Figure 2 shows the instantaneous total pressure distribution for the mesh №3 at $\lambda = 0.4$

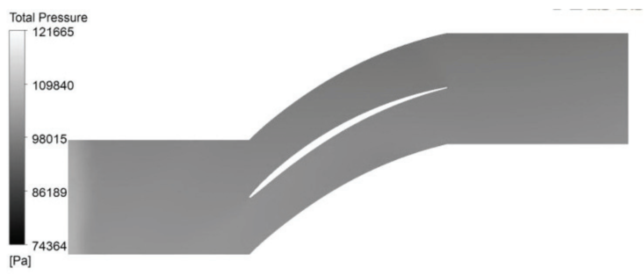


Figure 2 Instantaneous total pressure distribution for the mesh №3 at $\lambda = 0.4$

Research on the influence of the mesh was made by comparing the three calculations described above compressor cascade. As a quality criterion used mesh distribution of total pressure losses, which is obtained by the calculation shown in Fig. 3. According given distributions shows that almost coincides with the experimental distribution of losses obtained on the mesh number 3. Variant number 2 shows almost similar results to the experiment, and the coarsest mesh gives too blurry wake. In general, increasing the dimension of the mesh, the wakes are stretched.

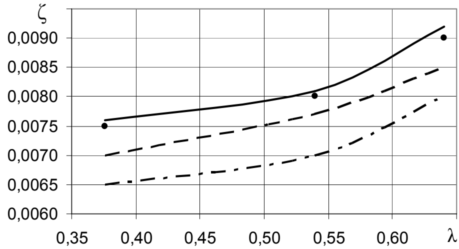


Fig.3 Distribution of total pressure losses

– · – · - mesh №1; – – – - mesh №2; — - mesh №3; • - experiment data [5].

Thus, the mesh number 3 gives the most reliable results.

Conclusions

In this paper we estimated the influence of the quality of the mesh for the simulation of axial-flow compressor cascade on validity the results. The results of numerical simulation and physical experiments are compared.

The study showed that a preference for the calculation of the flow in the compressor cascade should be given to adaptive meshes and cell size in mesh should be small enough.

References

1. Терещенко Ю.М. Аэродинамическое совершенствование лопаточних аппаратов компрессоров / Ю.М. Терещенко // – М.: Машиностроение, 1987. – 168с.
2. Терещенко Ю.М. Теорія теплових двигунів / Ю.М. Терещенко, Л.Г. Бойко, С.О. Дмитрієв та ін.; за ред. Ю.М. Терещенка. // – К.: Вища шк., 2001. – 382с.
3. Бойко А.В. Применение вычислительной аэродинамики к оптимизации лопаток турбомашин / А.В. Бойко, Ю.Н. Говорущенко, М.В. Бурлака // – Х.: НТУ «ХПИ», 2012. – 192с.
4. Menter F.R. Two-equation eddy viscosity turbulence models for engineering applications// AIAA J.- 1994. - 32, №11. - P.1299-13102
5. Аэродинамические характеристики компрессорных решеток / В.С. Свечников, А.Б. Кириллов // Технический отчет ЦАГИ №142. – М.: ЦАГИ, 1957. – 54с.

UDC 629.735.083.004.58:004.801.3(045)

O.S. Yakushenko, PhD (engineering), O.V. Popov, PhD (engineering), K.V. Doroshenko, PhD (engineering),Y.Y. Tereshchenko, PhD (engineering), V.E. Miltsov, P.O. Vlasenko (National Aviation University, Ukraine, Kyiv)

GAS TURBINE ENGINES DIAGNOSING WITH NEURAL NETWORK: DATA FOR STATIC NETWORK TRAINING

The problem of preparation of data for neural networks training to recognition of a technical state of gas turbine engines is considered. These data consist of train and test sets. These data are received as result of mathematical simulation of engine operation process. They should include registered parameters of engine operation process, represent wide range of modes and exploitation conditions, enclose measurement errors of these parameters.

Problem statement

Utilization of neural network is the mainstream of development of the automated engine diagnosing systems. Flexibility and polymorphism of its structure are distinctive features of such diagnostics systems.

This work is continuation of the works described in articles [1÷5]. In these works approaches to the problem of neural network primary optimization are considered. These approaches include:

– date generation for networks train;
– the choice of training method;
– the choice of network structure and its neurons types;
– final optimization method.

All these works were fulfilled for train and test data sets composed with diagnostic deviations [1,4]. Some assumptions and simplifications have been made. The result of it is necessity of elaboration of train and test sets obtain methods.

The analysis of researches and publications

In articles [1÷5] questions of a choice of a neural network train method and definition of its structure are already considered. These researches were fulfilled for engine ПС-90А [6,7]. In research [1÷5] diagnostic deviations of thermodynamic parameters from etalon values have been used to train and optimize diagnosing network. For calculations of these diagnostic deviations the mathematical model of an etalon engine has been used. Besides it these deviations have been gotten for engine in standard atmospheric conditions. It has led to necessity of inclusion in final algorithm of methods of operation process parameters reduction to standard atmospheric conditions which creates additional diagnosing errors. Train and test sets have been generated to describe only one operation mode. Additional analysis of relation between diagnostic deviations and operation mode has shown significant dependence between them. And, at last, the sets don't include registered parameters measurement errors.

Considering it the purpose of this work is elaboration of method of train and test set creation. These sets have to ensure creation and optimization of a static neural network intended for gas turbine engine diagnosing by thermodynamic parameters

in wide range of modes and environment conditions by registered parameters measured with errors.
Data set for train of a neural network to recognition of engine flow part defects.
As a base algorithm for calculation of train and test data sets the algorithms shown in [1,4] is used. Case of gradual degradation of a flow part is considered. Sets will include parameters of serviceable and defect engines. Single and double defects will be taken into account.

Main changes in the algorithms [1,4]

Firstly, in numerical experiment train and test sets will be calculated for some range of engine modes. As diagnosing modes high modes will be used. It permits to decrease influence of parameters measurement errors on results of engine diagnosing.
As mode parameter in numerical experiment frequency of a low pressure rotor is used. The range of this parameter has to include all take-off modes: nominal and maximal modes. Taking into account information in [6,7] as range for mode parameter it is necessary to choice the range 85,3–93,5 %%.
Secondly, in numerical experiment train and test sets will be calculated not only for standard atmospheric conditions but also for all possible conditions of aircraft take-off. Taking into account information in [6÷8] as such it is necessary to accept next ranges:
– barometric height of an airdrome from: minus 200 m to 2000 m;
– stagnant temperature in inlet duct of engine: from minus 40 ºC to plus
40 ºC;
– humidity: from 20 to 100 %%.
Unlike algorithms [1,4] train and test set will include not diagnostic deviations of registered parameters from etalon values but values of these parameters. Besides seven registered diagnosing parameters (frequency of a high pressure rotor; fan exit stagnation pressure; compressor exit stagnation pressure; compressor exit stagnation temperature; turbine exit stagnation temperature; fuel consumption; ratio of turbine exit stagnation pressure and atmospheric pressures) to data sets mode parameters have to be included (stagnation temperature in inlet duct; stagnation pressure in inlet duct; frequency of a low pressure rotor).
Measurement errors are the last factor that should be taken into account in algorithm of sets generation. To do it to values of all these ten parameters random variables which simulate random components of these parameter's measurement errors will be added. Errors for all parameters have normal distribution with zero average and standard deviations which are defined by registration system characteristics for corresponding parameters (tab.1).

Conclusions

The work describes approach to preparation of data for neural networks training for gas turbine engine technical state recognition. This approach ensures accuracy of diagnosing by means of exception from diagnosing process of additional algorithms and models and by account of parameters registration errors.

Table 1

Characteristic of parameters used for neural network training

Parameter	Units	Registration range	Registration error	Standard deviation of registration errors
Barometric height, H_b	*km*	*-0,3..13*	*0,03*	*0,01*
Mach number, M	-	*0..0,9*	*0,02*	*0,0066*
Inlet duct stagnation temperature, T^*_{in}	*K*	*210..320*	*0,11*	*0,0367*
Frequency of a low pressure rotor, n_{lp}	*%*	*1,7…108*	*0,16*	*0,053*
Frequency of a high pressure rotor, n_{hp}	*%*	*0,6…106*	*0,16*	*0,053*
Fan exit stagnation pressure, P^*_f	*kPa*	*25…200*	*5*	*1,67*
Compressor exit stagnation pressure, P^*_c	*kPa*	*300…3600*	*81*	*27*
Compressor exit stagnation temperature, T^*_c	*K*	*300…920*	*5,5*	*1,8*
Turbine exit stagnation temperature, T^*_t	*K*	*300…1230*	*4,6*	*1,53*
Fuel consumption, G_f	*кg/h*	*550…7200*	*200*	*68*
Ratio of turbine exit stagnation pressure and atmospheric pressures, $\overline{P_t^*}$	-	*1..1,9*	*0,035*	*0,0117*

Such approach includes next main points:
– train and test data sets will be calculated not only for a certain mode but for some range of engine modes;
– train and test sets will be calculated not only for standard atmospheric conditions but also for all conditions of aircraft take-off;
– the sets will consist of not diagnostic deviations of registered parameters from etalon values but of values of these parameters including mode and environment parameters;
– parameters in data sets will be also generated with a glance to random component of measurement error.

References

1. Кучер О.Г. Розпізнавання технічного стану авіаційних ГТД з використанням нейронних мереж / О.Г. Кучер, О.С. Якушенко, В.Ю. Сухоруков // Вісник двигунобудування: – Запоріжжя: ЗНТУ, ХАІ, ОАО Мотор Січ, №1, 2002. – С. 101 - 106.

2. Кучер А.Г. Многокритериальное диагностирование проточной части авиационных газотурбинных двигателей / А.Г. Кучер, С.А. Дмитриев, А.В. Попов, А.С. Якушенко // Вісник двигунобудування. Зб. наук. пр. – Запоріжжя: ОАО Мотор-Січ. – 2009. – № 3. – С. 166 - 171.

3. Кучер О.Г. Первинна оптимізація архітектури нейронної мережі / О.Г. Кучер, О.С. Якушенко, В.М. Степаненко, В.Є. Мільцов // Вісник двигунобудування. Зб. наук. пр. – Запоріжжя: ОАО Мотор-Січ. – 2009. – № 3. – С. 166 - 171

4. Якушенко О.С. Нейронні мережі для діагностування газотурбінних двигунів / О.С. Якушенко // Вісник НАУ. – Київ. – 2004. – № 2 (20). – С. 67 - 71.

5. Якушенко О.С. Оптимізація розміру нейронної мережі діагностування ТРДД з урахуванням ефекту перенавчання / О.С. Якушенко // Вісник НАУ. – 2010. – № 1 (42). – С.58 - 64.

6. Матейко Г.П. Конструкция и эксплуатация силовых установок ПС-90А и ВСУ ТА-12-60 самолета Ту-204 / Г.П. Матейко // Учебное пособие. – Ульяновск: УВАУ ГА, 1996. – 111 с.

7. Соловьев Б.А. Устройство и эксплуатация силовых установок самолетов Ил-96-300, Ту-204, Ил-114 / Б.А. Соловьев, А.А. Иноземцев, А.А. Куландин, И.А. Рожков, В.С. Акуленко // Учеб. пособие для вузов, Под ред. Соловьева. – М.: Транспорт, 1993. – 171 с.

8. ГОСТ 24631-81 Атмосферы справочные. Параметры. – Введ. 01.07.1982. – М.: Изд-во стандартов, 1981. – 30 с.

UDC 621.002: 621.82

A.V. Goroshko, Ph.D., V.P. Royzman, D.Sc.,
(Khmelnitsky National University, Ukraine, Khmelnitsky)

SOLUTION OF INVERSE PROBLEMS OF DYNAMICS OF AN AIRCRAFT ENGINE TURBOPUMP TO REDUCE ITS VIBRATION

Solved the inverse problem of searching for valid values for eccentricities specified in specifications values support reactions for balancing on low speed balancing machines. Performed parametric identification eccentricities stiffness, mass, reduced to a mathematical model describing the rotor. Balancing was made at the operating frequencies.

Introduction.

Turbopump containing high-speed rotors are widespread in the missile, aircraft, chemical and other industries. When operating turbopump often have higher vibrations. Since the analyzed type of TNA -150, had increased vibration caused by an imbalance of the rotor, it was necessary to understand the reasons for this, reduce vibration, rotor deformation, stress and strain on its bearings. Attempts to reduce the vibration of the rotor by reducing allowable values of the residual imbalances when the low-frequency balancing in two planes of correction is given positive results, increasing the complexity and cost of the process.

Formulation and solution of the inverse optimization allowable eccentricity

Initially, it was decided to formulate and solve the inverse problem with multiple wording: is it possible to do by balancing the low-frequency vibration and reduce support reactions to the desired level, and, if so, what should be the value of the residual imbalances on disks (or eccentricities).

Was chosen for this mathematical model of three-mass turbopump, written equations relating eccentricities with support reaction.

Due to the fact that precise values of the stiffness and the critical speed of the rotor have been known, but their calculation by the drawing data would be very problematic and questionable results, it was decided to test the static rotor and a static experimental influence coefficients.

Static tests rotor TNA-150 to determine the influence coefficients were carried out on the machine DM -30M . As a result of experiments matrix was prepared compliances $\mathbf{A}'$, whose elements a_{ij} are the coefficients of static effect, equal to the magnitude of deflection in *i*- th section from the action of a unit force in *j*- th section, i, j =1,2,3. Based on the static influence coefficients by solving the determinant of the secular equation D

$$D = \begin{vmatrix} m_1\alpha_{11}\omega^2 - 1 & m_2\alpha_{12}\omega^2 & m_4\alpha_{13}\omega^2 \\ m_1\alpha_{21}\omega^2 & m_2\alpha_{22}\omega^2 - 1 & m_3\alpha_{23}\omega^2 \\ m_1\alpha_{31}\omega^2 & m_2\alpha_{32}\omega^2 & m_3\alpha_{33}\omega^2 - 1 \end{vmatrix} = 0, \tag{1}$$

where m_1 =4,05 kg, m_2 =2,74 kg, m_3 =11 kg, refined the critical frequency of the rotor on rigid supports: ω_1 =20,5·10^2 1/s, ω_2 =32,5·10^2 1/s, corresponding n_1 =19500 rpm, n_2 =31100 rpm.

The difference between the critical speed of the rotor, the resulting solutions of the determinant of the secular equation (1), drawn up on the basis of the static influence coefficients, and indeed, was 3400 rpm, i.e. 21% 16100 rpm.

Determination of permissible values of eccentricities and disk impellers made in accordance with the multiple approaches to solving inverse problems, described in [1], which are as follows.

Denote $\mathbf{Д} = \{\Delta_1, \Delta_2, ..., \Delta_n\}$ - vector whose components are the product of the masses of disks and their residual eccentricities, ie imbalances, where n - number of disks. Vector $\mathbf{Y} = \{y_1, y_2, ..., y_n\}$ deflection values satisfy

$$\mathbf{Y} = \omega^2 \mathbf{AY} + \omega^2 \mathbf{A'Д},$$

where $\mathbf{A'}$ - compliance matrix α_{ij}, experimentally determined and $\mathbf{A}$ - matrix composed of works $\alpha_{ij} M_j$, where M_j - mass disks. Hence $\mathbf{Y} = \omega^2 \left(E - \omega^2 \mathbf{A}\right)^{-1} \cdot \mathbf{A'Д}$, where E - identity matrix.

Expressions for the reactions of the rotor poles are of the form:

$$R_i = \sum_{j=1}^{n} b_{ij} \left(M_i y_i + \Delta_i\right) \omega_i^2, \; i = 1, 2,$$

where b_{ij} - known quantities, expressed in terms of distance from the plane to the planes landing disks respective supports. Valid values eccentricities impellers and drives can be found by solving the problem of vector optimization, where optimality criteria have $\Delta_i \to \max, \; i$ =1,2,3, and restrictions for the support reactions are inequalities $|R_i| <$ 300 N, i =1, 2, and bounded by the values of deflections 0,1 mm.

Inverse problem showed that exceedance values for support reactions in 300 N, it is necessary that the values of admissible residual eccentricities in each section did not exceed 0,0008 mm, i.e. permissible unbalance should not exceed 0,04 g·cm, single-precision balancing machines 5 g·cm.

Making technologists withstand such eccentricities values at the current balancing equipment and balancing technology is unrealistic, and possible imbalance in the operation, so it was concluded that, in this structure, the unit assigned task of balancing the low-frequency correction in two planes has no solutions in practice and should be search for a fundamentally different way of reducing decreasing of products. It has been suggested that the rotor can not be regarded as rigid, and hence it is impossible to balance at low speed without the flexibility of the rotor. To test this hypothesis, it was necessary to test dynamic rotor, which is much more complicated static, but is much more accurate and informative than them.

Dynamic tests rotor broke up to 18000 rpm. Then cut off the power to the motor and the rotor rotates freely to a stop. Record strain gauges and vibration sensors was conducted throughout the speed range, from 2000 rpm during acceleration and in some modes - at a constant frequency and shutter speed freewheel.

Point values of deflections allowed to formulate and solve the inverse second task - parametric identification eccentricities and elastic-inertial characteristics of the rotor.

Formulation and solution of the problem of identification of eccentricities

The purpose of the inverse problem was posed to the measured deflections in three sections of the rotor to identify the size and location of the eccentricities (imbalances) of each of the masses for subsequent installation of compensating balances their loads. But compiled equations to solve this problem will find not only the values of eccentricities, but also more accurately than in static tests - stiffness values and calculate the critical frequency of the rotor.

To write the equations of motion of the rotor were used integrodifferential depending bending theory, whereby each of the three sections of the rotor in projections on two mutually perpendicular planes were recorded equations relating unknown stiffness distribution EJ, masses m and eccentricities e with deflections y rotor shaft.

$$\beta_0 K''_{zz}(Z,\omega_j) + 2\beta_1 K'(Z,\omega_j) + \beta_2 K(Z,\omega_j) - e_y\omega_j^2 = \omega_j^2 y \quad , \quad (2)$$

where $\beta_i = \beta_i(Z) = \dfrac{1}{m}\cdot\dfrac{d^{(i)}EJ}{dZ^i}$, i=0,1,2, $K(Z,\omega) = y''/\left[1+(y')^2\right]^{3/2}$ – curvature of the elastic line of the rotor, Z – coordinate rotor section, measured along the axis of rotation.

Using the obtained values of the projections of the rotor shaft deflections measured at speeds 14100, 15000, 15600, 16000 rpm and four first derivatives, constituted by two systems of linear algebraic equations of type (2) for each of the calculated cross sections 1, 2, 3, which identified eccentricities, stiffness and weight.

Prior to solving systems of equations (2) were calculated condition number of their matrices, whose values were within 3,2-6,7. From this it follows that the possible error in determining the unknown could be up to 134% with precision instrumentation for measuring the deflection of 15%. To improve the accuracy of the calculations was applied a statistical method to ensure the stability of mathematical models [2]. In this case, the measurement of deflections were repeated at least 50 times and found the expectations and values of the phases of these deflections. These average values and were substituted into equation (2), thus reducing the possible error in the solution to more than 7 times.

Using the identified values of β_0 and β_1, for each of the 3 sections found values of the reduced mass m_i and rigidities EJ_i, i = 1,2,3 rotor shaft according to the formulas:

$$m(Z) = M \cdot \exp\left(\int_0^Z \frac{\beta_1}{\beta_0} dZ \right), \quad EJ(Z) = m(Z) \cdot \beta_0(Z),$$

where M - rotor mass.

Further, according to the formulas $D_i = M_i \sqrt{e_{xi}^2 + e_{yi}^2}$, $\varphi_i = arctg\left(e_{yi}^2 / e_{xi}^2\right)$ i =1,2,3 determined the magnitude of the imbalance of the rotor angle and compiled them with the axis OX chosen coordinate system: D_1 =23,7 г·см, D_2 =2,48 г·см, D_3 =30,6 г·см, φ_1 =95°, φ_2 =170°, φ_3 =102°3′ and compensated for their.

As a result of balancing correction weights maximum deflection of the rotor shaft in the range 2000-18000 rpm reduced by approximately 6 times, the vibration amplitude poles - 4 times, the static stresses in the material of the shaft – 3,5 times, and dynamic - 3 times.

Next, we calculated the critical frequencies of the rotor for the identified stiffness and mass, reduced to the highest dynamic model. To do this, from the known values EJ for portions of the rotor using integral Mora calculated values of the coefficients of influence, and then from the expression (1) found ω_1 =1732 1/s и ω_2 =2625 1/s, corresponding n_1 =16500 rpm, n_2 =25080 rpm.

The difference between the first critical speed, identified by the calculated mass and stiffness, and a critical frequency of the rotor during operation the TNA measured is 400 rpm i.e. 2,49% of 16100 rpm.

Conclusions

In this paper we have solved the inverse dynamics problem. Calculated values and phase angles of the eccentricities allowed to make balancing on the operating speed in three planes of correction, which resulted in vibration down about 6 times, the amplitude of vibration supports - 4 times the static stresses in the material of the shaft - 3.5 times, and dynamic - 3 times.

References

1. V. Royzman, A. Goroshko. Multiple inverse problem. - Journal Of Vibroengineering. September 2012. Volume 14, ISSUE 3. ISSN 1392-8716. P. 1417-1424
2. Goroshko Andrii. Ways to improve the accuracy of solutions of inverse problems / A.V. Goroshko, V.P. Royzman // Journal of Khmelnitsky National University. - 2013. Number 6. - P. 60-69

UDC 629.735.03:681.518.54(045)

V.V. Kozlov , Ph.D. (National Aviation University, Ukraine, Kyiv)

OPERATIVE CONTROL OF TECHNICAL STATE OF GAS TURBINE UNITS

Analysis of existing methods of on-line diagnostics of gas turbine engines is given. Definition of methods of important scientific and applied problem of parametric control efficiency quality of parametric analysis is decrypted.

Introduction

At the present days more often in aviation, energetic and gas transportation, different methods of technical condition estimation are used, and also systems and means of diagnostics of objects of this direction. One of such ways is the well-known way of technical state diagnostic of axial compressor [1] of gas turbine engine (GTE) by such criteria as deviation of efficiency coefficient from its initial value$\Delta\eta_к$. For determination of this criteria, rotational speed of compressor at one of its operational modes n_p is measured, and according to the basic characteristic of the compressor correspondent basic pressure ratio is determined. After this by changing of rotational speed of compressor the pressure ratio of compressor is regulated with correspondence to its basic value $\pi_{кб}$ and measure correspondent rotational speed $n_б$, and the deviation of efficiency coefficient of compressor is found by the dependence:

$$\Delta\eta_к = k(\Delta n / n_p),$$

where $\Delta n = n_б - n_p$ – difference between rotational speeds, which corresponds to basic value $\pi_{кб,}$ and initial rotational speed at operating mode, k = 1,0…2,5 – constant coefficient, which depends on the type of compressor.

Assume that this is not enough for estimation of compressor state. It is known that, operating mode of compressor determined by the values reduced to ACS rotational speeds $n_{пр}$, and air consumption $G_{пр}$ through compressor, determined by the parameters of working body at the input to the compressor [2]. That's why it is impossible to determine technical state of flow part of compressor only with measurement of $n_{пр}$. Even if during this process values of gas pressure ratio $\pi_к^*$ at this value of $n_{пр}$, at the initial and current state of compressor, coefficient of efficiency determined during this process. It is known that coefficient of efficiency depends not only from the compressor state but also from the value of $G_{пр}$, which is not taken into account in the methodic [1].

So, the existing diagnostic methods, also those which have authorization documents are not totally objective. Even the determination of efficiency coefficient is not the solution of this problem. That's why development of new (objective) diagnostic method of compressor unit GTP state is necessary.

Ways of increasing of effectiveness of estimation of technical condition of compressor unit.

After analysis of considered methods, it is possible to say that when using some dependences for estimation of compressor technical state it is necessary first- to provide measurements of their parameters only on the same modes, second- the amount of this parameters must be enough, third- process of measurement of determined parameters must have not significant influence on the margin of gas dynamic stability of compressor and its other characteristics. If the dependence by which the technical state is estimated contains values of total temperature and pressure, the measuring devices of this total pressure and temperature must be installed in the elements of the flow part, for example in the inlet guide vanes and outlet directing vanes.

Improved system of control of technical state of axial compressor GTP

In the base of improvement of control system an invention [25], in which air consumption and its temperature, pressure ratio in the compressor, and rotational speed is measured according to the basic characteristics and correspondent mathematical dependences on the base of measured and reduced to the standard atmospheric conditions parameters, determine relative change of coefficient of efficiency of compressor, with the application of similarity of modes, which provides increasing of accuracy of determination of relative change of coefficient of efficiency of the compressor, and by this the increasing of objectiveness of its technical state control.

The task is regulated by the fact that in the method of control of technical state of axial compressor, by the way of determination of its coefficient of efficiency change at the exploitation mode, measure compressor rotor rotational speed, degree of compressor pressure ratio, coefficient of proportionality is determined, which links change of coefficient of efficiency with the measured parameters, in accordance with the invention air consumption through compressor is measured, firstly cross-sectional areas of the flow part at the input and output of the compressor and values of their average diameters from basic characteristics of the compressor at the constant reduced values of rotational speed and air consumption found correspondent to them output values of degree of pressure ratio ($\pi^*_{ки}$) and coefficient of efficiency ($\eta^*_{ки}$), and the change of coefficient of efficiency calculated by the dependence:

$$\delta\,\eta^*_{к} = a\delta\,\pi^*_{к}\,, \tag{1}$$

where $\delta\,\eta^*_{к}$ – relative change of the compressor coefficient of efficiency,

$$\delta\,\pi^*_{к} = (\pi^*_{ки} - \pi^*_{кр}) / \pi^*_{ки}\,, \tag{2}$$

where $\delta\,\pi^*_{к}$ – relative change of degree of pressure ratio,

$\pi^*_{кр}$ – measured degree of pressure ratio,

Ad the changed value of coefficient of efficiency ($\eta^*_{кр}$) is determined by the formula:

$$\eta^*_{кр} = \frac{\pi_{кр}^{*\frac{k-1}{k}} - 1}{\dfrac{Z\pi^2 D^2_{ср} n^2_{пр}}{3600\,C_p\,288}\left[1 - \dfrac{1 + \dfrac{F_в}{F_к}\left(\pi^*_{кр}\right)^{-\frac{1}{n'_k}}}{1 + \dfrac{F_в}{F_к}\left(\pi^*_{кu}\right)^{-\frac{1}{n_k}}}\left(1 - \dfrac{3600 C_p\, 288\left(\pi_{кu}^{*\frac{k-1}{k}}\right)}{Z\pi^2 D^2_{ср}\, n^2_{пр}\, \eta^*_{кu}}\right)\right]}$$

Example of numerical calculation of coefficient "a" i $\delta\eta^*_{кр}$.

Initial data for the numerical calculation of axial compressor are the following: $Z = 13$; $D_{ср} = 0.52 м$; $\frac{F_в}{F_к} = 3.86$; $C_p = 1005 Дж/(мК)$; $k = 1{,}4$; $n_{пр} = 10700$ $об/хв$; $\pi^*_{кu} = 15.7$. O the base of values and measured parameters $(n, G_г, \pi^*_к, T^*_в)$ the dependence on the fig. 1 was constructed. It follows from the obtained dependence that at the real change of coefficient of efficiency on 1…2% value "*a*" for the given compressor type can be accepted as constant and equal to 0,17.

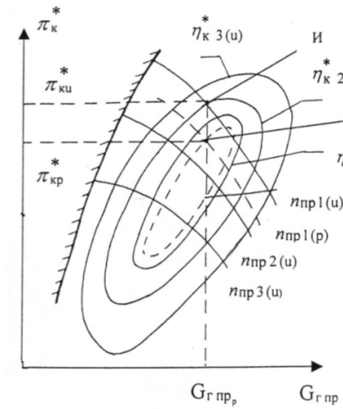


Fig.3. Output characteristic of axial compressor

Conclusion

Positive effect from the improved control system consist in the increasing of accuracy of determination of relative change of compressor coefficient of efficiency and correspondingly the objectiveness of control of technical state of axial compressor and possibility of its application for operative control of technical state of gas turbine units.

References

1. *Лозицкий Л.П.* Оценка технического состояния авиационных ГТД /Л.П.Лозицкий, А.К.Янко, В.Ф.Лапшов. – М.: Транспорт, 1982. – 160 с.

2.Г.М.Горбунов, Э.Л.Солохин. Испытание авиационных воздушно-реактивных двигателей. – М.: Машиностроение, 1967. – 256 с.

3.А.С.СССР №987443, GOIM 15/00, 1983, БИ №1.

4. А.С.СССР №1121594, GOIM 15/00, 1984, БИ №40.

5. А.С.СССР №800773, GOIM 15/00, 1981, БИ №4.

6. Деклар.пат.51156А України, МПК7 G01M 15/00, №2002010522; Заявл. 21.01.02; Опубл.15.11.02, Бюл. №11.-3 с.

UDC 621.694.2:629.3082.3(045)

Gvozdetskiy I.I., Kinaschuk I.F., Kirchu F.I., Kinaschuk M.I..
(National Aviation University, Ukraine)

METHOD OF CONSUMPTION DETERMINATION THROUGH SECONDARY FLOW OF TFE.

Methodic of consumption determination through secondary flow of TFE by measurement of total pressures and temperatures and way of determination of coefficient of flow coining were considered.

Introduction

Total air consumption through the engine $G_{\mathrm{air}\,\Sigma} = G_{\mathrm{air1}} + G_{\mathrm{air2}}$ is measured with the help of measuring device which is installed before the inlet of TFE. For determination of air consumption through core counter G_{air1} difficult indirect method is used, based on united solution of heat balance equations and gas consumption through first nozzle diaphragm of high pressure turbine [1]

$$G_{\mathrm{g}} T_{\mathrm{t}}^{*} = G_{\mathrm{c}} T_{\mathrm{HPC}}^{*} + \frac{G_{\mathrm{f}}}{G_{\mathrm{g}}} H_{\mathrm{u}} \eta_{\mathrm{z}}; \qquad G_{\mathrm{air}}(1-\kappa_1) + G_{\mathrm{f}} = A_{\mathrm{т}} \frac{\sigma_{\mathrm{CC}} P_{\mathrm{HPC}}^{*}}{\sqrt{T_{\mathrm{g}}^{*}}}. \quad (1)$$

This method differs by big amount of measured parameters $(T_{\mathrm{HPC}}^{*}, P_{\mathrm{HPC}}^{*}, G_f)$, some inaccuracy during estimation of coefficients of combustion chamber $(\sigma_{CC}, \eta_{\mathrm{z}})$ and necessity of precise determination of coefficient of gas consumption through high pressure turbine $A_{\mathrm{т}}$.

Method of air consumption determination through secondary flow of tfe.

Determination of consumption through primary flow $G_{\mathrm{air}\,1}$, by means of determination of pressures and temperatures of gas flow in core contour nozzle, as in the case of THE, differs by not high accuracy because of high unevenness of gas flow parameters, gas temperature is main there. Absence of combustion chamber as the main source of temperature unevenness in secondary flow of TFE, allows assuming that air consumption $G_{\mathrm{air}\,2}$ can be determined with the help of measurements of gas flow with higher accuracy in secondary flow.

For checking of this assumption division of parameters of gas flow in secondary flow (at the nozzle cross-section and in transfer channel after low pressure compressor) were measured on specialy equipped TFE АИ-25, and also division of totall pressure at the cross-section of primary flow nozzle P_{c1}^{*}.After averaging of results of measurements of some devices on the same measurements zones, radial fields of measured parameters were found. Estimation of uneveness degree of fields was made in the range of reduced number of rotation of high pressure rotor $n_{\mathrm{red.\,hpc}}$ from 80 to 100%.

Degree of unevenness of total temperature at the cross-section of secondary flow nozzle was near constant at the whole range of change $n_{\text{пр. квт}}$ and was only 0,3. With the increasing of rotational speed the unevennes degree of high pressure fields increase. At the maximal $n_{\text{пр. квт}} = 100\%$ especially noticeable increasing of unevenness degree of primary flow nozzle $\delta p^*_{\text{c}_1} = 18\%$; unevenness degree in secondary flow in this case after compressor exceeds $\delta p^*_{\text{кнт}_2} = 8\%$, and on the nozzle cross-section $\delta p^*_{\text{c}_2} = 6\%$, or on 3 times less than on the cross-section of primary flow.

At all modes value $\sum_5^1 \frac{P^*_{\text{c2}_\text{i}} q(\lambda_{\text{c2}_\text{i}})}{\sqrt{T^*_{\text{c2}_\text{i}}}}$ was the same as $\frac{P^*_{\text{c2 ср}} q(\lambda_{\text{c2}})_{\text{ср}}}{\sqrt{T^*_{\text{c2 ср}}}}$, value which was calculated by mean values of total pressure $P^*_{\text{c2 ср}}$ and temperature $T^*_{\text{c2 ср}}$ in assumption that $P_\text{c} = P_\text{н}$ so, air consumption $G_{\text{air 2}}$, can be calculated with the help of averaged parameters using the formula of one dimension flow.

$$G_{\text{air 2}} = \frac{m_\text{в} P^*_{\text{c2 ср}} q(\lambda_{\text{c2}})_{\text{ср}} F_{\text{c2}}}{\sqrt{T^*_{\text{c2 ср}}}} \tag{2}$$

Measurement of static pressure at the middle radius in the secondary flow nozzle showed that P_{c2}, in the whole range of pre-critical modes of flow out from nozzle is greater than $P_\text{н}$

For determination of air flow rate $G_{\text{air 1}}$, with the help of indirect method $A_\text{т}$ parameter was found by the way of special testing of high pressure compressor of АИ-25. Numerical values of α_{c2} were determined by the experimental coefficients of μ_{c2}, obtained during testing of model of double contour nozzle. Consumption coefficient during pre-critical flow out of nozzle, which is conning $\mu_\text{c} = \frac{G_\text{д}}{G_{\text{ід}}}$ takes into account difference of real process of flow with losses $(\sigma_\text{c}, \varphi_\text{c})$ and unevenness fields P^*_c and P_c at the output of nozzle from ideal flow process, without losses at full expansion ($P_\text{c} = P_\text{н}$)[2].

In the range of modes with degree of expansion $\pi^*_\text{c} = 1{,}3 \div 2{,}0$ for the nozzles ВРД, which has $\varphi_\text{c} = 0{,}97 \div 0{,}985$, value $\sigma_\text{c}^{\frac{k-1}{k}} \varphi_\text{c}$ is constant and for correspondent φ_c equals to 0,95—0,96.

Results of determination of air consumption $G_{\text{air}\,2}$ by parameters which were determined in the secondary flow nozzle, were compared (fig. 1, curve 1) with the results of calculations of air consumption by the formula

$$G_{\text{air2}} = G_{\text{air}\,\Sigma} - G_{\text{air1}} \tag{3}$$

This comparison shows that method of determination of air consumption through secondary flow of TFE, provides the same accuracy as the method, based on the determination of $A_{\text{т}}$, differs in the less amount of measured parameters and necessary calculations. Calculation G_{air2} in the condition $\widetilde{P}_{\text{c}} = \widetilde{P}_{\text{н}}$ (curve 3) gives increased values. When we use measured statistical pressure at the middle radius (curve 2) difference from the results obtained by the method with usage $A_{\text{т}}$ decreases.

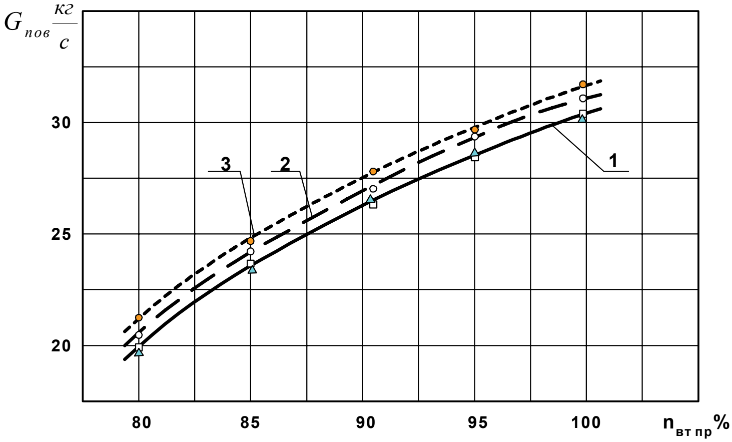


Fig.1. Comparison of different methods of determination of air consumption through secondary flow:

curve 1- △ - calculation by formula (3); □- calculation with the usage of $A_{\text{т}}$; curve 2- calculation by the formula (2) at $P_{\text{c}} = P_{\text{c2}}$, $\alpha_{\text{c2}} = 1$, curve 3-calculation by the formula (1) at $P_{\text{c}} = P_{\text{н}}$, $\alpha_{\text{c2}} = 1$.

Determination of $A_{\text{т}}$ by calculation method is difficult, first of all because of value F_{ca} which must be known in the conditions of operation on the engine. Determination of $A_{\text{т}}$ with the help of testing of nozzle diaphragm also allows calculation corrections. Almost precise value of $A_{\text{т}}$ for turbofan engine can be found only during special testing of high pressure compressor, when hot gas flows through turbine with the same temperature as in the engine. But even usage of $A_{\text{т}}$, obtained during testing of compressor, at different examples of the engine connected with the error of 1% in the determination of G_{air1} caused by the difference of F_{ca} in allowable range. Additional errors appear during measurements $P^*_{\text{HPC}}, T^*_{\text{HPC}}, G_{\text{f}}$, choosing of coefficients $\sigma_{\text{CC}}, \eta_{\text{z}}$, and during the process of calculations with the help of complicated methodic with the usage of nomograms [I].

Method of losses determination in the secondary flow directly by the formula (3) allows measurements of only two parameters of gas flow on the engine: P^*_{c2}, and T^*_{c2}. Experimental determination of μ_{c} is more simple than special testing of compressor for accurate determination of $A_{\text{т}}$; values of μ_{c}, obtained at the model is applicable for all serial engine specimens.

Value of the area F_{c2}, is easy to control at all engines. The change F_{c2}, at the hot state is easy to determine by the calculation method (for AI-25 as the result of expansion of hot nozzle of primary flow $F_{\text{c2 гор}} = 0{,}98 F_{\text{c2}}$) or to use optical methods which found their application during engine testings with afterburner for regulated nozzles.

Conclusions

So, significant reducing of temperature unevenness in the secondary flow of TFE, insignificant unevenness of total pressure fields in connection with the way of determination of coefficient of coining of flow by experimental consumption characteristics of nozzle, allows to determine consumption directly by the formula (3) with relatively high accuracy.

Way of determination of flow coining coefficient illuminates necessity of measurement of total pressure with high errors on the cross-section of nozzle, can be applied at practice for the determination by stagnated parameters in jet nozzle as the gas consumption and thrust force. Method of consumption determination through secondary flow is simpler than indirect method which is based on the usage of parameter $A_{\text{т}}$.

References

1. Нечаев Ю.Н., Федоров Р.Н., Говоров А.Н. Теория авиационных двигателей. 4.2 – М.: ВВНА им. Н.Е.Жуковского, 1972. – 395с.
2. Кулик Н.С. Параметрические методы оценки технического состояния авиационных ГТД. К.: КИИГА, 1993. – 139 с.

UDC 621.002: 621.82

E.P. Yasinitskiy (National Aviation University, Ukraine)

CONTROL SYSTEM OF VALVES GAS COMPRESSOR UNIT (GPU)

Introduction

Nowadays, the share of the gas transportation system of modern automatic control systems (ACS) compressor shop (station) CS (CS) based on microprocessor technology not fully meet modern requirements. Commonly used systems that were delivered during the construction of the station with gas compressor unit (GPU). These systems are not only obsolete, but also come unusable because of its service life and physical deterioration of elements of the system.

Modern ACS based on microprocessor technology in the structure has highly productive equipment that allows to solve complex management tasks with high accuracy and speed. They also have in their composition separate modules for control stop GPA in extreme conditions, such as device failure and control.

The main performance problems

The main problems in the operation of GPA are:

- the function, ACS staff requirements of normative document PAT "Ukrtransgaz" - SDA 60.3-30019801-65:2008 "Automatic control of gas compressor units . Basic requirements."
- low speed cranes and, as a consequence , the delay time on the process of emergency or emergency stop GPA .
- absence of an independent mechanism for emergency management taps gas piping as part of SBS staff relay control system at their failure or power failure;
- low speed systems, the complexity of configuring and adjusting the control algorithm;
- The lack of autonomous emergency units
- stop and, as a consequence, lack of emergency stop GPA at failure of ACS. Rearrange the cranes in this case is done manually;
- lack of spare parts (especially for the import ACS). Frequent breakdown of worn equipment not allow you to quickly and accurately perform the repair ACS.

Solution of the problem

When working on the reconstruction of GPU replacing obsolete by modern ACS, which include device control stop GPA in extreme conditions - emergency stop unit (ESU) .

Complexity due to the introduction of new features ACS carry out work on gas transmission facilities and significant material cost.

Due to the slow pace of these works , as well as to meet the requirements of the JMA 60.3-30019801-65:2008 mandatory carriage ESU ACS , as well as to provide control valves gas piping in an emergency TOV "Kotris" developed and implemented in a stand-alone operation crane control system with emergency stop blocks .

The system is designed for automatic and manual control valves (pneumatically, electrically) Command ACS GPU or operator -controlled rate of speed change, control and emergency stop serviceability GPU failure ACS.

This system provides control of cranes in an emergency after receiving a digital signal or refusal ACS operator command from the remote emergency stop and manual control valves with panel - mimic.

The system is mandatory for the design of new and maintenance of existing facilities on the ACS GPA PAT "Ukrtransgas".

The system provides a complete technical

device and can be integrated into any SAU GPA as a separate component by the minimal improvement.

It consists of the following main elements (Figure 1):

- mnemoscheme - panel control buttons with physical taps;
-control device taps;
-unit emergency stop;
-block main and backup power.
-Remote Emergency Management.

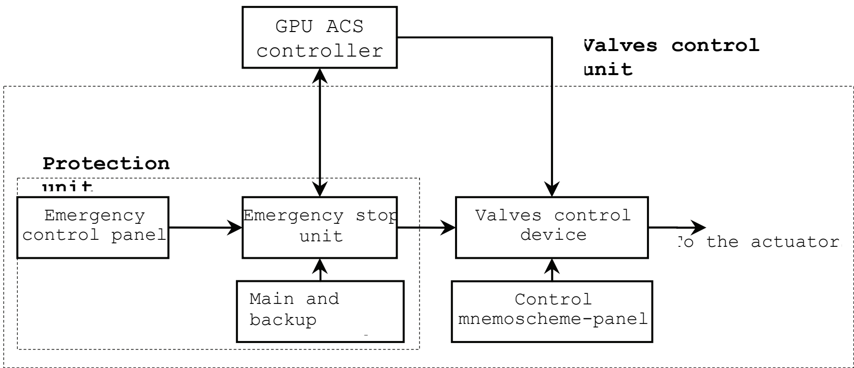


Fig.1 Valves control system structural scheme

Emergency control panel, emergency stop unit, main and backup power supply unit functionally combined into protection unit. Constructively the equipment of unit placed in a separate enclosure (fig. 3). Control mnemoscheme-panel with emergency control panel (fig. 2)

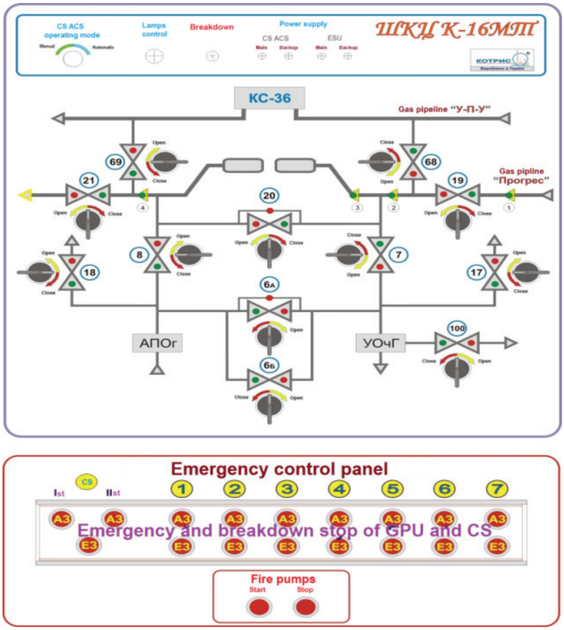


Fig. 2. Mnemoscheme-pannel and emergency control panel

Control valve device (CVD) provides control of the gas valves strapping GTA. It performs the following functions:

-formation of the impulse voltage for biasing the rod from the place of the solenoid valves;
-connect the power to the solenoid control circuit;
-control circuit integrity valve control;
-analysis of limit switches of valve;
-formation signal passing commands to the solenoid valves;
-providing galvanic isolation of signal and power circuits.

CVD electronic device which is housed in a separate housing. At the top of the housing is installed LED display showing the following information:

-command for opening the valve;
-team to close the valve;
-control circuit to control the opening of the valve;
-control circuit controls the closing of the valve;
-valve is open and the valve is closed.

Control signal to the controller comes from CVD ACS through ESU at the automatic control panel, panel-pnemo-scheme at the manual. When the emergency situations: failure of ACS, as well as pressing the "emergency stop" signal to the control unit is formed CVD emergency stop algorithm that performs an emergency stop GTA.

Connect external wiring to the CVD performed using demountable terminals mounted in CVD.

Emergency stop unit consists of a control module, implemented on the basis of microcontroller Atmega128 (Atmel), input-output modules (8 inputs and 8 outputs for each module) and input modules (16 inputs for each module). All modules are installed on the backplane.

Upon cancellation ACS GPU or when the signal from the remote controller ESU emergency control algorithm starts work, emergency stop and not respond to the controller control system ACS GPU.

Blocks of the main and backup power provides independence from ACS GPU power electricity system and ensure proper operation in extreme cases.

Fig. 3. General view of the cabinet ACS GPU

Conclusions:

Implementation into existing control systems ACS GPU taps allow without special equipment to ensure compliance with the requirements of the JMA 60.3-30019801-65:2008, improve operational safety CS(shop)CS, by reducing the time permutation cranes GPU and CS in emergency situations.

References

1.СОУ 60.3-30019801-65:2008. Системи автоматичного керування газоперекачувальними агрегатами. Основні технічні вимоги. – К.: ДК «Укртрансгаз». – 2008. – 56с.

2.Артемова Т.Г. Эксплуатация компрессорных станций магистральных газопроводов. – М.: Недра, 2000. – 176с.

3.КозаченкоА.Н. Эксплуатация компрессорных станций магистральных газопроводов. – М.: Нефть и газ, 1999. – 463

UDC 629.735.083.06(045)

S. Dmitriev Prof. Dr Sci. Eng., V.Burlakov, PhD Eng.,
O.Popov, PhD Eng., D.Popov
(National Aviation University, Ukraine, Kyiv)

FORMALIZATION OF PROCEDURES AND DETERMINING THE OPTIMAL MAINTENANCE OF AIRCRAFT AND AIRCRAFT ENGINES PROGRAMS

Maintenance program is essential for all modern aircraft and aircraft engines and may include continuous and periodic monitoring of performance, automated periodic inspections, regulations eliminate failures and faults handling. Each component of the program is characterized by a number of parameters that are part of the performance.

The process of maintaining the airworthiness of aircraft and aircraft engine within the prescribed period of service (resource) includes: keeping the operator of the terms and conditions of flight and technical operation of aircraft; implementation of the approved maintenance program with the evaluation of its effectiveness. Maintenance program is essential for all modern aircraft and aircraft engines and may include continuous and periodic monitoring of performance, automated periodic inspections, regulations eliminate failures and faults handling. Each component of the program is characterized by a number of parameters that are part of the performance, which are specified in the requirements, such as the frequency, scope and duration, strategies and tools for maintenance and others. From the correctness of reasoning, proof and deciding on the values of these parameters depend on both the level of reliability of aircraft in service, and so the complexity and cost of achieving that level.

Formation reliability of aviation technology is a complex process, covering the stages of design, manufacture and operation of which are linked to each other and are the constituent elements of a single management system.

Works in various stages involving decisions that have specific features at each stage and different information provision about the properties of objects of exploitation, requiring the need to use new methodological approaches in optimization solutions.

Content management in the design phase consists of providing balanced characteristics and properties of products of aviation equipment on the defining set of attributes. In this case, the optimized functional diagram of system reliability component elements, modes, controls and operational adaptability of components.

During operation phase, for given characteristics and properties of the objects of exploitation, control actions are: the volume and frequency of maintenance optimization are carried out for the effect - environmental controls and diagnostics, which are used, performance and features of the organization of work maintenance operator. The operator is entitled, within the constraints of the certification requirements, to decide the issue airworthiness object and the frequency of performance, given its own parameters and operating conditions. Frequency of works set on the basis of operational reliability and adaptability facilities maintenance.

The introduction of new principles of maintenance does not begin with the introduction of variable in the design and development of a maintenance program with the help of a comprehensive analysis of the design, possible failures and identify effective and appropriate measures to prevent them. Adding variable in structure, the necessity of which is in the process of developing a program, only enhances the efficacy of the new guidelines.

Solution of complex technical evaluation of products, taking into account all possible methods of control performance of individual structural elements of aircraft, components, systems and engines in general requires the development of administrative mechanisms that allow decisions under conditions of uncertainty, incompleteness and ambiguity of the original information.

The methods of fuzzy clustering situations and recognition methods allow the current situation to build a classification model of decision making and managers to find the best solution in a given situation.

Measurement is defined as a procedure for comparing objects with the appropriate parameters (features). Each alternative $v_i \in V$ (or $v^i \in V$) is the set of parameters

$$v_{(i)}^i = V^i\left(v_1^i, v_2^i, \dots, v_n^i\right),\ i = 1,2,\dots,n,$$

where i - the alternative;

n - dimension of space.

As this scale is constructed without reference to specific, real solutions, it can be called a benchmark - a tool by which the assessment will then be made real decisions.

Multicriteria decision model for individual optimal solution vector is defined as a criterion in the form

$$K(v) = \{k_1(v), k_2(v), \dots, k_m(v)\}.$$

The components of the vector criterion is a scalar function defined on V and measure the quality of a decision on a scale previously defined. In general they are not compatible. Problem of choosing the optimal alternative to a formal set of criteria is to find mapping $C[v(t)] = \{v \in V\}$, that each vector $v(t)$ assigns to the real number $W_i(t)$

$$W(t) = v(t) = v[v_1(t), v_2(t), \dots, v_m(t)],$$

which determines the degree of the advantages of this solution.

The technique is based on the use of a priori estimates of interval parameters, followed by calculation of a posteriori estimates in accordance with the increasing amount of information.

This sequential decision tasks, depending on the accuracy and reliability of available information is the basis of the adaptive management process design development, establishment and adjustment of maintenance items of aviation equipment

Development and implementation of new principles of maintenance shows that the practical implementation of advanced techniques, resulting in a dramatic increase in information. To optimize the frequency and scope of the aircraft product maintenance essential information which was presented in previous works.

To form a comprehensive summary of product characteristics of the performance properties of aviation equipment allocated «n» signs. Each attribute supplied in accordance with «m» states. A comprehensive description of the performance properties of the product is written in sequence, creating an ordered cortege:

$$V_K = \left\{ x_1^{i_1}, x_2^{i_2}, .. x_j^{i_j} .... x_n^{i_n} \right\},$$

where $i_j \begin{pmatrix} j = 1 \div n \\ i = 1 \div m \end{pmatrix}$ – set of states j-th feature.

Based on the classification performance properties of the grounds and conditions defining cortege for each element of a complex system of aircraft (Table1).

Table1

Classification performance properties of the grounds and conditions

code	The dominant factor	Working hours element failures, h.	Multiplicity backup functions	Efficiency means and methods	Average control time element, min.	Average recovery time element
1	fact of failure	less 1500	0	0 – 0,2	> 60	> 2
2	failure leads to an incident	$1500 \div 7500$	$\frac{1}{2} \div \frac{3}{2}$	0,21 – 0,4	$30 \div 60$	$1 \div 2$
3	failure without consequences	$7501 \div 33500$	$\frac{3}{2} \div \frac{5}{2}$	0,41 – 0,6	$15 \div 30$	$0{,}5 \div 1$
4	-	$33501 \div 165000$	$\frac{5}{2} \div \frac{7}{2}$	0,61 – 0,8	to 15	to 0,5
5	-	$165001 \div 840000$	$\frac{7}{2} \div \frac{9}{2}$	0,8 – 1,0	-	-
6	-	840001 and more	more $\frac{9}{2}$	-	-	-

None of the alternatives that are not included in the set of Pareto optimal is not recognized by either method. And if there is some measure for comparing alternatives, establishment of benefits between them, and hence the choice of a preferred alternative, which would be the best solution desired.

Based on the comparison element of the tuple with the basic "B" performance are such alternatives Pareto optimum that satisfy all attribute value tuple. Maintenance management process is based on the implementation of control actions, which is based on an assessment of the effect of the operation of the aircraft for possible modifying object properties and operation is given by:

$$e = f_e \sum \left[x_j^i - Б_j^i \right],$$

where $j = 1 \div n$ - the set of states j- th feature.

Based on the comparison and evaluation of the degree of deviation from the basic characteristics of the products of vectors solved the problem of managing the maintenance.

From the study it follows that for the comparative analysis of alternatives can be used together structure and function of vector criteria. To determine the comparison of the set of basic alternatives and to establish a system of benefits between them and the best decision that is optimal , solutions proposed to use a set of efficient Pareto optimal solutions .

Thus, the goal of development is maximum harmonization of methods and technologies of formation maintenance programs of aircraft, conducted by the existence of effective procedures for constructing the reference class of situations, making it possible to build an effective decision-making scheme. They are based on calculations for this specific situation of each of the degrees of membership of sample classes, and then selecting the solution that corresponds to one class or a reference situation in which this situation belongs to the greatest extent.

Selection of great number of base alternatives, determinate measure for their comparison and setting of the system of advantages between them - are foundation of decision-making the best. The selection of this great number will shorten the subsequent analysis and will decrease the amount of calculations for the processes control of technical exploitation.

Conclusion

Multicriteria problems have a characteristic, which is the main difference is that there is no single point of view, but there are many effective decisions, or decisions, Pareto optimal. Pareto optimality is alternatives, such that the transition from one to the other alternatives can not improve the value of one or more criteria without worsening at least one criterion.

It should be noted that in certain models optimize completeness and frequency of preventive measures to manage the state of operation of complex objects is still not completed development of multiparametric optimization method. When developing regulations maintenance aircraft range activities wealth management of complex systems is largely determined by the expert.

References

1. *Ногин В. Д.* Принятие решений в многокритериальной среде: количественный подход.– М.: ФИЗМАТЛИТ, 2002.–144с.

2. *В. І. Бурлаков к.т.н., Д. В. Попов, О. В. Попов,* Прийняття рішень при вирішенні багатокритеріальних задач технічної експлуатації. Сб.наук.пр. «Сучасні авіацій технології» Матеріали VIII міжнародної науково-технічної конференції “АВІА-2007”, -Т.2. – К.: НАУ,2007.- С.33.26–33.29

UDC 629.7.083

A.A. Tamargazin, Doctor of Engineering Science (NAU, Ukraine, Kyiv)
I.I. Linnik, Candidate of Engineering Science (NAU, Ukraine, Kyiv)
T.Y. Kramarenko (NAU, Ukraine, Kyiv)

IMPROVING OF AIRCRAFT GROUND HANDLING MANAGEMENT SYSTEM AT THE AIRPORT

The article deals with aircraft ground handling considered as an interrelated system of processes and sub-processes. The article proposes a scheme for improved dispatcher ground handling management of aircraft and communications schemes in the new structure of aircraft ground handling. The processes of strategic and seasonal planning were developed within the concept of building of the information-management system for the airport.

In conditions of market relations development particularly urgent problem of the most efficient use of the company's production potential is becoming more important, which is impossible without effectively built system of production process control, as well as correct and accurate planning of resources for the production process.

With increasing requirements to quality of administrative decisions, a very important factor for the successful operation of the aviation enterprise in modern conditions is a rational system of production process control and resource planning. However, the building of only rational management system is not enough. In conditions of a highly-developed technological production, along with material flows, information flows increase and the last ones have the most significant effect on the management process. Therefore, timely and operative processing of incoming information is one of the most urgent tasks determining the quality of management. The primary tool, allowing to solve the task of handling greater flow of information is information systems. In the operational management of production information systems allow to automate a huge number of routine operations, and display information in real time for making decisions by management. At strategic management information systems act as a means of various kinds of calculations. Their use allows fairly accurately estimate the resource needs to identify "bottlenecks", to analyze the situation "what if".

The problem of reorganizing the system of operational management, resource planning and their information support needs to be considered in complex. Without constructing a rational system of management it is impossible to implement information systems effectively as they will simply automate the problems that already exist in the system of operational management. On the other hand, the rational management system cannot work without the implementation of information systems, since the requirements for information security management system only increase.

Assessment of the current state of air transport showed that the industry is in a difficult situation. The civil aviation needs reformation, one of the areas which should be reformed is the airport networks with the release of airports that can become national hubs.

Analysis of the world reforming experience of airports shows that at creating a hub it is important to focus on:

– Reconstruction of the airport terminal under clear organization of passenger flows;

– Modification of the automatic baggage sorting system;

– Increase of productivity lines of passengers and luggage registering and monitoring;

– Elimination of congestion in the landside of the airport;

– Re-equipment of information system;

– Reconstruction of the airfield for aircraft landing with increased passenger capacity;

– Reorganization of the management system.

Analysis of the aircraft ground handling management system showed that there are some disadvantages that do not allow to manage this process.

The disadvantages of the control system are the following:

– No single control point of apron resources. At the absence of a single coordinator on the apron dispatchers of apron management cannot make decisions about the priority of flights service.

– There are no clear rules for the distribution of resources between processes of ground service and others. Including the lack of short-term planning, this leads to the diversion of resources to lower priority tasks. The more priority tasks appearing later are left in expectation mode.

– Virtually there are no long-term (prospective) planning of technical and human resources.

– There is no tool of quickly planning the distribution of resources to tasks for the next few hours. Dispatchers work in a rapid response. Accordingly, it is impossible to foresee a situation of resources lack for the emerging problem. Dispatcher of apron control recognizes about deviations only on the fact - often too late to rectify the situation. The existing system of communication leads to an overload of dispatchers as a consequence - the possible loss of operational information and, accordingly, errors in scheduling.

Part of the above mentioned disadvantages relay to the problems of informational support in the airport "Borispol", so problems with aircraft ground handling management are not only in ineffective organizational management structure, but also in their lack of information support. Information systems analysis showed that except controlling a central schedule system and a daily flight plan system of other systems which automate management processes of aircraft ground handling and planning there are virtually no resources.

Comparative analysis of foreign and domestic experience showed significant differences in the principles of the organization of airport activities. On the west there is quite clear separation of three subjects: Airport operator (usually the airport belongs to government authorities); Companies that provide ground handling services; Airlines.

At the same time, the company providing ground handling services can be both independent and belong to the operator of the airport or the airline. In the case if ground handling agent supplies the airport operator, there are set of strict rules of separation of business management and airport ground handling activities. Nevertheless, in a number of European airports till the mid of 90s there was a monopoly on the provision of ground handling services. Compared with airports, where there was no monopoly, prices services in monopolized airports were higher and quality was lower.

There are no clear separation of such concepts as the airport operator and ground handling agent in Ukraine. Basically, the airport has a monopoly on the provision of ground handling services. Under such conditions, monopolists almost do not have economic incentive to improve the quality of service and to lower prices. If we talk about the survival of the airport, then the monopoly structure is admissible and even economically justified, but at a certain airport development lack of competitive environment will adversely affect the price and quality of ground handling services.

Large contribution to the problem of improving the organization of management at transport enterprises and information support of management systems was made by such authors as: Galaburda V.G., Goncharuk O.V., Gromov N.N., Persianov V.A., Rezer S.M., Uskov N.S., Fedina T.V., Fedorov L.S. and others - in the field of effective management of transport systems; Andrianov V.V., Artamonov B.V., Bragin V.A., Volkov L.P., Dounaev O.N., Kosichenko E.F., Kurilo V.M., Makarov E.V., Nikulin H. F., Romanov L.G., etc. - in the field of air transport; Bakaev A.A., Bardiner S.M., Gusyatiner A.M., Nikolaev A.B., Tulupov L.P., Tsarev P.M., etc. - in the field of information support at transport enterprises; Andronov A.M., Valkov V.M., Vershin V.E., Rudelson L.E., Sevastyanov N.P. etc. - in the field of information security in air transport . Scientific researches tend to focus on specific aspects of transport management. Number of works summarizing in complex a wide range of managerial, organizational, economic and technological problems in the functioning of the airport is limited, and that led to the choice of the theme of these researches, as well as their goals and objectives.

The objective of this research was the complex formation of a rational system of aircraft ground handling management at the airport. To do this, the following tasks were solved:

– the activity data and level of organization of aircraft ground handling management system of leading airport in Ukraine were analyzed;

– foreign experience in the organization and functional distribution of the responsibilities of business entities operating in the airport was studied;

– the main directions in improving of ground handling control at the airport were defined;

– methodical proposals for introducing resource planning system for aircraft ground service were developed;

– the concept of phased implementation of information systems (IS) was developed, which is the result of a single information space, providing full management processes and resource planning for aircraft ground service;

– a comprehensive assessment of proposed actions to reorganize the aircraft ground handling control systems and information support was given.

The subject of research are questions of effective management by the process of aircraft ground handling and opportunities of its information provision, taking into account features of airports in Ukraine and market requirements .

The object of research was made one of the most modern and the most perspective airports in Ukraine is International airport "Borispol". Methodological basis for the research were the works of domestic and foreign scientists, guidance and regulations of aviation authorities, international conventions and guidelines in the field of airport operations.

Scientific novelty of the research is to develop a methodical, organizational and information support in making management decisions about aircraft ground handling control. In the result of the made researches the following was developed:

– Technique of construction and model of dispatcher control system of aircraft ground handling activities;

– Technique of planning system construction and providing with resources the process of aircraft ground handling;

– the concept of a phased establishment of information-management system of the airport, providing the process of resources planning and activities for the operational management of aircraft ground handling was developed.

The practical significance of this research is the ability to use its regulations, conclusions and recommendations for working out projects and programs, organizational, economic and information development of other airports in the country.

Conclusions. Aircraft ground handling was considered as an interrelated system of processes and sub-processes. On the basis of this classification a scheme of improved dispatcher aircraft ground handling management has been proposed, as well as communication schemes in the new structure. For organizations planning system the processes of strategic and seasonal planning have been described and their implementation is necessary for building the system. To ensure the implementation of the proposed measures to reorganize management system, the concept of building an information-management system for the airport, providing information support of ground handling and planning. Assessment of developed set of measures showed that its implementation will improve the efficiency of ground handling management and reduces the costs of its implementation.

References

1. Airport Handling Manual. IATA, 2003.
2. Baggage Service Manual. IATA, 2003.
3. Common Use Terminal Equipment (CUTE) Systems. (Recommended Practice 1797). – IATA, 1994.
4. Август-Вильгельм Шеер. Бизнес-процессы. Основные понятия. Теория. Методы. – М.: Весть МетаТехнология, 1999. – 458 с.
5. Бабкин Е.В. Управление качеством транспортной продукции: Учеб. пособие. – СПб, 1998. – 198 с.
6. Бакаев А.А., Гриценко В.И., Бажан Л.И., Попченко В.И. Экономико-математическое моделирование развития транспортных систем. – Киев: Наук. думка, 1991. – 151 с.

UDC 620.178.16(045)

A.I. Bogdanovych, PhD Engineering (Nation Aviation University, Ukraine)

ESTIMATION OF KINETIC CHARACTERISTICS AND MODIFICATION ACTIVATION ENERGY OF "ШХ15" IN AVIATION FUEL "ТС-l"

As a result of the tribokinetic tests of the "ШХ 15" realization in aviation fuel "ТС-1" and according to the experimental-calculating method of kinetic characteristics estimation and activation energy of the2-nd stage triboreaction-mechanical-chemical modification 0.296 kj/mol. This is by 3-4 time less than analogues value of activation energy modification "ШХ 15" in fuel aviation "РТ" 0.921-1,354 kj/mol.

Setup of the problem. The development of modern aviation, military, automotive engineering is impossible without increasing the reliability, durability, productivity, cost-efficiency of machines, mechanisms and their units. These requirements are especially important in designing, manufacturing and operation of the above mentioned items as well as in operation. Increased reliability, durability and cost-efficiency of these items depend on the surface durability of their individual units. In its turn, the surface durability (wear-firmness) of structural materials of triboconnections cannot be increased and the antiwear properties of fuel and lubricants cannot be improved without conducting tribotechnical tests. But for conducting such tests it's necessary to use universal, energy, integral and invariant criteria, at least in one of the value ranges of loads (P), sliding speed and temperatures. The criterion that meets all the above mentioned requirements is activation energy, which is the whole three stages of triboreaction [1]. This criterion is in fact an energy criterion, integral and universal in application, invariant in the normal mechanical-chemical wear range, i.e. in the range of structural adaptation of the triboconnection materials, which has been proved experimentally [1]. The kinetic characteristics and activation energy of the 2-nd stage - mechanical-chemical modification (E^M) for aviation fuel "РТ" and hydraulic oil "АМГ-10" have also determined [2].

The aim of the work is to determine of the kinetic characteristics and activation energy of the 2-nd stage triboreaction - mechanical-chemical modification (E^M) for aviation fuel "ТС-1".

Calculation - experimental part. To achievement the aim we used tribokinetic tests to determine the kinetic characteristics and wear activation energy "ШХ 15" in aviation fuel "ТС-1" ("ДСТУ 320.001249943.011-99"), the producted of the Kremenchug. Oil - processing plant conducted on the friction machine "КИИГА-2" [3]. Both hard-phased elements were produced of ball-bearing steel "ШХ15" (ГОСТ 801-78). Tests were conducted with axis load P=98,l H, slide speed V_{ck}=l,18 m/c without excess pressure in the cell, at two temperatures: T_1=333°K and T_2=303°K. Then, with the help of instrumental microscope "МИМ-7" at 70-multipes increment the diameter of the spot wear of every ball was measured in two interperpendicular directions and the arithmetic value of diameters of the spots wear d, the mean value d of three of spots wear d_c and the mean value d_c of three or more tests were calculated. According to the method of carrying out tribokinetic tests, we calculated the value of the every ball were, which is the geometric form of the ball segment, whose base diameter is the diameter spot wear. The sum of the wear volume of three balls (volume wear summary of one test) and calculation of the arithmetic mean value of value wear sum of three or more tests V_c. The results of these tests are given into table 1.

The next stage of the tribokinetic experiment is to calculate the speed of reaction wear ω:

$$\omega = \frac{ДVc}{Дt_c} = \frac{Vct_i - Vct_{i-1}}{t_i - t_{i-1}}, \qquad (1)$$

where: V_{Cti} and V_{Cti-1} – are mean values of the summary wear of the tree balls at t_i time moment and t_{i-1} respectively.

The results of these calculations of w for every interval of time Δt are given into table 1. The order of the N^P wear reaction was calculated for the initial Δt_1 and the last Δt_3 interval of time using the next formula:

$$N^p = \frac{lg\, \omega_1 / \omega_3}{lg\, Vc_1 / Vc_3}, \qquad (2)$$

where: w_1 and w_3 is speed of wear for Δt_1 and Δt_3 interval time respectively;

V_{C1} and V_{C3} are means of the three balls for Δt_1 and Δt_3 time intervals respectively.

The calculation results of the order of N^P wear reaction are also given in table 1.

Table 1

Characteristics of the referred to as 3-d stage triboreaction-wear surface destruction

Temperature of testing, T, °K	Time of the tests, t_i, $x10^3$, s	Mean values of summary volumes of wear of 3 tests, $V_c x10^{-3}$, mm^3	Speed of wear for intervals of time, $\Delta t x10^6$, mm^3/s	Order of wear N^P for Δt time interval	Constants of wear speed $K^P x10^{-3}$, s^{-1}	Mean Values K^P, K_S^P $x10^{-3}$, s^{-1}	Coefficient of deviation of estimation of K^P, w,%	Graphical value of K^P
303	1,8	0,87934	-	0,84	-	0,47455	4,6	tg24,5°=0,4557
	2,4	1,18034	0,50167		0,48713			
	3,0	1,58446	0,67353		0,48722			
	3,6	2,07816	0,82283		0,44931			
333	1,8	0,91013	-	1,01	-	0,98132	8,3	tg43,5°=0,9490
	2,4	1,71737	1,3454		1,02565			
	3,0	2,9643	2,07821		0,88781			
	3,6	5,61713	4,42168		1,0305			

The constants of speed wear K^P were calculated with the help of V_c final value in Δt time intervals, i.e. using the formula:

$$K^P = \frac{\Delta V_C}{\Delta t \cdot V_{C\,\mathrm{ap}}} = \frac{w}{V_{C\,\mathrm{ap}}}, \qquad (3)$$

where: V_{Cap} is the mean arithmetic value of V_C at the beginning and at the end of Δt interval.

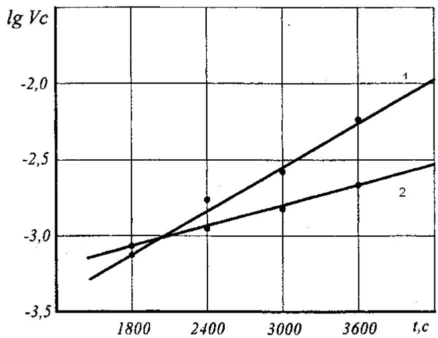


Figure l. Dependence logarithm of mean values of sum wear volumes of three balls during three tests (lgV_C) on the time tests: 1 - at 333°K, 2 - at 303°K.

The results of these calculations are given into table 1. We also give the mean arithmetic values of K^P and deviation coefficient of K^P-W, estimation which was calculated according to method the calculation measurement errors of physical quantity [1]. We build the diagram of lgV_c from time (t) dependence (fig.1)

Kinetic characteristics of the 2-d stage triboreaction has been determine of according to the secondary structure related area:

$$\delta = \frac{S_{BC}}{S_K} 100\%, \qquad (4)$$

where: $S_K = S_1 + S_2 + S_3$ - full contact area equal to the sum of areas wear of three balls;

S_{BC} - secondary structure area, calculate to formula:

$$S_{BC} = S_K - \frac{\Delta V_{cp}}{\Delta t \cdot K^P \cdot h_{BC}}, \qquad (5)$$

where: $\Delta V_{cp} = V_{cp\ ti} - V_{cp\ ti-1}$ is the interval of sum wear value meanings of three balls according to two interval Δt, $V_{cp\ ti}$- according to t_i and $V_{cp\ ti-1}$- t_{i-1};

h_{BC} is secondary structure thickness or mechanical-chemical modification thickness.

Calculation results. Calculation results were S_{BC} and □δ according determined to equations (4) and (5), calculation results of the reaction modification (N^M) order speed the constants modification (K^M), coefficients deviation estimation of K^M – W^M are given in table 2.

Table 2

Kinetic characteristics of the 2-nd stage triboreaction modification

Value						Mean values K^M, K_c^M x10^{-4}, s^{-1}	Coefficient of deviation of the estimation of K^M, w_K, %	Graphical value of K^M
Temperature of the tests, T, °K	Time of the tests, t_i, x10^3, s	Secondary structure area, S_{BC}, mm^2	Secondary structure concerning area, δ, %	Order of modification for interval of time, N^M	Constants of speed of modification K^M x10^{-4}, s^{-1}			
333	1,8 2,4 3,0 3,6	2,06505 2,36979 3,05082 4,04623	89,814 86,478 83,449 80,163	N_{1-3} = 0,79	0,59626 0,63071 0,59416 0,62437	0,61138	3,1 %	tg147^0=0,613
303	1,8 2,4 3,0 3,6	1,77638 1,98882 2,2321 2,48635	89,613 86,480 83,425 80,341	N^M_{1-3} =0,87	0,60864 0,59313 0,59947 0,62761	0,60721	2,5%	tg148^0=0,601

For control adequacy of modification N^M and K^M determination of the kinetic characteristics, were calculated by equations (1) and (3). We build the diagram of lgδ from time (t) dependence (fig.2). The linear dependence of lgδ from t confirmed the order of the reaction N^M ~ 1 and set the value of K^M graphically, which is equal to the tangent of the angle of inclination of the straight line to axis OX. This K^M value is also given in table 2.

Thus, knowing the K^M value at both temperatures T_1=333°K and T_2=303°K, the value of the modification activation energy (E^M) calculated according to the equation of Arrenius:

$$E^M = \frac{RT_1T_2}{T_1 - T_2} ln \frac{K_1^p}{K_2^p} = \frac{1{,}9144T_1T_2}{T_1 - T_2} lg \frac{K_1^P}{K_2^P} =$$
$$= \frac{1{,}9144 \cdot 333 \cdot 303}{30} lg \frac{0{,}61138}{0{,}60721} = 0{,}296 \ (kj/mol),$$

where: R is universal gas constant.

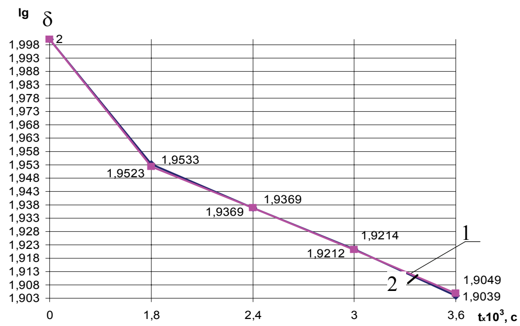


Figure 2. Dependence of lgδ from the tests time (t): 1 - at 333°K, 2 - at 303°K.

Conclusions

1. Calculation results of kinetic characteristics and modification activation energy have confirmed adequacy of normal mechanical-chemical wear kinetic model and adequacy of experimental-calculation method usually for estimation kinetic characteristics and activation energy of three stages triboreaction [1].

2. The established value of the 2-nd stage triboreaction activation energy, mechanical-chemical modification "ШХ 15" in aviation fuel "TC-1" (E^M_{TC-1} = 0,296 kj/mol) approximately 3-8 time less than the analogous value of E^M in "PT" fuel (E^M_{PT} = 0,921…1,354 kj/mol) [2].

3. The established value of E^M_{TC-1}=0,296 kj/mol in "TC-1" fuel have replenished the data bank of the "ШХ15" steel modification and antiwear properties of the "TC-1" fuel and matrixical energy - activation criterion of construction materials estimation, antiwear properties and modification of combustible - lubricant materials and combinations of these materials [4].

References

1. *Богданович А.И.* Кинетические и энергетико-активационные характеристики износостойкости и совместимости материалов трибосопряжений: автореф. дис. канд. техн. наук. - Киев, 1987.-20 с.

2. *Богданович О.І.* Використання енергії активації 2-ї стадії трібореакції як критерій оцінки механо-хімічного модифікування. – Вісник Харківського національного технічного університету сільського господарства ім. П.Василенка, вип. 39., Харків, 2005, с.141-148.

3. *Аксёнов А.Ф.* Трение и изнашивание металлов в углеводородных жидкостях. -М: Машиностроение, 1977.-147 с.

4. *Бершадский Л.И., Богданович А.И., Назаренко П.В.* Энергетико-активационный матричный критерий совместимости. В кн.: Триботехника - машиностроению: Тез. докладов III Моск.: научно-технической конференции (2-4 сентября 1987г.), М.,1987,с.67-68.

UDC 629.735.064.3-33

V.S. Butko Ph.D., Associate professor
(National Aviation University, Ukraine)

TRANSIENT RESPONSE OF HYDRAULIC PRESSURE REGULATORS

The analysis of characteristics of automatic pressure regulators of hydraulic systems, which determine the quality of transitional processes was performed and a functional that allows to determine the parameters of regulator was offered.

1. Introduction.

The estimation of transient process of automatic pressure regulator can be done by means of the index of regulator stability, which characterizes its extreme processing speed. Consequently, the degree of stability of pressure regulator can serve as the measure of its processing speed. It is significant that the decreasing of one index of the quality of transient process often leads to the increasing of another and vice versa. Therefore, while examining of the quality of transient response the main question is the receiving of automatic regulator with the advanced determined properties. It must ensure not only the stable functioning, but also the high indicators of transient process.

2. Problem formulation.

The investigation of quality of transient process involves the consideration of the influence of different factors on the indicators of quality. For these it is necessary to know the transfer function of the regulator and of the regulated object. The distinctive feature of the transfer function of pressure regulator is that the coefficients in nominator and denominator of transfer function are not independent. Analysis shows that they are related to each other, since they represent complex functions of physical parameters of a regulator (setting pressures, areas and lengths of saddles' perimeter, poppet mass, volumes of the liquid in pressure and drain chambers etc). That is why the reduction of the equation to the normalized function and determination of the optimal magnitudes of dimensionless factors is unacceptable in this case. The nominator of the transfer function of pressure regulator at distributing influences includes the differentiating operator of first and second power that sets the additional limits for searching the quality criteria of transient response, since it is necessary to take into account the influence of zeroes of the transfer function.

3. Derivation of the Fundamental Physical Relationships**.**

The most important parameter of the transient response of pressure regulator is the deflection of the error of regulation. The choice of the form of transient process of automatic pressure regulator depends on the requirements to its work. So, in one case we prefer to get the periodic pressure process, in another – overshoots. It is necessary to proceed on the problems of pressure regulation in the considered system. The system to be studied is illustrated in Fig 1. The valve consists of a conical-seat poppet of mass *m* loaded by a spring of stiffness *c*. The viscous and other friction forces acting on the poppet-piston are lumped in a damping constant $K_{v.}$. The pressure sensitive area of the poppet valve is denoted by F. In the case under consideration the added-volume accumulator is installed.

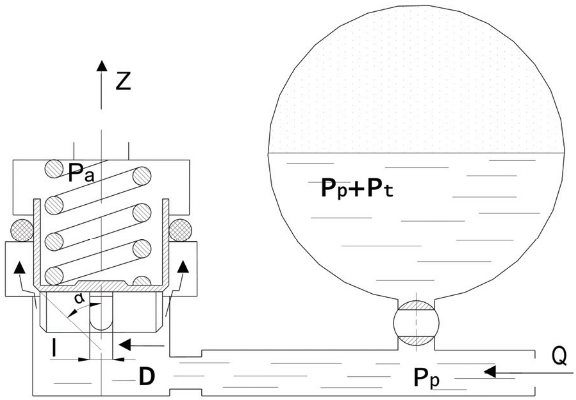


Figure 1. Schematic diagram of a pressure-controlled hydraulic system

The analysis involves the following basic assumptions:

1. Head losses in fluid passages are negligible.
2. Discharge coefficient of the valve does not change.
3. The fluid source is ideal.
4. Coulomb friction has been neglected.
5. All of the walls of the fluid passages and chambers are rigid.
6. Fluid pressure changes simultaneously in the whole hydraulic circuit.
7. The angle of discharge does not deviate.
8. Steady and unsteady fluid-flow-induced forces on the poppet valve are included in the effective spring and damping constants.
9. The inertia of the fluid in the pipeline is neglected.
10. Only small flow variations through the poppet valve are being considered.

The choice of functional, which corresponds to quality performance, is complicated problem, because it is connected with taking into account a lot of concrete conditions. They are, first of all, demands, which are made to the regulating system, simplicity of the further analysis of optimal system, etc. Therefore, if we consider that the minimum of error of transitional process corresponds to the minimum of integral

$$I = \int_0^\infty p^2(t)dt \,, \tag{1}$$

where p(t) is the dynamic component of pressure, rated to the respect of the new established level. The less integral, the better the system. For the ideal automatic pressure regulator p(t) = 0, correspondingly I ≡ 0. The ideal system can not be realized physically, these equalities are impracticable. That's why for the optimal systems the quality performance I reaches non-trivial minimum.

4. Dynamic analysis

The transfer function of automatic pressure regulator is given by:

$$W = \frac{p(s)}{Q(s)} = \frac{b_2 s^2 + b_1 s + b_0}{a_3 s^3 + a_2 s^2 + a_1 s + a_0}, \tag{2}$$

where

$$a_0 = K_m K_Q + \omega_0^2 (K_z + K_y); \qquad b_0 = \omega_0^2 K_f;$$

$$a_1 = K_c \omega_0^2 + K_m + 2n(K_z + K_y) K_0 K_Q; \qquad b_1 = 2nK_f;$$

$$a_2 = K_z + K_y + K_0 + 2nK_c; a_3 = K_c; \qquad b_2 = Kf;$$

The law of change of the main disturbing impact (Q = Q (t)) in hydraulic systems may be various. For the investigation of transitional processes it is convenient to use the step function.

Transient process in linear systems at stepped disturbing impact and zero initial conditions is equivalent to the transient process without disturbing impact in another linear system, for which the left part of differential equation is constant and the right part is equal to zero. Also the new (equivalent) initial conditions must be tided according to relations:

$$\begin{gathered} p(0) = -p_s = -\frac{b_0}{a_0} Q_v; \\ p(0) = \frac{b_2}{a_3} Q_v = \frac{Q_v}{K_c}; \\ \frac{d^2 p(0)}{dt^2} = \frac{Q_v}{a_3} \left(b_1 - \frac{a_2 b_2}{a_3} \right) = -\frac{Q_v}{K_c^2} K_p; \end{gathered} \tag{3}$$

Where p_s is the increment of pressure in the steady mode at increasing of the flow rate through the valve on value Q_d.

The value of the integral I for transient process we can calculate by Mandelshtam's and Papaleksi's method:

$$I = \frac{1}{a_0} \left(h_3 + \frac{a_2 a_3 h_1 + a_2^2 h_2}{a_1 a_2 - a_0 a_3} \right); \tag{4}$$

We can find the value of integral I by substituting the parameters of regulator in this formula, thus we can characterize the quality of the system. The less the integral, the better the pressure regulating hydraulic system.

For the further analysis we must express functions, which depend upon the initial conditions, through the physical parameters of regulator. At the same time we will insert the assumption of horizontality of static characteristic of pressure regulator that corresponds to the practical requirements to the equipment for stabilizing parameters of hydraulic systems. Then we will have:

$$h_1 = \frac{Q_s^2}{2K_c}\left(\frac{mK_p^2}{K_c^2} + \frac{F^2 + K_v K_p}{K_c}\right); \;\; h_2 = \frac{Q_s^2}{2K_c}\left(K_v - \frac{mK_p}{K_c}\right); \;\; h_3 = -\frac{Q_s^2}{2K_c}; \tag{5}$$

The expression for the integral quadratic error in the function of parameters of oscillated system and the value of stepped disturbing impact is as follows:

$$I = \frac{Q_v^2\left[m(FK_Q m + K_v^2 K_p) + K_v^3 K_c\right]}{2FK_Q^2\left[m(K_v K_p^2 + F^2 K_p - FK_c K_Q) + K_c K_v (K_p K_v + F^2)\right]}. \tag{6}$$

In general case, the solution determines the optimum vector of pressure regulator parameters. However, the problem of minimization of integral I with large quantity of variables is enough complicated and not always expedient, since the results on some variables can be trivial, for example, minimum of integral corresponds to the minimum of mass, etc. That’s why we should set additional (determined, for example, by practical reasoning) conditions on some coefficients, mark the variables and determine their optimal values on integrals I minimum. This approach allows to determine the values of optimal coefficient of regulators’ amplification on expense and the viscous friction coefficient:

$$K_Q^* = \frac{F}{3\sqrt{3}}\sqrt{\frac{c_l}{m}}; \quad K_v^* = \frac{m}{\sqrt{3}}\sqrt{\frac{c_l}{m}}; \tag{7}$$

where: $\sqrt{\frac{c_l}{m}} = \omega_l$ - is self cyclic frequency of oscillations at critical decrement (at the stability limits) for the low-lift valve $(Z \to 0)$ with the horizontal expense characteristic: $c_l = \frac{EF^2}{W}$ - is the rigidity of joint volume of fluid.

5. Conclusion.

We can see that the functional I depends upon the parameters of the system. Such parameters, at which I reaches the minimum corresponds to the optimal system. These dependences allow to determine in the first approach the main parameters of pressure regulator with their further precision, depending upon certain working conditions of automatic pressure regulator in hydraulic system.

References

1. Ричард К. Дорф, Роберт Х. Бишоп. “Современные системы управления.” Лаборатория базовых знаний, Москва, 2004, 831с.

2. J.F. Blackburn, G.Reethhof, J.L. Shearer. “Fluid power control.” The technology Press of M.I.T, 1959, 710p.

UDC 629.735.083.03.004:004.942 (045)

L.A. Zhuravlova, PhD Engineering (Nation Aviation University, Ukraine),
E.A. Sapeluk, PhD Engineering (Nation Aviation University, Ukraine)

FUZZY MODEL FOR DIAGNOSTICS OF GTE STATE

The paper introduces one approach to the generating of diagnostic decision for the aviation gas turbine engine malfunction, supported by the fuzzy model in MATLAB suit.

Problem identification. During operation of aviation gas turbine engines (GTE), certain deviations from operating parameters may occur being the evidence of some damage. Different combination of the various parameters changes of engine work can be caused by the different reasons. In this situation the information about the current state of GTE should be as full as possible. In particular, the expert thoughts may be involved to the decision making process. Therefore, the field data may involve both numeric and non-numeric information (linguistic), and some of them may involve mixed data. In order to process all data together and estimate the mutual effect of these, both the expert systems' and fuzzy systems' tools should be applied.

Problem state. The general idea is:

-to collect all possible data, which correlate with the object (i.e. MMEL &MEL recommendations, expert knowledge, results of technical diagnostics et.);

-to represent all data in the form of linguistic variables (fuzzification);

-arrange logical rules;

-to reflect input space of data to the output space through the fuzzy inference mechanism;

-defuzzificate the result and estimate it (the value of probability) for the further decision making process.

Conceptual considerations. The conceptual background of the problem of diagnosing gas turbine engine through the implementation of information technology decisions on the evaluation of their technical condition is associated with the need to describe the interrelated multiparameter objects. The basic requirement for the recognition algorithm causes manifestations of faults or deviations from normal operation is the ability to detect the state of an object when there are multiple channels of measurements of physical parameters (variables), change the values of which are interrelated and each of them characterizes the state of engine in whole.

There are several methods and techniques of test and functional diagnosis based on a study of thermal, gas dynamics, vibration and other parameters. These systems can detect approximately 50% of possible failures of gas turbine engines, but they are not always reliable because of the large number of them it is difficult to take into consideration for factors that influence the state of engine.

The problem of selection of informative features in assessing the technical condition of GTE is a general problem of minimizing the amount of initial information about identifiable states. The goal is to minimize the allocation of the initial information in the first place those signs, which deliver the necessary information about the differences between the recognition classes.

The problem solution is based on the approach, proposed by Shabaev R.R. The generic idea of the approach is the next: analysis of studies on the problem of choosing the most in-formative parameters of the organization of monitoring and diagnostics shows that most of the methods involve the tasks of minimizing the qualitative level, without calculating the quantitative estimates. With adequate mathematical models of complex technical objects (TBG) may develop appropriate ways to minimize, to compute "weight" values of the parameters of control (diagnosis) and, based on minimizing build-structed a set of parameters. The most informative combination of parameters in the procedures for diagnosis may be suggested as follows: $T_{04}^{1-10}, \pi_1, \pi_2, \pi\sum, n_2, n_1$. ("Temperature field" for the high or low pressure turbine, the pressure ratio of the compressors, the total pressure ratio of the compressors, frequency of rotation of the compressors).

Fuzzy system input data set. The set of fuzzy system input data involves: Temperature after HPT or LPT; LPC pressure ratio; HPC pressure ratio; Sum pressure ratio; HPC rotor frequency of rotation; LPC rotor frequency of rotation.

The field data are arranged as the initial table (fragment is presented by Table 1); 4 GTE modes are investigated.

Table1

Parameters recorded during different modes

#	parameters	modes			
		Idle	0.4 nominal	0.6 nominal	0.85 nominal
1.	n_{HPC}	12708....13533	13032	14225	15225
2.	n_{LPC}	3700	7530	8560	9725
3.	G_F	193	280	392	487
4.	T_{atm}	288	288	288	288
5.	P_{atm}	1.03	1.03	1.03	1.03
6.	T_{LPC}	283	287	291	294
7.	P_{LPC}	1.09	1.24	1.35	1.44
9.	T_{HPC}	333	438	500	546
10.	P_{HPC}	1.79	3.35	4.29	5.18
11.	T_{HPT}	685	650	677	721
12.	P_{HPT}	1.05	1.12	1.17	1.24

Operational constrains are the next:

1. Maximum n_{LPC} - on which the stator is turn-off is 6770-7270 rpm (41-44%).

2. Maximum allowable n_{LPC} - on the ground is 11610 rpm (98%).

3. Maximum allowable T_{HPT}- on the ground and during flight: take off mode- not more then 630; nominal mode- not more then 570; cruise mode- not more then 550; idle mode- not more than 600.

4. During idle mode π_{HPC} - not more than 10%.

Possible reasons for deviations from normal diagnostic parameters for modes of GTE and their expert thoughts are given in Table 2 (fragment).

Table 2

Possible reasons for diagnostic parameters deviations

Diagnostic parameter	Expert evaluation of the degree of parameter deviation	The combination of possible causes (diagnosis)
Increasing the temperature of gases after turbine	0.1	Slight overheating blades of GV third stage turbine OR Insignificant burning-out tube combustion chamber OR Slight contamination of high pressure compressor blades OR Slight warp blades of GV, low pressure compressor
	0.2	More significant overheating blades of GV third stage turbine; ORMore significant burning-out tube combustion chamber; ORMore significant contamination of the high pressure compressor blades ORA substantial warp blades of GV, low pressure compressor
	0.3	Significant overheating blades of GV third stage turbine OR Significant burning-out tube combustion chamber OR Significant contamination of high pressure compressor blades OR Significant warp blades of GV, low pressure compressor
	>0.5	Large blades overheat GV third stage turbine OR Great burning-out tube combustion chamber OR Great pollution high pressure compressor blades OR Great warp of blades GV, low pressure compressor

Input and output data justification. All input and output data (both numerical and linguistic) should be represented as linguistic variables. A linguistic variable is a quintuple (X,T(X),U,G,M,), where X is the name of the variable, T(X) is the term set, i.e. the set of names of linguistic values of X, U is the universe of discourse, G is the grammar to generate the names and M is a set of semantic rules for associating each X with its meaning. Each linguistic variable is represented as a *term-set*. As an example, some linguistic variables for stated GTE parameters, and their term-sets are given below.

Name of Linguistic Variable	Term-set	Subjective Probability
1. Temperature after HPT	Normal……………………………	>0.1< 0.2
	Augmented …………………..	>0.2, <0.3
	Dangerous..………………..………	< 0.5
2. LPC pressure ratio	Normal……………………..	< 0.1 >0.3
	Augmented ………………..	>0.3, < 0.7
	Dangerous…...………………	< 0.7 >0.1

Outputs in our case will be thrust and fuel consumption, because fuel consumption of an aircraft engine is a function of the power plant utilized and thrust required from the engine to perform certain tasks at certain altitudes and speeds.

1. Thrust
- Normal…………………………….…… < 0.1>0.2
- Augmented ……………..……………>0.2 <0.4
- Dangerous ……………………………….<0.4

2. Fuel consumption
- Normal………………………..< 0.1 >0.2
- Augmented …………………….>0.2 < 0.3
- Dangerous ………………………. <0.5

Membership Functions. In this fuzzy model there are 6 inputs (in the left upper side), and 2 outputs (right upper side). The tools that are situated in the down part of the screen give an opportunity to choose parameters, and write its names. For example, first our input, which is framed by red color, is temperature after HPT (Fig.1).

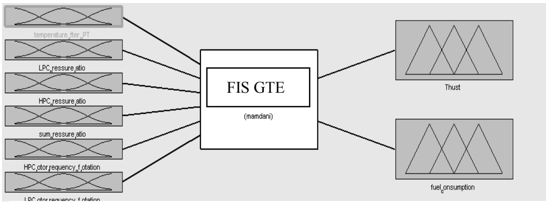


Figure 1. Fuzzy model in MATLAB suit

The example of membership functions of input signal is represented on figure2.

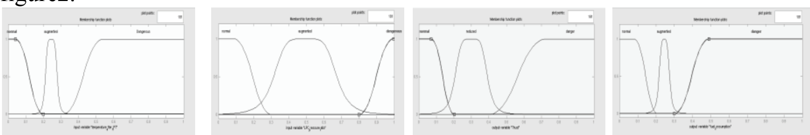


Figure 2. Membership functions for the linguistic variables

Fuzzy Rules Generation. Fuzzy rules are generated with the tools of the fuzzy system MATLAB suit (Fig.3.).

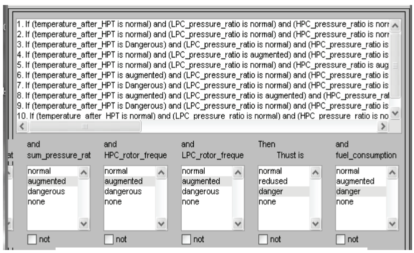


Figure 3. Fuzzy rules

Experiment Arrangement. Fuzzy model gives the opportunity to reveal the dangerous combinations of factors. The possible unfortunate combinations of factors can be investigated in Rule Viewer Suit (Fig.4).

At the top of the window is a field rules. In the bottom of the windows are the input and output linguistic variables of diagnostic parameters. Between the top and bottom of the window shows the design rules with complex antecedent (link) and integrated konsikventom (conclusion). The structure of the present rules or logical operators or and. In the window of each variable given the names of those functions accessories.

Modeling Results. Surface viewer simulates the response of the fuzzy model for the entire range of inputs that the system is configured to work for. The responses to the inputs are plotted against the inputs as a surface.

In Fig.5.the output surface for two inputs - sum pressure ratio and temperature after HPT - is shown. As it can be seen in case of sum pressure ratio augmentation and temperature after HPT dangerously increased then the thrust will be dangerously increased too, which sounds very rational. Fuzzy model diagnostic decisions are summarized in table 3.

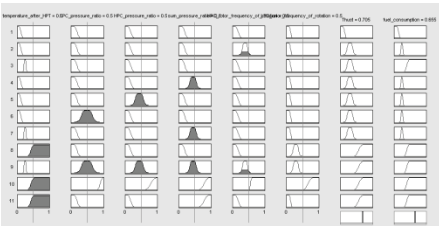


Figure 4. Rules Viewer

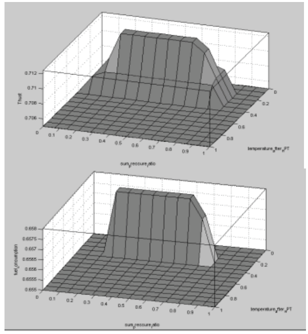


Figure 5. Results of modeling

Table 3

Diagnostic decisions

Parameters		1	2	3	4	5	6		7	8
		T_{HPT}	π^*_{LPC}	π^*_{HPC}	$\pi^*_{\Sigma C}$	n_{LPC}	n_{HPC}		P	G_F
1	if	N	N	N	N	N	N	than -	N	N
2		N	N	N	N	N	A		R	D
3		A	N	N	N	N	N		R	A
4		N	N	N	A	N	N		R	A
5		N	N	A	N	N	N		R	A
6		N	A	N	N	N	N		R	A
7		A	N	N	A	N	N		D	D
8		D	N	N	N	A	N		D	D
9		A	A	A	A	A	A		D	D
10		D	D	D	D	D	D		D	D
11		D	N	N	D	N	N		D	D

N-normal; A – augmented; D-dangerous.

Conclusions

Basing on results of modeling the most dangerous is T_{HPT} augmentation, because it can signalize about engine faults, such as blades overheating of third stage turbine GV, burn-out tube combustion chamber, contamination of high pressure compressor blades, blades overheating of low pressure compressor GV, which can cause serious reduction of thrust, and self turn-off, or fire of an engine.

UDC 629.735.03-226.2.002.71:620.178.3(043.2)

Yu.S.Nalimov, Ph.D. in Engineering (G.S.Pysarenko Institute for Problems of Strength, NAS of Ukraine, Ukraine, Kyiv)
E.I.Yurchenko, A.S.Tugarinov, Ph.D. in Engineering, (National Aviation University, Ukraine, Kyiv)

EFFECT OF MAGNETIC ABRASIVE MACHINING OF GAS TURBINE ENGINE BLADES IN REPAIR PROCESS ON THEIR SERVICE LIFE

The problem is possibility of gas turbine engine compressor blades fatigue strength improvement by their magnetic abrasive machining.

Currently, GTE blades serviceability restoration after their long-term service is an actual problem, since its solving will allow to extend their lifetime, reduce materials output ratio and will have significant economic effect.

Classification of typical gas turbine engine blade damages and their reasons has been given previously [1].

There are a lot of repair techniques for eliminating various GTE blade surface damages, restoring blade metal surface layer strength properties and thereby extending their service life.

Currently, strengthening technique method based on the surface plastic deformation (SPD) is widely used [2]. As SPD strengthening procedures, shot blasting, pneumodynamic machining, hydro- and pneumogrit blasting, vibration tumbling etc are widely used.

Magnetic abrasive machining (MAM) is used as a final machining combined with special coating deposition methods, particularly ion-plasma coating, and allows significant improvement of various component parts reliability and lifetime, including component parts with irregular space form, e.g., such as gas turbine engine blades. Service conditions improvement is associated with MAM method characteristics, since it combines both impact interaction of powder grit and processing surface, and effects, occurring at friction contact [3, 4].

Besides, original abrasive instrument at MAM has mobile coordination and allows locally affect individual areas of the component machined surface [5] as well as their damage sites.

At the same time, significant reduction of these damages effect, i.e. a sort of “healing” of defects is possible, due to the stress concentration reduction in these defects and formation in material surface layer of favorable compression residual stresses of 200+ mcm in depth.

At compressor blades repair after long-term service, various repair techniques for their restoration are used [2, 6].

One of these techniques is combined machining (MAM and ion-plasma titanium nitride (TiN) coating deposition) that has already shown purposefulness of its use for compressor blades reliability improvement, both new and after service, at their repair [7].

It is known that in service compressor blades undergo erosive wear. After running for more than 1,500 h, on the component part surface defects are registered in the form of cavity pockets, abrasive and corrosive wear traces.

Defective layer elimination is generally performed by manual grinding and polishing of the pockets and corrosion pits with abrasive disks using various pastes. In this process, rather thick material surface layer (up to 0.5…0.8 mm in depth) is eliminated near defects until their complete elimination. This technique results in the following negative moments:

- Pocket closure with material puddles, i.e. hidden defect formation.
- Violation of maximum allowable profile dimensions, i.e. complete component part rejection.
- Strength characteristics degradation at cyclic loading.

All these negative moments of the serial repair technique are not specific for the complex technique using MAM, because it provides not only uniform blade platform surface smoothing [3], but also component part surface layer strengthening [4, 5]. Furthermore, MAM blade technique and unit allows blade edge formation [4, 8] and various blade platform areas machining with controlled effect [5].

Magnetic abrasive blade platform machining may be not only polishing-strengthening operation, but also preliminary technological operation prior to coating deposition and the coating machining.

The study was performed on compressor blades after service (~ 2,000 h), made of 13H12N2V2MF steel (EI961). The blades were exposed to troubleshooting, primary machining (washing and coke cleaning) and then MAM machining and deposition of several TiN coating layers. The results of two blade batches fatigue resistance tests and fatigue curves, plotted using linear regression analysis method, are shown in Fig. 1.

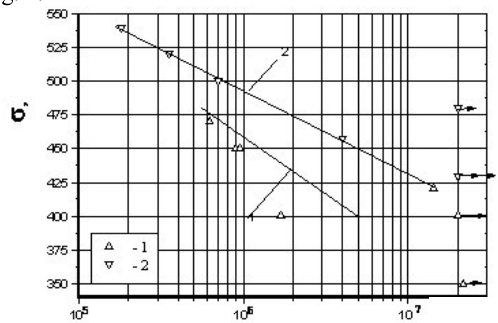


Fig. 1. Blade fatigue test results (13H12N2V2MF steel, running in service 2,000 h) after different repair techniques: *1* (Δ) – polishing; *2* (∇)– MAO+TiN+MAO+TiN

The first batch was exposed to blade platform polishing by repair base technique.

The second batch was machined by MAM method with subsequent TiN coating deposition 6…8 mcm in depth. Blade platform surface roughness after MAM+TiN+MAM+TiN repair technological cycle meets requirements to new component parts. Please, note high quality of thin leading and trailing blade edge coating, and that repeated MAM did not damage blade surface TiN coating, including the edge coating. It suggests high coating adhesion to the basis.

Test data analysis shows that the blades after polishing by repair base technique (Curve 1) have greater fatigue life scattering. Fatigue Curve 2 of the blades exposed to complex platform surface processing (MAM+TiN+MAM+TiN), is characterized with little test point scattering and higher narrow fatigue limit (σ_{-1} = 430 MPa).

Little test point scattering indicates stability of the blade surface layer properties after complex machining, and the narrow fatigue limit improvement based on 2.107 cycles for ~ 30 MPa provides activity of the surface residual compression stresses, occurring in material after magnetic abrasive machining.

Resume. Comparative fatigue tests of gas turbine engine blades exposed to magnetic abrasive machining after their certain service time show higher fatigue endurance limit and lower test point scattering, than in blades, exposed to fitting and polishing by repair base technique.

It is an evidence that the first type machining of the blades has greater effect on their fatigue life.

References

1. *Грязнов Б.А., Налимов Ю.С., Юрченко Е.И., Тугаринов А.С.* Характеристика типовых эксплуатационных повреждений лопаток газотурбинных двигалетей и их причины //Материалы IX международной научно-технической конференции «АВИА-2013» 21-23 мая. Киев. – 2013. – т.3. – С. 17.5-17.9.
2. *Барвинок В.А., Вишняков М.А.* Повышение усталостной прочности высоконагруженных деталей ГТД методов термопластического упрочнения //JSSN 0131-1336. Тяжелое машиностроение, 2004, № 40, С. 6-9.
3. *Шлюко В.Я., Майборода В.С., Гридачова Т.Я.* и др. Магнитно-абразивная обработка лопаток на установке типа кольцевой ванны //Авиац.пром-сть. 1985, - № 8, - С. 19-20.
4. *Майборода В.С., Степанов О.В.* О влиянии магнитно-абразивной обработки на свойства поверхности лопаток ГТД //Аваиац.пром-сть, - 1994. - № 11/12. – С. 32-34.
5. *Майборода В.С., Степанов О.В.* Формирование порошкового магнитно-абразивного инструмента при обработке лопаток газотурбинных двигателей //Порошк. металлургия. – 1996. - № 1/2. – С. 88-94.
6. *Шайдак Б., Иванов А., Иванов С.* Продление ресурса турбинных лопаток стационарных ГТД //Газотурбинные технологии, май-июнь 2003. С. 42-45.
7. *Грязнов Б.А., Майборода В.С., Налимов Ю.С* и др. Исследование влияния видов обработки поверхности и многослойного покрытия пера лопаток на их характеристики сопротивления усталости //Пробл.прочности. – 1999. - № 5. – С. 109-116.
8. Патент України № 18814 В24В 31/112. Спосіб магнітно-абразивної обробки /В.С.Майборода, А.В.Андрнов, О.В.Степанов та ін. – Надр. 25.12.97, Бюл. № 6.

UDC 629.735.03-226.2.:620.178.3(043.2)

Yu.S. Nalimov, Ph.D. in Engineering (G.S.Pysarenko Institute for Problems of Strength, NAS of Ukraine, Ukraine, Kyiv)
E.I. Yurchenko, A.S. Tugarinov, Ph.D. in Engineering, (National Aviation University, Ukraine, Kyiv)

GAS TURBINE ENGINE BLADES FATIQUE STRENGTH TEST AFTER WELDING REPAIR FOR THE PURPOSE OF THEIR AIRWORTHINESS MAINTENANCE

The problem is evaluation of possibility to support gas turbine engine blades airworthiness by their fatigue strength test after welding repair.

In service, gas-turbine engine (GTE) blades undergo erosive wear and corrosive damage. Furthermore, handling marks caused by foreign object entry into GTE gas-air flow duct may appear on the blade edges [1].

All these factors reduce cyclical strength of the blades. However, to save energy and material resources, actual task is to find reasonable repair procedures of gas-turbine engine blades, which would assure their serviceability at further service.

One of these procedures, especially, when it concerns blade edge repair, is fusion welding repair. It is possible under condition that repair technique provides uniform strength of a new and repaired blade pressure side considering difference between base metal and welding deposition mechanical properties at hazardous loading.

In rationally projected blade, proof strength value from root to mid-span section has insignificant changes [2]. Generally, in this part of the blade no defects and, respectively, repair allowed [3]. Therefore, allowable repair zone is within the limits from mid-span to end blade section. The experience of gas-compressor unit (GCU) blades service has shown that their serviceability is mainly limited to fatigue resistance. Then, under uniform strength condition it is necessary to maintain inequation

$$\frac{\sigma_{-1}^{p}}{\sigma_a} \geq \frac{\sigma_{-1}^{o} K}{\sigma_a} \text{или} \; \frac{\sigma_{-1}^{p}}{\sigma_{-1}^{o}} \geq K,$$

where σ_{-1}^{o} and σ_{-1}^{p} – limiting characteristics, fatigue endurance limits of new and repaired blade in the same sections

K – fatigue endurance limit of repaired blades reduction factor

Knowing *K* value for specific blades and stress distribution diagram along the blade platform length in relative coordinates $\sigma_a / \sigma_{a\,max}$, where $\sigma_{a\,max}$ – blade platform maximum stress amplitude, allowable blade platform repair zone may be determined. Figure 2 shows that the size of this zone is established from the point of *K* coordinate intersection with stress diagram to end section.

Described procedure of allowable blade repair zone determination [4] was used during fatigue resistance test of the following new and welding repaired turbine blades: GCU-C-6.3 free turbine (HN77TUR heat-resistant alloy), I stage of GTC-10-3 gas turbine complex (GTC) (HN65BMTU heat-resistant alloy) turbo-propeller engine (TPE), III stage of GTC-10-3 (20H12BNMF martensitic steel) TPE, and axial compressor rotor blades: zero stage of GT6-750 compressor (20H13 steel) and I stage of GTC-10-4 compressor (13H11N2K2MF chromium steel).

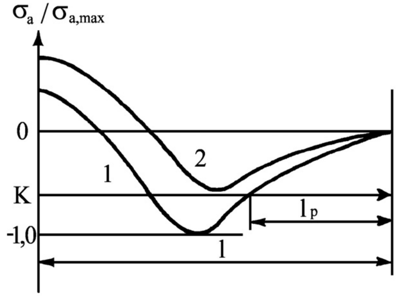


Fig 1. Blade repair zone determination diagram: *1* – leading edge; *2* – trailing edge; l_p – allowable repair zone; *l* – blade platform length

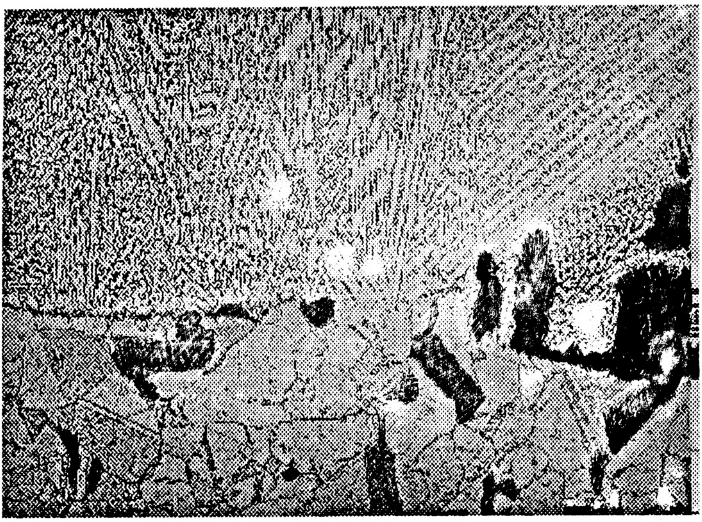


Fig. 2. Blade repair zone microstructure (HN77TUR alloy) after welding deposition

Repair of gas-compressor unit turbine and compressor blade platform was performed due to instructions, developed based on experimental-technological operations of Souzgaztechremont company jointly with E.O.Paton Institute of Electric Welding, NAS of Ukraine, and recommendations of G.S.Pysarenko Institute for Problems of Strength, NAS of Ukraine.

Metallographic tests have shown that at this welding deposition technique, great difference in microstructure of base and added metals was reported (Fig. 2). The structure of the latter metal has dendritic structure with sharp boundary of base metal. Fatigue cracks generated along added metal, there were no cases of crack generation on the line between base and added materials.

Thus, nickel wrought alloy and welding deposition mechanical properties difference is the most likely reason of HN77TUR and HN65BMTU heat-resistant alloy blade destruction in welding deposition zone.

Blade repair welding technique enhancement, providing smoothness of switch to the welding deposition material, close by its properties to the base metal, causes high fatigue blade resistance.

Welding repaired blades of GTC-10-4 compressor I stage made of 13H11N2V2MF steel, which were deposited in argon by KTI-10 electrode on leading and trailing edges in the middle of the blade platform length, were broken along base metal upon the I form bending vibrations.

Fatigue tests of welding repaired GCU compressor blades, made of 20X13 and 20X13BNMF steel, have shown that repair of these blades up to the middle of the platform is possible at the developed welding deposition technique with subsequent thermal and mechanical processing.

Thus, it is possible to repair those blade platform zones, which, considering repair technique and welding deposition properties, maintain required serviceability of the blades in interrepair time under service conditions. Gas-compressor unit pilot development supported this conclusion [5].

Tests of EI893 alloy I stage TPE blades after long-term service support conclusion on weld and base metals uniform strength at repair fusion welding.

Welding deposition (area of 1 cm^2) was performed using ChS-40 electrode wire without underlayer at the leading edge in zone, where the edge amplitude stress is $0.8\,\sigma_{max}$ upon this form of vibrations. Electrode wire mechanical properties are similar to EI893 alloy properties upon increased temperatures.

Figure 3 shows fatigue test results of the blades, welding repaired upon bending vibrations. For comparison it also presents fatigue curve of the blades after service for 25,000 h. It is evident that repaired blades have higher fatigue resistance, than the blades after service life.

Please, note virtually the same fatigue curve slopes in the Fig. 3 and little life scattering of repaired blades (correlation factor is $r_{y/x} = -0{,}9704$).

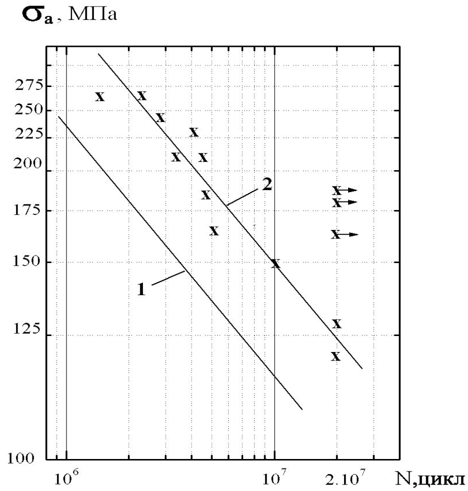


Fig. 3. GTC10-3% TPE I stage blade fatique curves: *1* – basic curve (after service life for 25 th.h); *2* – blades, welding repaired along the leading edge

Resume

Based on performed tests, procedure of allowable gas turbine engine blade repair zone determination was developed and presented. It was shown that fatigue tests of the welding repaired compressor blades by enhanced welding technique indicate uniform strength of added and base metals. It maintains required blade serviceability in interrepair time under service conditions.

References

1. *Грязнов Б.А., Налимов Ю.С., Юрченко Е.И., Тугаринов А.С.* Характеристика типовых эксплуатационных повреждений лопаток газотурбинных двигалетей и их причины //Материалы IX международной научно-технической конференции «АВИА-2013» 21-23 мая. Киев. – 2013. – т.3. – С. 17.5-17.9.

2. *Аронов Б.М., Жуковский М.Н., Журавлев В.А.* Профилирование лопаток авиационных газовых турбин. – М.: Машиностроение, 1975. – 192 с.

3. ОСТ 1 00304-79 Лопатки газотурбинных двигателей Нормирование повреждений лопаток компрессоров от попадания посторонних предметов. – Введ. 01.07.79.

4. А.С. 1677582 (СССР). Способ испытания на усталость конструкции /Б.А.Грязнов, С.С.Городецкий, Ю.С.Налимов и др. – Опубл. 15.09.91. Бюл. № 34.

5. *Грязнов Б.А., Городецкий С.С., Налимов Ю.С., Герасимчук О.Н.* Сопротивление усталости рабочих лопаток турбины и компрессоров, отремонтированных сваркой //Пробл.прочности. – 1994. - № 11. – С. 20-25.

UDC 621.646:629.735.03

Y.N.Rikunich, Y.B. Fedorichko
(PC «Kiev central bureau of valve design»),
E.I. Barilyuk, G.I.Zayonchkovskiy, PhD
(National Aviation University, Ukraine)

INCREASING SMALL ELECTROMAGNETIC VALVES RELIABILITY AND SERVICE LIFE

This article discusses the main actions taken for improving the reliability and service life of small solenoid valves that are used in aerospace products. These actions take into the consideration possible changes in the technical condition of parts and assemblies of valves during the lifelength of the valve under operating loads.

Development of modern aviation and space technic requires significant reduction of the development time and manufacturing application time for the new devices which have increased requirements for the reliability and lifelength. These demands are fully applicable to the development of small electromagnetic valves (EV), that are widely used for different purposes in aerospace units. However, traditional ways of ensuring reliability and safety of the small EV, that are based on the results of labor-intensive and prolonged endurance tests, no longer meet the requirements of the time.

More effective approaches should be implemented into the EV designing practice. One of which is the selection of the required valve workability reserves on the early stages of its design process. Such selection is based on the prediction of possible changes in the technical condition of the valve under operating loads during its lifelength.

This even on the stage of conceptual design of a new valve allows to:

- identify operational factors that have the greatest impact on changing the technical state of the valve elements and units during its lifetime;
- determine the structural elements of the valve, which limit its lifetime;
- timely develop concrete actions aimed to improve the design of the valve and to ensure the required level of reliability and durability.

As collected experience of the design of small EV for aerospace products shows the problem of providing the necessary indicators of maintainability and reliability of valves is connected with two problems: ensuring the fatigue strength of the structural components of the valve and ensuring parametric workability reserves of the valve [1].

It was chosen for the object of research the pneumatic valve with two-polarized electromagnetic drive (fig. 1). It is widely used in aerospace products because of the low energy requirement. For the evaluation of technical changes in the valves of such type and their main functional parameters it was conducted a resource testing of 5 sample valves until their full failure.

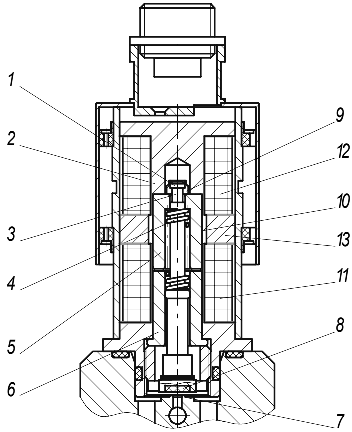


Fig. 1. The structural layout of the valve with two-polarized electromagnetic drive: 1 – head of the rod; 2 – the electromagnet 3 – neck of the rod; 4 – buffer spring, 5 – slide (anchor), 6 – bottom feet, 7 – seat 8 – slide 9 -lock washer, 10 – separator tube; 11 – closing winding, 12 – opening winding 13 – permanent magnet

Conducted longevity tests of the experimental group of valves showed that during the process of work there is a slight decrease in voltage U_{open} and time t_{open} of valve opening, slight decrease of U_{close} and time t_{close} of valve closing and significant reduction of the slide motion x_{slide}. The reason of this is the change of location of slide 5 against to the lock washer 9 and rod 1 because of wear of circular groove on the end surface of the slide 6 and plastic deformation of the moving assembly of the electromagnetic drive of the valve (in the first case it is the rod neck). When the value of the parameter x_{slide} reaches its critical number (0,1 mm) then the valve has a failure.

Obtained experimental dependencies of the change of the valve functional parameters from the number of work cycles have become the basis of the engineering methodic for the forecasting the operational changes of the valve functional parameters during lifetime. Further development of this methodic is the methodic for determining and science-based choice of parametrical work reserves of small EV. This methodic was implemented in PC «Kiev central bureau of valve design»).

Such analytical expressions for the determination of the work reserve of the valve parametrical work efficiency by its y_i functional parameter for the start valve condition after its manufacturing were obtained [2]:

- when the parameter y_i is limited from above $E^{\Sigma}_{k_{cr}}$

$$\eta_{y_{i0}} = 1 + \left[u_{y_i}\right]^{RS} \nu_{y_{in}} - \frac{\left[y_i\right]_a^{RS} k_{y_i} n_c^{\beta}}{m_{y_{i0}} m_{y_{in}}};$$

- when the parameter y_i is limited from below

$$\eta_{y_{i0}} = \frac{1}{1 - \left[u_{y_i}\right]^{RS} \cdot \nu_{y_{in}}} + \frac{k_{y_i} n_c^{\beta}}{\left[y_i\right]_b^{RS}},$$

where $\left[u_{y_i}\right]^{RS}$ – quantile of the normal distribution of the parameter y_i for the given in the RS probability of valve given work resource full wear; $\nu_{y_{in}}$ – coefficient of variation of the functional parameter y_i after n_c work cycles; k_{y_i} – coefficient which indicates the rate of functional parameter y_i change from the number of the work cycles; β – exponent which takes into account the nature of the functional parameter y_i change during lifetime.

Thus, to determine the initial values of the coefficients of the parametric work reserves of the designed valve on the stage of its development it is necessary to know the following raw statistics:

- starting mathematical expectation $m_{y_{i0}}$ and coefficient of the variation of the considered parameter $\nu_{y_{i0}}$;

- data on the predicted values $m_{y_{in}}$ and $\nu_{y_{in}}$ at the time which corresponds to the number of work cycles n_c;

- data on the nature of the valve functional parameter change with the work cycles $m_{y_{in}} = f(n_c)$.

These necessary statistical data is determined by summarizing the operating experience of the analog valves and by the results of recourse tests of the designed valve prototypes.

The developed methodic allows to determine on the early stages of designing such work reserve by its output functional parameters $\Delta y_{i0}^{WR}(t_0)$ and corresponding work reserve factors $\left[P_{y_i}\right]^{RS}$ that ensure its functional parameters during the lifetime are in the range determined by the RS with the given in the RS probability.

Experimental recourse tests of the valves of this type show that there is a critical element which limits the valve lifetime. It is rod element of the moving assembly of the electromagnetic derive – the rod. It works under significant cyclic impulse loads.

Considering from a physical point of view the process of fatigue damage accumulation in EV rod elements, it can be stated that the rate of degradation processes in the elements of the moving assembly of the valve is related to the magnitude of the kinetic energy of the contacting moving parts. It is possible with sufficient certainty to assume that some amount of the kinetic energy of the moving assembly during opening and closing is converted in the potential energy of the rod structural material deformation. The remaining part of the energy is dissipated through friction or because of specially installed damping unit. With the increase of work cycles number the quantity of those energetic conversions increases, what leads to the destruction of the elements. Thus from the energetic point of view the condition of indestructibility of the valve rod neck during work loads will be correctness of this inequality:

$$E_k^{MA}(1-K_{dis})n_c < E_{k_{cr}}^{\Sigma},$$

where E_k^{MA} – specific kinetic energy of the valve moving assembly. In the first approximation it can be determined as $E_k^{MA} = \frac{mV_{av}^2}{2} \Big/ f_{cross-cection_{\min}}$; m – mass of the moving assembly of the valve; V_{av} – average speed of moving assembly; $f_{cross-section_{\min}}$ – minimal area of cross-section of the rod element; K_{dis} – dissipation factor, which depends on kinematic layout of the valve moving assembly and existence of the damping element in its design; n_c – number of work cycles; – critical value of the specific kinetic energy that is collected in the rod material at which there is rod destruction.

The work reserve of valve rod elements by its fatigue strength by the criteria of specific kinetic energy of the valve moving assembly is determined as:

$$\eta_E = \frac{\left[E_{k_{cr}}^{MA}\right]_{n_c}}{\left(E_k^{MA}\right)_0},$$

where $\left[E_{k_{cr}}^{MA}\right]_{n_c}$ – is the critical value of specific kinetic energy of the valve moving assembly that corresponds to its work cycles n_c until the full destruction of the rod element, which is determined experimentally for different materials; $\left(E_k^{MA}\right)_0$ – specific kinetic energy of the valve moving assembly just after the valve was manufactured.

Such analytical dependency for determining work reserves of the rod elements of the electromagnetic valve was obtained [3]:

$$\eta_E \approx k_\chi(1{,}414[u]^{RS} \cdot \nu_{E_{k0}} + 1),$$

where k_χ – correction factor, which considers difference of the distribution law for the $\left(E_k^{MA}\right)_0$ and $\left(E_{k_{cr}}^{MA}\right)_{n_c}$ from the normal law; $[u]$ – quintile of the normal distribution; $\nu_{E_{k0}}$ – coefficient of variation for the parameter $\left(E_k^{MA}\right)_0$ in the initial section of the process.

For the practical realization of the developed methodic for determining the fatigue strength reserves of the valve rod elements, the experimental dependencies of the maximal work cycles number of the rod until it's destruction from the level of specific kinetic energy of valve moving assembly for different materials (08X18H10T, BT1-0, AK4-1) were obtained.

Main results of conducted research are implemented into the valve design process in PC «Kiev central bureau of valve design» in the form of the local standard СТУ-273:2012 "Methodic for calculation the work reserve of the electromagnetic valve during its desing" and as recommendations for the design improvement for the number of EV types that are designed in Kiev central bureau of valve design.

Summary:

1. It can be considered that the main way in the ensuring the necessary levels of reliability and durability of small electromagnetic valve is the implementation of science-based methods of determining the work reserves during the design process.
2. The analytical dependencies for determining parametrical and strength work reserves of the EV and reserves of stress fatigue of valve rod elements wit two-polarized electromagnetic drive were obtained. They allow to choose on the development stage the necessary valve parameters with a glance of the given in the requirement specification probability of work.
3. This engineering methodic of determining the work reserve of small EV had been implemented in PC «Kiev central bureau of valve design» as the local standard СТУ-273:2012 "Methodic for calculation the work reserve of the electromagnetic valve during its desing".

References

1. *Хильчевский В.В.* Надежность трубопроводной пневмогидроарматуры / В.В. Хильчевский, А.Е. Ситников, В.А. Ананьевский. – М.: Машиностроение, 1989. – 208 с.

2. *Рикуніч Ю.М.* Визначення параметричних запасів працездатності електромагнітних клапанів / Ю.М. Рикуніч, О.Є. Ситніков, Г.Й. Зайончковський // Промислова гідравліка і пневматика. 2011. №4 (34). – С. 50-54.

3. *Рыкунич Ю.Н.* Исследование по энергетическим критериям запасов работоспособности поляризованных двухпозиционных электромагнитных клапанов двигательных установок / Ю.Н. Рыкунич, А.Е. Ситников, Л.Г. Александров, Е.И. Барилюк, Г.Й. Зайончковський // Вісник ФГУП «НПО им. С.А. Лавочкина». Космонавтика и ракетостроение. – 2013. – (20). – С. 61-67.

UDC 621.391.372

Ganna Sokolovska (National Aviation University, Ukraine, Kyiv)

MEASUREMENT SYSTEMS OF CHARACTERISTICS OF RADIO EMISSION ON THE BASIS OF ACOUSTOOPTIC SPECTRUM ANALYZER

Examined the spread spectrum signals to provide interference protection of radiocommunication systems. Substantiates the use of acoustooptic spectrum analyzer to find the characteristics of broadband signals.

Introduction. The problem of providing reliable communications in conditions of organized and unintended interference and multiple access to the radio network during operation can be solved by using radio communication of spread spectrum signals transmitted [1-2].

The various issues of interference protection of radiocommunication systems with spreading signals are considered in a significant number of works of domestic and foreign specialists [1-4]. Nevertheless, the problem of the effectiveness of such systems, research and development of promising measures and ways of improving their interference protection remain relevant and important from both a theoretical and practical viewpoint.

For practical applications, including systems for radio with spread spectrum signals is an important and urgent problem of synthesis and analysis efficiency of optimal and suboptimal algorithms of the multialternative detection and discrimination of signals, joint detection and estimation of signal parameters, a consistent analysis to problems of detection, search broadband signals under different a priori uncertainty about the statistical characteristics of signal, channels and interference.

Interference protection of radiocommunication systems largely depends on account of the interference environment in which such systems operate. Most appropriate and perspective solution of this problem is the use acoustooptic devices, allowing practically in realtime and with a high degree of confidence recognize and evaluate the parameters of both wideband and interfering signals.

Statement of the problem. Justify the use of acoustooptic spectrum analyzers for measuring the characteristics of radio emission systems.

Radio communication systems that use spread spectrum signals have a number of advantages [2]:

- increased noise immunity;
- the energy secretive;
- providing the possibility for code division multiple access signals;
- ability to resist the intentional interference;
- increased bandwidth;
- the ability to measure the arrival time of signals with high accuracy and high resolution.

Methods for spreading the signal may be based on any of signal parameters modulation. The main methods are widely used in modern wireless systems are:

- the method of direct modulation of the carrier pseudorandom sequence;

- method of pseudorandom restructuring the operating frequency;
- method of pseudo-temporal pulse modulation;
- method of sharing various methods spreading.

It is known [1] that the spread spectrum signals have a number of advantages, but a synthesis of optimal and suboptimal algorithms for processing these signals in wireless communication systems leads to a multi-correlation processing, the number of channels and the complexity of which increases rapidly with the dimension of the parameters characterizing the signals used and defining structure of the processing system [1-2]. The implementation of such systems requires the provision of processing large amounts of information and are generally carried out with the help of specialized computing devices, such as acoustooptical spectrum analyzers.

Acoustooptical spectrum analyzers allow to successfully solve the problems associated with the formation and estimation of parameters and the shape of the instantaneous spectra of deterministic and random signals, parallel spectral analysis in a wide frequency range without conversion frequency in real time. Acoustooptical devices operating in real time, allow to carry out such tasks:

- correlation receiving of broadband signals;
- estimation of operating frequencies and spectral characteristics of the received signals;
- searchless the direction and frequency direction finding of sources of radiation.

Acoustooptical devices are promising for the processing of broadband signals in a retrieval system, synchronization, control parameters of interfering signals, as well as determining the coordinates of radiation sources.

Modern devices allow to implement using one of the spatial coordinate to the 10^3 parallel channels. At this speed reaches acoustooptical devices 10^9 operations per second, the frequency band of signals being processed is in the range of 50MHz, ..., 2GHz.

Application of acoustooptical devices for processing complex signals with large bases 10^3 is more preferable from the viewpoint of cost, while the bands of 200 MHz or more acoustooptical processing has no competition from digital equipment.

Acoustooptical devices consist of elements such:

- sources of optical coherent radiation;
- ultrasonic light modulators;
- optical processors;
- optoelectronic systems that enable transformation recorded optical radiation into electrical signals;
- processing system output signals of photodetectors, that form parameter estimation of the spectra analyzed signals.

The principle of operation of the acoustooptical spectrum analyzer is shown in Figure. 1.

As seen from Fig. 1, the input signal mixture is applied to ultrasonic light modulator. It is based on the diffraction of light by ultrasonic waves. Character of diffraction essentially depends on the ratio between the wavelength of light λ, length of the acoustic wave Λ and the width of the acoustic beam L. When the condition $Q << 1$, where $Q = \lambda L / n\Lambda^2$ - wave acoustooptic interaction parameter, the phase grating may be regarded as flat. Diffraction occurs in this case at any angle of incidence of light on the acoustic beam θ_0. The diffraction pattern a significant number of symmetrical with respect to the zero-order light intensity distribution.

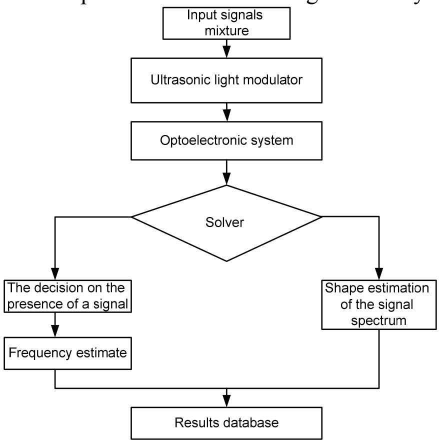


Fig. 1. Flowchart of acoustooptical spectrum analyzer

Significantly different character has diffraction at $Q >> 1$. Phase grating in this case is essentially a three-dimensional. Diffraction pattern occurs only at a certain angle of incidence of light on the wave front of the acoustic wave, which satisfies condition of Bragg

$$\sin\theta = \frac{\lambda}{2\Lambda}.$$

The Bragg diffraction occurs at high frequencies at large length of interaction of light with the acoustic wave and contains only one side of the diffraction peak. The advantages of the Bragg mode is a high diffraction efficiency and wider bandwidth.

To further analyze the processing of signals in the acoustooptical devices find transmittance or coefficient transparency of ultrasonic light modulator

$$T(x, y, t) = P_{ab}(x) P_H(y) \exp\{-j\psi S(t - x/V)\},$$

where ψ - phase modulation index; P_{ab} - defines the area of the aperture of ultrasonic light modulator along the x-axis, occupied by a signal at time *t*; $P_H(y)$ - spatial aperture function which characterizes the width of the channel on the y-axis, V - acoustic wave extension velocity along the x-axis.

Registration of optical signals for further processing are carried out of optoelectronic system that includes a linear array of photodetectors. Photodetectors operate on the principle of charge-coupled devices and output signals are defined as

$$p_i(t) = k_{np} \int_{t_H}^{t} G_i(t')dt' ,$$

where k_{np} - slope conversion of photodetectors, $G_i(t)$ - expression describing the electric signals.

The totality of output signal of working channels $\{p_i\}$ is input to solver. The structure and characteristics of the evaluation of generated signals depends on the operation mode of the acoustooptical spectrum analyzer.

Acoustooptical spectrum analyzer can act as a panoramic receiver when spetra used as the set of all radio signals in the analyzed frequency band. With this work the spectrum analyzer first decision of the presence of signals in the i-th channel by comparing the of signals $\{p_i\}$ with the threshold γ_{nop}:

$$\xi_i = \begin{cases} 1, & p_i(t) > \gamma_{nop} \\ 0, & p_i(t) < \gamma_{nop} \end{cases} .$$

And then assesses frequency of signals ξ_i

$$\hat{f}_c = \frac{L_f}{n} \sum_{i=1}^{n} i\xi_i ,$$

where L_f - a priori frequency interval.

Acoustooptical spectrum analyzer also can operate in the spectral analysis. In this case, using the of output signals of the amplitude quantization of working channels formed shape estimation of the amplitude of the signal.

In broadband radio frequent situations in receiving of broadband signals according to different kinds of interference, but to optimize the reception of signals against such interference, you should know at least the width of the frequency spectrum and interference.

Conclusions. The report presents a system of measuring the characteristics of radio emissions using acoustooptical spectrum analyzers. The advantages of using spread spectrum signals for radio systems. The application of the acoustooptical devices for performance evaluation of such signals. Shows the block diagram of acoustooptical spectrum analyzers. Shows the characteristics of signals that can be evaluated by various modes of spectrum analyzers.

References

1. Borisov V.I. Noise immunity radio system spread spectrum modulated carrier of signals by a sequence of pseudorandom / V.I. Borisov, V.M. Zinchuk, A.E. Limarev, N.P. Mukhin, G.S. Nakhmanson. - M.: Radio and communication, 2003. - 640 p.
2. Pickholtz R.L., Schilling D.L., Milstein L.B. Theory of spread-spectrum communications.// IEEE Trans. Com., 1982, vol.COM-30, №5, pp.855-884.
3. Acousto-optical signal processing. // IEEE, 1981, vol.69, № 1, -163 p.
4. Griffen R.D., Lee J.H. Acoustooptical design, implementation and evaluation.// Appl. Opt., 1994, vol.33, №29, pp.6774-6787.

UDC 620. 791.05.620.179.1

I.P. Belokur, Doctor of Technical Sciences
(National Aviation University, Kyiv, Ukraine)

USING NDT METHODS FOR MAINTENANCE DIAGNOSING

Introduction. Using NDT methods for maintenance of aircraft is connected with traceable parts and designs, which is achieved in different ways.

1. Primarily the materials of construction are selected. For example, the use of ultrasonic methods for choosing homogeneous materials with fine-grained structure, which dissipates the lowest ultrasonic waves at a frequency of oscillation of 1.8 ... 5.0 MHz. Magnetic particle testing is the most suitable materials with homogeneous ferromagnetic properties. To the best of eddy current testing are non-ferromagnetic materials with a uniform conductivity, for penetrant testing selected materials that are insoluble in organic solvents.

2. Selected materials and thickness of coatings (electroplating, chemical, paint) so that it was possible to perform eddy current, magnetic or ultrasonic inspection the base of the parts without removing the coating. For example, the thickness of the LPC for eddy current testing shall be not more than 0.5 mm. For capillary control parts must not be covered with plastic metals (cadmium, copper, silver, etc.), which have an elongation under load of greater elongation of the base material.

3. Selecting the shape and the control zone is dependent on the scheduled test method and vice versa - the control method is selected depending on the shape and the control zone. For example, the presence of narrow ribs and grooves, fillets small radius complicates control technology ultrasonic, eddy current and magnetic particle methods.

4. Take account of surface treatment method details when choosing a method of control - treatment should not interfere with the monitoring and detection of corrosion- fatigue cracks. Thus, the parts under the control during maintenance capillary method, in the final stages of production should not be subject shot-jetting or turning speed and surface heat treatment. Thus if there are occurrence of cracks with a small opening, which are not detected by capillary methods in such cases the methods of capillary as well as ultrasonic , eddy current , or others are not used.

5. Regulated roughness surface in the control zone. For most of the methods of control surface roughness should not be greater than Rz = 40. For structures that control the ultrasonic method there is also the roughness limit of the inner (bottom) surface: as a rule, it should be no greater than Rz = 80. For this method, you must also qualitatively processed pads for placement of ultrasonic transducers.

6. Provide accessibility to detail and nodes that are checked in the design OK by using hatches, windows review, removable panels and the like.

7. Assigned level of defect sizes to be detected and depending on the chosen method of control if there are no other restrictions. For example, to detect fatigue cracks surface -opening equals at least 1 micron surface roughness not greater than Rz = 12,5 mm capillary most suitable regulated by the control method.

When choosing an NDT method should take into account the influence of defects on the mechanical (operational) properties of controlled items.

Discussion of results. Defining the scope and frequency of diagnosis

Volume and control technology depends largely on the methods of exploitation AT - for resource status and combined.

If the operation is carried out by the state where are planning periodic control and validation work, which resulted in the decision on further operation. When combined method of operation of the items in the object is operated by the technical condition, the remainder - to the resource. Only 60 to 75% of the units and systems of modern aircraft fail to translate into operation of the state (the experience of the airlines "Pan American", "Air Canada" and others). Therefore, a combined method of operation is essential.

Switchover to the technical condition and operation of combined method assists to increase the level of reliability through the introduction of sun most careful control of a much larger number of parts OT in operation and maintenance. Greater attention is given to the definition of the state of the material used in the methods of inspection.

Procedure for maintenance and control depends on the type of the aircraft and may be different. However, the maintenance programs of different objects distinguish some general principles for the use of funds flaw. Consider the major ones. Frequent testing is supposed to execute visually. Check more frequently performed using tools of control. Most often are highly stressed and critical parts and components. At high operating time with the appearance of fatigue cracks and corrosion is expected to increase the number of parts that are controlled, diligence and frequency of inspection means inspection, the use of complex control.

Example - organization NDT aircraft type B - 707. At the initial stage of operation the airframe part undergoes of an intense verification inspection methods after 3000 hours. Through 12,500 hours (5 years of operation) all highly stressed elements are controlled assessing the state of the material properties. Next control is performs after 6500 hours (3 years after the first thorough control at a total operating time of 19,000 hours). After 25,000 hours of use aircraft (10 years of operation) performed a full inspection of materials , all critical elements to conduct control flaw detection methods were performed. With increasing developments and the emergence of fatigue cracks and corrosion test intervals are decreasing. Parts and components of structures with identical control charts are conventionally combined in groups.

To implement these principles for determining the frequency of monitoring is necessary to know the probability of occurrence of defects in critical detail in the different time periods of operation of the aircraft and the speed of development defects. Thus, if a defect is found in a large number of copies with significant operating time, it is necessary to significantly change the timing and frequency control.

Objectivity diagnosis is achieved by the presence of metrological provision NC.

Work on monitoring and diagnosis is the part of tasks and functions laboratories of NC businesses. Information gathered by the laboratory is used for generating proposals for the further operation. This information is also used for the correction of the maintenance and repair systems. Most objective correction of the system is provided with a detailed analysis of statistical information.

Expert and technological systems of diagnosing

Technical diagnostics based on methods of inspection is a reliable indicator of quality. Getting data about the characteristics, material properties and characteristics associated with OT a lot of information. In a practice world, are distinguished the expert systems are distinguished for maintenance which minimizes the volume of information and the probability of correct decisions increases.

Consider trends and prospects evaluate the technical condition of aircraft structures in the process of maintenance, repair and operation. Development of such systems are divided into five main areas.

The creation of non-destructive testing of elements, components, assemblies, aircraft systems;

The second - development of physical NDT methods of stress- strain state of diagnosis objects;

The third - the creation of methods of diagnosing test aircraft design based on NDT methods.

The fourth - building monitoring systems based on development of methods and tools for specific products;

The fifth – substantiation of the evaluation principles for certification of NDT AT.

Let us consider each of these areas.

1. Justified methodology for the selection of the aircraft parts and assemblies adjusted to NDT methods parts and assemblies of the aircraft. The technique is based on identifying the critical crack size and definition of the shape parameter of the defect, which lay in the control samples, and processing signals from sensors primary information of NDT.

Given that in the testing of aircraft typically use manual control, a method and apparatus that provide documentation of the origin and size of defects and computer processing of the results.

2. Taking into account and study the factors affecting the stress-strain state and fatigue, as well as develop effective methods and means to identify them. Structural heterogeneity Effects on the stress concentration, strength, corrosion resistance, plasticity, impermeability, wear, etc. Defects in welds play a role cuts weaken section creates stress concentration and volume stress. Found that when vibration loads, even small defects have a significant influence on the fatigue strength of the material. Defect is the more dangerous, less than the radius of curvature of its vertices and more than its size. The ductility of the material is sufficient to stop the growth of stresses in the areas of their concentration up until the average voltage in the weakened section does not reach the limit point. Studies have shown that the increased brittleness of steel may be due to the aging process of deformation in tension at the temperature of 100 ... 500° C. Hardening and aging caused by it greatly increases the brittleness of steel and shifts the threshold of the nominal strength to positive temperatures. Additional causes damage at operating voltages are residual stresses arising during welding and assembly due to the uneven distribution of temperature and force action on the metal expands when heated by the surrounding cooler metal. At a certain combination of non-uniform temperature distribution and the stiffness of the

object developing mechanical stress reaches the yield stress of the material that is accompanied by plastic deformation. Residual stresses also affect the tendency of the material and welds to brittle fracture. However, a compressive stress is a barrier to crack moving. Nature of the stress distribution is possible to establish the following methods: optical polarization, brittle coatings, magneto-elastic, eddy current methods. For this purpose, a range of the stress- strain indicators and instruments are applied. Physical and mechanical properties of the surface of the steel product austenitic and austenitic- ferritic grades are determined using eddy current devices operating at high frequencies of 100 ... 400 MHz.

Centers define the principles of quality assessment, develop programs and certification procedures and regulations, accreditation NDT divisions and technical diagnostics. Principles of NDT valuation and technical diagnostics are in check: normative and technical documentation on all types (methods) that are used in the enterprise; organizational structure control services; degree of participation of designers and engineers in the selection and appointment of monitoring and diagnosing; applied technologies and their changes, skills and responsibilities of radiographers; metrological provision of control; availability of documentation in the workplace; acceptance criteria (rejection) clearance testing results; state jobs and control plots.

Conclusion. Considered approaches implemented in aviation rules and successfully applied during the certification work in enterprises for producing, operating, servicing and repairing aircraft.

UDC 621.317 (043.2)

S.R. Sunetchiieva (National Aviation University, Ukraine, Kyiv)

PROCEDURE OF STATISTICAL DATA PROCESSING IN NON-DESTRUCTIVE TESTING

This article describes the method of result processing of non-destructive impedance control of composite products aviation destination, based on the identification of defects in products informative control parameters in cases where the law of distribution of the source data is different from normal. The results of experimental studies of the developed technique are imposed.

Composite materials are widely used in aircraft, as opposed to metal, they are formed from raw materials simultaneously with the formation of the materials themselves. Due to the complexity of the technology and the significant physical and mechanical differences between the individual components, such design elements are characterized by a wide range of possible defects.

In modern aircraft one of the most common methods of control of products from composite materials is the acoustic impedance method. It is based on an assessment of the differences in the values of the mechanical impedance of defective and defect-free controlled zones multilayer structures which defined on a substrate by means of excitement in it bending vibrations of low frequencies [1]. Today in aircraft industry surge impedance method takes a share of 90% in the control of cellular structures and items are made of laminated plastics.

In conducting the impulse impedance control resolution about damaged area in a controlled area taken in case of exceeding the limit values for one or more of informative parameters [1], which, in turn, set after setting stethoscope on standard samples coated with model defects. Standard samples made from materials similar to those used in controlled products, they have the same thickness and surface roughness.

During the initial control information signal of primary transducer that is exponentially damped radio pulse by means of an analog-to-digital converter is converted into a sequence of discrete samples S_k. Discrete implementation of an information signal may be exposed to noise with multiplicative m_k and additive n_k components. Thus, the conversion result can be written as:

$$x_k = m_k S_k + n_k$$

At the same time, the signal samples are composed of both deterministic S_{0k} and random ΔS_k components each of which carries information on the physical and mechanical characteristics of the controlled area.

The random component of the signal ΔS_k can be caused by many factors.

First, it is affected by uncontrollable variations of physical and mechanical characteristics of the scanned area of some average values. Composite materials are characterized by considerable heterogeneity of structures that may depend on both the components of the material and the design of the product. For example, in the control of cellular panel possible periodic change of rigidity: it may take the maximum value in the areas corresponding to the walls cellular panel and minimal in its middle. Also important in the control so-called friction noise.

Although friction noises have a wide spectrum, depending on the characteristics of the transducer and surface roughness controlled product, its influence on the results can be reduced as design methods - change the radius of curvature of the contact surface of the transducer, and the stage of processing - through the use of digital or analog filters to suppress the relevant sections of the spectrum of the signal transducer.

The influence of random components in an informative parameter when the final rule is based solely on the comparison of some threshold can lead to situations when the control region is mistaken for defective, or vice versa, the defect will be skipped.

In the case when the informative parameter the changes which the decision on the defect affects a random variable, the decision of the defect can be made on the basis of statistical criteria that include information about the laws of distribution of samples of evaluation information parameters obtained from a priori defective and defect-free areas of the product and the allowable values of errors of the first and second kind. Such statistical criteria include methods like Neyman-Pearson method, method of maximum likelihood, Minimax method, etc [2]. The most common information parameters that were obtained by converting the Hilbert: amplitude, phase and cumulative frequency of signal. But the main problem in the application of statistical criteria for decision-making is the assumption that the law of distribution of informative parameters are known and described analytically. Usually it is assumed that the input data have a normal distribution, but this is not always confirmed by experimental evaluation. The above situation is primarily associated with a high degree of heterogeneity of the structure of the composite, if the control object is a panel with cellular filler: the cellular edge has relatively greater rigidity than its center, and the use of the placeholder foam can unpredictable occurrence of areas of unequal density. At the same time, the performance difference between the laws of distribution of informative parameters can be used as an indicator on which diagnostic decision taken during the non-destructive testing [3,4].

Since the shape of the distribution is unknown then the question of its approximation.

Therefore, the paper proposes a method of processing information parameters derived from defect and without defect areas. Figure 1 illustrates a block diagram of a technique.

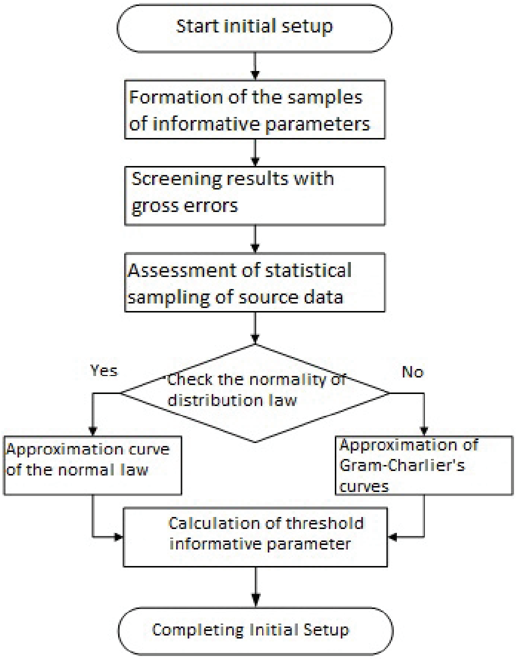


Fig. 1 Block diagram of the processing method of experimental data.

The technique of choice involves the following steps:

1) The operator must conduct alternate scanning defective and defect-free zones standard sample, followed by the formation of libraries of signals according to the type of area.

2) Based on the received signals form a sample of informative parameters: maximum amplitude, instantaneous frequency and cumulative phase.

3) Since the shape of the distribution is unknown, it should first validate the sample for normality. This check can be done according to criteria such as composite or criterion Frotsyni.

4) If the hypothesis of compliance is confirmed, you can use the standard formula for the normal law, or in another case, go to the procedure for approximating.

5) Completing Initial Setup.

It investigates the approximation of the laws of distribution using Gram-Charlier's curves. But using the Gramm-Charlier's approximation can be used only in cases where the law of data distribution is close to Gaussian. In the approximation of the laws of distribution with large values of the third and fourth orders can lead to negative values of approximation. To estimate the thresholds applying Gramm-Charlier series was performed numerical simulations.

Let the boundary change factor of asymmetry Sk will be limited by intervals $[-2;2]$ and kurtosis Ex $[-4;4]$. Simulation algorithm has the following form. To the expression of a series of Gram-Charlier which consists of three members cyclically substituted value Sk and Ex with increments of 0.2. Standard deviation σ of formula for normal distribution $f(x)$ was set equal to 1. Simulation results are shown in Figure 2

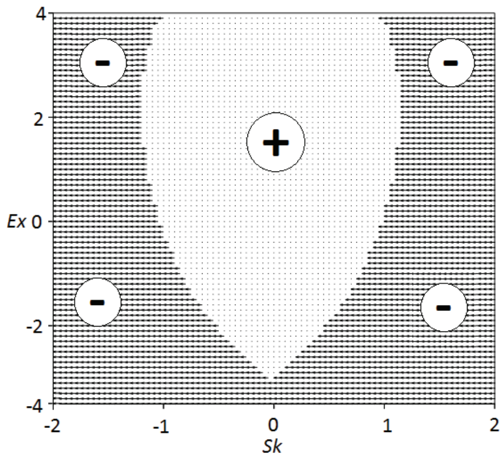


Fig. 2 Representation of positive (light area) and negative (dark area) areas of the function $f_A(x)$ based on the kurtosis and asymmetry coefficients.

Dark areas with the sign "-" marked the area where the curve $f_A(x)$ starts giving negative values. Light area with the sign "+" - marked the area where the curve $f_A(x)$ starts giving extremely positive values. As seen from the figure, the efficiency of both curves depends on the values of kurtosis and asymmetry.

More universal approximation are using Pearson curves, since they do not have such restrictions. These curves allow for the approximation of the laws of distribution to larger values of the coefficient of asymmetry and kurtosis, such as uniform, bimodal laws.

For the classification of the empirical distribution to any particular division of Pearson, it's to calculate the parameter χ :

$$\chi = \frac{\beta_1(\beta_2+3)^2}{4(2\beta_2-3\beta_1-6)(4\beta_2-3\beta_1)}$$

where $\beta_1 = \frac{\mu_3^2}{\mu_2^3}, \beta_2 = \frac{\mu_4}{\mu_2^2}$, де μ_2 , μ_3 , μ_4 - the second, third and fourth moments correspondingly.

Table 1

I type	$\chi < 0$
II type	$\chi = 0$ $1{,}8 \le \beta_2 < 3$
III type	$\chi = \pm\infty$
IV type	$0 < \chi < 1$
V type	$\chi = 1$
VI type	$\chi > 0$
VII type	$\chi = 0$ $3 < \beta_2 < \infty$
N type (Gauss, the normal distribution)	$\chi = 0$ $\beta_2 = 3$

Conclusion

The technique of data processing proposed in non-destructive testing of composite materials. The method and corresponding software approximation of the laws of distribution of informational signs other than Gaussian, which allowed more correctly calculate the threshold and increase the accuracy of the errors of the first and second kind.

References

1. Lange Y.V., Acoustic low-frequency methods and means of non-destructive testing of multilayer structures [Text]. , Lange Y.V - mechanical engineering 1991 — 272c

2. Kendal M., Distribution theory [Text]. Kendal, Stuart ect. Science, 1966.-588 c.

3. Sunetchiieva S.R., Approximation of the laws of distribution of informative parameters in non-destructive control of composite materials / E.F. Suslov / / East - European Journal of Advanced Technologies "Radio Engineering Information tools." 6/11 (60) 2012. – city Harkov.: Technological Center, 2012 - p.45-47.

4. Sunetchiieva S.R., Investigation of the distribution amplitudes of information signals pulse impedance flaw in the control of cellular panels / V.S. Eremenko, E.F. Suslov, A.V. Samoylichenko / /Material of XII International Scientific and Technical Conference " Electromagnetic and acoustic methods of nondestructive testing of materials and products Leotest 2012", Lviv. Center "Leotest-Medium" 2012 - p.50-55.

UDC 621.391.372

E. Volodarsky (National Technical University of Ukraine "KPI", Ukraine, Kyiv)
L. Kosheva, O. Bulyhina (National Aviation University, Ukraine, Kyiv)

METHOD OF MEASUREMENT THE HUMAN OPERATOR PROFESSIONAL FITNESS TO THE EXTREME ACTIVITY

New method of the assessing suitability of the human operator extreme activities is proposed. It is based on a three-component statistical criterion. In evaluating the suitability of an operator the stability of a generalized estimate of ratio of energy of the biological signal can be used. As a "benchmark" standards the indicators of the psycho-physiological state of a group of operators having a positive long experience are accepted. If number of samples obtained in the experimental study is limited, then to improve the reliability the robust procedure of estimation is proposed to use.

Introduction. Effectiveness of the human operator activities primarily depends on its suitability to carry out responsibilities for particular type of work. Activity, associated with the permanent change of physical and psychological pressures and with needs to take the adequate operational decision, is called as the extreme activity. Successful implementation of operators to such type activity depends primarily on the psycho-physiological state of operator [1]. For the extreme activity of operators their mental state and reaction on the transition from the "quiet" state to "excited" state is important. Research should be carried out in these both (calm and excited) states. As the initial information the EEG measurements are provided, which give α- rhythms of the brain. With this information, you can only judge a qualitative change in the psycho-physiological condition of the operator. The ability of the operator to mobilize his resources should be numerically characterized [2].

Basic material. As an integral assessment of the psycho-physiological state of operator, which characterizes his professional competence, the area under the curve of the spectral density of α- rhythm as an estimate of the "total energy" of operator is proposed to use. Under the operator total energy we mean an opportunity to mobilize its energy resources in emergency situations [3]. To quantify the operator total energy the relative measure – the coefficient of energy sustainability θ is introduced. It is the ratio of the total energy (TE) of α-rhythms in a quiet (TE_{calm}) and excited (TE_{excit}) states of the operator:

$$\theta = \frac{TE_{calm}}{TE_{excit}} \tag{1}$$

When $\theta = 1$, then in an emergency situation the energy TE of operator doesn't change, and he won't be able to react on stress factors.

The professional selection procedure can be regarded as a kind of test, in which the properties of the operator may be evaluated qualitatively and as well determine (measure) quantitatively. It is not at variance with conceptual foundations of psychological measurements [4].

These properties can be measured by specialized system of technical equipment. Calibration by traceability to standard units of measured physical variables are not required. It is enough to "bind" the measurement result to a reference value. There is a new approach to definition the reference value for such measurements, proposed in VIM-3, as a process of experimentally obtaining one or more quantity values that can reasonably be attributed to a given value [5].

For the formation of such reference value a group of operators was involved. They are members of winter expedition to the Antarctic station "Akademik Vernadsky"), having a positive (long and successful) experience in extreme conditions. The operators of this tested group have different qualifications. Individual biorhythms of operators vary throughout the day time as well depend on changes of atmospheric and climatic parameters. Consequently, the set of operators is a physical model of professional competence of operators of this type activity.

Changes to individual properties of the operators appear as variation (dispersion) of the coefficient energy sustainability in relation to its reference value, defined in the study of the group of operators:

$$\overline{\theta} = \frac{1}{N_3} \sum_{i=1}^{N_3} \overline{\theta}_i \qquad (2)$$

where $\overline{\theta}_i = \frac{1}{N_2} \sum_{j=1}^{N_2} \overline{\theta}_{ij}$ – the average value of energy sustainability of the *i*-th operator, N_2 – number of days of the experiment; N_3 – number of operators.

Mean value $\overline{\theta}_i$ takes into account the effect of the variability of the *i*-th operator biorhythms and their sensitivity to fluctuations of atmospheric and climatic conditions.

Thus, the variation σ_R^2 of coefficients of individual personal energy sustainability θ_i from a reference value $\overline{\theta}$, corresponding to the energy stability of the hypothetical ideal operator of the particular type activity, characterize the possible scattering. Within the range of this scattering the individual stability coefficients of operators are distributed. This coefficients confirmed suitability of operators for this kind of activity. This dispersion will be called as dispersion reproducibility σ_R^2 of the operator professional level.

In general σ_R^2 depends on three components:

σ_{op}^2 – variation of a scattering of integral properties of operators of the study group, which reflects their personality,

σ_d^2 – variation of scattering properties of the operators due to individual sensitivity to changes in operating conditions within specified limits,

σ_{ck}^2 – cyclical impact of variability of biorhythms during the day.

To find these variations the experiment was carried out. It allows to allocate the appropriate component. As a result of the experiment, the variation of the operator energy sustainability coefficients θ_i with respect to the reference value $\overline{\theta}$ is determined. It reflects the reproducibility of the suitability of the operators

$$\tilde{\sigma}_R^2 = Var\left(\bar{\theta}_i\right) = \frac{\sum_{i=1}^{N_3}\left(\bar{\theta}_i - \bar{\theta}\right)^2}{\left(N_3 - 1\right)}. \qquad (3)$$

Components of this variation can be used as admissible standard (norm) in the professional selection of operators for extreme activities.

Decision of professional competence is based on the statistical analysis of results of a number of study of psycho-physiological properties of the operator – applicant and comparison of their results with norms established in the experiment. Variation *var* (θ) of population of the considered component is evaluated on the basis of the variation $s^2(\theta)$ of the sample of limited number of observations.

In the experiment, usually is not possible to provide enough large number of observations for each statistical sample. In this case, the distribution will be characterized by asymmetry coefficient (central moment of the third order), which may lead to a false decision of a existence of outliers. In accordance with the classical approach, that pseudo- outlier should be excluded from the available data as further processing will lead to a reduction in the statistical reliability of the results. Therefore, to improve the accuracy of results and their reliability a robust procedure for assessing the results is proposed for use [5]. Such procedure is resistant to outliers and takes into account all available, even the "bad" data. Wherein the median absolute deviation criterion (*MAD*) is used

$$MAD = med\{|x_i - M_n|\}, \qquad (4)$$

where $M_n = med\{x_i\}$ – the median of the elements in the sample x_i, n – number of elements in the sample.

For more accurate estimation of the standard deviation s, the correction factor $k(n)$, depending on the sample size n, is used. The values of $k(n)$ are given in [7]. Then

$$s = k(n)MAD. \qquad (5)$$

Estimated value of standard deviation s takes into account all elements of a sample of small volume, which takes place during the selection process of candidate operators.

If the variance of ratio energy sustainability of the tested operator is estimated, then may be find the estimation of the statistical difference of variance $s^2(\theta_{ck})$ obtained for process of testing the operator-applicant, and the scattering rate obtained from joint physical modeling experiment. A statistical procedure for testing hypotheses from χ^2 chi-square [8] is used. Calculated is value

$$\frac{s^2(\theta_{ck})\cdot \nu_{ck}}{\sigma_{ck}^2} = \chi_{ck}^2, \qquad (6)$$

where $\nu_{ck} = N_3 N_2 (N_1 - 1)$– is the number of degrees of freedom.

The resulting value χ_{ck}^2 – is compared with the tabulated value of this statistic. By comparison the decision about the suitability of the prospective operator to extreme activity is being made.

Conclusion. Thus, the statistical model estimating the suitability of operators is proposed. It is based on establishing the reproducibility level of professional operators. This assessment allows to define some of the boundaries within which variation of the professional suitability is allowed. The two-step procedure is proposed. Objective statistical estimation for the integral indicator with a given statistical reliability to produce a decision on suitability of the operator as extreme and other activities is allowed.

References:

[1] Lacey I, 1967 *Somatic response* in Psychological stress (New York : Lacey) pp 14-37

[2] Hjelle, Larry A, Ziegler, Daniel J 2012 *Personality theories: basic assumptions, research, and applications*. McGraw-Hill

[3] Volodarskiy E T, Bulyhina O V 2012 *Statistical evaluation of proficiency of extreme activities* Information technology and computer engineering. (NTB) pp 71-78

[4] Maul A, Wilson M 2013 on the conceptual foundations of psychological measurement *Irribarra Journal of Physics* Conf. Series.

[5] Guide. International Vocabulary of Metrology – Basic and General Concepts and Associated Terms. VIM, 3rd edition, JCGM 200:2008.: ISO/IEC Guide 99-12:2007.

[6] Huber P J 1981 *Robust Statistics* (New York :Wiley).

[7] Randa, J 2005 *Update to Proposal for KCRV & Degree of Equivalence for GTRF Key Comparisons*. NIST

[8] Freund John E, Walpole Ronald E 1987 *Mathematical Statistics 4th Ed*. (New York: Prentice-Hall)

UDC 621.391.372

M. Burichenko, M. Dvornik, O.Ivanets, V. Kucherenko,
(National Aviation University, Ukraine, Kyiv)

APPLICATION OF ARTIFICIAL NEURAL NETWORKS FOR PROGNOSIS IN MEDICINE

There are two large groups of sources of uncertainty at various stages of construction of neural networks. These groups are discussed in the article andrecommendations for their reduction have been proposed.

Introduction. The process of diagnostics and prognostication of the state of cardiovascular system is very complicated, and includes a lot of various rates and big amount of uncertainty factors: raw data, environmental variables, process dynamics of the human body. That is why it is impossible to predict uniquely in medical-biological field. The wide usage of artificial neural networks (ANN) in medicine is required to solve the difficult scientific problems. The possibilities of ANN enable to work on a big data level and to take into consideration the majority of the influence factors and resolve the problem promptly.

Basic materia. Microinfarction appearance and the time of it's origin were predicted using artificial neural networks. The sources of uncertainty factors have been detected by the analysis of 128 ANN. This diagram represents the sources of uncertainty.

There are two groups of uncertainty while we are building ANN for it's prognosis. At the top of the chart there are the sources of uncertainty due to input data.

The rates of biological entity are characterized by unstable features which can vary by the influence of external and internal causes (stress influence, social environment, environmental cataclysms, magnetic oscillations etc). That's why the biological object's data are the source of uncertainty.

The research data also include a big amount of uncertainty factors. All these factors are represented in literature [1].

For the body state prognosis we used clinical evidence of cardiovascular system. For the 2 year period the physical examination data of 110 patients of cardiological unit have been analysed. These data included blood examination(Activated Partial thromboplastin time, Prothrombin index, Thrombin time, International normalized ratio, soluble fibrin monomer complex, Antithrombin, Fibrinogen, D-dimer , cholesterol, reactive protein, lipoproteins and others), 1870 characteristics in all. The metrics included the time from the beginning of the examination till the microinfarction formation t and the presence or absence of the microinfarction k . The test sample included diagnostic data of ten patients. The recommendations for the quantity of the raw data: after the realization of experiments it has been established, that it is necessary more than 100 raw data for the uncertainty reduction while building ANN.

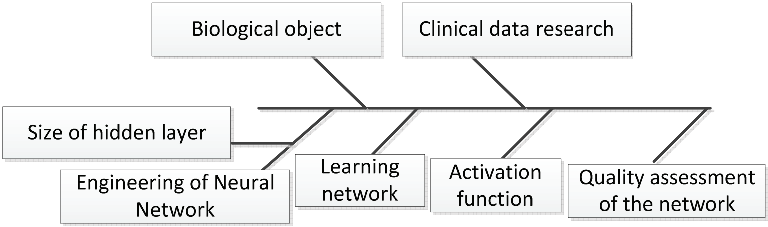


Figure.1 Ishikawa diagram.

The bottom of diagram represents the sources of uncertainty by building and analysis of raw data ANN. These sources can be divided into 4 groups: incorrect neural network planning, quality assessment of ANN, network training process and activation function.

While neural network planning in the first place it is necessary to decide an issue of ball quantity and neuron quantity in each ball.

The recommendations for uncertainty reduction while planning and selection the quantity of hidden balls. For the determination the level of general capacity of the network it is necessary to test the network occasionally by use of independent data set and stop testing if testing error grows up. But the time of training and required data quantity rises. The number of hidden balls of neural network can be corrected and some experiments may be needed to determine the optimal choice.

Estimation criteria of network operation. Estimation criteria should be divided into internal and external. Internal criteria are formed on the basis of data set information whereas external criteria use new information of tested data set, which elements were not used in training. The optimal complication of the network model is formed on the basis of internal and external criteria.

The recommendation for uncertainty reduction using regularity criteria consists in selection of network model which is at most exact in tested data set elements, which were not included intraining data set.

The recommendation for uncertainty reduction using minimal bias criteria require exact coincidence of reference quantity value for two models in which data of various data set of training network were used. Minimal bias criteria enables to choose the model which respond weakly for the changing of training data set and also enables to decide an issue of law restore for the noisy tested data.

The recommendation for uncertainty reduction using bias in the period of time criteria- enables to estimate the correlation level of variable. The certain signs can have various aftereffects, so separate prognostication ensures the best result.

The recommendation for uncertainty reduction using physical reliability criteria requires excluding of models which can provoke unreal results.

The network training

As a rule after neural network training the reference imaging of data is performed. If imaging accuracy is tolerable and errors are in valid limits it is considered that tolerable model is built and good quality of imaging should be expected. [2].

Causes of uncertainty increasing of data set can be provoked:

- imperfect data with high randomness. In this case requirements for the observation accuracy should be raised; in cases of time series the pitch of discretization can be required;

- negligible factors which determine the regularity. This problem can be solved by broadening of factors set;

After gaining the expected value absolute and relational errors can be received for the each pitch of prognostication. After receiving tolerable results of prognostification it can be considered that network has optimal complexity and is ready for data imaging.

The general scheme of uncertainty reduction while training the network:

1. The present example (first) and its input parameters are taken from the training selection. Then they are directed to the input synapses of the network. As a rule each input parameter is directed to one input synapse.

2. The neural network performs required number of operation cycles and input parameters vector transmittes to the neural association.

3. The signals of output neurons are measured.

4. Interpretation of received signals is performed and value has been estimated. It defines the difference between the network answer and required answer. The value is calculated with use of estimator. The less the value the better the recognized example and the nearer network answer. The value zero means that required goal is achieved. It should be noted that untrained neural network can produce correct answer only accidentally.

5. If value is zero nothing happens. On the basis of value correcting coefficients for the each matrix weight are calculated and than synaptic weight is adjusted (reverse functioning). The training means correction of synaptic weight.

6. Trancision to next example is occured, and the operations recur. Passing all examples is the cycle of training.

Each example has its own value during passing the cycle. Composite score of example set is calculated. If after passing some cycles the composite score is zero the training is finished [2].

The recomendations for uncertainty reduction using number of hidden elements. During the selection of hidden elements number the number of hidden elements h shouldn't be more than doubled number of input elements: $h \le 2i+1$, in addition it is necessary to select the lesser number of hidden elements. In addition the number of training data should be in $\frac{1}{e}$ times more than the number of network weight quantity. [3].

If data dimension can be reduced the lesser number of hidden units should be used.

When training using structureless input it is required that number of hidden units was larger than the entries. The number of hidden elements which are needed for the classification problem solving, should rise with rising the number of classes in which the space of entries is divided[4].

The activation functions of the element(neuron) summarize the balanced entries from all adjunct elements. This range is selected (0; - 1), or (-1; +1). Large values always shrink to add the reduced contribution. That is why the activation functions should be nonlinear [5].

The recommendations for uncertainty reduction: for the gaining qualitative results, the training, the control and the tested data set should be representative, in addition this data set should be representative separately. If trained data are not representative this model will be not so good or unsuitable [6] .

The error which is found at the expense of error, causes uncertainty while neural network planning uses for prognostication accuracy evaluation E_{bp} and uncertainty reduction:

$$E_{bp} = \frac{\sum |e_i|}{n_{bp}}, \tag{1}$$

the lower the value E_{bp} - the better prognosis. On the ground of experiment series the network GRNN 17:17-6-3-2:2 (figure.2). is optimal. This neural network shows the best result among 186 built neural networks. While it's building we used the rule of training with a teacher, sigma activation function, two hidden balls and 9 neurons.

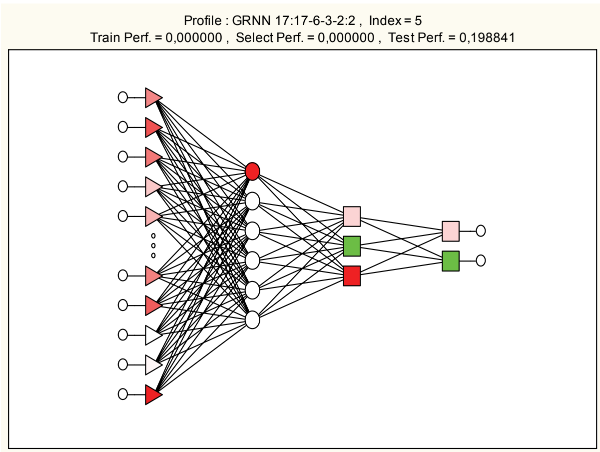


Figure.2 Neural network GRNN 17:17-6-3-2:2

The following architecture of neural networks is used:

1. Radially-basic network
2. Linear network
3. Multilayer perceptron
4. Neural network of general regression

Minimal error was showed in network, witch belongs to neural networks of general regression and has 17 input neurons, 6 and 3 neuronsin hidden balls. This network while training on tested set data has error 0,043, while check on tested data set - 0,001.

Conclusion At the article the results of ANN building have been analysed. The sources of uncertainty factors occurrence have been discovered. Approaches to the reduction of uncertainty with the recommendations have been proposed. The formula for forecast precision have been proposed. As an example the effective architectures of ANN have been built and estimated. These architectures are: multilayer perceptron, probability neural network, BPE network and its modifications. The network which could build prognostication with the minimal error of tested set belong to networks of general regression, the network which uses nuclear approximation for the regression building. This neural network can be used in cardiology for cardiac microinfarction prognostication.

References

[1] Володарский Е.Т. Особенности оценивания неопределенности результатов биологических испытаний /Е.Т. Володарский Л.А. Кошевая/ Системи обробки інформації. – 2010. – Вип. 4(85).– С.142-144.

[2] 1990F. Girossi, T. Poggio. Representation qualities of neural networks: Kolmogorov’s theorem is irrelevant. Neural Computation, 1(4):465-469,1989. 4

[3] R. Hecht-Neilson. Neurocomputing. Addison Wesley,

[4] Wei Li Yannan Zhao Yixu Song Zehong Yang COX-2 activity prediction in Chinese medicine using neural network based ensemble learning methods. IEEE International Joint Conference on Neural Networks, 2008, pp. 1853-1858

[5] A.J. Morris. Neural network for process control. Talk to NSYN Launch event, 29 september,199

[6] Muniz, A. Liu, W. Liu, H Assessment of the effects of subthalamic stimulation in Parkinson disease patients by artificial neural network. Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2009,pp. 5763-5766.

UDC 004.9 (045)

V.D. Kuzovyk, Doctor of Technical Sciences,
Y.Y. Onykiienko (National Aviation University, Kyiv, Ukraine)

HARDWARE AND SOFTWARE SYSTEM OF EVALUATION CRITERIA OF THE ADDITIONAL INFORMATION CNS

In the present paper discusses the application of existing approaches to evaluating additional information criterion function CNS of specialists extreme activities by creating hardware-software system, combining functional modules cephalography system, encephalography and heart rate variability.

Professional medical screening of specialists extreme activities (pilots, athletes) is essential for the prevention of possible diseases because the person can influence many extreme factors requires strong adaptive ability of functional systems. For example, despite the multi-level system of medical and biological selection of specialists extreme activities, supervision of physicians showed an increase in the incidence of headache, signs of sleepiness, discomfort from the heart, dizziness, a growing number of people with general weakness, signs of the emergence of depressive states and so on.

As part of the diversity of prepathological symptoms of specialists extreme activities predominate disorders of the central mechanisms of regulation. However, such a shift register using biomedical technologies and assess their degree is extremely difficult. Whereas, among the variety of existing hardware and software is difficult to single out a specific assessment that would be the level of its verbose met all the requirements imposed by this kind of research. Therefore, the problem of establishing additional criteria for the evaluation of functional reserves of central regulatory mechanisms through the creation of new biomedical technologies and in-depth analysis of the results is in order.

This work is a continuation of previous developments have shown the possibility of obtaining additional diagnostic information about the functional state of the central mechanisms regulating professionals adventure activities by switching to a modified examination techniques and special treatment outcomes cephalography system. [1,2]

The vertical position of the human body is supported by a complex reflex activity of the unconscious system analysis information by the central nervous system that has certain performance relationship reflex functions of biological rhythms brain function of the autonomic nervous system, other indicators of psychophysiological state. Therefore, a special system of biomedical of the CNS of specialists extreme activities to attract technology-based simultaneous information collection multilevel neural regulation and program-mathematical processing of data will enhance the level of inspection and collection of biomedical information.

Objective was to deepen biomedical research additional information criterion function CNS of specialists extreme activities by creating hardware-software system, combining functional modules cephalography system, encephalography and heart rate variability.

To identify additional criteria evaluation functions of central regulatory mechanisms in humans examined 24 men (aged 25-45 years), which consists of four stages. The first stage of the survey process includes determining psychological indicators. Mental testing defined followed by the allocation of specialist extreme activity to one of sixteen personality classification categories taking into account the anthropometric parameters (age, sex, height, weight). [3]

Each classification category is characterized by a set of qualitative and quantitative parameters, which makes it easy to track any - changes during the next stages of the evaluation function of the central mechanisms of regulation. The second phase of the study - evaluating the electrical activity of the brain using electroencephalography with additional visual and audio stimuli. Third stage - evaluation of autonomic regulation by heart rate variability. The last stage involves research activities resulting figures denote the reflections that appear as vibrational dynamics of movement in the vertical position of the body by cephalography system.

The technique of constructing and operating the project biomedical hardware and software system for non-invasive in-depth study of the functional state of the CNS. The main attention is paid to the creation of a new modified method of studying human cognition reflexes by applying integrated video recording performance resulting work statokinetic functions - cephalography system. The use of optical tools for the construction cephalography system picture needs to be taken into consideration the following technical steps:

- Building a scene in external coordinates using the transformation model coordinates;
- The transition from external coordinates to the coordinates of observation;
- Coordinate Transformation observations in normalized coordinates;
- Display of normalized coordinates in the coordinates of the device. [4-9]

Completed pilot comprehensive survey specialists extreme activities. An array of biomedical information on the characteristics of changes of physiological parameters, biological rhythms brain, autonomic regulation and cephalography system of specialist extreme activity under the influence of extreme conditions.

In analyzing the results of the study subjects, except for classical and electroencephalography and heart rate variability, proved the most informative of the maximum amplitude deviation statokinetic functions chart and index cephalography system P_{kfg}, calculated according to the parameters of frequency amplitude deviations from the standards in the areas of conventional mapping cephalography system picture.

Such indicators to assess the function of the central regulation of cognition stability. Except as provided in prior studies, they have a close correlation with changes in certain physiological parameters, they can be used as an additional performance characteristics of emotional state.

Research specialist extreme activity showed the presence of significant differences in outcomes research cephalography system after prolonged exposure to stressors compared to the original data.

Growth cephalography system amplitude characteristics were found in separate survey and these changes always have the appropriate parallel with changes in the autonomic system regulation and physiological functions, objectify definition hidden features of individual dysfunction in the central mechanisms of regulation.

Conclusions

Thus, the results of research are obvious practical value in terms of additional objective assessment of physiological functions and dysfunctions occult central regulatory mechanisms that dictate the need for further research in this direction. In the future, opens the possibility of introducing advanced technology control the functional state of the central nervous system of specialist extreme activity during the immediate implementation of the production function.

References

1. Babiyak, V. I., Lantsov, A. A., Bazarov, V. G. (1996). Klinicheskaya vestibulologiya: Rukovodstvo dlya vrachey. St-Peterburg: Gippokrat, 336.
2. Kuzovik, V. D., Gamov, V. G., Onykiienko, Y. Y. (2010). Osoblivosti programnogo zabezpechennya eksperimentalnih doslidzhen bioob'ektu. *Inzheneriya programnogo zabezpechennya*, №2, 68–75.
3. Ivanec O.B., Bulygina O.V., Dvornik M.V., Onykiienko, Y. Y. (2010). Vykorystannja merezh Petri dlja topologichnogo modeljuvannja. *Elektronika ta systemy upravlinnja*, №2, 129–134.
4. Tsai, R. (1987). A versatile camera calibration technique for high-accuracy 3D machine vision metrology using off-the-shelf TV cameras and lenses. *IEEE Int. Journal Robotics and Automation, Vol. 3(4)*, 323-344.
5. Zhang, Z. (1998). Determining the epipolar geometry and its uncertainty: A review. *International Journal of Computer Vision, Vol. 27(2)*, 161-195.
6. Malek, S., Zenati-Henda, N., Belhocine, M., Benbelkacem, S. (2008). Calibration Method for an Augmented Reality System. *Proceedings of World Academy of Science: Engineering & Technology, Vol. 47*, 310-315.
7. Heikkila, J. (2000). Geometric Camera Calibration Using Circular Control Points. *IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 22, No. 10*, 1066-1077.
8. Triggs, B., McLauchlan, P., Hartley, R., Fitzgibbon, A. (1999). Bundle Adjustment – A Modern Synthesis. *ICCV 99: Proceedings of the International Workshop on Vision Algorithms. Springer-Verlag*, 298-372.
9. Zhang, Z. (2000) A flexible new technique for camera calibration. *IEEE Trans. on PAMI, Vol. 22(11)*, 1330-1334.

UDC 004.891:616-072.8(045)

V.D. Kuzovyk, Dr. Of Technical sciences,
A. D. Gordieiev, Graduate student
(National Aviation University, Ukraine, Kyiv)

HARDWARE-SOFTWARE SYSTEM FOR EVALUATION OPERATOR'S PSYCHOPHYSIOLOGICAL STATE

The software and hardware complex, i.e. an automated expert system, allows a physician to classify operators according to their category of temperament and rigidity; to realize the analysis of received quantitative parameters of the electroencephalogram; to diagnose operator's psychophysiological state of cerebral cortex.

In today's world, there is a need of high-quality and fast evaluation of operators' psycho-physiological state (PPS) of health of different activities, such as pilots, polar explorers, athletes, drivers and others [1].

One of the effective means of evaluating of PPS of operator's cerebral cortex (OOC) is electroencephalography. However, modern researches of OCC with existing electroencephalographs have several disadvantages, which are interconnected: the effectiveness of measurement tools of OCC biosignals (the hardware of electroencephalograph) and quantitative methods of processing the data received (software part). To improve the efficiency of usage of OCC biosignals the diagnostic complex was developed – kephaloelectroencephalograph [2, 3].

The limbic system by interoceptive ways integrates information about the work at the operator's physic and psyche level and displays this information as OCC biosignals. Therefore, processing of this biosignals gives an opportunity to highlight the diagnostic informative component of operator's PPS. Researches show that the most diagnostically valuable signals are those of transient process of electroencephalogram that allow to predict the operator's PPS, that shows the perspective of this area of research [4, 5, 6].

Researches of following authors show the efficiency of transient signals for diagnostics of cerebral cortex. For example, Siver D. [7] notes that when operators are stimulated by light in the first phase of the received transient signals lowering the amplitude of the measured OCC biosignals may occur, reflecting the functional deterioration of the visual organs. Another scientist Jahno N.N. [8] noted that the first phase of the received transient signals reflects the operating status of the visual system, and further phases - the operating status of the limbic system and brain structures through which the signal of the visual stimulus passes thru.

Before measurements of OCC biosignals in the software part of the automated expert system to count the operator's individual characteristics, method of classification by category of operator's temperament and rigidity should be implemented [9]. However, each operator may be added to one of 16 or more categories, allowing to pre-group operators with same level of rigidity and characteristics of operator's PPS. This approach to the implementation of an experiment allows to create a computerized database of high-quality expert system.

Analyzing the above, it is necessary to develop a software-hardware system with an automated expert system that is able to classify the operators according to the parameters of rigidity, analyze electroencephalographic data for quantitative parameters and provide an opportunity to diagnose a health care professional psychophysiological state of operator's KGM.

To solve this problem the hardware-software system based on software package MatLab was developed, which has the following stages of work:

- determining the type of operator's temperament;
- classification of operators for rigidity parameters;
- methods implementation of measuring of the electroencephalographic data [5];
- processing of the received diagnostic data.

Realized approach allows to group operators by the 36th type of rigidity at this stage of the software development.

Implementation phase of measuring of the electroencephalographic data for operators provides a record of stationary and transient signals. The received signals are processed by the software section according the following stages:

- a stationary and transition signal is separated into pieces that can be considered as quasi-stationary;
- quasi-stationary signals for both recording modes are averaged in amplitude;
- averaged quasi-stationary signals are subjected to spectral analysis using Fourier's method and power spectral density (PSD) for a stationary recording and transient signal is received;
- the area under the graph baseband signal PSD of stationary recording and transient signals is calculated;
- using a special algorithm, with obtained PSD area, power coefficient (Q) is calculated [10] for a stationary recording and transient signals;
- the result power coefficient is compared with the energy coefficient calculated previously based on repeated measurements for the operator with the same category of temperament and rigidity parameters, which is stored in the database of the expert system. Based on the comparison the result of evaluation of psychophysiological state of operator's cerebral cortex is given.

Performance of all processing steps is presented in the program as appropriate calculations and graphs for clarity. For example of the application of signal processing the comparison graph of the PSD of a stationary recording (a) and transient (b) signals is shown in fig.1 for the operator with choleric type of temperament and depressed state of the nervous system. For this operator the resulting value of the energy coefficient is $Q_{dys} = 0.6449$.

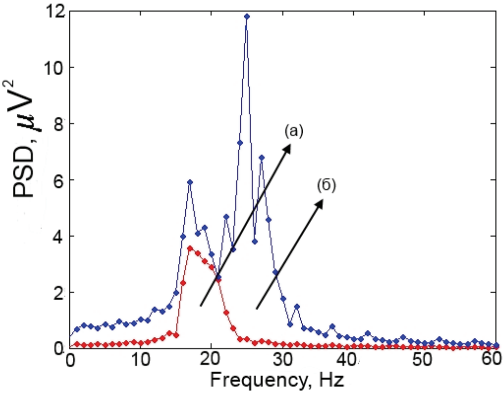


Fig. 1. Graph of power spectral density: a - for a stationary signal recording; b – for a transition signal recording.

To develop a quality expert system multiple measurements of the energy coefficient for healthy operators of various types of temperament were implemented. These data gave the possibility to calculate limits of the average power coefficient for healthy operators with a certain type of temperament. The average limits in which the operator of the choleric type of temperament has no dysfunction of cerebral cortex range Q_{hl} = (0.30 ÷ 0.60). Comparing the coefficient Q_{dys} of the operator with dysfunction of cerebral cortex with range of the coefficient Q_{hl} for healthy operators it's seen that given value of power coefficient of operator with dysfunction goes out of limits. It allows to talk about a high probability of the existence of the operator dysfunction of cerebral cortex.

Thus, there was created a hardware-software system that allows to classify operators according to the type of temperament and rigidity parameters, process the received electroencephalographic data and it includes automated expert system that is able to realize the diagnosis of operator's cerebral cortex. The present software can be used by doctors to evaluate psychophysiological state of cerebral cortex of different activities operators.

Conclusions

It was created hardware-software system that allows you to:

- classify operators by type of temperament and rigidity parameters;

- process recording EEG signals in stationary and transition modes based on quantification parameter;

- provide assessment of the psychophysiological state of the operator's cerebral cortex;

-it includes automated expert system for the diagnosis operator's psychophysiological state of the cerebral cortex.

References

1. Kuzovyk V. D. (2005). Novitni zasobi ocinku operatoriv ekstrimalnih vidiv diyalnosti. Visnik IASU (NAU), №5, 52-58.
2. Kuzovyk V. D., Koshevaya L.A., (2009). Nekotorie metodologicheskie aspektu ocenki effektivnosti medicinskogo vmeshatelstva. Electronika i sistemu ypravlinnya (NAU), № 2 (20), 18-37.
3. Kuzovyk V.D., Gamow V.G., Onykyenko Y.Y., (2010). Osobluvosti programnogo zabespechennya eksperementalnih doslidgen bioobekty. Ingeneriya programnogo zabespechennya, №2, 68-75.
4. Kuzovik V., Gordeev A., (2013). Futures psychophysiological evaluation of polar expeditions participants. Abstracts of VI International Antarctic conference, 404-405.
5. Kuzovik V.D., Gordieiev A.D., Buligina O.V. (2013). Aspectu planirovaniya I realizacii eksperementalnih issledovanii psihofiziologicheskogo sostoyaniya operatorov ekstrimalnih vidov deyatelnosti. 23-a internacionalnaya konferenciya "KrymIKo2013", "SVC-tehnika i telekomynikacionnie tehnologii", 1081-1082.
6. Kuzovyk V. D., Gordieiev A. D. (2013). Dagnostika I prognozyvannya psihofiziologichnogo stany operatoriv ekstrimalnih vidiv diyalnosti. Naykovo praktichna konferenciya "Infomacionnie tehnologii nevralgii, psihologii, epileptologii I medicinskoi statistiki", journal "Klinichna informatuka i telemeducuna"
7. Siver D. (2008). Maind mashini. Otkrivaem zanovo tehnologiu aydio-vizyalnoi stimylacii. Izdatelstvo "Cub", 184.
8. Yahno N. N., Shylman D. R. (2001). Bolezni nervnoi sistemu: rykovodstvo dla vrachey, T. 1 Moscow: Medicina, 744.
9. Bulygina O.V., Gamow V. G. (2010). Kopcentyalna model ocinyvannya psihofisiologichnogo stanu operatoriv ekstrimalnih vidiv diyalnosti. Visnik centralnogo naykovogo centry transportnoi akademii Ykraini "Avtoshlahovik ykraini", № 13, 165-168.
10. Volodarskiy E.T., Bulygina O.V., (2012). Statustuchne ocinyvannya profesiinoi prudatnosti operatoriv ekstrimalnih vudiv diyalnosti. Journal Informaciini tehnologui ta kompyterna injeneriya. VNTY, №3(25), 71-78, ISSN 1999-9941.

UDC 620.179.16

O.V. Monchenko, as.pr. (National Aviation University, Ukraine, Kyiv)

UNCERTAINLY ESTIMATION IN PHASE ULTRASOUND METHOD

The new multi-layer materials widely be used in aircraft. In the article present the new method of multi-layer material thickness measurement, which is based on the digital Hilbert transformation and the signal unwrapped phase analysis and offered uncertainly estimation for two-layers materials.

The work is devoted to issues of testing of the thickness of layers of multi-layer objects and environments, such as composite materials, etc. bimetals. In [1,2] proposed a new way to control the thickness of layers of multilayer media based on the echo–pulse ultrasonic method thickness measurement, which is based on the analysis phase characteristic of the signals. As an informative parameter determines the time position of the time jump of phase characteristic, which is due to the imposition probing and reflected signals.

The new method of a ultrasonic control of multi-layer structure method is based on usage Hilbert transform and signal phase unwrapping analysis. Hilbert transform gives possibility to find the unwrapped phase of a signal. When echo signals coincide, the unwrapped phase of signal is distorted. The moment of its distortion corresponds to a phase jump. The time definition of a phase jump gives a chance to estimate a time delay and find a material thickness.

Testing thickness h is calculated according to $h = 0,5c\tau,$ where c is the ultrasonic longitudinal waves pulse velocity in the layer, τ is impulse duration in test object (TO). In ultra-sound method τ is determine by amplitude characteristic [3], in phase ultrasound method – moment of phase jump.

If analytical expressions determining the thickness of layers of multilayer objects of control and accuracy of measurement indicators in the proposed method, taking into account the acoustic properties of environments.

In the case of TO (fig.1), the thickness of first layer is determined by the velocity of ultrasonic waves and the time interval distribution in this layer, which is limited by envelopes of the probe and the reflected signals; thickness of the second layer is determined from the known velocity of ultrasonic waves in the second layer and the time interval, which is limited by envelope of the reflected signal and the reflected signal jump of phase. In fig.1 U_{pr} – probing signal in TO, U_{ec} – echo signal, τ_1 – delay time in layer 1, τ_2 – delay time in layer 2.

The budget of uncertainty for phase ultrasound method for the case of double-layered TO is based on the analysis of Ishikawa diagram [4] (fig.2):

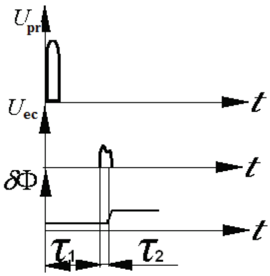


Figure 1. Allocation of time interval for case of two-layered TO

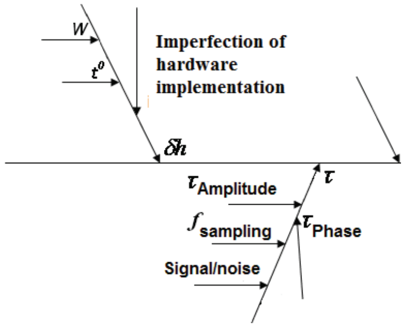


Figure 2. Ishikawa's diagram

According to Ishikawa's diagram (fig.2) is built a budget of uncertainty which is represented in tabl.1.

An alternative way of evaluating the propagation velocity of ultrasonic waves is evaluation of C by additional measurements on the reference sample, that sample with exactly known geometric dimensions.

The uncertainty is the case of the value of the time delay.

Uncertainty of time delay measurement has three main independent components:

1) the uncertainty due to sampling rate of the ADC (category B)

2) the uncertainty caused by the shape and position of Phase (Category B). The resulting of jump moment of Phase, indicating that the imposition reflected from the bottom of the TO signal.

The beginning of the time interval is known, so the error is determined by the jump moment detection.

Also this uncertainty include uncompensated component of methodical measurement errors, which caused by physical and mechanical properties of structural materials, resulting in a ratio of amplitudes of the probe and reflected m signals with a uniform distribution law and range.

3) the effect from value of the ratio S / N (Category A).

Counting uncorrelation for components of the error definition τ, its standard uncertainty is represented by standart formula.

In determination of σ_τ for double-layered TO is taken into account yet time allocation time of arrival of the envelope to determine the thickness of the first layer. This uncertainty is due to a form of ACS and is estimated by the formula:

$$\sigma_{\tau 1} = \frac{\sigma_n}{S_1},$$

Where σ_n – RMS of noise on comparator input (V), S_1 – slope of amplitude characteristic (V/s).

Table 1. Budget of uncertainty to determine the thickness of two-layered TO

Magnitude	RMS	Affecting factor	Type of uncertainty estimation	Distribution law	Total uncertainty	Affecting Coefficient
c	σ_c	c – passing velocity of ultrasonic waves in the thickness of the material	B	Uniform	$u_c^2 = \sigma_c^2$	$\frac{\tau}{2}$
τ	σ_τ	$\tau_{\text{amplitude}}$ – A form	B	Normal	$u_\tau^2 = \sigma^2_A + \sigma^2_P + +\sigma^2_{S/N} + \sigma^2_d$	$\frac{c}{2}$
		τ_{phase} – P form	B			
		f_{sampling} – sampling rate	B			
		S/N	A			
	$\sigma_{\delta h}$	t^0 – temperature	A	Uniform	$u_{\delta h}^2 = \sigma^2_{tem} + \sigma^2_{hum} + \sigma^2_{imp}$	1
		W – humidity	A			
		Imperfec-tion of hardware implementation	A			

2) the uncertainty caused by the sampling rate of the ADC (category B), which has a uniform distribution law:

$$\sigma_\tau = \frac{1}{f_{\text{sampling}}\sqrt{6}}.$$

The total root mean square error of the measurement time interval is equal to:

$$u_\tau = \sqrt{\sigma_A^2 + \sigma_P^2 + \sigma^2_{\text{sampling}} + \sigma^2_{S/N}},$$

here: σ_A –RMS allocation of time interval for amplitude characteristic,

σ_P – RMS allocation of time interval for phase response,

$\sigma^2_{\text{sampling}}$ – RMS due to sampling ADC

$\sigma_{S/N}$ – Uncertainty due to the signal / noise ratio.

The uncertainty is caused due to the value of δh

The value δh incorporates the influence factors of temperature, humidity, imperfection of hardware implementation. Direct estimation of parameters should be carried out by the results of measurements and can be reduced by multiple repeat measurements. Here are the possible factors of influence:

1) The change in temperature. The speed of ultrasound in the material varies depending on the temperature, usually increasing on cooling and decreasing when heated. For maximum measurement accuracy of ultrasound speed setting should be carried out at a temperature at which the measurements will be carried out.

2) Setting and measurement. Arises from device calibration and gives a systematic error in following measurements.

3) The error of indicator device. Determined by the accuracy of the indicator.

4) Surface curvature of TO. In unsteady transducer echo signals are distorted, which also leads to inaccurate indications. In such cases, it is convenient to use the V- shaped spring holder clamp, which regulates a clip and creates the correct orientation of the transducer to the surface of the device.

5) The length of the cable. In some cases, it is need for long cables. Cable length, which affects the operation of thickness gauge is determined by the terms of the measurement and depends on the frequency of transducer, as well as the accuracy requirements and minimum measuring range. We assume that the impact δh is measured by the uniform law.

Conclusions and Future Work

In proposed work the uncertainly analysis of the method is conducted, estimation of uncertainly develops for two-layers materials. Ishikawa's diagram build and budget of uncertainly to determine the thickness of two-layed TO.

In the near future the experimental research of this method will be proceeded with wide band ultrasonic transducer. More experimental and modelling work will commence on real multi-layer material structure to provide a comprehensive study of unwrap phase for ultrasound nondestructive examination.

References

1. V.S. Yeremenko, Y.V. Kuts and O.V. Monchenko, Ukraine Patent #18441, (15 November, 2006).
2. V.S. Yeremenko, Y.V. Kuts, A.G. Protasov, O.V. Monchenko, *Ultrasound Method of Multi-Layer Material Thickness Measurement*, Review of Quantitative Nondestructive Evaluation Vol. 28, University of Illinois – Chicago (UIC), July 2008. P.1115
3. J.L. Rose, *Ultrasonic Waves in Solid Media,* Cambridge University Press, Cambridge, 1999.
4. *Uncertainty of measurement. Part 3: Guide to the expression of uncertainty in measurement (GUM:1995) : ISO/IEC Guide 98–3:2008. – [Accepted 2008-09-30]. – Geneva : ISO, 2008. – 120 p. – (International standard).*

UDC 621.396.969.1

M.P. Mukhina, PhD (National Aviation University, Ukraine, Kyiv)

ALGORITHM OF GAUSSIAN PARTICLE FILTER FOR THE TRAJECTORY ESTIMATION IN CORRELATION EXTREME NAVIGATION SYSTEM

The problem statement for correlation extreme navigation system has been formulated in terms of probabilistic estimation of unmanned aircraft system (UAS) trajectory. Algorithm of Gaussian Particle Filter (GPF) has been proposed to use; results of trajectory estimation have been analyzed. Simulation has been done for additive system disturbances and measurement noise with known statistical parameters. The initial uncertainty in position has been added to prove the ability of GPF to work stable.

Introduction. Recent approaches to realization of UAV navigation includes conventional combination of two systems [1]: satellite navigation system (SNS) and inertial navigation system (INS). Accuracy degrading with time for INS is continuously compensated by SNS information, but the loss of satellite signal especially in urban environment can cause the significant errors in navigation solution and as a result to conflict situation.

Alternative source of navigation data in case of signal jamming can be correlation extreme navigation system (CENS) [2]. Principle of action of CENS is based on the comparison of cartographic data with current parameters of geophysical filed and finding the best matches which result in map positioning. The main feature of CENS is its quasi autonomous; the measurement of field parameter is jamproof and secure, but it is necessary to have access to map data. Accuracy of CENS depends on accuracy of cartographic data and on precision of field sensor. Among the limitations of CENS there are two significant: geophysical filed must have high informativity (high variation of field parameter) and dependence of coordinates on the field parameter is given as table function.

Problem statement. Let's consider the motion of UAS in horizontal plane. The vector $\mathbf{p}=[x,y,z]^T$ determines the position of body-fixed coordinate system (CS) in inertial one, and vector $\mathbf{V}=[\dot{x},\dot{y},\dot{z}]^T$ determines the linear velocities. The vector of angular orientation of body-fixed CS includes the main angles: pitch, roll and yaw: $\mathbf{б}=[\gamma,\vartheta,\psi]^T$. And correspondingly the vector $\mathbf{щ}=\left[\omega_x,\omega_y,\omega_z\right]^T$ contains the components of angular velocities.

Kinematic model of UAV is represented by rotation matrix from body-fixed CS to inertial:

$$\mathbf{R}(\alpha)=\begin{bmatrix} \cos\psi\cos\vartheta & -\sin\psi\cos\gamma+\cos\psi\sin\vartheta\sin\gamma & \sin\psi\sin\gamma+\cos\psi\cos\gamma\sin\vartheta \\ \sin\psi\cos\vartheta & \cos\psi\cos\gamma+\sin\psi\sin\vartheta\sin\gamma & -\cos\psi\sin\gamma+\sin\vartheta\sin\psi\cos\gamma \\ -\sin\vartheta & \cos\vartheta\sin\gamma & \cos\vartheta\cos\gamma \end{bmatrix}$$

and by transformation matrix of angular velocity vector:

$$\mathbf{T(щ)} = \begin{bmatrix} 1 & \sin\vartheta\tan\vartheta & \cos\vartheta\tan\vartheta \\ 0 & \cos\gamma & -\sin\gamma \\ 0 & \sin\gamma/\cos\vartheta & \cos\gamma/\cos\vartheta \end{bmatrix}.$$

Let's assume that the UAS flight is stabilized in horizontal plane, that is, $\gamma = \vartheta = 0$. In this case, the following will be correct: $\mathbf{T(щ)} = \mathbf{I}_{3\times3}, \mathbf{б} = \mathbf{щ}, \omega_z = \dot{\psi}$.

Let's write the state equation in matrix form as following:

$$\begin{aligned} \dot{\mathbf{p}} &= \mathbf{R}(\psi)\cdot\mathbf{V} + \mathbf{b} + \xi_v, \\ \dot{\mathbf{b}} &= \xi_b, \end{aligned} , \qquad (1)$$

where ξ_v is the white noise, ξ_b is white noise with small intensity, vector **b** describes the process of random walk caused by system disturbances including wind, turbulence, inaccuracy of model, etc. Let's introduce the time constant and represent the process (1) as first-order Markov process in continuous form as following:

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{b}_x \\ \dot{b}_y \end{bmatrix} = \begin{bmatrix} 0_{2\times2} & I_{2\times2} \\ 0_{2\times2} & 0_{2\times2} \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ b_x \\ b_y \end{bmatrix} + \begin{bmatrix} \mathbf{R}_{2\times2}(\psi) & 0_{2\times2} \\ 0_{2\times2} & 0_{2\times2} \end{bmatrix} \cdot \begin{bmatrix} v_x \\ v_y \\ \psi \\ z \end{bmatrix} + \begin{bmatrix} \xi_1 \\ \xi_2 \\ \xi_3 \\ \xi_4 \end{bmatrix}, \qquad (2)$$

where coordinate z is related to control vector , since it is assumed to be known from other sensor with required accuracy.

In discrete form the model (2) can be represented as

$$\mathbf{x}_{k+1} = \mathbf{F}\mathbf{x}_k + \mathbf{G}\mathbf{u}_k + \mathbf{L}\xi_k . \quad (3)$$

Components of system noise are assumed to be independent gaussian white noises, that is, they can be represented by covariance matrix as

$$M\left\{\mathbf{o}(t)\mathbf{o}^T(\tau)\right\} = \mathbf{У}\cdot\delta(t-\tau).$$

It is written for continuous form. Discrete form can be represented as $\mathbf{Q} = \mathbf{У}\Delta t$, that corresponds to random gaussian independent sequences ξ_k .

$$\mathbf{У} = \begin{bmatrix} \sigma_{vx}^2 & 0 & 0 & 0 \\ 0 & \sigma_{vy}^2 & 0 & 0 \\ 0 & 0 & \sigma_{bx}^2 & 0 \\ 0 & 0 & 0 & \sigma_{by}^2 \end{bmatrix}$$

Measurement model of CENS cannot be represented analytically, since dependence between measurement parameter of geophysical field and coordinates is table function taken from cartographic data. Measurement noise is represented by additive white noise with known variance σ_z^2 .

Analyses of possible solutions. Known problem statement of optimal statistic estimation [3] is formulated as following: to find the estimate of state vector $\mathbf{x}_k \in \mathbf{R}^n$, where $n \in N$ is the dimension of vector given at a set of discrete time moments with indexes $k \in N$. The evaluation of state vector $\mathbf{x}_k$ in time is described by stochastic equation:

$$\mathbf{x}_k = f_k\left(\mathbf{x}_{k-1}, \mathbf{o}_k\right), \quad (4)$$

where f_k is known transition function, in general case non-linear, that depends on state vector $\mathbf{x}_{k-1}$ and random disturbance $\mathbf{o}_k$. The state vector is observed and expressed by measurement equation as a random process $\mathbf{z}_k \in \mathbf{R}^m$

$$\mathbf{z}_k = h_k\left(\mathbf{x}_k, \zeta_k\right), \quad (5)$$

where h_k is known and also non-linear function of state vector and random measurement noise ζ_k . Statistical parameters of noise are assumed to be known.

If the noises are additive, then equations (4)-(5) can be represented as following:

$$\mathbf{x}_k = f_k\left(\mathbf{x}_{k-1}\right) + \mathbf{o}_k, \quad (6)$$

$$\mathbf{z}_k = h_k\left(\mathbf{x}_k\right) + \zeta_k . \quad (7)$$

Also there is an assumption that process $\mathbf{x}_k$ is Markov process and can be described by transition probability density function (pdf) $p\left(\mathbf{x}_k \mid \mathbf{x}_{k-1}\right)$. The likelihood function can be described by pdf $p\left(\mathbf{z}_k \mid \mathbf{x}_k\right)$.

To solve the problem of optimal estimation it is necessary to get the conditional pdf $p\left(\mathbf{x}_k \mid \mathbf{Z}_k\right)$, where $\mathbf{Z}_k$ is all series of measurements till moment *k*, that is $\mathbf{Z}_k = \left\{\mathbf{z}_i\right\}_{i=1}^{k}$. If the pdf is known at moment *k*-1, then it is possible to extrapolate it by Kolmogorov- Chapman equations:

$$p\left(\mathbf{x}_k \mid \mathbf{Z}_{k-1}\right) = \int p\left(\mathbf{x}_k \mid \mathbf{x}_{k-1}\right) p\left(\mathbf{x}_{k-1} \mid \mathbf{Z}_{k-1}\right) d\mathbf{x}_{k-1}. . \quad (8)$$

After new measurement $\mathbf{z}_k$ in moment *k* the extrapolated pdf $p\left(\mathbf{x}_k \mid \mathbf{Z}_{k-1}\right)$ can be corrected by using well known Bayesian formula:

$$\begin{gathered} p\left(\mathbf{x}_k \mid \mathbf{Z}_k\right) = p\left(\mathbf{x}_k \mid \mathbf{z}_k, \mathbf{Z}_{k-1}\right) = \frac{p\left(\mathbf{z}_k \mid \mathbf{x}_k, \mathbf{Z}_{k-1}\right) p\left(x_k \mid \mathbf{Z}_{k-1}\right)}{p\left(\mathbf{z}_k \mid \mathbf{Z}_{k-1}\right)} = , \\ = \eta^{-1} \cdot p\left(\mathbf{z}_k \mid \mathbf{x}_k\right) p\left(x_k \mid \mathbf{Z}_{k-1}\right), \end{gathered} \quad (9)$$

where value η^{-1} is normalized constant

$$\eta^{-1} = p\left(\mathbf{z}_k \mid \mathbf{Z}_{k-1}\right) = \int p\left(\mathbf{z}_k \mid \mathbf{x}_k\right) p\left(\mathbf{x}_k \mid \mathbf{Z}_{k-1}\right) d\mathbf{x}_k ,$$

that can be determined from the condition

$$\int p\left(\mathbf{x}_k \mid \mathbf{Z}_k\right) d\mathbf{x}_k = 1 .$$

If there is conditional pdf $p\left(\mathbf{x}_k \mid \mathbf{Z}_k\right)$, then it is possible to find the estimate of state vector $\hat{\mathbf{x}}_k$ according to the selected optimality criteria.

Thus, in general case, the problem of optimal estimation consists of two main stages: prediction-update, equations (8)-(9). But realization is complicated and possible only for a few cases. In general there is no closed-form expression for pdf $p\left(\mathbf{x}_k \mid \mathbf{Z}_k\right)$ due mainly to the unstructured non-linearity (6) and (7), and there is no solution that updates the conditional density analytically. The exception is the case of the linear state and measurement models with gaussian noises. In this case the optimum estimator is the Kalman filter [4].

Proposed solution. The dependence $z = h(x, y)$ is a table function (taken as digital elevation map (DEM) of San Francisco South 24K DEM file which is provided in MATLAB Mapping Toolbox™ mapdata folder). The trajectory pediction of UAS is done by GPF [5] with non-optimal resampling. Number of points in sample is 50. Variances are selected as $\sigma^2_{vx} = 1, \sigma^2_{vy} = 1, \sigma^2_{bx} = 1, \sigma^2_{by} = 1, \sigma^2_{z} = 1$. The initial uncertainty in UAS position is introduced by 50 m. Results of simulation are represented in Fig. 1. General variances of estimation errors (taking into account period of transient process) are 15.1022 m in X coordinate and 12.7925 m in Y coordinate (Fig. 2). Number of iteration required to settle the given level of estimation variance is 95.

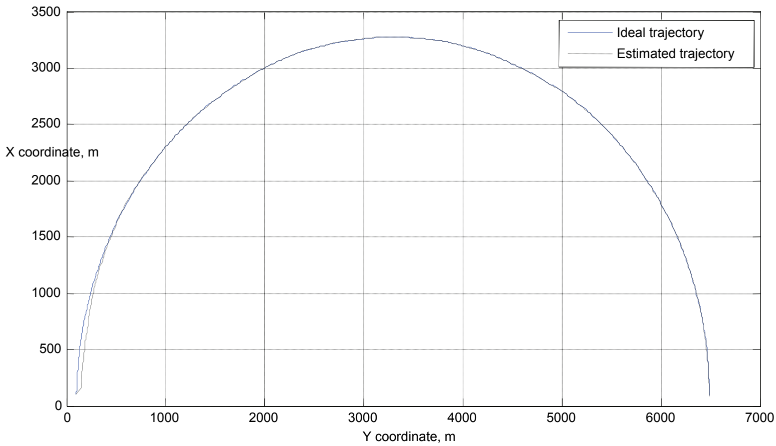


Fig. 1 Ideal and estimated trajectories

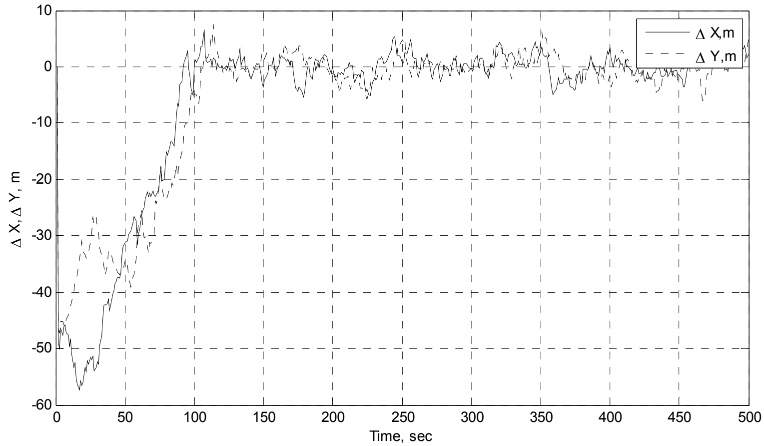


Fig. 2 Coordinates errors propagation

Let's increase the number of points in a sample to 100. The values of variances remain the same $\sigma^2_{vx} = 1, \sigma^2_{vy} = 1, \sigma^2_{bx} = 1, \sigma^2_{by} = 1, \sigma^2_{z} = 1$. As it can be seen from the results of simulation (Fig. 3), the error variances (for stable navigation solution) become smaller: in X coordinate - 2.1096 m and in Y coordinate - 2.9732 m. Number of iteration to reach the stable value of estimation error remains the same. But the computing efficiency drastically degrades.

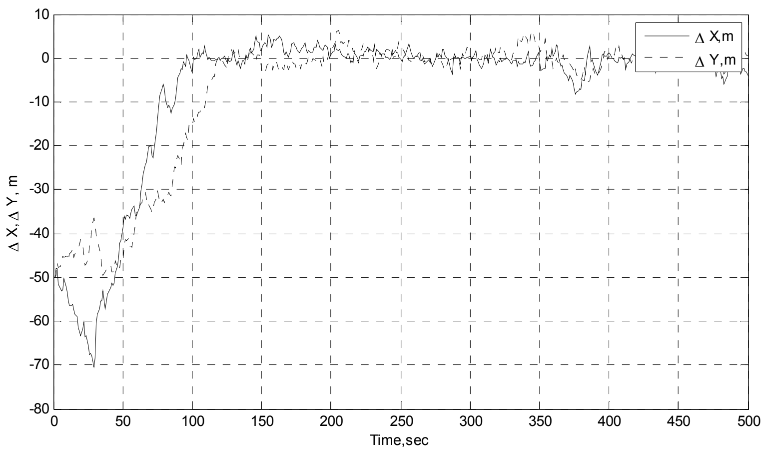


Fig. 3 Coordinates errors propagation with higher number of points in a sample

Now let's increase the system noise and measurement noise remains the same: $\sigma^2_{vx} = 2, \sigma^2_{vy} = 2, \sigma^2_{bx} = 2, \sigma^2_{by} = 2, \sigma^2_{z} = 1$. Number of points in sample is 50. Initial uncertainty remains the same - 50 m. The results of simulation are represented in Fig. 4. Error variance after reaching the stable navigation solution is increased (Fig. 5).

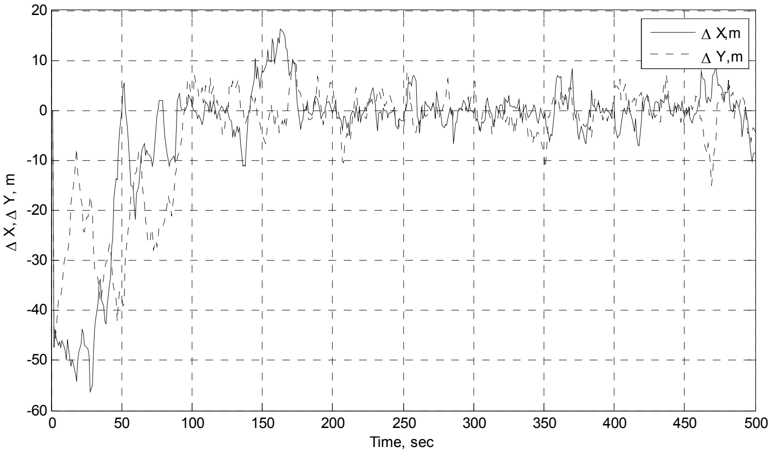


Fig. 4 Coordinate errors propagation for higher system noises

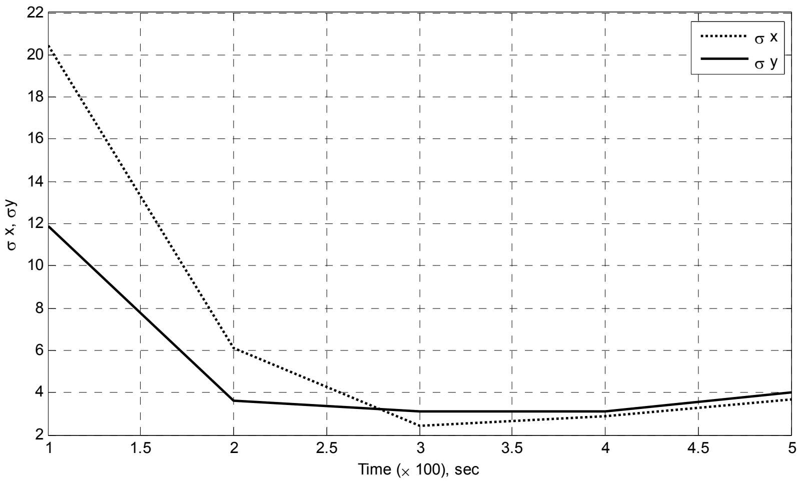


Fig. 5 Error variances propagation

Conclusions. The problem statement for correlation extreme navigation system has been formulated in terms of probabilistic estimation of UAS trajectory. Algorithm of GPF has been used to estimate UAS motion in horizontal plane with initial uncertainty in position. Geophysical field in the form of DEM has been selected to realize the likelihood function. Resampling of GPF has been done by non-optimal principle, nevertheless the results of simulation prove the stability of filter operation and quite high accuracy of estimation with error variances in the range

References

1. Філяшкін М.К., Синєглазов В.М., Захарін Ф.М., Аскеров Ш.І. Інтегрований навігаційний комплекс літальних апаратів малої авіації. - Електроніка та системи управління. К.:НАУ, №25. - 2010. с.108-114.
2. V. Kharchenko, M. Mukhina Correlation-extreme visual navigation of unmanned aircraft systems based on speed-up robust features // Aviation. No 2, volume 18, 2014.
3. Doucet A., Godsill S. and Andrieu C. On sequential Monte-Carlo sampling methods for Bayesian filtering // Statistics an Computing, Vol. 10, No. 3, pp. 197-208, 2000.
4. P.-J. Nordlund. Sequential Monte Carlo Filters and Integrated Navigation. Licenciate thesis, LinkÄopings University, 2002.
5. Arulampan S., Maskell S., Gordon N. and Clapp T. A tutorial on particle filters for on-line nonlinear/non-Gaussian Bayesian tracking // IEEE Transactions on Signal Processing, Vol. 50, No. 2, February 2002, pp. 174-188.

UDC 625.735.(043.2)

M.K. Filyashkin, prof. (*NAU, Ukraine, Kyiv*)

COMPARATIVE ANALYSIS OF DATA FUSION ALGORITHMS IN INERTIAL-SATELLITE NAVIGATION SYSTEMS

For inertial-satellite navigation systems is done the comparative analysis of data fusion algorithms that constructed based on Kalman filtering or by the compensation schemes. The errors of coordinate and velocity components estimates are investigated by two data fusion algorithms.

In solving the problem of data fusion in inertial navigation satellite systems (ISSN) is the most attractive, of course, Kalman filtering (KF). However, the use of KF meets certain difficulties in its implementation on board the aircraft. In particular, this divergence phenomenon that occurs when working with unknown stochastic signal at the input of the filter, which is typical for strapdown inertial navigation systems (SINS).

Currently in modern airborne complexes include algorithms optimal estimation of the state vector (KF algorithms), use of other methods of processing information homogeneous, well proven itself in practice. In particular, this method of mutual compensation (MC).

In [1] the filter of MC scheme is proposed, which provides the data fusion of observed navigational components of the state vector, with quality comparable to optimal KF.

Comparative analysis of different options of data fusion for the observed components of state vector becomes very urgent problem to develop and implement the processing algorithms for ISSN.

The comparative analyses of filtering methods will be limited only by linear filtering algorithms of signal-to-noise components with not-overlapped frequencies. That is, they have significant difference in the frequency characteristics of errors and work in real-time systems. Algorithms of data fusion in ISSN are related to mentioned type[2].

In conventional data fusion algorithms of ISNS the estimation of dead reckoning errors of SINS is done with the help of current information from satellite navigation system (SNS) or other radio systems [3] with further correction of output data of SINS. Such scheme is well known and called invariant integration scheme. Using this scheme the problem to estimate the errors of a subsystem taking into account errors of another is solved.

To synthesize optimal Kalman filter let's consider only longitudinal channel and take into account its independence on the lateral channel. Then the model of dead reckoning errors can be represented as:

$$\Delta\dot{X} = \Delta V_x; \quad \Delta\dot{V}_x = \Delta a_x; \quad \Delta\dot{a}_x = \xi_x$$

where ΔX, ΔV_x, Δa_x – errors of SINS in coordinate and its derivatives, respectively; ξ_x – accelerometer noise given as white noise with intensity S_{ax}.

Observation model will be written as:

$$Z_1 = X_{\text{INS}} - X_{\text{SNS}} = \Delta X + \varsigma_x;$$
$$Z_2 = V_{\text{INS}} - V_{\text{SNS}} = \Delta V + \varsigma_v;$$
$$X_{\text{INS}} = X^{\text{tr}} + \Delta X;\; V_{\text{INS}} = V^{\text{tr}} + \Delta V;$$
$$X_{\text{SNS}} = X^{\text{tr}} + \varsigma_x;\; V_{\text{SNS}} = V^{\text{tr}} + \varsigma_v.$$

The solution of given problem is the continuous reduced Kalman filter:

$$\Delta\dot{\hat{X}} = \Delta\hat{V} + K_{\text{F1}}(Z_1 - \Delta\hat{X});$$
$$\Delta\dot{\hat{V}} = \Delta\hat{a} + K_{\text{F2}}(Z_2 - \Delta\hat{V});$$
$$\Delta\dot{\hat{a}} = K_{\text{F3}}(Z_1 - \Delta\hat{X});$$

Here: X_{INS}, V_{INS} – coordinate and velocity measured by SINS; X_{SNS}, V_{SNS} – coordinate and velocity obtained from SNS receiver; X^{tr} – true value of coordinate; ΔX, ΔV – errors of SINS which are considered as systematic errors caused by gyroscope drifts and inaccuracy of accelerometers; ς_x, ς_v – white's noise components of SNS receiver; $K_{\text{F}i},\; i=\overline{1,3}$ – coefficients of filtering, which can be obtained as constants from steady-state Riccati equations.

Block diagram of the MC method realization is represented in Fig. 1. Here $F(p)$ – dynamic filter of MC scheme; X_{SINS}, X_{SNS} – navigation parameters

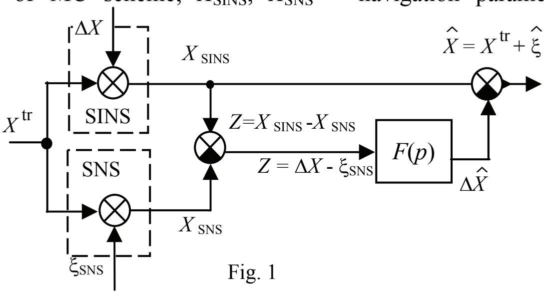


Fig. 1

(coordinates and velocity components) obtained from SINS and SNS; $\hat{X}$ – estimate of given navigation parameter; X^{true} – true value of navigation parameter; ΔX – error of SINS; ξ_{SNS} – noise component of SNS error; Z – navigation parameters of observation; $\hat{\xi} = [1 - F(p)]\Delta X + F(p)\xi_{\text{SNS}}$ – error of data fusion.

The data fusion algorithm based on the MC method has the following form:

$$\hat{X} = X_{\text{SINS}} - F(p)Z\ .$$

The equation of the MC scheme (Fig. 1) can be written as follows:

$$\hat{X} = X^{\text{tr}} + \Delta X - F(p)(\Delta X - \xi_{\text{SNS}}) \text{ or } \hat{X} = X^{\text{tr}} + [1 - F(p)]\Delta X + F(p)\xi_{\text{SNS}} = X^{\text{tr}} + \hat{\xi}.$$

The error $\hat{\xi}$ will be decreasing with greater difference between spectral characteristics of sensor errors ΔX and ξ_{SNS}. If the filter $F(p)$ is selected to minimize the distortion of disturbance ΔX and to suppress the noise ξ_{SNS}, then the error of complex system will be minimal/ With significant difference in frequency characteristics of noises at the output of filter *F*(*p*) (see Fig. 1) the disturbance ΔX will be reproduced without any changes, and at the output of compensation scheme the exact value of measured parameter X^{tr} is obtained, since

In [1] based on a second order filter Batervorta was synthesized dynamic filter MC with a rather simple model of compensation of inertia, which is a aperiodic filter with the unit speeding up

$$W_{\mathrm{comp}}(p) = (3T_{\mathrm{F}}p+1)/(T_{\mathrm{F}}p+1)\,. \tag{1}$$

The comparative analysis of data fusion algorithms that implement the method MC and algorithm KF was done by its mathematical simulation in software environment *Simulink*, as a part of *MATLAB*.

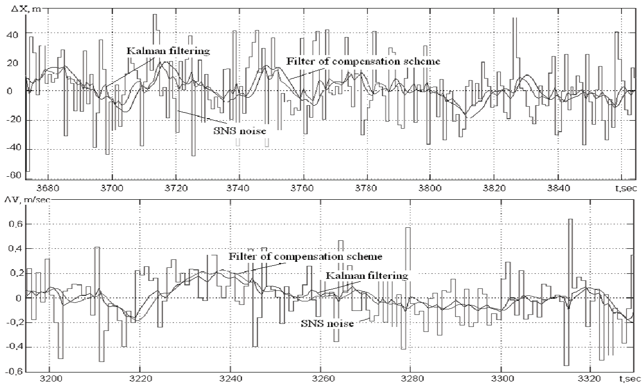


Fig. 2

Analyses of simulation results proves the identity of two data fusion schemes though the presence of Butterworth filter of the second order allows providing the more effective smoothing of noise components of SNS errors. Especially this phenomena is observed in the speed channel.

To improve the quality of estimation procedure of errors by MC method it is recommended sluggishness of filters Batervorta second order in the channel of coordinates compensate using a signal $\Delta\hat{V}$ from the channel of velocity estimation (see Fig. 3) and in the channel of velocity using a signal $\Delta\hat{a}$ from the channel of horizontal acceleration estimation.

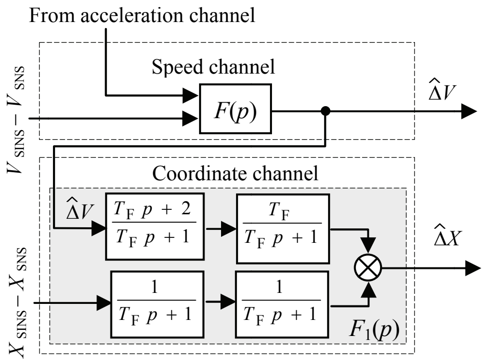


Fig. 3

Estimate of the horizontal component of acceleration is obtained by data fusion SINS and derivative of velocity signal supplied from the SNS. When differentiating of radio signals of SNS use the usual procedures of filtering for signals corrupted by noise

Fig. 3 illustrates a structure of a dynamic filter $F_1(p)$ in the channel circuits MC coordinates. Similarly, the structure has a filter $F(p)$ in the channel velocity, and acceleration channel remains inertia compensation filter circuit (1).

The simulation results which show errors estimation of coordinate and velocity for the different variants of integration are represented in Fig. 4.

The comparative analyses of simulation results shows that the accuracy of error estimation of the proposed scheme with dynamic filter $F(p)$, $F_1(p)$ (based on Butterworth filter) is almost the same as the accuracy of optimal Kalman filter, and simultaneously the quality of filtering of SNS noise components is higher.

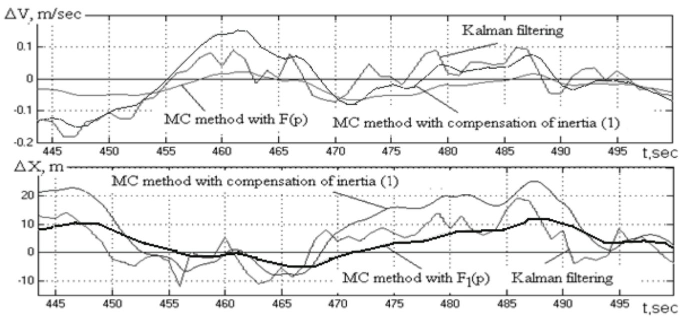


Fig. 4

Conclusions. The comparative analyses of data fusion schemes of aided SINS and SNS shows that the accuracy of navigation parameters estimation of compensation scheme with proposed dynamic filters is not inferior to algorithms of

Kalman filtering however the quality of filtering of SNS noise component is even higher. The significant drawback of compensation scheme to Kalman filtering is impossibility to estimate the non-observed components of state vector, therefore here it is necessary to have alternative methods of estimation of angular orientation parameters.

References

1.Філяшкін М.К., Марьясова Т.І. Алгоритми субоптимальної фільтрації в схемах комплексування інерціально-супутникових систем за методом компенсації // Електроніка та системи управління. – 2011 – №2. – С. 100-106.

2.Sineglazov V. M., Zakharin F. M. Peculiarities of future air navigation system based on inertial navigation systems/global positioning system. // Electronics and Control Systems . – 2012 – №4 (34). – С. 84-90.

3.Мухіна М.П. Алгоритм корекції інерціальної навігаційної системи на основі далекомірної інформації // Електроніка та системи управління. – 2012 – №1 – С. 43-49.

UDC 681.5.017

A. Ablesimov, professor (National Aviation University, Ukraine)

STABILITY BORDERS AND REGIONS OF STABILIZATION SYSTEMS OF INERTIAL CONTROL OBJECTS

The method of calculation and construction of the stability border and the region in the plane of the two parameters have been considered.

Performing by the automatic control systems (ACS) functions assigned to them is possible only when they are stable. If ACS is stable, all the transients caused by external influences will be damped and oscillations in a system will not arise. System stability is achieved only when there is a certain combination of its parameters, and provided with appropriate adjustments during maintenance.

Investigation of the influence of parameters on the stability of ACS management processes is performed during the system projecting. Solution of problem by constructing vectors of hodographs $\overline{A}(j\omega)$ or $\overline{W}_{\text{p}}(j\omega)$ for each change of a parameters is a very laborious work. It would be better to build the stability border in a space of variable parameters, which will divide regions of sustainable and unsustainable management. Further investigations will be reduced to the determination of the position of the operating point according to system parameters, which are interesting for the researcher, in one or another region.

Usually limited by two parameters of variation (A, B) for fixed values of the others. Stability region can be closed, that in general is not required. The equations of stability border may be defined with the help of the frequency criterias of Nyquist or Mikhailov

$$\left.\begin{array}{l} X(A,B,\omega)=0 \\ Y(A,B,\omega)=0 \end{array}\right\}; \quad \left.\begin{array}{l} U(A,B,\omega)=-1 \\ V(A,B,\omega)=\ \ 0 \end{array}\right\}.$$

Analysis of stabilization systems of inertial control objects shows that different in design systems have congruent structure and transfer functions of the same type. This allows us to consider a methodology of analyzing their stability based on the generalized block diagram shown in figure 1.

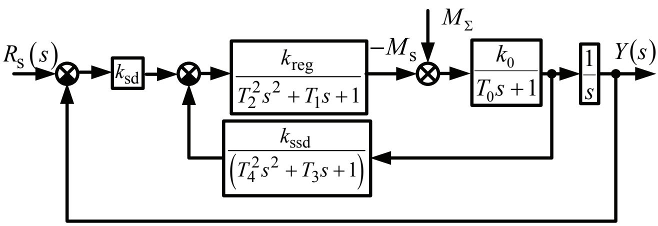


Fig.1 Generalized structural diagram of a typical stabilization system

In the block diagram the following notations are used:

$$W_0(s)=\frac{k_0}{(T_0 s+1)},\qquad W_{\text{reg}}(s)=\frac{k_{\text{reg}}}{T_2^2 s^2+T_1 s+1},\qquad W_{\text{ssd}}(s)=\frac{k_{\text{ssd}}}{T_4^2 s^2+T_3 s+1},$$

$W_{\text{sd}}(s)=k_{\text{sd}}$ - transfer functions of the inertial control object, regulator, sensor of speed deflection of control object, sensor of deflection of control object respectively;

M_Σ - total disturbing moment; M_{s} - stabilization moment.

Transform a block diagram of the form shown in Figure 2 selecting the channels of forming the stabilization moment. In the diagram introduced the notations of system stiffness G and damping D.

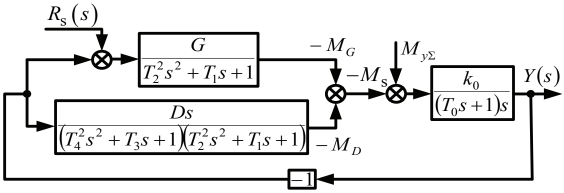


Fig.2 The structural diagram of a system with fission of forming channels of stabilization moment

Stiffness characterizes the ability of the system to counteract to the external disturbances. It is determined by the coefficients of strengthening of the deflection sensor and regulator $G=k_{\text{sd}}k_{\text{reg}}$.

Damping describes the ability of the system to put out vibrations arising in it. Damping depends from the coefficients of strengthening of the speed deflection sensor and regulator $D=k_{\text{ssd}}k_{\text{reg}}$.

Stiffness and damping directly influence on the formation of stabilizing moment and determines the effectiveness of systems countering to external disturbances. Will take stiffness G and damping D as variable parameters of system and find stability border and region in the plane of the selected parameters.

Let us find the transfer functions:

- by control signal

$$W_r(s)=\frac{k_0 G\left(T_4^2 s^2+T_3 s+1\right)}{A(s)},$$

- by external perturbation

$$W_m(s)=\frac{k_0\left(T_4^2 s^2+T_3 s+1\right)\left(T_2^2 s^2+Ts+1\right)}{A(s)}.$$

Here $A(s)$ - the characteristic polynomial of the sixth order

$$A(s)=a_6 s^6+a_5 s^5+a_4 s^4+a_3 s^3+\left(a_2+k_0 G T_4^2\right)s^2+k_0\left(D_\Sigma+G T_3\right)s+k_0 G$$

.

Coefficients of the characteristic polynomial are

$a_6 = T_4^2 T_2^2 T_0$;
$a_5 = T_4^2 T_2^2 + T_4^2 T_1\ T_0\ + T_3\ T_2^2 T_0$;
$a_4 = T_4^2 T_1\ + T_4^2 T_0\ + T_3 T_2^2 + T_3\ T_1\ T_0\ + T_2^2 T_0$;
$a_3 = T_4^2 + T_3 T_1\ + T_3\ T_0\ + T_2^2 + T_1\ T_0$;
$a_2 = T_3\ + T_1\ + T_0$.

The total damping $D_\Sigma = D_0 + D$ is determined by the sum of constant damping $D_0 = 1/k_0 = f_0$, caused by natural friction of inertial control object, and of external damping D , which is generated by the sensor of speed deflection of control object

Let us use the Mikhailov criterion for assessing the stability of the stabilization system

$$A(j\omega) = \left[-a_6\omega^6 + a_4\omega^4 - \left(a_2 + k_0 G T_4^2\right)\omega^2 + k_0 G\right] + \\ + j\left[a_5\omega^5 - a_3\omega^3 + k_0\left(D_\Sigma + G T_3\right)\omega\right].$$

Equating the real and imaginary parts to zero, we shall have

$$\left.\begin{aligned} X(\omega) &= -a_6\omega^6 + a_4\omega^4 - \left[a_2 + k_0 G_{\text{г}} T_4^2\right]\omega^2 + k_0 G_{\text{sb}} = 0 \\ Y(\omega) &= a_5\omega^5 - a_3\omega^3 + k_0\left(D_{\text{sbУ}} + G T_3\right)\omega = 0 \end{aligned}\right\},$$

where G_{sb} and $D_{\text{sb}\Sigma}$ - stiffness and total damping, that corresponds the stability border $D_{\text{sb}\Sigma} = F\left(G_{\text{sb}}\right)$.

On the basis of last equations will just find dependences of the boundary values of stiffness and total damping from the frequency

$$G_{\text{sb}}(\omega) = \frac{a_6\omega^4 - a_4\omega^2 + a_2}{k_0\left(1 - T_4^2\omega^2\right)}\omega^2;\ D_{\text{sb}\Sigma}(\omega) = \frac{a_3 - a_5\omega^2}{k_0}\omega^2 - G_{\text{sb}}(\omega) T_3.$$

According to the graph-analytical method [1] is constructed the stability border $D_{\text{sb}\Sigma} = F\left(G_{\text{sb}}\right)$ of the system (Fig. 3).

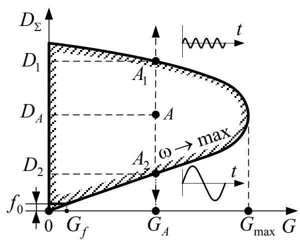


Fig.3 Region of stable management processes

Let us select the region of stability management, using the rule of applying shading [2]. For this we find the determinant

$$\begin{vmatrix} \frac{\partial X(G,D,\omega)}{\partial G} & \frac{\partial X(G,D,\omega)}{\partial D} \\ \frac{\partial Y(G,D,\omega)}{\partial G} & \frac{\partial Y(G,D,\omega)}{\partial D} \end{vmatrix} = \begin{vmatrix} k_0\left(1+T_4^2\omega^2\right) & 0 \\ k_0 T_3 \omega & k_0\omega \end{vmatrix} = k_0^2\omega\left(1+T_4^2\omega^2\right) > 0.$$

Since the determinant is greater than zero, we put shading on the left side, moving in the direction of increasing frequency $\omega \to \max$.

Stability border identified in the plane of variable parameters stability region. Inside this region, any selected operating point A, with parameters G_A and D_A corresponds to stable (damped) management processes.

Conclusions. The resulting stability border and region allow us to make a number of important conclusions:

- with decreasing the damping stability ACS retained until you reach the lower border of the stability region, where the frequency is relatively small. On reaching the lower border low frequency oscillations with large amplitudes are arising in the system.

- with increasing the damping stability ACS retained until you reach the upper border of the stability region, where the frequency is relatively high. On reaching the upper border high frequency oscillations with small amplitudes are arising in the system.

- for a given value of stiffness, for example G_A, limits of changing damping are strictly limited $D_1 < D_A < D_2$.

- the border of the stability region defines the limit of stiffness $G_{\max}$, which can be obtained for a given system.

- if the system is missing the sensor of speed deflection of control object it will be stable only for a small value of stiffness G_f, that corresponds the damping by friction f_0. Thus, the speed sensor expands the stability region of the system.

- the time constant $T_0 = \frac{J_0}{f_0}$ of the control object depends on its moment of inertia J_0 and is the scale of characteristics $G_{\text{sb}}(\omega)$ and $D_{\text{sb}\Sigma}(\omega)$. With the increasing of the moment of inertia is to the stability region expands proportionally. Therefore, to ensure stable mode of operation of ACS, where the control object has a large inertia, easier.

References

1. Ablesimov O.K.; Alexandrov E.E.; Alexandrova I.E. 2008. Automatic control of moving objects and technological processes. Kharkov: NTU “KhPI”. 443p. (in Ukrainian).

2. Ablesimov O.K. 2014. Course of the theory of automatic control. Kyiv: Osvita Ukrainy. 270p. (in Ukrainian).

UDC 629.735.018.006.26:629.7.05/.06(043.2)

V.M. Sineglazov, PhD,
S.O. Dolgorukov (National Aviation University, Kyiv, Ukraine)

OPTIMAL CHOICE OF THE TECHNICAL MEANS OF HEADING, PITCH AND BANK CHANNEL SUBSYSTEMS OF NAVIGATION EQUIPMENT SIMULATION TABLE

Design of large-scale systems has always been a complex task. In this article it is proposed multilevel multiobjective optimization methodology that can be implemented in the CAD software for the optimal choice of technical means.

Introduction. With the rapid development of unmanned aerial vehicles (UAV) there was necessary to create an integrated navigation systems (INS) that improve accuracy of navigation parameters through the use of UAV navigation systems running on different physical principles (complexing). To solve this problem in the INS are included: inertial navigation systems, which consist of accelerometers and gyroscopes, satellite navigation systems, magnetometers, air signals system, navigation system, odometer system, etc.

During the flight INS are subject to various influences that may adversely affect their accuracy and indicators of reliability, so there is a need for a means of providing technical testing navigation equipment in conditions close to the real flight.

In this paper, to solve this problem there is proposed to use the simalation table (ST), the structure of which is shown in Fig .1. ST must ensure tests on the parameters close to real, namely the angular positions, overload, angular velocity and acceleration of all control channels. To ensure these parameters on the technical design stage it is necessary to solve the task of developing assembly units, functional task, the task of developing algorithms and software, the task of selecting a set of technical means.

Indicator of efficiency when designing ST are criteria are accuracy, reliability and cost.

$$F = (F_1(x),...,F_i(x),...,F_l(x))\ , (i = 1,..,l)$$

Optimization problem is proposed to address with these criteria on the basis of a systematic approach when there are three levels of tasks: lower - lower-level goals, coordinating - objectives for the upper (coordinator) and the global - the goal of a whole system. In this regard, there are four different problems [1]: synthesis of coordinating element, methods (procedures) of coordination, problem of modification, decomposition.

It will allow to divide a complex optimization problem into several low-level subtasks. Solution to the global optimization problem is a vector solutions of coordinated lower-level subtasks. Methodology of this decomposition into subtasks and coordination for various models of hierarchical systems is considered in detail by Mesarovic M., J. Takahara et al [1].

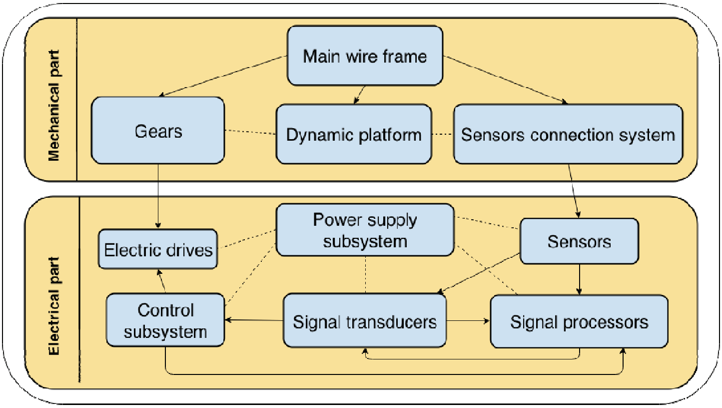


Fig. 1. Structure scheme of the simulation table for navigation equipment testing

To improve the efficiency of ST design there is proposed CAD system, the block diagram of which is shown in Figure 2.

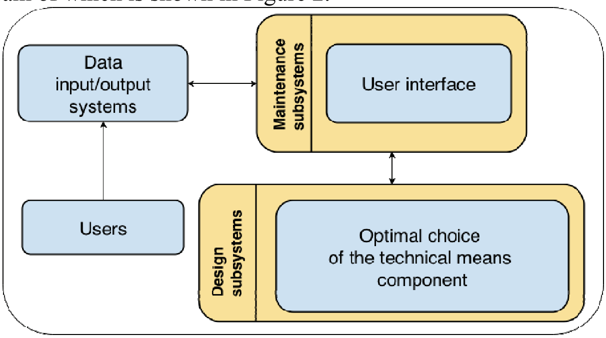


Fig. 2. Structure scheme of CAD software

Task statement. Consider the problem of multicriteria optimization of complex system consisting of subsystems, which has a two-level hierarchy with the criteria of the upper F and lower layer f. Top-level criteria are essential for all subsystems - performance, accuracy, reliability and cost (F_1, F_2, F_3).On the upper level there are limitations associated with the technical specifications for the entire system, which directly affect the optimization of the subsystems. That are such restrictions as providing predetermined angular positions, velocities, accelerations, mass of equipment under the test, dimensions ($G = \{G_1, G_2, G_3, G_4, G_5\}$).On the lower level design parameters of each subsystem are determined based on their own restrictions (g_j).These values should be defined in an array of variables that would have increased the maximum efficiency of the system, while providing optimality of each subsystem and satisfying all the constraints.Thus, the task has two types of objective functions for the criteria of the upper level and lower-level criteria that are linked through coordinating variables.

We assume that the performance of each subsystem can be expressed in terms of the criteria of technological quality indices f such as:

1. Indices of destination
   - Classificational (voltage, power)
   - Functional (performance, precision, limits of measurement)
   - Design (weight, dimensions)
   - Maintenance (electric power consumption)
2. Reliability indices
   - Reliability (mean time to first failure, the probability of failure-free operation for a certain period, the failure rate)
   - Durability
   - Repairability
3. Economical use of resources (energy convertion efficiency, energy consumption)
4. Standardization and unification
5. Security
6. Resilience to external influences
7. Economic.

Let us consider the main technological parameters of quality for ST subsystems.

For dynamic platform this is carrying capacity depending on the class of UAV, dimensions.

For gear units this is reliability, dimensions, accuracy, gear ratio, load indices.

For electric drives and control subsystem it is the weight, size, reliability, speed, control equipment, electric performance, stiffness of mechanical characteristics of the drive, smoothness of motion, accuracy of control.

For subsystems of information acquisition and transmission this is accuracy, sample rate, noise immunity.

For power subsystem - it is energy conversion efficiency, dimensions and weight, fault tolerance.

Moreover, all subsystems have their economic indices, such as fair cost.

As it can be seen, technological criteria of quality are comparable and in many cases conflicting.

ST design problem can be represented as a multi-level multi-criteria optimization problem formal statement of which is as follows.

$$\min_{\lambda} F(\lambda, y) = (F_1(\lambda, y), ..., F_i(\lambda, y), ..., F_l(\lambda, y)) \,, \; (i = 1,..,l) \,,$$

subject to: $G(\lambda, y) \le 0$, where (λ, y) are Pareto optimal for

$$\min_{x_j} f = \left(f_1(\lambda, x_1), ..., f_j(\lambda, x_j)\right), \; (j = 1, ..., k)$$

subject to: $g_1(\lambda, x_1),..., g_j(\lambda, x_j) \le 0$.

$\lambda \in X$, $x, y \in Y$, where $G(\lambda, y)$ - vector of system constraints; $g_j(\lambda, x_j)$ - vector of subsystems constraints; $F_i(i=1,..,l)$ - top-level goal functions; $f_j(j=1,...,k)$ - goal functions of the lower level; x_j – vector of subsystems variables; λ – vector of coordinating variables.

The task is to optimize the lower level for a tight budget for each subsystem λ_j coordinated so as to achieve the best solution of entire system as a whole (fig.3).

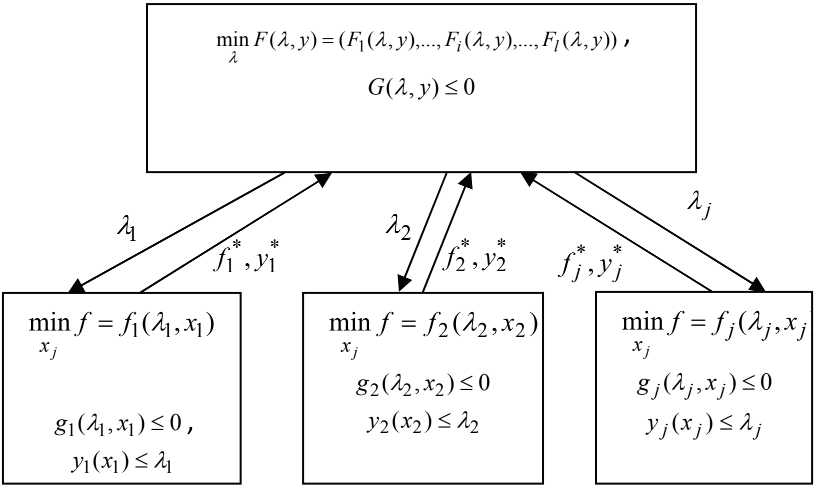


Fig. 3. The hierarchical structure of the problem of multicriteria optimization

A lot of traditional optimization techniques have been proposed for solving multiobjective optimization, such as the method of global criterion, the weighted sum of [2], ε - constraints [3], weighted metrics [4], the method of goal programming [4], lexicographic ordering method [4], a variety of interactive methods, etc. Most of these methods are based on the transformation of the problem into single criterion, and often have several disadvantages, such as the constant need for different adjustments of the method and receiving only a single solution at the end of each iteration.

For solving multiobjective problems there was proposed to use genetic algorithms (GAs) using a population approach and the concept of Pareto dominance in the process of finding solutions, where each iteration has more than one solution, and with each iteration, a new array of data is formed to find the optimal solutions. GA is often divided into two main groups: the dominated and nondominated sorting [2].Among modern methods one can distinguish genetic algorithm nondominant sort NSGA-II developed by Kalyanmoy Deb, Samir Agrawal, Amrit Pratap, and T Meyarivan [5], the algorithm with the archive, using the concept of force SPEA2 developed by Eckart Zitzler, Marco Laumanns and Lothar Thiele, the algorithm of particle swarm MOPSO [6] and GA based on the evaluation of the entropy [7,8].

Conclusions. There was proposed the solution of simulation table design problem by means of milti-level multicriteria optimization. Genetic algorithm approach is the modern and promising tool proven by variety of publications worldwide. It has undergo rapid growth during the last decade. The development of the CAD software on the basis of the described framework will be the goal of the future developments in this realm.

References

1. Mesarovic M. D., Macko D., Takahara Y. Theory of hierarchical multilevel systems. New York, Academic Press, 1970.
2. Miettinen, K. (1999). Nonlinear multi-objective optimization. Boston: Kluwer Academic Publishers.
3. Haimes, Y. Y., Lasdon, . S., & Wismer, D. A. (1971). On a bicriteriion formulation of the problem of integrated system identification and system optimization. IEEE Transactions on Systems, Man, and Cybernetics, 1(3), 296-297.
4. Steuer, R. E. (1986). Multiple criteria optimization: Theory, computation, and applications. John Wiley & Sons, Inc.
5. Deb, K., Pratap, A., Agarwal, S., & Meyarivan, T. (2002). A fast and elitist multi-objective genetic algorithm: NSGA-II. IEEE Transactions on Evolutionary Computation, 6(2), 182-197.
6. Coello, C. A. C., Pulido, G. T., & Lechuga, M. S. (2004). Handling multiple objectives with particle swarm optimization. IEEE Transactions one Evolutionary Computation, 8(3), 256-279.
7. Mehr, A., Azarm, S., “Diversity Assessment of Pareto Optimal Solutions: An Entropy Approach”, Proceedings of the IEEE World Congress on Evolutionary Computation, Honolulu, Hawaii, 2002.
8. S. Gunawan, A. Farhang-Mehr, and Shapour Azarm (2003). Multi-level Multi-objective Genetic Algorithm Using Entropy to Preserve Diversity. EMO, volume 2632 of Lecture Notes in Computer Science, page 148-161. Springer

UDC 629.735.018.006.26:629.7.05/.06(043.2)

B.V. Roman (National Aviation University, Kyiv, Ukraine)

INCREASE OF EFFECTIVENESS OF HARDWARE-IN-THE-LOOP TEST BENCH

Seminatural modeling of navigational equipment is simulation of aircraft motion during flight with help of hardware-in-the-loop test bench. Use of *hardware-in-the-loop test bench for testing navigation equipment is characterized by high quality of testing with relatively low time and cost of testing. Effectiveness of hardware-in-the-loop test bench is determined by variety of different criteria. Effectiveness can be calculated after determination of these criteria.*

Introduction. Hardware-in-the-loop (HIL) test bench for testing and verification of navigational equipment is designed to provide high-accuracy positioning, speed and acceler ations during testing, development or production of inertial systems and their components in aviation, defense, aerospace and marine industries. Use of such HIL test benches for modeling of aircraft flight allow to decrease time and cost of testing. Such tests are characterized by high accuracy and reliability. However, significant disadvantage of HIL test benches for testing of navigational equipment is their price. The cost of HIL test benches presented by different manufacturers such as Acutronic, Ideal Aerosmith, is rather high. So the task is to develop HIL test bench with sufficiently high characteristics at minimal cost.

HIL test benches for testing navigational equipment. HIL test benches for testing navigational equipment [1] designed to accurately reproduce the motion on axes of roll, pitch and yaw in the test lab.

They are developed in order to optimize and significantly reduce the complexity of the calibration process, inertial sensors, as well as to research and clarify the errors of micromechanical sensors and navigation systems based on them.

Their use reduces the time and reduces the cost spent on the development and production of navigation equipment. Often HIL test benches are used to calibrate inertial devices such as sensors of angular positions in production. Application of HIL test benches for seminatural testing of aerial vehicles reduces costs by reducing the number of field tests.

Structural diagram of a triaxial test bench is shown in Fig. 1.

The test program for the test object is formed on the basis of selected methods for determination of errors of tested equipment and is entered into the computer with installed special software.

Data from the computer is received through the data input-output board by the motor control system. This data is processed by a microcontroller/FPGA and converted into PWM control signals for the actuators. Equipment under test is mounted on moveable platform driven by three actuators, for roll pitch and yaw.

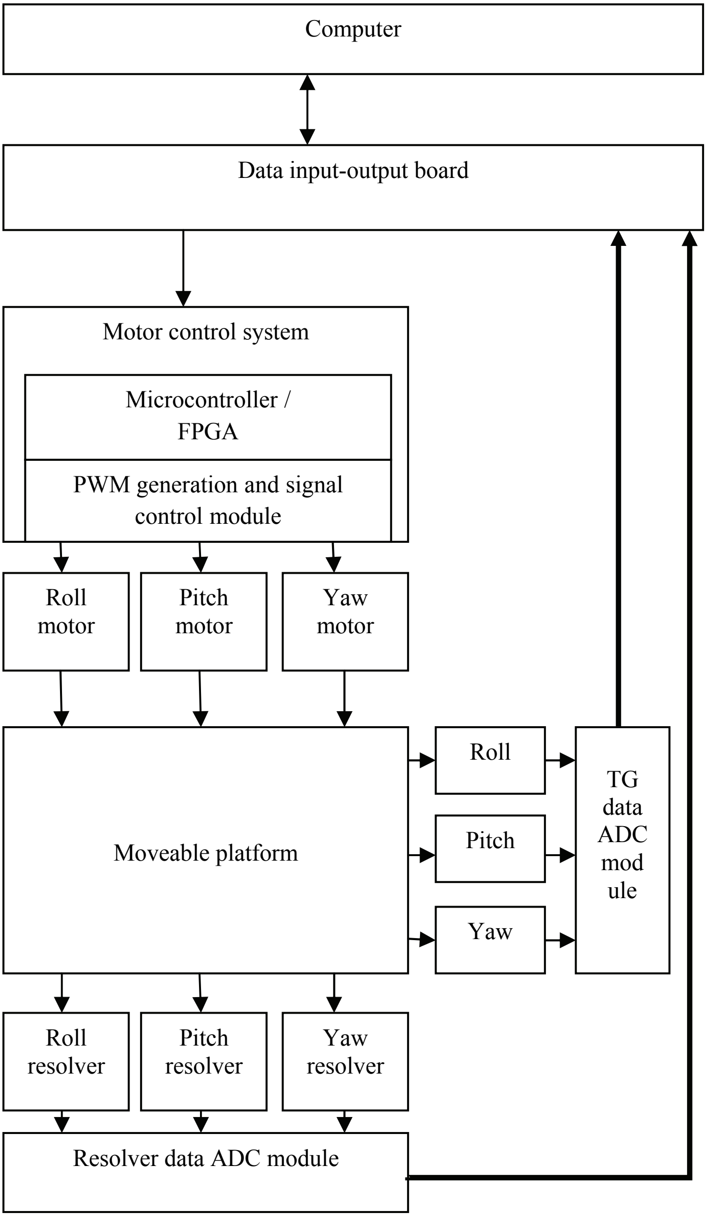


Figure 1. Structural diagram of a triaxial test bench

Resolvers and tachogenerators are also connected to axes of moveable platform to measure speed and angles of rotation of platform. Resolvers and tachogenerators transmit their data to corresponding ADC blocks, where data is transformed into digital form. After transformation this data comes back to the computer through data input-output board.

Use of microcontroller\FPGA in the system, reduces the load on the control program and allows to implement it in real time. This factor is one of the priority tasks of seminatural modeling, which makes it possible to increase the efficiency of the system as a whole.

Effectiveness of hardware-in-the-loop test bench calculation. HIL test bench for testing and verification of navigational equipment consists of three separate channels: for roll, pitch and yaw. Since channels have the same structure, lets consider them on example of one channel.

Effectiveness of HIL system for testing and verification of navigational equipment consists of set of different criteria [2]. Key criteria are energy efficiency(η), dimensions and weight, positioning accuracy, rotation speed, price indices, reliability.

To determine effectiveness of the system (E_{syst}) it is proposed to summarize effectiveness criteria (E_{crit}) with definite weighting coefficient (b) over price index (Pr):

$$E_{syst} = \frac{\Sigma(b * E_{crit})}{Pr}$$

From the structure of the system it is possible to identify two main parts affecting the effectiveness criteria (Fig. 2):

electronic part (motor control system);

mechanical part (ensuring the mobility of the system).

In turn, the control system consists of computing module (microcontroller / FPGA) and motor control unit (thyristor bridge circuit).

Mechanical part consists of motor, gear (wave gear) and moveable platform.

To calculate the **energy efficiency** of the system is necessary to multiply the energy efficiency of its components [3-5]. As the result, for triaxial test bench we will obtain:

$$\eta_{system} = \left(\frac{U * I - (P_{mat} + P_{wind} + P_{mech})}{U * I}\right) * \left(1 - (\psi_{fr} + \psi_h + \psi_b)\right) * \left(1 - \frac{(I_{in} - I_{out})}{I_{in}}\right)$$

Weight and dimensional characteristics (MS) are the weight (M), the payload capacity (L), the physical size of the HIL test bench (S). As a measure of Weight and dimensional characteristics is proposed to use a weighted sum :

$$MS = k_1 * \mathrm{M} + k_2 * L + k_3 * S$$

$$k_1 + k_2 + k_3 = 1$$

Where: k_1, k_2, k_3 – weight coefficients of weight, the payload capacity, the physical size of the HIL test bench correspondingly.

Price indices consist of cost of manufacturing (Pr_{prod}), cost of service (Pr_{serv}), cost of equipment testing ($Pr_{testing}$). Price index is calculated as:

$$Pr = Pr_{prod} + Pr_{serv} + Pr_{testing}$$

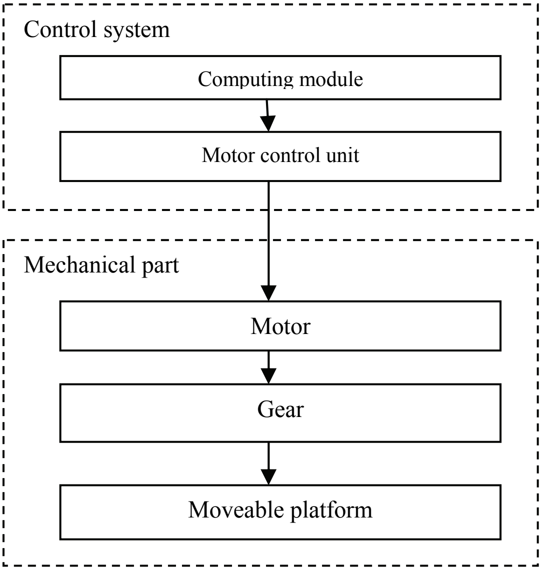


Figure 2. Main elements of HIL system chanel

Positioning accuracy (a) is determined by the ratio of positioning error and predetermined position signal (d_{in}). It includes: mechanical parts manufacturing errors(ε_{mech})(static error), control error (ε_{cs}), error caused by mechanical system nonlinearities(ε_{nonl}), transformation errors(ε_{conv})(ADC, DAC errors), measurement errors(ε_{meas}), random error caused by system noises(ε_{noise}):

$$a = \frac{d_{in} - d_{out}}{d_{in}} = \frac{d_{in} - (d_{in} - \varepsilon_{mech} - \varepsilon_{cs} - \varepsilon_{conv} - \varepsilon_{nonl}) - \varepsilon_{noise} - \varepsilon_{meas})}{d_{in}}$$

Rotation speed (V_{syst}) of HIL test bench platform is also one of key parameters characterizing effectiveness of system. Rotation speed of HIL test bench platform is tightly connected with characteristics of control system, motors, gear. For calculation of measure of rotation speed of platform it is proposed to use:

$$V_{syst} = V_{cs} * V_m * u_{gear}$$

Where: $V_{cs} -$ control system performance; $V_m -$ motor rotation speed; $u_{gear} -$ gear ratio.

Positioning accuracy and speed of HIL test bench platform rotation are tightly connected: the higher the accuracy of positioning is, the lower rotational speed of the platform will be.

The main **reliability index** is the probability of failure-free operation[2,9]. Probability of failure-free operation - the probability that within a given predetermined operating time interval no equipment failure occurs. In case of complex system like HIL test bench, shown in fig.1, probability of node failure-free operation probability (P_{syst}) will be determined as (11):

$$P_{syst} = P_{comp} * P_{pio} * P_{cs} * (P * (P_{m1} * (P_{tg1} + P_{r1}) + P_{m2} * (P_{tg2} + P_{r2}) + P_{m3} * (P_{tg3} + P_{r3})) + P_{adcr} * (P_{m1} * (P_{tg1} + P_{r1}) + P_{m2} * (P_{tg2} + P_{r2}) + P_{m3} * (P_{tg3} + P_{r3}))) \quad (11)$$

Where: $P_{comp} -$ probability of computer failure-free opration; $P_{pio} -$ probability of data input/output board failure-free operation; $P_{cs} -$ probability of control system failure-free operation; $P_{adctg} -$ probability of tachogenerators ADC unit failure-free operation; $P_{adcr} -$ probability of resolver ADC unit failure-free operation; $P_m -$ probability of corresponding motors failure-free operation; $P_{tg} -$ probability of tachogenerators failure-free operation; $P_r -$ probability of resolver failure-free operation;. Probability of failure-free operation of node is determined as:

$$P_{node} = 1 - i_{node}$$

Where: $i_{node} -$ probability of node failure.

As a result substituting we have:

$$E_{syst} = \frac{b_1 * \eta_{system} + b_2 * V_{syst} + b_3 * a + b_4 * P_{syst} + b_5 * MS}{Pr}$$

Where: $b_1 + b_2 + b_3 + b_4 + b_5 = 1$.

Conclusions. Effectiveness of HIL test bench is determined by set of different parameters, and can be increased by methods described above. Use of thyristor bridge circuit in system don't affect total system effectiveness a lot due to their high efficiency, but is necessary to provide motors rotation in both directions. Also it should be mentioned that to improve the reliability and maintainability of the whole system it is necessary to provide a modular structure with redundant critical components.

References

1. Acutronic website http://*www.acutronic.com*
2. Avduevskij B.C. “Reliability and effectiveness in technology. Handbook in ten volumes”, vol.5, Moskow, "MASHINOSTROENIE",1988, 319p. (in Russian)
3. Smiljanskij G.L. “APCS designer handbook”, Moskow, "MASHINOSTROENIE",1983, 527p. (in Russian)
4. Indicators and performance criteria of systems. http://victor-safronov.narod.ru/systems-analysis/lectures/rodionov/09.html
5. Total system efficiency http://www.powertransmission.com/issues/0210/efficiency.pdf
6. DC machine in the motor mode. http://feklistovstudio.narod.ru/5Dvig-DC.html
7. Strel'nikov V.N. “Determination of efficiency and axial forces in the major wave of gear reducers”, Kharkov, vestnik KhPI, 2002, pp3-14. (in Russian)
8. Gears efficiency. http://reductory.ru/literatura/detali-mashin-rjakhovskii/11-14-kpd-zubchatykh-peredach.html
9. Aleksandrovskaja L.N “Modern methods of ensuring reliability of complex technical systems”, Moskow, Logos, 2001, 208p. (in Russian)

UDC 681.5.017:621.176 (045)

V.V. Kalinichenko, Sen.Teacher, (NAU, Kyiv, Ukraine)
V. N. Fedosenko, Postgraduate student (NAU, Kyiv, Ukraine)
E. I. Andrienko (NAU, Kyiv, Ukraine)

THE METHODIC OF CLEANROOM VENTILATION AND AIR CONDITIONING SYSTEM DESIGN

The structure of computer-Aided Design of Cleanroom Ventilation and Air Conditioning System is proposed. The algorithms of air ducts design and optimal selection of ventilation equipment is developed.

Space requirements, in which it must be ensured conditions that it is necessary for technological processes of microelectronics were and are very tough. Top quality products , constant struggle to raise the productivity requires the precise control and coordination between the technological equipment, engineering and work organization, and all this is based on the strict observance of the surrounding space parameters, in turn, is based on cleanroom modern technologies.

Microelectronic devices manufacturers are widely used cleanrooms, where in the air it is supported size and number per cubic meter of particles such as dust, microbes, aerosol particles and chemical vapors in a certain predetermined range. In such premises it is necessary to minimize the entering, generation and storage of such particles indoors. The system of structural elements, pollution control system, VACS are responsible for it. The ventilation process includes the solution of following tasks: removing the exhaust air from the room and replacing it with the outer, air conditioning, filtering, heating or cooling, humidification or dehumidification, ionization. Ventilation type is selected based cleanliness class of room [1], which is determined by the type of technological process. The main functions of ventilation and air conditioning consist in the achievement and maintenance such parameters of cleanrooms as:

- specifiedcleanliness class (counting particle concentration);
- differential pressure between the clean rooms and ancillary zones;
- the required air flow rate in zones with a unidirectional flow of air (in case it is achieved by the ventilation system, instead of using the autonomousprocess unit);
- restoration time after making the cleanliness class of contaminants in clean room;
- microclimate parameters (temperature, relative humidity, air velocity), the required volume of outdoor air by sanitary-hygiene standards, removing harmful substances formed during the technological process, and, where appropriate, ensuring of smoke extraction during the fire.

These parameters must be performed for each cleanroom by providing the necessary air changes per hour, air flow rate, etc.

Block diagram of the ventilation system is shown in Fig. 1, and includes the following constituent elements: the air exit grilles, air valve, air ducts, filters, fans, silencers, central conditioning and air distributor.

Below it is a list of the main components that consist of the ventilation system and a brief description of each item:

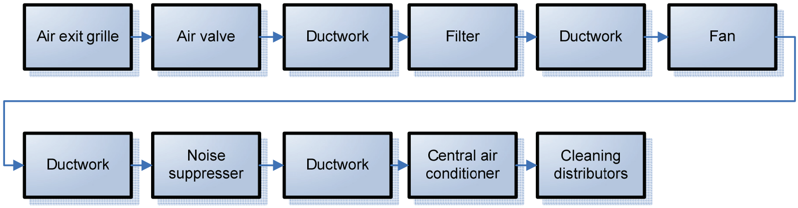


Fig.1 Block diagram of the VACS system

In cleanrooms it is used plenum-exhaust ventilation system. Depending on the method of plenum-exhaust ventilation system realization cleanrooms are divided into three main types [1].

1. Turbulently ventilated cleanroom.
2. Cleanroom with unidirectional airflow.
3. Cleanroom with a mixed stream.
4. Problems solved at VACS systemsdesign include:
5. calculation of air change;
6. aerodynamic calculation of the ducts network;
7. calculation of demand parameters of equipment: fan, air distributors;
8. theoptimal selection of equipment: air grille, air valve, fan, noise suppresser, air ducts, filters, central air conditioning, air distributors.

The task of ventilation and air conditioningdesign is considerably simplified if for its solution it is used computer-aided design.In this paper, theproblem of computer-aided design of cleanroomVACSbased on: the type of technological process, providing the necessary purity class, specified geometric dimensions of premises. To do this, it’s necessary to determine the basic initial data for cleanroom VACS calculation:

1. planning decisions with purity and pressure drop indication;
2. appointment of cleanroom (clean areas): product and process protection, protection of workers and the environment;
3. the release of harmful substances;
4. heatand moisture from the equipment;
5. numbers of employers;
6. construction area climate characteristic.

Using the VACS computer-aided design system provides the reduction of project development time, improving the system quality, execution of greater number of projects per unit time, improving the quality of working documentation and competitiveness of projects.

Computed-aided design subsystem of ducts network software includes: calculation of air exchange, ducts aerodynamic calculation. Initial data for type, speed of air flow and air exchange rates determination are taken.

Algorithm for calculating the duct system has the form.

1. Calculation of air in the room (cooling capacity) - the amount of air (m3) that comes inside.

2. Aerodynamic calculation ducts.

Load Definition separate settlement areas

System divided into separate sections and determine the air flow to each of them. Costs are determined by summing the costs of individual branches starting from the peripheral areas. The flow rates, the length of each section is applied to the axonometric scheme. Select mainstream.

The numbering of the main settlement areas path.

Identify the most longest chain of consecutive settlement sites. Fixed equipment and devices in which pressure losses occur: louvers, heaters, filters, etc.

Determination of the section line settlement sites

Sectional area of the settlement area f_p, m^2, defined by the formula

$$f_p = \frac{L_p}{v_T}$$

where L_p — calculated airflow at the site, m^3/c; v_T — Recommended air velocity in the area, m / s, on the basis of efficiency and quietness. Largest f_p standard size pick duct or channel so that the actual cross-sectional area was close to the calculated. $f_\Phi \approx f_p$

The result of the calculation are the values d or $a \times b$, conformity with the cross sectional area. For a rectangular duct, in addition, determine the equivalent diameter.

Determining the actual speed.

Actual speed is determined by the formula

$$v = \frac{L_p}{f_\Phi}$$

From this value is calculated on the portion of the dynamic pressure.

Determination of pressure loss due to friction.

From nomograms or tables define $R = f(v, d)$ or $\beta_ш$. Friction pressure on the current site are.

Determination of pressure losses in local resistances

For each species at the site of local resistance to Guides and the literature, determine the coefficient of local resistance ζ_j By $\sum\zeta_j$ and dynamic pressure determine the pressure loss in local resistance to the plot.

Determination of pressure losses on the settlement site

Pressure loss on the i-th site are $(R \cdot \beta_ш \cdot l + z)_i$

Determination of pressure losses in the system

The total loss of pressure in the system

$$\Delta p_П = \sum_{i=1}^{N} (R \cdot \beta_ш \cdot l + z) + \sum \Delta p_{об}$$

where $1 \ldots N$ - parcel numbers mainstream; $\Delta p_{об}$ - the pressure loss in the equipment and the other devices of the ventilation system.

Integration of all other parts of the system.

The ducts network computer-aided design subsystem software includes: fan design, cleaning distributors design, selection of other elements.

The algorithm for calculating the characteristics of the necessary equipment is of the form:

1. Fan design includes the determining:

– fan air supply:

$$L_{fan} = 1,1\ L_{sys},$$

where L_{sys} is load system m^3/hour;

– fan design pressure:

$$\Delta p_{fan} = 1,1(\Delta p_{aer} + \Delta p_{val} + \Delta p_{fil} + \Delta p_{c.a.c.} + \Delta p_{lat} + \Delta p_{att}),$$

where Δp_{aer} is pressure loss in the ducts network; Δp_{val} is pressure loss of air valve; Δp_{fil} is pressure loss of filters; $\Delta p_{c.a.c}$ is pressure loss of central air conditioner; Δp_{lat} is pressure loss of noise suppresser; Δp_{att} is pressure loss attenuator;

– motor power by formula

$$N = \frac{L_{fan}\Delta p_{fan}}{3600 \cdot 1000 \cdot \eta_{fan}},$$

where L_{fan} is supply fan; Δp_{fan} is the design pressure of the fan; η_{fan} is overall efficiency of aerodynamic characteristics fan.

2. Design of distributors:

– select the scheme of product supply air from distributors:

at the distribution of fan-jets:

$$\sqrt{F_{rz}} = (1.23 \ldots 3.3)(h - h_{rz}),$$

where F_{rz} is working zone square per one air distributor; h is installation height of air distributor; h_{rz} is working height;

in the distribution of compact axisymmetric jets:

$$\sqrt{F_{rz}} = (1.23 \ldots 2)(h - h_{rz});$$

– according to the selected value of F_{rz} it is determined the smallest number of air distributors

$$N = \frac{F_{\text{room}}}{F_{rz}},$$

where F_{room} is horse premises;

– determine the air supply for one air distributor

$$L_0 = \frac{L_{syst}}{N},$$

where L_{syst} - is intake air supplied to the space.

3. Other elements selection:

– intake grille is chosen depending on the ducts network;

– filter and noise suppresser are chosen by catalog, where, besides the overall dimensions and the nominal flow, it is given their aerodynamic resistance ΔpH;

– blocks of the heat exchange and mass exchange at now are chosen by the methodic developed by the companies manufactures and the pressure loss in them are given just below the stated supply.

Conclusions. The necessities of use computer-aided design system of clean rooms VACS. It is shown that the fundamental sources of data are: the type of technological process, cleanliness class and geometrical sizes of premises.

References

1. White W., Cleanroom Design. Moscow. 2004. pp. 19–21. (in Russian)
2. GOST 50766-95. Cleanrooms.Classification.Methods appraisals.Basic requirements. 1996. 33 p. (in Russian)
3. 3 Krasnov Y.S., Borisoglebskaya A.P., Antipov A.V. Ventilation and conditioning. Recommendations for the design, test and commissioning. Moscow. 2004. pp. 84-97. (in Russian)
4. GOST R ISO 14644-4-2002. Cleanrooms and associated controlled environments.Part 4.Design, construction and commissioning. 2002. 18 p. (in Russian)

UDC 681.5.017:621.176 (045)

V.V. Kalinichenko, Sen.Teacher, (NAU, Kyiv, Ukraine)
V.N. Fedosenko, Postgraduate student (NAU, Kyiv, Ukraine)
N.S. Voropaev, Student (NAU, Kyiv, Ukraine)

EFFECTIVENESS IMPROVEMENT OF CLEANROOM DESIGN

The problem of designing cleanroom, in particular their system components. The classification of the main structural elements: walls, ceilings, floors, windows, doors, lighting, coatings. The structure of computer-aided design system components.

Space requirements, which must be ensured that the necessary technological processes of microelectronics, were and are very tough. Top quality products, constant struggle to raise the productivity require precise control and coordination between the process equipment, engineering and work organization, and all this is based on the strict observance of the parameters of the surrounding space, in turn, is based on modern technology cleanroom.

Manufacturers microelectronic devices are widely used clean rooms where the air are supported in a certain predetermined range size and number per cubic meter of particles such as dust, microbes , aerosol particles and chemical vapors. In such areas it is necessary to minimize the introduction, generation and storage of such particles indoors. If necessary, they can also be controlled by other parameters such as humidity, pressure and temperature. Modern technological operations are conducted almost at the molecular level, but from the standpoint of physics process work product depends on the purity of the material, as measured by levels. lower than one impurity atom per trillion (10^{12}) atoms of the main substance.

To properly design, construct and operate clean rooms, it is necessary to know the relationship between the planning, design, materials, operators , etc., and “purity class”. Class clean room depends on the tasks to be solved in it. More sensitive to pollution produced products or process, the higher should be the level of cleanliness in the room. Higher purity requires certain design concepts and the best materials for interior surfaces of a room, as well as increased frequency of cleaning, better quality clothes, the best changing rooms, etc.

Over the last 20 years, class clean room based on the measurement of non-living in nature (non-native organisms) aerosol particle size > 0.5 mm or > 5 mm. U.S. Federal Standard 209E considering five particle sizes > 0.1 microns > 0.2 microns > 0.3 microns > 0.5 mm and > 5.0 mm. Also contemplated ultra-small (ultrafine) particles are defined as having a size of <0.02 microns and larger, or particulates having a size of > 5 micron. This method of classification is also used by international standards CEN and ISO.

Block diagram of cleanroom shown in Fig. 1 and includes the following elements: a system of structural elements, ventilation and air-conditioning control system.

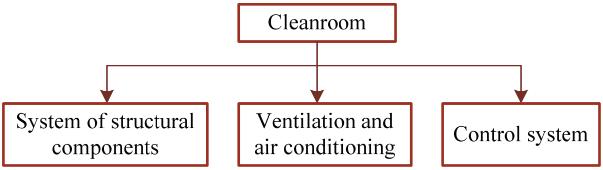


Fig.1. Block diagram of cleanroom

The system of structural elements consists of: subsystem ceilings, subsystem interior and exterior walls, floor subsystem, subsystem doors, windows subsystem, subsystem lighting.

Block diagram of this system is shown in Fig. 2.

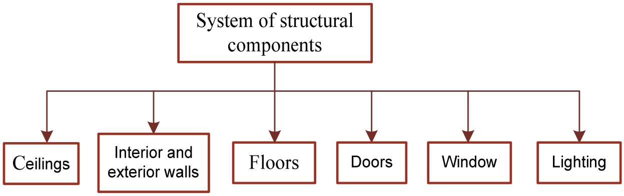


Fig. 2 Block diagram of the system of structural elements

In this paper, the task of designing a system of structural elements cleanroom based on the type of the process, providing the necessary purity class specified geometric dimensions premises. The task of designing structural elements includes:

– Choice of types of structural elements;

– Determine the number of structural elements and their sizes.

Demands to cleanrooms. The main criteria for the selection of structural materials and surfaces for cleanroom use: functionality, durability, ability to clean and repairable.

Condition cleanroom surfaces can have a significant effect on the purity of products produced in it. Therefore, materials used in the construction of clean rooms must be chosen taking into account that they will not generate particles or other contaminants which could contaminate the product. To achieve these goals, the materials must:

• easy to clean and, where necessary, be resistant to water , detergents and disinfectants;

• be strong, and do not emit particles to be chemically inert;

• if necessary, have antistatic properties.

Fig. 3 is presented in hierarchical order all the requirements that must be considered in the selection of materials for use in clean rooms [1].

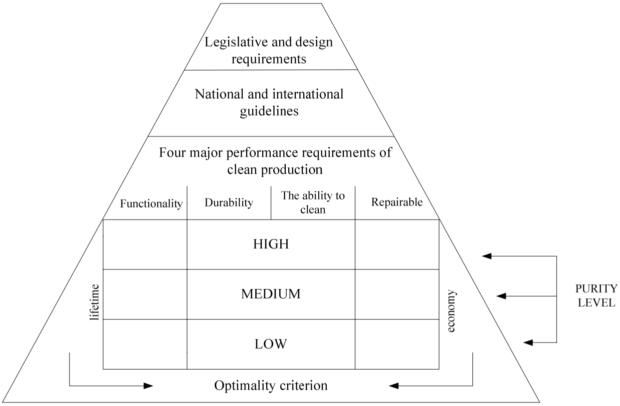


Fig. 3 Hierarchy of requirements for construction materials used in clean rooms

The materials which do not generate particles, and therefore are widely used in the construction of clean rooms are [2]:

–stainless steel;

–sheet metal, powder coated (or anodized aluminum sheet);

–sealed with concrete surface;

–plastic sheets joined by hot welding;

–coating of polymer non-shrink materials;

–ceramic materials;

–glass.

The task of designing cleanroom considerably simplified if its solution used computer-aided design. Structure of computer-aided design system of structural elements is presented in Fig. 4.

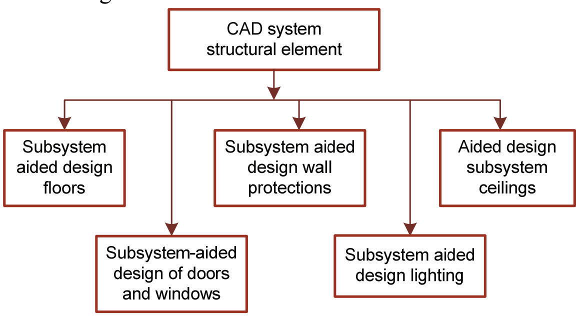


Fig. 4 Block diagram of the CAD system of structural elements

Block diagram of algorithmic support computer-aided design (Fig. 5) can be represented.

Selecting the type of the component on the basis of solving the problem of multi criteria optimization according to certain criteria above [4-7].

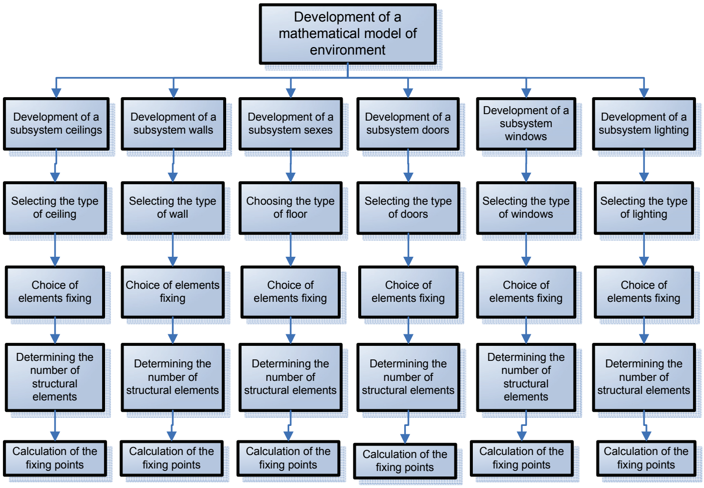


Fig. 5. Block diagram of algorithmic support computer-aided design

Conclusions. The necessity of using computer-aided design in the design of cleanrooms. It is shown that the fundamental source of data are: the type of process cleanliness class, with various facilities. It is shown that the main criteria for the design of cleanrooms is: functionality, durability, ability to clean and repairable.

References

1. White W., Cleanroom Design. Moscow. 2004. pp. 216–224.(in Russian).
2. GOST 50766-95. Cleanrooms. Classification. Methods appraisals. Basic requirements. 1996. 33 p.(in Russian).
3. Walling cleanroom. Miass LLC “Plant Miassky medical equip-ment” and ZAO “Aseptic medical system”.48 p. (in Russian).
4. Bejko I.V., Bagel B.N., Zin'ko P.N., Methods and algorithms for solving optimization problems . K.: Visha School. 1983. 511 p. (in Russian).
5. Borisov V.I., Vinogradskaya T.M., An algorithm for determination of the Pareto / / Proceedings of the 1st All-Union Conference on Operations Research. Minsk: Institute of Mathematics. 1975. (in Russian).
6. Venec V.I., Continuous algorithms for solving convex constrained minimization problems using the projection operation on the admissible set / / Automation and Remote Control. 1985. № 7. pp. 73-78. (in Russian).

UDC 681.5.015(045)

V.M. Sineglazov, PhD,
A. P. Godny (NAU, Kyiv, Ukraine)

INTEGRATION DESIGN COMPLEX OF CAD SYSTEMS

Presented CAD with an integrated environment introduces a new approach to managing the design process. Used in the proposed medium scenario design can greatly simplify the work of the designer. Available in medium monitor provides the flexibility of design processes with a flexible structure description of design procedures in the scenario design.

Computer-aided design system – an automated system that implements information technology performs the functions of design, is a logistical system designed to automate the design process, consisting of staff and number of technical, policy and other means of automation of its operations [1].

Using CAD allows solving the following economic and industrial problems:

- Fighting for the enhanced functionality of the products;
- Improved reliability and accuracy;
- Optimization of production cost;
- Fighting for the buyer;
- Accelerating production cycle;
- Short-term operation.

In the life cycle of industrial products, CAD solves the problem of automating during the design and production preparation.

The main objective of the CAD – improving the efficiency of work of engineers, including:

- Reducing the complexity of the design and planning;
- Reduction of the design;
- Reducing the cost of designing and manufacturing, reduction in operating costs;
- Improving the quality and feasibility level design results;
- Reducing the cost of natural modeling and testing.

Structurally CAD consists of the following modules: [1]

1.Designing mechanical components and their interaction;

1.1. Designing of the general form of the product;

1.2. Designing of construction;

1.3. Calculation of the strength of all parts and components;

1.4. Kinematic calculation;

2. Designing electrical circuits;

2.1. Development of electrical circuits, printed circuit boards, the choice of components;

2.2. Simulation system;

2.3. Creation system technical documentation.

Review of methods of design CAD. We can distinguish two fundamental approaches in the design of CAD in terms of information flow [2]:

• Integration "with each other"

• Integration using the integrating module

Integration of "everyone with everyone". This traditional approach to integration of systems, which establishes specialized communication interfaces for each pair of communicating applications (Fig. 1).

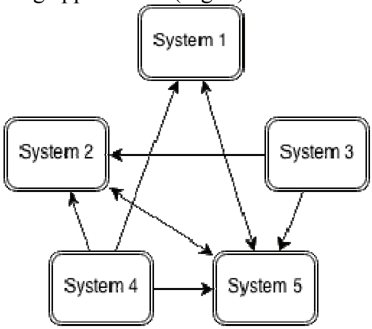


Fig. 1 Integration of "everyone with everyone"

This approach is good for some applications. When it is large, the work does not practically. Furthermore, it does not allow to build a qualitatively new requests to the combined data, i.e. qualitative gains from combining the data is not [2].

Using this approach, we have N systems, each system has a connection with multiple systems (from 1 to $N-1$), so for the whole system it is necessary to create from N to $\frac{N(N-1)}{2}$ pairs of the data transformations *"$W_i - W_j$"*, and/or *"$W_j - W_i$"*.

Integration using the integrating module (Application Service Bus). This approach implies the existence of a link between all the modules via Application Service Bus. It manages all available modules of the system, and is responsible for the interaction between the modules, data conversion (if needed), and quality control of the performed work (Fig. 2).

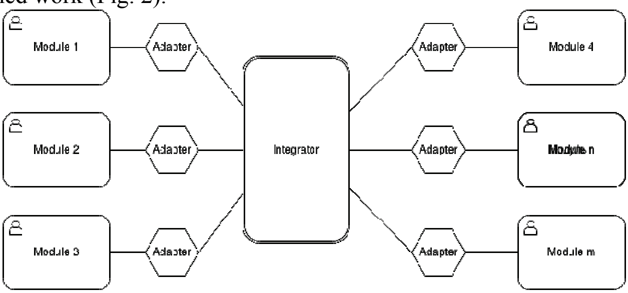


Fig. 2 Integration using the integrating module

Using this approach minimizes the cost of adding new modules and upgrades of current, reduces maintenance costs of the system as a whole, and simplifies the management of data flows in the system [3].

Typical problem of integration. The interaction of two or more application systems through the exchange of data.

Required components for integration:

1. Adapters applied to ASB systems for sending and receiving messages.
2. ASB, which should consist of at least:
3. Transport System
4. Conversion of data format messages
5. Routing (content) messages between application systems.

When using the Service Bus Applications we have *N* systems because each system is connected only to the Integrator, then the whole system is necessary to create *N* pairs of data transformations of the form "W_i-Integrator", "Integrator-W_i".

The advantages of this approach are obvious, but it requires the creation of an intermediate format, which should be strictly standardized (Fig. 3).

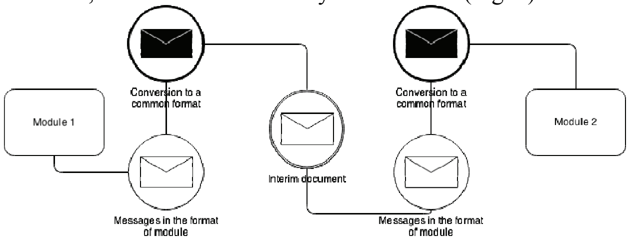


Fig. 3. Format conversion mechanism

In different types of CAD formats use different writing data. For example, image data recorded in the different CAD systems in the form of vectors (AutoCAD, a compass), and in the form of objects (SolidWorks). These record formats reflect declarative component design data *P*. Tables, text, mathematical formulas, used to describe the definition of the object and thus are included in *P*.

$$P = Pg\text{^}Ptb,b\text{^}P,\text{^}Pm, \quad (1)$$

here *Pg* is graphical; *Ptb* is tabular; *b* is textual; *Pm* is mathematical aspects of the data representation.

Declarative representation of the data reflects the essence of the object in the description of its static parameters. Parameters such as size, weight, material allow clearly and unambiguously define the steady state of the object. Usually the result of an object design using CAD is set just such data. In the process of designing a static description of the object plays a big role. Designer in the design process solves the problem of constructing an object from components, combining them with the static parameters.

Many data formats used by different software from different vendors, and therefore these formats have become a kind of standard. Such as, for example, dwg [5] – graphic presentation format for AutoCAD and Autodesk's Compass, db and dbf formats for tabular data systems dBase, Clipper, Paradox, sql format for relational databases MySQL, MSSQL, doc and rtf formats for text data in a word processor from Microsoft Word and many others.

In most CAD commands are used for constructing the standard elements of the set *X*, and usually record formats similar teams in different CAD systems coincide. Write commands graphics reflect procedural component design data processing commands *T*. Tables, text, mathematical calculations are also included in *T*.

T=-T^uT,ь uT,uT^,

here Tg is numerous commands of the graphic processor, *T^* is numerous commands spreadsheet processor. T^ is numerous commands word processor, uT is numerous commands mathematical processor.

Solution of the problem is the construction design of the coupled system descriptions of circuit elements. Operator implements communication between the descriptions of objects from a set of standard elements of *X*. For example, the standard elements of “point” and “line” may correspond to the operator “starts” that implements the expression “line starts with a dot.”

In summary, the system descriptions of the design object as follows:

$G = (P, T, K)$, where, P, T are set of design object descriptions, K is stereotyped relations between descriptions of the object.

The presence of *G* in the *T* component creates preconditions for the unification (integration) procedural data object to be created, cultivated in different systems and automation tools.

Thus, for example, the line being one of the elements of the assembly drawing, described in terminology reflects graphical aspect Pg declarative components *P* design data from a set of *X* standard elements. Command of the program processor that implements the construction of the line reflects the graphic aspect of the procedural components of Tg in *T* project data from a set of *X* standard elements that formed and descripted of the proposed facility. Construction of the line relative to other standard cells is regulated by a variety of drawing operators *P*, interoperable drawing elements from the set *X* of standard elements. Similarly, for other aspects of data.

Consequently, in modern CAD are implemented various ways to specify data, acceptable to design documentation, and created the preconditions for the development of methods and means of dynamic data integration.

A variety of classes of design operations in accordance with the level of complexity of project tasks and qualifications assure the combination of design operations and their use as a whole.

Simplicity and convenience of operations for the joint processing of graphics, text and spreadsheet object descriptions.

Support and combine object-oriented and subject-oriented descriptions of design processes with the ability to connect descriptions of the processes.

Evolutionary development, provide feedback based on the logging of user actions used in conjunction with data and their further structuring.

The accumulation of knowledge acquired for the subsequent synthesis of executable elements that allows developing evolutional system and configuring it to various classes of design objects.

Simplicity and convenience of management conversational interaction provides a unified operations dialog interaction kernel environment and a textual description dialogue procedures

Conclusions. It is proposed a new approach to the solution of the computer-aided design of complex objects. It supposes to unit separate CAD-systems.

References

1. Lee, K. CAD Basics (CAD/CMA/CAE), Peter Press, 2004.
2. Pozin, B. A. Modern software engineering tools for the creation of open information systems applications, ROSNY and IT UP: DBMS, 1995.
3. Berezhnoj, G. Problems building large IT systems, PCworld, 1998.
4. Soulless AN, AB Zhizhchenko Kulagin MV, Serebryakov VA Integrated Resources Information System of Sciences and Technology Digital Library. 2000.

UDC 621.548(045)

A.V. Kulbaka, Post-graduate student (NAU, Kyiv, Ukraine)

DYNAMIC DATA INTEGRATION IN THE DESIGN OF WIND-POWER PLANT

It is proposed a power plant represented a combination of turbo rotors: Darrieus and Savonius. It is showed that the optimal construction of this power plant is possible only by use the computer-aided design system. The structure scheme of computer-aided design system is developed.

Computer-aided design allows you to carry out the design in automatic mode and involves solving the following task: construction calculation to ensure maximum intake factor of wind power and the possibility of efficient operation at wind speeds below 2 m/s. The problem is to create an installation that is both effective in low winds of Ukraine and at the same time cost-effective in the production of energy. It should be divided into two separate sub-tasks – development Darrieus rotor that produce user-defined power and development of Savonius rotor that will ensure the largest possible reduction in starting torque of the total installation.

Below in Fig. 1 shows a block diagram of computer aided design installations.

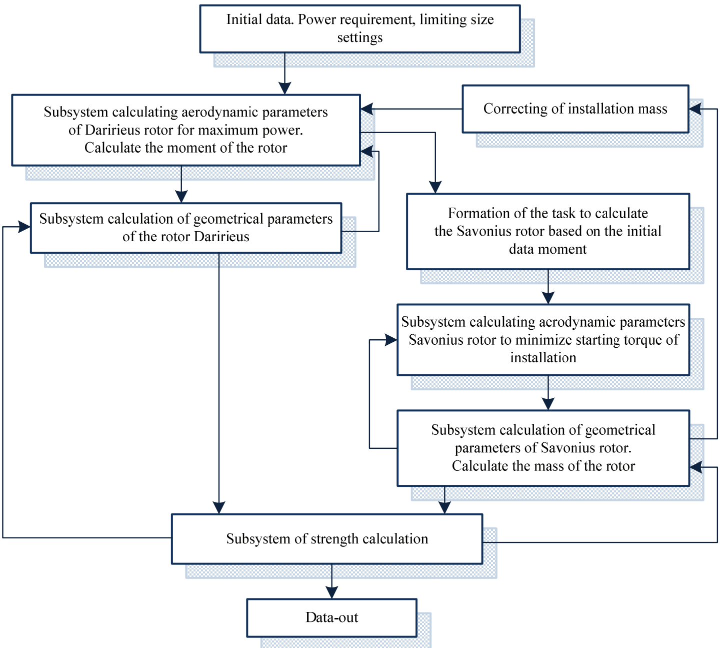


Fig. 1 Block diagram of computer aided design installations

Applications are made in the software package from Oracle. The project itself is made in the programming language Java due to the ease of integration programs written in that language, with different control systems. Thus the rank, the same code can be run under the operating systems Windows, Linux, FreeBSD, Solaris, Apple Mac, etc. This becomes very important when programs are loaded through the Internet and are used on different platforms. The first stage of work is to calculate the output parameters of the Darrieus rotor. Thus the main input parameter is the output of powerful rotor. Next, the program will perform the optimization of the parameters of the rotor Darries and display all possible structures that satisfy the input parameters. The next stage of the program is to calculate the Savonius rotor for maximum available geometrical parameters (height and width are limited size of the Darrieus rotor). The main output parameter is the starting moment whose value should be maximized to ensure minimal rotor momentum. After optimizing the parameters of both rotors it is necessary to recalculate starting torque and output power for both units.

Problem statement. Today, there are dozens of software products designed to meet the challenges of each stage of computer-aided design. Therefore, there is no need to deal with each individual task to create new software components that can solve such problems. From an economic point of view and from the point of view of simplicity of design makes sense to combine existing software products in an integrated suite of software products for the task.

Method of solution. To achieve this goal it is necessary to solve the following problems:

1. Choosing N software (W1, W2, W3, ..., WN), sharing which can solve the problem of automating the design of a product;
2. Methodology CAD design from the standpoint of redirecting information flows;
3. Integrating data in a single information process.

The first stage is unique for each separate task and depends on the capabilities and preferences of the customer, hence there is no optimal algorithm for solving this problem. Here an individual approach is used.

Standard business requirements:

- Guaranteed delivery of messages and single;
- Reliable operation with network, software and hardware faults (fault tolerance);
- High performance;
- Short development cycle for the integration project;
- The ability to easily build and reuse components;
- Low cost of ownership and maintenance of the system.

Standardization of data:

- As a standard message, body accepts standard XML;
- As a standard interface, description system accepts standard XSD;
- As a standard, modified standard XML messages accept XSLT;
- As a first access to the message body language, take XPATH;

These standards are well established and have wide support.

In practice, not all systems support XML-interface for data exchange. In this case, it is necessary to use ASB transformation services message format in XML-messages.

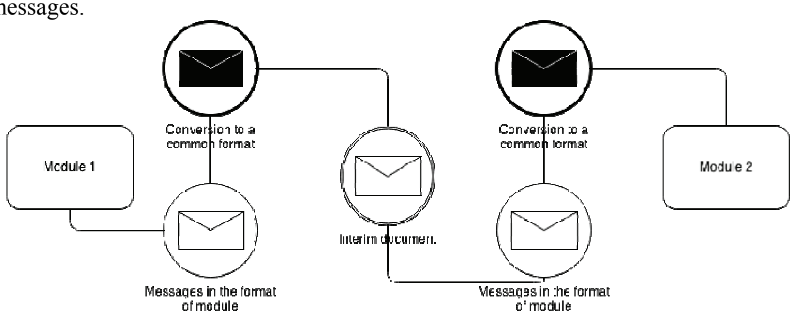


Fig. 2 Format conversion mechanism

If C1 and *C*2 formats – not XML, converters may be a specific software product. Nevertheless, even in this case, the conversion from XML in a simple straightforward format (e.g., comma delimited) can be performed using XSLT-transformation. Steps to change formats you can easily make at the ASB level. Received by ASB data will be converted to the intermediate XML format, and the output will be converted to the format of the recipient. Application systems themselves do not need to be reworked in this regard, because all conversions are performed at the level of ASB.

If the format is XML, the conversion can be performed by means of XSLT transformations.

The most common mode of transmission was and is still is working through the files. Some systems for interaction do the following: perform a data dump of C1, file transports by mail or through the carrier and loads into C2, and all operations are performed manually. This process does not meet the requirements of modern business.

File should be available for adapters that will pick up a directory of files and send them as messages to the server message queue of ASB. In addition, they must be configured to accept messages from the server. The best option is invariant to the OS adapters, for that purpose are perfect adapters, written in JAVA. Invariance of the software is very important because there are many products that work not only on Windows, but also on Linux, AIX, Sun Solaris, and others. Mostly, it does not matter which operating system is required for the server messages.

Having defined the general scheme of interaction modules, you must determine what kind of formats and data types used in today's CAD systems.

Conclusion. Presented CAD with an integrated environment introduces a new approach to managing the design process. Used in the proposed medium scenario design can greatly simplify the work of the designer. Available in medium monitor provides the flexibility of design processes with a flexible structure description of design procedures in the scenario design. Properties listed above for such CAD, coupled with the ability to integrate data of various aspects of presentation in a single information process, this system is isolated in a special class of software employed to integrate heterogeneous data.

However, investigated CAD with integrated environment does not have sufficient properties to assign a class to its CAD implementing dynamic data integration. This system is a tool for creating applied (final) CAD. The system has all the advantages presented only in the process of creating the ultimate CAD. During the operation created the ultimate CAD provides the designer the opportunity to log only project operations not provided for scenario planning.

References

1. Lee, K. CAD Basics (CAD/CMA/CAE), Peter Press, 2004.

2. Pozin, B. A. Modern software engineering tools for the creation of open information systems applications, ROSNY and IT UP: DBMS, 1995.

3. Berezhnoj, G. Problems building large IT systems, PCworld, 1998.

4. Soulless AN, AB Zhizhchenko Kulagin MV, Serebryakov VA Integrated Resources Information System of Sciences and Technology Digital Library. 2000.

UDC 621.548(045)

M.I. Krynetskyi, Sen. Teacher, V. N. Fedosenko, Postgraduate student, E. N. Radko (National Aviation University, Kyiv, Ukraine)

GEOMETRIC SIZES DETERMINATION OF CLEAN ZONES

We considered the construction of mathematical models in the "clean room". Defined the structure of mathematical models and suggested the algorithm of modeling the dynamics of pollution on the basis of the finite element method.

Introduction. In semiconductor production among all processes included in a wafer processing requires the most rigid control of the purity of air in the workplace.

Since the main contribution to the pollution of the environment in a clean production room (CPR) accounted for the operator and process equipment, there is a trend to the local clean volumes, free from human presence. Thus the major air pollutant becomes an atmospheric aerosol which was missed by the high purity filter, ie the fraction of submicron aerosol.

Properties of increasing its size with increasing relative humidity φ have only hygroscopic (hydrophilic) particles. Therefore it is important to analyze the nature of aerosol particles which are present in the clean room, their origin, as well as their impact on the quality of microelectronic products.

Particles are formed by mechanical friction, may remain after the grinding of siliconwafers. In the air guide networks because of erosion of the inner pipe surfacemicroparticles are formed as well as the air flow may comprise solid particles of salts formed in the irrigation chamber at the contact of air with water [1]. Minor decrease ofdensity in fine air filters can greatly reduce their effectiveness. Powerful source of technologically very dangerous aerosol are leaking exhaust system oil.

Intensity of oil mist generation consisting of droplets ranging in size from 0.01 to several microns, is very high. Generators of aerosol particles are all moving and friction knots, joints , control elements , a places subjected to thermal shock and vibration. The main source of aerosol particles is a human. Microparticles in 60% of cases are the cause of defect, of which the share accounted forman is 40 %.

As impurities in the air of the room may present different gases in the residual amount, as well as a pairs of chemicals and organic solvents. Large molecule gases such as NO_2 ,H_2Salso cause contamination during wafer processing . At a concentration of Oxidant about 10^{-5}% on unexposed areas during photolithography process photoresist islands are observed. This is the result that in a negative resist and unexposed areas the cross-linking reaction is also developed.

Depending on the chemical properties of the microparticles a serious impediment can be both large and ultrafine particles. The required purity of the air, corresponding to a given class CPR exists only at a certain height from the final filter to the place of wafer processing . During the dust generation indoors large particles fall down , and small scatter in different directions and , if not picked up by the flow of conditioned air , are accumulates in stagnant zones of CPR .

Water Microdroplets that present in the air can absorb soluble gases (SO_2, NO) and the oxidant (H_2O_2 ozone.) which react in a liquid phase with the production volatile substances .

Theory of condensation growth of aerosol particles under saturation conditions. Solutions of the task of condensation droplet growth are studied in [2], [3], [4] and many others [5-9].

The system of equations describing the transport of heat, steam and drops growth, or droplet with $r < 30$ micron evaporation can be represented as:

$$\frac{\partial \rho}{\partial t} = D_n \Delta \rho$$

$$\frac{\partial T_i}{\partial t} = \chi_i \Delta T_i$$

$$\frac{\partial m}{\partial t} = 4\pi r^2 D_n \frac{d\rho}{dr}\Big|_{r=R}$$

where ρ, D_n - the density and the diffusion coefficient of the pair respectively; T_i, χ_i - Temperature, thermal diffusivity; Air (i = 1) and the liquid (i = 2); *m*- the mass of the droplet surface.

Equation must be solved under the following conditions:

$$\rho = \rho_\infty, T_1 = T_\infty \quad npu \quad r \to \infty;$$

$$\rho = \rho_0, T_1 = T_2 = T \quad npu \quad r = R;$$

$$\left(LD_n \frac{\partial \rho}{\partial r} + k_1 \frac{\partial T_1}{\partial r} + k_2 \frac{\partial T_2}{\partial r} \right)\Big|_{r=R} = 0,$$

where L - the heat of condensation; k_1 and k_2 - the coefficients of thermal conductivities of air and water, respectively.

And $\chi = k / \rho c_p$, where c_p - specific heat of a substance .

However, this system also in practical calculations leads to a rather complex mathematical calculation. Further simplification can be done if the external conditions (temperature, pressure) are changing very slowly, using the so-called quasi-stationary approximation .

The Drop Growth in the atmosphere can be considered quasi-stationary approximation , not taking into account the internal and external convection and taking into account as an amendment temperature jump at the drop surface and concentration jump .

Mathematical description of heat and mass transfer processes. As shown above, the coarsening of particles due to the condensation with changes in relative humidity. This change can be observed not only in the air entering the clean room from the outside, but a certain gradient of relative humidity change takes place in the room due to changes in temperature fields , pressure, partial pressure of steam in the presence of air flow .

All the pattern of distribution of heat and humidity fields in the room can be described by the following system of differential equations:

$$\frac{\partial u}{\partial t}+\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}-\upsilon\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)+\frac{1}{\rho}\frac{\partial p}{\partial x}=0,$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+\frac{\partial v}{\partial y}-\upsilon\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial v}{\partial y^2}\right)+\frac{1}{\rho}\frac{\partial p}{dy}=0,$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$$

$$\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}-a\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)=\frac{I_q}{c_p\rho},$$

$$\frac{\partial p_{10}}{\partial t}+\frac{\partial p_{10}}{\partial x}+v\frac{\partial p_{10}}{\partial y}-D_{10}\left(\frac{\partial^2 p_{10}}{\partial x^2}+\frac{\partial^2 p_{10}}{\partial y^2}\right)=I_0$$

Here u and v - the velocity components along x and y; p - pressure; T - temperature; $p_{10}=p_1/p$ - a relative partial pressure of steam; ρ - density of the air; υ - the kinematic viscosity of air; a - the thermal diffusivity of the air; D_{10} - diffusion coefficient of water vapor; c_p - heat capacity; I_q and I_0 — sources .

First equations (Navier-Stokes equations) describe the motion of a viscous incompressible medium in the space (and the continuity equation of conservation of momentum) . The last two characterize the distribution of temperature and relative partial vapor pressure, iethermohydrometric field cleanroom.

As a result of the system equations solution we have $u(t,x,y), v(t,x,y)$... Than it's necessary to separate area of rooms with the lowest concentration of aerosol particle. These areas determine geometrical size of clean zones.

Conclusion. Improved integration of VLSI imposes more stringent requirements for air quality (number of dust, temperature and humidity) in clean rooms. Transition to clean local volumes, allowing to exclude contamination introduced by the operator and the equipment, leads to the fact that the main source of atmospheric aerosol pollution becomes. Mathematical modeling of the internal environment of the clean room, conducted using a known system of differential equations of heat and mass, allows the characterization of the velocity distribution of the air temperature. Relative partial pressure of water vapor in the room.

References

1. Unno K. Clean rooms. Current state and trends of the environment monitoring in semiconductor manufacturing / dzayreDancy, 1985, v.4, № 11. (in Russian).
2. FUCHS NA The evaporation and growth of droplets in a gaseous medium. Izd.ANSSSR 1958. .(in Russian).
3. Alexandrov ES Kondenatsionny growth drops of solution / FAO, 1967, 3, № 8. .(in Russian).
4. MASON B. Physics clouds. Wiley, New York, 1961. (in Russian).
5. Ceduna YS Physics Education liquid-phase in the atmosphere., Gidrometeoizdat, 1972. (in Russian).
6. MAZIN IP Some problems in the theory of cloud condensation nuclei / Meteorology and Hydrology, № 8, 1980. (in Russian).
7. Smirnov V.I.On equilibrium size and range of sizes of aerosol particles in a humid atmosphere / News ANSSSR FAO, 1978, v. 14, № 10. .(in Russian).
8. Kachurin L.G., Morachevskaya VT Kinetics of phase transitions of water in the atmosphere / Publisher LSU, 1965. (in Russian).
9. FUCHS NA The evaporation and growth of droplets in a gaseous medium. Izd.ANSSSR 1958. (in Russian).

UDC 004.891.3(045)

Yu.M. Kemeniash, Assistant. (National Aviation University, Kyiv, Ukraine), O. I. Chumachenko, Candidate of engineering. Associate Professor (National Technical University of Ukraine "Kyiv Polytechnic Institute", Kyiv, Ukraine)

AN INTELLIGENCE IMAGE PROCESSING SYSTEM

The task of integrated intellectual diagnostic system design is considered. This system is used for the diagnosis of tumour. The apparatuses of computer tomography and supersonic researches are used as the components of integrated intellectual diagnostic system. The results of computer tomography and supersonic researches diagnostics are used as inputs of artificial neuron net.

Ukraine is the second largest cancer diseases country in Europe. Every day in Ukraine get sick about 450 people and 250 people die from this disease.

According to the data of the Cancer Institute in 2009 961,183 person were officially registered in oncology centers. It is just officially registered, and how many people die from cancer without the proper diagnosis for one or another reason.

In last ten years the number of cancer patients increased by 25 % and every year this disease is steadily increasing by 2.5 – 3 %, and in addition cancer gets younger. It turns out that for life every fourth person gets cancer.

Early diagnosis of cancer is impossible without screening. Ideology of screening is based on the fact that the usual clinical research does not provide the detection of cancer at early stages. Therefore it is clear and reasonable to use such tools and diagnostic means which would be found tumour so early as it possible.

Currently, diagnosis of cancer on radiographs and photographs ultrasound research (USR) is the best known method. However, due to the fact that images can be large working area, about 10 – 30 % of the visible cancer tumorscan be unnoticed or be incorrectly identified as a result of the influence of human or technical factors.

There are two common methods of digital fluorography. The first method, as well as normal chest *X*-ray, uses photographs image on the fluorescent screen, but instead of *X*-ray film used charge-coupled device (CCD). The second technique uses a stratified cross-scan of the chest fan-shaped *X*-ray beam to the detection of transmitted radiation linear detector (similar to a conventional scanner for paper documents, where the linear detector moves along a sheet of paper). The second method allows you to use much smaller doses of radiation. Some lack the second method – more time imaging.

Tomography is the process of *X*-ray imaging, which is the most important method for the detection of pathologies. According to most researchers percentage reliability tomography in the diagnosis of cancer is 70 to 90 %.

X-ray computed tomography is a tomographic method study of human internal organs using *X*-rays. Ultrasound (US) is a non-invasive study of the human body by means of ultrasonic waves.

Of particular interest is the use in the diagnosis of the Doppler effect. The essence of the effect is to change the frequency of the sound due to the relative motion of the source and receiver sound. When the sound is reflected from a moving object, the frequency of the reflected signal varies (there is a frequency shift.

Structure of automated diagnostic system. Consider the functions performed by units Fig.1. Formation of the input data for the system diagnostics is carried out by applying an input device ready MRI image as a discrete image, or transfer images directly from the device MRI. After image processing specially designed software output as a presumptive diagnosis fed to the output device. Quality is determined by the operation of the diagnostic system to a greater extent the quality of the unit with the developed software. The example of MRI image is presented on Fig.2.

In medicine, the use of artificial intelligence allows you to make decisions at the level of a highly qualified specialist in the absence of his own. In this case, neural networks have several advantages compared with ES for example. It does not require a clear formalization of data. Neural networks make decisions based on experience gained by themselves. Decision taken by the neural network, is not definitive. Network issues a decision with the degree of confidence, that give to user opportunity to estimate its response. Neural network allows to simulate the situation decision. Neural networks provides high speed of answer (fraction of a seconds), so it can be used in dynamical systems requiring immediate decision. Capabilities of neural networks (correction of the classification model, minimizing the learning parameters, etc.) allow you to determine the direction of scientific research. Neural network technology is widely used in the diagnosis, as it is a special case of the classification of events. They have ability to carry out such a classification, generalizing previous experience and apply it in new cases.

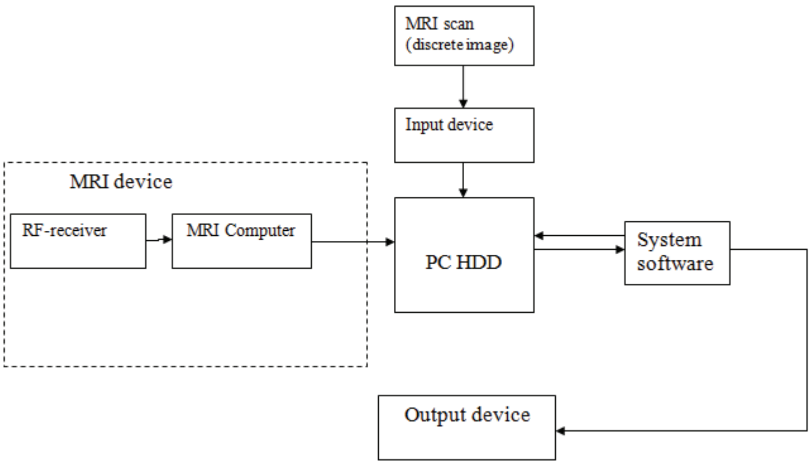


Fig.1 Functional diagram of the intelligence processing system

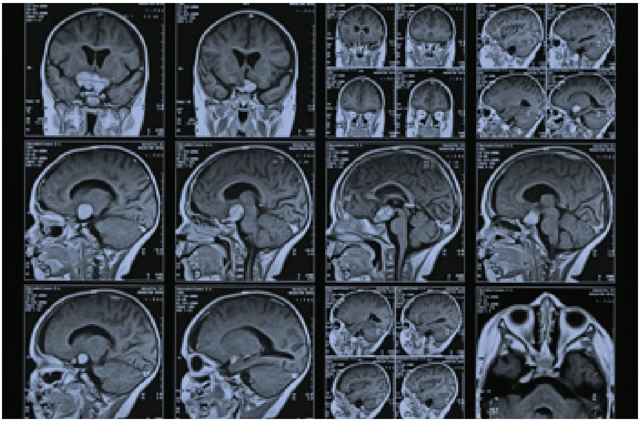


Fig. 2 MRI image sample

The main stages of intelligence processing system development, such as image processing and neural network functioning. First of all, developed processing system must correctly execute the MRI images processing (MRI scans inputs to the system as a discrete image).

Image processing and analysis - is step by step procedure, which depends on the results of the previous stage. To accomplish our task, the picture must go through several such stages.

The algorithm block-diagram of system processing is presented on Fig. 3.

The resulting binary, contoured image is input to the neural network (perceptron). The image comes in the form of a matrix of pixels. Image recognition and classification uses the following algorithms of ANN training.

Firstly we can formulate general rules for perceptron training.

Let's suppose the vector X comprises a recognizable feature values of the image (pixels) - (x1, x2, ...,xn), which are multiplied by the corresponding components of the vector of weights W - (w1, w2, ..., wn). These products are summarized. If the sum exceeds a threshold Θ, output OUT is equal to the neuron unit, otherwise - zero.

Pattern X sent to the system input and then calculates output OUT. If OUT is correct, nothing changes. But, if the output is wrong, weights attached to the inputs starts modification to increase system error.

Method consists of the following steps:

1. Selection of input image.
2. Transfer of characteristic image value to the perceptron input and OUT calculation.
3. If the output is correct, follow to the first step.
4. If output is wrong and equal to zero, then summarize all inputs values to their corresponding weights; if the output is wrong and equal to one, then subtract from weights all corresponding input values.
5. Follow to the first step.

For developed by me multilayer perceptron most appropriate is back propagation algorythm.

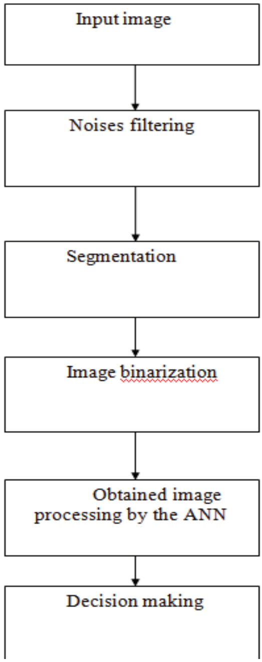


Fig. 3 Algorithm block-diagram

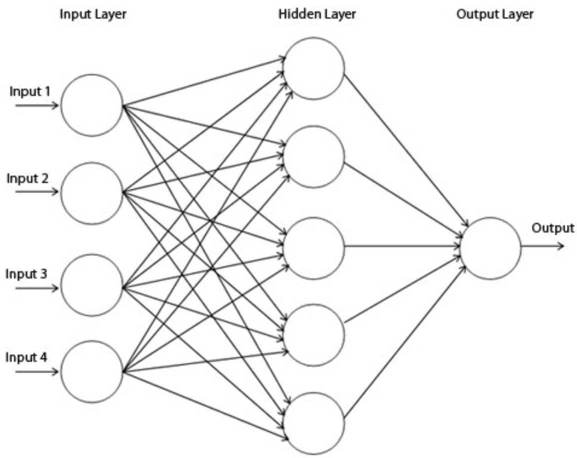


Fig. 4 Designed perceptron architecture

At each iteration of the back propagation algorithm neural network weight coefficients are modified to improve the example solving. Thus, one-loop optimization problem solved during the training process.

Conclusions. It is proposed the procedure of an intelligence image processing. It is shown that the best solution of it is the use of artificial neuron nets, for example perceptron.

References

1. Chan, H. P.; Helvie, M. A.; Sahier, B. "Digital mammography observer performance study of the effects of pixel size on the characterization of malignant and benign microcalcifications." *Academical Radiology*. 2001. no. 8. pp. 454–466.
2. Zhou, C.; Chan, H. P.; Petrick, N. "Computer image analysis: Estimation of breast density on mammograms." *Medical Physics*. 2001. no. 6. pp. 1056–1068.
3. Anguh, M. M.; Silva, A. C. "Multiscale segmentation and enhancement in mammograms" *Academical Radiology*. 2002. no. 6. pp. 183–191.
4. S.Haykin "Neural Networks and Learning Machines" (3rd edition),Prentice Hall, 2009, p.13-25, 37-39, 44-45
5. Cristopher M. Bishop "Neural networks for pattern recognition" Oxford, 1995, p.116- 126,140-148
6. Joseph P. Hornak "The basics of MRI", 2008

UDC 371.694:004:656.7(045)

Ju.M. Shmelev, Post-graduate student (NAU, Kyiv, Ukraine)

THE OPTIMAL REDISTRIBUTION TIME OF SIMULATOR TRAINING

The process of helicopter pilots training by simulator is considered. It is analyzed the aviation accidents due to human factor. It is proposed the way of estimation of helicopter pilots training efficiency in the simulator.

Nowadays, accidents are mostly attributable to the human factor, 80 – 90 % from all accidents, and, unfortunately, existing methods have not led to improvement of safety.

Pilots work is the most difficult type of human activity, consequently training is difficult as well. The process of professional training includes a wide variety of instruments and devices. The level of training should mainly guarantee safety. Since graduate flight school immediately take jobs in the crew of the helicopter.

Accident analysis and preconditions shows that factors such as the mistakes in flight operations , omissions and deficiencies in the organization and management of flights and aircrew training methodology , errors in piloting technique and operation of aviation equipment determines the overall accident rate and the reasons for them, they are notorious for its repeatability[1]–[5]. This causes the need to improve the organization and methodology of flight training for flight crews. For today the best way of pilot's training is to use simulators of different time. Unfortunately the training time is limited. So it is existed the important task of optimal redistribution the time of training.

Statement of the task. It is known the whole time of training, and a number of pilot's skills that have different important in piloting processes. It's necessary to redistribute the time of training in such way that to improve the effectiveness of training.

Review of known methods. The disadvantage of the well-known approach to the creating of an educational plan (Fig. 1) and, in particular, in the planning of learning on the computer, is their reliance on the so-called term "average student". However, even at constant composition of subjects skills individualization, redistribution of time for their development is relevant, taking into account the ability of each student and the complexity of the skills. This ability depends primarily on the quality of training or "progress" in the early stages and the degree of degradation throughout time (the ability to remember or forget given material).

Thus, it is necessary to study these abilities, which means to form a mathematical model of the quality of training and to estimate the parameters of the model for each individual group. Band which was obtained allows to formulate and to solve the direct problem of optimal scheduling of flexible learning, which should provide a positive effect, and its implementation is available in the computer lab.

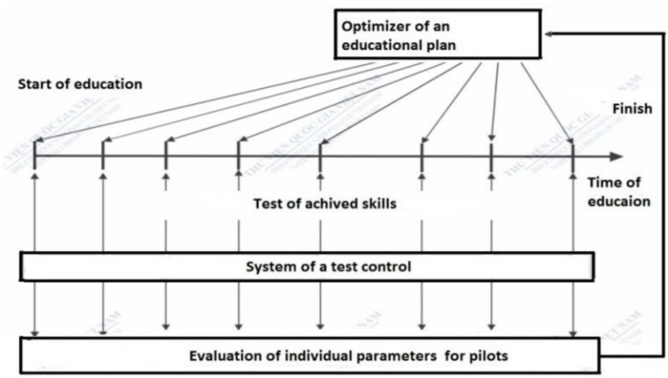


Fig. 1

It's necessary to take into account the disadvantage of the well-known approach. We take into account the most important factors affecting the development of one skill:

1.Coefficients which show the rate of influence of the human factor (significance coefficients);

2.Level of development of next skills, when current skill is based on previous;

3.Degree of degradation or "forgetting" previous skills, when next skill has to be developed;

4.Speed of skill development.

Algorithm of training optimization on the simulator. The algorithm of redistribution is based on the solution of the next tasks: the determination of coefficients which show the rate of influence of the human factor (significance coefficients), the estimation of level of development of next skills, when current skill is based on previous, the determination of the degree of degradation or "forgetting" previous skills, when next skill has to be developed, the estimation of the speed of skill development.

Construction of a graph to display optimization

The graphs consist of two axes:

• x-axis (time intervals) shows how much time you need to master a given skill based on the significance coefficients

• y-axis (performance measurement). We assigned a numeric value to a training, for example, the average loss if pilot makes error on a single helicopter flight training.

Move on to building graphics for the x axis, we determine the optimal time for training for each skill Tmax (their will be 3), taking into account the factor of significance, the Y axis will be based on the efficiency of exercise.

How the mark which estimates efficiency behaves with the increase of time dedicated for education? Obviously, trained pilot is safer than untrained. Training requires time. It is possible reasonably enough to suppose that exists some training time Tmax for the gaining certain skill. At time of educating more than Tmax gain of experience is absent.

At time of educating, insignificantly different from t = 0, admitting of specialist to the flight will bring the most major damage, thus the subsequent educating will result in reduction of this damage. Thus, time of educating is unequivalent on efficiency, and increase of efficiency certainly described by the function of decline of amount of errors from duration of training. It will be shown further, that reduction of training value Tmax allows to increase a general size of prevented mistakes which cause damage (risk, fine).

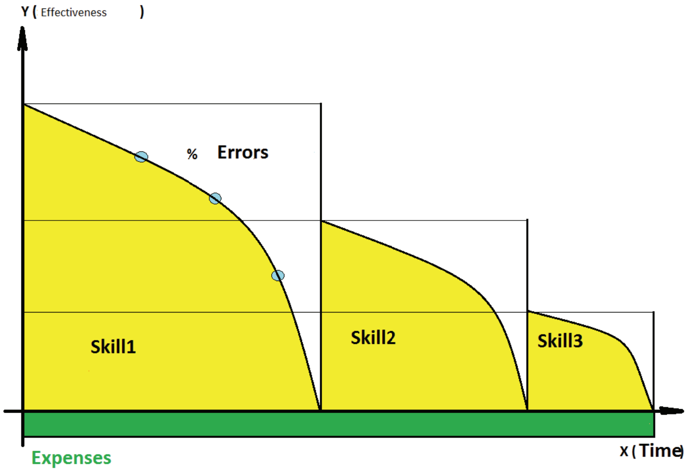


Fig. 2

We will enter the concept of functional of efficiency of the single training, qualitatively repeating the functional of errors, it's numeral values for time of completion of training of t= tmax are set from a condition, that general area (or certain integral) is equal to the value of middle damage when a specialist makes an error on the topic of the single training on real helicopter.

Conclusion. In this work we figured out the disadvantage of the well-known approach to the creating of an educational plan and, in particular, in the planning of learning on the computer, is their reliance on the so-called term "average student". And, even at constant composition of subjects we performed skills individualization, redistribution of time for their development, taking into account the ability of each student and the complexity of the skills. This ability depends primarily on the quality of training or "progress" in the early stages and the degree of degradation throughout time (the ability to remember or forget given material).

References

1. Alexeeva L.N. Formation of the flexible summary of education and studying in the middle specialized educational institutions. / Alexeeva L.N. abstract of dissertation candidate of technical science Moscow, 1997.– 272 p.

2. Network methods of planning and organization of training process / A.A. Ovchinnikov, V.S. Puchinskiy, H.F. Petrov.–M.: «The Higher School», 1972.– 157p.

3. Stratanovich R.L. Information Theory / R.L. Stratanovich. – M.: Soviet Radio, 1975. – 424 c.

4. Shennon K.E. Information Theory and Cybernetics Works / K.E. Shennon. Editor. R.L. Dobrushena. M., IL. 1963. – 832 p.

5. Yaglom A.M., Yaglom I.M. Probability and Information / A.M.Yaglom , I.M.Yaglom. – M.: Science, 1973.– 512 p.

UDC 621.396.933(045)

M.P. Mukhina, PhD (National Aviation University, Ukraine, Kyiv)
I.V. Seden, post-graduate student (National Aviation University, Ukraine, Kyiv)

ALGORITHM OF INERTIAL NAVIGATION SYSTEM CORRECTION BY MEANS OF CORRELATION EXTREME NAVIGATION SYSTEM

Possibilities of correction of inertial navigation systems from correlation extreme navigation systems, which work by terrain relief, were considered. Methods of investigation are mathematical and programming simulation. At simulation modeling the studied system is replaced with its simulator, with what machine experiments are made. The modeling usage allows estimating of the system performance, to carry out the most efficient coefficients for INS correction.

Introduction. Inertial navigation system is a universal navigation system for determination of trajectory motions, angular coordinates (roll, pitch and heading angles) and other parameters of the aircraft. Unlimited increasing of errors in time is essential disadvantage of INS, so the methods of correction of these systems are of great importance. For elimination of these factors the complexes, which provide the INS correction, are developed.

INS can be corrected by means of the satellite navigation system. In this complex the increasing of such parameters as accuracy of determination of coordinates, altitude and speed, clarification of heading, roll and pitch angles are provided. The main disadvantage of SNS is not high disturbance protection. During SNS rejection the correlated extreme navigation system can provide automatic correction of current coordinates.

Correlated extreme navigation system is the system of processing of information, which is represented as random functions (fields); it is assigned for determination of coordinates of motion. Navigation with usage of CENS is performed by means of information, obtained from geophysical fields with random structure, parameters of which are closely connected with definite parts of Earth surface.

The correlation between horizontal and vertical channels, foreseen in the structure of CENS, allows estimation of absolute altitude of flight using vertical accelerometer of inertial system, radio altimeter and on-board relief map. It provides possibility of INS correction in continuous mode. CENS error decreases in time, because clarification of relief by standard map is executed, and a quality of INS correction will increase.

So, CENS can be recommended as system for INS correction during a long time of both systems work.

Problem statement. Let's consider navigation complex, which includes all three channels of INS, they measure coordinates of spatial (x, y, H) and angular (φ, γ, ψ) position of the aircraft, radio altimeter, and onboard computer with relief map $f(x, y)$, recorded in its memory.

Data fusion of listed input information will be realized with the purpose of determination of errors of INS in measurement of coordinates $(\Delta x, \Delta y, \Delta H)$ and velocities $(\Delta V_x, \Delta V_y, \Delta V_H)$ of motion. Barometrical measuring devices are not included in the given navigation complex. Equations of errors of inertial systems look like:

$$\begin{aligned} &\Delta x' = \Delta V_x, \Delta V_x' = 0, \\ &\Delta y' = \Delta V_y, \Delta V_y' = 0, \\ &\Delta H_{in}' = \Delta V_H, \Delta V_H' = \delta_{jH}, \end{aligned} \tag{1}$$

where $\delta_{jH} = 2\frac{V}{R}\Delta V_x + \delta_{jz1}$ - random disturbance.

If we will introduce such designation $\mathbf{X} = \begin{bmatrix} H_{\text{iH}} & \Delta V_H \end{bmatrix}^T, \mathbf{Y} = \begin{bmatrix} \Delta x & \Delta V_x & \Delta y & \Delta V_y \end{bmatrix}^T, \boldsymbol{\xi} = \begin{bmatrix} 0 & \delta_{jH} \end{bmatrix}^T,$ then relation (1) will have canonical view:

$$\begin{aligned} &\dot{\mathbf{X}} = \mathbf{A}(\mathbf{Y}, t)\mathbf{X} + \boldsymbol{\xi} \\ &\mathbf{Y} = \mathbf{\Phi}(t)\mathbf{Y}, \end{aligned}$$

where ξ – white noise.

In our case

$$\mathbf{A}(\mathbf{Y}, t) = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix}, \mathbf{\Phi}(t) = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix},$$

and parameters of initial distribution of vector X_0 and intensity matrix S_x of noise $\xi(t)$ are equal to:

$$\mathbf{m} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \boldsymbol{\sigma} = \begin{bmatrix} \sigma_{H_0}^2 & 0 \\ 0 & \sigma_{VH_0}^2 \end{bmatrix}, \mathbf{S_x} = \begin{bmatrix} 0 & 0 \\ 0 & S_j \end{bmatrix}$$

where $\sigma_{H_0}^2, \sigma_{VH_0}^2$ are variances of initial errors of measurement of altitude and vertical speed; S_j is a spectrum density of noises of vertical accelerometer.

It is necessary to find the estimation of state vector $\hat{\mathbf{X}}$ for the time of correction of INS from the values of coordinates of CENS under condition, that error of determination of coordinates by CENS is much smaller, than cumulative error of INS about coordinates.

Algorithm of correction of inertial navigation system on the base of terrain relief. Transient curves and steady-state values of vertical parameters of motion, which are estimated, calculated for:

$$\sigma_{H_0} = 1500\text{m}, \sigma_{V_{H_0}} = 5\text{m}\times\text{sec}^{-1}, \sigma_{\sim} = 10\text{m},$$

$$\tau_{\sim} = 4\text{sec}, \sigma_j = 2\cdot 10^{-4}\,\text{м}\times\text{s}^{-2}, \tau_j = 1\text{sec}\ .$$

Block diagram of designed system according to the given conditions is represented on the following Fig.1.

Equations of errors of system “INS with position+velocity correction”:

Let’s designate:

$$\Delta S_i = S_i - S \qquad (2)$$

where ΔS_i is the error of measurement of coordinate S ;

$\Delta V_i = V_i - V$ is the error of measurement of velocity V;

$\Delta \dot{V} i = \dot{V} i - \dot{V}$ is the error of measurement of $\dot{V}$.

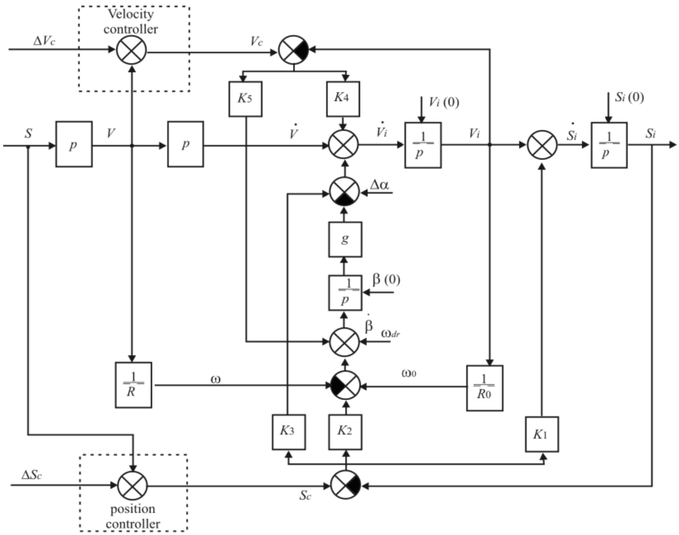


Fig.1

Let’s write the equation for adders 1, 2 and 3 of block diagram:

$$\dot{V} i = \dot{V} + K_4\left(V_c - V_i\right) + K_3\left(S_c - S_i\right) - \beta g + \Delta\alpha;$$

$$\dot{\beta} = -VR^{-1} + V_i R_0^{-1} + K_5\left(V_c - V_i\right) + \omega_{dr} + K_2\left(S_c - S_i\right);\ (3)$$

$$\dot{S}_i = V_i - K_1 S_i + K_1 S_c.$$

$$V_c - V_i - V + V = (V_c - V) + (V - V_i) = \Delta V_c - \Delta V_i$$

$$S_c - S_i - S + S = (S_c - S) + (S - S_i) = \Delta S_c - \Delta S_i$$

β is the small angle that characterizes the error of INS leveling;

$\Delta\alpha$ is the error of accelerometer;

ω_{dr} is the angular velocity of INS drift;

$S_c = S + \Delta S_c$ is the readings of position controller; ΔS_c is its error.

Let's rewrite equation (3) taking into account expression (2) as following:

$$\Delta\dot{V}i = \dot{V}i - \dot{V} = K_4\left(\Delta V_c - \Delta V_i\right) + K_3\left(\Delta S_c - \Delta S_i\right) - \beta g + \Delta\alpha$$

$$\Delta\dot{V}i + K_4\Delta V_i + K_3\Delta S_i = K_4\Delta V_c + K_3\Delta S_c - K_2\Delta S_c - \beta g + \Delta\alpha;$$

$$\dot{\beta} = R^{-1}\Delta V_i + K_5\Delta V_c - K_5\Delta V_i + \omega_{dr} + K_2\Delta S_c - K_2\Delta S_i$$

$$\dot{\beta} - R^{-1}\Delta V_i + K_5\Delta V_i + K_2\Delta S_i = K_5\Delta V_c + \omega_{dr} + K_2\Delta S_c;$$

$$\Delta\dot{S}_i - \Delta V_i + K_1\Delta S_i = K_1\Delta S_c.$$

Transforming expression into the Laplace operator form and taking into account the initial conditions we will obtain:

$$p\Delta V_i(p) + g\beta(p) + K_4\Delta V_i(p) + K_3\Delta S_i(p) =$$
$$= K_4\Delta V_c(p) + K_3\Delta S_c(p) + \Delta\alpha(p) + p\Delta V_i(0);$$

$$p\beta(p) - R^{-1}\Delta V_i(p) + K_5\Delta V_i(p) + K_2\Delta S_i(p) =$$
$$= K_5\Delta V_c(p) + \omega_{dr}(p) + K_2\Delta S_c(p) + p\beta(0);$$

$$p\Delta S_i(p) - \Delta V_i(p) + K_1\Delta S_i(p) = K_1\Delta S_c(p) + pS_i(0).$$

Let's designate: $X(p) = \left[\Delta V_i(p), \beta(p), \Delta S_i(p)\right]^T$ is state vector of the system.

Let's also designate:

$$f_V(p) = K_4\Delta V_c(p) + K_3\Delta S_c(p) + \Delta\alpha(p) + p\Delta V_i(0);$$
$$f_\beta(p) = K_5\Delta V_c(p) + \omega_{dr}(p) + K_2\Delta S_c(p) + p\beta(0);$$
$$f_S(p) = K_1\Delta S_c(p) + pS_i(0).$$

Column vector of absolute terms of system $\Phi(p) = \left[f_V(p), f_\beta(p), f_S(p)\right]^T$, and $\Delta(p)$ is the characteristic determinant of considered system, which has the following form:

$$\Delta(p)=\begin{bmatrix} \left[K_4+p\right] & g & K_3 \\ \left[K_5-R^{-1}\right] & p & K_2 \\ -1 & 0 & \left[K_1+p\right] \end{bmatrix}, \tag{4}$$

And the equation of considered system can be expressed as $\Delta(p)X(p)=\Phi(p)$.

According to equation (4) the characteristic equation can be written as following:

$$F(p)=(K_1+p)(K_4+p)p-gK_2+K_3p-(K_5-R^{-1})(K_1+p)g=0$$

$$p(K_1K_4+K_1p+K_4p+p^2)-K_2g+K_3p-g(K_1K_5-R^{-1}K_1+K_5p-R^{-1}p)=0$$

$$K_1K_4p+K_1p^2+K_4p^2+p^3-K_2g+K_3p-K_1K_5g+R^{-1}K_1g-K_5pg+R^{-1}pg=0$$

$$p^3+p^2(K_1+K_4)+p(K_1K_4-K_5g+K_3+R^{-1}g)-g(K_2+K_1K_5-R^{-1}K_1)=0$$

Let's suppose:

$$(p+\omega)(p^2+2\xi\omega p+\omega^2)=p^3+2\xi\omega p^2+\omega^2p+\omega p^2+2\xi\omega^2p+\omega^3$$

$$p^3+p^2(2\xi\omega+\omega)+p(\omega^2+2\xi\omega^2)+\omega^3=0$$

$$\omega=0.001$$

$$\xi=0.7$$

We obtain such equations:

$$K_1+K_4=2\xi\omega+\omega=2*0.7*0.001+0.001=0.0024=2.4*10^{-3}$$

$$K_1K_4-K_5g+K_3+R^{-1}g=\omega^2+2\xi\omega^2=0.000001+0.0000014=0.0000024=2.4*10^{-6}$$

$$-g(K_2+K_1K_5-R^{-1}K_1)=\omega^3=10^{-9};g(R^{-1}K_1-K_2-K_1K_5)=10^{-9}$$

$$R=6.371*10^6m$$

$$\frac{1}{R}=156.96*10^{-9}m^{-1}$$

$$g\frac{1}{R}=1.538*10^{-6}\sec^{-2}$$

$$K_2 = K_5 = 1$$

$$156.96 * 10^{-9} K_1 - 1 - K_1 = 10^{-10}$$

$$-0.9999998431 K_1 = 1.0000000001$$

$$K_1 = -1$$

$$K_1 + K_4 = 0.0024;$$

$$K_4 = 0.0024 - K_1 = 1.0024;$$

$$-1.0024 + K_3 - 9.8 + 1.538 * 10^{-6} = 2.4 * 10^{-6}$$

$$K_3 = 10.8$$

By means of calculated coefficients of correction we simulate the scheme “INS with velocity and position correction” in Simulink (Fig.2).

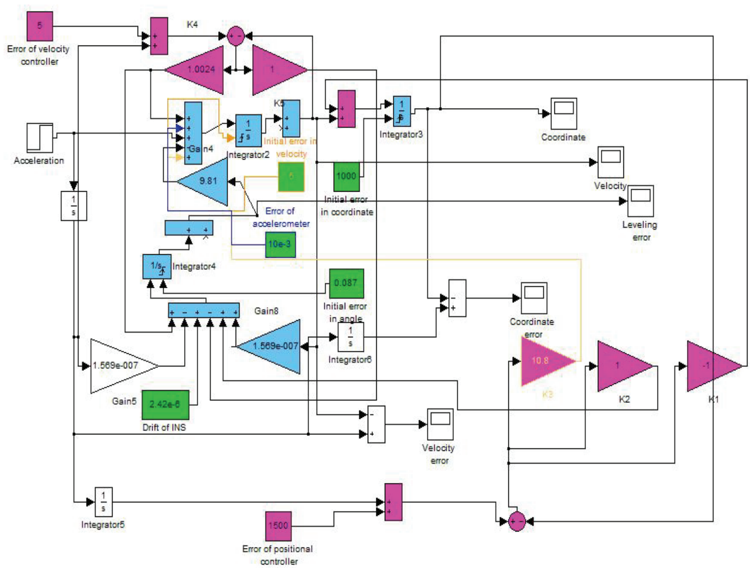


Fig.2

We obtain the graphs of leveling (Fig.3), coordinate (Fig.4) and velocity (Fig.5) errors. Steady-state value of leveling error is -0.35. Steady-state value of leveling error is -23, 24.Steady-state value of leveling error is -0.8.

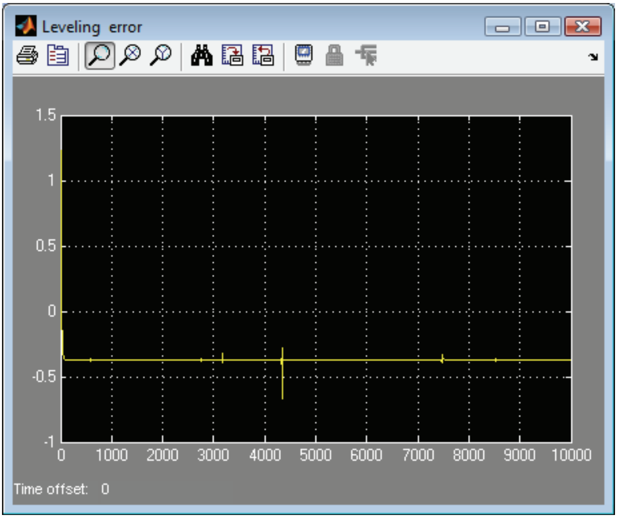

Leveling error
1.5
1
0.5
0
-0.5
-1
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
Time offset: 0

Fig.3

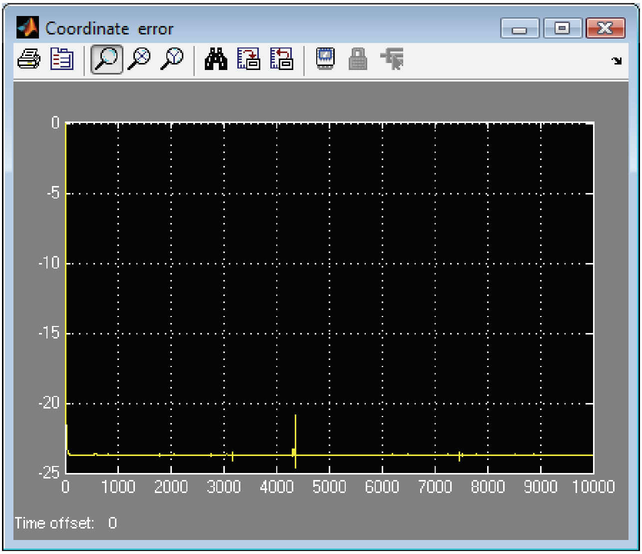

Coordinate error
0
-5
-10
-15
-20
-25
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
Time offset: 0

Fig.4

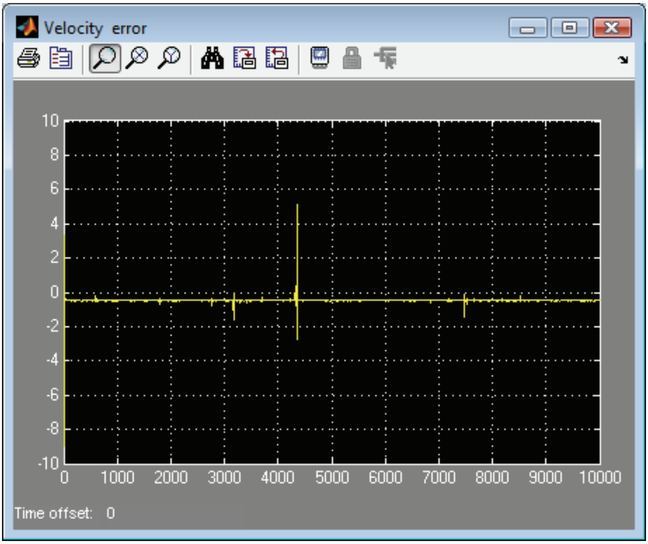


Fig.5

Conclusion. Novel technique of INS application together with CENS is used for INS correction. Combining of INS with CENS yields promising results. Using complex ICENS is a good approach in terms of full autonomy, reliability, efficiency and accuracy. However, the placement of such system requires further research. The task was to develop an algorithm support of ICENS. The developed product allows INS correction. Recurrent-searching estimation of aircraft coordinates was applied for this.

References

1. Філяшкін М.К. Інерціально-супутникові навігаційні системи/ М.К. Філяшкін, В.О. Рогожин, А.В. Скрипець, Т.І. Лукінова.-К.:НАУ-друк, 2009.-272с.

2. Білоглазов І.М. Основи навігації по геофізичним полям/ І.М. Білоглазов, Г.І.Чигин, Г.П. Джанжгава. – М.: Наука, 1985.-328с.

UDC 681.5(015)

O.V. Melnikov, PhD (NAU, Kyiv, Ukraine)
O.V. Glushko, R. Yu. Tkachev, candidate of technical sciences
(Donbass State Technical University, Ukraine, Alchevsk)

ON STABILITY PROVIDING METHOD OF CONTINUED FRACTION APPROXIMATION

Approximation stability problem in using continued fractions for process identification is considered. Algorithm of altering experimental sequence to be used for continued fraction convolution in order to guarantee stability of approximation is proposed.

Using continued fractions as general mathematical apparatus for approximations is a prospective approach in system identification which has great number of advantages such as quite good calculation stability, possibility of effective implementation on the basis of modern microcontrollers… [1]. This prospective approach can be used for both parametrical and structural parametrical identification identification problems, when experimental data represents sequences of measured values of input and corresponding output variables in discrete moments of time [1]–[3].

Main problems in realization of these identification approaches in practice are problems of instability and bad convergence [3]. These problems arise when order of continued fraction approximant is too low so that approximant is insufficient to fit experimental curve well. Usually such situations take place when experimental data is affected with noise of significantly high amplitude level (in respect to wanted signal).

We propose new algorithm for identification of time-delay systems from noisy transient responses using mathematical apparatus of continued fractions and special stabilization procedure that allows to solve the problem of instability and gurantee correct steady-state value of model's transient process.

Analog-to-digital convertors (ADC) provide information on technological process's parameters in digital form as results of measurements in discrete moments of time. Usually sampling period of ADC is constant so that experimental data can be easily represented in a form of formal Laurent series:

$$f(z) = c_0 + c_1 z^{-1} + c_2 z^{-2} + c_3 z^{-3} \ldots, \qquad (1)$$

where $\{c_k\}_{k=0}^{m}$ is experimental output sequence, $c_k \in R$; T is sampling period, *s*; $z = e^{Ts}$; $s = \sigma + j\omega$.

Continued fractions can be used for approximation of analytic functions. Continued fraction approximations take on values in the extended complex plane and may converge in regions that contain isolated singularities of the function to be represented.

Forming of continued fractions can be realized with different methods, in this paper we consider Rutishauser's method to be used for this purpose. Rutishauser's method is determined by the formula [4]:

$$f(z) \approx \frac{c_0}{1 -} \frac{q_1^{(0)} z^{-1}}{1} \frac{e_1^{(0)} z^{-1}}{- \quad 1} \frac{q_2^{(0)} z^{-1}}{- \quad 1} \frac{e_2^{(0)} z^{-1}}{- \quad 1} - \ldots =$$

$$= \cfrac{c_0}{1 - \cfrac{q_1^{(0)} z^{-1}}{1 - \cfrac{e_1^{(0)} z^{-1}}{1 - \cfrac{q_2^{(0)} z^{-1}}{\ddots \; 1 - \cfrac{q_{n-1}^{(0)} z^{-1}}{1 - e_{n-1}^{(0)} z^{-1}}}}}} = \frac{P(c_0, \{e^{(0)}\}, \{q^{(0)}\})}{Q(\{e^{(0)}\}, \{q^{(0)}\})}, \tag{2}$$

where $e_m^{(n)} \in C,\ q_m^{(n)} \in C,\ f(z) \in \hat{C},\ \hat{C} = C \cup [\infty];$ $\{e_m^{(n)}\}$ and $\{q_m^{(n)}\}$ are sequences determined with following relations: $e_m^{(n)} = q_m^{(n+1)} - q_m^{(n)} + q_{m-1}^{(n+1)};$ $q_{m+1}^{(n)} = \frac{e_m^{(n+1)}}{e_m^{(n)}} q_m^{(n+1)};$ m = 1, 2, 3…; n = 0, 1, 2, 3…; except $e_0^{(n)} = 0$ and $q_1^{(n)} = \frac{c_{n+1}}{c_n}$.

To fully automatize stability-correction, we propose to execute stability analysis with Shure's criterion (or other algebraic criterion) [5]: for characteristic polynomial of the discrete-time transfer function:

$$D(z) = a_0 + a_1 z + a_2 z^2 + \ldots + a_n z^n.$$

consiquent matrices

$$\Delta_k = \begin{vmatrix} a_0 & 0 & 0 & \cdots & 0 & a_n & a_{n-1} & \cdots & a_{b-k+1} \\ a_1 & a_0 & 0 & \cdots & 0 & 0 & a_n & \cdots & a_{b-k+2} \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots & \vdots & \cdots & \vdots \\ a_{k-1} & a_{k-2} & a_{k-3} & \cdots & a_0 & 0 & 0 & \cdots & a_n \\ a_n & 0 & 0 & \cdots & 0 & a_0 & a_1 & \cdots & a_{k-1} \\ a_{n-1} & a_n & 0 & \cdots & 0 & 0 & a_0 & \cdots & a_{k-2} \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots & \vdots & \cdots & \vdots \\ & & & \cdots & & & & \cdots & \\ a_{n-k+1} & a_{n-k+2} & a_{n-k+3} & \cdots & a_n & 0 & 0 & \cdots & a_0 \end{vmatrix}. \tag{3}$$

should have number of sign changes equal to the order of characteristic polynomial, that's: $\Delta_1 < 0$, $\Delta_2 > 0$, $\Delta_3 < 0$, $\Delta_4 > 0$ … $(-1)^n \Delta_n > 0$.

Δ 's in (3) can be expressed in terms of $\{c\}$ and therefore, stability conditions can be formulated as a system of n nonlinear inequations:

$$\begin{cases} \Delta_1(\{c\}_n) < 0; \\ \Delta_2(\{c\}_n) > 0; \\ \Delta_3(\{c\}_n) < 0; \\ \vdots \\ (-1)^n \Delta_n(\{c\}_n) > 0. \end{cases} \qquad (4)$$

Let's introduce corrected sequence $\{\overline{c}\}$ that makes (4) held:

$$\overline{c}_i = c_i + d_i,$$

where d_i are correcting differences (that assumed to be admissible small) that are defined based on absolute value of differences between current, next and previous values in experimental sequence.

Therefore, we can determine stable approximation with solution of optimization problem, where minimizing functional can be formulated as

$$J = \sum_{i=0}^{n} (\overline{c}_i - c_i)^2 \to \min. \qquad (5)$$

Then, using $\{\overline{c}\}$ for continued fraction expansion we'll retrieve stable approximation of order n.

Conclusion. Such a way proposed method of identification allows to solve the stability problem of continued fraction approximations.

References

1. Kartashov V. Ya. "Is the equivalence of discrete models possible?" *Promichlennie sistemi i kontrolleri*. 2006. no. 8. pp. 40–44. (in Russian).

2. Glushko O. V. Structutal-parametric Identification of Recycle Systems. Materials of 14th International Olympiad on Automatic Control (Baltic Olympiad). Saint-Petersburg: National Research University of Information Technologies, Mechanics and Optics Saint Petersburg State University, 2011. pp. 129–133.

3. Glushko, O. V.; Denishik, S. S.; Tkachov, R. Yu. "Solution of real life structural-parametric identification problems using continued fractions." 2013. *Proceedings of "Tarapov Readings 2013,"* Kharkov. pp. 79–80.

4. Baker, G. A.; Graves-Morris, P. Pade approximants. London: Addison-Wesley publishing, 1981. 502 p.

5. Ogata, K. Discrete-time control systems. 2nd ed. New Jersey: PTR Prentice Hall, Upper Saddle River, 1995. 761 p.

UDC 121.548.5(045)

D.P. Karabetsky(National Aviation University, Kyiv, Ukraine)

SOFTWARE CONTROL SYSTEM OF SOLAR POWER PLANT

Any mechanical object must consists of hardware or software blocks that could be connected into one general control system. This kind of control system will concentrate regulations or behavior of smaller control blocks that could implement one part of control cycle and could be denoted from the general unit. This means control system could provide modularization. We will describe several modules that will form a control system of solar power plant with the meaning that each of this modules could be ejected, changed or improved.

Introduction. As known, the actual power of solar panels and their charging current value – are directly dependent on the angle of incidence for these modules on sunlight and the density of incident sunlight. Based on this, solar modules in a fixed position that is relative to the sun – brings a smaller effect then same modules with sun tracking mechanism.

Installation of solar modules on the rotaty mechanism allows us to always keep our solar panels toward the angle of inclination and the direction of sun's motion.

Through the use of solar panels on the rotary mechanism and a constant orientation to the sun, by the angle of incidence of sunlight on the solar modules and the direction of movement of the sun across the sky, it is possible to achieve a substantial increase in the efficiency of solar cells.

Such a "modernization" of existing solar installations in comparison with fixed, can increase the production of electricity in the winter about to 10 %, and in the summer up to 40 %.

And the main part of solving this kind of task is development of control system, that has access to each valuable part of solar power plant.

Control system descriptive model of solar power plant.

Solar power plant consists of such main structural blocks:

- Accumulative power supply;
- microcontroller unit subsystem;
- motor drivers;
- feedback subsystem.

Each of this blocks represent independent part of solar power plant in general vision, where they could be modified or improved.

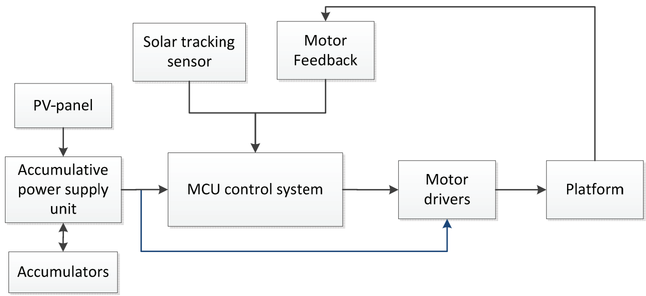


Fig. 1. Structural scheme of solar power plant.

When we talk about software control system, we need to introduce more detailed configuration of hardware parts of solar power plant and identify responsibilities for them.

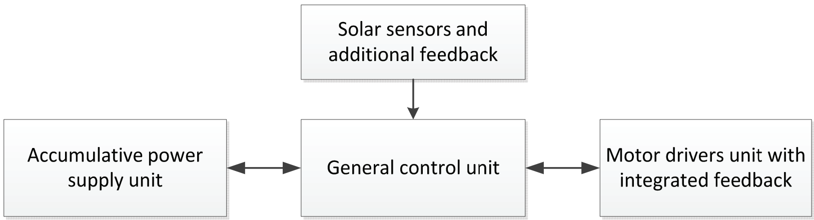


Fig. 2. Structural scheme of control system.

The main control subsystem of solar rotary platform is *general control unit* entrusted with solving the following problems:

- mathematical models of control;
- communication with accumulative power supply unit;
- issuing control signals to electronic circuits, such as motor drivers;
- collecting and processing of global feedback;
- providing and communicating with a computer with the state of control cycle;
- the possibility of debugging.

As the main part of the control device is used Microcontroller ARM Cortex-M3 from the company ST Microelectronic. For the purposes of mathematical models of control microcontroller has a large amount of RAM, type of SRAM.

To communicate with system units we are using I2C and USART interfaces to initiate bidirectional data exchange.

Also allow the possibility to have a "black box" as SD-cards that can be installed and extracted from the control device. During control cycle, solar power plant constantly record the current state of all units connected to the system and on the execution of the control and data from sensors that can later help in finding reasons that caused some errors in or not performing control cycle.

For communication with PC, the main control unit uses USART interface, it is a most reasonable decision, because on the market there are many possible kinds of links over USART, such as a USB-UASRT converters or RF-links.

For debugging and programming of microcontrollers at units JTAG interface and programming environment Keil MDK are used.

Solar and additional feedback unit provides two classes of sensors:

• determination of the destructive forces that could impact platform via three axes accelerometer located on cascade of solar panels. This sensors in realtimetransfers data of vibrations and can generate interruption if fluctuations in one of the axes is more than recommended (recommended value can be programmed for each platform separately solar);

• light sensor, device which gives information on the movement of the sun relative to the cascade cells and normal axis. This information is a source of relative implicit feedback and used tracking management system.

Motor drivers are used to implement high-level and encapsulated logic of physical drivers control, where motor feedback lines directly fetched. This unit performs horizontally or vertically rotationthat managed frommain control unit with simplified signal that contains time and angle of rotation (or distance) that motor must perform.

Accumulative power supply unit is the intelligent distribution power supply, which takes all responsibilities to charge accumulator from solar power plant's current and to ensure that all management/control units have required power to operate as desired in any global power state of the plant. This means that if solar power plant does not generate enough power, the power supply unit must use energy from accumulators.

Control algorithm. To minimize the misalignment angle and improve the current-voltage characteristics we will further consider the structure and we will propose method of controlling a solar power plant.

We will map the general mechanism of control system in block diagram form (fig. 3).

The second phase begins to initialize the system configuration and move control system units in standby mode (motor driver units, periphery of the MCU etc). After completion of the initialization phase, the control program runs.

The control system will collect all the supporting data to calculate the new position of the platform at the end of the system stage and will request enable signal from the vibration sensor. This sensor is used to determine the external conditions for the correct operation of the platform, namely vibrations of the panels because of the wind. If there are no issues with wind, control system begins regulation of mechanical platform according to the criterion of efficiency. If control system identified issues to work correctly, it runs the emergency management cycle with isolated parking platform at a fixed time. Operation of the system will continue work as long as enable signal set. When enable signal diactiveted power plant goes to service mode.

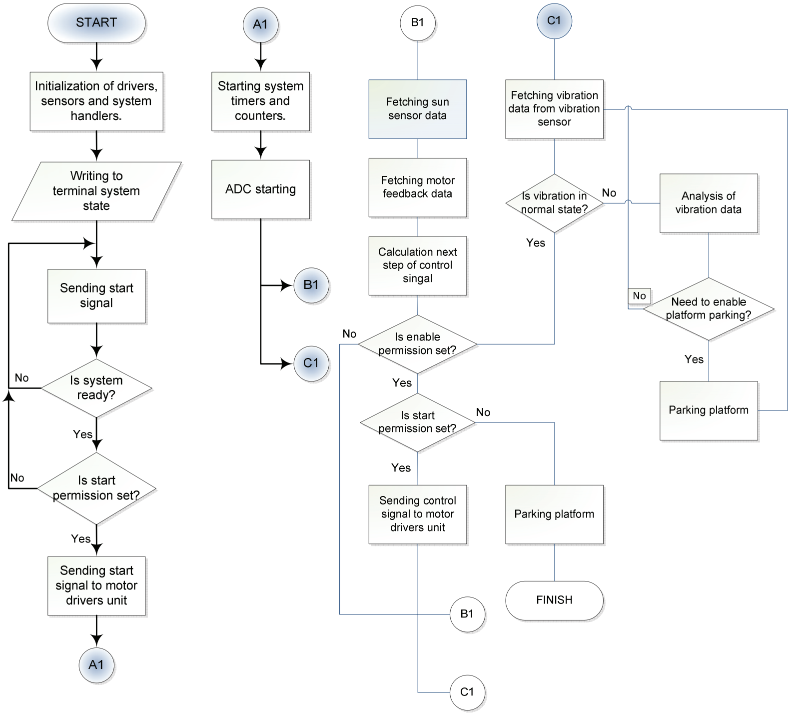


Fig. 3.Block diagram of the general mechanism of control.

Conclusions

As summary, electronic units of solar power plant are designed not to just implement control and management of the mechanics and solar cells, they was build by principles to make any unit reusable. This means that any part of the system, that we call “unit”, must not be highly specialized and used only for this (specific) task, it means that all of the units could be used at any future projects, that will require such functionality.

References

1. V. M. Sineglazov, D. P. Karabetsky Computer-aided design of motor driver for solar power plant. Electronics and Control Systems 2013. № 3(37).
2. Robert H. Bishop, The Mechatronics handbook. CRC Press, 2002.
3. Graham C. Goodwin. Control System Design. Prentice Hall, 2010.

UDC 621.012.011.56:061

P. Pavlenko, Dr.Sci., prof.; S. Tolbatov, graduate student

(National Aviation University, Ukraine, Kiev)

DEVELOPMENT OF INFORMATION SYSTEM OF THE ASSESSMENT OF COMPLEXITY OF PROJECT WORKS

The materials deals with the approaches to the information system construction for analyzing work complexity. The author considers business logic and access logic to the database, as a basis of software implementation and in future presentation logic.

I. Introduction

There are several basic approaches to design an architecture of the corporate information systems in economic and financial activities filed. The following functional components of the information systems could be highlighted [1]:

1. Presentation Layer (PL).
2. Business Layer (BL).
3. Access Layer (AL), architecture of the system could be represented on the fig. 1.

Development and implementation of the work complexity information system should meet the following requirements of the business:

1. The reliability of system functioning and data storage. As far as distributed systems of the analysis are intended to be used by tens of thousands of users all around the world the reliability issue becomes very significant.

2. Security. The data that is stored in a database is usually a trade secret and any leak could lead to customers' losses as well as system owner. Complicated mechanisms and algorithms are implemented to avoid an unauthorized access, system corruption etc.

3. System flexibility. Due to large amount of users the system flexibility meaning possibility of new versions development and releases (for all three layers: PL, BL, AL) could be provided in two-layer or three-layer architectures only.

Two-level information systems architecture should be implemented along with the relevant software in order to be used by medium business enterprises.

II. MAIN BODY

The purpose of this article is to design the information system architecture to accommodate the work complexity software development. The input and output data should be determined before information system architecture development. This data will be processed by information system and finally passed to the user.

It is used to develop the software for the mathematical model of the work complexity assessment particularly for the 'creative potential' aspect of the credit and factor model that is considered in the publication [2].

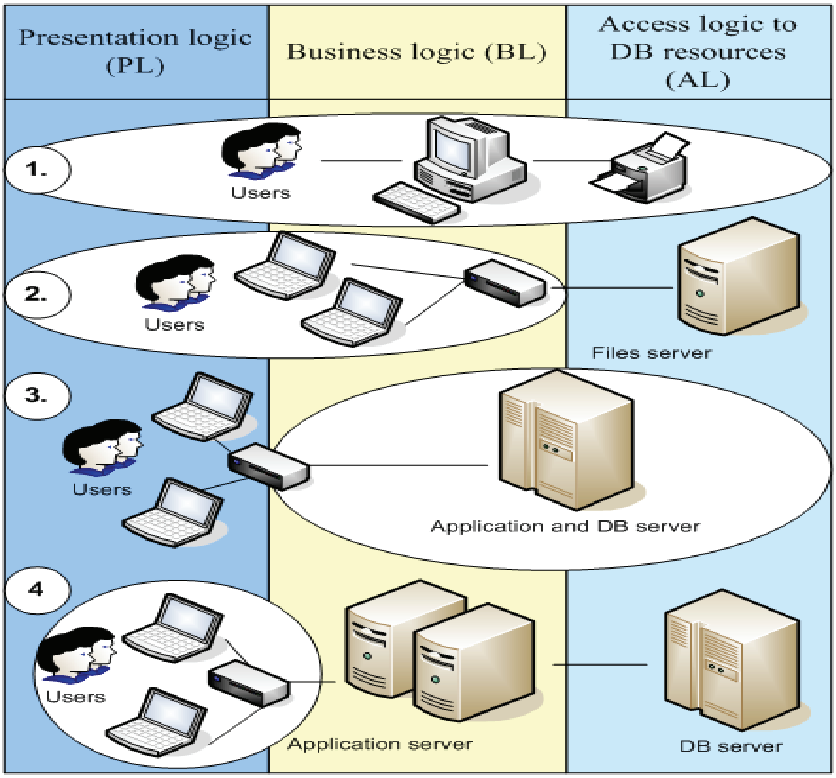


Fig. 1. The information system architecture

The data structure and the data interrelations are represented by the ERM model (entity-relationship model) which is intended to describe the conceptual scheme of the domain. This model helped to find out the quintessence and relations between them. Later during the database design and software development, the ERM model is transformed into the certain scheme of database based on the chosen model.

The certain entities and attributes that describe the aspects of the developed system are depicted on the schemes below. For the proposed calculations algorithms the business logic is represented as appropriate operators of the mathematical functions. The attributes are represented as relevant characteristics of aspects, namely evaluative judgments, value coefficient and observatory factor.

The data formats diversity (in terms of measurement units) that is used for work complexity assessment leads to issues of data integration within the common database with further processing.

Hence the information system structure could be represented by the software modules which are responsible for the data processing and calculations. The modular structure of the information system is depicted on the figure 2.

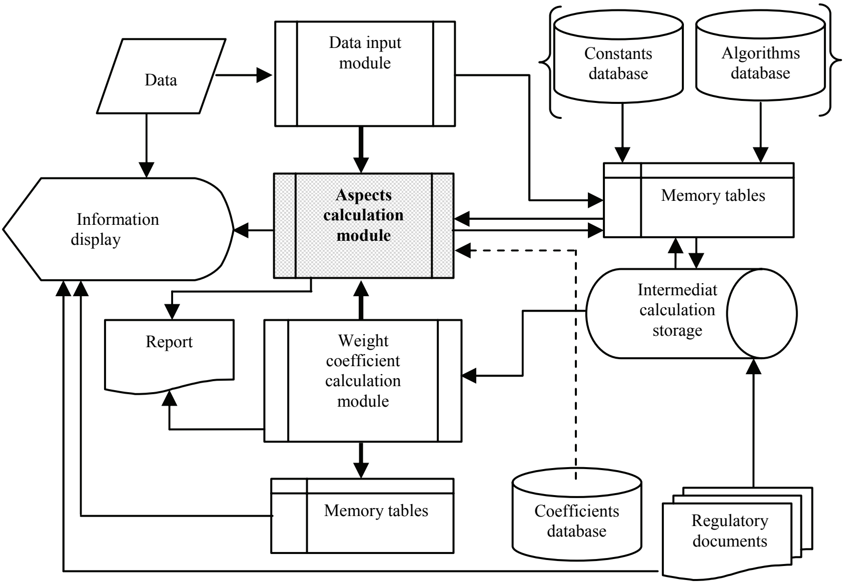


Fig. 2. Block diagram of the information system

The information system could be represented by the following main blocks (modules):

1. Data input module. This module is used for variable data input which characterizes the certain aspects of the particular work as well as necessary calculations. Basically this module represents Presentation Layer.
2. Aspects calculation module. Basically this is the main module of system calculations. It is responsible for the quantitative assessment of each aspect of the work model. The Business Layer is implemented here and servers to provide the necessary interconnection between all the modules as well as implementation of calculation algorithms.
3. Weight coefficients calculation module. This module belongs to BL as well. Pairwise comparison algorithms are implemented here for aspects to calculate the weight coefficients. The author suggests considering this implementation as a separate module in order to meet the requirements for calculations stated in the given technique which will remain constant and will not depend on work features.

Such approach should simplify the development process and further module operations and improvements.

4. Memory table. These tables serve as intermediate database for storing the entered values and intermediate calculations. These tables could be implemented in the relevant areas of the RAM (random access memory). Essentially all the data exchange between the calculation modules and database are performed through these tables. The access logic to DB resources (AL) is also implemented according to the approach mentioned above.

5. Database. The given group of modules comprises a wide range of databases which are responsible for the storing of constant values, different regulatory guides required for the data input and calculations.

6. Report. This module is responsible for data visualization and reports making. Reports could be designed and implemented in advance to meet all the customers' needs.

III. Conclusions

Description of the main modules of offered information system, and their function for the subsequent realization in the form of information technology. Two-level information system architecture of the work complexity assessment has been developed. The architecture considered in the article could be used as technical design specification for the appropriate software development which could be used by enterprises experts as automated solutions for setting and definition of labor quotes and salary rates.

References

1. Pavlenko P.M. Model of criterion of efficiency of modern methods of analysis of works / P.M. Pavlenko, V.V. Treytyak, S.V. Tolbatov // Announcer of the Tchernihiv state technological university. Series: Engineerings sciences – 2013. №3.– of S. 149-157. (in Ukrainian).

2. Tolbatov S.V. Model of analysis of methods of determination of estimation of complication of works / S.V. Tolbatov // Announcer of the Khmel'nickogo national university – 2013. №3– of S. 58-64. (in Ukrainian).

3. Chernysheva T.U. Model of a multicriteria assessment of experts//Almanac of modern science and education. – 2008 . – No. 9 (16). – Page 242-245. (in Russian).

UDC 005.311.2:004.94

V. Treityak
(National Aviation University, Ukraine, Kiev)

INFORMATION TECHNOLOGY OF CONSOLIDATION AND SYNCHRONIZATION OF PRODUCTION AND NORMATIVELY CERTIFICATE INFORMATION

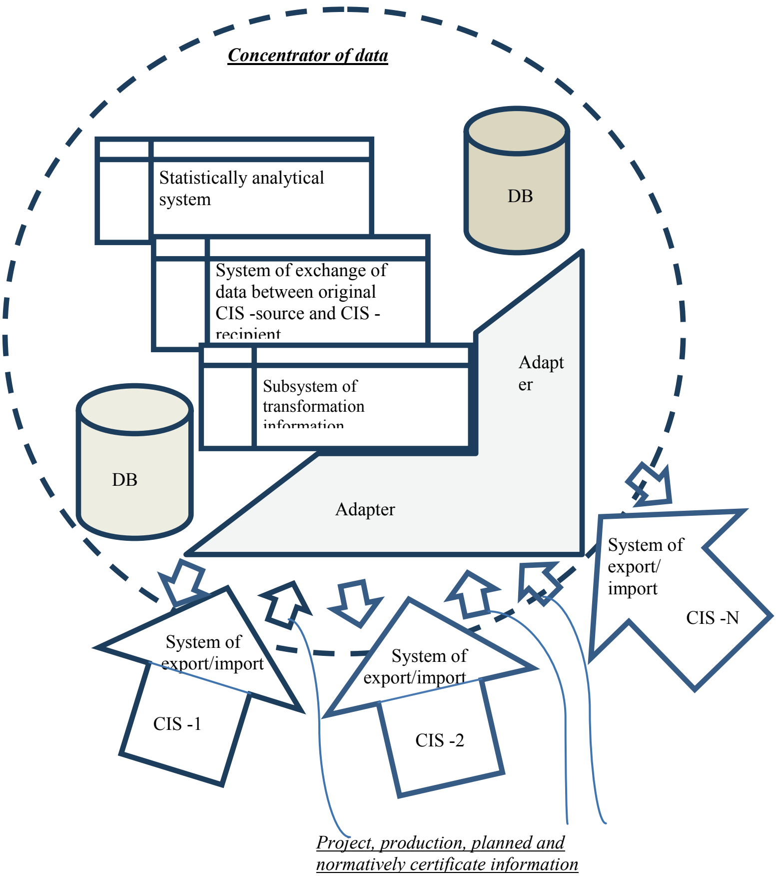
The basic aspects of information technology of consolidation and synchronization of information, which provides authenticity and operationability of presentation of project, are presented in materials, production, planned and normatively certificate information.

In the process of development of industrial enterprise repeatedly grow him informative streams and the more important is become by correct organization of these streams into an enterprise. The analysis of problems of automation of industrial enterprises shows that «partial automation», that did not decide the presence of a few computer-integrated systems (CIS) of the production setting problems of creation of single computer-integrated informative space of enterprise. Historically on the industrial enterprises of Ukraine function independently one from other different CIS from different developers. Some production tasks decide uneffective or does not decide in general without the general use of project, production, planned and normatively certificate information a few CIS simultaneously. Obviously, that actuality of task of integration of information and systems becomes important depending on the level of its use in general control system by an enterprise. That for acceptance of reliable decisions in the scales of management an enterprise actual information is needed from different subsections and services of enterprise, and, as a result, from different CIS of the production setting.

Solving problem integration of information, the IT-specialists of enterprise develop the limited integration decisions, putting right the exchange of data between two concrete CIS of the production setting. Advantage of such approach is the use of «own» for CIS of mechanisms of exchange of data. However conditioned pointlessness of the use of this approach is the basic failings, which are related to insufficient flexibility and scaleableness of such decisions, which result in heavy tolls in support these limited decisions in the conditions of informative space of enterprise which constantly broadens and changes.

A concept «consolidations of information» is one of widely in-use at creation of the unique informative environment. Realization of consolidation of information foresees the construction of the unique consolidated environment with a central link – separate CIS, which executes the functions of management of integration and exchange of data processes between the different production systems.

Thus in a central knot – concentrator of data formed and take place not only logical copulas transformation information but information about that, where exactly (in which original CIS -source) information are but also these. In other words, a concentrator of data is separate CIS with an own database and in default of delivery of necessary information can be both the depository of information and to carry out processing of these data. It is necessary to mark, that the concentrator of data executes the functions of the system of maintainance of information here, accordingly, has an own database and programmatic instruments which allow to organize the unique the informative environment of information is consolidated. Gone into detail conceptual chart of the unique consolidated environment of information on picture 1 it is presented the generalized chart of flow of data.



Pic.1 – Conceptual chart of the unique consolidated informative environment

At lower level the placed original *CIS* -sources which are gap-filling own registers and reference books in the formats and structures of presentation of information. The systems are passed by information from the databases on a higher level. It is thus foreseen that information *CIS* can also be original *CIS* -sources, getting information from a higher level.

It follows notices, that the exchange of data with a higher level is foreseen with the use of the separate module – system of export-import of *CIS*. It can be both module which is built-in directly in *CIS* and module which is external and developed specially for organization of the unique consolidated informative environment.

The central element of chart is *CIS* «Concentrator of data». It consists of central database, and also from the programmatic modules which provide, from one side, co-operate with the original *CIS* -sources of information (but from *CIS* - «receiver of information»), and de autre part – processing of data, which are kept in a central database and drafting of any reports which are included in the external contour of the unique consolidated informative environment.

It is rotined on a chart, that under every functioning *CIS* it is needed to create the transformer-interface of co-operation, which on a chart is marked as «Adapter for *CIS* -I», where I-relative sequence number of functioning *CIS*. For providing of speed of connecting of new *CIS* to the unique consolidated informative environment, to the decline of general prime price of development and accompaniment of all architecture an adapter must be universal and put right, but not developed every time «from a zero» under every *CIS*.

For providing of authenticity of presentation of information it is necessary to conduct the proper converting of information from one format in other. It is de bene-esse possible to decide the task of converting of information 2 variants:

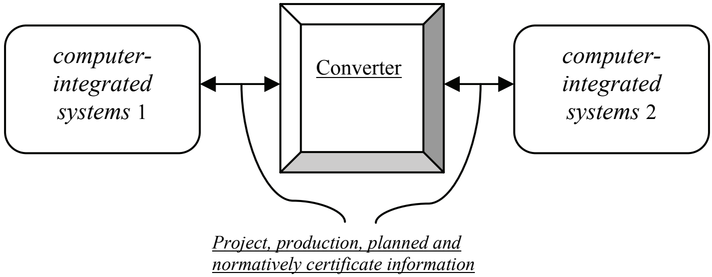
1. Writing of functions of the direct converting of information is from one structure in other.
2. Creation summarizing, most complete layout of data, which is able to convert any formats of *CIS*.

The first variant is more frequent used for integration of information by virtue of the simplicity: it is necessary to place accordance of the different fields of bases given and carry information a few (more frequent all) simple queries. It will be easily decided a task, if to examine media conversion from one *CIS* in other, that from more complete and clear structure in more simple, however there are complications at reverse transformation of information.

The second variant is more universal for realization of the scale integrating informative system, which is fixed in basis of information technology of consolidation and synchronization of production and normatively certificate information. Advantages of this variant followings:

1.Possibility of creation of «standard» presentation of information. In future, at bringing of update in existent *CIS* of the production setting it can be accepted decision about the use of this format in quality a basic – «internal standard».

2.Converters of information from *CIS* of the production setting it is possible to develop without the account of that, what *CIS* presentation of information is for (pic. 2). Information, which will be translated in the unique «standard» format, can be converted in the format of dear *CIS* of the production setting which takes part in the exchange of data within the framework of the unique consolidated informative environment.



Pic.2 – A chart of converting of information is with the use of converter

3.This format can be extended regardless of format of presentation in functionings *CIS*. Creation of such format is the first step on the way of creation of the unique consolidated informative environment of information, as a format becomes the universal language of exchange of data. Bringing in in converting and media of the third and next *CIS* conversion will be carried out independently, as already there will be the unique format of exchange of data in the consolidated informative environment.

Resume

Information technology of consolidation and synchronization of information is developed provides «clear» presentation of on-line and reliable production data for computer-integrated systems which carry out processing of data in the consolidated informative environment of enterprise. The uses of the developed information technology allow to use unique unifier of exchange of data, as an universal language for all consolidated environment of information and to connect new CIS are computer-integrated to the exchange by expansion of format and addition the template of transformation of information.

UDC 620.179:534.6

Filonenko S.F., Dr.Sci., prof.; Nimchenko T.V., PhD
(National Aviation University, Ukraine, Kiev)

ANALYSIS OF THE AMPLITUDE PARAMETERS OF ACOUSTIC EMISSION BY FRICTION COMPOSITES

We analyzed the results of handling of amplitude parameters of real resulting signal of acoustic emission by friction of surfaces, made of composite material. Transition of the friction assembly, which precedes the stage of catastrophic wear and tear, brings to rise of speeds of change of amplitude parameters of acoustic emission resulting signal.

Assignment formulation. In recent years more and more attention is paid to researching of friction assemblies of composite materials (CM).

One of the most sensitive methods, which is widely used in researches of friction assemblies made of CM, is method of acoustic emission (AE). As the results of published researches show, the method of AE has high reaction to change of mechanisms of friction and wear and tear, and lets get significant amount of information about processes. But interpretation of the registered information (acoustic radiation) produces considerable difficulties and is a problem of use of the AE method for control and diagnosis of friction assemblies made of traditional and CM. First of all, it is determined by difficulties of experimental researches that are connected with identification of developing processes. From the other side, significant amount of the analyzed AE characteristics (amplitude and energy, their statistic characteristics) needs determination of their information capability and sensibility to changing processes that develop in surface layer of CM. From this point of view, theoretical researches, connected with getting of expected regularities of changing of AE characteristics by variation of conditions of friction and wear and tear in friction contact zone, acquire high value. Such regularities can be a basis in development of methods of control and diagnosis of friction assemblies made of CM [1 – 3].

Research tasks. Regularities of speed of changing of amplitude parameters of AE resulting signal will be shown as well. We will also give information about the fact that during transition from stage of normal wear and tear to the stage before catastrophic wear and tear we can see increase of speed of change of average level of amplitude of AE resulting signal, speed of its standard deviation and dispersion.

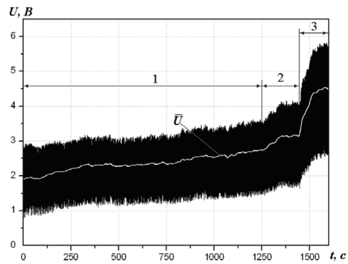
Experimental results. We made samples in the form of bushing, made of steel 30XGCA and aluminum alloy D16 with carbide surface layer VK6, for making researches of AE during friction of layers, made of CM. Sizes of the samples were: outer diameter 28 mm; inner diameter 20 mm; height 22 mm. Test of the samples was made with use of the constructive scheme “disk-disk”. Contact interaction of the samples was made on frontal surface layers with carbide cover. Tests were made on testing machine CMT-1 with the help of computer control of its work modes. For the scheme, we used, one of the samples was fixed and the other one rotated in the spindle of the testing machine. Size of the area of contact interaction of the samples was given with use of slits on the frontal layers of the samples.

Depth of slits was 5mm and they were steadily placed on the frontal layer of the samples. On such conditions the layer of contact interaction was characterized with the help of the coefficient of overlap K_S , which shows connection of the whole area of the frontal layer with contacting area of the frontal layer. During the tests value of the coefficient K_S was K_S =0,25. Rotation speed of the driving shaft of the friction machine CMT-1 was 500 rpm. Axial load intensity to a pair of friction was given with the help of device for axial load set and was 450 H. Oil M10G2K was used for lubricating environment. Oil consumption was 1,2 lph.

For researching of AE signals we used acoustic-emissive diagnostic complex. It consists of AE detector (DAE), AE signal amplifier (AESE), and mobile computer (MC) with mathematical software (MS). AE detector was set on the fixed sample. DAE was made of piezoelectric ceramics ZTC-19. By setting of the detector, its surface was lubricated with acousto-transparent lubricant. AE registered signals were coming from exit of the detector to AESA, and then to MC.

Handling of AE signals, using MS, was made in MC. According to the results of handling of parameters of AE registered signals we formed data, which were kept in form of logical bodies. The results of handling were shown at the monitor screen in form of graphic curves (AE signals amplitude in time), they also were transformed in sizes for mathematical software for Windows. This software was used for making static handling of parameters of registered AE signals.

During tests, AE signal was registered at all stages of friction and wear and tear of the samples, including the stage of catastrophic wear and tear. Dependence of change of amplitude of the registered resulting signal is shown in pic.1.

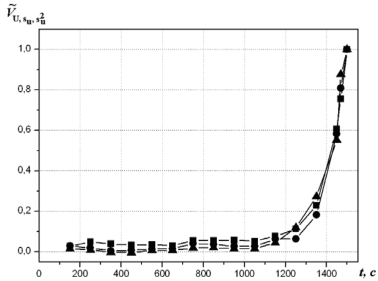


Pic.1 – Graph of dependence of change of amplitude of AE resulting signal in time in relative units during friction of samples surface layers with BK6 cover: 1 – stage of normal wear and tear; 2 – stage, which precedes catastrophic destruction of surfaces; 3 – stage of catastrophic wear and tear (destruction) of the surface layers; $\overline{U}$ – average level of amplitude of AE resulting signal, respectively.

Having looked at pic.1 it can be seen that AE resulting signal is permanent for given test conditions at all stages of wear and tear. Such AE signal can be characterized by average level of amplitude and value of its dispersion. At the stage of normal wear and tear of the samples (stage 1, pic.1) we can see gradual increase of average level of amplitude ($\overline{U}$) of AE resulting signal. By making the curve $\overline{U}$

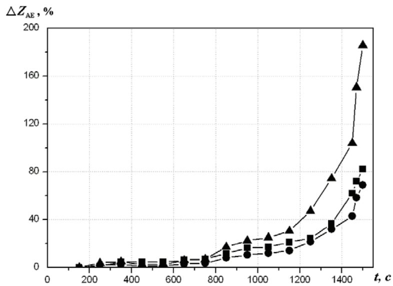
(pic.1), averaging time of amplitude of AE resulting signal was 15s. Increase of average level of AE amplitude can be observed at stages 2 and 3 (pic.1) as well. However, its increase is higher than at stage 1.

At the same time there is a peculiarity in character of change of acoustic radiation during transition to stages 2 and 3. We can observe the increase of not only average level of amplitude parameters of AE resulting signal but also values of their dispersion. Results of statistic of treatment of AE parameters at all analyzed stages in the form of a graph of change speed of average level of amplitude of AE resulting signal, and also change speed of its standard deviation and dispersion in time are shown in pic.2. Graphs in pic.2 are given in normalized units. By making the graphs (pic.2) length of the sampling for statistic analysis of the data with definition of change speed of average level of amplitude of AE resulting signal, and also change speed of its standard deviation and dispersion at stage 1 (pic.1) was 100s. At stages 2 and 3 (pic.1) length of sampling was 50s. Quantity of observed points was 10000 and 5000, respectively.



Pic.2 – Graphs of speed of change of amplitude parameters of AE resulting signal (pic.1) at stages 1, 2 and primary phase of stage 3 in time in normalized units during friction of the samples with BK6 cover: ■ - speed of change of average level of amplitude $\widetilde{V}_{\overline{U}}$; ● - speed of change of standard deviation of average level of amplitude $\widetilde{V}_{S_{\overline{U}}}$; ▲ – speed of change of dispersion of average level of amplitude $\widetilde{V}_{S^2_{\overline{U}}}$

Having looked at pic.2 it can be seen that at the stage of stable wear and tear (stage 1) speed of change of amplitude parameters of AE resulting signal are almost permanent. During transition to stage 2, that is the stage, which precedes the stage of catastrophic wear and tear, we can observe rise of speed of change of all analyzed AE parameters. Then we see rise of speed of change of AE amplitude parameters. But rise of speed of change of dispersion of average level of amplitude of AE resulting signal advances both: rise of speeds of change of average level of amplitude and speed of change of its standard deviation (pic.2). During transition to stage 3, rise of speed of change of dispersion of average level of amplitude of AE resulting signal becomes slower to other analyzed parameters. Such changes of parameters of AE resulting signal can be seen at dependencies of percentage increase of amplitude parameters of AE resulting signal in time (pic.3).



Pic. 3 – Graph of percentage increase of amplitude parameters of AE resulting signal (pic. 1) at stages 1, 2 and at the primary phase of the stage 3 in time during friction of the samples with BK6 cover: ■ - percentage increase of average level of amplitude ($\overline{U}$), its standard deviation ● ($s_{\overline{U}}$) and dyspercia ▲($s_{\overline{U}}^2$)

Having looked at pic.3 it can be seen that during friction and wear and tear of the samples with BK6 cover we can observe increase of amplitude parameters of AE resulting signals. Big percentage increase of analyzed parameters happens together with transition to the stage, which precedes the stage of catastrophic wear and tear (stage 2, pic.1). At the same time percentage increase of average level of amplitude of AE resulting signal advances both: percentage increase of average level of amplitude and percentage increase of its standard deviation.

Resume

We made experimental researches of AE during friction of surface layers, made of CM. All the received results showed rather good compliance with the results of theoretic researches [3]. It was determined that speed of change of AE amplitude parameters stays almost permanent at the stage of normal wear and tear of the friction assembly. However, transition of the friction assembly to the stage, which precedes the stage of catastrophic wear and tear, brings to increase of speed of rise of parameters of acoustic radiation.

References

1. Rubtsov V.E. The use of acoustic emission analysis for the wear in sliding friction / V.E. Rubtsov, A.V. Kolubaev, V.L. Popov// Letters to ZHTF. – 2013.- Vol. 4: 79–86.

2. Filonenko S.F. Simulation of acoustic emission signals in friction and wear surfaces of composite materials / S.F. Filonenko, A.P. Kosmach// Proceedings of the CSTU.-2013.-No3. – P. 88–96.

3. Filonenko S.F. Analysis of speed of acoustic emision parameters by friction of surfaces of composite materials / S.F. Filonenko, T.V. Nimchenko, T.N.Kositskaia // Proceedings of National Aviation University. – 2014. – №2(59). – C. 73 – 82.

UDC 004:37

V.V. Gavrylenko, Doctor of Physical and Mathematical Sciences (National Transport University, Ukraine, Kyiv)
P. Pavlenko, PhD in Sciences, prof. (National Aviation University, Ukraine, Kiev)
O.A. Galkin, Candidate of Physical and Mathematical Sciences (National Transport University, Ukraine, Kyiv)
O.P. Kovalchuk (National Transport University, Ukraine, Kyiv)

USING CLOUD SERVICES IN EDUCATIONAL PROCESS

Cloud computing is an emerging, on- internet such as, software, hardware, data storage and infrastructure. This paper presents the strict authentication system by introducing the multi-level authentication technique which generates/authenticates the password in multiple levels to access the cloud services.demand and internet- based technology. It provides variety of services over

Cloud computing technology is an open standard, service-based, Internet-centric, safe, convenient data storage and network computing service. Cloud computing is an internet-based model for enabling convenient, on-demand network access to a shared pool of configurable computing resources. It provides various services over internet such as software, hardware, data storage and infrastructure. Cloud computing providers deliver the applications via internet, which are accessed from web browsers, desktop and mobile apps. Cloud Computing Technologies are grouped into 4 sections: they are, SaaS, DSaaS, IaaS and PaaS. SaaS (Software as a Service) is an on-demand application service. It delivers software as a service over the Internet. It eliminates the need of installing and running the application on the customer's own computers. PaaS (Platform as a Service) is an on-demand platform service to host customer application [1].

PaaS is delivery of computing platforms and/or solution stack as a service, often consuming cloud infrastructure and sustaining cloud applications. It facilitates deployment of applications without the cost and complexity of buying and managing the underlying hardware and software layers. It improves the flexibility in having multiple platforms in business environment. DSaaS (Data Storage as Services) is an on- demand storage service. Cloud computing provides internet- based on demand back up storage services to a customer. In this service, customers can keep their data backup remotely over internet servers. These backup data maintenance is taken care by DsaaS service Provider. Cloud DsaaS service providers are responsible for keeping the customer data confidential. Here customers need not worry on setting up the large discs array to keep their huge amount of data. IaaS (Infrastructure as a Service) is an on- demand infrastructure service. It delivers the computer infrastructure – typically a platform virtualization environment – as a service, along with raw (block) storage and networking [2]. Rather than purchasing servers, software, data-center space or network equipment, clients can buy those resources as a fully outsourced service.

To access these cloud services securely, cloud authentication systems are using different methods like: i) Simple text password ii) Third party authentication iii) Graphical password iv) Biometric and v) 3D password object. The weakness of textual password authentication system is that it is easy to break and vulnerable to dictionary or brute force attacks. Third party authentication is not preferred for smaller cloud deployment. Graphical passwords have memory space that is less than or equal to the textual password space. Graphical passwords are based on the idea that users can recall and recognize pictures better than words. However, some of the graphical password schemes require a long time to be performed. Bio-metric authentications such as, fingerprints, palm prints, hand geometry, face recognition, voice recognition, iris recognition, and retina recognition, have been proposed in literature [3]. Each bio-metric recognition scheme has its own advantages and disadvantages based on many factors such as consistency, uniqueness, and acceptability. One of the main drawbacks of applying bio-metrics is its intrusiveness upon a user's personal characteristic. In addition, most bio-metric systems require a special scanning device to authenticate users, which is no applicable for remote and Internet users. 3D- password does not support the multiple levels of authentication. Another simple approach is to use one/combination of the above techniques in multi-level authentication, so that, probability of breaking such a password is reduced to a large extent. Hence it has motivated us to introduce a multi-level authentication technique in secure cloud transmission for ensuring the strict authentication [4].

This technique authenticates the cloud access in multiple levels. It generates the password and concatenates the generated password at multiple levels. Based on the leaf level concatenated password, one can access the cloud services provided that the password authentication is successful in all the previous levels. We study the architecture of multi-level password generation technique. This technique has two separate entities: i) Cloud service provider, who provides the cloud services and ii) Authenticated client organizations that access the cloud services (Before using cloud services, company authentication confirms with service agreement and other formal procedure from cloud vendors). This architecture helps in checking the authentication against the services and privileges. It also helps to ensure which customer has what kind of privileges to use cloud services. This is evaluated by multiple levels authentications. First level of authentication is organization level password authentication/generation. It is for ensuring the cloud access authentication from cloud vendor. If unauthenticated organization or hackers tries to access the cloud services, they are going to terminate in this level itself. Second level of authentication is a team level password authentication/ generation. It is to authenticate the team for particular cloud service. Like this, authentication system can have third, fourth, fifth etc level. Finally, the last level will be the user level password authentication/generation, which ensures that customer/end user has particular privileges and permission. We brief the activities of multi-level authentication system. Authentication activities take place in organization, team and user levels [5]. First activity happens at organization level. It reads the authentication password and checks to authenticate the organization for cloud access and then it enters into a second level authentication. The second activity happens at team level. It reads the team login details and checks for authentication. It is a team authentication activity, once authentication done; it then enters into a user level authentication [6]. User level activity reads the authentication information to check for the user per mission and privileges.

We present the data flow diagram and algorithm of multi-level password generation technique and show the DFD Level 0 for multi-level password generation and authentication system. Password generation will happen between the cloud service provider and cloud customer and then the password gets authenticated while accessing the cloud service. Then we show the DFD level 1 for the multi-level authentication system. This DFD describes detailed flow of password authentication process [7].

Conclusions. Cloud computing provides various internet-based, on demand services like software, hardware, server, infrastructure and data storage. To provide privacy services to the intended customer, it is a better option to use multi-level password generation and authentication technique. This technique helps in generating the password in many levels of organization so that the strict authentication and authorization is possible. The security levels of cloud environment can be further improved by multi-level of authentication. This is the future work of our research. Our future work will be carried out in adding multi-dimensional password generation method to multi-level authentication technique.

References

1. IEEE - The Application of Cloud Computing in Education Informatization, Modern Educational Tech... center Bo Wang, HongYu Xing.

2. Technologies cloud authentication system http://www.ca.com/us/authentication-system.aspx

3. X. Suo, Y. Zhu, G. S. Owen, “Graphical passwords: A survey,” in Proc. 21st Annual Computer Security Application. Conf. Dec. 5–9, 2005, pp. 463–472.

4. S. Wiedenbeck, J. Waters, J.-C. Birget, A. Brodskiy, and N. Memon, “Authentication using graphical passwords: Basic results,” in Proc. Human-Comput. Interaction Int., Las Vegas, NV, Jul. 25–27, 2005.

5. Fawaz A. Alsulaiman and Abdulmotaleb El Saddik,“Three-Dimensional Password for More Secure Authentication,” IEEE, http://ieeexplore.ieee.org., Last Updated – 6 Feb 2008

6. Cloud Computing services & comparisons http://www.thbs.com/pdfs/Comparison%20of%20Cloud%20computing%20services.pdf

7. A User Identity Management Protocol for Cloud Computing Paradigm Safiriyu Eludiora1, Olatunde Abiona2, Ayodeji Oluwatope1, Adeniran Oluwaranti1, Clement Onime3,Lawrence Kehinde apered in Int. J. Communications, Network and System Sciences, 2011, 4, 152-163

UDC 621.855.001.24

O.I. Pilipenko Dr. Sc., A. V. Poluyan Phd Student Eng.
(Chernihiv National Technological University, Ukraine, Chernihiv)
D. Barannik, graduate student
(National Aviation University, Ukraine, Kyiv)

3D MODELING OF EXPERIMENTAL STAND FOR RESEARCH N-MASS CHAIN TRANSMISSION

There are constructed 3D models of experimental stand of Fundamental Machine Design Department and oscillograms are analyzed by average value of the dynamic loading chain contours.

Application of modern of program complexes computer 3D modeling published in [1-3]. The software SolidWorks is equipped with the technology for fast detect basic tendencies of change of time series and determining the optimal solution with use minimum number of repetitions. Linear dynamic analysis is based on frequency investigations. Software calculates the reaction of model by means of summation influences of every mode (functions, equation) on loading [4]. The equations of motion are not only linked the parameters of mass, rigidity and damping, but depends on the coordinate system used to describe them. In cases where the linear dynamic analysis generates false results, such as a violation of the assumptions on which it is based, uses a non-linear dynamic analysis is based on the incremental method of managing loading. It is used to solve the problems of nonlinearity, caused by material behavior, large displacements and contact conditions.

In nonlinear dynamic analysis equation equilibrium of dynamic system in the time interval t + Dt, will have the form [4]:

$$[M]^{t+D_t}\{\ddot{U}\}^{(i)} + [C]^{t+D_t}\{\dot{U}\}^{(i)} + {}^{t+D_t}[K]^{(i)}\, {}^{t+D_t}[DU]^{(i)} = {}^{t+D_t}\{R\} - {}^{t+D_t}\{F\}^{(i-1)}, \qquad (1)$$

where $[M]$ – matrix of mass system;

$[C]$ – damping matrix of the system;

${}^{t+D_t}[K]^{(i)}$ – stiffness matrix of the system;

${}^{t+D_t}\{R\}^{(i)}$ – vector of external nodal loads applied;

${}^{t+D_t}\{F\}^{(i-1)}$ – vector of internal forces generated in the nodes upon repetition $(i-1)$;

${}^{t+D_t}[DU]^{(i)}$ – vector of nodal displacements at increasing repetition (i);

${}^{t+D_t}\{U\}^{(i)}$ – complete displacement vector to repeat (i);

${}^{t+D_t}\{\dot{U}\}^{(i)}$ – vector full speed on repeat (i);

${}^{t+D_t}\{\ddot{U}\}^{(i)}$ – vector of full acceleration on repeat (i).

Using implicit time integration schemes such as Newmark-Beta or Wilson-Theta and using the iterative Newton method, equation (1) has the form:

$${}^{t+D_t}[\overline{K}]^{(i)}\{DU\}^{(i)} = {}^{t+D_t}\{\overline{R}\}^{(i)},$$

where ${}^{t+D_t}\{\overline{R}\}^{(i)}$ – effective loading vector;

$$ {}^{t+D_t}\{\overline{R}\}^{(i)} = {}^{t+D_t}\{R\} - {}^{t+D_t}\{F\}^{(i-1)} + [M]\left(-a_0\left({}^{t+D_t}\{U\}^{(i-1)} - {}^{t}\{U\}\right) + a_2\,{}^{t}\{\dot{U}\} + a_3\,{}^{t}\{\ddot{U}\}\right) + $$

$$ + [C]\left(-a_1\left({}^{t+D_t}\{U\}^{(i-1)} - {}^{t}\{U\}\right) + a_4\,{}^{t}\{\dot{U}\} + a_5\,{}^{t}\{\ddot{U}\}\right) $$

${}^{t+D_t}[\overline{K}]^{(i)}$ – effective stiffness matrix;

$$ {}^{t+D_t}[\overline{K}]^{(i)} = {}^{t+D_t}[K]^{(i)} + a_0[M] + a_1[C] $$

a_0, a_1, a_2, a_3, a_4 i a_5 – constants implicit integration methods.

Iterative schemes for solving nonlinear dynamic analysis available: Newton-Raphson algorithm (NR) and variable algorithm Newton-Raphson (MNR).

In Fig. 1 and 2 are photos of the experimental stand [5] equipped a metal and polymeric chains and sprockets.

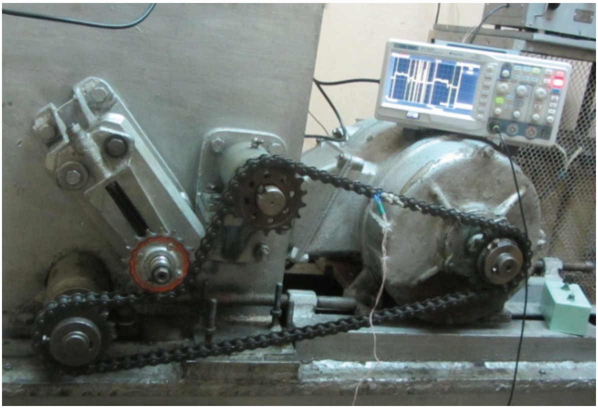


Fig. 1. The experimental stand is equipped with a metal chain transmission

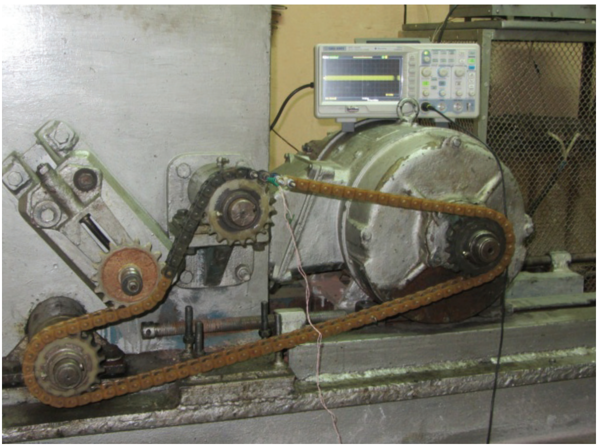


Fig. 2. The experimental stand is equipped with polymeric chain transmission

Construct a 3D models (Fig. 3, 4) of the stands represented in the photo (Fig. 1, 2), with the software SolidWorks.

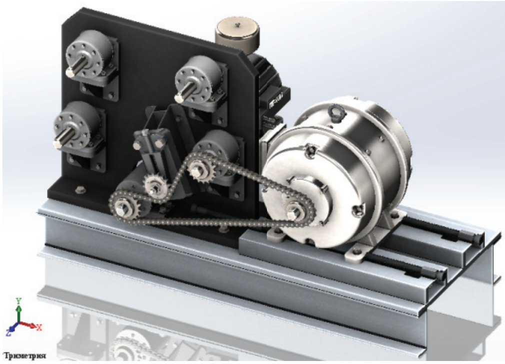


Fig. 3. 3D model of experimental stand in metal performance

Fig. 4. 3D model of experimental stand in polymer performance

Comparatives oscillograms theoretical (red curve) and experimental (blue curve) investigation the dynamic loadings in chain metal and polymer contours (Fig. 5, 6) are present.

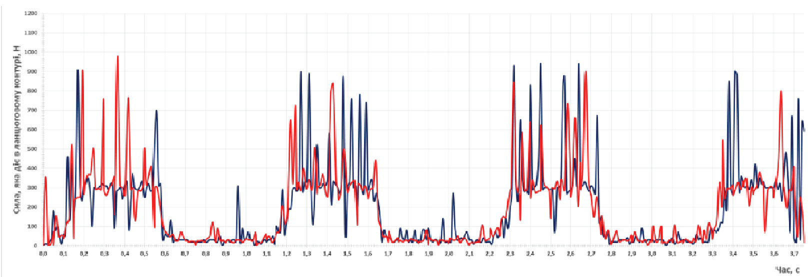


Fig. 5. Oscillograms theoretical and experimental investigation of the dynamic loading in contours in the metal performing

(mean experimental oscillograms – 191N, theoretical – 182N).

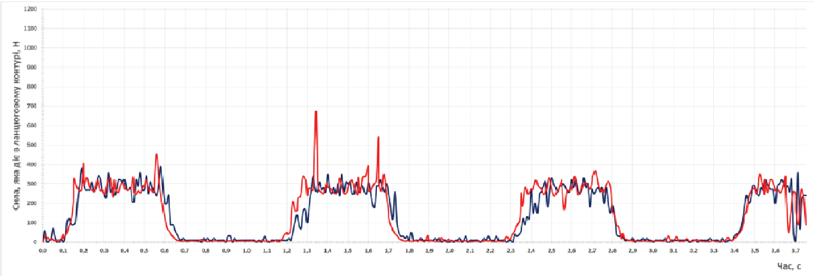


Fig. 6. Oscillograms theoretical and experimental investigation of the dynamic loading in contours in the polymeric performing
(mean experimental oscillograms – 128N, theoretical – 134N).

From the analysis of the mean oscillograms dynamic loading (Fig. 5, 6), it follows that the discrepancy data does not exceed 5%. Based on this is possible to consider expedient and effective use of software product SolidWorks for the investigation of chain contours of any complexity.

Conclusion

From the analysis of oscillograms dynamic loading of metal and polymer chain contours as a result of 3D modeling and of the experiment investigation, it follows expediency constructing 3D models and application them for further research because data discrepancy does not exceed 5%.

References

1. Пилипенко О.І., Полуян А.В. Комплексна оцінка аналізу руху ролика ланцюга за допомогою програмного продукту SolidWorks. Вісник ЧДТУ № 65(2), серія ТН. Чернігів. 2013.

2. Пилипенко О.І., Полуян А.В. 3D computer modeling of chain transmission in metal and polymer design. Вісник національного університету "Львівська політехніка" №772. Львів. Вид-во Львівської політехніки, 2013, С.89-97 ISSN 0321-0499.

3. Пилипенко О.І., Полуян А.В. Порівняльний аналіз динаміки ланцюгової передачі в металевому та полімерному виконанні. Вісник ЧДТУ № 67(3), серія ТН. Чернігів. 2013. – С. 15-21.

4. http://help.solidworks.com.

5. Пилипенко О.И., Лабудько В.А., Радченко С.В.Стенд для испытаний и исследований передач гибкой связью. А.с. № 1717988 Б.И. № 9, 1992.

UDC 681.518:629.1

Baranov G.L., Doctor of science in technology
(National transport university, Ukraine, Kyiv)
P. Pavlenko, Dr.Sci., prof.
(National Aviation University, Ukraine, Kyiv)
Tyhonov I.V., Doctor of Philosophy
(Kyiv State Academy of Water Transport, Ukraine, Kyiv)
Mironova V.L., Doctor of Philosophy (National transport university, Ukraine, Kyiv)
Prohorenko O.M. (National transport university, Ukraine, Kyiv)

VEHICLE TRAFFIC SAFETY CONTROL IN NON-STATIONARY ENVIRONMENT

The technology of modules solution integration for guaranteed vehicle safety control in the terms of combating factors of inhomogeneous and non-stationary environment is proposed. Multi-agents solutions due to the rational messaging improve the efficiency and safety of traffic in space and time

Nowadays high speed vehicle (HSV) acquire the rapid evolution in all types of modern transport, including space, air, water and land. Any HSV performs transport work in the terms of effect of non-stationary environment [1]. The main criteria of any HSV performance are: traffic safety (no accidents and disasters) on the positionally defined trajectory by the given route in the space-time continuum; life safety on biodiversity in the surrounding routes environment; economic performance safety (profitability) of multi-agents manufacturing organizations (MAMO) of intellectual transport systems (ITS). Removing the contradiction performance criteria, that conflict between the requirements of different MAMO, ergatic means of operative control, ITS participants, operating on the different levels hierarchical single process of interaction, is the main condition of synergetic (with out accidents, death and bankruptcy) effect ITS and set of HSV performance.

<u>1. Continuous Acquisition and Lifecycle Support – CALS</u> technologies are realized by the modern means of computer technique and information technologies on the all stages of any HSV life cycle and the centers of service routes and traffic of entire regions ITS [2].

<u>2. Conceptual analysis of activity components ITS.</u>

Every MAMO provides control of complex dynamic systems (CDS), which efficiently uses available resources (material, energy, information, materials - MEIM) according to informed PLM (product lifecycle management) decisions. Professional division of labor between existing MAMO should ensure synergic effect with integral indicators of functional stability of ITS with all HSV on the planned route of their movement. The expedition in different in different natural environments is prematurely interrupted due to emergency events, recorded by official statistical agencies [1,2]. objective causes of accidents and disasters primarily caused by errors or mistakes at all stages of the life cycle of technical objects. Known CALS technology of cross-cutting automate a significant amount of the functioning MAMO ITS still do not provide the desired level of efficiency received results for each lifecycle of ITS active component. The analysis determined the relevance of improving the efficiency of the dialogue interaction of intelligent agents and data integration tools derived by modes of distributed exchange of focused messages between ITS participants.

3. Architectural design based vehicle operation technologies.

CALC technology combines the principles, methods and tools of ergatic ITS computer and information technology use to perform functions of collection, storage, processing, transfer and use of data. Increase of productivity and efficiency of ITS CALS technologies focused on the following areas:

1. Integration of expert IAS knowledge to get the latest practical PLM solutions, that are able to quickly and flexibly generate targeted results for every problem.
2. Determination of the overall and intermediate objectives in obtaining objects of knowledge context and describe (LO – learning objects).
3. Formalization of task management using the grammar logic algorithms (GLA) with the standard algebra.
4. Harmonization of MAMO process software management based on directive-command and situational hierarchical description of problem situations using appropriate resources.
5. Optimization of information and computing technology to produce effective results in accordance with the wide range of requirements during their practical use
6. Automatically update the constructed joint interaction of program unit due to application terminal automatons (ATA) and human-machine interfaces (HMI).

Automation of technological interaction processes by CDS synergetic situation requires real knowledge of MAMO, HSV and ITS objects, their reflection in a distributed memory CALS availability components. The effectiveness of existing database management systems will be available, if source text - messages have LO common to HMI – ATA components interrelationships according to the rules of GLA algebra. Coded ontological concepts reflect the specific conditions of CDS components on every lifecycle support. System of rules based on combinations of standard and unified concepts improves efficiency of human and automaton intelligent.

Open system Interconnection for vehicle traffic control (VTC) in accordance with International Organization for Standardization procedures of vehicle navigation services forms available specific service management levels. The absence or little available service vehicle operation control generates errors of False Rejection (or Acceptance) rate. Under these conditions and active factors of the external environment Vehicle Collision Avoidance System is not able to guarantee the safety status projection demain. So the architectural design vehicle safety and security automation traffic control is constructed as a hierarchical, multi-channel and multimodal integrated system. The main components of such a system are: VMHS – Vehicle Message Handing System; VTC – Vehicle Traffic Control; VCAS – Vehicle Collision Avoidance System; VDCE – Vehicle Data Communication Equipment; VDLS – Vehicle Data Link System; VTM – Vehicle Traffic Management; VTS – Vehicle Traffic Service; VAC – Vehicle Administrative Communication.

4. The predicates algebra language as description instrument.

Product Lifecycle Management (PLM) ITS will allow to build the predicative representation [3] of non-obvious knowledge IAS. The Intelligence of CALS information technologies formalizes learning objects for two basic classes. Objective logic describes the facts in the form of elements of pre-selected universe U_{lo}

$$U_{lo} =< S_i, P_i, R_{ij} >, \quad (1)$$

where $s_i \in S_i, \forall i = \overline{1,n}$ - basic components that make up S_i;

$p_i \in P_i, \forall i = \overline{1,m}$ - basic properties and qualities of each component;

$r_{ji} \in R_{ij}, \forall i,j = n \times m$ – basic relation, communication, interaction between components, which implement technological operations.

Functional logic describes GLA due to another universe:

$$U_{flk} =< d_k, mo_k, ml_k, \delta_k >, \quad (2)$$

where d_k - specific unified and standardized trivial task under the theme of professional activities of IAS;

mo_k - corresponding formalized model that replaces concrete real objects for problem solving;

me_k - necessary reasonable and verifiable methods that guarantees the output data in a form of documented results;

δ_k - condition for activating the means for the automatic solution of this problem d_k by obtaining a given input data required forms upshot of this problem.

The experience of experts and professionals IAS $\in$ ITS integrates both parts and forms the single universe:

$$U_{ITS} = \{U_{loi}\} \cup \{U_{flk}\}, \quad (3)$$

Where P_o $(x_1, x_2, \dots x_l)$ - predicate operations on finite sets of variables that are pre-defined, classified and parameterized in the areas of task [3].

Predicates allow searching the required LO components in the single information model, which includes: a basic set of concepts; relations between the previous notions of summaries; templates - formalism for the characterization of existing knowledge of experts - professionals for the CALS technology use. Predicates are recorded according to formulas with basic algebra of logic elements and operations.

5. Required compatibility performance inteligence system

Automatic processing, computing and symbolic transformations require prior formation flow of compatibility progtams. Base flow determine sequences: IAS task; task complexes of components thematic areas combinatorial interaction; trivial tasks with resource data. A base flow management session is structured according to thematic areas [4]. Each session has fixed terms of start and end of program transformations. *Service Context* implements interactive work of IAS in order to form (input, control, unify) the typical human tasks. Essence features and specificity of HMI use determines vehicle sphere. User interface allows creating tasks for operational transport work as a transition from the current state to the future, taking into account existing constraints. Final state determines the mode of means guaranteed adaptive management response.

Service availability subject realizes approval task complex in accordance with structure diagram of component interaction. Limited space-time continuum characterizes lifecycle support.

Service decomposition program manages operation units. Model resource datas with the help of standard tools lets get and visualize the results. Display the user required results closes the cycle of three streams, and returns status *Service Context*. Hierarchical decomposition of command and policy management can have more levels of interaction. Between each pair of interaction levels is necessary to create templates for input and output interfaces. Total number of configuration interfaces requires testing and verification of logic circuits interaction. Intellectual level of the integrated system is formed by LO katalogues. Levels of decomposition for solving practical problems include conceptual, logical and physical Design. The quality of design required compatibility performance process determines the quality of product lifecycle management. The example of required software and hardware complexes integration into a single adaptive transport information and control system is given in paper [4].

Conclusion.

Based on considerations above the following combination can give useful results for improving safety, security and protection vehicle lifecycle in non-stationary environment.

At first, formal information CALs technology should be built and researched, which helps to identify all the links between the intelligence components learning objects vehicle traffic control.

Secondary, to improve the situation in the raising risk of accidents with the vehicle collision avoidance system should be carried out by learning objects in non-stationary environment.

References

1. Dovidnyk z bezpeky dorozhnoho rukhu. Oslo-Moskva-Helsinky, 2001, 751s.
2. Pryzhbyl P. Telematyka na transporte. Perevod s cheshskoho. Pod obshchey redaktsyey prof. V.V. Sylyanova / P. Pryzhbyl, M. Svytek. – M.: MADY(HTU), 2003 – 540s.
3. Bondarenko M.F. Moz·hopodobnye struktury: spravochnoe posobye. Tom pervyy / M.F. Bondarenko, YU.P. Shabanov-Kushnarenko: pod red. akad. NAN Ukrayny Y.V. Serhyenka. – K:Naukova dumka, 2011. – 460s.
4. Baranov H.L. Intehratsiya informatsiynykh tekhnolohiy na transporti:navch.posib / H.L. Baranov, S.A. Banishevskyy, V.L. Mironova, D.V. Pasechnyk. – K.:NTU, 2009. – 198s.

UDC 005.311.2:004.94

Andriy Khlevnyy (NAU, Ukraine, Kyiv)

THE METHOD OF ANALYSIS AND PERFORMANCE MANAGEMENT OF DISPERSED PRODUCTION PLANNING

The article presents a calculation method of management index, and offers a calculation model of the required number of experts for effective production planning. There was created a method of analysis and performance management of dispersed production planning.

Problem statement. The problem of determining management efficiency of production planning (PP) at domestic industrial enterprises is very important and requires an immediate solution. The use of modern information technologies and management approaches serves to improve the efficiency of PP system. At present time there are no means for analyzing and determining the efficiency of PP systems before and after the introduction of computer-aided management systems of PP.

Objectives: To present the results of theoretical and methodological researches on development of management tools of PP and define its efficiency at industrial enterprises.

Research results: Solving the problem of scientific analysis method development and performance management of production planning requires the implementation of several generalized stages. We will introduce the given stages in brief:

Calculating the span of control. PP management is a complex dynamic process which involves information, material and human resources. Their number and usage rate depends on the efficiency of PP. However, the existing calculation rates of resources and their control are out of date with the development of information technologies and do not meet the needs of time.

To solve the problem of calculating the rate for PP processes control we used a structural approach. The structural approach provides using of many concepts [1], but we distinguish two main concepts: division of labor and control coverage as critical ones for performance indices of subdivision work involved in PP and which have a direct impact on key performance index such as an average cost of developing a DED set (design-engineering documentation). As the components of this index is the number of relevant experts and indirectly the number of control levels that affects the rate of approval of documents and errors caused by a human factor.

The study of existing schemes of formal organizational structures of PP allowed to define main levels of horizontal and functional division of labor (Fig. 1).

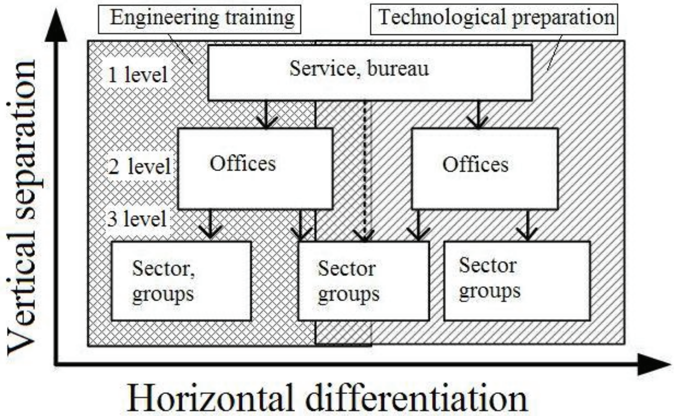


Figure 1. The division of labor when performing a function of production planning.

The purpose of vertical division of labor in the system of PP – is the formalization of relationship flow and authority which structure is used in PDM systems for workflow within the limits of mechanisms for approving PP documents.

Horizontal differentiation reflects the degree of division of labor between individual structural units within the upper level of PP functions, such division is presented by designing and technological preproduction. In modern PP systems an average degree of vertical division is equal to 3, and horizontally it can range from 5 to 15 organizational units. For describing the division of labor, we introduce a concept of organizational graph (Fig. 2) and organizational matrix (Table 1).

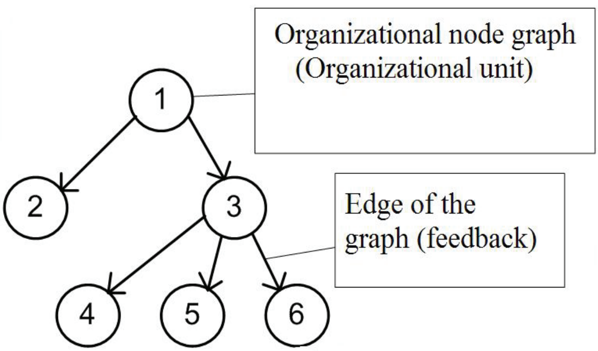


Figure 2. organizational graph

Formation of the organizational matrix is according to the rules of graph theory [2]:

1. Rectangular matrix, its dimension is determined by the number of organizational units

Table 1

Organizational matrix

	O_1	O_2	O_3	O_4	O_5	O_6
O_1	**0**	1	1	0	0	0
O_2	0	**0**	0	0	0	0
O_3	0	0	**0**	1	1	1
O_4	0	0	0	**0**	0	0
O_5	0	0	0	0	**0**	0
O_6	0	0	0	0	0	**0**

$\hat{I}_i, i = \{1 \div n\}$.

2. Main diagonal elements of the matrix are equal to zero $O_{ij} = 0, i = j$.

3. Elements that are at the intersection of organizational units, and which have a connection, equate to one. And horizontally there are elements above the level of subordination, that is we consider the connection from the first to the second and third one, from the third to the fourth one.

4. Number of connections - K_3 (one directional) in the organizational structure is equal to a half of the number of organizational matrix elements K_E which have the value -1 $K_3 = K_E, \{O_{ij} = 1\}$.

5. Number of control levels - (main index for building a workflow system using PDM systems) is the number of matrix rows $\kappa_O \{O_{ij} = 1\}$ in which there is at least one unit increased by one, $K_{PK} = \kappa_O \{O_{ij} = 1\} + 1$.

Control rate or control coverage is a quantitative index that describes the number of employees (size of the Organizational Unit) that are subordinated to one Manager/Head.

The most significant works in the field of control rates belong to B.Z. Mylner [3], who offered the following formula (1) to determine the number of potential relationships (contacts) of Manager/Head, depending on the number of subordinate employees (n):

$$K_{\hat{A}} = \frac{n \cdot 2^n}{2} + n - 1 \qquad (1)$$

However, formula application gives an idea of possible number of relationships and does not characterize their complexity, therefore we suggest to introduce the concept of management index I_K, which would take into account these aspects under the conditions of dispersed enterprises PP.

The model of interrelation "Manager/Head of the organizational unit – subordinate employee" can be considered as a combination of factors which describe the level of complexity of these interrelations. Taking into consideration the peculiarities of extended enterprises and analysis of corresponding models we suggest using the following factors on the definition of rating scales:

1. Geographical distance of subdivisions. Modern extended enterprise (or some of their subdivisions that fulfill the functions of PP) can be separated both within one enterprise and within the city, which greatly complicates the management process.

2. The uniformity of functions that should be controlled by Manager/Head of the organizational unit of PP.

3. The complexity of functions. Management is considered in terms of Manager's possible analysis of typical, standardized functions of subordinate employees, that is we examine the required level of competence and time necessary for management.

4. Management and control. The factor reflects the time spent by Manager/Head on management of subdivisions.

5. Coordination. We consider the aspect that takes into account Manager's load to coordinate the work of his/her subdivisions with other organizational units within technological process.

6. Planning. The factor considers management in terms of independence of divisional Manager concerning work planning of the organizational unit.

Management index is calculated according to the formula:

$$I_K = \sum_{i=1}^{6} g_i \cdot f_i \tag{2}$$

where g_i - weighting factors which are calculated using the pair-wise comparison [4]; f_i - points, assigned to each factor by experts $f_i = \{1 \div 5\}$ [4].

The level of control coverage is determined using management index (Table 2).

Table 2.

The level of control coverage depending on the management index

Management index, I_K	Standard coverage control, man	K_B, number of potential relationships, pcs	% times, spent in leadership positions
1	7-9	454-2312	50%
2	6-8	197-1431	40%
3	5-7	84-454	35%
4	4-6	35-197	30%
5	3-5	14-84	25%

Data concerning percentage of time used to organize the work of subordinate employees (management of the organizational structure) is used in the simulation model of experts interrelation in PP system of the expanded production as statistical data for modeling of information flows, processes for documents approval in PDM system in the course of mathematical description of corresponding functions by means of statistical models.

Input data for these calculations is the number of experts involved in PP as one of the key performance index. This number shall be calculated in accordance with the standards of designing and process flow documentation development.

Development of a calculation model to define the required number of experts in PP.

The number of employees engaged in PP depends on a number of factors: production volume, rate of introducing new product specimens to the market, condition of single information environment and software and hardware used to develop DED.

Majority of machine manufacturing companies during the period of late 90 's - early 2000's (approximately until 2006) in the framework of dynamic market practically abandoned planned management of economic and financial activity and, as a consequence work measurement of experts involved in PP in compliance with the standards established on the basis of industry-specific standards.

Planning was carried out mainly by means of managing salary budget, when some certain percentage from production volume was allocated for PP direction, and staff formation was based on the market value of experts (design engineer, production engineer).

However, processes of entering into overseas markets, introduction of modern information technologies, creation of united information space of PP within the framework of expanded production on the one hand created necessary conditions for the revision of planning approaches, and on the other hand allowed to use a new approach to this matter in connection with such possibilities, as documented «Work Flow» procedures in PDM systems that simplifies time tracking procedures required for the development of DED sets.

Let’s examine a model to determine the required amount of experts for product design and production engineering planning, on the basis of company planned target in respect of production output, taking into account inter-industry time standards for the development of design-engineering documentation.

The number of experts involved in product design and production engineering planning is calculated according to the formula:

$$C_{КТБ} = C_K + C_T + C_I \qquad (3)$$

Based on the formula 3 the number of employees who participate in documentation development can be conditionally divided into two groups: employees who are directly involved in the development of DED (4) and employees who perform managerial and administrative functions:

$$C_{K+T} = C_K + C_T \qquad (4)$$

Rate indices C_{K+T} and C_I o are connected by the coefficient η_1 , which in practice takes values from 0.10 to 0.20 that is weight rate percentage of employees engaged in performance management and administrative functions in the total number of employees of Bureau for Design and Technology is equal to 10-20%:

$$\eta_I = \frac{C_I}{C_К + C_Т + C_I} = \{0{,}1 \div 0{,}2\} \tag{5}$$

As a rule, calculation of employees number required for DED development is based on the nomenclature plan of products per year or the planned number of DED sets $N_{КТДП} = \sum_{i=1}^{n} N_{КТДП_i}$ and time of their development $T_{КТД} = T_{КД} + T_{ТД}$:

$$C_{К+Т} = \frac{N_{КТДП} \cdot T_{КТД}}{Ф_{РЧ}} \tag{6},$$

where $Ф_{РЧ}$ - fund of annual working time.

Further, according to the established company coefficient η_I based on the formulas 5 and 6 we determine the required number of employees engaged in managerial and administrative functions:

$$C_I = \frac{C_{К+Т}}{(1-\eta_I)} \tag{7}.$$

It should be noted that this approach gives a general idea about the required number of staff taking into account only working time standard and does not take into consideration the complexity of documentation, automating development aids and many other factors.

A model for determining the required number of experts, as a function of several variables can be represented as follows:

$$C_{К+Т} = f(П_О, к_П) \tag{8},$$

where $П_О$ - basic parameters of the project, which is being developed (Table 3);

$к_П$ - correction coefficients (Table 4)

Table 3

Basic project parameetrs

№	Name parameter	The range of the parameter
1.	Object design	Card numbers
2.	Design stage	According to the stages
3.	Category novelty	A-D
4.	The actual format	A0-A4
5.	Whole leaves	The actual value
6.	Group collapsible	I-IV

Table 4

Correction coefficients

№	Name of factor	The range of the factor
1.	Seriality production	1,0 – 1,2
2.	% adjustment (modification)	0,1 – 1,0
3.	Experience an employee	1,2 – 1,0
4.	Related work	1,0 – 2,1
5.	Features of Product	1,0 – 1,2
6.	Performance of frames and stamps	1,2 – 0,8
7.	Software	1,2 – 0,72
8.	Scale drawings	1,0 – 1,15
9.	Readiness drawings	0,6 – 1,0
10.	Density filling drawings	0,8 – 1,2
11.	% using the basic version	1,0 – 0,2
12.	Language requirement	1,0 – 1,5
13.	Using applications	0,15 – 1,0
14.	Combining drawings	1,0 – 1,15

It should be noted that basic project parameters $П_0$ define time rates t_n for developing documentation in accordance with the regulatory tables. Correction coefficients are used to take into account all design environment and formula 8 can be written as follows:

$$C_{К+Т} = \frac{\sum_{i=1}^{14} t_Н \cdot k_{П_i}}{Ф_{РЧ}} \quad (9).$$

It is important to note that the abovementioned coefficients do not take into account work features of experts involved in DED development in a single information field, which can significantly adjust coefficients 4,7 , which have one of the largest variation range.

Developing a method implementation algorithm.

Due to a large number of models, algorithms and approaches that are used for modeling and analysis of key performance indices in the course of PP within the framework of coordinated interaction between experts, the method of analysis and performance management of dispersed production planning was developed, this method logically combines the indicated interrelated modeling tools to assess the quality of PP management system. The method provides a preliminary analysis of enterprise production program and planned number of DED sets required in the reporting year according to the production program.

The next step is to analyze and calculate the required number of experts involved in PP in terms of direct development of DED sets. After complete calculation of the required number of experts involved in PP, it is necessary to make calculation and analyze control standards in the existing management system in accordance with the approved structure of subordination and interrelations, which are described afore.

As a result of calculations we obtain the management index and optimize the organizational structure of PP. Management index also allows to determine the statistical data regarding time of employment in the processes of approving documents and use them in simulation models taking into account daily schedule.

The following steps involve the development of six models which supplement each other and are the basis for filling attributes of seventh model eEPS. Exactly attributes of eEPS model allow to get value in the time of key performance indices and use them for calculating the efficiency of PP management system.

According to the algorithm of evaluation method for the quality of management system [5], which is added to general method of analysis and performance management [6], simulation modeling can be carried out both directly for determining the quantitative and qualitative changes in the system after the implementation of measures for its optimization and permanently to monitor the dynamics of efficiency index change in time for managerial decision-making.

Conclusions

We have developed the calculation method of control standards and management index, and offered the calculation model of the required number of experts for effective planning of dispersed production.

We have created and presented in the form of algorithm the method of analysis and performance management of dispersed of production planning.

References

1. *Жук К.Д.* Исследование структуры и моделирование логико-динамических систем/ Жук К.Д., *Тимченко А.А., Доленко Т.И. – К.: Наук. Думка, 1975. – 197 с.*
2. *Фрэнк Харари. Теория графов./ Фрэнк Харари . – Едиториал УРСС, 2003. – 296 с.*
3. *Б.З. Мильнер. Теория организации. Издание второе, переработанное и дополненное./ Б.З. Мильнер. –М.: ИНФРА-М, 2000.–655с.*
4. *Павленко, П.М. Метод відбору ключових показників ефективності технологічної підготовки виробництва / П.М. Павленко, А.О. Хлевний // Вісник інженерної академії України. – 2013. – №3-4. – С.189-194.*
5. *Хлевний А.О.* Метод оцінки якості системи управління технологічною підготовкою виробництва// Вісник Хмельницького національного університету – 2013. – №4. – С.85-92.
6. *P. Pavlenko* The method of analysis and performance management of dispersed production planning/ P. Pavlenko, A. Khlevnoj// Вісник НАУ 2014 №2.– С. 55-61

UDC 004.421:005.32:331.101.3:65(043)

S.V. Koziyakov (NAU, Kiev, Ukraine)

USING ARIS SIMULATION TOOLSET FOR MODELING THE PROCESS OF EVALUATING IT-SPECIALISTS' MOTIVATION TO WORK

The article represents the functional modeling of evaluating IT-specialists' motivation to work with the help of aris simulation tools which allow to describe the main elements of a new information technology.

An effective managing and high feedback from the staff are impossible without a targeted and skilful influence on the staff's motivation, without a high-quality system stimulating work. Developing and implementing the system of motivation any company wants to increase its efficiency.

An IT - specialist's type of motivation determines the range of his needs [1]. Every need is satisfied by an IT - specialist in different activities through using a variety of motivators. In such a way a relation exists between the needs of IT-specialists and motivators necessary for the stimulation of their work. For example, if an IT - specialist has an evident type of motivation in the form of award, the meaning of material motivators will outweight the meaning of social and psychological motivators which is proved by the corresponding range of needs.

An IT-specialist's efficiency of work depends on the structure of his inner motives (needs and values) as well as on the efficiency of the stimulating system which exists in this company.

To implement an effective motivation policy of managing the staff one should create a motivation mechanism which takes into account different factors. The motivation mechanism of a company is a complex system of motivating factors (motives) and of the ways to influence (stimuli) the staff to guarantee the achievement of the motivation policy's aims [2].

The mechanism of motivation should be developed taking into account the peculiarities of the staff which has their own needs, interests, preferences and values. This mechanism must take into consideration the existing structure of management, the factors which influence the company from inside and outside as well as the traditions formed in the company and the working experience.

That's why the process of evaluation an IT-specialist's work motivation should be developed and formalized in such a way that will allow to get the necessary information to choose this or that set of motivators. The choice must be made taking into consideration the prognosis of satisfying the needs of an IT-specialist with the help of the motivators set which is financed on certain levels.

The analysis done of functional possibilities of modern information technologies in modeling the working processes showed that the functional models made with the help of ARIS describe the working processes in a company with a fast changing incoming information most accurately. This means that the developed functional models will be oriented on modeling the object under the condition of changing the incoming data every now and then. According to the studies of foreign authors one can get the fullest functional modeling of working processes on the basis of ARIS eEPC (extended Event Driven Process Chain) notation. This is an extended notation describing the process chain which manages the events. ARIS – (stands for Architecture of Integrated Information Systems) is a methodology which integrates a set of various methods starting with the description of business processes to the realization of applied systems which in their turn automatize these processes. It also includes documenting data about the systems and their processes. This means that ARIS is a totality of information technologies and tools which provide the development and design of integrated systems for informational support of various production processes in managing and making decisions.

ARIS tool set represents a fulfiled methodology of formalizing the information about the company's activity and it also shows the information in the form of informational models which are good for understanding and analysis. One of the most important aspects in describing the models of production processes is the reflection of administrative influences, reverse connections in the control and management of the procedure on this model. The models created with the help of the mentioned tools reflect the existing situation in a company. The level of detailing depends on the aims of the project.

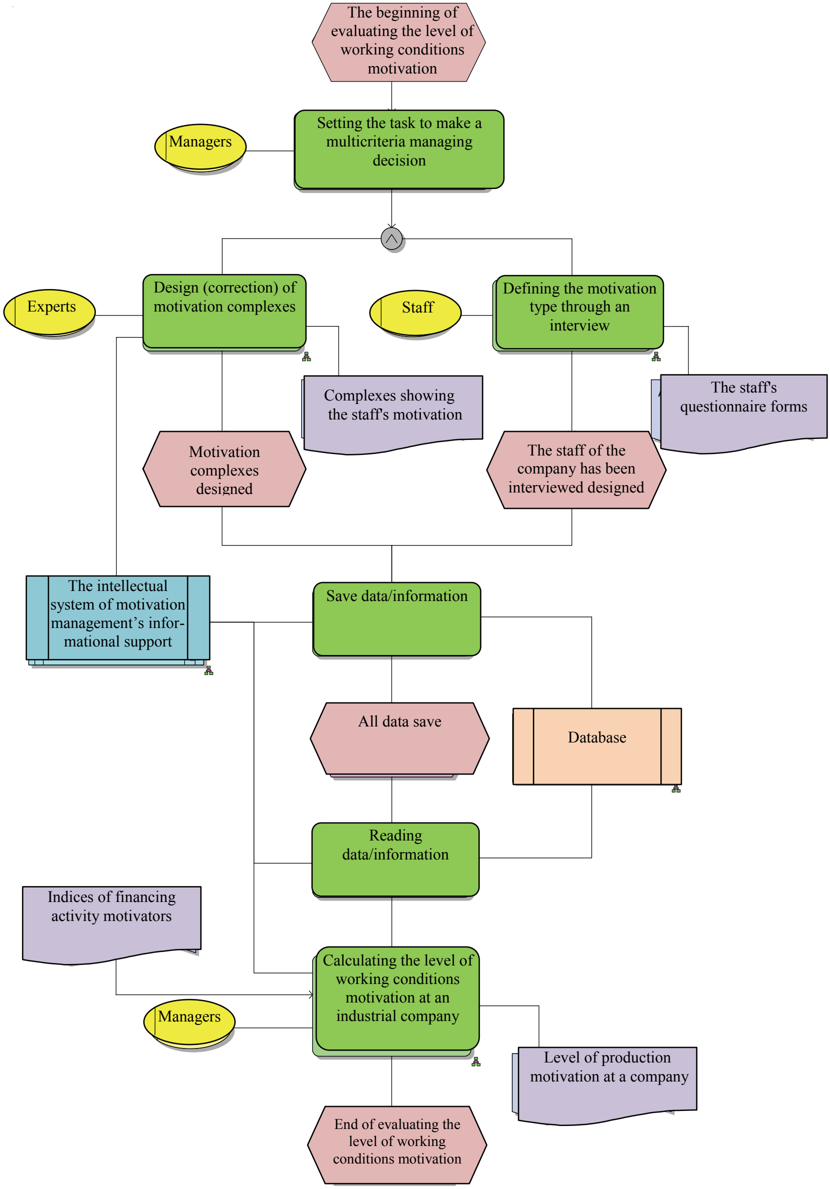
ARIS implements the principles of structural analysis when the company is looked at as a complex which consists of different components in structure and these in their turn have different connections between them. Therefore, the following instrumental tool allows to determine and represent in the models the main components of a company, active processes and the interconnection between all these components.

Evaluating the motivation of IT-specialists to work is aimed at defining the correspondence of the existing motivation set to the motives and expectations of IT-specialists. It is suggested to evaluate according to the method of multicriteria choice of motivation complex results. [3].

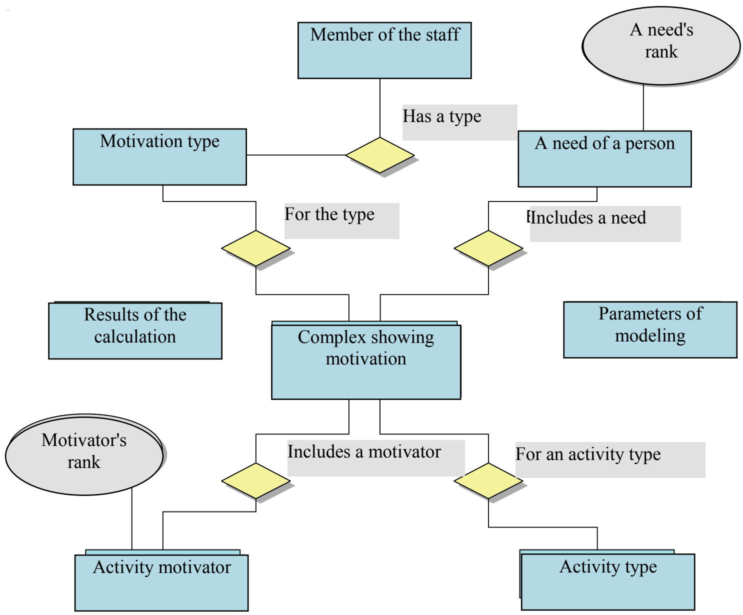
The functional eEPC model of the process of evaluating the staff's productive motivation with the help of ARIS Simulation is shown on drawing 1.

Three organizing items take part in the process of evaluating the IT-specialists productive motivation (see drawing 1): the staff (IT - specialists), an expert and a manager (director), each of them performs his own functions.

The interaction of the members in this process is provided by the intellectual system of informational support of the motivation management process which also provides storing and processing data according to the model represented in drawing 2.

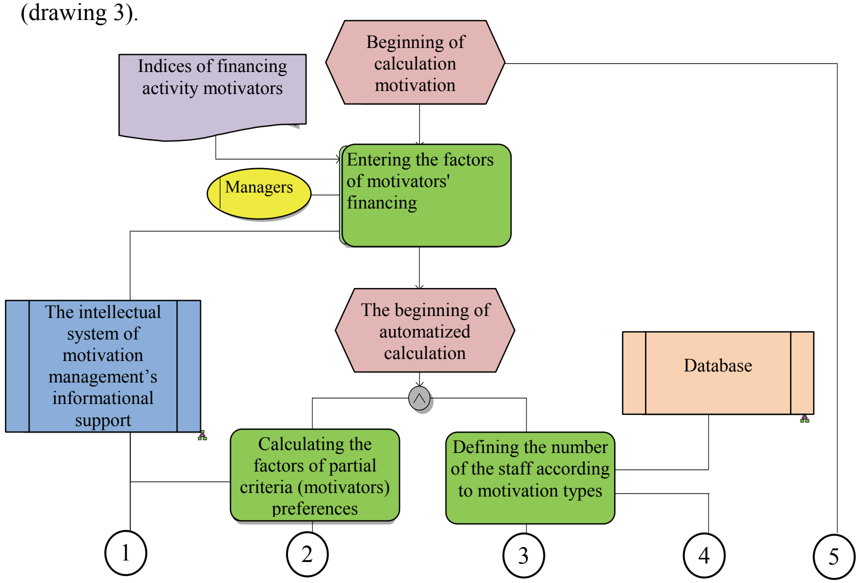


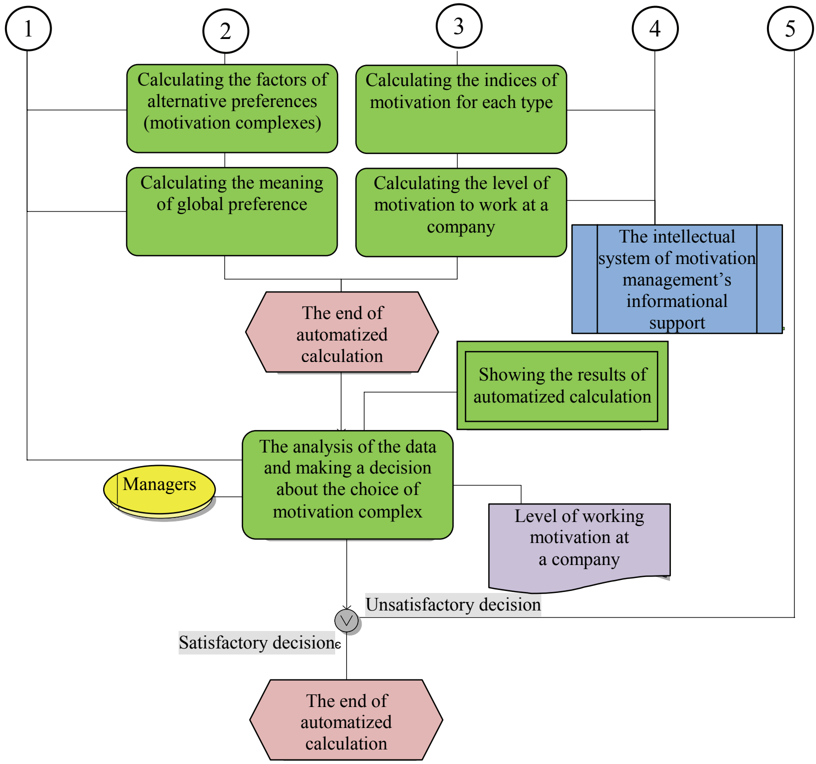
Drawing 1. The fragment of a functional eEPC model of the process evaluating IT-specialists motivation with the help of ARIS Simulation



Drawing 2. The conceptual model of the data in the process evaluating IT-specialists motivation in ARIS Simulation notation

The informational support of the motivation managing process needs the fulfillment of corresponding calculations. This is shown in the functional model (drawing 3).





Drawing 3. Functional eEPC model of automatised calculations of evaluating IT-specialists motivation carried out

Conclusions

The designed functional models of evaluating IT-specialists motivation with the help of ARIS Simulation tools give an opportunity to conceptually describe the main elements of a new information technology and define the list of necessary participants of the process, conceptual structure of data and the list of necessary automatic calculations for its usage.

References

1. Егоршин А.П. Мотивация трудовой деятельности/ А.П Егоршин // М.: ИНФРА-М, 2006. – 320 с.
2. Информационные системы и технологии в экономике и управлении: учеб. пособие / под ред. Проф. В.В. Трофимова. – 2-е изд. перераб. и доп. – М.: Высшее образование, 2007. – 480 с.
3. Павленко П.М., Козьяков С.В. Метод багатокритеріального вибору комплексу мотивації IT – фахівців промислового підприємства/ П.М. Павленко, С.В. Козьяков// Вимірювальна та обчислювальна техніка в технологічних процесах – 2013. № 4– С. 138-142.

UDC 004.94:378.14 (043.2)

Y.V. Vlasenko
(National aviation university, Ukraine, Kyiv)

METHOD OF ESTIMATING THE INTEGRATED COMPETENCE OF AN IT-SPECIALIST

The article describes a method of estimation and visualization of the results of evaluating (sub-) groups of attributes, which allows comparing equal competence of experts and calculating a generalized index termed "compliance coefficient".

The method of estimating the integrated competence of a technical specialist is based on using an individual staff competence model, which includes as components such feature vectors as: knowledge, skills and abilities (KSA); professionally important qualities (PIQ); and motivation (MT), with the possibility of viewing each of them in turn as a set of sub-attributes. Attributes can be measured using different scales. In particular, the biomedical and physical dimensions characteristics of PIQ are to be measured using an interval scale and/or absolute scale, for which there are computerized processing methods. The results of these measurements can be included in the data on which the decision regarding the level of competence of the technical specialist is made, either directly or subject to transformation into values of an average four-point scale.

Thus, it is possible to consistently process the results of performance during the acquisition of the appropriate technical profile, that is, professional education (marks in the diploma), expertise survey, testing, and certification, expressed as average estimates. The result of applying the model of individual competence of an employee should be a reliable conclusion as to compliance of the competence of the specialist (who is the object of analysis), to a reference value corresponding to the standard for the given technical profile, or a negative result.

To achieve this aim, an automated system of evaluation of competence (ASEC) has been developed, which actually is an expert decision support system (EDSS) constructed on the basis of an instrument shell and designed to assess the state of complex systems (objects) where a significant number of important factors is available, or on the basis of a personnel management system. In these circumstances, it is postulated that there are connections and interdependencies between the factors that may not have been clearly defined when beginning to use the system. The scheme of information links in the application of ASEC is shown in Fig. 1.

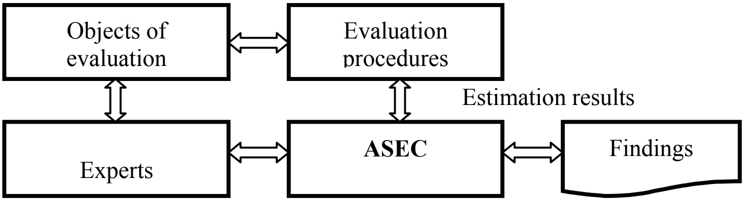


Figure 1 -The scheme of information links in ASEC

I. The source data for evaluation

For each of the technical specialists (object of comparison) that are undergoing competency assessment a personogram containing a set of attributes is completed. The values are the three groups of estimates obtained according to the average four-point scale (AFPS) or converted to its values.

The first group includes the overall results of the specialist's expert evaluation, which indirectly determine the level of knowledge, skills and abilities. This group of data reflects the personality traits such as intelligence, creativity, independent thinking, good memory, diligence and patience in achieving the goal, and the ability to apply their KSA in practice.

The second group of estimates is the results of expert evaluation of professionally important qualities (PIQ) of the specialist under evaluation. An example of a source of such assessments may be the so-called sixteen personality factors test by Cattell – a questionnaire of the level of subjective control.

The third group of estimates comprises the results of expert assessment of the motivational component. The most common methods for identifying staff motivation are interviews, tests and questionnaires. The interview may be conducted using the S.T.A.R. method. In Ukrainian testing practice, the most commonly used tests are such as the Smeykal-Kučer method of estimation, the method of "career anchors" by E. Schein, the method labor motive diagnosis by V. Gerchikov, etc.

II. Visualization of the results of evaluation evidence

Take a circle and divide it into n (number of partial indicators) sectors. For each of the objects of comparison (OC) mark the distance along the radius proportional to the values of the partial indicators vi thus obtaining a polygon. In the graphical representation of calculation results in MS Excel in the form of a so-called radar chart this polygon (Fig. 2) is a visualized image of the personogram of a specialist under evaluation or of any single feature vector that compose it. The area of the polygon can be calculated using the formula:

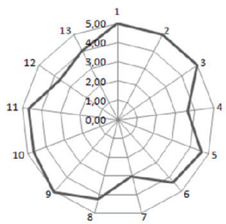


Fig. 2 – Radar chart estimation of the level of KSA

$$S_P = \sum_{i=1}^{n} S_i, \qquad (1)$$

where S_i – is the area of a triangle formed by connecting the adjacent values v_i and v_{i+1}.

To calculate the area of a triangle of arbitrary orientation, we'll use the calculation formula for a rectangular coordinate system:

$$S_\Delta = \left|\left[x_1(y_2 - y_3) + x_2(y_3 - y_1) + x_3(y_1 - y_2)\right]\right| / 2. \qquad (2)$$

If one of the vertices of a triangle, for example, the third, is located at the zero (origin) point, (2) is simplified:

$$S_\Delta = \left|x_1 y_2 + x_2(-y_1)\right| / 2. \qquad (3)$$

In a general case,

$$S_i = |x_i y_{i+1} + x_{i+1}(-y_i)|/2 \,, \qquad (4)$$
where $x_i = v_i \sin[\alpha(i-1)]; \quad y_i = v_i \cos[\alpha(i-1)]; \quad \alpha = 2\pi/n$.

The reference space in the form of a regular polygon inscribed in a circle with a radius corresponding to the maximum value vmax for the selected scale, is an ideal formalized image of a technical specialist – the benchmark. Its area SR can be calculated using formula (4), provided vi = vmax.

Compliance coefficient of the jth evaluated specialist to the ideal image is calculated as:

$$K_{CB_j} = S_{P_j} / S_R \qquad (5)$$

For example, for a certain technical specialist M., whose level of KSA was acknowledged as the best according to the results of testing (the test consists of 13 questions), the arithmetic mean of the estimates (AME) is equal to 4.38; the value of estimates measured by means of the average four-point scale are presented in Table 1, and the visualized results are shown in Fig. 2.

Table 1

The results of estimating the level of specialist KSA

№ of task	1	2	3	4	5	6	7	8	9	10	11	12	13
EAFPS	5,00	5,00	5,00	3,66	4,66	4,33	3,00	4,23	5,00	4,66	4,66	3,67	4,04

Calculated according to formula (5), the value of the coefficient of compliance Ксвj ≈ 0,77.

III. Data processing

Preprocessing of the collected and accumulated data on the specialist under assessment should provide for an analysis of information from all sources, its systematization and preparation for computerized processing by means of applications that are part of the software equipment of human resource system of the enterprise.

We use logical methods to describe the subject area and represent the model of the evaluated specialists data processing in the language of predicate calculus.

Let M = $\{m_j\}$, j = 1 ...,m be a set of technical specialists assessed per their level of competence; the potency or cardinal number of the set is equal to m. Each element mj of this set has a range of properties (attributes). Let us select the main ones and represent them as a set of attributes V = $\{v_i\}$, i = 1...,n; or example, professionally important qualities (PIQ) of the specialist: v_1 - discipline, v_2 - perseverance, v_3 - determination and so on. Then the set-theoretic language can be written: mj Є M and has the property $m_j|V(m_j)$.

In essence, each attribute is a linguistic variable: "discipline," "perseverance," "determination," and so on, which can be estimated within the range of the average four-point scale [2.00 ... 5.00].

We assume that the limiting value of the estimated fuzzy values is the number $\alpha \geq 4.00$, which in the theory of fuzzy sets is called the α-cut of the membership function. In other words, we assume that the assessment m_j Є M of an attribute vi, the value $\alpha \geq 4.00$ characterizes the best qualities of the specialist, while $\alpha < 4.00$ points to the contrary.

Consider the predicate $G(m_j(v_i))$ which means that a certain specialist m_j Є M has all n properties v_i Є V, that can be measured in the range [2,00... 5,00]. Then the axioms are true that define the groups of competent and incompetent specialists, respectively:

Axiom 1. $\forall m_j G(m_j(v_1 \wedge v_2 \wedge \ldots \wedge v_n) \geq 4{,}00) \rightarrow 1$;

Axiom 2. $\forall m_j G(m_j(v_1 \wedge v_2 \wedge \ldots \wedge v_n) < 4{,}00) \rightarrow 0$.

For the group of specialists of the required level of competence, processing continues. We write predicates according to the model:

Predicate 1. $\exists m_j \exists v_i G(m_j, v_1) \rightarrow 1$;

Predicate 2. $\exists m_j \exists v_i G(m_j, v_1 \wedge v_2) \rightarrow 1$;

Predicate n. $\exists m_j \exists v_i G(m_j, v_1 \wedge v_2 \wedge \ldots \wedge v_n) \rightarrow 1$

The sequence of further processing is as follows:

1. For each group (subgroup) of the set of equilibrium properties (attributes), the coefficient of competency compliance for the j[th] specialist is calculated as per formula (5):

$$K_{CB_j} = S_{П_j} / S_Э$$

2. A matrix V of m × k dimension is formed, where m equals the number of objects of comparison; k is the number of groups of (sub-)attributes (partial characteristics) of the objects of comparison.

3. The column vector R is calculated as the vector whose are components ($r_1 \ldots r_n$) by the expression: R = V×W,

where W is the column vector of the values of the weight factors of the characteristics, as determined by experts.

4. A specialist is selected whose expertise corresponds to the maximum value of the element from the column vector R; or several objects in the order of decreasing the values of the estimates of r_j.

In case the assessments of the r_j competence coincide for individual specialists under evaluation, a quasi-order of the elements of the set is formed, for example, for five evaluated specialists:

$$(m_1(R) = m_3(R)) > (m_2(R) = m_4(R)) > m_5(R).$$

The final rankings with some additional conditions will be presented as a series of advantages (for the same example):

$$m_1(R) \succ m_3(R) \succ m_2(R) \succ m_4(R) \succ m_5(R) \qquad (6)$$

Here the "$\succ$"sign denotes the relation of advantage.

5. The series of advantages (6) and the final statement about each of the specialists assessed concerning the levels of their professional competence are provided to the decision maker, as the output.

IV. Assessing the accuracy of the characteristics of the developed method

To estimate the accuracy of the proposed method we use reduced error as a limit for permissible basic error:

$$p = \Delta / X_N \, , \qquad (7)$$

where Δ is the absolute error of estimation results; X_N is the scale length.

In our case, the result of evaluation contained four significant digits, that is, any evaluation of the results (the coefficients of compliance) may be varied in the range of 0,6400... 0,9999 (XN = 0,9999 - 0,6400 = 0.3500) with an absolute error $\Delta \leq 0{,}0001$, and the reduced error is: $p = 0{,}0001 / 0{,}3500 \approx \pm 0{,}0003$.

With the same number of significant digits, the weight handling of medium and median estimates of the compared objects (results of the evaluation may vary in the range 4.000 ... 5.000) gives $p = 0{,}001 / 1{,}000 \approx \pm 0{,}001$.

Thus there is a notable three-fold advantage in the accuracy of the proposed method.

Sensitivity S characterizes the ability of any measurements interpreter to respond to changing input values and is estimated by the ratio of the output signal change Y_{out} to the input signal change X_{in}. Sensitivity is usually a dimensional quantity, which serves a variety of units that depend on the nature of input and output variables.

In general, sensitivity S is defined as a derivative of the transformation:

$$S = dY / dX \approx \Delta Y_{out} / \Delta X_{in} \, . \qquad (8)$$

It is apparent that sensitivity decreases with increasing the number of characteristics (partial performance), but is sufficient for differentiating the specialists by their competence, if any given assessment differs by ± 0.01 points.

Calculated values of similar characteristics for other methodologies of assessing the integrated competence of a technical specialist are not available in the literature that has been analyzed.

Conclusion

1 A method of estimation and visualization of the results of evaluating (sub-) groups of attributes has been developed, which allows comparing equal competence of experts and calculating a generalized index termed “compliance coefficient”

2 A method has been developed for estimating the rating technical specialists of a given enterprise based on a formalized model of processing the data about the employee being evaluated, which may reduce the subjectivity in assessing and comparing the selection of personalized data of personogram (the values of the results of expert estimation of individual parameters) according to certain rules and formulation of recommendations for decision makers.

3 Performance testing on real data has been carried out of the assessment method for integrated competence of technical specialists and its software implementation, which confirmed the possibility of ensuring objectivity during the proficiency test to determine the competence level of a specialist.

4 Characteristics of the proposed methodology have been evaluated (defining the error and sensitivity) and were found sufficient for practical application of the method.

UDC 004.056.5(045)

N.S. Pelikh (National Aviation University, Ukraine, Kyiv)

THE REALIBILITY MODEL OF INFORMATION SECURITY SYSTEMS

A reliability model of information security systems depending on the number of hacking attempts was created. The necessity of using multileveled information security systems was justified. A model of calculation the degradation of information security systems for the period of time since the development to the commissioning was created.

1. Introduction

With the proliferation of information technology, organizations are becoming increasingly dependent on information systems, and, consequently, more vulnerable to security threats. The network architecture of the distributed computing environment, came where the security depends on all items, as well as for its breach was sufficient to gain access to one of them.

The urgency of the problems of information technologies is the avowed that is confirmed by the large number of court cases regarding misconduct of information with restricted access. Different organizations have multi-million losses as a result of ineffective security of sensitive information. However, the analysis of statistical data on violations said about problems in this area, which in most cases are caused by flawed design and insufficient reliability of information security systems.

Nowadays, the importance of information security is not in doubt. All information security systems (ISS) must include adequate countermeasures of external and internal threats. Without a doubt, it to be an ISS complex, but at the same time, should involve the emergence of specific threats.

For the organization, which creates ISS, the prime interest has the investment value and the size of the theoretically possible information losses without any security. The financial costs and the size of the general damages of ISS hacking are also interesting.

2. ISS reliability calculation depending on the hacking attempts

Figure 1 includes calculation of ISS reliability [2] depending on the hacking attempts. The investments in the ISS are greater than or equal to the information importance. The reliability of ISS is shown as determined number of hacking attempts, when next attempt result does not depend of the previous ones. The ISS reliability determines on *m* hacking attempt is shown by the formula:

$$P(x) = (p_{xall})^{m-1} \cdot p_x = (\frac{x}{H+x})^{m-1} \cdot \frac{H}{H+x} \qquad (1)$$

where, p_{xall} is the value of ISS reliability;
m is a successful attempt to break into ISS;
H is the financial loss in the absence of ISS;
x is the investments to ISS at the level of reliability of p_x;
p_x is a level of reliability at the level of investment.

Figure 1 presents the value of ISS reliability *P(x)* by the formula (1). According to the calculation the curves $P_m(X)$ and *P(m)* fully match.

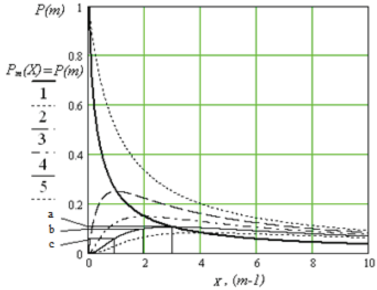


Fig. 1 – ISS reliability value *P(m)* depending on the *m* hacking attempts:
1 when $m = 1$; 2 when $m = 2$; … 5 when $m = 5$; $X = x/H$ – the value of financial loss;
$P_m(X)$ is the curve, which determines the maximum reliability value depending on the size of investments in ISS; *a, b, c* – the probability of *4, 3, 2* hacking attempts with the amount of investments in ISS which was calculated for 4 attempts of hacking.

Since the curve (fig. 1) is with the cost to breaking with the fourth attempt, the maximum probability of hacking have to spend $x=3H$. It is obvious that with this investment level, the hacking probability on the first attempt is minimal. The hacking probability on second (point b, fig. 1) and third (point b, fig. 1) attempts will increase. Opposite, if the organization invests in ISS, it will be more optimally the required cost for hacking with the fourth (point a, fig. 1) attempt, the probability of hacking will diminish, according to the curve, which is the maximum *(x=4H)* in the direction of increasing *x*. In this case, the probability of hacking protection on the fourth attempt will diminish depending on the investment.

3. Using the multilevel security for increasing the ISS reliability

Figure 2 presents the calculations result which proves that using of one-leveled ISS is totally ineffective, because even the endless investment in ISS upgrading can't guarantee the sufficient level of reliability. Minimum number of ISS that can be used to achieve the required level of reliability must be at least two. Using of multilevel security guaranties the increasing of ISS reliability with the same investment.

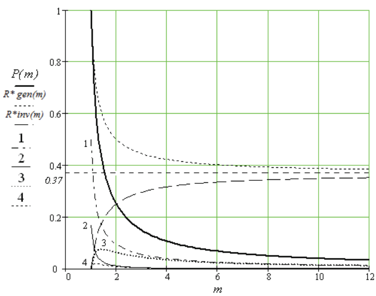


Fig. 2 – the calculation of ISS reliability with using the multilevel ISS;
P (m) is the curve, which determines the maximum value of ISS depending

on the attempts of hacking $m \geq 1$;
R^* *gen (m)* is the quantity of full losses after ISS hacking;
R^* *inv (m)* is the quantity of investments losses after ISS hacking;
1 – Quantity of the risk of losses when hacking two-leveled ISS R^* *gen (m1, m2)*;
2 – Quantity of the risk of losses when hacking three-leveled ISS R^* *gen (m1, m2, m3)*;
3 – Quantity of risks loss of investments in two-leveled ISS R^* *inv (m1, m2)*;
4 – Quantity of risks loss of investments in three-leveled ISS R^* *inv (m1, m2, m3)*.

In table 1 there are the numerical values of ISS that show the reliability of it hacking and general damages or loss investment only. The calculations are carried out for *m1=m2=m3=2*, i.e. hacking at each level from the second attempt. A justification for this assumption is related to the fact that the maximum probability of investment losses arises from the first to the second hacking attempts. So we can assume that for multilevel ISS the calculation of hacking into the second attempt for each level is sufficient. Unlike the case of one-leveled ISS, the probability of losing the investment for the nested ISS hacking at the endless attempts is reduced to zero. It should be noted that the increase in the size of the investment in ISS reduces not only the probability of complete loss, but also the most investment.

Security levels	The probability of losses	$m_1 = m_2 = m_3$					
		1	2	3	4	5	6
2	R^* *gen (m1,m2)*	0,5	9,4 10^{-2}	5,5 10^{-2}	3,9 10^{-2}	3,0 10^{-2}	2,5 10^{-2}
	R^* *inv (m1,m2)*	0	6.3 10^{-2}	4,4 10^{-2}	3,3 10^{-2}	2.7 10^{-2}	2,2 10^{-2}
3	R^**gen (m1,m2, m3)*	1,7 10^{-1}	1,0 10^{-2}	3,8 10^{-3}	2, 0 10^{-3}	1,2 10^{-3}	8,0 10^{-4}
	R^* *inv (m1,m2,m3)*	0	7,8 10^{-3}	3,3 10^{-3}	1,8 10^{-3}	1.1 10^{-3}	7,5 10^{-4}

4. The ISS reliability in time

The level of ISS reliability in time is also important [3] taking into account the of ISS degradation since the development to the commissioning. The reliability of ISS in time is indicated by the following formula:

$$(t_0 + t) \cdot p'(t) = f(t)$$

(2)

where, t_0 is the time since the creation of the ISS till the start of using;
t is the time within which the information is protected;
$p'(t)$ is the level of ISS reliability in time;
$f(t)$ is any positive function.

With the expression (2), we can say that for reliability ISS function protection risks $f(t)$ while increasing time for t must be at least constant. The decreasing of $f(t)$ in time means that ISS is not reliable and it must be upgraded. The increasing of $f(t)$ over time means that the ISS is more efficient.

Thus, if ISS is not certified in time for the assessment of the degradation it is necessary to consider the case where $f(t)$=*const*, which provides the lowest possible reliability in time. At the same time, the expression (2) can serve as a criterion of ISS reliability in time. If we know the $p'(0)$ at $t=0$ and probability $p'(t_1)$

after some time $t=t_1$, we can infer about the level of ISS reliability. Condition $f(t)=const$ responses the minimum required level of ISS reliability.

Figure 3 shows the dependency of probability of ISS hacking $P_m(t)$ with time and the number of attempts to break into the m attempt. The graph shows, when hacking attempts are increase the required time is reduced. As a result, with the same reliability level the probability of ISS hacking from first attempt are decreased.

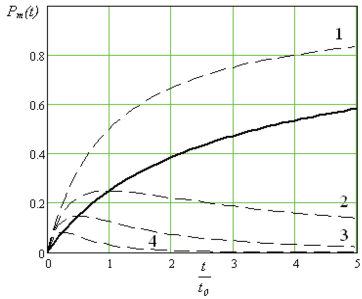


Fig. 3 – the dependency of hacking probability $P_m(t)$ from t/t_0 with $\alpha \approx 1$: curve 1 is the one attempt hacking to $m = 1$, the curve 2 – two attempts $m = 2$, curve 3 – three attempts $m = 3$, curve 4 - after five attempts at $m = 5$. Continuous line corresponds to the $P(t)$ is the maximum hacking probability.

5. Conclusions.

This article presents the results of the previous research on the techniques and improving the ISS reliability. An important role in the ISS development, according to the authors, has the level of ISS reliability depending on the number of hacking attempts; importance of using the multi-level ISS that provide solid protection of sensitive information; the optimum investments value for the ISS development. Cited research makes it possible to count the optimal ISS settings on the stage of development in order to identify and ensure the optimum level of reliability.

6. References

1. *Домарев В.В.* Безопасность информационных технологий. Системный подход / Домарев В.В. - К.:ООО «ТИД «ДС», 2004. - 992 с

2. *Журиленко Б.Є., Николаева Н.К., Пелих Н.С.* Оптимальные финансовые затраты и основные критерии построения или модернизации комплекса технической защиты информации // Правове, нормативне та метрологічне забезпечення системи захисту інформації в Україні: Науково-технічний збірник. – Київ, КПІ НДЦ «Тезіс», 2011. - Випуск 1 (22). - С.33-43

3. *Журиленко Б.Є., Николаева Н.К., Пелих Н.С.* Оценка стойкости технической защиты информации во времени / // Захист інформації: науково-технічний журнал. – Київ: НАУ, №1(54), 2012. с.104-108

Zaritskyi O., Phd (Firma "T.M.M." Ltd, Ukraine, Kyiv)
P. Pavlenko, Dr.Sci., prof. (National Aviation University, Ukraine, Kiev)
Sudik V., (Allbau Software Competence Center in Ukraine)

DEVELOPING ANALYSIS OF JOB COMPLEXITY FOR NEEDS OF NATIONAL TRADE MARKET

In article, the author describes in shot the main task and structure of job model for needs of Ukrainian trade market. The author have been working for a long time on the basic methods of functional job model, its components and main features of modeling process of complex social technical system «human-job» from the creative potential prospective.

Estimation of job complexity combine at least three areas of activity: job analysis, job descriptions and job specifications. Let's describe in short this three area for further expounding of main idea.

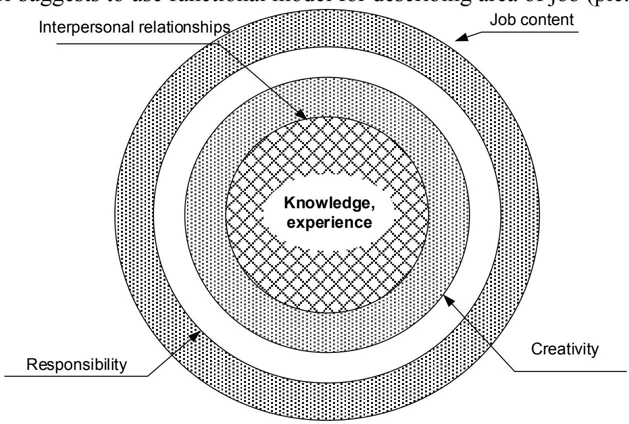
Job analysis is the procedure through which you determine the duties of these positions and the characteristics of the people to hire for them. As a rule information of job analysis used for writing job descriptions and job specifications.

Job description in common is a list of a job's duties, responsibilities, reporting relationships, working conditions, and supervisory responsibilities, as mentioned before one of products of a job analysis.

Job specification in common is a list of a job's "human requirements", that is, the requisite education, skills, personality, and so on — another product of a job analysis.

Having this income information, we can start procedure of estimation of job complexity. For fulfilling the procedure, we also need to have a mathematical model of job, algorithm of modeling and of cause, software for computerization such a difficult task.

Author suggests to use functional model for describing area of job (pic. 1).



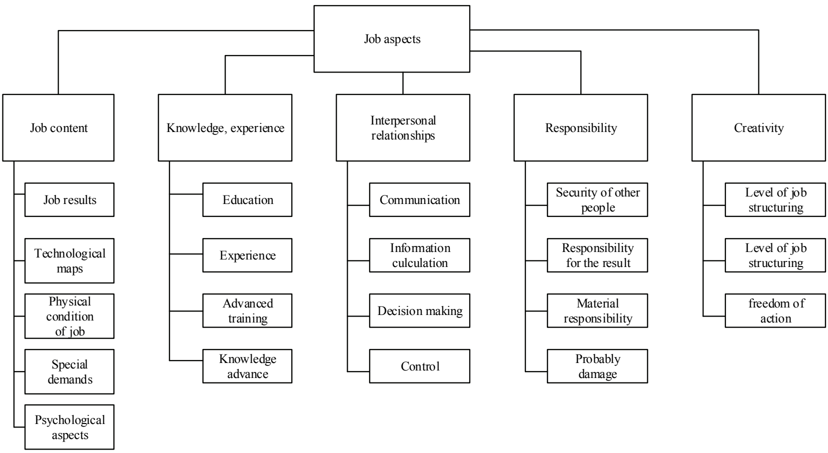
Picture 1. Functional area of job

Functional model describes entirety of functional subsystem, process and relationship between subsystems from the interaction, influence and information translation prospective. Functional model in common can be describe like functional areas, which describe job from such prospective: job content, creativity, knowledge and experience, responsibility and interpersonal relationship.

The worker-oriented approach to job analysis has been used for many years, and many standardized instruments that implement this philosophical approach to work measurement have been developed. These instruments have been used to address a variety of personnel needs, including grouping jobs for classification purposes, conducting synthetic (or job-component) validation studies (e.g., McCormick, 1959, and setting compensation rates [1-6].

The goal of "worker-oriented" job analysis is to be able to analyze -- and meaningfully compare -- even highly task- dissimilar jobs; this is accomplished by describing each job using a common profile, or metric, of work activities [7]

In mathematical model functional areas are described by author using equations in three-dimension area of aspects, which characterizes functional area with necessary level of detail. Structure of aspects present on picture 2.



Picture 2. Aspects of functions job model.

In common mathematical model can be presented like a function of five variables (aspects), which as well are functions of variable subfactors (aspects less levels) (1)

$$Q_p = f\left\{F_i f\left(sF_j\right)\right\} \text{ (1)},$$

Q_p - Quantity of points, which job were been estimated by experts according to special scales;

F_i - Job model factors (aspects), $i = \{1 \div 5\}$;

sF_j - Job model subfactors.

For the modeling, using mathematical model the experts normally collects one or more of the following types of information via the job analysis:

1.**Work activities.** First, collects information about the job's actual work activities, such as cleaning, selling, teaching, calculation or painting. This list may also include how, why, and when the worker performs each activity. As a rule each activity described by scale of importance.

2.**Human behaviors**. The specialist may also collect information about human behaviors like sensing, communicating, deciding, and writing. Included here would be information regarding job demands such as lifting weights or walking long distances.

3.**Machines, tools, equipment, and work aids**. This category includes information regarding tools used, materials processed, knowledge dealt with or applied (such as finance or law), and services rendered (such as counseling or repairing).

4.**Job content**. Included here is information about such matters as physical working conditions, work schedule, and the organizational and social context—for instance, the number of people with whom the employee would normally interact. Information regarding incentives might also be included here.

5.**Human requirements**. This includes information regarding the job's human requirements, such as job-related knowledge or skills (education, training, work experience) and required personal attributes (aptitudes, physical characteristics, personality, interests).

Conclusion. Aspects of functional job model can be used by information technology and mathematical specialists for developing software for implementation of mathematical model. Such kind of model will be useful for HR specialists for making job complexity estimation.

References

1. Ash, R. A., & Edgell, S. L. (1975). A note on the readability of the Position Analysis Questionnaire (PAQ). Journal of Applied Psychology, 60, 765-766.
2. Ash, R. A., & Levine, E. L. (1980). A framework for evaluating job analysis methods. Personnel, 57, 53-59.
3. Cornelius, E. T., & Hakel, M. D. (1978). A study to develop an improved enlisted performance evaluation system for the U.S. Coast Guard. Washington, DC: Department of Transportation.
4. Cunningham, J. W. (1964). Worker-oriented job variables: Their factor structure and use in determining job requirements. Unpublished doctoral dissertation, Purdue University.
5. Cunningham, J. W., & Ballentine, R. D. (1982). The general work inventory. Raleigh, NC: Authors.
6. Harvey, R. J. (1993, May). The common-metric questionnaire: Applications and current research. In S. Fine (Chair), Multipurpose job analysis: New approaches supporting integrated human resource management. Symposium presented at the annual conference of the Society for Industrial and Organizational Psychology, San Francisco.
7. McCormick, E. J. (1959). The development of processes for indirect or synthetic validity: III. Application of job analysis to indirect validity: A symposium. Personnel Psychology, 12, 402-413.

UDC 004.896: 629.3.081.4

M.V. Dvoieglazova, candidate of technical sciences (Chernigiv State Institute of Economic and Management, Ukraine, Chernigiv)
T. Zaharchuk, Research Associate
(National Aviation University, Ukraine, Kiev)

DETERMINATION OF EFFICIENCY OF FUNCTIONING OF THE INTEGRATED INFORMATIVE SYSTEM

Expedience of the use of method of DEA is considered for determination of efficiency of functioning of the integrated informative system, what skadaet'sya from the informative system of enterprise and informative system of project which will be realized on this enterprise. It is set that the use of method of DEA allows to promote quality of management the integrated informative systems. A method of DEA can be basis of the formalized method of research of efficiency of the difficult informative systems.

Today for effective realization of innovative and investment projects there is a necessity to unite the informative systems of enterprise and project in the unique an informative complex is computer-integrated with the purpose of increase of functioning and development of organization. As a result of association of two systems in the unique informative complex possible existence of great number of variants them the eventual state and to estimate efficiency each of them is a labour intensive enough task.

The row of attractive properties has a method of DEA, in a that number it:
- allows to calculate one agregirovaniy index of efficiency for every object, does not need here a priori task of weigher coefficients for variables used in an analysis [1,2,3]:
- does not have not what limits on the functional form of dependence between entrances and outputs, as kus eye-linear a limit of efficiency is non-parametric;
- a plural of effective objects is optimum after Pareto.

Tool, used for research of efficiency of co-operation of the difficult hierarchical systems, in our view, it is possible to divide levels into three:
- base tool: theory of plurals, theory of the graphs, mathematical programming, theory of diferenciaciynikh equalizations, statistical methods, and in.;
- the specialized methods are researches of efficiency, which are built on the basis of tool of the first level (for example, method of DEA, imitation design);
- methods which combine in itself the different instruments of the first two levels.

The choice of tool is determined a solvable task and level of complication of the probed system. A research method is presented [4].

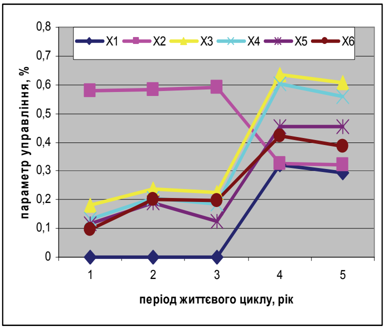
On the first stage of research it is necessary to conduct the capture of statistical data about the object of research. In quality an object the informative systems of enterprise (IS1) and informative system of project which will be realized on this enterprise are used (IS2). The systems are variables in time. That their functioning and co-operation for all life cycle of project is examined – 5 years (10 epoches).

On the second stage the estimation of dynamics of the informative systems is conducted in problem space by the construction of phase portraits of the systems. Thereon the stage the parameters of firmness of the systems, and presence in them of atraktoriv of the first family, are determined (to the type «center»). The offered tool is a mathematical design.

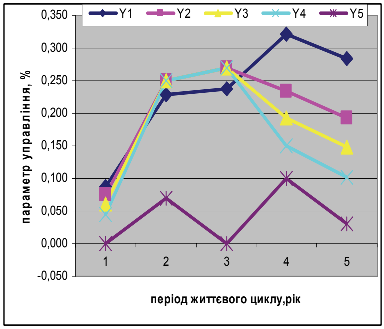
The estimation of co-operation of two informative systems is on the next stage conducted in their problem spaces. An instrument of analysis is a theory of the graphs.

Efficiency of functioning is estimated by the neuron model of co-operation of entrances/outputs of the separate systems. It is thus necessary to create the structure of neuron network and get management vectors and parameters of management the systems. An instrument is a neuron design.

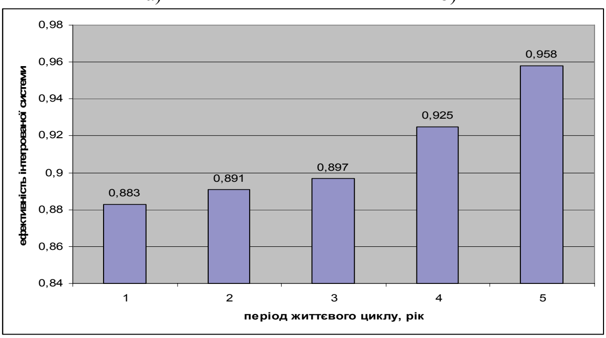
On fig.1 the presented dynamics of parameters of management the integrated informative system (a, b) which provide achievement of the maximally possible at the set terms effective state the integrated system (c).



a)



b)



c)

Fig. 1. Achievement of the effective state the integrated informative system: a) management the change of entrances of the system; b) management a change the outputs of the system; c) dynamics of maximally possible efficiency of the system

From to fig.1 evidently, that efficiency of the integrated informative system arrives at a maximal value on the fifth year of realization of investment project.

Estimating efficiency of the difficult system, which has a hierarchical structure, there is a problem of estimation of efficiency of subsystems on the different levels of hierarchy, and also problem of aggregation of estimations of efficiency of separate objects in the unique estimation of efficiency of the systems. Thus, a necessity appears for modification of the offered method for the decision of the put problems.

Conclusions

It is set that the use of method of DEA allows to promote quality of management the integrated informative systems. A method of DEA can be basis of the formalized method of research of efficiency of the difficult informative systems.

References

1. Cooper, W. W. Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References, and DEA-Solver Software / W. W. Cooper, L. M. Seiford, K. Tone.– Boston : Kluwer Academic Publishers, 2000. – 318 p.

2. Data Envelopment Analysis: Theory, Methodology, and Application / A. Charnes, W. W. Cooper, A. Y. Lewin, L. M. Seiford. – Boston : Kluwer AcademicPublishers, 1994. – 513 p.

3. Efficiency and Productivity Analysis in the 21st Century : Proceedings of International DEA Symposium (24–26 June 2002, Moscow, Russia) / Institute for Systems Analysis of Russian Academy of Sciences; Global S. Consulting Company.– Moscow : International Research Institute of Management Sciences, 2002. – 178 p.

4. Двоєглазова М.В. Управління інтеграцією інформаційних систем підприємства та проектів розвитку машинобудівної галузі: Дис. канд. техн. наук: 05.13.06. – Київ, 2012. – 207 с.

UDC 621.623

V.I. Kalchenko PhD in Science, V.V. Kalchenko, PhD in Science, A.M. Yeroshenko PhD in Science, A.V. Kolohoida (ChNTU, Ukraine, Chernihiv)

COMPUTER DESIGN OF FINISH PROCESSING OF NON-RIGID DETAILS

Educed features of finish treatment of non-rigid details of air-space, machine-building and other industries. Offer general methodology of computer design of processing polishing of non-rigid details. An algorithm over of creation of working model of the system "workpart - grain - copula" and results of calculation of proposed thermomechanical model are brought.

Requirements to exactness of sizes and quality of superficial layer of various details increase constantly, together with it an all greater value is acquired by the finish operations of treatment, such as grinding, tweaking, polishing and other. Unlike the operations of cutting by a bladed instrument, treatment an abrasive instrument is small investigational, by principal reason what stochastic character of process is. At abrasive treatment on the parameters of treatment considerable character influence, not only cutting modes but also choice of instrument and it description. Thus, for example, sizes, form and location of abrasive grains in a grinding wheel, and accordingly and cutting corners, have probabilistic character. In connection with what microcutting forces constantly change by value and by direction of action that especially negatively affects quality of treatment of non-rigid details. Thus, research of process of abrasive, finish treatment of non-rigid details is an actual task.

In air-space, machine-building and other industries non-rigid details are widely widespread such, as crankshaft and camshaft, compressor and turbine shoulder-blades, thecal forms, needle-shaped details and other. In work [1] investigational traditional processing schemes gas-turbine shoulder-blades and the new method processing of workers and base surfaces of shoulder-blade offers by an abrasive ribbon by means of robot with the system numerical control PM-01. A module 3D design of process of creation and removal of assumption is in-process conducted, the numeral values of cutting forces and their change are however certain in the process of treatment, a degree and form of deformations of shoulder-blade are not investigational in the process of polishing of internal and external profiles of peer and transitional edges.

In a number of works from the computer design of grinding process [2, 3] basic attention is spared to the structure and properties of grinding wheel, as the least proof link. As a result of researches methodologies of choice are offered as copulas, concentrations et cetera, from the terms of optimal firmness and turning of working surface of instrument. At a traditional mathematical and computer design the weak element of the working system is tools that tests most deformations and determines exactness of treatment, however at polishing of non-rigid details maximal size of deformations of it is observed exactly in a detail. Insufficient inflexibility of detail predetermines the necessity of application of additional equipment and specific charts of treatment, and also lays on a limit on the modes of cutting that diminishes the productivity usually. As known, complete deformation of purveyance during treatment for time unit is determined:

$$\varepsilon = \varepsilon_{elastic} + \varepsilon_{plastic} + \varepsilon_{creep},$$

where $\varepsilon_{elastic}$ – elastic component; $\varepsilon_{plastic}$ – plastic component; ε_{creep} – creep deformation.

The necessary condition of calculation is the use of terms of equilibrium, terms of compatibility of deformations, kinematics dependences between deformations and moving. At the computer design of treatment cutting, the process of destruction is examined as cyclic. A criterion for the removal of shaving accept by means of method of in good time certain surface

$$f = \sqrt{\left(\frac{\sigma_n}{\sigma_f}\right)^2 + \left(\frac{\tau}{\tau_f}\right)^2}, \ \sigma_n = \max(\sigma_2, 0).$$

Destruction arises up, at $f \geq 1$, in this case the resiliency of element equals a zero.

In basis of realization of method of complete elements in such software products, as ANSYS, LS-Dyna, Abaqus and other nonlinear mechanics of the tensely-deformed body, that is base on row of fundamental laws and equalizations, is fixed:

1. Law of maintenance of mass: $\rho \cdot J = \rho_0$, where $J = \det(F)$ – Jacobian, or relative volume presently to time; ρ, ρ_0 – accordingly actual and initial to the closeness of material; $F = \dfrac{\partial x_i}{\partial X_j}$ – gradient of motion.

2. A law of conservation of energy is on condition of absence of thermal sources: $\rho_0 \cdot \dot{\omega}^{int} = \dot{F} \cdot \sigma$, where $\dot{F}$ – speed of gradient of motion; $\dot{\omega}^{int}$ – speed of change of internal energy(internal power).

3. Law of maintenance of amount of motion: $\rho \cdot \ddot{u}_i = \rho \cdot f_i + \sigma_{ij,j}$, where f_i – closeness of by volume forces; $\sigma_{ij,j}$ – derivatives of part of component of tensor of tensions of Cauchies σ_{ij}.

4. Equalization of equilibrium $f = f_{load} + f_{contact} - I$, where f_{load} – a volume is erected and external, that operate on a body; $f_{contact}$ – erected forces and pin borders of body; I – internal forces.

5. Law of heat-conducting of Fourier $\rho \cdot C \cdot \dfrac{\partial T}{\partial \tau} = \dfrac{\partial}{\partial x_i}\left(\dfrac{\partial T}{\partial x_j}\right) + Q$, where $Q = \eta \cdot \sigma_{ij} \cdot \dot{\varepsilon}_{ij}$ – power of by volume and thermal sources.

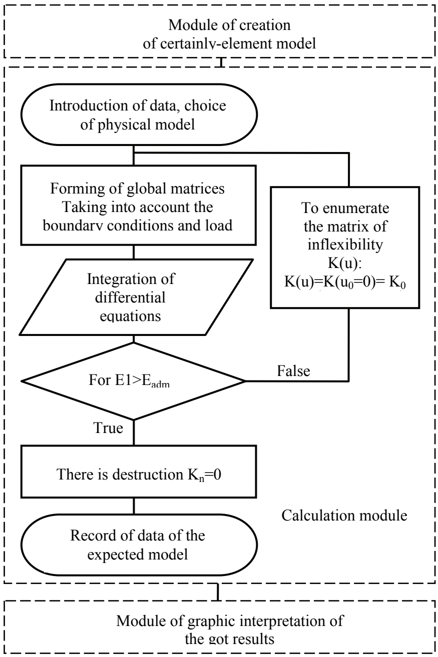
6. Maximum terms: $\sigma_{ij} \cdot n_i = P$ – forces are on the border of body, $u = U$ – moving is to the border of body, $(\sigma^+ + \sigma^-) \cdot n = 0$ – forces are on a pin border, at

$u^{+} = u^{-}$, $\lambda \cdot \dfrac{\partial T}{\partial x_i} \cdot n_i = q_s, T = T_s$ – thermal streams, or set temperatures on a border accordingly, where $q_s = \tau_n \cdot \dot{u}$. Together a thermal stream must be up-diffused between shaving, purveyance and instrument.

7. hypothesis of destruction, and law of friction $\tau = -\mu|\sigma_n|\tau_{max} \dfrac{\Delta \mathbf{v}}{\|\Delta \mathbf{v}\|}$.

Decisions carry out on the basis of continued model in approaches of Lagrang and Euler. General methodology of construction of complete-element model for the tasks of creation is driven to work [4]. With the aim of construction of three-dimensional model of the cutting system "workpart - grain - copula" it is expedient to use the system SolidWorks, the task of parameters of materials of tool and detail comes true in LSPrePost.

A block is a chart of realization of programmatic calculation on slave on scheme 1.

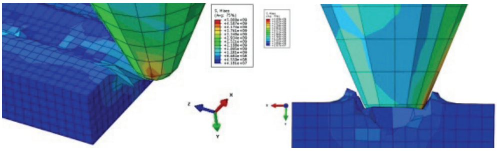


Scheme 1 – Flow-chart of computer design of finish processing

Will undertake a thermomechanical study of process of grinding of needle-shaped detail one abrasive grain. The resiliency of detail is determined by it geometry and method of fixing. The rightness of choice and construction of model of instrument influences on adequacy of design of process of finish treatment. In-process [3] but other similar, it is suggested to design abrasive grains in form rectangular parallelepiped, cone, spheroid, ellipsoid, octahedron and other In this case design of sharpening of needle-shaped surface abrasive tool with the middle size of grains of 160 micrometer, in quality of geometrical model of grain accept a cone with the radius of rounding at a top.

With the aim of the most complete reflection of terms of fixing of grain in a copula and grant to grain of necessary orientation will model a copula in a kind to the parallelepiped, choose properties of material of that most near to properties of ceramic copula. At creation of net of complete elements on the surface of instrument accept the size of elements of grain less than sizes of elements of copula, with the aim of reduction of machine time to the calculation of the system, and taking into account insignificant losses of exactness on a copula. Accept the sizes of net of detail variables, thus the size of her increases at remote from a zone treatments.

The results of calculation are brought around to scheme 2.



Scheme 2 – Results of calculation are on temperature and pin indexes

Conclusion

The features of finish processing of non-rigid details of air-space, machine-building and other industries are in-process analysed. Offer general methodology of computer design of treatment grinding of non-rigid details. An algorithm over of creation of working model of the system "workpart - grain - copula" and results of calculation of an offer thermo-mechanical model are brought.

References

1. Кальченко В.І., Кальченко В.В., Кологойда А.В., Кириенко С.Ю. Шлифование криволинейных поверхностей лопаток газотурбинных двигателей абразивной лентой при помощи робота с ЧПУ РМ-01. / Вестник двигателестроения: Научно-технический журнал – Запорожье ОАО «Мотор Сич», 2012. – №1 – С 181-185.

2. Бабенко Е.А., Федорович В.А. 3D моделирование процесса алмазного шлифования методом конечных элементов. // Резание и инструмент в технологических системах: Междунар. науч.-техн. сб. – Харьков: НТУ «ХПИ», 2010. – Вып.78. – С.15-23.

3. 3D-моделирование алмазно-абразивных инструментов и процессов шлифования: Учебн. пособие / А.И. Грабченко, В.Л. Доброскок, В.А. Федорович. – Харьков: НТУ «ХПИ», 2006. – 364 с.

4. Криворучко Д.В., Залога В.А., Корбач В.Г. 3D Моделирование рабочих процессов резания методом конечных элементов. / Уч. пос. Сумы, 2008, – 326 с.

UDC 621.623

V.I. Kalchenko, PhD in Sciences, D.V. Kalchenko, (ChNTU, Ukraine, Chernihiv)

3D-MODELING DESIGN OF MAIN AND ROD JOURNALS WITH CROSSED AXES CRANKSHAFT AND CIRCLE GRINDING PROCESS

Based on research of developed 3D-modeling prototypes, a new method was introduced providing the technology of main and rod journals with crossed axes crankshafts and circle grinding process in one setting, which provides stabilization of allowance removal and feeding on a circuit.

Requirements for precise machining of crankshafts used in automotive, aircraft, tractor, shipbuilding and other modern engineering industries are constantly increasing. It also should be provided high performance processing, which requires the development of more effective all-purpose crankshaft grinding techniques.

For the first time machining of main and rod journals in one setting was introduced by the company Junker (Germany) [1, 2]. Machining of main journals is like on a grinding machine. When machining of rod journals its contact with the circle occurs due to reciprocating motion in a plane passing through the axis of tool and crankshaft rotation which provides journal running per one workpiece cycle. During crankshaft rotation contact point wheel with the workpiece is out of the plane passing through the axis of tool and workpiece rotation, which leads to a change in the insert depth, and it is always larger than the allowance removal. This results in uneven allowance removal, reduces productivity and performance of machining.

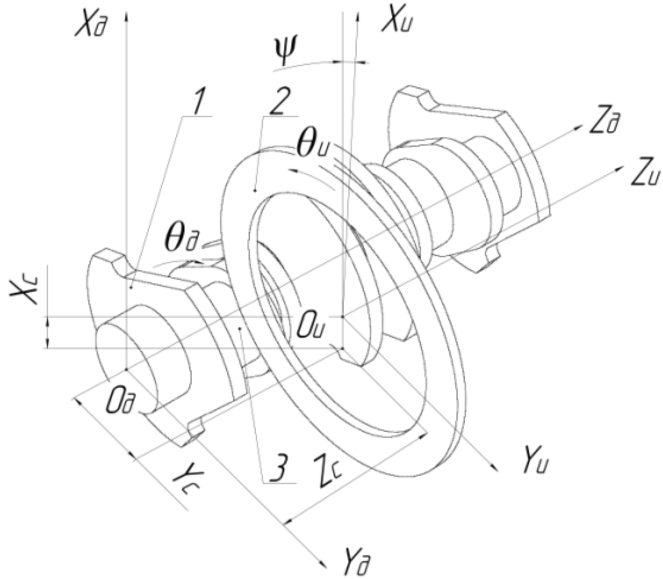
The aim of this work is to improve the performance and accuracy of main and rod journal machining in one setting by a narrow circle of supersolid materials at high speed deep grinding with crossed axes of the tool and the crankshaft due to stabilization of cutting depth stabilization, circuit feeding and allowance removal area at a uniform workpiece rotation. This can be achieved by synchronous vertical and transverse movements of the grinding wheel in case of rod journals machining.

The scheme of the new method of main and rod journals with crossed axes deep grinding 2 and workpiece 1 (Fig. 1), which after tapping, roughing allowance is removed with wheel face due to the longitudinal displacement, and finish grinding of main and rod journals are performed by periphery. The use of narrow circle provides versatility. Since the forces act towards the axial direction – the direction of maximum stiffness of crankshaft, it improves machining performance.

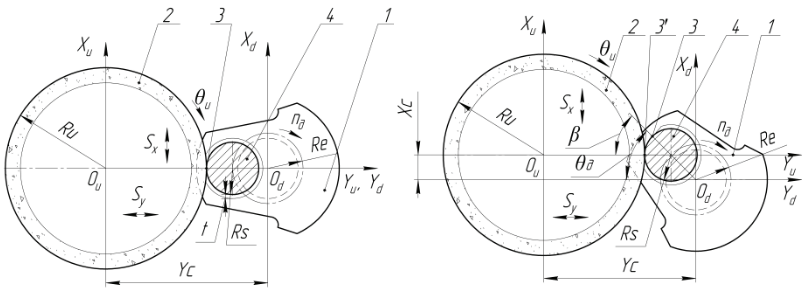
At a uniform rotation of the crankshaft 1 by an angle θ_∂ (Fig. 2, б) the point of contact with 3 laps 2 workpiece 1 moves at an angle $\beta=\theta_\partial$ from the horizontal plane of the rod journal 4. Due to synchronous vertical and transverse movements of the grinding wheel a constant cutting depth t (Fig. 2a) (depth is equal to the allowance), the circuit feeding and allowance removal area is provided. This improves the machining performance and quality. Circuit feeding is equal to

$$S_к = R_S \cdot \beta, \tag{1}$$

where R_s – semidiameter of rod journal crankshaft (Fig. 2, б); β – angle between contact points 3 та 3'.



Scheme1 – The design scheme of crankshaft grinding



a b

Scheme 2 – Scheme design rod journal new method

Semidiameter-vector of the machined crankshaft surface is described by the product of the crankshaft tool module, orientation and shaping module. [4, 5]

(2)

where $C^{u}_{Z_u(i)\cdot\theta_u\cdot R_u(i)}$ – cylinder module tool surface; – spherical module orientation of the grinding wheel on the workpiece coordinate system; – forming a cylindrical module, which defines the movement of the tool relatively to the workpiece; subscript ψ, x_c, $z_д$, $\theta_д$, y_c, $z_и(i)$, $\theta_и$, $R_и(i)$ – reasons of one-coordinate matrix.

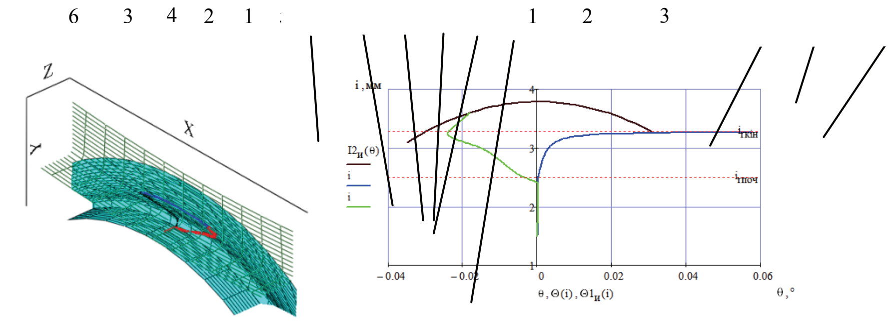
The workpiece surface depends on 6 parameters. These equations illustrates

$$z_\partial = \theta_\partial \cdot p, \quad (3)$$
$$X_c(\theta_\partial) = R_e \cdot \sin\theta_\partial, \quad (4)$$
$$Y_c(\theta_\partial) = R_u + R_s + R_e \cdot \cos\theta_\partial. \quad (5)$$
$$\overline{V} \cdot \overline{n} = 0, \quad (6)$$

where Re – the eccentricity of (the semidiameter rotation of the rod journal relatively to the main journal axis of the crankshaft); Ru – semidiameter of the grinding wheel; $\overline{n}$ – the unit vector normal to the surface of the tool; $\overline{V}$ – the relative velocity vector tool in the workpiece coordinate system.

Contact patch of cervical grinding wheel 4 under the machining of the cylindrical portion is shown in the Scheme 3, and by the intersection 1, 2, 3 based grinding wheel 6 and the end of the workpiece 5.

The Scheme 3b shows the lines : 1 – the intersection of the grinding wheel and the workpiece end; 2 – the intersection of the outer cylinder and workpiece grinding wheel; 3 – contact [5, 6].



a b

Scheme 3 – Intersection of the grinding wheel and shaft journal
a – contact patch of a workpiece with grinding circle
b – intersection line of grinding wheel and shaft journal

Specific grinding performance Q(i) is calculated by the formula

(7)

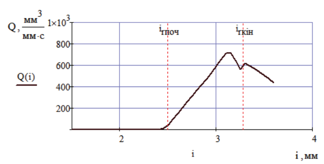
where Vn – the projection of the relative velocity in the direction normal to the surface of the circle; Rи (i) – i-semidiameter of grinding wheel; θ1(i), θ2(i) –entry and exit angles of grinding workpiece wheel.

Contact area S is derived from the equation

$$S = \int_{i1}^{i2} \int_{\theta 1(i)}^{\theta 2(i)} Ru(i) d\theta di, \quad (8)$$

where i1, i2 – limits of intergration.

The Scheme 4 shows specific capacity deployed on the x-axis which coincides with the periphery of the circle.



Scheme 4 – Distribution of the specific grinding performance under shaft journal machining

Conclusion

Three-dimensional geometric modeling of the tools is proposed as well as allowance removal and shaping of main and rod journals of crankshafts based on three standardized modules: the instrumental one, orientation and formation. Based on research modeling prototypes, a new method was introduced providing the technology of main and rod journals with crossed axes crankshafts and circle grinding process in one setting, which provides stabilization of cutting depth, feeding on a circuit and allowance removal area at uniform workpiece rotation. Machining is performed by one narrow wheel improving versatility of new technology and enables to machine main and rod journals of various crankshafts.

This technique can be applied to various complex profile cylindrical surfaces with crossed axes of the tool and workpiece grinding processes.

References

1. Шлифование коленчатых валов кругами из кубического нитрида бора// Проспект фирмы «Junker maschinen» на станки «JUCRANK 1000», «JUCRANK 3000», «JUCRANK 5000», «JUCRANK 6000». Erwin Junker. Maschinen fabric Gmbh, Junkerstraβe 2. 77787 Nordrash. Germany. 2006, 8с.

2. CBN crankshaft grinding// Prospect firm «Junker maschinen» on machines «JUCRANK 1000», «JUCRANK 3000», «JUCRANK 5000», «JUCRANK 6S/L/XL». Erwin Junker. Maschinen fabric Gmbh, Junkerstraβe 2. 77787 Nordrash. Germany. 2012, 12p.

3. *Решетов Д.Н., Портман В.Т.* Точность металлорежущих станков. – М.: Машиностроение, 1996. – 336 с.

4. *Грабченко А.И., Кальченко В.И, Кальченко В.В.* Шлифование со скрещивающимися осями инструмента и детали (Монография). – Чернигов: ЧДТУ, 2009. – 256 с.

5. *Кальченко В.И., Погиба Н.Н., Кальченко Д.В.* Повышение производительности и точности шлифования со скрещивающимися осями эльборового круга и ступенчатого валика. // Резание и инструмент в технологических системах. Межд. научн.- техн. сб. – Харьков: НТУ «ХПИ» . – 2011. Вып. 80 с. 131-140.

6. *Кальченко В.І., Кальченко Д.В.* Модульне 3D-моделювання інструментів, процесу зняття припуску та формоутворення при шліфуванні зі схрещеними осями ступінчастого вала і круга. // Вісник Чернігівського державного технологічного університету. Серія «Технічні науки» : науковий збірник / Черніг. держ. технол. ун-т. – Чернігів : Черніг. держ. технол. ун-т, 2013 №3 (67). –291 с.

UDC 621.923.42

Y.Zharii, candidate of technical sciences
H.Veremei, senior lecturer
(Chernihiv National University Of Technology, Ukraine, Chernihiv)

THE GEOMETRY MATHEMATICAL MODELLING OF THE OVERHAULED VALVE-SEAT SURFACES IN THE VALVE TIMING GEAR

The analytical methods within geometry modelling of the overhauled valve-seat surfaces in the valve timing gear have been considered. The mathematical model to analyze the state of the working valve-seat surfaces under the wear for the purpose to form their parameters of quality within overhaul's process has been offered.

Generalized 3D - model of the forming process for the valve seat worn surfaces of the valve timing gear in the overhauled repair requires the development of a mathematical model describing the geometry of these surfaces.

The general processing scheme of a valve seat under the wear with description of the constructive and geometrical parameters of the metal-working equipment, affects the quality of the overhaul's process, was submitted in the articles [2, 5].

To describe the surface's state of a worn valve seat [7, 8] the usage of spatial equation in explicit form $z = f(x, y)$ is proposed. Wherein the analytical model of the surfaces is constructed as a generalized polynomial

$$Q(x, y) = \sum_{k=1}^{n} c_k \cdot \varphi_k(x, y) , \tag{1}$$

where $c_1, c_2, ...c_n$ - the coefficients to be determined; $\varphi_1(x, y), ...\varphi_n(x, y)$ - system of basic functions of a certain functional space must meet the necessary requirements of continuity and smoothness.

To adjust the more precise model will use the interpolation scheme when the function $z = f(x, y)$ and the polynomial $Q(x, y)$ coincide on a given system of points in the S – area (limited with inner and outer radiuses of the valve seat)

$$Q(x_i, y_i) = f(x_i, y_i) = z_i\ ,\ \ i = 1, ...n. \tag{2}$$

Unknown model parameters $c_1, c_2, ...c_n$ are obtained from a system of linear equations [1]:

$$z_i = \sum_{k=1}^{n} c_k \cdot \varphi_k(x_i, y_i)\ , i = 1, ...n, \tag{3}$$

where (x_i, y_i, z_i) - the starting points of the working surfaces of the area S. System (3) has a unique solution if its determinant is not zero:

$$\Delta = \begin{vmatrix} \varphi_1(x_1, y_1) & \varphi_2(x_1, y_1) & \ldots & \varphi_n(x_1, y_1) \\ \varphi_1(x_2, y_2) & \varphi_2(x_2, y_2) & \ldots & \varphi_n(x_2, y_2) \\ \ldots & \ldots & \ldots & \ldots \\ \varphi_1(x_n, y_n) & \varphi_2(x_n, y_n) & \ldots & \varphi_n(x_n, y_n) \end{vmatrix} \neq 0. \quad (4)$$

To develop maximally-considered working surfaces model the system of basis functions must be chosen by the way which is able to describe the exact process caused the deterioration of the valve seat. Therefore, to describe irregular surfaces and ensure the fulfillment of condition (4), taking into account the topography of the working part [7, 8] as the basis functions - quadric is proposed to use:

$$\varphi_k(x, y) = \sqrt{(x - x_k)^2 + (y - y_k)^2 + A_\varphi}\ , \quad (5)$$

where A_φ - the parameter that affects the curvature of the modeled surface and can be specified as a experimentally substantiated constant ($A_\varphi \geq 0$). Computation of the determinant (4) and the solution of linear equations (3) are carried out using matrix functions of MathCAD [4].

Spatial model (1) can be used for further three-dimensional analysis of the valve seat worn surfaces and settings before surface's overhaul. To this purpose the extremes (maxima and minima) of the original surface of each of the chamfers *(A, B, C)* through the points $(x,y) \in S$ should be researched:

$$Q_{\min}^{A,B,C} = \min[Q(x_i, y_i)],\ Q_{\max}^{A,B,C} = \max[Q(x_i, y_i)],\ i = 1,\ldots n. \quad (6)$$

At the found minimum points (x_j, y_j) $(j = 1,\ldots k)$ for each chamfer is possible to calculate the value $Z_{\min}^{A,B,C}$ of the processed surfaces for the base from the general equation of a right circular cone

$$Z_{\min}^{A,B,C} = \min[Z(x_i, y_i)]\ ,\ Z(x, y) = p \cdot \sqrt{x^2 + y^2} \quad (7)$$

where p - parameter defined for each of the facets [10], based on the standards of forming parameters of the finished valve seat:

$$p_A = \frac{(R_1 - R_0) \cdot tg\alpha_1}{R_1},\ \ p_B = \frac{(R_2 - R_1) \cdot tg\alpha_2}{R_1},\ \ p_C = \frac{(R_3 - R_2) \cdot tg\alpha_3}{R_2}. \quad (8)$$

The decision on the feasibility and advisability of the parts can be taken upon detection of deeper than $Z_{\min}^{A,B,C}$ - the original surface depressions on at least one of the chamfers of the valve seat *(A, B, C),* that is when

$$Q_{\min}^{A,B,C} < Z_{\min}^{A,B,C}. \quad (9)$$

If worn seat is suitable for processing, the maximum deviation of the peaks and valleys across the surface to be overhauled can be determined (1):

$$\Delta_{\max}^{Q} = \max_{A,B,C}\left[Q_{\max}^{A,B,C} - Q_{\min}^{A,B,C}\right], \quad (10)$$

that allows to pick the best overall allowance for processing,

$$Z_{общ} = \Delta^{Q}_{\max} \,. \quad (11)$$

Three-dimensional analysis allows highly-precise degree to control of roughness parameters as at any point of the predetermined area S can be processed to determine the function of the deviation of the surface (1) for the base (7):

$$r(x,y) = Q(x,y) - Z(x,y)\,. \quad (12)$$

Then the average R_a and RMS R_q asperity in accordance with the standards of ISO-4287 [3] can be calculated analytically:

$$R_a = \frac{1}{S}\iint_S |r(x,y)|dxdy\,,\ R_q = \sqrt{\frac{1}{S}\iint_S r^2(x,y)dxdy}\,. \quad (13)$$

Dimensional analysis involves the use of cross sections obtained by the intersection of 3D-model of the overhauled surface with define planes. In the general case, the slicing plane might be taken a plane of a general position, then the line of intersection with surface its can be defined (1) by the system of equations

$$\begin{cases} A_1 x + B_1 y + C_1 z + D_1 = 0 \\ z = Q(x,y). \end{cases} \quad (14)$$

A solution of (14) can be obtained by any of the numerical [1] techniques (iterations of Newton's method, etc.), however, more efficient, from the standpoint of the computer implementation, the transition from a problem to a differential algebraic [6]. For this purpose the system can lead to a nonlinear equation

$$F(x,y) = A_1 x + B_1 y + C_1 Q(x,y) + D_1 = 0, \quad (15)$$

where the function of line of intersection - *y (x)* is contained in an implicit form, and its derivative has the form

$$\frac{dy}{dx} = -\frac{F'_x(x,y)}{F'_y(x,y)} = \Phi(x,y). \quad (16)$$

Setting the initial approximation for the required line in implicit form ($y_0 = y(x_0)$, $z_0 = z(x_0)$) and using the numerical solution of (15) Runge-Kutta method [4], the equation of the curve in space

$$\begin{cases} y = y(x) \\ z = z(x). \end{cases} \quad (17)$$

If to apply to the system (14) the intersecting vertical planes passing through the axis Oz (when $C_1 = D_1 = 0$) it is possible to construct a family of plane curves (17) of the form $z = z(x)$ in the coordinates profile and to use them to control the taper cutting zone. Having built in the *j-th* processing step (Fig. 2, b) [10] on the points of the curve $z_i = z(x_i)$ *(i = 1, ... n)* linear regression [4] for each of the chamfers (*A, B, C*) the straight-line equation can be obtained:

$$z^{A,B,C}(x) = x \cdot tg\alpha^{A,B,C} + b^{A,B,C}\,, \quad (18)$$

where $tg\alpha^{A,B,C}$ - the angular coefficient of the line.

Then, through the definition of error built in tilt angles and base line might be evaluated by deviations from the cutting area for each of the taper seat chamfer on the *j-th* processing step:

$$\Delta\alpha^{A,B,C} = arctq(tg\alpha^{A,B,C}) - \alpha_{1,2,3}\,. \tag{19}$$

To analyze the roundness of the chamfers in the first equation (14) the horizontal plane ($A_1 = B_1 = 0$, $z = const$) is used allowing to build a profile of a family of plane coordinates curves of the form $y = y(x)$. Each such plane curve can be investigated by calculating the roundness on deviations from the basic points of the circle (for example, through the construction of non-linear regression [4]). However, if in the course of processing the estimated standard error almost unchanged reasons set using this method, is more complicated. It is therefore proposed to use a piecemeal approach - through the construction of auxiliary circles (internal and external), circumscribed about triangles.

For this (by selection or using functions [4]) three points are selected which most closely spaced from the origin $O(x_0, y_0)$ (the center of the base) and three ones - from the most distant point of $O(x_0, y_0)$ (Fig. 3, a) [10].

Through nearby points $A_m(x_1^m, y_1^m)$, $B_m(x_2^m, y_2^m)$, $C_m(x_3^m, y_3^m)$ the inner circumscribed circle is constructed, through the outermost point - $A_M(x_1^M, y_1^M)$, $B_M(x_2^M, y_2^M)$, $C_M(x_3^M, y_3^M)$ the outer inscribed circle.

To calculate the inner R_M and outer R_m radiuses of the circumscribed circles the sinus and cosines theorem for triangles composed of selected points [1]. For a triangle (Fig. 3,b) [10] formulas are:

$$R = \frac{c}{\sqrt{1-\cos^2\gamma}}\,, \tag{20}$$

where $a = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$; $b = \sqrt{(x_3 - x_1)^2 + (y_3 - y_1)^2}$;

$c = \sqrt{(x_3 - x_2)^2 + (y_3 - y_2)^2}$; $\cos\gamma = \dfrac{a^2 + b^2 - c^2}{2ab}$.

Then the calculation of the radial spread

$$\Delta R = R_M - R_m \tag{21}$$

allows to estimate the degree of similarity of the curve and a circle. At the initial stage of the processing of such variation in the radiuses can be significant due to the topographical features of the surface finish. At the final stage R_M and R_m the must match the allowance of the chamfer radius.

Center of the circumscribed circle around the triangle is the point of intersection of the middle perpendicular to its sides (Fig. 3, b) [10]. To define the coordinates of the center a system of linear equations of the form can be used:

$$\begin{cases} (x_1 - x_2)(x - \frac{x_1 + x_2}{2}) + (y_1 - y_2)(y - \frac{y_1 + y_2}{2}) = 0 \\ (x_2 - x_3)(x - \frac{x_2 + x_3}{2}) + (y_2 - y_3)(y - \frac{y_2 + y_3}{2}) = 0 \end{cases}, \tag{22}$$

The solution of equation system (22) will give the possibility to calculate the coordinates of the centers of $O_M(x_M, y_M)$ - external and $O_m(x_m, y_m)$ - internal circles. Then the calculation of the maximum deviation of the obtained centers O_M or O_m from the basic one $O(x_0, y_0)$ will allow to assess the degree of coaxiality of the coordinate systems in the processing of the valve seat.

Conclusions

Within considering the analytical methods for geometry modelling of the overhauled valve-seat surfaces in the valve timing gear have been the mathematical model to analyze the state of the working valve-seat surfaces under the wear for the purpose to form their parameters of quality within overhaul’s process.

References

1. Бронштейн И.Н., Семендяев К.А. Справочник по математике.– М.: Наука, 1981. – 720 с.
2. Кальченко В.И., Кальченко В.В., Веремей Г.А. Технологические методы достижения точности сопряжения «клапан-седло» в двигателе внутреннего сгорания / Вісник СевНТУ: зб. наук. пр. Вип. 121/2011. Серія: Машиноприладобудування та транспорт. – Севастополь, 2011. – С.18-21.
3. Допуски и посадки. Справочник / Под ред. Мягкова В. Д. – Л.: Машиностроение, 1982. – Ч. 2, 447 с.
4. Дьяконов В. MATHCAD 8/2000:специальный справочник.– СПб.: «Питер», 2000. – 592с.
5. Веремей Г.А. Методы повышения качества поверхностей сопряжения деталей в двигателях внутреннего сгорания// // Вісник Чернігівського державного технологічного університету: Збірник – Чернігів : ЧДТУ, 2011, №3(51). – С.79-83
6. Турчак Л.И. Основы численных методов: уч. пособие. – М.: Наука, 1987. – 320 с.
7. Carlson R.E., Foley T.A. The parameter R^2 in multiquadric interpolations. Comp. Math. Applic., 21 (9) (1991), pp. 29–42.
8. Hardy R.L. Multiquadric equations of topography and other irregular surfaces. J. Geoph. Res., 76 (1971), pp. 1905-1915.
9. Решетов Д.Н., Портман В.Т. Точность металлорежущих станков. – М.: Машиностроение, 1986. – 336 с.
10. Веремей Г.О. Математичне моделювання формоутворення відновлюваних поверхонь сідла клапана у газорозподільному механізмі / // Вісник Чернігівського національного технологічного університету: Збірник – Чернігів : ЧНТУ, 2014, №). – С. (у друці)

UDC 621.922

V.Y. Solod (docent, candidate of technical sciences, DSTU, Ukraine, Dneprodzerzhinsk)
D.G. Muzychka (DSTU, Ukraine, Dneprodzerzhinsk)
A.Y. Gorshkov (DSTU, Ukraine, Dneprodzerzhinsk)

MATHEMATICAL MODEL OF «GRAIN-BUNDLE» SYSTEM UNDER STRAIN

There was elaborated a mathematical model for calculating the temperature fields and the total strains resulting from temperature and pressure factors in the diamond wheel and the bundle area adjacent to it. The set task is solved by using the grid with absolute implicit scheme.

High requirements for precision and quality of machine parts, lead to an increase in the proportion of abrasive machining in total amount of machining. However, abrasive machining process is accompanied by high thermal stresses affecting the quality of the machined workpiece and cutting tool performance [1]. It is assumed that one of the ways to use the abrasive tool is the selection of such characteristics of abrasive wheels and cutting conditions under which the instrument will operate in self-sharpening mode.

The main condition of the wheel efficiency in this mode is the equality of the strains on the boundary grain-bunch, arising from the effects of temperature and pressure factors and the tensile strength of bundles during compression [2]:

$$\sigma_p + \sigma_\theta = [\sigma_{сж}], \text{ Па.} \quad (1)$$

The containment strength of diamond grains is largely predetermined by the temperature of surface layer of the bunch, the height of which is commensurate with the depth of their embedment.

Let us present cutting grains of diamond tools shaped like a prism and a square pyramid, which over time wears out and turns into a truncated pyramid [3].

The above described conditions [4] of fixing grains in cutting wheel, and its loading conditions, enable us to reduce the solution from the volume to a flat one (Fig. 1). We denote: W – width of the grain at its base; H – the depth of grain embedment in bundle of the wheel; $X(\tau)$ – height of the raised part of the grain, where τ – stands for the working time of grain; L – half the distance between two adjacent grains; ψ – the apex angle of the grain; γ - front angle. In schematic form of the process we can set $\psi = 90^0$ and $\gamma = -45^0$.

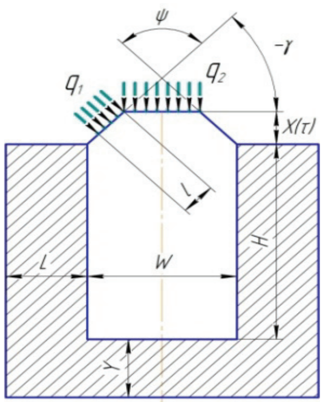


Fig. 1. The scheme of embedment of grain in the bundle of the wheel

Thus, the height of the raised part of unworn grains is $X(0) = W/2$.

Thermal processes occurring in the system grain-bundle should be considered as two separate stages: heating (contact period) and cooling stage (cooling period).

Let us consider the thermal processes occurring during the contact period. Temperatures generated in this period, are primarily due to the heat flow $q_1(\tau)$ and $q_2(\tau)$, acting respectively on the front and rear surfaces of the grain. At that the flux $q_2(\tau)$ is uniformly distributed across the rear surface and the flow $q_1(\tau)$ – along the average probable length of the contact l.

The heat flux density at the front surface can be calculated by the formula:

$$q_1 = \frac{P_{zz} \cdot V \cdot f}{S_1} k_1 , \qquad (2)$$

where P_{zz} - horizontal component of the cutting force, allowing for the friction force on the rear surface; V – wheel speed; S_1 – front surface with heat flow q_1 distributed over it; f – the coefficient of friction between the grains and the material processed; k_1 – portion of heat coming in through the front surface of the grain.

The heat flow density at the back surface will be:

$$q_2 = \frac{P_y \cdot V \cdot f}{S_2} k_2 , \qquad (3)$$

where P_y - the vertical component of the cutting force; S_2 – rear area surface of grain; k_2 – the proportion of heat coming into the grain through the rear surface.

The technique of calculating the horizontal and vertical components of the cutting forces allowing for the deterioration of grain on the back surface was elaborated in [3].

The surface of the raised part of grains is considered heat-insulated because the coolant does not flow into the zone of direct contact between grain and machine part [5].

After the grain exits the contact area with the workpiece (during cooling) the effect of thermal flows stops, i.e. $q_1 = q_2 = 0$, and on the boundary of the grain with cooling liquid and the bundle with cooling liquid there occur convective heat exchange.

We denote the studied areas of grain and the bundles as G_1 and G_2 (Fig. 2). At that

$$G_1 = \{x \in [0,W],\ y \in [0,B_1]\} \text{ and } G_2 = \{x \in [-L,W+L],\ y \in [-Y,B_2]\},$$

where $B_1 = \begin{cases} x+H,\ x < X(\tau) \\ X(\tau)+H,\ X(\tau) \le x \le W - X(\tau) \\ 2X(0) - x + H,\ x > W - X(\tau) \end{cases}$ and $B_2 = \begin{cases} H,\ x < 0 \\ 0,\ 0 \le x \le W \\ H,\ x > W \end{cases}$.

It is necessary to find functions $T_1(x, y,\tau)$ and $T_2(x, y,\tau)$ (the temperature of grain and bundle, respectively), defined in areas $G_1 \times [0,T_{раб}]$ и $G_2 \times [0,T_{раб}]$, which will be the solutions to the equations

$$\frac{\partial T_1}{\partial \tau} = a_1 \left(\frac{\partial^2 T_1}{\partial x^2} + \frac{\partial^2 T_1}{\partial y^2} \right) \quad \text{and} \quad \frac{\partial T_2}{\partial \tau} = a_2 \left(\frac{\partial^2 T_2}{\partial x^2} + \frac{\partial^2 T_2}{\partial y^2} \right), \tag{4}$$

and which will satisfy the boundary and initial conditions. Here a_1 and a_2 – are coefficients of thermal conductivity of grain and bundle, respectively. Within the boundaries of expected temperatures they can be considered constant, i.e. independent of temperature [7-8].

We will now define the boundary and initial conditions for the contact period:

a) in the range of 1 and 4 we accept the terms of insulation as follows:

$$\frac{\partial T_1}{\partial n} = 0\,, \tag{5}$$

where n - is the normal to the limit surface;

b) on the boundary 2 there is a uniformly distributed heat flow q_1:

$$\frac{\partial T_1}{\partial n} = \frac{q_1}{\lambda_1}\,, \tag{6}$$

where λ_1 - is the thermal conductivity of the grain.

c) on the border 3 there is a uniformly distributed heat flow q_2:

$$\frac{\partial T_1}{\partial n} = \frac{q_2}{\lambda_1}\,, \tag{7}$$

d) limits of 6 and 9 will be considered thermally insulated:

$$\frac{\partial T_2}{\partial n} = 0\,. \tag{8}$$

During cooling there occurs convective heat exchange with the coolant:

a) in the ranges 1, 2, 3, 4

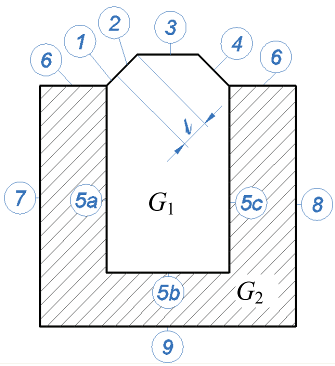


Fig. 2. Boundaries of calculated fields.

$$\frac{\partial T_1}{\partial n} = \frac{-\alpha_1}{\lambda_1}\left(T_{1\Gamma} - T_p\right), \tag{9}$$

where α_1 – is the heat emission coefficient between grain and cooling mixture; $T_{1\Gamma}$ – is temperature of the grain on the border with coolant; $T_p(\tau)$ – is the temperature of the coolant;

b) at the boundary 6:

$$\frac{\partial T_2}{\partial n} = \frac{-\alpha_2}{\lambda_2}\left(T_{2\Gamma} - T_p\right), \tag{10}$$

where α_2 – is coefficient of heat emission between the bindle and the liquid; $T_{2\Gamma}$ – is the temperature of the bunch on the border with the liquid.

On the boundaries of interaction of grain with bundles 5a, 5b, 5c the contact is considered to be perfect [7-9]. Therefore, it is advisable to use limiting condition of the fourth kind within these boundaries:

$$\begin{cases} T_1 = T_2 \\ \lambda_1 \dfrac{\partial T_1}{\partial n} = \lambda_2 \dfrac{\partial T_2}{\partial n} \end{cases}, \tag{11}$$

where λ_2 – is the thermal conductivity of the bundle.

Given that the boundaries 7 and 8 border on the same boundaries of the neighboring grains, it can be assumed that the temperature at the boundary 7 in area G_2 is equal to the temperature at the boundary 8 in area G'_2. Thus, for the boundaries of 7 and 8 we can use the periodicity condition:

$$T_2\,|_7 = T_2\,|_8\,. \tag{12}$$

Let us consider the initial conditions. We assume that at the initial point of time t = 0 the temperature of the bundle and grain coincide with the temperature of environment T_{cp}= 20^0. Then

$$\begin{matrix} T_1\,|_{t=0} = T_{cp} \\ T_2\,|_{t=0} = T_{cp} \end{matrix}\,. \tag{13}$$

Thus, the present mathematical model is an equation of heat conductivity (4) with boundary conditions (5) - (10) and the initial condition (13).

This problem was solved by using the implicit grid scheme [10]:

$$\frac{T_{i,j}^{n+1} - T_{i,j}^{n}}{\Delta\tau} = a\left(\frac{T_{i-1,j}^{n+1} - 2T_{i,j}^{n+1} + T_{i+1,j}^{n+1}}{\Delta^2} + \frac{T_{i,j-1}^{n+1} - 2T_{i,j}^{n+1} + T_{i,j+1}^{n+1}}{\Delta^2}\right). \tag{14}$$

At this, the equation (14), it was solved separately for the grain temperature T_1 and for the temperature of the bundle T_2.

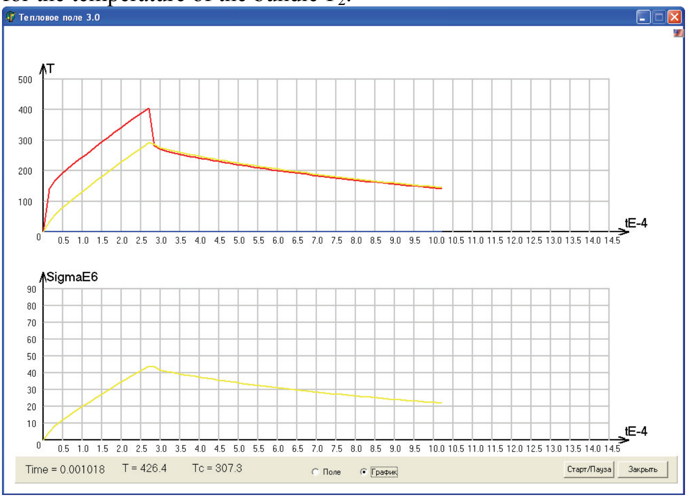


Fig. 3. The temperature distribution in the diamond grains and the adjacent area of the bond B2-01.

Fig. 3 shows a fragment of the results of the program «Thermal field of 3.0» There were simulated conditions of processing of hard alloy T15K6 (S_{np} = 0,6 m/min, S_n = 0,25 mm/stroke; n = 3800 min^{-1}) by cup diamond wheel with outer diameter 150 mm and width range of diamond layer 10 mm, grain size 100/80, 100% concentration, with bond B2-01.

The graphs reflect the dependence of temperature (upper graph, º C) and the total strains (the lower graph, Pa) on time in selected points of time.

Conclusions

Having calculated the values of temperature fields and the total strains at the boundary grain-bundle, we can now choose cutting conditions and wheel characteristics, which will enable it to operate in a self-sharpening mode.

References

1. *Каленов В. Н.* Исследование температурных явлений и теплового баланса при шлифовании хрупких тугоплавких металлов. // «[Тр.] Моск. авиац. ин-та», 1977. - Вып. 402. – С. 26-30.
2. *Солод В.Ю., Музычка Д.Г.* Температурные напряжения, действующие на границе зерно – связка. // Системные технологии: Региональный межвузовский сборник научных трудов. – Вып. 1. – Днепропетровск, 1997. – С. 65-70.
3. *Солод В.Ю., Музычка Д.Г.* Исследование устойчивости зерна в связке круга с учетом его износа по задней поверхности. // Системные технологии: Региональный межвузовский сборник научных трудов. - Вып. 2 (13). – Днепропетровск, 2001. – С. 168-174.
4. *Солод В.Ю., Музычка Д.Г.* Напряжения на границе зерно-связка. // Системные технологии: Региональный межвузовский сборник научных трудов. Юбил. вып., посвящ. 80-лет. ДГТУ. – Днепропетровск: Системні технології, 2000. – С. 336-340.
5. *Резников А.Н.* Теплофизика процессов механической обработки материалов. – М.: Машиностроение, 1981. – 279 с.
6. *Тихонцов А.М., Чухно С.И., Коробочка А.Н.* Тепловые процессы при механической обработке материалов резанием. – К.: УМК ВО, 1992.- 286 с.
7. *Лыков А.В.* Теория теплопроводности: – М.: Высшая школа, 1967. – 600 с.
8. *Лыков А.В.* Тепломассообмен: – М.: Энергия, 1978. – 479 с.
9. *Гордеев А.В.* Решение задачи о нестационарном теплообмене с разрывными граничными условиями. – Саратов: Изд-во Саратовского университета, 1975. – 81 с.
10. *Самарский А. А.* Введение в теорию разностных схем: – М.: Наука, 1971. – 553 с.

UDC 004.052(042.3)

O. Cherednikov, M. Yurchenko, V. Tolkachew
(Chernihiv National Technological University, Ukraine, Chernihiv
Public organization: «Institute of Standardization
of the Trade and Accounting Nomenclature»)
A. Sereda, graduate student
(National Aviation University, Ukraine, Kiev)

THE TRANSFORMATION OF THE METHODOLOGY OF THE «PRODUCTION-REALIZATION-CONSUMPTION» SYSTEM INFLUENCED BY INFORMATION TECHNOLOGIES

Critical reconsideration of conceptual thesises of information technologies and commodity-money relations of internal markets promotes the development of the model of intellectual mobile interactive organization based on the virtual principles of self-organization. The grouping of information, based on classification and coding systems, is suggested. It allows presenting technical and economic data in a form suitable for input and processing by users of any grounding level.

At the conjuncture of the globalizing world a consumer makes demands on commodities, namely on the nomenclature and the quality of the good, the price and the speed of meeting the needs. But the existence of the enormous array of information, gathered from millions of web sites, does not often help and complicates the process of "Choice".

Growing demands and permanent development of new information and communication technologies create backgrounds for development of new organizational forms of the modern virtual market [1-3]. The Institute of Standardization of the Trade and Accounting Nomenclature (ISTAN) is an active participant of various international and regional projects on standardization, certification, metrology and unification of a wide range of products and participates in international co-ordination of the network of research, educational, administrative, commercial and other organizations, which provide complex information service. (fig.1).

Fig.1. Functional structure of CPRGS

Formalized and structured information, gathered in one Intercontinental global project, which covers all the Noosphere, will help users not only to make the right choice, but also to reduce the time spent on these actions. As a result, various types of resources - CPUs, memory, software, data sets, information bases, computer networks – will form a common field, and all the resources will become accessible everywhere, regardless of their location.

Currently both consumer and manufacturer use different approaches and standards at all stages of the product lifecycle. Traditionally, cooperating firms located in different states have certain technical and legal barriers. For example, a firm in Germany will use generally the DIN standards, Ukrainian one – the SSU, American one – the ANSI system. In this case, there are problems in ordering (which appear because of the wording ambiguity of product's "Nature", construction documentation and normative documents which describe it, transferring the technology to production and to the firms, which supply materials and component parts), as well as in normal consumer usage (fig. 2).

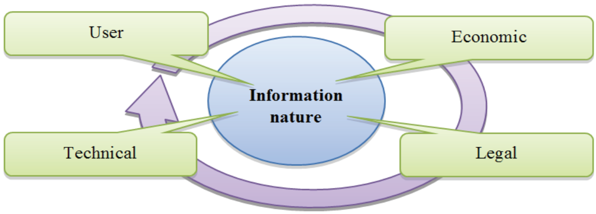


Fig.2. Structure of information nature.

To solve these contradictions it is necessary to choose a common system of standards and to work solely with it. The offered system of coding and systematization of objects by identifying, ranging and giving them an arbitory notation (a code), provides recognition of any "purchase-sale-production" object among a great number of others at all stages of product lifecycle (beginning from creation and finishing with utilization) in close cooperation of all participants of the market for identification and fast response to requests.

Studying the information space (and in particular the global market of information) is of special theoretical and practical interest. It is the purpose of creation of the integrated "Three-headed" Internet portal for the consumer, the seller and the manufacturer. (fig.3).

So, we have approached the review of the Consumer Public Register of Goods and Services (CPRGS) as a universal, open, public and free alternative to all systems of product and service coding. (Fig. 4).

The producer, who created an account in the CPRGS system, has an opportunity of the effective sale of his products. It promotes the increase in the product nomenclature, the expansion of production and the upgrade of production capacities. Friendly and functional interface will allow "Producer" to place full, unified and systematized information on the products, with receiving a universal code for every unit of the product nomenclature. ET-code is a unified and recognizable classification code, which is a medium of all information about the product.

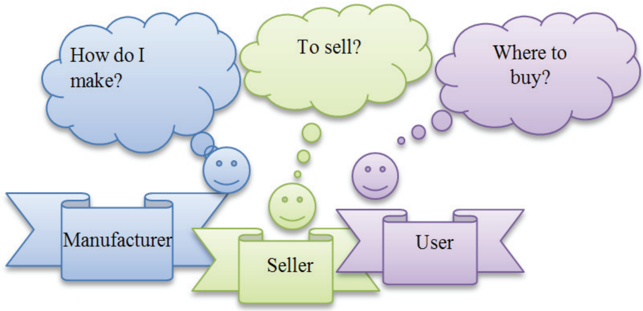


Fig.3. «Three-headed» purpose of the Internet portal

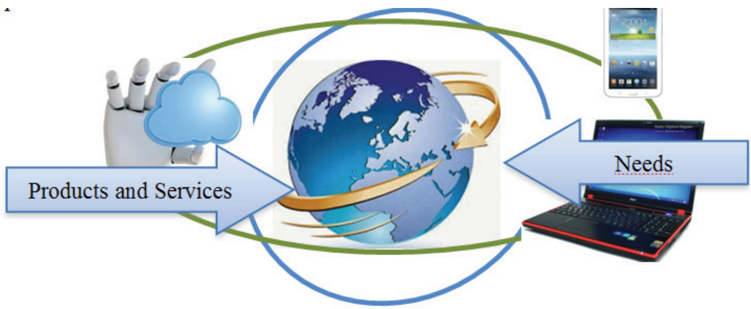


Fig.4. Intercontinental connections in the CPRGS system.

The solution of AT designing problem requires the ongoing coordination of the research directions and is performed in cooperation of specialized departments in the organizations (experimental design bureaus or scientific research institutes) according to the nature of tasks, their subject and the amount of works. This circumstance should be considered in case of parallelization of designing process during the creation of the distributed computer networks.

Methodological basis of such an approach is the aggregate and decompositional analysis of AT, which represents projected systems in the form of the set of interconnected elements (fig. 5). Corporativity, distribution (including the spatio-temporal one) and interdisciplinarity of the modern aviation complex development brings specifics in this process and determines the need of careful organization, coordination of collaborators' works and also searching for high-speed and effective methods of information transfer and exchange.

Currently, the last factor has the particular importance. Existing data mediums (for example, graphical or printed materials sent by mail, meetings of specialists sent by the organizations, CD disks) are outdated and don't correspond to the computing aids, which are used by the majority of firms (including firms that are connected in local networks). Automation of these processes can become an important factor of increase in efficiency of designing during the corporate developments. It determines the relevance of creation problem of the information exchange with the central mechanisms of administration at a head developer infrastructure. Effective and profitable connection for administration and message exchange is necessary.

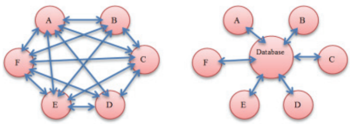


Fig. 5 The advantage of a unified data model: a - decentralized and b - centralized interaction of attributes

The markers of virtual organization are: [1-3]:

- consolidation of independent market subjects;
- combination of resources of the firms, which are the members of the network;
- the product or service can be both traditional, and virtual;
- geographical remoteness of virtual organization elements; coordination of its actions is performed through a common information space.

Functional characteristics, inherent for the majority of virtual organizations, used in the system:

- high organizational flexibility;
- combination of key technologies and competences;
- orientation to information technologies;
- liberalization and updating of information access;
- globality of the network participants interactions;
- transformation of consumers into active participants of reproduction process;
- availability of the global choice field of and the use of resources for the cost optimization.

The synergy effect in virtual organization is reached due to consolidation of key characteristics and resources of the partner firms by the coordinator, and also due to smoothing of economic and regional separation of the network elements [4].

Production enterprises have an opportunity to create the Internet shop with one click of a mouse for the first time. The high-class specialists of the "Institute of Standardization of the Trade and Accounting Nomenclature" public organization, who provide functioning and support of the CPRGS, will provide the translation of information on the main languages of the world, thereby expanding the client base of "Producer" infinitely and making the product available for a wide range of "Consumers".

For the "Seller", the CPRGS is intercontinental trading facility which covers a boundless complex of goods and services in any corner of the Noosphere.

The "Seller" receives the unique tool, that allowes organizing the interaction between the "Producer" and the "Consumer".

The CPRGS system allows to conduct financial activitiy according to the international legislation, to create all necessary documentation about the carried-out transactions automatically, to perform transactions of purchase and sale of products at any place of the world, regardless of variety of transaction partisipants' financial systems, and to receive guarantees of investments and protection against "dirty" participants of the market.

Availability of the private account in the CPRGS system allows to purchase necessary products using any device. It does not matter whether he buys 100 tons of aluminum in Siberia or two nails in Ukraine. The user will be able to make any transaction via the display of the mobile phone.

For the "Consumer", the CPRGS provides a boundless list of goods and services with orientation to the region and delivery time. The adaptive system of search allows to sort products by a set of parameters: price, quality, delivery time, etc. The scale of alternatives with full information on them is automatically formed after the request reation. The consumer also has an opportunity to participate in forming of production programs of various firms. The intellectual part of the CPRGS system and the system of transaction responses and ratings provide elimination of unfair participants of the market, which minimizes any possible risks for the "Consumer".

References

1. *Режабек, Б. Г.* Учение В. И. Вернадского о Ноосфере и поиск пути выхода из глобальных кризисов / Век глобализации. Выпуск №1/2008 С. – 159–167.
2. *Сливицкий, А.Б.* Интеллектуализация научно-производственной корпорации как фактор инновационного развития // Актуальные проблемы научно-технологической и инновационной политики в контексте формирования общеевропейского научного пространства: опыт и перспективы. Материалы междунар. симпоз. (Киев, 16-17 июня 2010 г.). – Киев: Феникс, 2010.
3. *Катенев, В. И.* Сетевой подход к организации взаимодействия предпринимательских структур / В. И. Катенев – СПб.: Изд-во СПбГУЭФ, 2007. – 217 с.
4. *Адаменко, Е. Ю.* Интеллектуальноемкие инновационные продукты в маркетинге / Е. Адаменко // Маркетинг. - 2013. - № 6. - С. 61-69.
5. *Толкачев, В.М.* Иновационные информационные технологи всистеме «потребление -производство» Комплексне забезпечення якості технологічних процесів та систем (КЗЯТПтС - 2014): тези доп. IV міжнар. наук.-практ. конф., (Чернігів, 19-21 трав. 2014 р.). – Чернігів: ЧДТУ, 2014. – С. 282-287.

UDC 004.67

A.A. Borisov, S.G. Bondarenko
(Chernihiv National Technological University, Ukraine, Chernihiv)
V. Kudryakov (National Aviation University, Ukraine, Kyiv)

INFORMATION ANALYSIS ASPECTS SPATIAL DIMENSION RELATIONS

Is provided information technology of the sized analysis of technical system, methods of control over analysis process.

The present state of the art consists of a comprehensive account of all stages of the life cycle of the machine when it is in the design and development of the informational aspects of the system approach to the description of technological methods to provide the required performance of the product.

Urgency of the task is due on the one hand demanding to ensure dimensional accuracy of machined parts and working relationships with ever-increasing loads and speeds, at high and low temperatures. And on the other - the predominance of todays formalized design approach that cannot effectively meet these requirements ensuring minimal cost.

The aim is to increase the accuracy of assembly units of machines at the stages of design, manufacture and operation.

To achieve this goal it is necessary to solve the following problems:

1. Consider existing techniques dimensional analysis of machine design.

2. Develop a simulation model and a common methodology for analyzing the accuracy of dimension, realizing the single-stage design of machines, as well as communication of operational parameters and manufacturing techniques to provide the required durability of the machine.

3. Develop a methodology for accounting Dimensional analysis of the impact of wear and deformation of contact surfaces that occur during the operation of the machine.

4. Investigate features enable operating parameters in calculation schemes dimensional analysis.

5. Develop an automated system of dimension accuracy analysis of spatial dimensional chains, taking into account the performance of interfaces to the machine.

Thus, the actual problem is the improvement of the theory of dimensional analysis as the basis for its further development and empowerment in terms of improving the reliability of the results and performance calculations.

One of the important tasks of accuracy, which can be solved during the manufacturing of machine tools, is the communication between the geometrical characteristics of the machine and its official designation. Proper functioning of the machine and its components is provided primarily by the existing relative position or movement of the actuator surfaces which are described by the geometric characteristics, such as size, relative rotations (parallel, perpendicular) and the relative location of surfaces or items. In compiled product details are interrelated and interdependent. So that any deviation of the size, shape and arrangement of the axis or surfaces of any of the parts or can cause the deviation of the variation in the location of other parts of the assembly unit. These deviations, collectively in some way influence the qualitative characteristics of the product.

System dimensional relations machine in the design formed by the steps [2,3]:

- Identify types of links through which the machine performs it's official tasks;
- Identify critical to function machine features;
- Determining the accuracy of needed critical to function surfaces of the machine;
- Ensure that the critical surfaces are made of dimensionally stable materials;
- Manufacturing of high tolerance mating parts;
- The desired final capability type of the machine is determined by the final dimensional tolerance required for the process.

The design of any machine in its essence is a system of at least two sets of links that interact: the material properties and dimensional. In accordance with the principles of the structural system it is uniquely described by its structure, which is a set of components (elements) and the links between them.

To implement such a system of connections necessary to prepare and implement a manufacturing process, which is a system of top-level hierarchy of interrelated elements are pre-production, the basic technological processes, technical quality control, work organization, management processes, and the like. Manufacturing process contains multiple links: size, kinematic, dynamic, chemical, and temporary, economic. properties of materials and information (Figure 1).

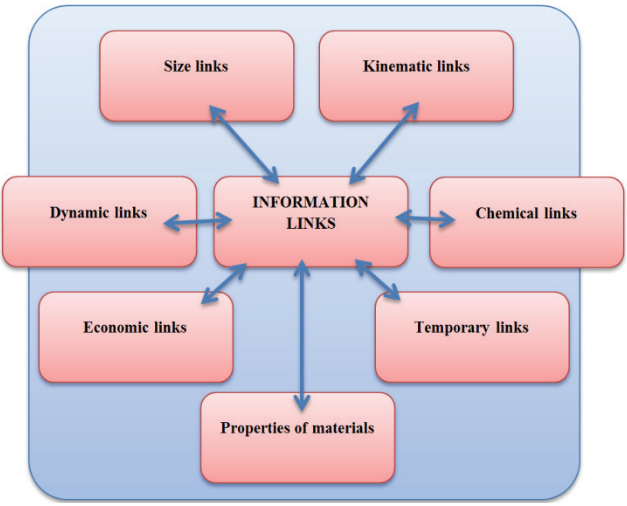


Fig. 1. Multiple links of manufacturing process

One of the most important tools for creating high-quality machines that can operate with high reliability over the lifetime is dimensional analysis. It helps to ensure the required accuracy of the functional parameters of products and link together many of the basic characteristics of the various stages of the life cycle of the machine. In this dimensional analysis is also a link between the stages of design and technological preparation of production to release new products. Important is the fact that this analysis is a versatile tool that is suitable for the calculation of any design or a single node. Analytical dependences between the parameters and the parameters of the call destination relations of critical surfaces expressed by equations of type

$$\Pi_i = f(x_{1_i}, x_{2_i}, \dots, x_{n_i}),$$

where Пi – setting career-purpose machine;

xi − the parameters of one of the types of relationships of critical surfaces machined from which the value Пi.

As per the original equation, and unknown n, then it can only unleash the selection argument values of xi [2]. Selection can give an infinite number of solutions, but other possible solutions of the original equation do not exist. Some reduction in the number of solutions can be achieved, given the experience in solving similar problems in the past, as well as time saving.

The principal difference between the calculation of spatial dimensional chains of linear and angular is that the nominal values and tolerances of linear (x, y, z) and angular (φ, ψ, θ) parameters are considered as interrelated values.

In general, the equation of dimensional relationships can be represented as a system of equations [2]:

$$\begin{cases} \overline{R} = \sum_{i=1}^{m} M_i \overline{R}_j \\ M_j = \prod_{j=1}^{i} M'_{i-j+1}, i = 1,2, \dots, m, \end{cases}$$

where $\overline{R_j}$ – radius vector of locking units dimensional spatial chain;

M_i – rotation matrix of i-th coordinate system;

M_{i-j+1} – rotation matrix (i-j +1)-th coordinate system relative to the conjugated (i-j)-th coordinate system;

m – number of constituent parts of the spatial dimensional chains.

As can be seen from the system of equations, linear dimension level locking circuit depends on the spatial linear and angular dimensions of the components parts, and the angular size - only on the angular size.

There are programs for calculating spatial dimensional relationships are built on different methods [3]. Computer-aided design CAD/CAM/CAE in conjunction with network technologies have generated new strategy for the integrated production of CIM, successfully realized now by many foreign industrial companies. Especially effective implementation of CIM strategy manifests itself on engineering plants that are characterized by significant amounts of information for the design work using dimensional analysis.

Under dimensional (or geometrical dimension) bonds understanding the totality of information on deviations in size, shape and arrangement of surfaces, assigned to design documentation provided in the technological processes and implemented during operation. This information is statistical in nature. It will depend on the statistical properties of the sizes and the number and type of dimensional relations. As well as determining the geometric relationship, kinematic determination of the relative movement of the elements, dynamic, chemical, etc. When considering the processes of manufacturing machinery, discrete communication between elements of machines and communication processes. In the production of machines dimensional communication processes determine sized machine communication, and in the design process requirements to dimensional relations machine, the requirements for dimensional relations process.

Performances of all types of links of the production process are random deviations, which in turn affect the performance quality products. Random deviations occur in the links of all kinds of relationships and their compatible influence on each other makes it even more random each of them, but in modern conditions during the manufacture of products in small batches no statistical indicators and reference data do not meet the accepted mathematical proofs. Therefore it is necessary in each case to investigate the probabilistic nature of the dimensional relations.

Formalization of such size relations dimensional chains, in particular, in determining the relative errors based implicitly defined planes is extremely difficult. When you try to formalize the spatial dimension due sized chains links which lie in different planes for the use of known methods for calculating the size of chains have to make the following assumption: the angles between the planes, where are the links of the chain dimension, are nominal. The exclusion of error angular arrangement of planes, certainly significantly reduces the accuracy of the calculation.

For prototyping electronic products use different CAD systems with multiple standards describe the geometry of the parts (wireframe, surface and solid) with the material properties, loads and other features for engineering analysis.

The relative position of parts can be represented as a coordinate system with elastic (variables) properties (Fig. 2).

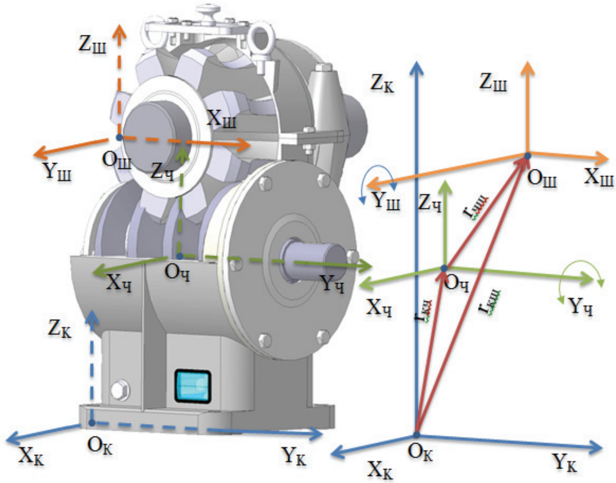


Fig. 2. Scheme of local and general basic coordinate systems sized gear
Indices: K - body; W - a worm; W – gear

To implement the necessary connections needed by precision surface machines can be used by different types of communication. Types and forms of these high tolerance surface machines set on the basis of its function as a result of examining aggregate type and nature of the necessary linkages. Success in identifying critical surface machine depends on how deeply their functions can be represented.

Findings

You need to apply new information about objects representing the dimensional analysis and on this basis to further improve the existing methods of analyzing size and processing.

Improving theory dimensional analysis, processes and structures based on the most perfect synthesis of existing concepts and methods with their modernization by developing mathematical models that take into account the mutual influence of dimensional parameters and deviations from the arrangement of surfaces and application of mathematical and computer modeling.

Implementation of information technologies provide machine builders developed methods of design, production and operation of machines, effectively providing the required accuracy. Highly relevant is to improve methods of dimensional analysis in the following areas:

1) The development and practical application of methods for calculating spatial dimensional chains.

2) The creation of complex structures analysis techniques allowing the required quality of the product.

3) Accounting resizing machines in operation and development of techniques to enable operational ties dimensional chain by analyzing the functionality of parts and assemblies.

The mathematics as well as the software for dimensional analysis of structures and processes, as well as the correctness of the results of research and theoretical developments confirmed by experimental verification and trial operation of machine-building enterprises.

Improving the accuracy and reliability of estimation error in determining the relative location of the knots, increase productivity and reduce the cost of tooling, by automating the investigation of spatial dimensional relations is an important task in the production technology.

References

1. Бондаренко, С.Г. Розмірні зв'язки конструкцій і технологічних процесів: монографія / С.Г. Бондаренко, О.М. Чередніков; за заг. ред. С.Г. Бондаренка / – Чернігів: Черніг. держ. технол. ун-т., 2013. – 532 с.
2. Борисов, О.О. Інтегрована система підтримки розмірного аналізу / Чередніков О.М. Текст. //Вісник Національного університету «Львівська політехніка» – Львів: видавництво Львівської політехніки. – 2012. - №7(46). - С. 75-79.
3. Колесов И. М. Основы технологии машиностроения.- М.: Высшая школа,1999.- 414с.
4. Масягин, В. Б. Автоматизация размерного анализа осесимметричных конструкций Текст. / В. Б. Масягин // Омский научный вестник: Приборы, машины и технологии. 2008. - № 2(68). - С. 25-28.

UDC 681.2

O.M. Bezvesilna, doctor of technical sciences
(National Technical University of Ukraine “Kyiv Polytechnic Institute”, Ukraine, Kyiv),
L.O. Chepiuk, (Zhytomyr State Technological University, Ukraine, Zhytomyr),
A. D. Nalyvaik , candidate of engineering sciences
(National Aviation University, Ukraine, Kyiv)

VIBRATING-STRING ACCRLEROMETR FOR ROBOTICS COMPLEXES ON AIR- AND SPACECRAFT

The aspects of vibrating string accelerometers construction in moving objects control systems were considered.

During the vibration and impacts, during the changes in the velocity of moving objects (including robots) the accelerations arise, which must be considered and, hence, measured.

The device for measuring the acceleration of moving objects (robots) during their operation is called an accelerometer.

Accelerometers are the most important elements of the navigation and control systems, so their design and manufacturing are presented with very high demands. They must have the high accuracy and sensitivity, a wide range of measured acceleration and linearity, stability of readings and insensitivity to vibration and impact actions, to temperature and pressure changes of the external environment [1].

Currently the transducers with frequency output signal instead of traditional transducers with amplitude-modulated output signal in the form of voltage or current are increasingly being introduced in measurement practices.

Vibrating string accelerometers are related to the accelerometers with frequency output. The operation principle of vibrating string accelerometers is based on the string’s ability to change the frequency of its natural oscillations when changing its tension.

Pic.1 represents the vibrating string accelerometer scheme. When exposed to inertial mass *m*, which is consolidated on a ridgepole 2, the acceleration *a* of string tension force 1 will change to the value *ma*, and the frequency of oscillation will be determined by the expression [2]:

$$f = \frac{1}{2l}\sqrt{\frac{T_0 + \frac{ma}{s}}{\rho}} \qquad (1)$$

where l – string length; T_0 – initial tension; ρ – density of a string material; s – cross-sectional string area.

Excitation of string vibrations and the frequency measurement is performed in the following way: the string is placed in a constant magnetic field. During the fluctuation the growing EMF will occur; the positive feedback is used to support oscillation. To eliminate the feedback component that is frequency-independent, the string is included to the bridge circuit. Measuring the frequency f in one way or another, it's possible to monitor the changes in object acceleration, where the device in question is installed [2].

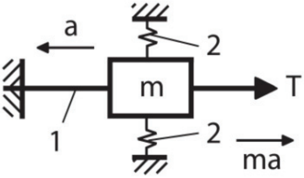


Fig.1. Vibrating string accelerometer scheme

As the formula (1) shows, the vibrating string accelerometer has a non-linear quadratic characteristic.

Decomposing the expression 1 in the row, we will obtain:

$$f = f_0[1+\frac{1}{2}\cdot\frac{m}{sT_0}a-\frac{1}{8}\cdot\left(\frac{m}{sT_0}\right)^2 a^2+\frac{1}{16}\cdot\left(\frac{m}{sT_0}\right)^3 a^3-\ldots], \quad (2)$$

where $f_0 = \frac{1}{2l}\sqrt{T_0/\rho}$ – frequency of own string oscillation with no acceleration.

The following expression is valid for $ma/s \ll T_0$, which is almost always true in practice, since to ensure the string's stable oscillations the considerable tension T_0 must be applied [2].

In accordance to the relation (2), the frequency deviation from its initial value can be considered as a linear function from the acceleration *a*:

$$\Delta f = f - f_0 = \frac{1}{2}\cdot\frac{mf_0}{sT_0}a[1-\frac{1}{4}\cdot\frac{m}{sT_0}a+\frac{1}{8}\cdot\left(\frac{m}{sT_0}\right)^2 a^2-\cdots]\cdot \quad (3)$$

Such linearization fault will not exceed the first rejected decomposition member.

$$\delta \le 0.25\frac{ma}{sT_0}\cdot \quad (4)$$

The differential scheme of vibrating string accelerometer (Fig.2) has a higher linearity. Unlike the scheme in Fig.1, in the differential vibrating string accelerometers scheme the tension of strings 1 and 3, connected with the inertial mass m, which is attached to the ridgepole 2, will change [2].

Difference of two string frequencies:

$$f_1 - f_2 = \frac{1}{2l}[(T_0+0.5ma/s)/\rho]^{0.5}-\frac{1}{2l}[(T_0-0.5ma/s)/\rho]^{0.5}. \quad (5)$$

If $T_0 \gg 0,5ma/s$, then, decomposing the expression (5) in a row

$$f_1 - f_2 = \frac{1}{2}\cdot\frac{mf_0}{sT_0}a[1+\frac{1}{8}\cdot\left(\frac{ma}{sT_0}\right)^2+\cdots],$$

we will obtain that the non-linearity of differential vibrating string accelerometer will not exceed the value

$$\delta \le 0.25\cdot\left(\frac{ma}{2sT_0}\right)^2\cdot \quad (6)$$

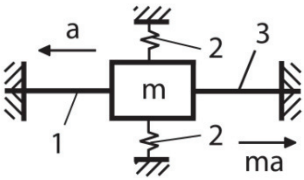


Fig.2. Differential scheme of vibrating string accelerometer

It's noticeable from comparison of (3) i (5), that vibrating string differential accelerometer has better linearity than the simple one.

For vibrating string accelerometer to have a linear dependency of the frequency from the acceleration, it is necessary to introduce the special corrective effect [2].

The law of corrective effect change *T(a)* for the simple scheme of vibrating string accelerometer:

$$T(a) = (T_0 k^2 / f_0^2) a^2 + (2kT_0 / f_0) a - ma / s. \tag{7}$$

So, the correction must be linear quadratic one. Though if

$$k = \frac{mf_0}{2sT_0}, \tag{8}$$

then the correction will be purely quadratic.

The law of corrective effect change for the differential vibrating string accelerometer:

$$T(a) = m^2 f_0^2 / (4k^2 s T_0) - T_0 + k^2 T_0 a^2 / (4 f_0^2). \tag{9}$$

If the condition (7) will correspond to the differential vibrating string accelerometer, then the law of corrective effect change *T(a)* depending on the current acceleration will have the form:

$$T(a) = \frac{ma^2}{16 T_0 s^2}$$

Herewith,

$$f_1 - f_2 = \frac{mf_0}{2sT_0} a.$$

The most convenient and easiest way to implement the resulting corrective law is the support of constant and equal frequency of two string's sum crystal oscillator. Square difference of two string's frequencies will linearly depend on acceleration of their sum will be kept constant [2].

$$f_1 - f_2 = \frac{mf_0^2 a}{T_0 s (f_1 + f_2)}.$$

Stabilization of vibrating string differential accelerometer total frequency eliminates temperature faults, associated with the different coefficients of string and case expansion of the device.

Such linearization faults are related to the methodological errors. By administering the corresponding corrective effect, the linearization fault may be eliminated, which provides the strict linear dependence of the frequency from the acceleration.

Vibrating string accelerometer instrumental fault is determined by the change of sensitivity k as the result of various effects during the device operation. The value of k is the function of several parameters, e.g. $k=f(m, T_0, s, \rho, L)$.

Parameters can be changed due to the influence of temperature on size and construction elements elasticity modulus, due to the influence of the environment on the oscillation parts, due to the generator instability. It's necessary to consider the presence of automatic string tension control faults, frequency string oscillation measurement faults and so on. The accuracy of vibrating string accelerometers is influenced by connection peculiarities of strings with inertial mass and device case, the relative magnitude of longitudinal and transverse stiffness of inertial mass suspension. During the vibrating string accelerometer construction the difficulties of mainly technological character must be overcame and special measures to decrease the number of faults, inherent in string transducers must be taken [1].

It's is necessary to have a solid foundation of string ends to eliminate cornering of the extreme string intersection and to disperse the energy through the attachment places. Temperature coefficients of linear expansion case and strings must be the same to avoid the change in string tension when temperature changes. The quality sealing of string ends is required, the string material must have the stable characteristics. The currently known accelerometers of such type have the sensitivity threshold equal to 10^{-6} g.

Vibrating string accelerometers have the highest measurement accuracy, high vibration and impact durability, reliability, frequency-modulated output signal, high power signal output, and also the small size and weight, compared to the other known accelerometer types. The disadvantages include their high cost, due to the technological challenges in manufacturing, effects of temperature and humidity on the measurement accuracy, and also the non-linear characteristics. It's possible to significantly reduce the effects of temperature and humidity, and also to significantly linearize the characteristics, using the differential scheme of vibrating string accelerometer.

Conclusions

Differential vibrating string accelerometers usage in management systems provides the means of the more accurate determination of moving object's parameters.

References

1. Безвесільна О.М. Авіаційні гравіметричні системи та гравіметри: Монографія/ Безвесільна О.М.– Житомир : ЖДТУ, 2007. – 604 с.
2. Навигационные приборы и системы / Б.Б.Самотокин, В.В. Мелешко, Ю.В. Степанковский. – К.: Вища шк. Главное изд-во. 1986. – 343 с.

UDC 004.056.5

O. V. Boychenko, Doctor of Engineering Sciences,
(Tavricheskiy national university, Russian Federation, Simferopol'),
A. D. Nalyvaiko , Candidate of Engineering Sciences.
(National Aviation University, Ukraine)

INFORMATIVE SAFETY ECONOMIC CONTROL SYSTEM

It is set the analysis problems of informative safety of economic control system that the present systems of defense can not provide the maintenance of sufficient level confidentiality of informative resources while. The vital necessity decision of problem of protecting from the computer viruses of management information's is certain. The complex use the system of informative safety is offered in economic control system.

Together with intensive development of the informative-analytic systems and facilities of information transfer the more actual is become by the problem of providing of informative safety. Research of functioning of the modern informative systems and facilities of informative defense shows that the present systems of defense can not provide the maintenance of sufficient level of confidentiality of informative resources while [1].

The special actuality is presently acquired by the problem of fight against computer viruses in the complex of informative safety measures. So, as compared to the last year the number of harmful objects, daily processed by the anti-virus programs, was increased in 1,5 times and made 315 thousands in a day.

On the average in 2013 the anti-virus programs reflected more than 4,5 million internet-attacks every day. Even one time during a year the victims of similar attacks were become by 41,6% users in the whole world. In respect of local threats, for passing almost 3 milliards of infections were 12 months prevented at an exposure 1,8 million potentially dangerous programs.

The main sources of server-threats are acknowledged Russia and USA – 45% internet-attacks in 2013 were conducted with the use of harmful resources, located on territory of these states.

The analysis of проблематики of viral activity in the informative networks of management allows selecting countries with the highest risk of infection during surfing in Network. The overhead lines of rating occupied the countries of the former CIS, including Russia, bedding on 4th position – exploit the more than half (54,5%) of the Russian users was exposed to the server-attacks during the last 12 months.

Among attacks, using to vulnerability in software, 90,52% were aimed on Java. Thus actively used vulnerability of this product of Oracle in server-attacks – for them now are in the great number of the specialized sets of harmful software.

The amount of the mobile viral programs grew in 2013 not only, they also became more difficult and more dangerous. Only for October was found out almost 20 thousand new copies, and it is a half of all standards, found in 2012. More than 104 thousand new modifications of the mobile harmful programs were exposed only in 2013, that there is a more last year's index on 125%, and most serious from them were aimed at the theft of money and confidential information. Thus the platform of Android still remains the primary objective of malefactors (on it 98,05% all mobile threats are directed).

An analysis shows that the most dangerous harmful program presently is the mobile viral program Obad. Obad spreads in a number of methods, most known among which is the use preliminary formed mobile botnet. Obad also functional enough and plugs in itself three exploit, backdoor, mechanisms of work in botnet, and also a number of other possibilities.

The tendency of complication of the mobile harmful programs actively proceeds in 2014. Thus, basic aspiration of malefactors is money facilities of users, the instrument of access to which are mobile Trojans. Development of mobile phishing proceeds actively, bank Trojans and other facilities by which malefactors get access to bank account proprietors of mobile devices. The special danger is presented by wide distribution of the mobile viral programs, using to vulnerability in the platform of Android, that results in at the infection of mobile devices. Wide distribution was got also by trade mobile botnet for subsequent distribution with their help of strange harmful applications [2].

Along with the indicated problem of wide distribution of viral attacks on the informative networks of management, does not lose the actuality et al to the type of threats to information. It, foremost, facilities of realization of threat of opening to confidential information by an unauthorized division to the bases to information, and also by listening of ductings. In any case receipts of information, which are acquisition of some person or group of persons, inflicts it other persons to the proprietors substantial loss.

The unauthorized use of informative resources, from one side, is the mean of opening or compromising of information, and from other – has an independent value, as, even not touching intended for an user or system information, can inflict a certain detriment to the users and administration.

The special danger is presently presented by the problem computer viruses because of absence of effective mechanism of defense. Other unauthorized access paths are added to the reliable blocking at the correctly developed system of providing of informative safety.

The complex of the fixed assets which are used for creation of mechanism of defense includes 5 basic constituents:

- hardwires which are electric, electro mechanics and electronic devices;
- software, specially intended for implementation of functions of privy;
- organizational-technical and organizational and legal measures, carried out in the process of creation and exploitation of the computing engineering and apparatus of telecommunications;
- ethical methods of defense;
- Legislative methods of defense, which regulate the rules of the use, treatment and information of the limited access transfer [3].

The separate group of measures of informative defense is the use of cryptography along with application of digital signature, access control, authentifications and by a management routing.

Requirement on defense of information from an unauthorized division directed on achievement (in certain combination) of three basic properties of information which is subject to defense:

- confidentiality;
- integrity (authenticity, exactness, protected);
- readiness (availability, necessity) [4].

The very important element of the system of privy in the modern economic systems is defense of communication, which is directed on prevention of possibility of unauthorized division to confidential information, circulatory on ductings of connection of different kinds, networks.

Conclusions

Decision of problems of informative safety, related to the computer viruses, two directions provide for in the method of protecting from viruses:

- application of «program analyzers» of programmatic facilities, protected from possibility of unauthorized modification (differentiating of access, methods of self-control and самовосстановления);
- use of the special programs-analyzers which carry out permanent control of rejections in-process application programs, periodic verification of presence of other possible tracks of viral activity (exposure of violations of integrity of software), and also entrance control of the new programs before their use (on characteristic presence bits in their tell of viral educations).

Control of integrity of the programs is executed internal facilities at every start of the program on implementation and consists in comparing of check sums of separate blocks of the programs to their standard sums. Such control is used in the programs for the internal use.

Working out the total, it should be noted that a privy can decide different methods, but most reliability and efficiency is owned by the systems and facilities which are built on the base of cryptographic methods.

References

1. Mel'nikov Y.N. Multilevel safety in corporate networks // Materials of international conference «Informative facilities and technologies», on October, 17-19, 2000 – M., 2000. – P. 157-165.

2. Gostev A. Experts told that waited the Internet in 2014 // [Electronic resource]: http://www.aif.by/vybor/tech/item/26419-inet.html

3. Khorev A.A. Organization of priv from a loss on the technical ductings // Special. technique. – M., 2006. – N 3. – P. 53 – 64.

4. Titorenko G.A. Information technologies in marketing. – M., 2001 – 236 p.

UDC 004.9

S. V. Holub, Ph.D., prof. (CNU, Ukraine, Cherkasy)
V. Y. Nemchekno, postgraduate (CSTU, Ukraine , Cherkasy)
A.V. Dzyubanenko, postgraduate student (NAU, Kyiv, Ukraine)

INFORMATION TECHNOLOGY OF ADAPTIVE FORMATION OVERLAPPING LEVELS OF MONITORING SYSTEMS

The paper-work is devoted to the development of information technology monitoring systems. Considers the construction of adaptive overlapping level structure of the system of multilevel data conversion processing.

At present, the use and development of monitoring systems is extremely important question scientific research and practical applications, as they allow make conclusions about certain events based with only the previous data obtained by observation. The overall goal of such systems is to build a model that would seem to reflect the maximum flow of the process of the object.

Feature of modern monitoring systems is that they operate according to the different types that are often contradictory. This leads to the fact that a linear relationship between them may not be possible, and as a result, building on their base model problem of extraordinary complexity.

To simplify this task can be split processing information for a plurality of sub-tasks, each of which operates the only group of input parameters of the original object. The combination of these subtasks can describe the behavior of the object.

In this regard in [1] proposes to submit information monitoring system as multi-information processing systems, which are formed by the combination of the hierarchical model of the objects.

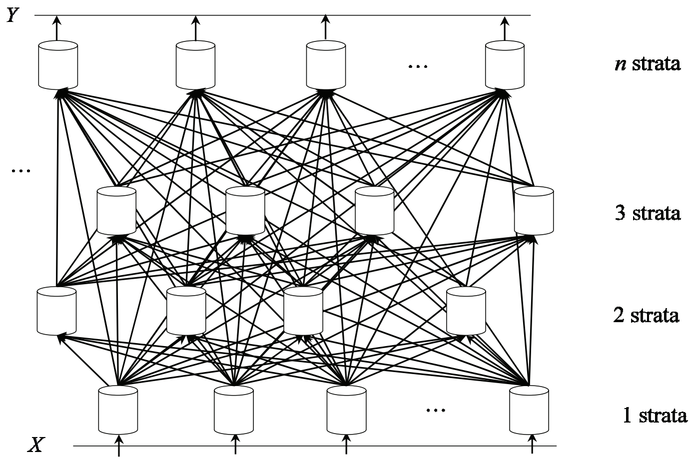


Figure. 1. The multilevel structure of information processing systems

Each of these system appears set of so-called strata [2], which reflect the logical level of information processing.

Each strata consists of a set of models that model a specific setting. The set of executions of models and relations between them form the structure of multi-level systems of information transformation.

In Fig. 1 {X} is the set of input elements; {Y} is the set of output elements.

With this approach is important question in the coordination structure of such systems.

In [3] proposed to use the method of synthesis of the rising elements of a complex system that is coming out of one model serves as the primary description of the other models.

As is often the case with real physical processes in the original description contained or partial, corrupted data, or even to constructing an appropriate data model is not enough. Therefore, in [4] considered duplication technology multilevel structure of the information processing system, which is multiple reuse of simulation results of the same models. However, according to data presented in [5] with an increasing number of levels increases as the construction of models and runtime system as a whole. Also, the time of termination of construction of models directly given by the researcher in the process of formation of the structure of the system. Therefore, an important issue is the improvement of technology overlapping levels.

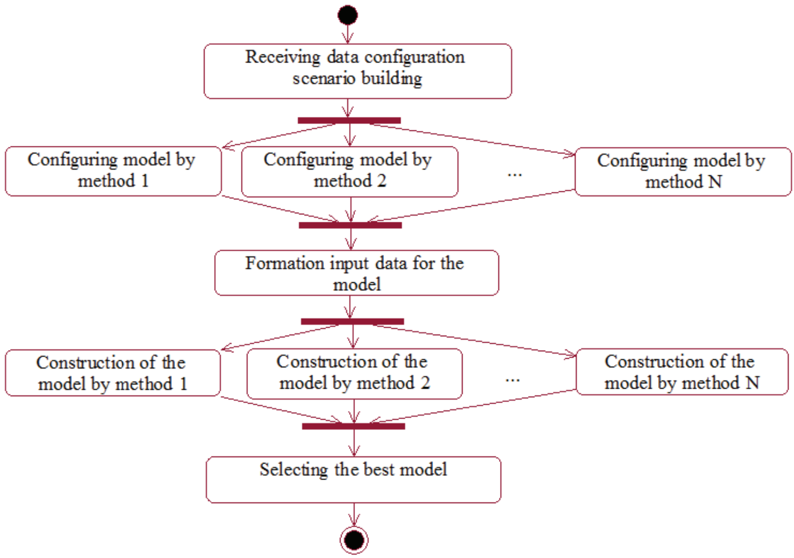


Fig. 2. Process of constructing a model structure of transformation multilevel information processing systems

In [1] the technology of adaptive formation overlapping levels, which is the gradual exclusion of overlapping levels of models, the quality of which is lower than the prior models. The process continues until the quality of the model is improved.

The current paper shows the information technology of adaptive formation overlapping levels of monitoring systems.

On fig. 2 presented the process of constructing a model of the structure of multilevel transformation information.

On fig. 3 presented the process of building adaptive overlapping system structure of multilevel data transformation processing.

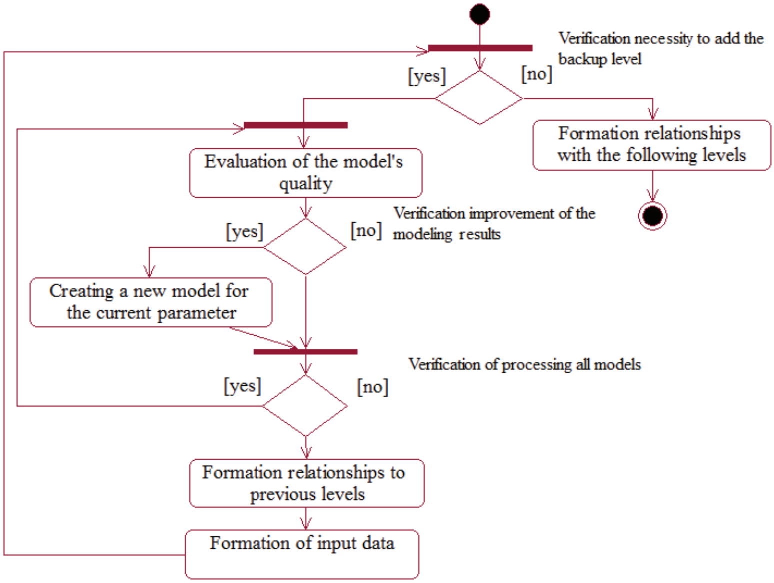


Fig. 3. Process of building adaptive overlapping level system structure transformation of multilevel information processing systems

Described information technology can be used for create software for the automated management of monitoring systems.

References

1. Holub S.V. Adaptyvne formuvannya dublyuyuchykh rivniv v strukturi iyerarkhichnykh system bahatorivnevoho sotsiohihiyenichnoho monitorynhu / S.V. Holub, V.Yu. Nemchenko // Induktyvne modelyuvannya skladnykh system. Zbirnyk naukovykh prats' – Kyyiv: Mizhnar. nauk.- navch. tsentr inform. tekhnolohiy ta system NAN ta MON Ukrayiny, 2011.- Vyp. 1. – S. 41 – 48
2. Mesarovych M. Teoryya yerarkhycheskykh mnohourovnevыkh system /M.Mesarovych, D.Mako, Y.Takakhara. – M.: Myr. – 1973. – 344s.
3. Holub S.V. Koordynatsiya vzayemodiy lokal'nykh ahrehativ v

strukturi system bahatorivnevoho peretvorennya monitorynhovoyi informatsiyi / S.V. Holub // Visnyk Skhidnoukrayins'koho natsional'noho universytetu imeni Volodymyra Dalya. – 2009. – # 6(136). – Chastyna 1. – S. 325-329.

4. Holub S.V. Formuvannya dublyuyuchykh rivniv v iyerarkhichnykh strukturakh avtomatyzovanykh system bahatorivnevoho peretvorennya informatsiyi / S.V. Holub, V.V. Nemchenko, V.Yu. Nechyporenko // Visnyk Skhidnoukrayins'koho natsional'noho universytetu imeni Volodymyra Dalya. – 2011. – #9. – S. 294–297.

5. Nemchenko V.Yu. Vdoskonalennya metodu dublyuyuchykh rivniv dlya adaptuvannya systemy bahatorivnevoho peretvorennya informatsiyi z metoyu strukturnoyi optymizatsiyi systemy upravlinnya navchal'nym protsesom // Intelektual'ni systemy pryynyattya rishen' ta problemy obchyslyuval'noho intelektu: Materialy mizhnarodnoyi naukovoyi konferentsiyi. – Kherson: KhNTU, 2012. – S. 140 – 142.

UDC 621.391

B.P. Ivanov
(Central Reserch of Armament of Armed Forces of Ukraine, Ukraine, Kiev)
D.P. Kucherov, doctor of science
(National Aviation University, Ukraine, Kiev)

THE TASK OF TRACKING A MOBILE ROBOTIC SYSTEMS ON A ROUTE

The report considers the problem of delivery a cargo by remotely controlled a robotic systems wheel type. It is assumed that the movement of vehicles along the route takes place column, which are arranged at the start of the machine, the route consists of straight and curved portions movement. Determined to motion parameters column machines and the law of motion control for movement along a predetermined path.

The report considers the problem of ensuring the delivery of goods from one point to another in a minimum time. Consignment cannot be delivered by one vehicle, but it is possible to redistribute evenly between vehicles of a one class. Delivery is carried out by vehicles that allow remote control, for example, that can occur in cases associated with increased risk for life staff. As vehicles are selected the wheeled vehicles that can be moving on a dry, inviscid coating.

This problem relates to the problems of group control (control collective behavior) mobile robots, that is enough actual direction of the modern robotics.

Solution of the problem tend to select the travel route of a vehicles and tracking the movement of a group (for example, see [1-5]).

We assume that the load shedding associated only with a reduction of group elements, and the reasons leading to a reduction in the number of group elements are absent. In this case, the main task of collective management will considered the minimum time of delivery.

This problem is sufficiently popular among researchers engaged in remote controlled moving transport platform. The main attention is paid to the definition of a mathematical model for remote control and the construction of this model for the optimal control for a single platform. The task could be complicated by the introduction of additional rigid mechanical links. While in areas curved path of motion of this principle is similar to the movement of the tow snakes. Recently, however, there are increasing development-oriented collective (group) management, does not imply the presence of rigid connections between individual members of the group. Such works include work such as [1, 3], which offers the possibility of a tree view in the form of a "master-slave" and the division of the system into subsystems management software and positional control. The "master" (leader) defines the objectives of motion and sequence, "slave" follows the "master".

To determine the design requirements for the system management is needed of information on the potential possibilities of the system, which will ensure the safety of traffic on the route.

We assume key performance indicators of this problem are the delivery time and no loss of cargo during movement.

Thus, the main aim of the paper is to provide a minimum time of delivery a group that consists of n - robotic vehicles.

The problem of delivery is stated as that allowed its distribution between individual vehicles in equal portions. Thus, the choice of the number of vehicles depends on the volume of cargo. A load on a separate vehicle is completely determined of dimensions of robotic agents.

Movement group performed on the track of arbitrary shape with a constant adhesion to the road surface. The track consists of portions of rectilinear and curvilinear motion. Vehicles are moving in the column of the n-machines. At the same time lead car takes leadership group, it has complete information about the ultimate task of following groups and also has navigation and communication tools, as members of the group and the operator in a position to suggest certain actions in the process of solving the problem. Generalized scheme of robotic movement means shown in Figure 1.

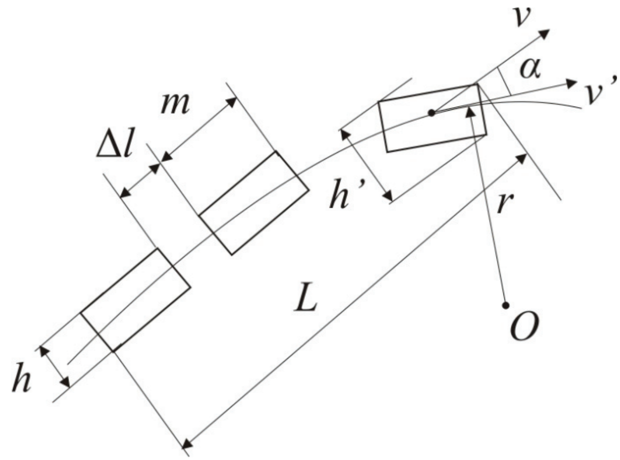


Fig. 1. A scheme of movement of the mobile robotic systems

On Fig. 1 introduced the notation h '- width of the corridor, O - the center of rotation, r - turning radius, v, v' - velocity vectors and its tangential component.

Required to determine the maximum parameters follow a group of n-vehicles into account the curved trajectory.

In order to ensure group's safety on the route are assigned a constant distance Δl between the cars and transverse interval Δh, during which cars do not come out. The route consists of a section start, plot movement on the track and finish area. The sections of start and finish are not point. It is assumed that the areas start / finish line, turning movement is performed with an acceleration, on the straight portion of is uniform motion performed. Size L column on the route agreed with the number of machines in the group, the size of individual vehicle and the value m distance Δl

$$L = (n-1)\Delta l + nm \tag{1}$$

and cannot go beyond a certain value $\Delta\delta$, the maximum value of which will be determined by the geometry of the rotation, the motion parameters and the number of vehicles.

We assume that the movement of a group of vehicles in the absence of a rigid connection between the elements of the group, allowing the group to consider each element separately and setting its average values for the corridor and a maximum average speed.

We will seek the average vehicle speed on a section of curvilinear motion of radius r under the conditions that the average speed on a uniform plot v, car deviates from the normal when turning no more than an angle α and gravity during movement of the car does not change. Then the speed of the vehicle is determined by the formula

$$v = \sqrt{\frac{gr}{tg\beta}}\ , \tag{2}$$

where g = 9.8 m/s^2 - acceleration of gravity, and the maximum speed in the curved section of track with a radius r_{max} and the angle of deviation from the normal β_{max} is

$$v_{\max} = \sqrt{\frac{gr_{\max}}{tg\beta_{\max}}}\ . \tag{3}$$

The maximum width of the corridor is determined as the difference between the radii of the two points of the machine - the most distant from the rotation center and closest thereto. Consequently, at the curved portion of the movement to the dimensions of the vehicle horizontally m and h the vertical the corridor is value

$$\frac{m^2}{r} + h\cos\alpha \le h_{доп}\ . \tag{4}$$

In (4), the maximum width of the corridor is defined at the minimum r and at the maximum α.

The repetition interval should provide time for slowing down to a complete stop if the vehicle in front applies the emergency brake. From course physics we know that the braking distance S_m determined vehicle speed v at the beginning of braking and friction coefficient μ

$$S_{т} = \frac{v^2}{\mu g}\ . \tag{5}$$

Obviously, the choice of the distance in the group, based on the terms of traffic safety, to exceed this distance in 2 .. 3 times, namely

$$\Delta l=(2\ldots3)S_m. \tag{6}$$

Thus, formulas (1) - (5), taking into account the comments (6) fully define the requirements for the movement of the group on the route.

Dynamics of the route described by differential equations of the form, in accordance with [1, 3]

$$\dot{x}_i = y_i,\ \ \dot{y}_i = u_i(x, y, z)\ , \tag{7}$$

where $x=\{x_1,\ldots, x_n\}$, $y=\{y_1,\ldots, y_n\}$, $z=\{z_1,\ldots, z_n\}$ – position, velocity and acceleration of the center of mass n machines in Cartesian coordinates, and $u_i(x, y, z)$ - the control action that is meaningful acceleration the i-th machine.

We assume that the system has the exchange of information and every machine available information about parameters of the motion the neighboring machine, namely j-th means have the information about j-1 and j +1 machines, n-th has information about (n-1)-*th* machine.

Then, the control law that provides the tracking on a trajectory can be described as

$$u_i = c_k V_i \,, \tag{8}$$

where $c_k \neq 0$, k=1, 2, 3,

$$V_i = (x_i - x_{i-1},\;\; y_i - y_{i-1},\;\; z_i - z_{i-1})\,. \tag{9}$$

and i=1…n.

Control law (8), (9) is smooth in the coordinates x, y, z function, it is allows to realize a system with feedback control, its effectiveness is determined by an appropriate choice of c_k. When the law (8), (9) is performed, each machine should be strictly on a route determined by the master.

Conclusions

In the article the requirements to parameters for mobile robotic systems motion as a column machines, conditions for performing motion based representations of the physical laws of motion of vehicles. The actual dynamics of the route is determined by a mathematical model of the system, representing a system of differential equations of second order. Further research should focus on optimizing the control law.

References

1. *Кунцевич В.М.* Некоторые задачи управления групповым движением подвижных роботов / Кунцевич В.М. // Проблемы управления и автоматики. - № 1. – 2012. – с. 5-18.

2. *Ларин В.Б.* Об отслеживании программной траектории колесным транспортным роботом / Ларин В.Б. // Проблемы управления и автоматики. - № 1. – 2013. – с. 139-146.

3. *Морозов Ю.В.* Модификация и сравнительный анализ гладких законов управления группой агентов / Морозов Ю.В. // Автоматика и телемеханика. - № 11. – 2012. – с. 96-113.

4. *Кучеров Д.П.* Интеграционный подход к задаче выбора маршрута группы БПЛА / Кучеров Д.П., Козуб А.Н. // Искусственный интеллект. - № 4 (62). – 2013. – С. 333-343.

5. *Кучеров Д.П.* Планирование маршрута БПЛА / Кучеров Д.П., Козуб А.Н. // Вісник східноукраїнського національного університету імені Володимира Даля. - № 5. – 2013. – С. 189-192.

UDC 537.622+539+003.3

V. V. Kovalchuk, Habil. Dr. Sci. (State Environmental University, Ukraine, Odessa)
V. P. Kvasnikov, Habil. Dr. Sci. (State Aviation University, Ukraine, Kyiv)
V. L. Kostenko, Habil. Dr. Sci.(State Polytechnic University, Ukraine, Odessa)
O. O. Panchenko (State Computer Science Technology College, Ukraine, Odessa)

FORMATION'S PROCEDURE OF THE NANOCLUSTERS: HETEROTRANSITIONS AND HETEROSYSTEMS AT THE INFORMATION TECHNOLOGY

In this paper, we have discussed the theoretical and experimental results of quantum-dimensional system like nanoclusters. Our results are important for an engeneering science for investigation, visualization and generation parts of the intellectual system.

An semiconductor surface is specific surface disordered phase (SDP) and the main peculiarities of modern nanoelectronic devices depend on the individual parameters of the surface phase. Furthermore, the reactions of atomic hydrogen (H), fluorine (F), chlorine (Cl) and bromine (Br) with Si surface were widely studied experimentally and many investigators have observed the semiconductor SDP directly [1-3]. For a quantitative analyses of nanostructures like nanoclusters (NC) creation in Si and other solid materials the clusters distribution along the surface is necessary.

On the other hand, the recent progress in the combination of visualization with simulation techniques have concurred to obtain spectacular results in the investigation of chemical reaction mechanisms as well [4]. The traditional quantum chemical ab initio methods, based on the Hartree-Fock scheme have become well established in studies of the electronic and geometrical structure of the solid NC [1]. Therefore, the surface NC as real objects and model in the nanoelectronic's material for intelectual system is great interest.

Our Model Molecular Graphics Package (MMGP) which is specially designed so as to allow for high-level computerized visualization in molecular science. MMGP contains many interfaces with quantum chemical programs such as the semiempirical and molecular surface geometry generation, which is based on the interatomic potential (for example, Modified Stillinger-Weber (MSW)).

In the paper development and applications of the MMGP to the Si-NC was demonstrated. The MMGP generates detailed and easily interpretable and aesthetically appealing graphics representing models of molecular structures and related properties. The package offers a high level of interactivity through the use of the mouse and via a large set of menus and submenu, organized in such a way so as to enable users to learn rapidly the basic operations leading to efficient visualization (see Fig 1).

For all the menu items, a help facility has been implemented. Various representation options and attributes may be selected for adapting the visual output to personal needs and preferences: the molecular structures may be represented as discrete dots, and the global appearance may be modified via attributeS such as back ground appearance, perspective or orthogonal projection and others. The purpose of the MMGP is the interactive visual representation of three-dimensional (3D) models of molecular structures and properties for research. Due to the flexibility of the data- and program-structure, various chemical systems ranging from small compounds (clusters) to large macromolecules may be investigated; additional interfaces and tools can easily be implemented.

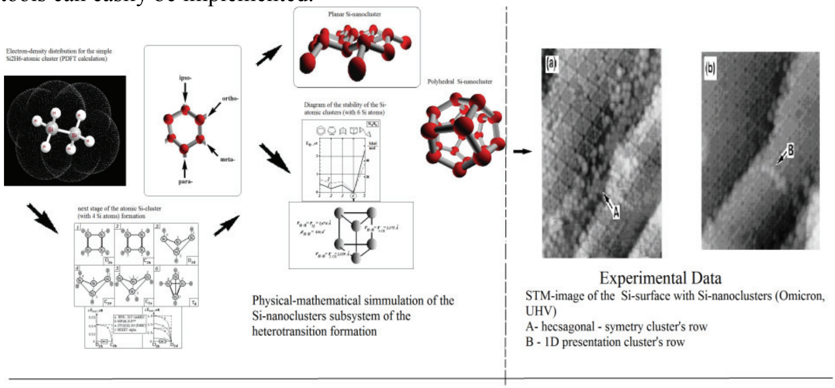


Fig 1. *3D*-representation of the nanocluster's formation

The MMGP contains the tools which are neccessary for the investigation and visualization of the results generated by the calculation program-package contains:

- Modified IEHT-α method.

This is for semiempirical calculations of one-electron level energies, wave functions and other parameters of electronic structure of NC. The estimation of the total energy of clusters which has different size is follows:

$$E_{tot} = \sum_{A\neq B} \frac{Q_A(\vec{r}_{AB}) - Q^*_A(\vec{r}_{AB})}{r_{AB}} + \sum_i g_i E_i - (E_{ee} + E_{exc}) \qquad (1)$$

$$E_{exc} = \sum_{A\neq B,}^{all} \sum_{\mu\neq\nu}^{occ} \frac{1}{r_{AB}} \nu_{AB} S^2_{\mu\nu} \qquad (2)$$

ν_{AB} is the fitting parameter.

- POTENTIAL package.

This is simulation programme for calculations based on different types of interaction potentials. One of them is modified Stillinger-Weber-type potential [2]. Hamiltonian is follows:

$$H(\vec{r}_1, \vec{r}_2 \ldots \vec{r}_N, \vec{p}_1, \vec{p}_2 \ldots \vec{p}_N) = \sum_{i=1}^{N} \frac{p_i^2}{2m} + \sum_{i<j}^{N} V^{(2)}_{\text{int}}(\vec{r}_{ij}) + \sum_{i<j<k}^{N} V^{(3)}_{\text{int}}(\vec{r}_{ij}, \vec{r}_{ik}, \vec{r}_{jk}), \qquad (3)$$

$\vec{r}_1, \vec{r}_2 \ldots \vec{r}_N$ are coordinates of the atoms. $V_{(2)int}$ is the twin potential (4); $V_{(3)int}$ tree-part *SW*-potential :

$$V_{\text{int}}^{(2)}(\vec{r}_{ij}) = \begin{cases} A\left(B\dfrac{1}{r_{ij}^{p}} - 1\right)\exp\left(\dfrac{\Lambda}{r_{ij} - a}\right) \\ 0, others \end{cases}, \vec{r}_{ij} < 2{,}5\,\sigma_{AB} \tag{4}$$

$$V_{\text{int}}^{(3)}(\vec{r}_{ij}, \vec{r}_{ik}, \vec{r}_{jk}) = \Pi_{ijk} + \Pi_{kij} + \Pi_{jki} \tag{5}$$

$$\Pi_{ijk} = \Lambda\left(\cos\theta_{jik} + \frac{1}{3}\right)^2 \exp\left(\frac{\delta_{ijk}}{r_{ij} - a} + \frac{\delta_{ijk}}{r_{ik} - a}\right)$$

$\Theta_{ijк}$ is angle, $\vec{r}_{ij}$ and $\vec{r}_{jk}$, $\vec{r}_{ij} = \left|\vec{r}_i - \vec{r}_j\right|$ is the vector between *i* and *j* atoms in units of the equilibrium distance between nearest atoms in thestructure ($\vec{r}_0$). For *Si* $\vec{r}_0$ = *2,351A (*modified SW*),* and $\vec{r}_0$=*2,0951A* (original SW). The energy unit equal *E = 2,1675* eV *i.e* $E_{Si\text{-}Si}$ in the crystal *Si* . The parameters of the modified SW-potential are presnt in the [3].

- Graphic Package is a geometrical program based on *3D*-representation of the investigation of NC.

We will report the results of test calculation for adsorption processes*,* optics properties of the closely packed and ball-like Si NC. Real surface objects may be built by introducing stereochemistry, i.e., the 3D atomic positions, and it is important to visualize them as molecular models with the usual rendering techniques leading to 3D perception. MMGP visualization allows investigators to emphasize at length the different aspects of molecular structure of surface: chemical topology, conformational details, etc.

We applied the MMGP to the Si-SDP. With the appearance of semiempirical methods the calculation of the equilibrium geometry and visualization of quite large model became possible (*N=125* Atoms). The calculation bond lengths of some surface are given in ref. [5-7].

As one can see from these data the calculated interatomic are in a quite good agreement with the experimental ones. Especially, the changes of the Si - Si bond, going from a small Si -NC (2-10 atoms) to big are accurately described. We find the energies of NC, binding energy per atom and interection energy of the systems «NC-SDP» are obtained for more stable geometry. Furthermore, the energetic positions and equilibrium distances as well as of silicon are described rather well.

Other example of the adsorption process and chemical reactions on semiconductor surfaces is the interaction with halogen-atoms [6]. When using the model to represent the SDP, a choice has to be made about the NC size, that is, the number of atoms which are treated explicity in the calculation, and the level of precision of the required computation. Fortunately, the chemisorption of atoms on SDP seems to be of local character. This fact is greately supported by ab initio model calculations, and particularly by the calculations for the chemisorption of F and Cl on Si-SDP.

In our calculation the single NC contains 10-100 Si atoms, representing the first four layers of the Si-SDP. We regard this model as hypothetical molecules (quasimolecules) and do try to compare the computed results (for example, magic numbers) directly to experimental data of the corresponding impurities in the solids or chemisorbed systems [1]. The mass spectra of charged NC, where magic numbers are observed [3].

Take into account the internal structure of the ball-like Si NC we investigate theoretically the adsorbtion and scattering of light by ones. The theory for the interaction of electromagnetic fields with local charge-carrier near boundary of the small spherical semiconductor microcrystals was presented in [8]. In the [5,8] the dipole moments of NC (using MMGP) and transition dipole moments for local bulk states and local exterior surface states were calculated. It was shown that the dipole moments of the transitions for local states of the Si NC are large compared to the typical values of transition dipole moments for Si - NC.

Conclusion

We have shown that the calculated energy and geometrical characteristics by MMGP are in satisfactory agreement with the experiment and others ab initio calculations [1-8]. The present calculations show that the MMGP can be used to obtain a detailed and reasonably accurate description of various aspects of the small halogen-Si-NC. In view of interest of a physicist for the visualization of such NC, one may foresee that the data banks that represent the major types of stable systems will soon be available. Therefore, it is important for a physicist to have at hand the computer tools allowing visualization and generation of computational information. The combination MMGP with molecular dynamics in connection with technique of simulated annealing, makes it a very useful tool for the determination of geometries of large NC. Reconstruction processes at Si SDP or amorphous solids can be studied also in this way.

References

1. Kovalchuk V.V. Nanoelectronic's material for intelectual system // Visnyk Dnipropetrovskogo Universytetu. Fizyka. Radio-electronika. – 2013.-No 2. (Issue 20), V. 21.- P.129-133.
2. Kovalchuk V.V., Afanas'eva O.V., Rats V.O., Michalko M.V. Nanoparticle's morphology for the robot intelectual systems // Aviation in the XXI Century. Materials of the Word Congress. - Sept.25-27, 2012.- P.1.9.62-1.9.65
3. Marsen B., Lonfat M., Scheier P., Sattler K. The energy gap of pristine silicon clusters // J.Electr.Spectr.Rel.Phenom.- 2008. - v. 109. - p.157-168
4. Calculation of Molecules, Clusters and Solids with DFT-LDA Scheme / Blaudeck P., Freuenheim Th., Seifert G. and others. // J. Phys.: Condensed Matter. — 2012. — vol. 4. — P. 6368 — 6371.
5. Kovalchuk V.V., Dolinska L.V. Principles of research of the devices providing of nanomeasuring // Metrology and devices. - 2010. - №4(24).-C.49-59
6. Kovalchuk V.V. Cluster morphology of silicon nanoparticles // Semiconductor physics, quantum electronics & Optoelectronics. - 2007.- v. 10, № 4. P. 81-86.
7. Kovalchuk V.V. Cluster modification semiconductor's heterostructures.- Kiyv: Hi-Tech, 2007.-309 p.
8. V. Kovalchuk, V.L. Kostenko, A. Panchenko Algorithm and process control subsystem build nanocluster substance / // Bulletin of the Engineering Academy of Ukraine. - 2014. - № 2. - P.121-126.

UDC 621.317

V.Y. Kucheruk, Sc.D., S.Sh.Katsyv, Ph.D., V.S. Mankovska, assistant
(Vinnytsia National Technical University, Ukraine),
M.V. Mykhalko (National Aviation University, Ukraine)

RESEARCH OF THE «DETERMINED CHAOS» PHENOMENON IN THE RL-DIODE ELECTRIC CIRCUIT OF SINUSOIDAL CURRENT

Annotation. *Reasons and conditions of chaotic oscillations in the nonlinear RL-diode electric circuit of sinusoidal current are analyzed. A diode is presented by the circuit of substitution that generally includes a nonlinear resistor and two nonlinear capacities – barrier and diffusive. To calculate the transition process a differential equation, which due to the non-linearity of a number of parameters is modified by the method of polygonal approximation, is proposed. The dependence of attractor form on a linear inductor and frequency is explored.*

When creating parametric resistive transducers for metrology (in particular, resolution ability) it is quite often needed to convert very small changes of the output resistance, for example, strain measurements.

This in turn leads to increased random noise on a useful signal that increases the random error of measurement. That is why the increased sensitivity of resistive transducers while ensuring a low level of random noise is an aim.

One way to accomplish this task is the use of RL-diode generators of chaotic oscillations [1-7]. However, in scientific literature the problem of mathematical modeling of physical processes in the RL-diode circuit and the causes of deterministic chaos in it are not considered in detail.

Analysis of the causes and conditions of chaotic oscillations in RL-diode circuits is the subject of the research described in this paper. For this purpose the diode substitution scheme for a diode is considered [8].

Substitution scheme for a diode

The substitution scheme for a diode in the mode of small signal (more generally) is presented on fig.1.

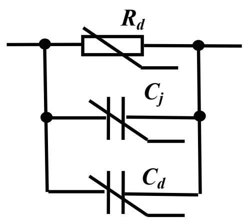


Fig. 1 – Substitution scheme for a diode in the mode of small signal

According to this scheme a diode is a parallel connection of nonlinear resistor R_d and two nonlinear capacities – barrier C_j and diffusive C_d.

A barrier capacity is determined by the formula:

$$C_j = \frac{C_{j0}}{\left(1 - \frac{U}{U_D}\right)^n}, \tag{1}$$

where C_{j0} – a barrier capacity at a zero voltage of diode; U – voltage of diode; U_D – diffusive voltage of diode; n – technology ratio in the range $(\frac{1}{3} \ldots \frac{2}{3})$.

A diffusive capacity is determined by:

$$C_d = \frac{\tau_B I_S}{m U_T} e^{\frac{U}{m U_T}}, \tag{2}$$

where I_S – thermal current of diode; τ_B – life-time of non-core charge carrier; U –diode voltage; U_T – thermal voltage of diode; m – coefficient of emission.

It should be noted that in the mode of direct voltage at $U \geq U_D$ it is possible to ignore a barrier capacity. In the mode of reverse voltage it is possible to ignore a diffusive capacity.

Analysis of the mode of operations of RL-diode electric circuit of sinusoidal current

The processes in the RL-diode circuit (Fig. 2) with the input sinusoidal voltage are considered. In the most general case, the substitution scheme for this circuit is shown in Figure 3. This scheme contains three nonlinear elements: resistor R_d, C_j and diffusive capacity C_d. Thus, the resistance of the resistor depends on the diode current; the capacities depend on the diode voltage.

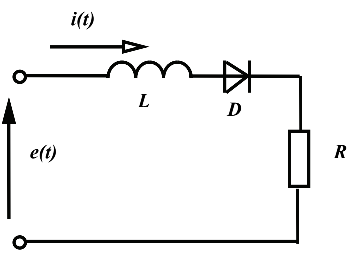


Fig. 2 – RL-diode electric circuit of sinusoidal current

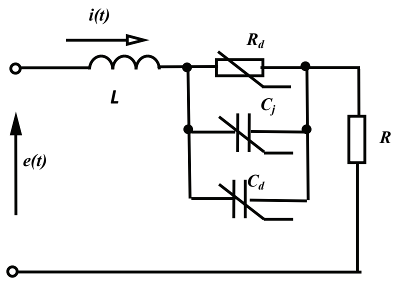


Fig. 3 – Substitution scheme for the RL-diode electric circuit of sinusoidal current

The system of equations for the scheme according to Kirchhoff's laws is shown in Figure 3. It is assumed that the current i_1 passes through the resistor R_d, the current i_2 through the capacity C_j and the current i_3 through the capacity C_d. As the voltage is the same it is denoted by U_C.

$$
\begin{aligned}
& i = i_1 + i_2 + i_3 \\
& L\frac{di}{dt} + Ri + R_d(i_1)i_1 = e \\
& R_d(i_1)i_1 = U_C \\
& i_2 = C_j(U_C)\frac{dU_C}{dt} \\
& i_3 = C_d(U_C)\frac{dU_C}{dt}
\end{aligned} \tag{3}
$$

It follows

$$
\begin{aligned}
& i_1 = \frac{U_C}{R_d(i_1)}, \\
& i = \frac{U_C}{R_d(i_1)} + C_j(U_C)\frac{dU_C}{dt} + C_d(U_C)\frac{dU_C}{dt},
\end{aligned}
$$

and, finally,

$$
\begin{aligned}
& L\frac{d\left(\frac{U_C}{R_d(i_1)} + C_j(U_C)\frac{dU_C}{dt} + C_d(U_C)\frac{dU_C}{dt}\right)}{dt} + \\
& + R\left(\frac{U_C}{R_d(i_1)} + C_j(U_C)\frac{dU_C}{dt} + C_d(U_C)\frac{dU_C}{dt}\right) + U_C = \\
& = \frac{L}{R_d(i_1)}\frac{dU_C}{dt} + LC_j(U_C)\frac{d^2U_C}{dt^2} + LC_d(U_C)\frac{d^2U_C}{dt^2} + \\
& + \frac{R}{R_d(i_1)}U_C + RC_j(U_C)\frac{dU_C}{dt} + RC_d(U_C)\frac{dU_C}{dt} + U_C = e.
\end{aligned}
$$

The final expression for the differential equations of the second order that subjects the behavior of the electrical circuit is proposed.

$$
\begin{aligned}
& \left(LC_j(U_C) + LC_d(U_C)\right)\frac{d^2U_C}{dt^2} + \\
& + \left(\frac{L}{R_d(i_1)} + RC_j(U_C) + RC_d(U_C)\right)\frac{dU_C}{dt} + \\
& + \left(\frac{R}{R_d(i_1)} + 1\right)U_C = e.
\end{aligned}
$$

This differential equation is performed by an operator in a general form. The operator equation of the 2-th Kirchhoff's law for this circuit is:

$$
I(s)\left(R + sL + Z_d(s)\right) = E(s),
$$

where $Z_d(s)$ – full operator resistance of the substitution scheme for a diode that is defined as

$$Z_d(s) = \frac{R_d(i_1)\frac{1}{sC_j(U_C)}\frac{1}{sC_d(U_C)}}{R_d(i_1)\frac{1}{sC_j(U_C)} + R_d(i_1)\frac{1}{sC_d(U_C)} + \frac{1}{sC_j(U_C)}\frac{1}{sC_d(U_C)}}.$$

Then, operator image of the current of the circuit is

$$I(s) = \frac{E(s)}{(R + sL + Z_d(s))}.$$

Due to the substantial nonlinearity $Z_d(s)$ it is impossible to get the original circuit current *i(t)* in a general view.

Therefore, let's solve a problem in numerical form for one of the types of diodes and the specific values *e(t)*, *R*, *L*.

Let: $e(t) = 3\sin(\omega t)$ [B], $f = 10$ [kGc], $L = 50$ [mGn], $R = 2$ [kOm] and the type of diode – *1N457*.

Note, the parameters of the diode are taken from a database of the MicroCap software. The parameters required to define the formulas (1, 2) C_j and C_d partially are taken from a database of the MicroCap software and partially are taken from in the common form for a wide class of the diode models. Taking into account that the diode parameters are significantly different for forward and reverse voltage, the circuit has a modified mode analysis by polygonal approximation using transient characteristics and Duhamel integral. All calculations are performed in MathCAD.

Due to the labour-consuming mode the calculations are performed for four oscillation periods. Based on the results of the calculations the dependence *U2=f(U1)* was built, where *U2=IR*. The graph of this function is shown in Figure 4. The graph demonstrates that at the above-mentioned parameters the circuit mode has chaotic oscillations. Certainly, the form of these oscillations of the actual diode may differ significantly from the calculation form because, firstly, the parameters required to define the formulas (1, 2) C_j and C_d are taken from in the common form for a wide class of the diode models and, secondly, any numerical calculations in nonlinear circuits always give tolerance.

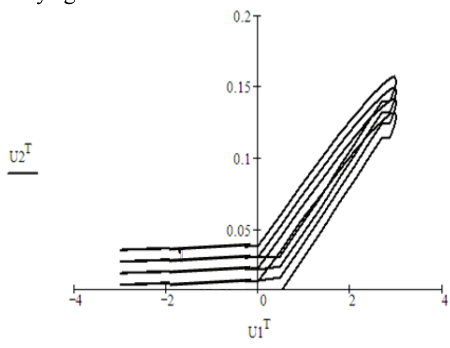


Fig. 4 – Graph of dependence *U2=f(U1)*: at $f = 10$ [kGc], $L = 50$ [mGn], $R = 2$ [kOm]

The calculations of the circuit mode are also performed at other values of inductance and frequency in order to evaluate the influence of these parameters on chaotic oscillations.

Conclusion

The current in the circuit doesn't die out to zero and a new period begins with a non-zero initial conditions at the end of the period in the RL-diode circuits of sinusoidal current if the period of oscillations is commensurate with the time constant of the transition process. Thus, due to essential non-linearity of parameters of the substitution scheme for a diode there is practically the ongoing transitional process in the circuit that takes the form of chaotic oscillations. While increasing the inductance of the circuit the scale of the attractor increases. In the case of increasing the frequency of the input voltage there is a tendency of some displacement of the attractor towards negative voltages.

References

1. V. Kucheruk, Z. L. Warsza, V. Sevastyanow, W. Mankowska Generator oscylacji chaotycznych o układzie RL-dioda jako przetwornikrezystancja-napięcie. PRZEGLĄD ELEKTROTECHNICZNY, ISSN 0033-2097, R. 89 NR 10/2013.

2. Aissi C., Kazakos D.A., Review of Chaotic Circuits, Simulation and Implementation. Proceeding of the 10th *WSEAS International Conference on Circuits*, Vouliagmeni, Athens, Greece, July 10-12, (2006), 125-131.

3. Кучерук В.Ю., Севастьянов В.Н., Маньковськая В.С.: Об основных принципах создания измерительных устройств с использованием генераторов хаотических колебаний.

4. Alam J., Anwar S.: Chasing Chaos with an RL-Diode Circuit. LUMS School of Science and Engineering. – March 24, 2010.

5. Azzonz A., Hasler M.: Orbits of the RL-Diode. *Circuits and Systems,* Vol. 37, (1990), n. 11, 1330-1338.

6. Korotkii V.P.: Transducer in a Dynamic Chaos Regime. *Measurement Techniques* October 2001, Volume 44, n. 10, 989 -92 Transl. from *Izmieritel'naja Tekhnika* (2001) n.10, 17-19.

7. Satoshi Tanaka, Jun Noguchi, Shinichi Higuchi, Takashi Matsumoto. Bifurcation Analysis of a Driven RL-Diode Circuit. *Математический анализ* (1991). n. 760, 111-128.

8. Уве Наундорф.: Аналоговая электроника. Основы, расчет, моделирование. Москва: Техносфера, 2008. – 472 с.

UDC 681.2

V.P. Kvasnikov, doctor of technical sciences
(National Aviation University, Ukraine, Kyiv),
O.M. Bezvesilna, doctor of technical sciences
(National Technical University of Ukraine "Kyiv Polytechnic Institute", Ukraine, Kyiv)
A.H. Tkachuk, candidate of technical sciences
(Zhytomyr State Technological University, Ukraine, Zhytomyr)

GRAVIMETR FOR ROBOTICS COMPLEXES ON AIR- AND SPACECRAFT

The gravimeter with two-degree dynamically customized gyroscope which used in robotics complexes on air- and spacecraft as a means to measure the gravity is considered.

The information about the gravity is needed in correction of the systems of inertial navigation of rockets, for realization of aims of robotics complexes in aviation and space technique, for engineering geology, archaeology. To determine the characteristics of the Earth's gravity field the gravimeter is most useful [1,2].

All kinds of modern gravimeters analyzed in [2], which describes their design and operating principle.

Gravimeter (Fig. 1) contains a two-degree dynamically customized gyroscope (1) with a rotor (2). To a gyroscope are connected a transmitter of an angle of a turn (3), transmitter of a moment (4), low-pass filter (5) and device (6) for an evaluation of an output signal of gravimeter. The centre of mass of a rotor is displaced concerning it of an axes of rotation on magnitude l.

The multiple precision of measurements of acceleration of gravity is ensured because the centre of masses of a rotor is displaced concerning it of an axes of rotation. Therefore this gravimeter fulfils an immediate measurement of acceleration of gravity. These measurements are fulfilled with the help of transmitter of an angle of a turn.

The most part of a power of errors in a measuring signal is concentrated on frequencies above 0.1 radian/sec. Therefore low-pass filter can execute a filtration of errors in a measuring signal. The device of an evaluation of an output signal will transform a result of a filtration to an output signal of gravimeter.

Also at use of the modern digital computing device there is a possibility to fulfill a filtration of a measuring signal in view of its two-dimensional character. Thus it is necessary to accumulate result of measurements and to consider them in fixation to coordinates of points on a surface of the Earth.

Thus, the essential errors of measurements are eliminated from an output signal of gravimeter. If these errors to not eliminate, their magnitude can be commensurable with a value of a useful signal. Therefore offered method of handling of measuring information allows essentially to increase of measurement accuracy of acceleration of gravity.

Gravimeter works as follows. At exposition of work of gravimeter basic positions are taken from [2].

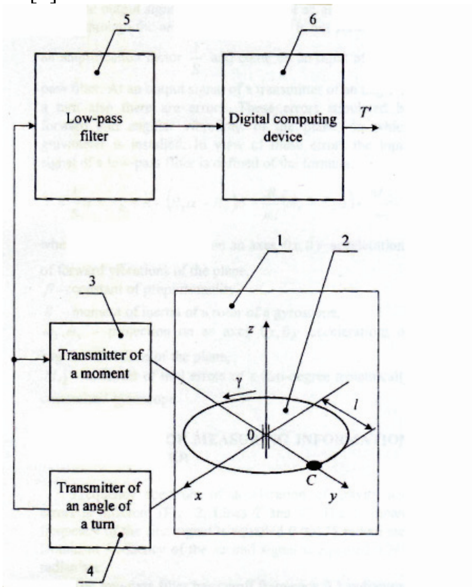


Fig.1.The block diagram of gravimeter

Rotor of a gyroscope rotation by an angular velocity γ. At a lack of exterior actions the rotor rotates in a horizontal plane. At presence of acceleration of gravity along an axes of rotation the moment M_g is created and the rotor begins to deviate:

$$M_g = mgl \cdot \cos\alpha,$$

where m − mass of a rotor, l − displacement of a centre of masses of a rotor concerning it of an axes of rotation, α - angle of a deviation of a rotor.

The moment $M_{\ddot{h}}$ from vertical acceleration $\ddot{h}$ along an axes of sensitivity of gravimeter is equaled:

$$M_{\ddot{h}} = m\ddot{h}l \cdot \cos\alpha.$$

The moment M_T elastic forces of the elements of a suspension bracket of a rotor is equaled:

$$M_T = C_x \alpha,$$

where C_x - rigidity of the elastic elements of a suspension bracket at their torsion.

The centrifugal moment M_u is equaled:

$$M_u = I\dot{\gamma}^2 \sin\alpha,$$

where I -moment of inertia of a rotor, γ - angular velocity of rotation of a rotor.

If to accept, that α<< 1 radian, it is possible to note:

$$C_x\alpha + I\dot{\gamma}^2\alpha = -mgl + ml\ddot{h}.$$

From here, by designating $k = C_x + I\dot{\gamma}^2$, we obtain:

$$\alpha = -\frac{ml}{C_x + I\dot{\gamma}^2}\left(g + \ddot{h}\right) = -\frac{ml}{k}\left(g + \ddot{h}\right).$$

By designating $S = \frac{ml}{k}$, we obtain an entering signal k of a low-pass filter:

$$T = \frac{1}{S}\alpha = -g + \ddot{h}.$$

From here

$$\alpha = (-g + \ddot{h}) \cdot S.$$

Thus, the angle a deviation of a rotor is proportional to acceleration of gravity g and vertical acceleration $\ddot{h}$ of the plane or spacecraft.

The output signal of a transmitter of an angle of a turn passes through the amplifier (in a Fig. 1 is not shown) with an amplification factor $\frac{1}{S}$ and come on an input of a low-pass filter. At an output signal of a transmitter of an angle of a turn also there are errors. These errors stipulated by forward and angular vibrations of the plane, on which gravimeter is installed. In view of these errors the input signal of a low-pass filter is defined of the formula:

$$T = \frac{1}{S}\alpha = -g + \ddot{h} - \left(R_x\alpha - R_y\right)\beta - \frac{B}{ml}\left(\dot{\omega}_x + \dot{\omega}_y\alpha\right) + \frac{M_{i2}}{ml},$$

where R_x, R_y – projection on an axes *Ox, Oy* accelerations of forward vibrations of the plane, β – constant of proportionality, B - moment of inertia of a rotor of a gyroscope, $\dot{\omega}_x, \dot{\omega}_y$ – projection on an axes *Ox, Oy* accelerations of angular vibrations of the plane or spacecraft, M_{i2} – moment of tool errors of a two-degree dynamically customized gyroscope.

The filtration of the gravity measuring information can be executed by the one-dimensional filter for the array of data. These data are received along one line of flight of aircraft gravity system. Such filtration is carried out during flight in rate of receipt of the data or at processing gravity measurements after flight.

In the given research other variant is offered also. It consists in formation two-dimensional array of the gravity measuring information on anomalies of acceleration of gravity. The array is formed in fixation to coordinates of points of a surface of the Earth, in which these data were received. This array corresponded to series lines of flight. After that carry out a filtration of the generated array with the help of two-dimensional digital low-pass filter. Two-dimensional correlation in a useful signal about anomalies of acceleration of gravity in addition take into account. Such filtration can be executed at processing results of gravity measurements after flight.

Interrelation of such approach with the basic requirements to gravimetric survey on some district are considered.

Known regional and detailed gravimetric survey [2]. The regional gravimetric survey is displayed on cards of scale 1:200 000 with section of isolines through 2 mGal. The gravimetric survey is continuous. The cards, made by results of survey, give representations about general structure of an abnormal field, his basic features and regularity. The cards of anomalies are used at the decision of astronomical and geodetic tasks. The anomalies at regional shooting also provide the decision of tectonic tasks.

The detailed gravimetric survey will be carried out in conditions, when the regional survey is already carried out and basic regularity and the properties of an abnormal field are known. The detailed survey differs from regional survey to structure of a network and flights, scales of cards and accuracy of definition of anomalies, ways of their processing and interpretation [3].

Conclusion

The gravimeter with two-degree dynamically customized gyroscope which used in robotics complexes on air- and spacecraft as a means to measure the gravity is considered. It was established, that this gravimeter provides precision measurement of gravity is much higher than known today gravimeters.

References

3.Кваснiков В.П. Траєкторне керування манiпуляцiйними роботами в просторi базових координат / В.П. Кваснiков, М.М. Вохмянiн // Наукоємнi технологiї: Науковий журнал. – Київ: НАУ-друк, 2009. – № 3. – С. 66-68

4.Безвесiльна О.М. П’єзоелектричний гравiметр авiацiйної гравiметричної системи: монографiя / О. М. Безвесiльна, А.Г. Ткачук. – Житомир : ЖДТУ, 2007. – 604 с.

5.Безвесiльна О.М. Системи наведення та стабiлiзацiї озброєння: монографiя / О.М. Безвесiльна, В.П. Кваснiков, В.Г. Цiрук, В.В. Чiковани. – Київ: НАУ, 2014. – 176 с.

UDC 681.2

V.P.Kvasnikov, Dr.Sci.Tech (National Aviation University, Ukraine, Kiev)
T.I. Ganeva (Odessa State Academy of Technical Regulation and Quality, Ukraine, Odessa)

SEMICONDUCTOR STRAIN TRANSDUCERS FOR CONTROL SYSTEMS DEFLECTED MODE

The directions of development and creation of controlling systems with the using of the strain-sensitive of elements and strain transducer on the basis of semiconductor materials with the improved metrological characteristics are shown.

On the basis of the comparative analysis, semiconductor strain-sensitive of elements are significantly greater strain-sensitivity and high output measuring circuits, simplifying the implementation of the circuit engineering devices.

The most important feature is the ability of semiconductor resistive-strain changes in a wide range of electrophysical properties of that principle is not feasible in the wire and foil. However, commercially available semiconductor resistive-strain and strain transducer have low precision, narrow range and unstable output characteristics, require complex setup procedures during the production. In this regard, the development of suitable semiconductor strain-sensitive of elements and strain transducer on the basis of the progressive design and technological solutions to create semiconductor structures with specified metrological characteristics: sensitivity, output level, the linearity of the output characteristics, thus contributing to improve the range and accuracy of measurements.

A mathematical model that defines the interrelation of the output signal strain transducer mechanical stresses generated during deformation. Resistance elementary section of the conducting channel structure length dx is determined by the following dependence:

$$dR_\kappa = \frac{R_\kappa}{L} dx = \frac{\rho dx}{ZW}, \qquad (1)$$

where R_κ - channel resistance, Ohm; L - length of the channel, m; ρ - resistivity, Ohm·m; Z - channel width, m; W - channel depth, m.

However, the distribution of charge carriers in the channel affect the value of the control potential (V_G) and the output voltage strain transducer (V_D). The impact of these electrical parameters leads to what depth of the region rich in electrons exit strain transducer larger than the entrance.

In this case the channel depth is at a distance W from the input x is:

$$W(x)=\frac{Q_S(x)}{eN_D}=\frac{\varepsilon_0\varepsilon SiO_2}{eN_D d}\left|-V_G+V(x)+\frac{2kT}{e}\ln\frac{N_D}{\left(\sqrt{N_C N_V}\exp\left[\frac{-\left(E_G(0)-\alpha X\right)}{2kT}\right]\right)}\right|, \quad (2)$$

where ε_{SiO2} - relative permittivity of the dielectric under the gate electrode; d - thickness of the dielectric, m; $V(x)$ - voltage at a distance x from the entrance strain transducer, V.

When the strain changes strain transducer resistivity semiconducting crystal (resistive-strain effect)

$$\rho=\rho_0\left(1+\pi_l X\right), \quad (3)$$

where ρ_0 - unstrained semiconductor resistivity, Ohm·m; π_l - longitudinal coefficient of piezoresistance, Pa^{-1}. Longitudinal coefficient of piezoresistance determined by the parameters of the crystal lattice, the crystallographic direction and conductivity type semiconductor.

The most important stage in the production strain transducer are: oxidation, photolithography, diffusion. From these stages depends the accuracy of the topological parameters, which according to the analysis of mathematical models are among the defining accuracy.

Prototypes were made on silicon wafers of *n*-type conductivity, doped with phosphorus or antimony. Level of the selected semiconductor manufacturing technology allows you to play strain transducer topological parameters with the following values of the absolute errors: $\Delta Z = 10^{-6}$ m; $\Delta L_0 = 10^{-6}$ m; $\Delta d = 10^{-7}$ m.

Experimental validation of the results of mathematical modeling and performance of the proposed structure of a semiconductor strain transducer carried out at a constant temperature of the scheme shown in Fig. 1.

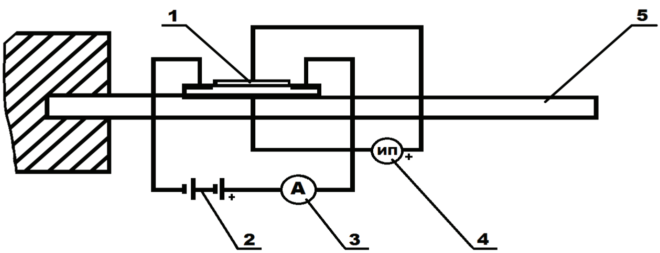


Fig. 1. The experimental scheme
1 - strain transducer; 2 - DC (power source); 3 - microammeter;
4 - regulated power supply; 5 - cantilever beam

To study samples strain transducer fixed on cantilever beam of constant cross section, made of a dielectric material. One end of the beam was rigidly fixed, but to the free end of the beam load is applied, determining deformation strain transducer. The long side of samples oriented along the axis of the beam.

Value of the mechanical stress caused by deformation of the installation site strain transducer was determined from the known expression of Experimental Mechanics

$$X = C_1 \varepsilon = \frac{3C_1 ah}{2b^3} l, \tag{4}$$

where *a* - distance from the center of the sample up to the free end of the beam, m; *h* - thickness of the beam, m; *b* - length of the beam, m; *l* - the amount of bending in the vertical direction, m; C_1 - modulus of elasticity of the beam material, Pa.

Experimental studies conducted at different voltages at the output of the semiconductor strain transducer and the gate electrode, confirmed the adequacy of the mathematical model and the effectiveness of established methodologies for developing semiconductor strain transducers.

The analysis of errors identified the dominant factors that have a major impact on the error output strain transducer. Calculated reduced error strain transducer measurements made on modern integrated technology is not more than 0,5%.

Several versions of integrated semiconductor structures strain transducers.

One option is a split cells deposited on a flexible basis. Each cell is a semiconductor strain transducer. The interconnections are performed in a film form. This design decision allows determining the strain in detail and design of complex geometric shape with a rough surface.

The second option is an integral strain transducer silicon membrane formed on the surface of which four semiconductor strain transducer united in a bridge circuit metallization. The silicon diaphragm is mounted on a dielectric substrate and placed in a metal housing. Application-driven elements in the strain transducer to simplify the setup process, improve the reliability and accuracy of balancing strain scheme. It should be noted that the location on the silicon semiconductor strain transducers membrane can be changed depending on the required sensitivity, precision, and the operating range of the measured values findings.

Conclusion

Held information analysis currently used strain transducers, confirming the relevance of development elements based on new semiconductor materials and structures to improve the metrological characteristics of existing materials.

The influence of strain on the basic parameters of the structures formed on various semiconductors and identified the possibility of their use as strain transducers. Based on research results of the mathematical model developed methods strain transducers semiconductor design, allowing to predict the metrological characteristics of the design phase.

Designed strain transducer semiconductor containing on the surface of a single crystal silicon *n*-type conductivity silicon dioxide dielectric layer, and the insulated electrode, which can improve the sensitivity and accuracy of the parameters of the materials and products.

Designed semiconductor strain transducer containing on a surface of a single crystal of silicon of n-type of conductivity a dielectric layer of dioxide of silicon, and also an isolated electrode that allows to improve sensitivity and accuracy of determination of parameters of materials and products is developed.

References

1. Озаренко. А.В. Исследование влияния деформации на сопротивление полупроводниковых управляемых тензорезисторов / А.В. Озаренко // Наука и устойчивое развитие общества. Наследие В.И. Вернадского: сб. материалов II Междунар. науч.-практ. конф. – Тамбов, 2007. – С. 76 – 78.

2. Левина Е.С., Новицкий П.В. Измерительные преобразователи. - Л.: Энергоатомиздат, 1980.

3. Аш Ж. Датчики измерительных систем: В 2 книгах/Аш Ж. [пер. с франц.]-М.: Мир, 1992.- 480с.

UDC 621.865

V.P. Kvasnikov, Dr.Sci.Tech (National Aviation University, Ukraine, Kiev)
S.V. Marchenkova (National Aviation University, Ukraine, Kiev)

IMPLEMENTATION ALGORITHM OF DIAGNOSTIC ENGINE PERFORMANCE FOR MOBILE ROBOT

Method of construction of mathematical model mobile robot zone (img 1) makes formation of actor-agent which is defined by a tabular form and agent which is described in an analytical form based on the quantitative and qualitative information which is entered by the operator and data from robot sensors. Thus synthesized mathematical description of relationships tasks verbally using attribute “Name”.

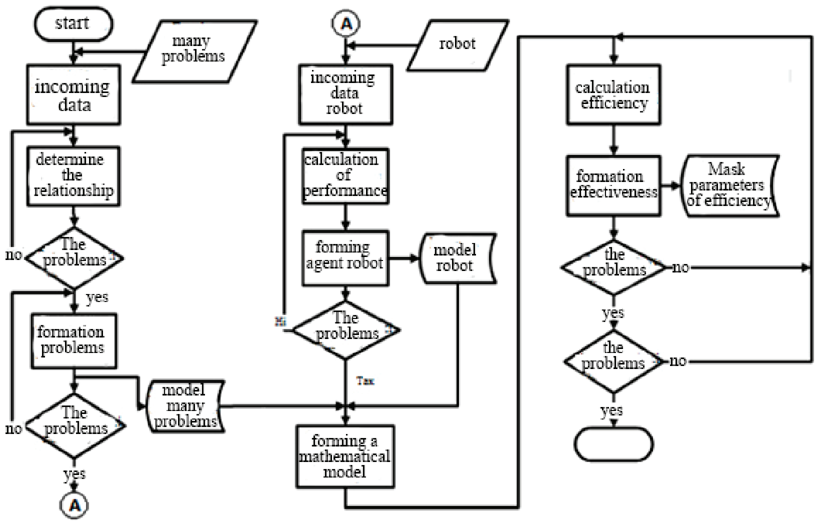


Image 1 - block diagram of the construction of mathematical model of the mobile robot working zone

Synthesized multicomponent structure of the mathematical model of the working area, where each agent actors characterized by the following attributes: Pj «Price», Tj «Execution time», Lj «Address», «Changing robot location while task executes» Qj “State”, "Changing energy charge level while task executes" / "Ancestor / descendant."

Agent that describes a mathematical model has the following set of attributes: Li «Address», Li (t) «Calculated location", "Target location», Vi «Speed", "The direction of movement», ξi «The energy», ξi (min) «Minimum energy», ξi (t) «The calculated energy" "target energy», Qi «State". The structure of the mathematical model agent, describing diagnostic work has form

$$
\begin{cases}
V_i' = arctg\left(\frac{2\pi R|n_2-n_1|}{lN\Delta t}\right); \\
V_i = \frac{\pi R|n_2+n_1|}{N\Delta t}\cos\left(arctg\left(\frac{2\pi R|n_2-n_1|}{lN\Delta t}\right)\right); \\
x_i'(\Delta t) = x_i + V_i\,\Delta t\,sin\alpha; \\
y_i'(\Delta t) = y_i + V_i\,\Delta t\,cos\alpha; \\
\xi_i' = a_0\Delta t^3 + a_1\Delta t^2 + a_2\Delta t + a_3;
\end{cases}
\quad (2)
$$

where R - radius of the wheel (tabulated values), n - number of encoder pulses per period Δt, N- number of pulses per revolution encoder wheel (tabulated values); l - the axial distance between the wheels; Vi describes the velocity of the robot; describes the angle of the velocity vector of the wheel axis robot, xi, yi - initial coordinates work; - Coordinates -Work agent at time Δt; describes the change enerhozaryadiv; Δt - fixed time calculation performance.

To determine the effectiveness of the many tasks by robot using mathematical model, introduced function - "robot - tasks", taking into account the cost of energy intensity of the robots movement to the j-th task and function "robot - task", which evaluates the distance between the i-th task of the robot and provision of job opportunities for robots dispersal of the working area (1).

To test the adequacy of the mathematical model, made physical model was built. Model adequacy measured by conventional methods with using Fisher criterion by outgoing coordinate (energy charge level of the robot). Test result - the value of the Fisher criterion = 3,61 when table value = $F_0\,(f_1, f_2) = 3$ and significance level = α = 0,05. It indicates adequacy of the model.

Rms relative error of calculations do not more 0,8%, maximum relative error – 1,6%. The maximum relative calculations error of the robot – 1%

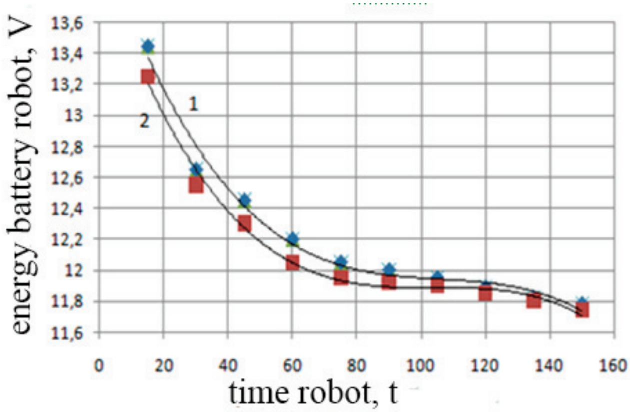


Image 2 - Assess the adequacy of the model work 1 - experimental; 2 - generated by the model

Conclusion

Nowadays direction of the robotics development characterized by the extension of the scope of mobile robots in the industry, domestic sphere, social sphere. Amount of robots for a period 2011-2013 has more than doubled from 8,6 to 18.2 millions.

Having analyzed mobile robot intelligent control system work proposed new method of assessing the complexity of managing, which has quantitative and qualitative indicators. Method of construction of mobile robots information system as an expandable system of process management proposed. Method of communication between processes in the information system of mobile robot similar methods of information sharing on the Internet proposed. Using the proposed method can successfully work on mobile information systems of independent teams and individual developers.

References

1. Ахо А. Хопкрофт Дж., Ульман Дж. Построение и анализ вычислительных алгоритмов. – М.: Мир, 1979. – 536 с.
2. Герасимов Б.М., Глуцкий В.И., Рабчун А.А. Система поддержки принятия решений в АСУ реального времени // Искусственный интеллект. – 2000. – № 3. – С. 39-47.
3. Киселев Д.В., Ющенко А.С. Система нечеткого управления конфигурацией шасси мобильного робота // Труды 12 науч.-техн. конф. «Робототехника для экстремальных условий». – СПб. – 2001.
4. Лебедев Д.В., Ткаченко А.И. Информационно-алгоритмические аспекты управления подвижными объектами. – К.: Наук. думка, 2000. – 370 с

UDC 621.313.84(045)

V.S. Martyniuk, c.s. (NAU, Ukraine, Kyiv),
V.O. Grishin, g.s. (College of NAU, Ukraine, Kryvyi Rig)

VOLTAGE CONTROL SYSTEM OF MAGNETOELECTRIC GENERATOR

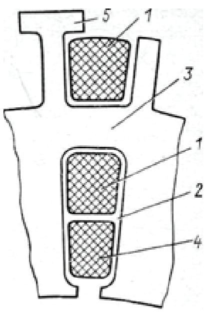
The principles of construction and comparative evaluation of voltage regulating systems of magnetoelectric generator.

Introduction

Creation of airplanes with an all-electric equipment (AAEE) requires the new powerful systems of power supply on a few MV·A.

Development of the independent systems of power supply and electromechanics for AAEE requires achievement of next characteristics:

− minimum mass and overall dimensions;
− maximumefficiency;
− minimum values of production and exploitation;
− limitation of electromagnetic time constant;
− possibility of operation, both in the mode of generator and motor;
− harmonicity of voltage shape or minimum pulsation of the rectified voltage;
− high mechanical durability, first of all circulating elements of construction;
− compatibility of electromachines with the electronic apparatus of control and system of power supply;
− requirement of inflexibility of external characteristic;
− workability of construction of both electromachine and all structural site which it is included in.



The output parameters of machines with permanent magnets correspond to the above-mentioned requirements to the electric machines.

The regulated synchronous generator with permanent magnets with excitation of armature back, offered by A. I. Bertinov and worked out to the industrial prototypes jointly withV. Andrejev and S. Mizjurin, has for this purpose an additional toroidalwinding of magnetic bias 1 (fig. 1), located in overhead part of stator slot 2 and back which embraces it, 3. For the placing of magnetic biaswinding in overhead part of stator sheet of generator there is the special comb 5.

Fig.1. Stator slot with armature winding and bias winding, where: 1 − bias winding; 2 − stator slot; 3 − stator back; 4 − armature winding; 5 – comb.

Essence of voltageregulating by means of saturation of core parts by a direct current consists in change ofmagnetic core resistance in the back of armature 3 (fig. 1).

The value of necessary MMF of bias winding is usually small, as there are not air gaps on the path of bias flux. The expense of power on regulating is also insignificant. Regulating system consumes minimal power in the operating mode of generator and maximal in the open circuit mode. According to A. I. Bertinov`s data a regulated magneto-electric generator of power 1000 BA at f = 400 Hz spends on regulating in the operating mode a 3% of nominal power and up to 10% at idling. Due to the presence of bias winding and rack on stator a mass of regulated generator increases in comparison with uncontrolled approximately on 25÷30%, and relative power, necessary for the feed of bias winding, diminishes with the increase of generator power. Bias winding as a result of air gaps absence on the path of the created flux has large inductance.

A calculation of regulating performance of generator and choice of parameters of bias winding is a difficult task, interfaced with account of nonlinear characteristics of bias areas of generator core, that are under the simultaneous action of permanent magnet MMF of generator rotor and MMF of immobile bias winding.

The accounting of nonlinear characteristics of bias areas allows to define inductance and time constant of bias winding, and also dynamicbehavior of all regulating system in whole. Thus exactness of voltage stabilizing is not limited to the parameters of generator, but depends only on the used regulator.

At all advantages of this method it has a substantial defect, which consists in that a maximal depth of flux change of Φ_δ is in the air gap of generator $k_{\Phi\delta}$= $\Phi_{\delta max}/\Phi_{\delta min} \leq 2$. Therefore this method finds application for synchronous generators with permanent magnets which operate with constant rotation frequency n = constant at the variable load. To the lacks of this regulating method also follows to refer the necessity of complication of generator construction due to the presence of bias winding, and also increasing of itsmass and sizes.

There is also voltage control mode at the expense of mechanical moving ofparts of magnetic core of generator relative to each other (fig.2).

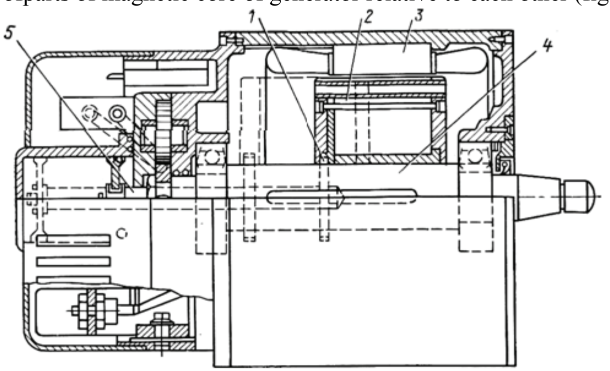


Fig. 2. AC generator with permanent magnets with voltage regulating at the expense of axial rotor moving relative to stator, where: 1 − washer; 2 − rotor; 3 − stator; 4 − shaft; 5 − piston.

Essence of voltage regulating consists in pulling-out of rotor from the air gap or pull-in, if frequency of rotation accordingly increases or diminishes.

In a fig. 2 a three-phase alternator is represented with a rotor 2 with permanent magnets, pressed-on on a shaft 4 on the sliding landing. From the left butt end of generator the hydraulic system which contains a hydraulic driver and block of its control is set. The piston 5 is mechanically connected with the washer 1, to which a rotor is hardly fastened 2. At moving of piston 5 a rotor 2 moves along a shaft 4. Controller of hydraulic drive contains an electromagnetic valve, amplifier and element which reacts on deviation of generator voltage from nominal value. If generator voltage becomes higher nominal value then sensor through an amplifier plugs in a winding of electromagnetic valve to generator voltage and valve opened. Thus moving of piston 5 will happen and rotor 2 will begin to pull out from a stator 3, a generator voltage will go down here. At generator voltage below nominal takes place a pull-in of rotor 2 in the air gap of stator 3 and increase of voltage. At presence of highly sensitive element (Zener) in CU at application of this method the high static accuracy controling of voltage (to ±1%) can be got. However presence of movable parts in a regulator does this system in the dynamic mode by very inertia, that is its considerable disadvantage. The controling system is structurally difficult and unreliable.

So,to the known magnetoelectric generators such disadvantages are inherent, as absence of direct method of voltage regulating as a result of difficulty of change of permanent magnet flux, dispersion of magnet`s characteristics, which is determined by character of technological processes of their making, relatively high cost of generators.

The purpose of article is a receipt of magnetoelectric generator, in which the non-linearity of function of $B = f(H)$ at the change of load and speed of drivemotor is eliminated, simultaneous bias by the constant (from the excitation winding) and variable (from a rotatory rotor with permanent magnets) fields is diminished, eliminated regulator influence on exactness of voltage stabilizing, diminished inductance of excitation winding, depth of flux change in an air gap is increased, and voltage regulating is carried out by the common action of centrifugal regulator of magnetic flux value and direct-current of excitation.

Solution of problem

The general substantial sign of invention object is application of mobile rotor, in which regulating of magnetic flux value is carried out by moving of rotor relative to stator along shaft, what stabilizing of initial voltage of generator is due to.

In a fig.3 the general view of magnetoelectric generator is represente

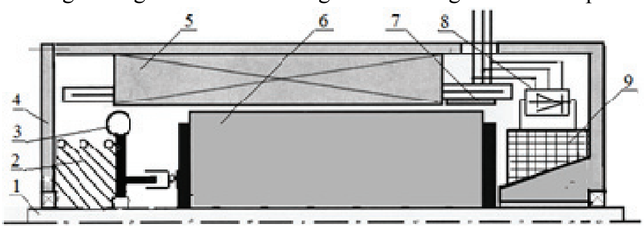


Fig. 3. General view of magnetoelectric generator

where: 1 −active shaft; 2 − spring; 3 − centrifugal regulator; 4 − diamagnetic bearing unit; 5 −armature; 6 – permanentmagnet; 7 − ferromagnetic shunt; 8 − valve; 9 − winding of inductor.

Location of elements 2 and 3 corresponds high speed of drive motor rotation. A ferromagnetic shunt 7 does impossible demagnetization of permanent magnet 6during its pulling out outside stator. At diminishing of shaft 1 rotation speed a centrifugal regulator 3 and spring 2 moves a permanent magnet 6 to the left, that results in the increase of magnetic flux of excitationand, thus, to stabilizing of EMF in accordance with a formula:

$$E = 4{,}44\, f\, w\, k_w\, k_c \Phi$$

As known, voltageat the synchronous generator output equals to:

$$U = E - jx_d I_d - jx_q I_q - R_a I$$

therefore at the increase of generator load it is necessary to increase EMF*E* for stabilizing of voltage*U*.At the increase of generator load a current grows automatically in the inductor winding 9, that results in voltage stabilizing. It is possible to substitute valve 8by a voltage regulator and, thus, realize the desirable law of regulating.

Thus the value of permanent magnet flux is regulated by the change of area of the mutual overlap of stator and rotor, and influence of generator load change is compensated by the change of excitation current.Electrical schematic of impulse voltage regulator of PMG is shown in the fig. 4. Regulator consists of: amplifier on the transistors T1, T2; source of standard voltage ($C_т$, R2); source of sawtooth voltage (VD1, C1, R1). The voltage of generator is supplied through the $T_р$ transformer and the $R_{уст}$potentiometer to the input of circuit VD1-C1. Pulsating voltage $U_{C1}$with thesawtoothedcomponentappears at the R1 resistor. With the increase of voltage$U_Г$(fig. 3) capacitor C1 is charged; after achievement of U_{max} capacitor C1 begins to discharge on the resistor R1 up to the value(U_{max} – U_{C1})/U_{max}= 0,1…0,15. In fig. 5,a the sawtooth curve U_{C1} is represented by the dotted line.

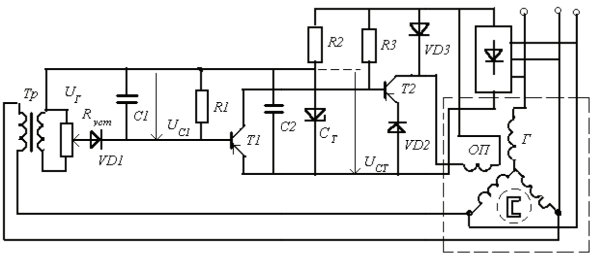


Fig.4**.** Electrical schematic of voltage regulator

The constant component U_{C1} thus will be proportional to the value of variable voltage. The difference between standard voltage of stabilitron U_{CT} and voltage U_{C1}issuppliedto the transistor amplifier input. As it is obvious from fig. 5, the transistor T1is switched on during the area б-вand isswitched off during the area а-б. Relative duration of itsopening linearly grows with reduction of the constant component U_{C1}, that is with reduction of generator voltage. Time of the relative opening of the transistor T1grows with decrease of generator voltage, and the time of relative opening of the transistor T2 – is decreased and average value of the current $I_П$=I_{K2}inthe bias winding ОП (fig. 4) is also decreased, that results in increase of generator voltage.The diode VD2 assists to the active shutdown of the transistor T2, the capacitor C2 smooths out the pulsations of voltag**e** at stabilitrone C_T, and the diode VD3 – smooths out the pulsations of bias winding current and protects the transistor T2 from break- down by electromotive force of self-induction of winding ОП at swithing-off of the transistor T2.

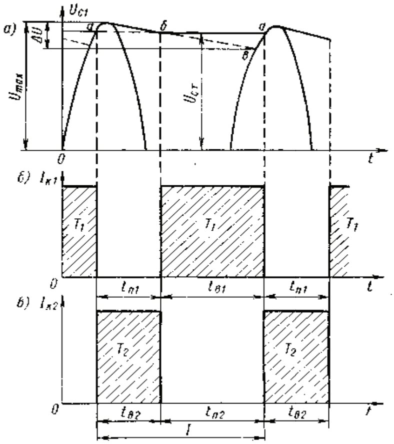


Fig. 5. Temporal diagrams of transistor amplifier

Conclusions

The turned out results: direct method of voltage regulating, linearity of function of $B = f(H)$ at the change of load and speed of drivemotor, eliminated regulator influence on exactness of voltage stabilizing, diminished inductance of excitation winding, depth of flux change in an air gap is increased, and voltage regulating is carried out by the common action of centrifugal regulator of magnetic flux value and direct-current of excitation.

The similar voltage regulators have an error no more ±2%. The cascade set with the impulsive voltage regulator of PMG with magnetic bias of armature can be built-in into aircraft engine and to have with it identicalterms of maintenance.

References

Balagurov V. A., Galteev F. F. Electrical generators with permanent magnets. − M. : Energoatomizdat, 1988. − 280. (in Russian).

UDC 66.047

K.J. Okhrimenko, c.t.s., honorable professor of ChSTU;
V.A. Koretskyi, Master of Engineering
(Cherkasy State Technological UniversityUkraine, Cherkasy),
O.I. Osmolovskyi, Ph. D. (National Aviation University, Ukraine)

APPROACHES TO THE AUTOMATION OF THE PROCESSES OF ACOUSTIC DRYING AND TO THE DESIGN OF SOUND GENERATORS

In the given article are represented the approaches to the control of acoustic drying process of porous materials and the approaches to the design of dynamic sirens using modern simulation software for aerodynamic calculations.

Operation of drying materials is widely used in many branches of industry. To date, the industry has very high demands to the quality of the dried product, hence the high requirements to the drying installations. In the field of technology of drying, we can see the progress: developed design of dryers, improved software for process control, carried out the work for automation of drying process. However, most of all modern dryers operate using traditional (convection and thermal) technology. Along recent years the interest in non-traditional and non-thermal dewatering was significantly increased. This is due to the fact that alternative methods are superior to traditional drying in many ways [1]. One of these methods is acoustic drying. The essence of the process is to effect on the material by the high-intensity sound waves (150-180 dB). Acoustic waves cause the strain of capillary-porous structure of dried material, which in turn greatly increases the diffusion coefficient. Compared to the traditional methods, the acoustic method has several advantages:

- higher economic efficiency compared to the traditional methods;
- short drying time and as a result-high performance of dryers;
- drying can take place with minimal heating of the material (the “cold drying”) that allows you to dry your product without exposing its thermal effects and significantly reduce the defect of products;
- acousticdrying is favorable for nature because it has no harmful emissions to the environment.

Study of the effects of sound on the drying of the material associated with the studies of heterogeneous processes in multiphase structures of type “gas-liquid in pores”.

For the industrial implementation of this technology must be developedautomation techniques for the control of acoustic drying process.In [2] for the first time was represented a method of acoustic drying in which the drying process was conducted with alternating intervals between acoustic impact. In this case the time of the pause is determined by the following formula:

$$\Delta\tau = \frac{\Delta U_{\tau}(x)^2}{a\Delta U_x}, \quad (1)$$

a – diffusion coefficient, $\Delta U_{\tau}(x)$–difference of the humidity on the surface of material along pause, ΔU_x – difference of the humidity along the pore length of the material on the interval.

This method is characterized by significant energy savings due to pauses. To automate the process, namely to calculate the duration of breaks and time between them, we must determine the diffusion coefficient$a$.The diffusion coefficient depends on the material properties (porosity, permeability, initial moisture content), as well as on sound field parameters (frequency and intensity of the sound). On the parameter$a$ can also influence the availability of heat supply. The diffusion coefficient is determined from the experiment of drying the material. Method of determining of coefficient $a$based on experimental data, is given in [3].

Numerous studies show that the speed of the sound of drying depends on the intensity of sound in the chamber. As source of sound energy on experimental dryer in the Institute of Applied and Theoretical Mechanics SD RAS was used Hartmann air jet generator. Due to the low efficiency of this type of generators, they require high energy consumption for compressing of the air. The alternative high intensitysound generator is dynamic siren.

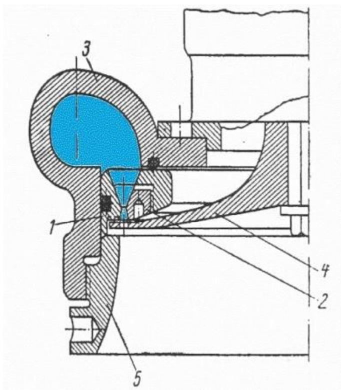


Fig. 1 – Dynamic siren of VNITI UZG-4A type.[4].

These sound generators are more complicated in design, but they have a higher coefficient of efficiency. The expediency of such sound sources has been justified on the experimental drying installation of "Acoustica resource" Ltd., which has been equipped with a low pressure dynamic siren.

Currently, the authors of the articleare working on improving and upgrading the dynamic sirens type UZG-4A (fig. 1).

Working principle of a siren is the next: compressed air enters into the reservoir (3) and passes through the nozzles (1) of the stator (2); rotor (4) driven by the engine cuts off the air flow through the nozzle and thus generates a sound that extends into the chamber through the horn (5). According to [4] the sound intensity and power of these sources depends on the flow rate, air pressure and the design parameters of the sirens. The stator (2) consists of two parts. It technologically allows making Laval nozzles in the stator. The correct calculation of aerodynamic parameters and selection of the correct configuration of siren elements, calculation of the length and angle of Laval nozzles and other parameters requires using of modern software based on the finite element method. Efficiency coefficient and sound pressure generated by the siren depends on the correct calculation of these parameters. To optimize the shape and angle of the paddles on the first step was carried out a simulation of air flow in the air reservoir of a siren.

The next step is calculation of Laval nozzle. In accordance with [4] siren sound characteristics depend directly on the outlet air flow velocity at the nozzle exit. Fig. 2 shows the spreading of velocities in Laval nozzle of rectangular shape.The parameters of nozzles selected by the series of experiments by FEM simulation program for aerodynamic calculations.

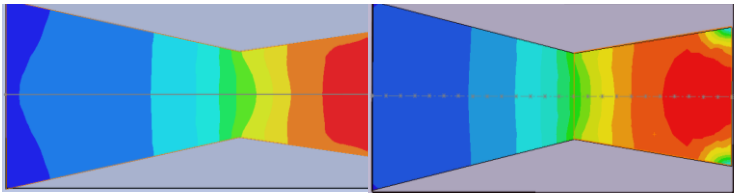


Fig. 2- Calculation of Laval nozzle. Left – correctly calculated nozzle, right -the nozzle calculated incorrectly (flow disruption occurs).

The nozzles are rectangular. According to [4] siren with rectangular nozzles have a higher efficiency compared with the sirens with classic round nozzles. Fig.3 shows the diagrams of nozzle area variation for round and rectangular nozzles during rotor rotation. The air flow through the opening is defined by the integral of the function of changing area of the nozzles. From the charts on Fig. 3 we can see that in the case of rectangular openingsin the stator and rotor the law of changing flow rate through the closing in time openings is trapezoidal and in the case of round holes it is closely to sinusoidal.

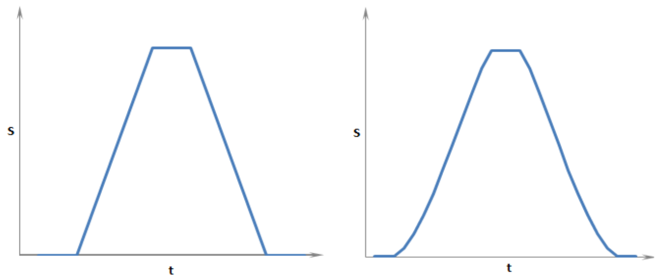


Fig. 3 - changing the area of the opening *S*in time *t*.Left – rectangular opening, right – round opening.

We shall notice that the start and closing of the rectangular hole is more abrupt thanfor the round hole. This leads to a more abrupt ejection of air from the nozzle of the siren, hence the more abrupt changes in air pressure at the siren outlet. Increasing of the pressure gradient at the moment of opening and closing of the nozzleslead to the increasing of particle velocity of acoustic wave. According to the formula for sound intensity: $I = p_0 v/2$, where p_0-pressure wave amplitude, v – particle velocity, change of the sound intensity is directly proportional to the change in particle velocity. Thus, despite the technological complexity of the stator with rectangular nozzles, we can get the sound intensity increase as compared with the stator with round nozzles.

The problem of the approximate calculation of compressed air consumption through the openings of variable area (during rotation of the rotor) can be solved as stationary. With some stepin time using FEM software we do a series of virtual experiments with different positions of the rotor relative to the stator holes (Fig. 4). Flow rate through the siren during its work calculated by the average flow rate among experiments in series.

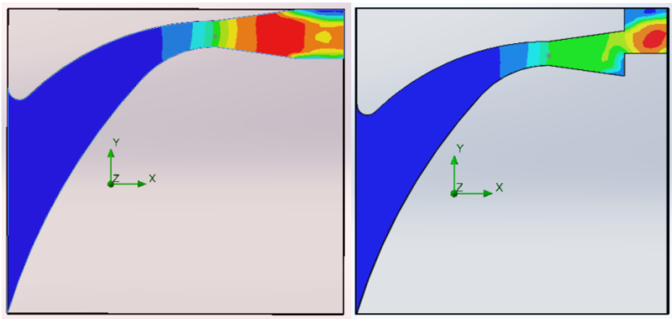


Fig.4 - Calculation of the air flow rate through the nozzle of variable area.

Conclusion

To automate the process of acoustic drying can be used mathematical technique developed by the researchers from ITAM SD RAS, that can be applied to calculate diffusion coefficient, and hence to calculate the mode of the sound impact on the material. To control the sound intensitywe can change the flow rate and pressure of the air in the dynamic siren.

References

1. T. Kudra, A.S. Mujumdar - Sonic drying // Advanced drying technologies. MarcelDekkerInc. NewYork, 2002.
2. Патент №2062416 – Способ акустической сушки капиллярно-пористых материалов/ Глазнев В.Н., Глинский А.Б., патентообладатель: Институт теоретической и прикладной механики СО РАН, Заявка №94027716, зарегистрирован 20.06.1996г., 6 стр.
3. А.А. Жилин, А.В. Федоров – Описание экстракции влаги из зернистых насыпок под воздействием акусто-конвективного потока // Современная наука: исследования, идеи, результаты, технологии №1 (12) 2013 г.
4. В.А. Веллер, Б.И. Степанов – Ультразвуковые сирены с приводом от электродвигателя // Акустический журнал Т.IX, Вып. 3 1963 г.

UDC 621.391.26

V. V. Skachkov, DSc, H. D. Bratchenko, DSc, A. N. Efimchikov, PhD
(Odessa State Academy of Technical Regulation and Quality, Ukraine, Odessa),
V. M. Ilchenko, PhD (National Aviation University, Ukraine)

INFLUENCE OF INTRASYSTEM PERTURBATIONS ON GRADIENT ADAPTATION PROCESS OF INFORMATION SYSTEM TO THE EXTERNAL ENVIRONMENT

Results of the study of convergence of parameter vectors estimates obtained by gradient methods in the process of information system adaptation to the external environment in conditions of intrasystem perturbations are presented. Analytical expressions for the evaluation of the quality of adaptation depending on the variance of intrasystem perturbations are obtained.

Resistance to electronic countermeasures is one of the main tactical and technical requirements for modern and perspective robotic technical reconnaissance complexes. Source of information in such information systems can be a television and photographic equipment on the board unmanned aircraft [1]. Under the conditions of electronic countermeasures to control such a system requires its adaptation to the jamming environment. Thus on each of the data receiving antennas instead of the usual is advisable to use adaptive antenna arrays.

For understanding the intrasystem perturbations influence on the quality of functioning information system, adapting to external influences, it is expedient to combine the parameters of the useful signals, external and internal interference single measure of the system efficiency - its criterion functional. Such an approach can be realized only at a known algorithm of information processing in the system and availability of information about the external processes. In this case, the task of evaluating the effectiveness of the adaptive system is reduced to a multi-dimensional extremal problem for which solution is widely used well-designed gradient methods [2, 3].

However, in the analytical description of gradient methods, as a rule, do not take into account the impact intrasystem perturbations on process of adaptation to the external environment. In particular, in the adaptive signal processing systems with the method of steepest descent filtration error $\mathbf{E}$ is calculated as the difference $\mathbf{E} = \mathbf{S}_0 - \widehat{\mathbf{S}}$ between the reconstructed signal and the reference value $\mathbf{S}_0$ of the quality criterion defined or formed on the observation data [4, 5]. Adaptive estimation $\widehat{\mathbf{S}}$ of vector $\mathbf{S}$ is corrected or recomputed on base of observed process $\mathbf{U}$ and the filtering error signal $\mathbf{E} = \mathbf{S}_0 - \widehat{\mathbf{S}}$. Observed process $\mathbf{U}$ is an additive mixture of the useful signal $\mathbf{S}$ and the external noise $\mathbf{N}$. In practice, the assumption that the useful signal is known, and its shape is determined by the signal $\mathbf{S}_0$ had not fulfilled strictly due to the fact that the received signal can not be known a priori, and therefore it should be considered in some sense as unknown.

The aim of this paper is to develop the analytical apparatus for evaluating and studying the convergence of the gradient algorithm of the system adaptation to the external environment in conditions of intrasystem perturbations.

Generalization of the problem of adaptive signal filtration allows you to select in any of the adaptive information system interrelated subsystems: subsystem of surveillance; subsystem of referent signals; subsystem of error and subsystem of adaptation (Fig. 1) [5].

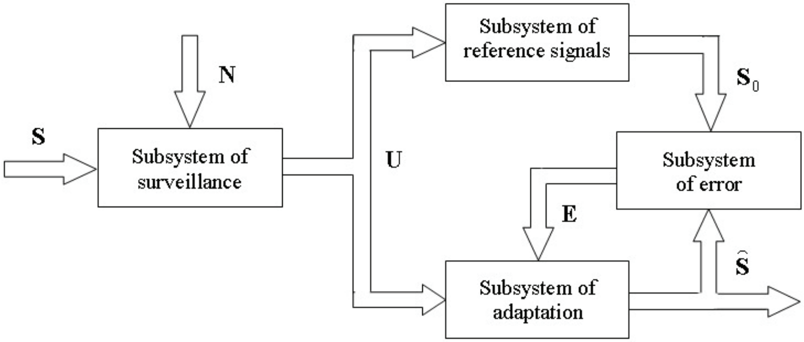


Fig. 1. Generalized structure of the adaptive system

Fig. 1 shows the relationship of subsystems constituting the adaptive system. This partition of adaptive system into subsystems is nonstandard, since the control object here is in explicit form not appear, and the error has a more generalized form than usual prediction error. However, such a structure allows you to focus on the features of the submission intrasystem perturbations present in each of the above subsystems adaptive system.

Let for adaptive system shown in Fig. 1, it is necessary to obtain an estimate $\hat{\mathbf{S}}(t)$ and this estimate must satisfy the criteria of the minimal distance to the reference signal $\mathbf{S}_0(t)$

$$\left\|\mathbf{S}_0(t)-\hat{\mathbf{S}}(t)\right\|^2=\min_{\mathbf{U}(t)}\left\|\mathbf{S}_0(t)-\mathbf{U}(t)\right\|^2 . \tag{1}$$

Evaluation formed in the subsystem of adaptation on algorithm

$$\hat{\mathbf{S}}(t)=\sum_{i=1}^{N} w_i(t)\mathbf{U}_i(t),$$

where $\mathbf{W}^T(t)=\left[\, w_1(t) \quad \ldots \quad w_i(t) \quad \ldots \quad w_N(t)\right]$ – the parametric vector of the system;

$\mathbf{U}_i(t)$ – observed vector process, $i=\overline{1,\, N}$.

According to Theorem of projection [6], the optimal by (1) the parametric vector of adaptive system $\mathbf{W}(t)$ in steady state must satisfy the condition

$$M\left[\mathbf{E}^T(t)\,\mathbf{U}_i(t)\right]=0\,;\qquad \mathbf{E}\,(t)=\mathbf{S}_0\,(t)-\sum_{i=1}^{N} w_i(t)\mathbf{U}_i(t)\,.$$

Hence, the model of chain parametric adaptive control by vector system $\mathbf{W}(t)$ has the form

$$\mathbf{W}(t)=\gamma\int \mathbf{E}^T(t)\left[\mathbf{U}_1(t)\quad \ldots\quad \mathbf{U}_i(t)\quad \ldots\quad \mathbf{U}_N(t)\right]dt\ , \tag{2}$$

where γ – regulating characteristic of the control circuit.

Expression (2) describes the system's process of parametric adaptation that is based on the correlation feedback. Systems with correlation control studied well enough and are widely used in the practice of adaptive signal processing [4, 7]. In contrast to the known results we are interested in the influence of intrasystem perturbations on the process of adapting this class of systems.

If as the integrator is used aperiodic link of circuit with a time constant T: $F(p)=(T\,p+1)^{-1}$, then (2) takes the form

$$T\frac{d\,\mathbf{W}(t)}{d\,t}+\mathbf{W}(t)=-\gamma\left[\widehat{\mathbf{A}}\,(t)\mathbf{W}(t)-\widehat{\boldsymbol{\alpha}}(t)\right], \tag{3}$$

where the matrix $\widehat{\mathbf{A}}\,(t)$ and vector $\widehat{\boldsymbol{\alpha}}(t)$ combine the results of multiplication complex vectors:

$$\widehat{\mathbf{A}}\,(t)=\left[A_{i\,j}\right]=\left[\mathbf{U}_i^T(t)\ \mathbf{U}_j(t)\right];\ \ \widehat{\boldsymbol{\alpha}}(t)=\left[\alpha_{0i}\right]=\left[\mathbf{S}_0^T\,(t)\mathbf{U}_i(t)\right];$$

$\widehat{\mathbf{A}}\,(t)\mathbf{W}(t)-\widehat{\boldsymbol{\alpha}}(t)=\widehat{\nabla}_{\mathbf{W}}(t)$ – estimate of the true value of the gradient $\nabla_{\mathbf{W}}(t)$ of the quadratic error function $\|\mathbf{E}(t)\|^2=M\left[\mathbf{E}^T(t)\,\mathbf{E}\,(t)\right]$.

We write the true value of the gradient $\nabla_{\mathbf{W}}(t)$ of the quadratic function $\|\mathbf{E}(t)\|^2=M\left[\mathbf{E}^T(t)\mathbf{E}\,(t)\right]$ as $\nabla_{\mathbf{W}}(t)=\mathbf{A}\ \mathbf{W}(t)-\boldsymbol{\alpha}$, where $\mathbf{A}=M\left[\widehat{\mathbf{A}}\,(t)\right]$; $\boldsymbol{\alpha}=M\left[\widehat{\boldsymbol{\alpha}}(t)\right]$; and present the perturbed estimate $\widehat{\nabla}_{\mathbf{W}}(t)$ of the gradient $\nabla_{\mathbf{W}}(t)$ in additive form $\widehat{\nabla}_{\mathbf{W}}(t)=\nabla_{\mathbf{W}}(t)+\mathbf{Z}\,(t)$, where $\mathbf{Z}(t)$ – random vector noise of gradient generated by intrasystem perturbations. After this the discrete analogue of process (3) with the perturbed evaluation of gradient has the form

$$\mathbf{W}(n+1)=\mathbf{W}(n)+(T\,\Delta F)^{-1}\left\{\gamma\ \widehat{\boldsymbol{\alpha}}(n)-\left[\mathbf{I}+\gamma\,\widehat{\mathbf{A}}\,(n)\right]\mathbf{W}(n)\right\},$$

where $\widehat{\boldsymbol{\alpha}}(n)=\boldsymbol{\alpha}+\Delta\,\boldsymbol{\alpha}(n)$; $\widehat{\mathbf{A}}\,(n)=\mathbf{A}+\Delta\mathbf{A}\,(n)$;

$\Delta\mathbf{A}(n)$, $\Delta\,\boldsymbol{\alpha}(n)$ – matrix and vector of intrasystem perturbations, respectively;

ΔF – spectral width of the observed process.

After grouping summands expression for perturbed parametric vector $\mathbf{W}(n+1)$ of adaptive system takes the form

$$\mathbf{W}(n+1)=\mathbf{W}(n)+(T\Delta F)^{-1}(\mathbf{I}+\gamma\mathbf{A})\left[\mathbf{W}_{\text{opt}}-\mathbf{W}(n)+\Delta\mathbf{W}(n)\right],$$

where $\mathbf{W}_{\text{opt}}=\gamma(\mathbf{I}+\gamma\mathbf{A})^{-1}\boldsymbol{\alpha}$ – the optimal value of parameter vector of the adaptive system at steady state in the absence of intrasystem perturbations ;

$\Delta\mathbf{W}(n)=-\gamma(\mathbf{I}+\gamma\mathbf{A})^{-1}[\Delta\mathbf{A}(n)\mathbf{W}(n)-\Delta\,\boldsymbol{\alpha}(n)]$ – random displacement of parameter vector of the adaptive system under the influence of intrasystem perturbations $\Delta\mathbf{A}(n)$, $\Delta\,\boldsymbol{\alpha}(n)$.

On an arbitrary adaptation step perturbed parametric vector of system $\mathbf{W}(n+1)$ has a value

$$\mathbf{W}(n+1)=\left(\mathbf{I}-\mathbf{G}^{n}\right)\mathbf{W}_{\text{opt}}+(\mathbf{I}-\mathbf{G})\sum_{i=0}^{n-1}\mathbf{G}^{i}\,\Delta\mathbf{W}(n-i), \tag{4}$$

where $\mathbf{G}=\mathbf{I}-(T\,\Delta F)^{-1}(\mathbf{I}+\gamma\,\mathbf{A})$.

Expression (4) is a generalized because it reflects the process of changing parameter vector system in the process its adaptation in conditions of intrasystem perturbations in system itself. If the presence of intrasystem perturbations neglected: $\Delta\mathbf{W}(n-i)=0$, then from (4) follows known particular case of presentation of the gradient method of adapting the system [4, 8].

Assuming that the perturbing vector processes $\Delta\mathbf{W}(i)$; $i=\overline{1,\,N}$ in (4) have the same variance, taken into account their mutual uncorrelated, we have

$$\frac{M\left[\Delta\mathbf{W}^{T}(i)\,\Delta\mathbf{W}(j)\right]}{\left\|\mathbf{W}_{\text{opt}}\right\|^{2}}=\begin{cases}\sigma_{\mathbf{W}}^{2}, & \text{if } i=j;\\ 0, & \text{if } i\neq j.\end{cases}$$

When adapting the system mean square approximation to a reference vector $\mathbf{S}_{0}(n)$ varies as

$$\left\|\mathbf{E}(n)\right\|^{2}=\left\|\mathbf{S}_{0}(n)-\mathbf{W}^{T}(n)\mathbf{U}(n)\right\|^{2}. \tag{5}$$

After substituting the parameter vector (4) in (5) and a series of transformations we have the representation of the process mean square approximation to the reference signal in conditions of intrasystem perturbation

$$\begin{aligned}\left\|\mathbf{E}(n)\right\|^{2}&=\left\|\mathbf{E}\left(\mathbf{W}_{\text{opt}}\right)\right\|^{2}+\mathbf{W}_{\text{opt}}^{T}\,\mathbf{G}^{n}\,\mathbf{A}\,\mathbf{G}^{n}\,\mathbf{W}_{\text{opt}}+\\&+\sigma_{\mathbf{W}}^{2}\left\|\mathbf{W}_{\text{opt}}\right\|^{2}\,\text{tr}\left[\sum_{i=0}^{n-1}\mathbf{G}^{i}(\mathbf{I}-\mathbf{G})\mathbf{A}\,(\mathbf{I}-\mathbf{G})\mathbf{G}^{i}\right].\end{aligned} \tag{6}$$

If in the system are performed the appropriate conditions for the convergence of its adaptation algorithm, in the steady-state approximation (6) has as its limit value

$$\lim_{n\to\infty} \left\| \mathbf{E}(n) \right\|^2 = \left\| \mathbf{E}\left(\mathbf{W}_{\text{opt}}\right) \right\|^2 + \sigma_{\mathbf{W}}^2 \left\| \mathbf{W}_{\text{opt}} \right\|^2 \operatorname{tr} \mathbf{K} \ , \qquad (7)$$

where $\mathbf{K} = \lim_{n\to\infty} \sum_{i=0}^{n-1} \mathbf{G}^i \left(\mathbf{I} - \mathbf{G}\right) \mathbf{A} \left(\mathbf{I} - \mathbf{G}\right) \mathbf{G}^i$ – positive definite matrix.

From (7) follows that due to the presence of intrasystem perturbations fluctuations of parameter vector adaptive system lead to an increase at steady state approximation error to the reference signal compared to $\left\| \mathbf{E}\left(\mathbf{W}_{\text{opt}}\right) \right\|^2 = \mathbf{E}_{\min}^2$.

Conclusions

Based on the results of analysis (6) can be argued that intrasystem perturbations do not influence the convergence and stability of the adaptation process. However, as follows from (7), in conditions of intrasystem perturbations the limiting estimate parametric vector of the system obtained in the process of adapting by the gradient method of steepest descent will be shifted by some amount relative to its optimum value. The magnitude and nature of the displacement are determined by the properties of intrasystem perturbations.

Hence it is quite obvious the need to develop gradient methods are not critical to the presence in the system of intrasystem perturbing processes.

References

1. Скачков В. В. Науковий підхід до розвідки / В. В. Скачков, О. М. Єфимчиков // Оборонний вісник. – 2012. – № 7. – С. 10-13.
2. Беклемишев Д. В. Курс аналитической геометрии и линейной алгебры / Д. В. Беклемишев. – М.: Наука, 1987. – 320 с.
3. Гилл Ф. Численные методы условной оптимизации: Пер. с англ. / Ф. Гилл, У. Мюррей. – М.: Наука, 1977. – 292 с.
4. Адаптивные фильтры: Пер. с англ. / П. М. Грант, К. Ф. Н. Коуэн, Б. Фридлендер и др.; Под ред. К. Ф. Н. Коуэна и П. М. Гранта. – М.: Мир, 1988. – 392 с.
5. Устойчивость адаптивных систем: Пер. с англ. / Андерсон Б., Битмид Р., Джонсон К. и др. – М.: Мир, 1989. – 263 с.
6. Гантмахер Ф. Р. Теория матриц / Ф. Р. Гантмахер – М.: Наука, 1988. –552 с.
7. Гейбриэл У. Ф. Введение в теорию адаптивных антенных решёток / У. Ф. Гейбриэл // ТИИЭР. – 1976. – №2. – С. 55–96.
8. Уидроу Б. Адаптивная обработка сигналов: Пер. с англ. / Б. Уидроу, С. Стирнз. –М.: Радио и связь, 1989. – 440 с.

UDC 621.317

O. M. Vasilevskyi, Ph. D. (Ministry of Education and Science of Ukraine, Kyiv),
O.I. Osmolovskyi, Ph. D. (National Aviation University, Ukraine)

ELEMENTS OF THE THEORY OF CONSTRUCTION OF METHODS ASSESSMENT OF DYNAMIC UNCERTAINTY IN MEASUREMENT OF PARAMETERS MOTION ROBOTIC COMPLEXES

Proposed a new approach to evaluating uncertainty during dynamic measurement is suggested, which is based on the use of the power spectrum of the input signal and a priori data of the frequency characteristics of the measurement means utilised.

When reporting on the results of dynamic measurements, it is necessary to provide a quantitative assessment of the quality of the experiment in order that its reliability may be correctly appraised [1-4]. Without such a reference value, the results of dynamic measurement can neither be compared with other equivalent studies, nor with standard reference values. It is therefore necessary to develop a uniform and understandable assessment methodology of the quality characteristics of dynamic measurements.

In drawing up relevant differential equations, input signals are recorded on the right, i.e. the reason that led the MM to function, while the left side of the differential equation, describes the output signal (or response of the MM), and for linear transducers, it is written in the form [3, 5]

$$\sum_{i=0}^{n} a_i y^i(t) = \sum_{k=0}^{m} b_k x^k(t), \tag{1}$$

where $x(t)$, $y(t)$ are respectively the input and output values; i, k are the order derivatives; and a, b are the coefficients that characterize the properties of the MM.

To express the differential equation in the area of frequency, the differentiation symbol $j\omega$ may replace d/dt as the time coordinate, and then the equation (1) takes the form

$$\frac{y(j\omega)}{x(j\omega)} = S_0 \frac{b_m(j\omega)^m + b_{m-1}(j\omega)^{m-1} + \ldots + 1}{a_n(j\omega)^n + a_{n-1}(j\omega)^{n-1} + \ldots + 1},$$

or

$$y(j\omega) = S(j\omega)x(j\omega), \tag{2}$$

where $y(j\omega)$, $x(j\omega)$ are respectively the spectral functions of the input and output measurement signal; $S_0 = b_0/a_0$ is the static sensitivity, i.e. the sensitivity to the constant input value (when $j\omega = 0$); $S(j\omega)$ is the transfer function of the MM or operational sensitivity.

The most typical properties of the MM are dynamic characteristics, which are described by differential equations of the first or second order, although in some cases, the third or higher order [5-7].

Information about the dynamic characteristics should be found in the regulatory and technical documentation of the MM, although if data is not available, it can be obtained on the basis of a priori data on the MM.

To express the experimental uncertainty of the results of dynamic measurements, it may be convenient for practical use to refer to the frequency characteristics of the measuring means [5], listed in Tab. 1.

Table 1

Transmission functions for the most typical dynamic links

Frequency characteristics of the MM	Typical Units
$S(j\omega) = K$ where K is the transmission coefficient	Non-inertial (ideal measurement transducer)
$S(j\omega) = \dfrac{K}{1 + j\omega\tau}$ where τ is the time constant determined by the parameters of the MM	Aperiodic (temperature transducer)
$S(j\omega) = \dfrac{K}{j\omega}$	Integrated (integrated amplification)
$S(j\omega) = K(1 + j\omega\tau)$	Forcing (differential amplification)
$S(j\omega) = exp(-j\omega\tau)$	Delay (analog-to-digital converters)
$S(j\omega) = \dfrac{K}{1 + j\omega\tau_1 - \omega^2\tau_2^2} = \dfrac{K}{1 + 2j\omega\beta\tau - \omega^2\tau^2}$	Oscillating (electromechanical transducers)

It is also known that the existing international experience in the concept of evaluation and expression of measurement uncertainty [1] does not describe how to undertake estimation of dynamic uncertainties in the performance of metrological works (or experiments in dynamic modes of MM).

[1] only makes it apparent that in existence there are ways of estimation as demonstrated by type A and type B, and in addition ways to demonstrate uncertainties, which may be standard, combined or enhanced. The definitions of these uncertainties are given in [1]. A well-known approach, as investigated in the papers [3, 6-9], is that dynamic uncertainty is calculated as a standard uncertainty of type B, itself determined by the dynamic error value divided by the square root of 3 (assuming a uniform distribution law).

Using classical theory in the measurement of dynamic error in the expression of dynamic uncertainty is unacceptable, given the concept of measurement uncertainty expression, which, as set out in the international standard [1], is moving away from the concept of measurement error, as such, which does not use known values, and cannot have absolute values. This is as opposed to measurement uncertainty, which can be evaluated, and for a particular measurement result is not a single value, but has an infinite number of values, which are scattered around the result.

Consequently, there is a need to develop a new approach to the expression of dynamic uncertainty that can be evaluated without using the classic dynamic errors used in error theory.

The measurement of dynamic uncertainty depends on measurement uncertainty that is conditional on the responses of the measurement means to determine the speed (frequency) of the input signal, which is itself dependent both on the dynamic properties of the measurement means and on the frequency spectrum of the input signal.

Dynamic uncertainty measurement $u_D[y(t)]$ can be expressed by the square root of the integral of the product of the square of the spectral function of the input signal and the square of the modulus of the frequency response of the measurement means that is used during dynamic measurements over a wide range of frequencies [8]

$$u_D[y(t)] = \sqrt{\frac{1}{2\pi}\int_{-\infty}^{\infty} |S(j\omega)|^2 |X(j\omega)|^2 \,\mathrm{d}\omega} \,, \qquad (3)$$

where $|S(j\omega)|$ is the modulus of the frequency characteristics of the MM that is used for dynamic measurement, or the amplitude frequency characteristics of the MM, which is defined by formula [7]

$$|S(j\omega)| = \sqrt{a^2(\omega) + b^2(\omega)} \,, \qquad (4)$$

where $a(\omega)$, $b(\omega)$ are respectively the real and imaginary parts of the frequency characteristics of $S(j\omega)$ of measuring instruments; $X(j\omega)$ is the spectral function of the input signal that is associated with the input time function $x(t)$ of the Laplace expansion [5]

$$X(j\omega) = \int_{0}^{\infty} x(t) e^{-j\omega_0 t} dt \,, \qquad (5)$$

where ω_0 is the frequency of the input signal.

The upper limit of integral equation (5) on a finite time interval can be changed by the total observation time T.

If the measured signal $x(t)$ is determined by sampling, then the integration of equation (5) can be replaced by a summation operation, when the following substitutions are made: t is replaced by nT_a, where n varies from 0 to $N-1$, through T_a which designates a sampling period, then $x(t)$ has the form $x(nT_a)$, and $e^{-j\omega_0 t}$ is replaced by $e^{-j\omega_0 n T_a}$ [7].

Should such replacements be made in equation (5), it may then be written in a discrete form [5, 9]

$$X_d(j\omega)=\sum_{n=0}^{N-1} x(nT_a)e^{-j\omega_0 nT_a}=$$

$$=\sum_{n=0}^{N-1} x(nT_a)\cos\omega_0 nT_a - j\sum_{n=0}^{N-1} x(nT_a)\sin\omega_0 nT_a\,, \tag{6}$$

where $\omega_0 = 2\pi k/(NT_a)$, $k = 0,1,\ldots,N-1$.

In this case, so that the discrete spectral function value corresponds to a continuous spectral function, it needs to be multiplied by the sampling interval [7, 9]

$$X(j\omega)=T_a X_d(j\omega). \tag{7}$$

During dynamic sampling measurements during the production of a signal, the equation to express dynamic uncertainty (3), taking into account equations (6) and (7), may be written in the form

$$u_D[y(t_i)]=\sqrt{\frac{T_a}{N}\sum_{\mathrm{k}=0}^{N-1}\sum_{n=0}^{N-1} x^2(nT_a)e^{-j\frac{4\pi nk}{N}} A^2\left(k\frac{2\pi}{NT_a}\right)}\,, \tag{8}$$

where $A\left(k\frac{2\pi}{NT_a}\right)=A(\omega)=|S(j\omega)|$ represents the amplitude frequency characteristics of the MM supported by the dynamic measurement values taken: $\Delta\omega=\frac{2\pi}{NT_a}$ is the interval of the discrete defined frequency values: T_a is the sampling time; N is the number of samples; NT_a is the total duration of observation.

Given the above, a way of expressing the dynamic uncertainty of measuring includes the following stages: the execution of dynamic measurements; determination of the frequency response measurement tools used; determination of the spectral function of the input signal; dynamic evaluation of uncertainty of a measuring instrument.

Conclusions

A new approach to the expression of experimental dynamic uncertainty in dynamic measurements is proposed on the basis of a priori information on the frequency characteristics of the Measurement Means and the spectral functions of the input signal. These allow us to obtain evaluations of the results of dynamic measurements to international requirements for the precision specifications. The proposed approach to estimating dynamic uncertainties can be used for measurement means which are characterized by dynamic circuits of any type under the operation of a stationary random input signal.

References

1. ISO/IEC Guide 98-1:2009 «Uncertainty of measurement – Part 1: Introduction to the expression of uncertainty in measurement». – Geneva (Switzerland): ISO. – 2009. – 32 p.

2. IEC GUIDE 115-2007 «Application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector». – Geneva (Switzerland): IEC. – 2007. – 54 p.

3. Elster C., Eichstädt S., Link A. Uncertainty evaluation of dynamic measurements in line with GUM. In XIX IMEKO World Congress on Fundamental and Applied Metrology, 2009.

4. Esward T. J., Elster C., Hessling J. P. Analysis of dynamic measurements: new challenges require new solutions. In XIX IMEKO World Congress on Fundamental and Applied Metrology, 2009.

5. Eichstädt S. Analysis of Dynamic Measurements - Evaluation of dynamic measurement uncertainty, 2012.

6. Eichstädt S., Link A., Elster C. Dynamic Uncertainty for Compensated Second-Order Systems. Sensors 2010, 10, 7621-7631.

7. Elster C., Link A. Analysis of dynamic measurements: compensation of dynamic error and evaluation of uncertainty, in "Advanced Mathematical & Computational Tools in Metrology VIII", Series on Advances in Mathematics for Applied Sciences vol. 78, 2009, 80-89, World Scientific New Jersey.

8. Vasilevskyi O. M. Method of dynamic expression of uncertainty of measurement. – *DEVICES AND METHODS OF MEASUREMENTS*, 2013, 2, P. 109 – 113.

9. Vasilevskyi O. M. Estimation of dynamic measurements uncertainty. *Visnyk Vinnytskogo politekhnichnogo instytutu*, 2011, 3, P. 9 - 13.

UDC 621.762

L.R. Vishnyakov, D-r Eng.Sci., (IPMS NAS Ukraine, Kyiv, Ukraine),
V.J. Kokhaniy, scientist (IPMS NAS Ukraine, Kyiv, Ukraine),
V.P. Kvasnikov , D-r Eng.Sci., prof., (NAU, Kyiv, Ukraine),
I.I. Chernyiavskiy, scientist (ASTC «Antonov», IPMS NAS, Kyiv, Ukraine),
O.V. Zubkov, postgraduate student (IPMS NAS Ukraine, Kyiv, Ukraine)

INVESTIGATION OF KNITTED SOLDERED COPPER WIRE MESHES FOR LIGHTNING PROTECTION OF CARBON FIBER COMPOSITE SKIN OF AIRCRAFT

Infliction of direct lightning strike upon a carbon fiber composite skin is analyzed. Zones are described for lightning protection of aircraft and also given parameters of test pulse current of lightning. Advantages resulting from using of mesh fabrics for energy dissipation are envisaged. Formation of electric contacts when soldering copper wire mesh is studied.

The modern aircrafts and wind power units use increasingly more composites based on carbon fibers with epoxy matrices. The percentage of Carbon fiber composites in commercial aircrafts are continually enlarging and reaches, for instance in An-148, 20-22 %, whereas in aircrafts of worldwide producers (Boeing–787, Airbus–350, etc.) is approaching 50 % [1].

Structures from CFC have some advantages such as light weight, high elastic-strength properties, labor savings and low manufacturing costs, etc. versus metallic ones. However, high electric resistance is there shortage that has different values and depends on carbon fiber orientation within a composite. The specific resistance of a CFC has usually a value between $1\text{-}2\cdot10^{-3}$ Ohm·cm (for single direction arrangement of carbon fibers) to 10-100 Ohm·cm (for transverse direction arrangement of fibers) [2].

In connection with the above said, when thermal and electrical current loads are applied (to 200 кA), the direct lightning strike to a polymer composite causes an ohmic heating reaching several hundred grades which inflicts a destruction to the binder and severe gas evolution. The resultant gas produces a high internal pressure within the CFC, and as a consequence, the CFC layers separate and the destruction has a form of through holes and delaminations across a great area around the point of contact with the lightning streamer (Fig. 1) [3-6].

The worldwide aircraft producers try to solve the problem via metallization of the CFC structure surfaces exposed to lightning strikes, in particular, fuel tanks mounted at the aircraft wings [1, 3, 4].

The metallization can be performed through formation upon them either copper or aluminum perforated foils (of such US companies as «Dexmet» [7] and «Astrostrike» [8]), and also woven or non-woven wire meshes, or by applying metalized coatings on the CFC surfaces [3, 4, 9].

(a) (b) (c)

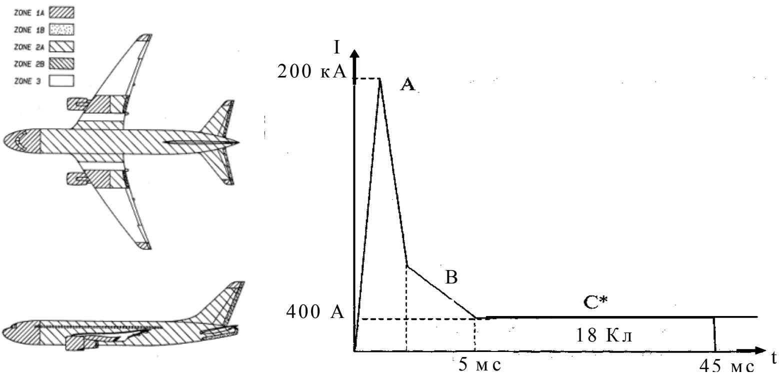
Fig. 1. Comparison of lightning tests of panels with lightning protection foil (a) and without it (b) damage of CFC skin of aircraft after the lightning strike (c) [7]

As per qualification requirements relative to conditions of service and environment for board equipment, an aircraft can be divided into zones that differ when exposed to lightning strike [10]. The test impulse 1A, given in Fig. 2b, is determinative when testing the endurance of the fuel tank panel for exposure to lightning discharge. It should be noted, that high current and short component are not permitted because they lead to burning or high temperature capable to ignite the fuel vapors. Fig. 2a shows the aircraft lightning protection zones. Current impulses that are typical for zone 1A (Fig. 2b) should include the following components of an idealized lightning impulse [1, 4]:

A - is the component with a peak amplitude 200 kA (± 10 %) and an action integral 2×10^6 A^2 s (±20 %);

B - is the component with an averaged amplitude 2 kA (± 20 %) and transferable charge 10 Coulomb (± 10 %);

C* - is the component with amplitude 400 A and transferable charge 18 Coulomb (±20%) during the action time of 45 sec.



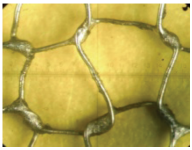
(a) (b)

Fig. 2. Lightning protection zones of aircraft (a) and test current impulse for zone 1A (b) [1]

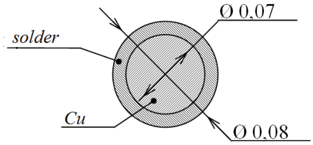
One of the promising method of manufacturing metallized layers is the use of lightweight knitted soldered meshes that are applied upon the CFC part surfaces. Such meshes exhibit dissipative effect that is manifested in supplemental expenditure of energy under the lightning strikes, and for evaporation of a light solder, and pulling out wires from the binder [4, 9].

The aim of this work is to study application of copper knitted soldered meshes as reinforcing elements to surface layers of carbon fiber composites.

Loop-like structure (Fig. 3a) of such meshes is formed from thin copper wires of 0.08-0.12 mm in diameter, which are covered with a solder [3, 4, 9]. Among the existing light solders for covering of copper wires, we selected solder TLS-61 because of its lower melting temperature, small density, low specific electric resistance and high strength as compared with solders of this group [11].



(a)



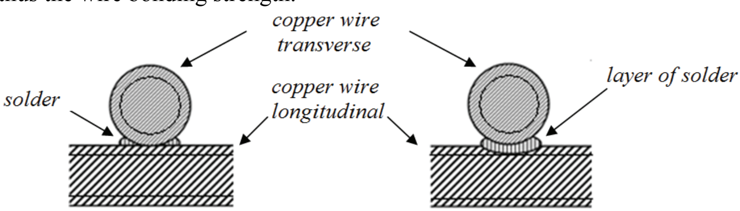
(b)

Fig. 3. Fragment of knitted soldered mesh (a), schematically showed copper wire with solder TLS-61(b)

Further soldering of loop-like cells of such a mesh ends in a soldered wire carcass, which preserves the form of knitted loops. Unlike knitted non-soldered meshes, lightning conductor carcasses made of soldered meshes are less stretchable; mobility of such a fabric structure is reserved at the expense of deformation and displacement of the loops relative to each other.

The amount of the solder in the mesh should be optimized in order to provide the sufficient strength for bonding of structural elements (loops) at a minimum weight. To optimize the structure of the knitted soldered mesh, the wire contribution, in their sites of interweaving, to the overall contact resistance is evaluated. Experiments on measuring specific surface electric resistance for copper meshes are conducted with the use of all-purpose measuring device P4833 [9].

It was found during the experiment that two types of contacts are existing when soldering: direct contact of copper tinned wires (Fig.4a) and contact of copper tinned wires through an additional layer of solder (Fig.4b), which increases the soldering area, thus the wire bonding strength.



a) (b)

Fig. 4. Schematically representation of contacts of knitted soldered mesh with direct contacts of tinned wires (a) and with contacts of tinned wires through a layer of solder (b)

The experiment showed that specific surface electric resistance of the meshes, being soldered as per scheme in Fig 4a, is high in comparison to the electric resistance when they are soldered as per scheme in Fig. 4b. This can be explained by a higher area for wire contacts, comparing to scheme 4b. At the same time, higher specific electric resistance of the solder does not produces a noticeable effect on the characteristic of the contacts between the wires because of low thicknesses of the solder applied upon the wire cores.

The diagram in Fig 5 shows the dependency of specific surface electric resistance on the areal density of a mesh manufactured using two versions of soldering, where can be seen data on meshes manufactured from a single, double and triple wire. The conductivity characteristics of the mesh per version 1 are lower than per version 2, and the data scattering of electric resistance (shaded areas) allow optimization of the mesh architecture in relation not only to its structure but to its method of soldering too.

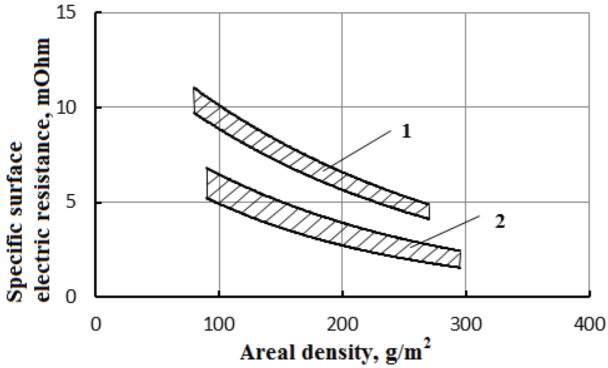


Fig. 5. Dependency of specific surface electric resistance on areal density of knitted soldered meshes with wire diameter of 0.08 mm and soldering method for contacts per scheme in Fig. 4a (1) and Fig. 4b (2)

It should be underlined that when selecting a type of copper mesh as element of lightning protection, one should keep in mind that with increasing the areal density (equivalent to increased quantity of conductive wires) the overall weight of the copper mesh used increases too.

The described features of the structure and soldering method of knitted soldered meshes manifest a potential for their useful application to lightning protection systems for CFCs, both airplanes and wind turbine blades.

Conclusions

1. The volume of using carbon fiber composites in commercial airplanes is increasing every year. A lightning strike to carbon plastics structures conceals a risk of destruction because of their low electric conductivity.

2. One of feasible method of lightning protection for such structures is application of a metallized layer made of knitted soldered wire meshes.

3. The effect of two techniques of soldering on the overall specific surface electric resistance of the meshes is determined. The dependence is established relative to the effect of the wire loop contacts on the mesh electric resistance useful

for optimization of the mesh architecture with different areal densities and their processing.

References

1. Aerospace Recommended Practice ARP 5414. Aircraft lightning zoning. SAE; 1999.
2. IEC 61400-24, "Wind turbines - Part 24: Lightning protection", International Electrotechnical Commission. Switzerland. 2010 (Edition 1.0). 153 p.
3. *L.R. Vishnyakov, A.M.Barannikov, Yu.F.Grin, Z.N.Demidenko.* Manufacturing of products from polymer composites surface-reinforced with copper knitted meshes // Bulletin of Engineer Academy of Ukraine. – – 2009. – № 3-4. – pp. 182-186.
4. *L.R. Vishnyakov, O.K. Nedzelskiy, Yu.F.Grin, I.I.Chernyavskiy, Yu.M. Vasilenkov.* Simulated lightning current tests of composite materials with lightning protection based on copper knitted wires // Bulletin of Engineer Academy of Ukraine. – 2009. – № 3-4. – pp. 187-191.
5. *Toshio Ogasawara, Yoshiyasu Hirano, Akinori Yoshimura.* Coupled thermal-electrical analysis for carbon fiber/epoxy composites exposed to simulated lightning current // Composites. – 2010. – Part A. – № 41. – pp. 973-981
6. *Yoshiyasu Hirano, Shingo Katsumata, Yutaka Iwahori, Akira Todoroki.* Artificial lightning testing on graphite/epoxy composite laminate. Composites. – 2010. – Part A. – № 41. – pp. 1461-1470
7. MicroGrid and Metal Foil [Electronic resources] http://www.dexmet.com/Products.html.
8. Astroseal Products [Electronic resources] http://www.astrostrike.com/index.html.
9. *L.R. Vishnyakov, I.I.Chernyavskiy, O.V.Zubkov*, Study of potential for lightning protection for composite materials reinforced with copper knitted mesh // Bulletin of Engineer Academy of Ukraine. – 2012. – № 2. – pp. 143-148.
10. Qualifying requirements QR–160D. Conditions of service and environment for board equipment. Requirements, norms and test methods. / M. : Aviation Register of International Aviation Committee. – 2004. – 327 p.
11. *Osintsev O.E., Fedorov* V.N. Copper and copper alloys. Home and aboard grades / Reference book M.: Machine Building. – 2004. – 336 p.

UDC 004.056.5:343.326 (045)

O.G. Korchenko, Prof Dr Eng (National Aviation University, Kyiv, Ukraine)
S.O. Gnatyuk, PhD Assoc Prof (National Aviation University, Kyiv, Ukraine)

COMPLEX APPROACH TO MITIGATE CYBERTHREATS IN CIVIL AVIATION

In the paper the analysis of guidance aviation security documents was carried out. These documents parts related to cyberthreats in civil aviation were defined and also the complex approach to provide the cybersecurity of critical aviation information systems was proposed.

Cyberterrorism evolution shows that attacks in cyberspace [1] today have a strong political overtones and more evident in cybernetic influence on international level. Only the first half of 2014 may be noted such cyberincidents: hackers broke into the Schengen Information System; powerful DDoS attack focused on biggest NATO sites from pseudo-Ukrainian groups named «CyberBerkut» & «Anonymous Ukraine»; cyberattacks on Ukrainian Cabinet of Ministers, Prosecutor General's Office of Ukraine & National Security and Defense Council of Ukraine; 1.3 millions of big communication operator Orange France were victims of cyberattack focused on their personnel data; Russia launched large-scale cyberwar against Ukraine, it is bound to the revolutionary events and carries political overtones to destabilize the situation in the state and the violation of its sovereignty & integrity; powerful DDoS attacks from Russian Federation territory on Ukrainian Central Election Commission in preparation and voting in Presidential election. Cyberattacks and acts of cyberterrorism are very crucial for critical infrastructure of any state, because these may have serious and tragic consequences. For instance in Civil Aviation (CA) any unauthorized access to control system calls into shot hundreds and thousands of passengers' lives. CA is moving away from traditional radar systems in favor of more modern digital tools connection – the problem is that new technologies potentially allow attackers get stuck between the pilot and dispatcher.

The guidance aviation security documents declare following requirements to ensure cybersecurity [1]: *1. ECAC Doc 30* [2] declares that measures addressing cyber threats to CA have been included in the National Civil Aviation Security Programme, the National Quality Control Programme and the National Civil Aviation Security Training Programme. A set of security control consists of below measures [2]: 1) Implementation of effective measures to protect Critical Aviation Information Systems (CAIS); 2) Including the CAIS in their threats assessment processes; 3) Separating the CAIS networks from public; 4) Responsibility for securing CAIS is allocated by operators to a properly selected, recruited and trained individual; 5) Security measures are considered in the design, implementation, operation and disposal of new CAIS; 6) Supply chain security measures for hardware and software should be applied to CAIS; 7) Remote access to CAIS is only permitted under pre-arranged and secure conditions; 8) Cyber attack incidents must be recorded for future evaluation and counter & preventive measures efficiency increasing. *2*. It is also worth noting that the most comprehensive list of measures to mitigate cyberthreats' negative influence on CAIS there is in *ICAO Doc 8973* [3]. Among them is noted as follows: 1) Administrative Measures; 2) Virtual (Logic) Control Measures; 3) Physical Controls. Besides this document, also focuses on CAIS: security by design, networks separation & secured remote access for legitimate users, supply chain security & cyber attack incidents records [3]. Despite the examples of the last cyberattacks and requirements of guidance aviation security documents, the *main purpose* of this paper is offer an integrated approach to mitigate cyberthreats and provide CA cybersecurity.

The cybersecurity will be successful only if a comprehensive approach to building a system of CAIS security. That's why complex approach includes a set of organizational and engineering measures that are intended to secure from disclosure, leakage and unauthorized access. Let's look at stages of CAIS' complex information security system (CISS) development in detail (steps from 1st to 13th): *1. Documents Preparing*. At this stage, the project of documents is prepared that defines the organizational component of the system (the order project of CISS creation, the condition project of Information Security (IS) service, projects on job descriptions, procedures etc.) that are approved by the administration. It can be also created an IS service or appointed persons who are entrusted to ensure IS and control over them. Responsibility relies on the owner of the system. *2. Audit*. The following documents are developed: the Certificate of CAIS inspection; the list of CAIS objects which require protection. During the CAIS inspection should be analyzed and described: the general block diagram and structure; types and characteristics of liaison channels; interactive features of separate components, their mutual influence in private; possible restrictions etc. Such characteristics of the physical environment are a subject matter of the analysis: territorial arrangement of CAIS components; availability of territory protection and facility access procedure; the influence of environment factors, protection from the means of technical investigation; availability of communication elements, life-support systems and communications, which have an output for borders of a controllable zone; availability and characteristics of grounding systems; storage conditions of magnetic, paper and other data carriers; availability of the design and operational documentation on components of physical environment. *3. Threats & Violator Model Development*. Using the information which is presented in the Environment Certificate of Inspection of CAIS operation, the potential threats to the data are defined. There is a research of some possible ways for CAIS data threats realization that is: outflow channels; special purpose channels & unauthorized data access methods. The results of Environmental Inspection of CAIS operation affirm the list of protection objects, as well as potential data threats are defined and the model of threats and violator model are developed. Threats model is the abstract formalized or unformalized methods and means description of threats realization. Violator model is the comprehensive structured characteristic of the perpetrator which is used together with the threats model for development of IS policy. On what information properties violation or CAIS threat is directed: confidentiality violation, integrity violation, data availability violation, surveillance and management of CAIS violation. *4. Security Policy Development*. Security policy is a set of requirements, rules, restrictions, and recommendations etc. which regulate the data processing order and directed on IS from the certain cyber threats. Security policy offers the following guarantees: a) It is provided an adequacy of IS level to a level of its criticality in CAIS; b) Realization of IS measures profitability; c) In any environment of CAIS operation the assessment and testing are provided; d) Personification of security policy positions is provided, the reporting (registration, audit) for all critical from the security point of view resources to which an access is provided during CAIS operation; e) The personnel and users are provided with the Full Documentation Set according to the IS support; f) Critical from the point of view of IS CAIS technologies (function) have all corresponding support plans of continuous work and its renewal in case of unforeseen situations. *5. Technical Specification*. The main stages of technical specification formation: a) Classification and description of CAIS resources; b) Development of an information model for existing CAIS, information CAIS flows, interfaces between the user and CAIS etc; c) A list of threats and possible channels of information leakage determination; d) Expert Assessments of expected loss in case of threats; e) Identification of security services; f) Requirements identification for organizational, physical and other protective measures implemented in addition to the complex software and hardware protection; g) Requirements identification for metrological work; h) Models identification that is designed, and technological stand; i) Cost-efficiency assessment of selected assets; j) Making the final decision on the CISS content. *6. Technical Project*. CISS technical project is developed on founding and in accordance with technical specification on CISS creation. In the process of CISS project development there are proved and designed decisions which give an opportunity to realize technical specification requirements, to provide compatibility and co-operation of different CISS components, and also different measures and technical specification methods. A technical project on CISS creation includes: a) Development of general design decisions necessary for realization of technical specification on CISS requirements; b) The decision on CISS structure, operation algorithms and conditions of use of defense (security) facilities; c) The decision on CISS architecture and implementation mechanism, defined by a functional structure of IS services; d) Procedure description of technical events on support of CISS development sequence, architecture, tests, the operational environment and CISS documentation according to the set of realization guarantees of security services; e) Development, registration, coordination and the documentation affirmation corresponding to the technical specification size, on CISS; f) Documentation development on IS resources supply and-or technical requirements on their development; g) Preparation and documentation registration on security means deliveries or production containing them in the structure, for CISS complete set (configuration); h) Development, registration and the affirmation of working and operational CISS documentation and, if necessary, its separate component parts. *7. IS Plan*. At this stage it is required to realize organizational, primary, technical and basic technical measures of restricted access IS, to establish required IS zones, to lead certification of technical equipment of an information activity support, IS means, workplaces (facilities) according to the IS requirements. *8. Operational Documentation*. At this stage there is a development, registration and the affirmation of working and operational documentation and, if necessary, its separate parts. The working documentation contains detailed decisions on CISS design realization, maintenance of CISS management and interaction of its components, and also the necessary documentation for testing, carrying out of starting-up and adjustment works, carrying out CISS tests. *9. CISS Implementation*. Implementation of organizational IS measures in CAIS provides: work on administrative documents preparations which regulate an activity of CISS support; compiling of instruction to person who participates in processing or IS in CAIS according to the list specified in the project on CISS; completion of work and the affirmation of documents which are included into IS plan in CAIS except those documents for which the results of the following stages are necessary. Commissioning works, according to the requirements of the preliminary CISS design in CAIS, provide installation, initialization and testing the work ability of CISS. *10. Preliminary Tests*. The purpose of the preliminary tests is checking the work ability of the CISS and possibility of taking it to the research operation. The CISS work ability and its compliance with technical specification requirements is checked during the tests. Preliminary tests are carried out according to the program and test methods. Developer of the CISS prepares program and test methods and the customer agrees CAIS. *11. Research Operation*. During research operation of the CISS: a) Technologies of information processing, a turnover of machine data carriers, management of security means, access differentiations of users to CAIS resources and the automated control over users' actions are examined; b) Employees and IS users get practical skills with the help of technical and hardware-software IS means, study conditions of organizational and administrative documents concerning access differentiation to technical means and information resources; c) Performing (if necessary) the revision of the software, additional tuning and configuration. According to the results of the arbitrary shape work the report on completion of the research is operation drawn up, which includes the conclusion on the possibility (impossibility) of CISS representation on the public examination. *12. Public Examination*. Public examination of the CISS is a separate step of acceptance tests of the CAIS. Public examination is conducted to determine CISS conformity with the requirements of normative documents on IS and its possibility of introducing CISS consisting of CAIS in the operation (exploitation). *13. CISS Support*. CISS support contains (accordantly IS plan and operational documentation): warranty & after sales technical service.

Accordingly in this paper, based on guidance aviation security documents and analysis of last attacks in cyberspace, the complex approach to ensure CA cybersecurity was offered. It consists of 13 steps (from documents preparing to exploitation and support) and allows to provide an effective cybersecurity of CAIS.

References

1. ISO / IEC 27032, Information technology – Security techniques – Guidelines for cybersecurity – 2012 – 50 p.

2. ECAC Policy Statement in the Field of Civil Aviation Security, 13th edition, 2010, 138 p.

3. Aviation Security Manual, 8th edition, ICAO, 2011, 748 p.

UDC 003.26:004.056.55:621.39 (045)

Ye.V. Vasiliu, Prof Dr Eng, I.V. Limar, Postgraduate Student
(O.S. Popov Odesa National Academy of Telecommunications, Odesa, Ukraine)

MUTUAL CONTROL BASED ON QUANTUM SECRET SHARING FOR REMOTE ACCESS IN ELECTORAL PROCESS AUTOMATION SYSTEM

A set of arrangements to ensure mutual control of parties to the vote count procedure in the course of electoral process is suggested. The scheme is based on quantum secret sharing technologies. A remote access capability is assumed to be provided in the form of video surveillance of paper media count and access of authorized persons to the server of interregional electoral body. In addition, remote deblocking device to control physical access to ballots and access to vote count recording device are provided.

The problem of providing information security in the course of political electoral process is characterised with participation of representatives from various adversary political parties in vote count, which, on the one hand, distrust each other and, on the other hand, may potentially prove to be unfair. These specific features require that a concept of secret sharing, which is well known in cryptology, should be used in the election automation system. This being the case, it is helpful to provide secret recovery capability for parties at an arbitrary distance from one another. There are at least two reasons for that. Firstly, such scheme will make it possible for any required number of observers to provide the preset control in the situations, where their arrival directly in the place of voting is difficult, dangerous or fundamentally impossible: election in commercial or military ships, temporary isolation of voting station because of a natural disaster or military operations and the like. Secondly, if remote access is used, then control will not be limited to exclusively local group of observers. If, for instance, a disputable or conflict situation arises, observers from any area of the country and any authorized organization can immediately become engaged in the control process. At the same time, transmission of data via communication line carries a threat of unauthorized access to such line and malicious distortion of information. In view of the said circumstances, using quantum cryptography becomes necessary in order to implement the principle of secret sharing, because schemes based on quantum technology conceptually possess a property of 'alerting' the receiving party of that the system is tampered. The cryptographic protection design of the domestic electoral process automation system based on quantum technology is also justified by the necessity to provide information security of the specialized government authorities of Ukraine. This follows from the fact that for the time being, with exception of Vernam cipher (one-time pad) all existing classical (non-quantum) encryption systems have only computational security. On the other hand, some quantum cryptography protocols are, essentially, a quantum equivalent of one-time pad and cannot be broken by cryptanalysis, however large is the computational power available to the adverse party. This being the case, quantum cryptosystems are free from the shortcomings inherent to Vernam cipher, which seriously limit its practical use. Use of quantum cryptography scheme in election automation systems has not yet been described in literature and, in this regard, the concept proposed in this report is novel.

HBB99 protocol [1] is the most commonly known implementation of quantum secret sharing. However, the solution proposed in [1] does not allow secret sharing among more than 4 parties that is unacceptable in the case at hand. Scheme [2], which allows expanding the secret sharing capability to an arbitrary number of parties, was proposed later based on HBB99 protocol. The principle of scheme [2] is as follows. Several parties *n* wish to use the secret sharing procedure. With this in mind, a sequence of *n*-qubit Greenberger–Horne–Zeilinger (GHZ) states is prepared:

$$|\psi\rangle_{GHZ} = \frac{1}{\sqrt{2}}(|000 \dots 0\rangle + |111 \dots 1\rangle) \tag{1}$$

where states $|0\rangle = |z+\rangle$ and $|1\rangle = |z-\rangle$ are the eigenstates for the case when the photon's polarization is measured in the rectilinear basis (denoted here as *z*). First, for simplicity's sake, it is assumed that the number of parties *n* is 3 (this, essentially, is the HBB99 scheme). One of the parties, which is usually called Alice, keeps one photon of the GHZ triplet, while sending one of the two other photons to each of Bob and Charlie. Then all secret sharing parties (in this simplified case, the names of the three parties are Alice, Bob, and Charlie) randomly choose the polarization measurement basis for one photon available to every party. We should note that such random choice is made independently by each of the parties and is kept secret from the other members of the group. If the measurement is made in the diagonal basis (denoted here as *x*) or circular basis (denoted *y*), the eigenstates are expressed as follows:

$$|0\rangle_x = |+x\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle), \qquad |1\rangle_x = |-x\rangle = \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle) \tag{2}$$

$$|0\rangle_y = |+y\rangle = \frac{1}{\sqrt{2}}(|0\rangle + i|1\rangle), \qquad |1\rangle_y = |-y\rangle = \frac{1}{\sqrt{2}}(|0\rangle - i|1\rangle) \tag{3}$$

On the other hand, eigenstates in rectilinear basis can be expressed in terms of eigenstates in diagonal and circular bases:

$$|0\rangle = \frac{1}{\sqrt{2}}(|0\rangle_x + |1\rangle_x), \qquad |1\rangle = \frac{1}{\sqrt{2}}(|0\rangle_x - |1\rangle_x) \tag{4}$$

$$|0\rangle = \frac{1}{\sqrt{2}}\left(|0\rangle_y + |1\rangle_y\right), \qquad |1\rangle = -\frac{i}{\sqrt{2}}\left(|0\rangle_y - |1\rangle_y\right) \tag{5}$$

Quantum measurement in diagonal and circular bases can produce values of 0 and 1, depending on polarization. Only a half of the performed measurements can be used for secret recovery procedure because the bases chosen by various parties must coincide that takes place only in 50 percent of all cases if the basis is chosen randomly.

Then the number of secret sharing parties is increased from 3 to an arbitrary number. The set of *n*-qubit GHZ states used for the secret sharing procedure takes the form of sequence $[b_1(j), b_2(j), \dots, b_i(j), \dots, b_n(j)]$, where j is used to denote every GHZ state and the subscript denotes the number of the particle in a GHZ state that is possessed by every corresponding party (Alice, Bob and so on). This being the case, it is assumed that when the *i*th party uses a diagonal basis for measurement, *b* becomes zero $b_i(j) = 0$, and when circular basis is chosen, *b*, accordingly, becomes "1" $b_i(j) = 1$. From equations (4) and (5) it follows that component $|00 \dots 0\rangle$ is expressed as:

$$|00\ldots 0\rangle = \prod_{i=1}^{n}\left(\sqrt{\frac{1}{2}}\left(|0\rangle_{b_i} + |1\rangle_{b_i}\right)\right) \quad (6)$$

In turn, component $|11\ldots 1\rangle$ is written as:

$$|11\ldots 1\rangle = \prod_{i=1}^{n}\left(\frac{-i}{\sqrt{2}}\left(|0\rangle_{b_i} - |1\rangle_{b_i}\right)\right) \quad (7)$$

Due to the reasons described in [2], the case when a circular basis is chosen for measurement by an odd number of parties cannot be used for secret sharing. If, however, the circular basis is chosen by an even number of parties, every GHZ-state is written as:

$$|\psi\rangle_{GHZ} = \frac{1}{2^{(n+1)/2}}\left(\prod_{i=1}^{n}\left(\sqrt{\frac{1}{2}}\left(|0\rangle_{b_i} + |1\rangle_{b_i}\right)\right) \pm \prod_{i=1}^{n}\left(\sqrt{\frac{1}{2}}\left(|0\rangle_{b_i} - |1\rangle_{b_i}\right)\right)\right) \quad (8)$$

If the circular basis is chosen by an even number of secret sharing parties, then the result of the qubit state measurement by Alice is unambiguously defined by the measurement results of the other qubits. Therefore, the n-1 members of the group other than Alice can unambiguously determine the results of Alice's measurement by jointly opening the results of their measurements to each other. If, on the other hand, even one member of the group is insufficient to achieve n-1 parties, then the secret recovery becomes impossible. In the simplest case, where there are only 3 parties (Alice, Bob and Charlie), when, for instance, the results of quantum measurement are $|100\rangle$, value 1 of the measurement results for Alice's qubit is calculated using formula:

$$l_{Alice} = l_1 = l_2 \oplus l_3 \oplus 1 \quad (9)$$

In this case l_1 and l_2 are measurement results of, accordingly, Bob's and Charlie's qubits that have value 0. Generalized formula (9) within the framework of this scheme is applicable to all and only those cases, when the number of the parties, which chosen the circular basis, is 2(2k+1), where k is a nonnegative integer and takes the form:

$$l_{Alice} = l_1 = l_2 \oplus l_3 \oplus \ldots \oplus l_n \oplus 1 \quad (10)$$

On the other hand, for cases where the number of the members of the group, which performed their measurements in the circular basis, is 4k, the computation is made using formula:

$$l_{Alice} = l_1 = l_2 \oplus l_3 \oplus \ldots \oplus l_n \quad (11)$$

Therefore, if secret sharing is required for n parties with subsequent secret recovery (for instance, classical bit sequences) by a subgroup of n-1 members of the original group, it is sufficient to perform the following steps: a) the party originally possessing the secret (in this case, Alice) prepares the GHZ-state of n objects of microworld (as a rule, photons) in, which can be used technologically for the purposes of quantum cryptography; b) Alice keeps one particle (one qubit of quantum information) and sends the reset of the particles of the GHZ-state to the other n-1 members of the group, one photon for each party; c) each of the parties randomly and independently of the other members of the group chooses one of the two possible measurement bases (diagonal or circular) of the quantum state of the particle it possesses; then the quantum measurement procedure is conducted and both as the result of the measurement (0 or 1) and the chosen bases are saved; d) steps a)-c) are repeated as many times as required to allow the encoding, so that, the number of measurements must be at least 2 times higher than the number of classical bits in the sequence, because a half of the measurements cannot be used for secret recovery; e) after step d) is completed, every party sends Alice using a classical communication line information on the basis (diagonal or circular), which was chosen for the measurements; Alice counts the measurements made using the circular basis and informs the parties that this round of measurements is useless (when the number of parties, which chose the circular basis is odd) or communicates the parties the necessity to save more measurement results and the multiple of the even number of measurements in the circular basis ($2(2k+1)$ or $4k$) while number k is not disclosed; Alice asks that a part of the measurement results should be sent her in the course of encoding in order to check for wiretapping, because if there are 50% useless measurement results, then a conclusion on can be made that no wiretapping occurred, while the percentage of useless results fluctuating around 75% gives every reason to believe that the information is intercepted and completely invalidate the results obtained after the last secure transmission of data. The classical bit strings checked for wiretapping can be recovered jointly by n-1 parties.

We propose the following design of a secret sharing system within the framework of automation and measures to provide comprehensive electoral process security (Fig. 1). The secret must be initially generated by the automatic device without human participation. In the course of preparing for the election and before its commencement, such device must be checked by a commission, which must include engineers specializing in information protection.

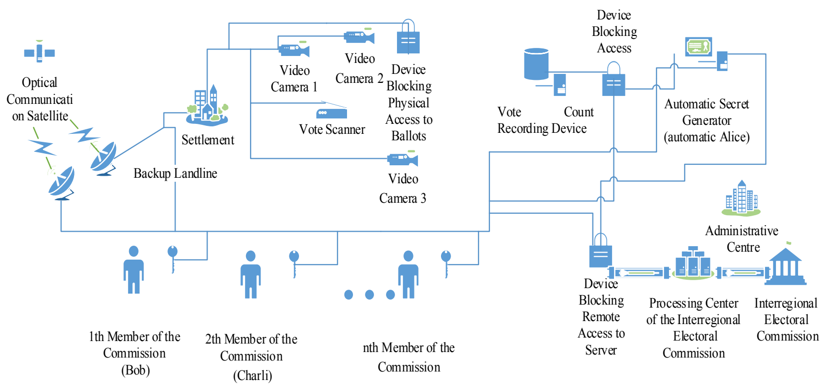


Fig. 1. Information Security Scheme of Vote Count Procedure based on Quantum Secret Sharing

Then the said device ("automatic Alice") must be sealed. A secret can be generated as many times as needed and then sent to three blocking devices: devices blocking physical access to vote scanner at the voting station, devices blocking access to the medium recording the vote count by the members of electoral commissions (remote from the voting station) and the device blocking remote access of the members of the commission to the server of the interregional electoral body. The secret must be transmitted via communication lines with quantum cryptography (preferably), for instance, by quantum secure direct communication protocol or after encryption using classical cryptography. The vote scanner must be observed by mutually checking video cameras from three points. This being the case, information from the video cameras must also be transmitted ciphered in order to prevent malicious distortion of video surveillance results in the communication line. Encryption can be performed by methods of quantum and classical cryptography.

Once the voting is completed and before the ballot box is deblocked, the remote observers and the members of the commission must make sure that exclusively authorized persons are in the voting station premises and the box and the blocking device have no physical damage. If the video surveillance data show that the vote count can be started, the secret sharing parties issue a signal to the access control device. Then, in the course of vote count (using an electronic scanner or visually using video cameras) the members of the commission record the data from every ballot using the special device. Every such recording is possible only if all members of the commission agree to it: if they do, they will jointly deblock the recording device every time. The data from the remote voting station (population center, military or commercial ship) are transmitted optically via geosynchronous satellite. In case of adverse weather conditions, which exist for a long time, the transmission must be made via a backup fiber-optic landline. For sea ships such transmission can be done via a government communication station of a consulate in the nearest port.

In addition to mutual control during vote count, the system also provides the members of the commission with remote access to the server of interregional electoral body. Such access can also be provided exclusively on a mutual basis and controlled by the secret sharing system.

Conclusions

The system of mutual and remote access of the members of electoral commissions and international observers to the media used in the course of electoral process can significantly improve the efficiency of vote count performance. On the other hand, in order to ensure the required level of information security in view of the risk that information can be intercepted in communication lines, it is helpful and necessary to use such quantum cryptography instruments as secret sharing technology.

References

1. Hillery M. Quantum Secret Sharing / M. Hillery, V. Buzek, A. Berthiaume // Physical Review A.-1999.-V.59, issue 3.-P.1829-1834.

2. Xiao L. Efficient Multiparty Quantum-Secret-Sharing Schemes / L. Xiao, G.L. Long, F.G. Deng, J.W. Pan // Physical Review A.-2004.-V.69, issue 5.-052307.

UDC 004.056.55 (045)

V.Yu. Kovtun, PhD Assoc Prof (National Aviation University, Kyiv, Ukraine)
A.O. Okhrimenko, Postgraduate Student
(National Aviation University, Kyiv, Ukraine)
O.L. Stokipniy, PhD
(Kharkiv National University of Economic, Kharkiv, Ukraine)

INTEGER REPRESENTATION WITH DELAYED CARRY

Performance improving of cryptographic transformations with public key is actual problem. Performance improving of operations on integers is a potential solution to this problem. Authors propose DCF representation of integers in which the number is split into machine words , where each word has information block and carry block.

Modern society is inconceivable without information and telecommunication systems. The greatest growth of information is observed in industry, commerce, finance, banking, educational and scientific fields. Information is one of the main factor that determines the development of technology and resources in general. Therefore, problem of data privacy and protection of personal information becomes very important. Development of information security systems aimed to solve this system. Public key cryptographic operations are the basis of modern information security systems and they are used in a wide range of networking protocols to provide authentication, non-repudiation, digital signature and private-key exchange. Public-key operations are some of the most computationally intensive functions occurring in cryptography. Therefore, improving performance of public-key operations is an urgent problem.

Public-key operations are based on mathematical problems, which currently admit no efficient solution that are inherent in certain integer factorization, discrete logarithm, and elliptic curve relationships [1]. In most of these tasks operations on integers are used. So, it is proposed to improve performance of cryptographic operations with public key by increasing the productivity of operations on integers. Improvement of representation of integers is one of the ways to improve the performance of operations on integers, because it allows further algorithms modifying on them.

There are many representations of integers that can be divided into positional and nonpositional [2]. Each representation is strictly oriented to perform specific tasks in modern cryptography. In normal representation, integers in field $\mathbf{GF}(p)$ are represented by binary vector with length l (an array of machine words with binary length w):

$$b_{l-1}2^{l-1}+b_{l-2}2^{l-2}+\cdots+b_1 2^1+b_0=a_{n-1}2^{(n-1)w}+a_{n-2}2^{(n-2)w}+\cdots+a_1 2^w+a_0,$$

where $n=\left\lceil \frac{l}{w} \right\rceil$ - number of machine words needed for representation of binary number length l ; b_i - binary coefficients; a_j - machine words with length w . In

Non-adjacent form (NAF) [4], binary number $b_{l-1}2^{l-1}+b_{l-2}2^{l-2}+\cdots+b_1 2^1+b_0$ is given by

$$b_{l-1}2^{l-1}+b_{l-2}2^{l-2}+\cdots+b_1 2^1+b_0=a_{n-1}2^{(k-1)}+a_{n-2}2^{(k-2)}+\cdots+a_1 2+a_0,$$

where k – number of coefficients a_j needed to represent binary number length l; b_i – binary coefficients; $a_j\in\{-1,0,1\}$ - coefficients. This list is intended to illustrate the diversity of approaches and can be expanded significantly, but the analysis of various representations of integers is out of the scope of this paper.

Despite the widespread use of the described representations of integers, they are not without some drawbacks, among them – the low efficiency of the implementation on modern microprocessors. All above representations provide carry or loan operations, which is extremely inefficient implemented by modern processors, because not conform the pairing instructions conditions. Significant performance increase in operations on integers can be achieved by delaying higher to lower bit carry operations and delaying lower to higher bit loan operations.

Propose a new integers representation, so-called DCF (Delayed Carry Form) representation with delayed carry [3], Fig. 1. Number $a=d_{\mathrm{DCF}}$ in the DCF is a sequence of machine words $d_{\mathrm{DCF}}=\{d_{n-1},\ldots,d_1,d_0\}_{\mathrm{DCF}}$, w-bits length, such that each machine word $d_i^{(w)}=a_i^{(r)}\,||\,a_i^{(v)}$, where r – length in bits of carry for $a_i^{(r)}$ and v – length in bits of number $a_i^{(v)}$. In DCF-representation, number a with binary length l in n blocks with length v bits, will contain $n\cdot r$–bits of redundant information used for carries.

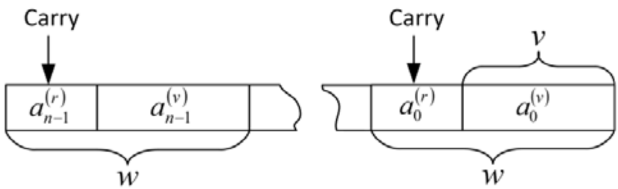


Fig. 1. DCF representation of integer

CPU operates integers in DCF representation as machine word, in which some bits are allocated for carry accumulation and some bits are allocated directly to store the number itself. CPU operations on machine word that contain carries are straightforward.

To convert an integer into DCF representation, you need to reserve (reset) r-bits for carry block $a_i^{(r)}$ in the w-bit machine word $d_i^{(w)}$. The remaining v-bits are filled with bits of integer in a continuous binary form, Fig. 2.

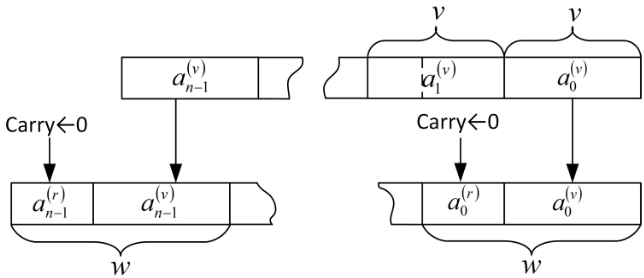


Fig. 2. Converting integer to DCF

Efficient program implementation depends on the partition of the w-bits machine word per r-bit carry block and v-bit information block.

Length ratio of carry and information block affects saved carry and loans amount, redundancy of integer representations and performance.

Number of bits r allocated for storing carry should be determined for performance reasons. Alignment of one, two or more bytes is chosen on the grounds of maximum possible storage for carry. Thus, it is necessary to allocate one byte for storage carries in range {-127, 128}, which may store 128 results of addition and 127 results of subtraction operations, or 255 addition / subtraction operations.

Using this approach, there is redundancy of the DCF representation of integers, through the allocation of r bits in each machine word for carry or loan.

Analytical assessment of redundancy can be done as $R(d_{DCF}) = \left\lceil w \cdot n \cdot \left(\frac{w}{w-r} - 1 \right) \right\rceil$ or $R(d_{DCF}) = \left\lceil w \cdot n \cdot \left(\frac{w}{v} - 1 \right) \right\rceil$, where n count of machine words.

Table 1 shows the evaluation of redundancy in bytes for DCF-representations of machine words with different carry block sizes.

Table 1.

Dependence of the redundancy of integers DCF-representations on the delayed carry block size

Size of carry block, bits	Possibility of usage		Redundancy, bytes	
	w =32 bit	w =64 bit	w =32 bit	w =64 bit
8	+	+	4/3 n	8/7 n
16	+	+	4 n	8/3 n
24	+	+	12 n	24/5 n
32	-	+	-	8 n

Signs "+" marks words length that support the carry blocks with given size in bits.

Feature of the proposed DCF-representation of integers is absence of necessity of accounting of carries and loans, that allows eliminating extra assignment operations and checks while implementation on high-level languages, as well as eliminating analysis of the flags register for carry possibility. In turn, this leads to increasing efficiency of software implementation on superscalar CPU architecture and capabilities of modern compilers for branch prediction, parallel execution of instructions, loop unrolling, etc.

Considering the specialty of DCF-arithmetic when the order of addition and subtraction of integers on the machine word is not important, it is possible to parallel processing of addition and subtraction of the corresponding words.

Possible to use various parallelization techniques, such as OpenMP multithreading technology, or NVIDIA CUDA technology performing each operation in a separate thread, Fig. 3.

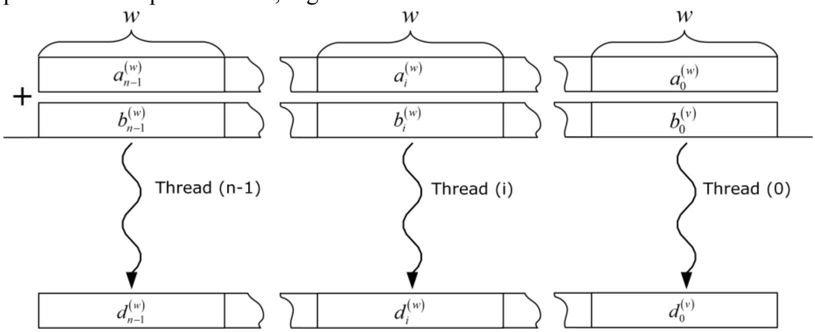


Fig. 3. Threading model based on NVIDIA CUDA technology

Conclusions

Proposes a new representation of integers with a delayed carry (DCF), for solving the problem of increasing the productivity of cryptographic transformations with public key.

The possibility of using different technologies parallelization software implementation of algorithms for arithmetic operations DCF numbers was shown.

References

1. Cohen H., Frey G. (2006). Handbook of Elliptic and Hyperelliptic Curve Cryptography. Discrete Mathematics and its Applications. Chapman & Hall/CRC.

2. Knuth, Donald E. (1998), The Art of Computer Programming. Third edn. Vol.2: Seminumerical Algorithms, Addison-Wesley.

3. Kovtun V., Okhrimenko A. (2013), Integer multiplication with delayed carry in public-key cryptosystems, in Ponomarenko V.S. (Ed.), Information technologies in management, education and science, Cifrova drukarnya №1, Kharkiv, pp. 69-82.

4. Preparata Franco P. (1971). On the Representation of Integers in Nonadjacent Form, SIAM Journal on Applied Mathematics, Vol. 21 (4). pp. 630-635.

UDC 004.056: 656.7.043 (045)

A.L. Antipov (Irkutsk, Eastern Siberia Air Navigation, FSUE ATM Corporation)
N.A. Kinash, A.I. Trufanov (Irkutsk, Irkutsk State Technical University, RF)
A.A. Tikhomirov (Incheon, Republic of Korea, INHA University)
S.O. Gnatyuk, R.A. Umerov (Kyiv, Ukraine, National Aviation University)

DYNAMIC ONTOLOGY OF AIR TRAFFIC MANAGEMENT SYSTEMS: NETWORKING AND MODELING

Ontology of air traffic management systems as complex network structures has been proposed. The ontology provides studies and practice with detailed description of the phenomenon within the domain. Pertinent complex networks based on top level ontology promote effective robustness analysis of the systems.

Contemporary approaches to air transport organization are based on Global Air Traffic Management Operational Concept (Doc 9854), developed at the meetings of the International Civil Aviation Organization ICAO. In the concept a statement of a comprehensive Air Traffic Management (ATM) system is declared as its principle is up to and beyond 2025. The goals of evolutionary development and improvement of the ATM system depend directly on the ability of ATM community to define the expected performances clearly, to establish appropriate time frame, and to set realistic goals and make changes in an economical manner, taking into account the available opportunities at any given time throughout the planning period [1].

The ATM system is a class of information systems. In turn, aviation security is a class of information security subsystems. Modern information systems according to [2] increasingly are voluminous entities of interacting actors of different nature – conscious and unconscious ones, to form non-trivial organizational and technological structures. Any information system in conjunction with information security component and its environment, as well as pertinent threats forms complex meta-system that apply meta-language which is able to find means of making decisions when necessary improvements cannot be made [3]. Clearly component, functional and structural complexities of such systems might be a main cause of concomitant destabilizing factors.

Building ontology of the ATM system promotes in performance the next tasks:

1. Constructing a transparent understanding of the structure of information.
2. Reusability of domain knowledge.
3. Setting of boundaries in the subject area.
4. Distinction between domain knowledge and operational knowledge.
5. Reduction of creating fragmentary information security policies that do not cover the whole ATM system and emergence of different interpretations of same terms [4,5].

When one creates a Top-Level Ontology (TLO) it is always a question is asked what concepts and approaches for the construction are to be built on. So, John Owl ontology [6] implements a philosophical approach to identification of basic categories of being, WordNet ontology [7] reflects the linguistic approach to the analysis of categories of reality.

Certainly, the approaches and concepts for TLO should be flexible, able to describe a variety of phenomena and semantic details of diverse domains.

Most developers and researchers of ontology as a specification of limited use language concepts – or philosophical basic terms (essence, matter, space), or linguistic structures (actor, role, action, process). However, it is possible to use concepts from other models and theories that have broader semantic features (in particular the theory of complex networks).

To construct a dynamic meta-ontology and its provision it seemed reasonable to use such tools as complex networks. Network models significantly enrich domain of information security if compare with the description, performed on the basis of component or functional analysis. The work [8] demonstrates how complex networks might be applied to classify vulnerabilities with effective risk prediction and threat analysis.

ATM system and its subsystem of Air Traffic Control (ATC), might be treated as a network structure, working in line with complex network nature. The approach [9] aimed to represent the ATC subsystem as multi-directed graph which conceptually forms a composite network. Central information actors of the composite network are a air traffic controller (officer) and the airline transport pilot. The composite network is built on management of actor's interactions. The resulting structure is analyzed using metrics network. All instances of the ontology (flying control officer, airline transport pilot, flight radio support tools, etc.), and all layers has attributes. For example, all equipment nodes of an Air Traffic Control Center have a high centrality value. If destructed those will cause changes in all instances of other concepts and all metrics in all layers are to be recalculated. Thus, one can monitor the role of nodes in a network to identify the most vulnerable areas, to predict attacks, and to assess cross-impact of diverse network layers. Centrality is a network metric and an attribute of a particular node "importance" both (Degree centrality of a node is determined by the number of its connections).

The technique of complex networks as specification language provides a high expression level of the ontology, i.e, level of detailing of concept description included in the ontology. Mainly this is due to instrumental richness of calculations, visualizations and descriptions of complex networks with metrics (centralities, intermediations, clustering coefficients, etc.) and models (composite, multiplex, classic ones). Complex networks promote description of multilayer structures with a large number of elements in textual and visual forms both. While visualizing a selected network model, some structural features – patterns, hubs, patterns and motifs – become visible and transparent.

An Applied security ontology has been built on the basis of top-level Ontology for ATM. The former has significant advantages if compare with ontology, formed on the basis of a TLO which uses limited linguistic concepts and approaches for a specification language. Principles of complex networks are the axioms for ontology. These define basic statements, structure and scope of the ontology. Composite network as a kind of complex networks is a main parent concept in this applied ontology. The network consists of several interconnected layers. Each layer might be considered separately as a classic complex network. The concept “layer” is a parent and a child both for concepts “link” and “node”. Legal, organizational, technical and social strata are instances of the concept “layer”. The instances of concepts “link” and “node” might be represented by only one mapping for simplification.

While working with applied security ontology it is constructed as follows. For example, one intends to raise the level of aviation security. Then, for description of the domain it is necessary to select a stem (multiplex) network model from the top-level ontology. Finally a selected piece of the study is represented with a stem network with multiple layers. Each layer is considered as a single classic complex network.

By utilization of stem network models the next opportunities become available:

1. Analysis and evaluation of the effects of destruction of a single node (e.g., the Control Tower), that affects both on the network to which it, the node, belongs (air), but also on other interconnected networks.

2. Simulation of scenarios of aggregate attacks.

3. Identification of hidden (“latent”) processes, including covered threats by analyzing the existence of patterns and specific stable structures (these structures presents in networks stable typical combinations of nodes and links).

4. Identifying the most important (from a security standpoint) nodes of a network by calculating “sensitive” metrics.

5. Finding vulnerabilities of a network.

6. Search specific structural entities at the national and international levels.

It seems to take into account integrate «Swiss Cheese» model of accidents [10] as Prerequisite to building an applied aviation security ontology. According to the model it is recognized that “accidents in complex systems occur through the concatenation of multiple factors, where each may be necessary but where they are only jointly sufficient to produce the accident”. Since the complex systems, such as aviation ones, possess extremely strong protection on several levels, internal, single isolated failures rarely bring to serious consequences in the systems. Technical failures in equipment or operational errors never cause destructions in security protection unit, but rather serve as triggering events. Violations of security barriers and destruction of safety structures are only delayed consequences of decisions taken at the highest levels of a system. These do not become apparent until their impact or potential disruption will not be initiated by the confluence of specific operational circumstances. Under these specific circumstances, human error or active failures at the operational level act as triggers for latent conditions that lead to violations inherent for the protection system.

In concept, that nominated by the model [11], all accidents involve a combination of active and latent conditions.

It is of sense to consider the following special case of applied aviation security ontology of Air Traffic Control subsystem under at external destabilizing actions. An air traffic controller, located in a Control Center (Control Tower), supports radio exchange with an airline transport pilot on the aircraft. An attacker using his radio equipment tries to seize control of the air traffic controller tasks, and intend to suppress the radio signal between the ATC center and the aircraft. By using the principles outlined above, one can construct a simplified composite network that covers only part of the ontology with two layers: organizational and technical ones.

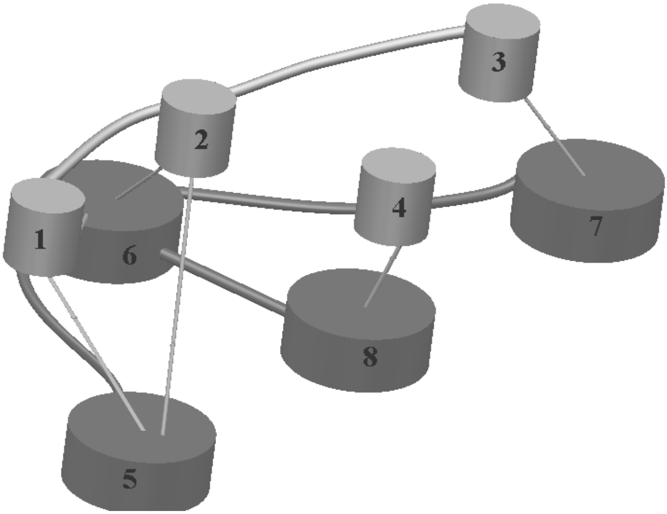


Fig. Applied aviation security ontology of Air Traffic Control system

Fig. shows the resulting security ontology subsystem ontology security subsystem controllers, where blue objects (1 – Security service, 2 – Air traffic controller, 3 – Airline transport pilot, 4 – Malefactor) belong to the organizational layer, and red objects (5 – ATC Center-Control Tower, 6 – Control tower radio station, 7 – Aircraft radio station, 8 – Malefactor radio equipment) are included into the technical layer.

Conclusions

The developed meta-ontology of ATM systems, and in particular the Applied aviation security ontology of Air Traffic Control system allows to:

1. Describe in details phenomena of this domain with a visual rendering.
2. Generate portable system.
3. Design and implement effective security policies, taking into account the vast range of possible factors that might be differentiated in accordance with the tasks presented in an organized, consistent manner.
4. Ensure a common comprehensive understanding of the security policies of all actors in the information society.
5. Perform effective classification of vulnerabilities, simulate threat scenarios and evaluate risks.
6. Simulate scenarios of complex combined attacks.

7. Suggest ideologies, practices, models and approaches understandable to diverse experts and officers (control sector, management etc).

8. Identify specific structural entities at the national and international levels.

References

1. Doc 9882 ИКАО, Manual on Air Traffic Management System Requirements. First Edition. 999 University Street, Montréal, Quebec, Canada H3C 5H7, 2008. – 67 p. http://www.emfa.pt/infoaero/conteudos/galeria/ICAO/Docs_Pagos/9882_cons_en%5B1%5D.pdf (Uploading date: June 17, 2014).

2. Tikhomirov A., Trufanov A. Smart World as an evolution conception of information society. http://www.pitt.edu/~super1/lecture/lec50371/_in-dex.htm, (Uploading date: June 17, 2014).

3. Beer S. Brain of the Firm Wiley; Second edition (June 8, 1995) – 416 p.

4. Donner M. Toward a Security Ontology. IEEE Security and Privacy, 2003.

5. Denker G.Access Control and Data Integrity for DAML- +OIL and DAML-S, SRI In-ternational, USA, 2002.

6. Sowa J.F. Knowledge Representation: Logical, Philosophical, and Computational Foundations. Boston, MA: PWS Publishing Co., 1995.

7. Miller G.A., Beckwith R. Introduction to WordNet: An Online Lexical Database // International Journal of Lexicography. Vol.3. No.4. 1990. – 86p. http://wordnetcode.princeton.edu/5papers.pdf (Uploading date: June 17, 2014).

8. Tikhomirov A.,Trufanov A., Dmitrienko N., Rossodivita A., Shubnikov E.. Classification of Attacks in Simulation Studies of Complex Networks Vulnerabilities. – 2012, №1, p.46-52.

9. Antipov A., Trufanov A. Grapgh-model of enterprise information resources. Security of Information Technologies – 2008. №3, p. 47-48.

10. Reason J., Hollnagel E., Paries J. Revisiting the «Swiss Cheese» model of accidents. Eurocontrol Experimental Centre Centre de Bois des Bordes B.P.15 F – 91222 Brétigny-sur-Orge Cedex. Project Safbuild – EEC Note No. 13/06, October 2006, – http://www.eurocontrol.int/eec/gallery/content/public/document/eec/report/2006/017_Swiss_Cheese_Model.pdf (Uploading date: June 17, 2014).

11. Doc 9859 Safety Management Manual (SMM) Third Edition. 999 University Street, Montréal, Quebec, Canada H3C 5H7, 2013, 251 p. http://www.icao.int/safety/SafetyManagement/Documents/Doc.9859.3rd%20Edition.alltext.en.pdf (Uploading date: June 17, 2014).

UDC 003.26: 004.056.55: 621.39 (045)

M.O. Ryabyy, PhD (European University, Kyiv, Ukraine)
V.M. Kinzeryavyy, PhD (National Aviation University, Ukraine)

COMPARATIVE ANALYSIS OF METHODS OF POST-QUANTUM CRYPTOGRAPHY BASED ON LATTICE THEORY

In work made the analysis of post-quantum methods of information protection, based on the theory of lattice. This is the characteristics of the main directions of the development of post-quantum cryptography based on lattice theory, analyzed advantages and disadvantages.

The systems of asymmetric encryption underlie a multitude of encryption (PGP, S/MIME), and network protocols (SSL, TLS, SSH and others), as well as an electronic digital signature protocols and in the systems of organization of the network infrastructure.

At the moment, the widely used asymmetric encryption system, based on two types of problems of the theory of numbers are: tasks of factorization of integers; tasks of discrete logarithm. Inversion of these tasks was considered impossible for a reasonable time due to the lack of a polynomial time algorithm execution. Since the second half of the 90-ies of 20th century, begins a period of "Quantum revolution" in the theory of algorithms.

In 1995 Peter Shor showed polynomial algorithms of conversion described above problems on quantum computers [1], thereby defining the period of existence of the systems to the emergence of quantum calculators sufficient dimensionality. Zhuan experiment in 2001 demonstrated the performance of shore's factorization algorithm for number 15 on 7-cubic hybrid quantum computer, built out of 10^{18}-molecules consisting of five fluorine atoms and two carbon atoms, with a record of using radio signals and for reading techniques of nuclear magnetic resonance.

In 1996, Grover demonstrated the General method of searching the database with the complexity of $O(\sqrt{N})$ that allows us to implement decoding of symmetric encryption algorithms, equivalent to the double reduction key cipher [2]. In practice, the work of the algorithm was tested on 2 cubic quantum computer.

In 1997 was presented to the algorithm of Brassard- Høyer-Tappa, based on the algorithm of grower, which implements the search function hash collisions with the complexity $O(\sqrt[3]{\frac{N}{r}})$ where N -power space busting, and r is the number of prototypes hash-functions on one image [3].

Thus, all types used in practice, asymmetric encryption systems, as well as key stage encryption-hashing ceased to be difficult to reverse. Need to search crypto-stabile to quantum computers, tasks for post-quantum era.

Today, quantum computer can destroy most if not all traditional cryptosystems that are used in practice, namely, all the systems on the basis of factorization of integers (e.g. RSA) or discrete task logarithm (both traditional and on elliptic curves Diffie-Hellman and DSA; as well as the entire cryptography based on pairing). Although there are mechanisms of classical cryptography, which are not exposed to the action of quantum computers. Some of the classic crypto schemes, based on computationally-demanding tasks differ from the above and much more difficult to solve, they remain independent of quantum computing. The term "post-quantum cryptography" was proposed by Dr. Bernstein and has already become a universally accepted in cryptographic literature. It represents the part of cryptography that remained after the emergence of quantum computers and quantum attacks.

Till nowadays offered many quantum technologies protect information that differ in both the main principles laid at their base, and the degree of their reliability, as well as the methods of practical implementation. However, classical Cryptography (post quantum) continues its development in cryptography, based on the theory of lattice and cryptosystems-based syndromes. The aim is to analyze the methods of post-quantum cryptography based on lattice theory, the definition of their advantages and disadvantages.

In 1996 the Hungarian mathematician Mìklos Ajtai IBM researcher in his work [4] showed that [5]: maybe, it is possible to build a one-way function based on SVP-assignments, on the basis of grid, find a shortest nonzero vector (shortest vector problem, SVP); later researchers have improved the result of the one-way function with a secret (trapdoor function) – variant of one-way functions, fast spinning (compared to the speed of getting the image functions) in the presence of the additional information; cashing in the probabilistic version of the knapsack problem, SVP has no probabilistic to polynomial algorithm solution, that is not investigated quantum computers in polynomial time; among the class of NP-problems, SVP-problem is the most difficult, is NP-complete.

The results of Ajtai, as well as unsuccessful attempts to implement quantum algorithms solving lattice theory, by analogy with proposed by Shor in 1987, effective multi block reduction supplement [6] to the polynomial algorithm for L^3 or LLL [7] Lenstra, Lenstra and Lovas, allowing approximately solve the SVP and close to them, problems with arbitrarily specified precision, made these problems most likely contenders for the realization of crypto-stable in quantum encryption systems.

All cryptographic systems theory of the lattice can be divided into two types: 1. Who have clearly proved crypto-stable, but not effective at runtime of the algorithm of encryption/decryption and/or characterized by the rapid growth of public and private keys from the key parameters of encryption, such as the dimension of the lattice. Such systems include encryption, cryptography based on: SVP, uSVP, SIVP tasks; 2. Effective time encryption/decryption and costs on storage of open and private keys that do not have clearly proven crypto-stable. To such systems of adopted classification system, based on some partial in parametric sense cases lattice theory problems or based on lattice of cycling that forms their basis. These include NTRU (Draft standard of IEEE 1363.1) encryption [8].

NTRU encryption system based on task NTRU Convolution modular lattice (NTRU Convolution modular lattice, NTRU CML), which is a special case of CVP-tasks. Basis of encryption is the convolution operation on the ring of modular polynomials (with integer coefficients). Under the cover of polynomials in this case understand their multiplication, with a given rule convolution $x^i = 1$ where $= const$.

Today, this system has received the most applications among all systems of encryption based on lattice theory. The reason for this is the high performance of the algorithm, combined with the small size of the public and private keys [9]. The main disadvantage of NTRU encryption is the lack of a theoretical substantiation of the crypto-stable [9] score is experimental, based on the fastest variant of the algorithm of reduction of lattice-block algorithm Korkina-Zolotareva (block BKZ-Korkin, Zolotarev-LLL).

One of the most researched systems encryption based on lattice theory problems have encryption Ajtai-Dvorka (Ajtai-Dwork) is devoid of errors decoding the message, Goldwasser, Goldwasser and Halevi (GGH) [10]-AD_{GGH} uSVP-based tasks. The main disadvantage of system encryption AD_{GGH}, is the rapid increase in the size of the public and private keys, depending on the dimension of the lattice basis [9], which complicates the practical application of this system.

Asymmetric encryption Regev ($Regev_{05}$) based on LWE-problem with clear proof of crypto-stable and combines a relatively high speed encryption/decryption, and relatively small public and private keys [9].

Table 1

A comparative analysis of systems of encryption based on the lattice [11]

System encryption	Difficulty of setting			
	Cryptic stability	The size of the public key	The size of the private key	Encryption, decryption
AD_{GGH}	$O(n^{11}) - uSVP$	$O(N^5 \log N)$	$O(N^2)$	$\approx O(n^{\log_2 c}),\ c < 3$
$Regev_{05}$	$\tilde{O}(n^{1.5}) - SVP$	$O(N^2 \log^2 N)$	$O(N \log N)$	$\tilde{O}(n)$
$Gentry_{mrf}$	$2^k - SIVP$	$\tilde{O}(k^{3.5})$	$\tilde{O}(k)$	$\tilde{O}(k^7)$
NTRU	$10^{0.0826n-2.58}$ *сек.*	$\approx \frac{1}{2} N \log_2 \frac{N}{4}$	$\approx \dfrac{N(n-k)\log_2 \frac{N}{4}}{2n \log_p q}$	$O(n^2)$

where n – the size of the grid N – volume basis grid in bits, k – the level of security at bits regarding symmetrical encryption algorithm, p – small module q – a great module.

In June 2009, Craig Gentry [12] demonstrated implementation of honorific encryption on perfect lattice [9] for the operations of addition and multiplication ($Gentry_{mrf}$). Honorific encryption provides a homomorphism on some operations between source data and encrypted information. This type of encryption allows us to implement the processing of encrypted data (search by fields) without the need for their complete transcripts, which ensures the confidentiality of information stored on remote servers, including when exchanging data through a non-secure channel Internet. Hypothesis about the possibility honorific encryption was proposed by Ronald Linn Rivest, a quarter of a century after futile attempts at implementation, he suggested a fundamental inability to construct such systems.

In work the analysis of post-quantum methods of information protection, based on the theory of lattice. This characterization of the main directions of the development of post-quantum cryptography based on lattice theory, analyzed advantages and disadvantages.

The analysis of existing methods of post-quantum cryptography showed that to implement in real cryptic systems, still need to resolve a number of problems of technological nature. Also, the removal of the existing contradictions "crypto-stable theoretically" and "empirically effective" between systems of asymmetric encryption based on lattice theory problems, opens a promising direction in fundamental and applied mathematical research in the field of post-quantum cryptography.

References

1. Shor P.W. Polynomial-time algorithms for prime factorization and discrete logarithms on a quantum computer. SIAM J. Com., 26:5, 1997, p. 1484-1509.
2. Grover L. K. A fast quantum mechanical algorithm for database search, Proceedings of the 28th ACM STOC, 1996, p. 212–219.
3. Brassard G., Hoyer P., Tapp A., Quantum cryptanalysis of hash and claw-free functions, ACM SIGACT, 28:2, 1997, p. 14–19.
4. Ajtai M. Generating Hard Instances of Lattice Problem. Proc. of 28th ACM Symp. on Theory of Comp. Philadelphia: ACM Press, 1996, p. 99-108.
5. Шокуров А.В., Кузюрин Н.Н., Фомин С.А. Курс лекций «Решетки, алгоритмы и современная криптография» [Електронний ресурс] - 2008. - 127 с. // <http://discopal.ispras.ru/ru.lectures-lattice-based-cryptography.htm>
6. Schnorr C. P. A hierarchy of polynomial time lattice basis reduction algorithms. Theoretical Computer Science, 1987, 53(2-3), p.201-224.
7. Lenstra A.K., Lenstra H. W., Lovasz L. Factoring polynomials with rational coefficients. Math. Ann., 1982, 261(4), p. 515-534.
8. Hoffstein J., Pipher J., Silverman J. H. NTRU: A ring-based public key cryptosystem. In ANTS-III, 1998, p. 267–288.
9. Усатюк В.С. Обзор систем ассиметричного шифрования на основе задач теории решеток криптостойких к квантовым вычислительным машинам. – Братск: Братский государственный университет.
10. Goldreich O., Goldwasser S., Halevi S. Eliminating decryption errors in the Ajtai-Dwork cryptosystem. In CRYPTO ’97, 1997, p. 105–111.
11. Kawachi A., Tanaka K., Xagawa K. Multi-Bit Cryptosystems based on Lattice Problems. - In Proc. 10th international conference on Practice and theory in public-key cryptography, 2007, p. 315-329.
12. Gentry C. Fully homomorphic encryption using ideal lattices. Annual ACM Symposium on Theory of Computing. Proceedings of the 41st annual ACM symposium on Theory of computing. 2009, p. 169-178.

UDC 003.26:004.056.55 (045)

O.G. Korchenko, Prof Dr Eng (National Aviation University, Kyiv, Ukraine)
M.V. Zakharova, PhD, Associate Professor
(Cherkasy State Technological University, Cherkasy, Ukraine)

ADAPTIVE MECHANISMS USING IN INFORMATION RESOURCES SECURITY SYSTEMS

For organizations that operate in a competitive environment that is changing, it is necessary to use adaptive approach to solving the problem of protecting of the information resources. The using of the adaptive mechanisms can determine the impact of external and internal factors on the efficiency of the operation SSIR, identify flaws in its projection.

Today there are many information systems that are constantly changing, their resources improve, they are growing in scale and become more complicate in its structure. Accordingly, the number of vulnerabilities and the impact of threats increases. Therefore, it is necessary to use adaptive protection, which allows maintaining of a certain level of protection of resources in terms of changes of conditions of operation of the system, on the one hand, and flexibility of requirements of protection - on the other.

In modern publications about developing of effective methods of the projection of security systems it is often recommended to use relatively inexpensive ways and means of providing safety to minimize the total damage for violations of safety and reduce the cost of implementing of SSIR. This approach is effective only for small enterprises. It is necessary to use an adaptive approach to solving the problem of protecting information resources (IR) for large organizations that operate in a competitive environment that is changing.

Security tools must constantly improve and develop, so the problem of constructing of adaptive SSIR is relevant. In this regard, the aim of this work is to study the characteristics of the use of adaptive mechanisms to improve the functioning of the security systems of information resources (SSIR).

The adaptation process is an adaptation to the current conditions. The higher the level of adaptation, the more reliable system is, the higher the degree of its survival and effectiveness. Features and properties are formed during the adaptation that are most beneficial and through which the system can exist in a particular environment.

The peculiarity of adaptive SSIR is using of adaptive mechanisms that provide solutions of a number of interrelated tasks: gathering and analyzing information about the state of the system; assessment of the environment; taking a decision about the necessity of using of protective measures; choice of control parameters; synthesis schemes of adaptation and implementation of its mechanisms; determination of the effectiveness of the security system.

Using an adaptive approach to building a SSIR, it is necessary to follow the sequence of actions (Fig.1):

1. The acquisition and analysis of the information about the state of the system.

2. Analysis of requirements, identification of the problems for solving.

3. Forming of the matrices of adaptive expertise and on their basis establishment of initial systems of fuzzy rules and classifiers [1].

4. Classification of security threats (ST) and remedies. A set of threats to the system is formed, finding of the vulnerabilities of its resources. In expanding of the set known as ST it is necessary to classify them with the following adaptation of the information fields by studying fuzzy systems. Changing of the set ST will be accompanied by the correction or extension of the system of fuzzy rules. Means of security of IR with due regard for their orientation are also selected. Requirements for their effectiveness can vary significantly in relation to the decision of the specific problem of protection [2].

5. Preliminary statistical analysis, obtaining of the control indices, regularities.

6. Establishing of the systems of fuzzy rules. Matrices of adaptive peer reviews are formed, initial systems of fuzzy rules are based on their basis. Knowing the fuzzy meanings and membership function of the coefficient of the danger ST, it is possible to take into consideration of the probability of realization of ST.

7. Construction of the model SSIR.

8. Transfer of the experience of the adaptive SSIR regarding to security policy.

9. Adapting system. The adaptation process is associated with the solving the classification task, which leads to increased information field known as ST. The adaptation process is also associated with the training of fuzzy systems that adequately modifies system of fuzzy predicate rules, assigns to the conformity known as ST means of protection IR.

10. The correction of the matrices of initial estimates and systems of fuzzy rules according to the results of adaptation.

11. The formulation of the new fuzzy rules in the case of expansion of classification, development of specifications to create new means of security.

12. Formation of the complex of security evaluation. Security evaluation of the IR is the process of establishing correspondence between the security result and the desired goal. Expert assessment of the reliability of neutralizing known ST known means and potential losses is formed, arising from the experience of experts. Loss from sale of ST in SSIR should be measured in relative values. Calculation of the potential loss is held for a certain period of time, taking into account the frequency of activation of the ST [3]. Security evaluation of the IR is held on the basis of comparison of the indicator of regulatory protection and value-based comparison of information security without using and in conditions of using set of effective tools.

13. Systems effectiveness evaluation. To evaluate the adaptive mechanisms and of the evaluation and ranking are used.

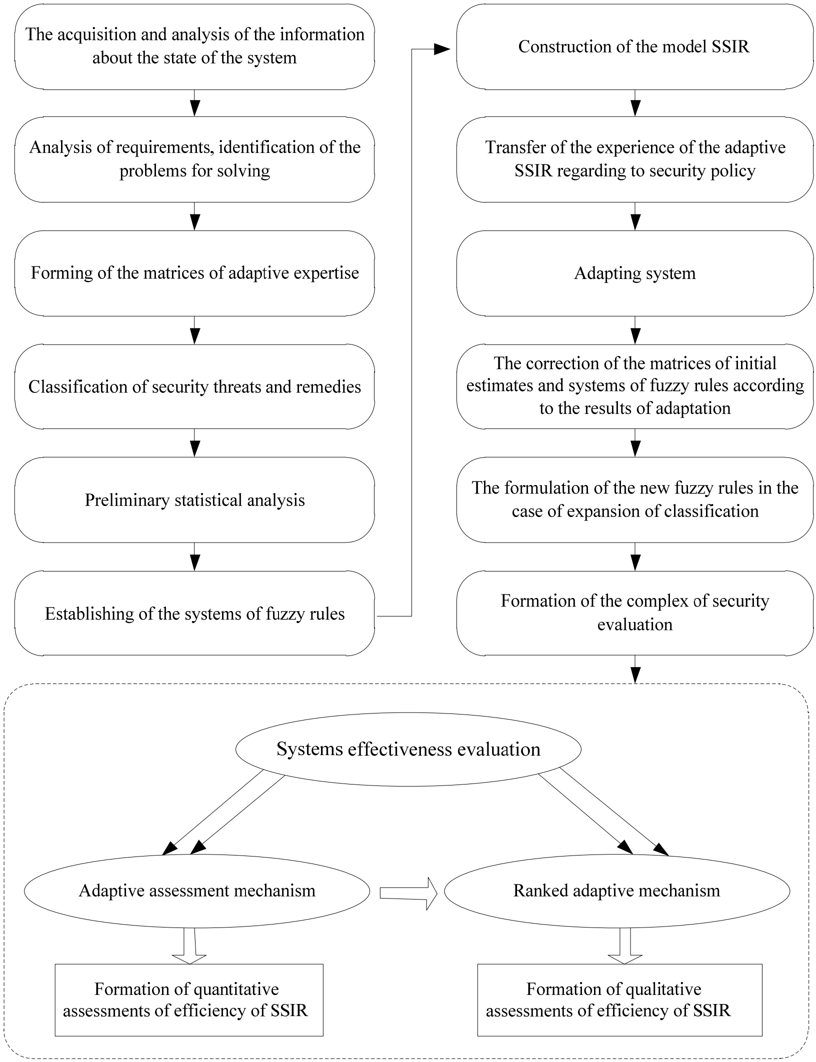


Fig. 1 Schematic reflection of sequences of actions in constructing adaptive SSIR

Adaptive assessment mechanism generates a quantitative assessment of the efficiency of the SSIR by determining the degree of accomplishment of the adaptive regulations that regulate its operation. On the basis of this regulation and the actual state with the help of the procedure of adaptive normalization adaptive norm of the estimate for the next period is formed. Further evaluation procedure by comparing the state with the norm quantitative evaluation of the SSIR is determined by quantification of the efficiency

Ranked adaptive mechanism generates a qualitative evaluation, comparing the resulting estimated in an adaptive assessment mechanism with adaptive norm. With the help of the normalization procedure the adaptive norm of the ranking is formed and ranking procedure let to determine the rank. The use of adaptive assessment mechanisms and ranking can consistently identify quantitative and qualitative evaluations. State is compared with the norm and evaluation is defined. Then, on the base of the evaluation the norm of ranking is corrected that is used to determine rank.

Adaptability of the mechanism is provided with the continuous evaluation norms and norms ranking. Adaptive assessment mechanisms and ranking are relating to the intellectual mechanisms of the functioning system with possibilities multi-tiered setup and decision-making in conditions of fuzzy or quality teams.

Conclusions

Thus, the use of adaptive mechanisms makes it possible to determine the impact of the adaptive mechanisms makes it possible to determine the impact of objective and subjective, external and internal factors on the efficiency of the operation SSIR, allows detect flaws in its design, diagnose the state of SSIR and development for the future.

References

1. Корченко А.Г. Построение систем защиты информации на нечетких множествах. / А.Г. Корченко – К.:«МК-Пресс», 2006. – 316 с.

2. Корченко А.Г. Методологія синтезу механізмів захисту інформаційних ресурсів / А.Г. Корченко, Є.В. Паціра, М.В. Захарова // Защита информации: Сборник научних трудов.- К.: НАУ, 2008. – С.99-102.

3. Захарова М.В. Метод побудови систем адаптивного захисту інформації/ М.В. Захарова // Вісник інженерної академії Уркраїни.- 2013. № 3-4. – С.57 – 61.

4. Нестерук Ф.., Адаптивные средства обеспечения безопасности информационных систем. / Ф.Г. Нестерук., А.В. Суханов, Л.Г. Нестерук, Г.Ф. Нестерук. Под ред. Л. Г. Осовецкого. СПб.: Изд-во Политехнического университета, 2008. – 626 с.

5. Суханов А.В. Представление знаний в адаптивных средствах мониторинга ИС / А.В Суханов., А.А. Павлютенков // Защита информации. Инсайд – №4. – 2008. – С.64 – 68.

UDC 004.056.5 (045)

V.O. Gnatyuk, Postgraduate Student (National Aviation University, Ukraine, Kyiv)

BASIC CRITERIA OF CERT'S WORKING EFFICIENCY

This paper shows the need to assess the effectiveness of the CERT. Introduced basic performance indicators CERT. Using indicators will enable: make quick management decisions, evaluate the qualification level of CERT, etc.. In addition, by influencing the actions of professionals CERT and their correction can improve information security of the individual and the state as a whole.

One of the important stages of information security is the management of information security incidents [1]. According to [2], there are many approaches to defining incident classification and separation from other related concepts (eg, event security incident, the incident safety cyber incident etc.). Today there are functioning teams that respond to computer emergencies (CERT). According to [3] there are 284 of them from 61 countries. As it was shown by the analysis, evaluation of the effectiveness of the CERT has been overlooked, and because of the performance of these commands depends IB as an organization, and the state as a whole. Given this assessment of CERT is extremely relevant scientific and technical challenge.

The purpose of this work is to introduce basic working efficiency of cyber incidents responding teams.

Given in [4,5], each reference to CERT - Z_j, where j is a serial number handling, should be described by the set of parameters:

$$Z_j \in \left\{ \begin{matrix} ІЗ^j, Т_{від}{}^j,\ Т_{зак}{}^j,\ К_{поч}{}^j,\ К_{кін}{}^j,\ П_{п}{}^j,\ Р_{кін}{}^j,\ С_{звер}{}^j,\ ТР_1{}^j,\ ТВ_1{}^j,\ ТР_2{}^j, \\ ТВ_2{}^j,\ ТР_3{}^j,\ ТВ_3{}^j,\ ТР_4{}^j,\ ТВ_4{}^j,\ К_{некор}{}^j,\ О_{клієн}{}^j,\ І_{проак}{}^j,\ В_{зах}{}^j,\ Т^j_{ріш} \end{matrix} \right\}.$$

Table 1 shows the parameters of appeals received by the CERT, their descriptions and possible values.

Parameters of appeals *Table 1*

Parameter	Description	Possible values
ІЗ	incident or request for services	1-incident 0-request
$Т_{від}$	opening	time, date
$Т_{зак}$	closing	time, date
$К_{поч}$	primary category	1,2,3…n - category
$К_{кін}$	final category	1,2,3…n - category
$П_{п}$	priority	1,2,3…n - category
$Р_{кін}$	final level of solution	1,2,3,4 - levels
$С_{звер}$	condition	0-opened, 1-closed
$ТР_n$	duration of consideration at the n-level	time, date
$ТВ_n$	duration of the solution at the n- level	time, date
$К_{некор}$	incorrect assignment	units

$O_{клієн}$	customer rating	0,1,2,3,4,5
$I_{проак}$	solution proactively	1-yes, 0-no
$B_{зах}$	response measures price allotted time for	USD
$T_{ріш}$	allotted time for decision in accordance with the	time, date

The proposed criteria to evaluate the CERT's effectiveness for the required period:

1) Total number of referencings:

$$К_{зверн} = TS + TN,$$

where TS -is the total number of requests for services:

$$TS = \sum_{j=1}^{К_{зверн}} 1, \forall Z_j, \text{ for which } I3^j = 0,$$

TN is the total number of incidents:

$$TN = \sum_{j=1}^{К_{зверн}} 1, \forall Z_j, \text{ for which } I3^j = 1.$$

2) The total number of closed incidents:

$$TN_{end} = \sum_{i=1}^{К_{зверн}} 1, \forall Z_j, \text{ for which } C^j_{звер} = 1, I3^j = 1.$$

Here is an example. Let's have 5 incidents, 3 of which are closed, so $TN_{end} = 3$.

3) Incidents are resolved at n level of support:

$$Q_{fln} = \sum_{j=1}^{К_{зверн}} 1, \forall Z_j, \text{ for which } C^j_{звер} = 1, P^j_{кін} = \text{n level}, I3^j = 1\}.$$

Let's suppose that there are 3 closed incidents. The level of resolution of the 1st incident is "3", the 2nd incident- "2", the 3rd incident is "2". Hence, $Q_{fl2} = 2$ units.

4) The average processing time of the incident at the –n level is:

$$T_{срел} = \frac{\sum_{j=1}^{TN} TP^j_n, I3^j = 1}{TN_n},$$

Where TN_n is the total number of incidents at the n level.

Before CERT's worker starts solving the incident or its transmission to the next level of support it takes time to review the incident. Let's suppose that there are 3 incidents. Time for considering the 1st incident on the 2nd level support is 123 s., 2nd incident – 54 s., 3rd incident – 362 s. Thus, $T_{сре2} = \frac{123 + 54 + 362}{3} = 179{,}66$ s.

5) Number of incidents incorrectly assigned to CERT's employees:

$$Q_{pds} = \sum_{j=1}^{K_{зверн}} 1, \forall Z_j, \text{ for which } K^j_{некор} > 0, ІЗ^j = 1.$$

Let's have 3 incidents, 2 of which are incorrectly assigned CERT's staff, accordingly: $Q_{pds} = 2$ units.

6) Number of closed incidents incorrectly assigned to CERT employees:

$$Q_{pdsend} = \sum_{j=1}^{K_{зверн}} 1, \forall Z_j, \text{ for which } K^j_{некор} > 0, C^j_{звер} = 1, ІЗ^j = 1.$$

It is calculated as in the previous indicator, the only condition that the incident should be closed.

7) Incidents resolved within a specified time according to priority:

$$Q_{ap} = \sum_{j=1}^{K_{зверн}} 1, \forall Z_j, \text{ for which } C^j_{звер} = 1, (T^j_{зак} - T^j_{від}) \le T^j_{ріш}, ІЗ^j = 1.$$

Let's suppose that there are 3 closed incidents with the priority "2". Each incident, according to priority, has allotted time decision. Opening time of the 1st incident is 11:12:30 date 17/05/14, the closing - 12:40:36 date 17/05/14; the opening of the 2nd incident - 12:12:52 date 17/05/14, the closing - 14:10:14 date 17/05/14; the opening of the 3rd incident - 20:50:34 date 17/05/14, closing time - 1:40:43 date 18/05/14. The time allotted for the decision in accordance with the incident priority "2" is 2 hours. = 7200 s. For convenience, we convert in seconds and calculate the time spent on resolving incidents. 1st incident - 5286 s., 2nd incident - 7042 s., 3rd incident - 17408 s. Hence, $Q_{ap} = 2$ units.

8) The average time to resolve an incident at the n level of support is:

$$T_{cpsn} = \frac{\sum_{j=1}^{TN} TB^j_n, ІЗ^j = 1}{TN_n}.$$

Let's suppose, 3 incidents are resolved at the 1st level. The duration of the first solution is 4625 s., second – 8569 s., third – 4563 s. Hence $T_{cps1} = \frac{4625+7569+5563}{3} = 5919$ s.

9) Average time addressing the incident:

$$T_{срв} = \frac{\sum_{j=1}^{K_{зверн}} (T^j_{зак} - T^j_{від}), \forall Z_j, \text{ for which } C^j_{звер} = 1, ІЗ^j = 1}{TN_{end}}.$$

Let's suppose there are 3 closed incidents, duration of the first solution is 3625 s., second - 8569 s., third - 4563 s. Hence $T_{срв} = \frac{3625+8569+4563}{3} = 5585{,}66$ s.

10) Misclassified incidents:

$$Q_{is} = \sum_{j=1}^{K_{зверн}} 1, \forall Z_j, \text{ for which } C^j_{звер} = 1, K^j_{поч} \ne K^j_{кін}, ІЗ^j = 1.$$

When registering, a category is assigned to every referencing, which facilitates its handling and subsequent analysis. When an appeal is closed, the corresponding entry indicates its true category. The indicator reflects the number of times the two categories do not match. Let's assume that there are 5 closed incidents initial category of incident does not meet the final in 3 of them. According $Q_{is} = 3$ units.

11) An appeal received by CERT professionals «directly», bypass Level 1:

$$Q_{pfl} = \sum_{j=1}^{К_{зверн}} 1, \forall Z_j, \text{ for which } (TP_1^j + TB_1^j) = 0.$$

For each appeal is given time for its consideration and decision. This indicator captures all requests that are not spent time on the 1st level. Let's suppose we have 100 requests. Time spent for consideration and decision at the 1st level is absent in 5 appeals. According $Q_{pfl} = 5$ units.

12) Average customer satisfaction rating:

$$CS = \frac{\sum_{j=1}^{К_{зверн}} O^j_{клієн}}{К_{зверн}}.$$

Let's suppose CERT processed 5 applications, customers put on a 5-point scale (0 to 5) appropriate assessment: first appeal "5", the second appeal "4", 3rd appeal "5", 4 th reference "2", 5th appeal "0". Calculate $CS = \dfrac{5+4+5+2+0}{5} = 3,2.$

13) Total number of incidents resolved correctly from the first time:

$$Q_{rsf} = TN_{end} - Q_{pdsend}.$$

Let's suppose we have the total number of closed incidents, which is 100 units. And have a total number of incidents incorrectly assigned to support staff – 90 units, then $Q_{rsf} = 100 - 90 = 10$ units.

14) Total number of incidents resolved proactively:

$$Q_{rp} = \sum_{j=1}^{К_{зверн}} 1, \forall Z_j, \text{ for which } C^j_{звер} = 1, I^j_{проак}, I3^j = 1.$$

This figure is calculated by summing closed incidents which have been resolved proactively. Let's suppose there are 100 closed incidents, among them resolved proactively - 5 units. So $Q_{rp} = 5$ units.

15) The average time to resolve incidents by priority:

$$T_{cpNi} = \frac{\sum_{j=1}^{К_{зверн}} (T^j_{зак} - T^j_{від}), \forall Z_j, \text{ for which } C^j_{звер} = 1, П^i_n = i}{TN_{endi}},$$

where TN_{endi} - is the total number of closed incidents for the *i*-th priority.

Let's suppose that for priority "1" have 3 closed incidents. Time for opening the 1st incident - 11:12:30 date 05/17/14, the closing - 12:40:36 date 17/05/14; the opening of the 2nd incident - 12:12:52 date 17/05/14, the closing - 14:10:14 date 17/05/14; the opening of the 3rd incident - 20:50:34 date 17/05/14, closing time - 1:40:43 date 05/18/14. For convenience, we convert in seconds and calculate the time spent on resolving incidents. 1st incident – 5286 s., 2nd incident – 7042 s., 3rd incident – 17408 s. Now calculate $T_{срN1} = \frac{5286 + 7042 + 17408}{3} = 9912$ s. = 2 h 45 min 12 s.

16) The average cost of response to the incident:

$$ACR = \frac{\sum_{j=1}^{K_{зверн}} B^j_{зах},\ \forall Z_j, \text{ for which } IЗ^j = 1,\ C^j_{звер} = 1}{TN_{end}}.$$

For example, let’s take 3 closed incidents cost response for which to the 1st incident is \$ 100, 2nd - \$ 150, 3rd – 250 USD. Hence, $ACR = \frac{100 + 150 + 250}{3} =$ $= 166{,}66$ USD.

Conclusions

Thus was introduced the basic performance indicators of responding teams to cyber incidents. Report them should be performed regularly, such as once a week to get a picture of the changes, which could be defined trends. Using indicators will enable: make quick management decisions, evaluate the qualification level of CERT, improve the efficiency of CERT, reduce losses associated with incidents, improve productivity of users to effectively use the staff to increase the accuracy of the information in the configuration database, increase satisfaction of users and customers, and so on. In addition, by influencing the actions of professionals CERT and their correction can improve IB organizations and individual states as a whole.

References

1. ISO / IEC 27035:2011, Information technology – Security techniques-Information security incident management.—2011.—p. 78.

2. Гнатюк В.О. Аналіз дефініцій поняття «інцидент» та його інтерпретація у кіберпросторі // В.О.Гнатюк / Безпека інформації. – №3 (19). – 2013. – С. 175-180.

3. Computer Emergency Response Team of Ukraine [Електронний ресурс]. - Режим доступу: http://cert.gov.ua/?page_id=207.(04.06.14)

4. Бон Я.В. ИТ Сервис-менеджмент, введение / под ред. Яна Ван Бона; пер. с англ. осуществлен компанией «IT Expert», 2003. – 240 с.

5. Метрики для управления ИТ-услугами / Питер Брукс; пер. с англ. – М.: Альпина Бизнес Букс, 2008. – 283 с.

UDC 004.056 (045)

Yu.B. Kovalenko, PhD (Nation Aviation University, Ukraine, Kyiv)
E.O. Sokolov, Student (Nation Aviation University, Ukraine, Kyiv)

SYSTEM AND MODELS FOR COMPUTER NETWORKS AND SYSTEMS PENETRATION TESTING

Consideration of the use of penetration testing as a method to improve security level of computer networks and systems. The description of test conduction stages. The description of BlackBox and WhiteBox models along with their visualization.

As a result of active development of information technology in recent years the level of cyber-attacks has increased significantly. Currently there exist many methods to protect information from unauthorized access. On our mind the most effective method to protect information is «penetration testing».

Penetration testing (pentest – tests to overcome the security) serves as a detailed analysis of network and systems in terms of potential attacker. The main point of this test is the sanctioned attempt to circumvent the existing complex of system's information protection means. Penetration testing allows to obtain objective rating of how easy it is to gain access to corporate network or website resources, in which way and using what vulnerabilities.

Modern developments in the field of information security consider resistance to distributed attacks as the main objective of any information protection system complex. Attack on the computer system is considered to be an action or a sequence of interrelated actions of the attacker, which lead to the implementation of threat using the vulnerabilities of particular computer system. Obviously, it is necessary to have formal description of attacker's potential actions and ways of their implementation, in order to increase the effectiveness of information protection system complex.

For successful attack implementation attacker has to obtain an intelligence on target object in order to find vulnerabilities, which can be used in future.

The aim of the research is to identify the weak points of information protection system. According to the aim of the research there has been considered the objective: to design a model of information threats' forming process in automated systems.

Penetration testing is necessary for identifying potential penetration scenario into the network with different purposes (to gain administrative rights in domain or database, to create the traces of the attacker in critical systems).

Penetration testing allows to obtain objective rating of how easy it is to commit unauthorized access to corporate network or website resources of your company, in which way and using what vulnerabilities or gaps in the system.

Conducting penetration testing allows to examine the level of protection and maturity of information security control system.

External penetration test is performed from public networks and simulates attacker's behavior, Internet attacker's (using social engineering or not). External penetration tests differ by the initially given information to the specialist performing the test.

Typical penetration scenario looks as follows – penetration possibility into the system is being explored using information attack on one or several workstations or also servers. If the attack was successful, with a help of captured workstations or servers a hidden communication channel will be installed that will allow to control seized computers remotely, and these sites are used for further penetration into previously identified targets inside the perimeter of the informational system that is being attacked. The hidden channel is provided with a special reversing Trojan program that implements bypass of personal data and corporate firewalls, antiviruses, content-filters, attack detection systems and any other technical protection means of perimeter's communication channels with external environment.

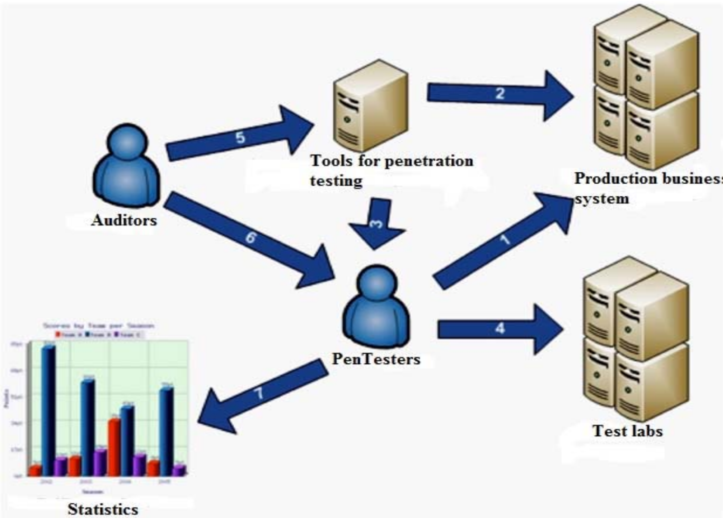


Fig.1. Penetration testing system

Website Security Audit for website vulnerabilities – is a powerful tool for providing resource's information security. Web-application is considered to be a very important asset, regardless of what functions it performs on the enterprise. The resource has to work stably and smoothly. These conditions can only be ensured by providing proper care for resource security, in particular website security audit.

Website penetration testing system - is a complex of means for website errors and vulnerabilities detection, using which attackers can attack or break into the website. There are many interpretations of the term "penetration testing", but most of them are based on one of the two variants: it's either simulation of real attacker's actions to implement unauthorized access to an information system, that corresponds to the definition of the term "penetration testing" on the west market of security services, or instrumental vulnerability analysis and found vulnerabilities critical assessment for business that in the determined space of English users is better known as “security assessment”

The main aim of this thesis is the creation of penetration testing system, which allows to identify the current level of website protection.

Penetration testing scenario includes the following steps: 1) Test planning; 2) Information gathering; 3) Searching for vulnerabilities; 4) System penetration; 5) Report submission; 6) System cleanout from test traces.

There are such approaches for test conduction: 1) White box – the conductor has a full access to systems and information about them; 2) Black box – simulates a group of hackers that have only the name of the company and in fact nothing else about the targeted system; 3) Grey Box – provides simulation of hackers that possess partial information.

There exist many methodologies to conduct penetration testing, among which the most useful are Information Systems Security Assessment Framework (ISSAF), NIST 800-42 Guideline on Network Security Testing, Open Source Security Testing Methodology Manual (OSSTMM), Open Web Application Security Project (OWASP), Wireless Penetration Testing Framework. The best methodology for website testing is OWASP as it has been created to provide web-applications security.

As a result, we create a report that contains a detailed description of the work, all identified vulnerabilities and ways of their implementation. Also report contains recommendations to eliminate found vulnerabilities.

Penetration test allows to separate critical security problems, which require immediate attention, unlike those that are less of a threat.

Black-Box pentest is also known as external testing. Using this approach, security auditor will assess organisation’s network infrastructure form a remote location place and will not know all internal technologies, which are used here. In fact, while using this approach, auditor (Black Hat) likens to the attackers malicious behavior and applies all familiar to him hacking techniques and tools. At this, it is important to understand and classify all found vulnerabilities according to the risk level (low, medium or high). In general, risk can be measured according to the threat through the identified vulnerability and according to losses that occurred after the successful penetration. After pentest completion the report with all the necessary information regarding security level of organisation’s network infrastructure, classification of all identified risks in a business-context is being created.

Fig.2. BlackBox penetration testing system model

White-Box pentest also known as internal testing. At this, auditor (White Hat) has to know the structure of the network infrastructure and all available services of the organisation. White-Box pentest is similar to Black-Box pentest, but it does not require steps like, identification of testing limits, information gathering about targeted system and identification of services, which are working on a target hosts. White-Box pentest allows to identify and eliminate all vulnerabilities in the system that, of course, will increase system security level. Besides, this approach can be easily integrated into a regular cycle of product development, produced by the organisation that will eradicate any possible security problems on the early stage, before they will be detected and used by malefactor.

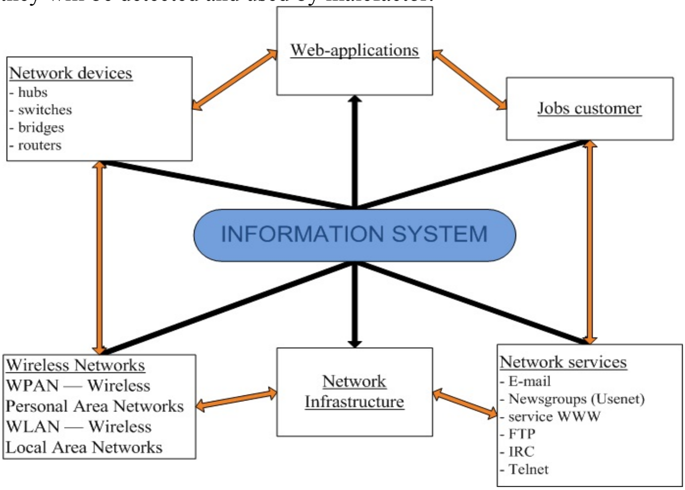


Fig.3. WhiteBox penetration testing system model

To summarize the presented material, need for compliance with the regulatory factors has to be noted – standards, laws, infrastructure solutions, a library of best practices of ITIL, which will help to improve the security of computer networks and systems. It is advisable to take a proactive defense that includes penetration testing. This kind of approach is the only way to get a realistic picture of the security system's state, and thus to gain a control of the IT environment that is constantly growing. As a result of the penetration test, we can get a real view of company's information security level. And we can also make a recommendations for improving security level of the information system.

References

1. Assuring Security by Penetration Testing. Master the art of penetration testing with BackTrack // Packt Publishing Ltd.- Birmingham, 2011. – 373 p.

2. ISO/IEC 27001:2005, Information technology — Security techniques — Information security management systems — Requirements.

UDC 003.26:621.39+530.145 (045)

S.O. Gnatyuk, PhD Assoc Prof (National Aviation University, Kyiv, Ukraine)
T.O. Zhmurko, Postgraduate Student (National Aviation University, Kyiv, Ukraine)

QUANTUM GAME THEORY IN CLASSIFICATION OF QUANTUM INFORMATION SECURITY METHODS

Today critical decisions majority, taken at different levels, depends on basic security features of valuable information, which nowadays stored and processed by information systems. Most of these systems rely on modern classic cryptosystems, which introduce potential security holes. For that reason, new ways of protecting important information need to be found. One of them can be quantum cryptography.

Information security is one of the most important problems of the modern information society. The growing connectivity between information systems (IS), the Internet, and other infrastructures creates opportunities for violators to disrupt telecommunications, electrical power, and other critical services. Government, private sector, and personal activities continue to move to networked operations, digital systems add ever more capabilities and wireless systems become more ubiquitous. In Ukraine IS are used particularly in banking sector, in public administration, on strategically important economic units, in national security, military and most elements of critical national infrastructure protection. However, with the increasing of information importance, the cyberthreats amount is growing proportionally. Based on the CERT-UA report [2] during 2011-2013 their team handled more than 600 computer incidents aimed to cause harm information basic security features. Mainly threats were such as spread of malicious software and phishing links, DDoS attacks, combat activities botnets etc. They were mostly focused on government information resources of state and national educational institutions and the banking sector. During last year CERT-UA team handled 214 incidents, among them: 55 – focused on the Ukrainian government sector, 50 – Bot networks, 48 – Phishing, 20 – Vulnerabilities exploitation, 13 – DDoS, 15 – Malware, 12 – Unauthorized access, but unfortunately it's only officially declared incidents and mainly relating to government information resources. Among all other spheres of human activity, susceptible to cyberattacks, banking system of Ukraine is most progressive. Banks created their own cyberincidents respond departments, use the experience of more progressive countries, and rely on international security standards.

Thus, there is a critical need to develop and implement modern and effective information security systems, which can reliably guarantee data safety, given that critical decisions majority, taken at different levels (from president to ordinary citizen), depends on basic security features (integrity, availability, confidentiality) of relevant and valuable information. However, particularly vulnerable spot for violation of information security is a data network, since it is impossible to guarantee the safety of data when passing them through a public medium (Internet, telephone lines, radio). Therefore, the information transmitted on different networks, particularly in need of protection. In this case, the main way of protection is using the cryptographic methods. Recent research has shown that classical cryptography gives a cause to look for new outlooks [4-8].

For instance, all public-key cryptoalgorithms rely on complex mathematical problem (one-way function with secret). Standards based on these algorithms are using in government institutions and commercial organizations IS. Their security (unbreakability) is hypothetical and can be disproved in the nearest future.

However, the discovery by Peter Shor (1994) a polynomial algorithm allowing fast factorization of integers with a quantum computer destroys previous confidence in reliability of classical cryptography. Therefore, contemporary society needs to find a new option to secure information, which became essential and very expensive resource. One possibility is using quantum cryptography (QC) instead of classical [1, 4, 8].

QC lies at the intersection of information theory, classical cryptography and quantum mechanics. In addition to this, information security QC methods is guaranteed by the laws of quantum physics [9] (non-cloning theorem – impossibility duplicate an unknown quantum state, impossibility of taking a measurement without perturbing the system, impossibility simultaneously measure the polarization of a photon in the vertical-horizontal basis and simultaneously in the diagonal basis, etc.). QC currently includes such areas as (see Fig.): quantum key distribution (QKD), quantum digital signature, quantum secret sharing, quantum stream cipher, quantum secure direct communication (QSDC) [7] and quantum game theory.

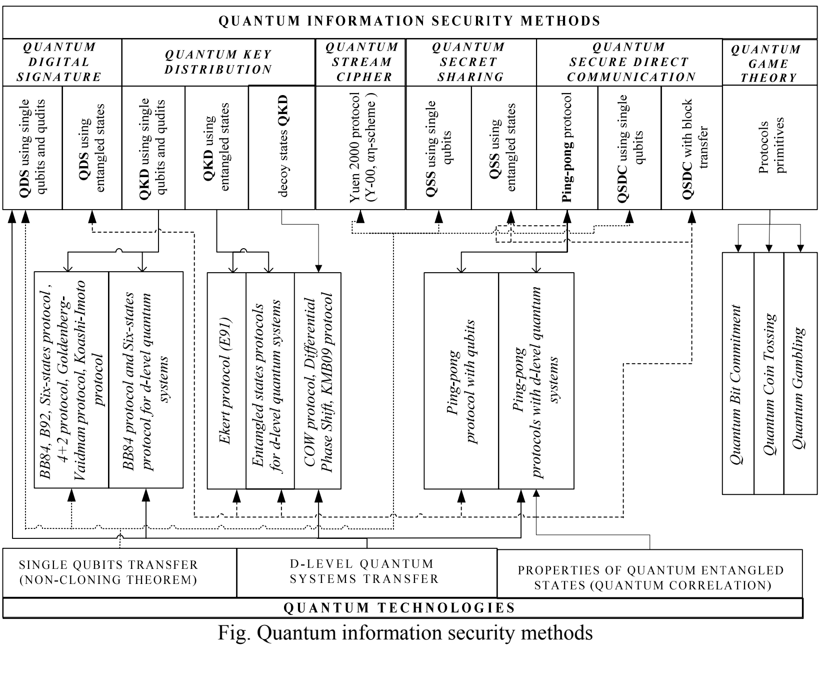


Fig. Quantum information security methods

In last decade quantum cryptography has attracted considerable interest among specialists in information security. The overwhelming majority of research projects in quantum cryptography are related to the development of QKD and QSDC protocols. Generalized classification & systematization was done in [5-7], but since then, a lot new issues were made (for instance decoy states protocols and quantum games not included in it), so its need to be expanded, to help estimate the level of the latest achievements and allow using quantum technologies with full efficiency. From this viewpoint the analysis of existed new quantum technologies was carried out in the paper.

The combination of game theory and quantum information led to the new field of *quantum games*. The classical theory of games, which is a well established discipline of applied mathematics, and quantum communication are both concerned with information and how information is processed and utilized. Game theory analyzes situations of interactive decision making and provides models of conflict and cooperation.

Bit commitment protocol involves two users called A and B. At the commitment stage the user A chooses the value of a secret bit (0 or 1) and sends some information about his choice to user B in such a way that using the information provide by user A the user B cannot reliably determine the secret bit value chosen by A. To be more precise, in the ideal case the probability for user B to correctly identify the bit value chosen by user A is exactly 1/2 (i.e. it is equal to the probability of simply guessing the bit value) regardless of whether or not he uses the information supplied by user A. Then at the disclosure stage the user B can ask user A to provide him the rest information on the value of the chosen secret bit so that in the ideal case the user B reliably recovers the secret bit value. In addition, there should be no possibility for user A to change his mind and alter the chosen bit value after the commitment stage and before the disclosure state without being caught by user B. These quantum protocols have caused much controversy in the scientific community, opinions divided, and for many years it was considered inappropriate to use them. But in 2013 scientists [3] (University of Geneva, National University of Singapore, University of Cambridge) sent encrypted data between pairs of sites in Geneva and Singapore, kept "perfectly secure" for fifteen milliseconds - putting into practice what cryptographers call a 'bit commitment' protocol, using the combined power of quantum theory and relativity.

The distant *coin tossing* protocol includes two distant users A and B, who do not trust each other and can employ any physically realizable opportunities to cheat, should exchange appropriate information so that at the end of the protocol (in the ideal case with the unit probability) they accept the arising bit as an honest lot. If the users have only access to the classical communication channel, the problem can even seem unsolvable.

Quantum coin tossing uses quantum coins which, unlike conventional, may be in an infinite number of states. Also, there may be some mixed states, which explain by the superposition phenomenon in quantum mechanics. Using a mixed position guarantees one of the parties a constant win. If user A uses a mixed state, in any case, regardless of the actions of user B with his coin, and provided a preliminary agreement on a finite number of moves, user A will win, because at the end of the game will be able to convert her coin with mixed states into pure (absolute state).

Classical versions of these protocols are based on unproved computational complexity of some trapdoor functions which require exponentially large resources to calculate their inverse on the classical computer.

Conclusions

Scientists of the leading countries of the world carry out active research in the field of quantum cryptography, nevertheless, there are still many problems requiring attention. Furthermore, a lot of things need to be done to implement quantum technology in widespread use. Quantum technologies therefore represent an important step towards improving the security of IS against cyberterrorists attacks.

References

1. Cerf N., Bourennane M., Karlsson A., Gisin N.. Security of quantum key distribution using d-level systems, Physical Review Letters, Vol. 88, № 12, 127902, 2002.

2. Computer Emergency Response Team of Ukraine [Online]. Available: http://cert.gov.ua/

3. Experimental Bit Commitment Based on Quantum Communication and Special Relativity, Phys. Rev. Lett. 111, 180504 – Published 1 November 2013.

4. Gisin N. Quantum cryptography / N. Gisin, G. Ribordy, W. Tittel, H. Zbinden // Review of Modern Physics. – 2002. – Vol.74, Iss.1. – PP. 145-195.

5. Korchenko O. Quantum Secure Telecommunication Systems / O. Korchenko, P. Vorobiyenko, M. Lutskiy, Ye. Vasiliu, S. Gnatyuk // Telecommunications Networks – Current Status and Future Trends (Edited by J.H. Ortiz). – InTech, 2010. – PP. 211-236.

6. Korchenko O., Vasiliu E., Gnatyuk S. Modern directions of quantum cryptography, in Proceedings of IV World Congress «AVIATION IN THE XXI-st CENTURY» – «Safety in Aviation and Space Technologies», September 21–23, 2010, Kyiv, Ukraine. NAU Publ., 2010. pp. 17.1-17.4.

7. Korchenko O., Vasiliu E., Gnatyuk S. Modern quantum technologies of information security. [Online]. Available: arXiv: 1005.5553v2

8. Nielsen M., Chuang I., Quantum Computation and Quantum Information, Cambridge University Press, 2000.

UDC 004.056.53:004.492.3 (045)

A.I. Hizun (National Aviation University, Kyiv, Ukraine)
S.I. Topcheev (National Aviation University, Kyiv, Ukraine)
M.O. Ryabyy, PhD (European University, Kyiv, Ukraine)

BASE PARAMETERS OF FORECASTING AND IDENTIFICATION OF COMPUTER ATTACKS IN INFORMATION AND COMMUNICATION SYSTEMS

The questions connected with forecasting, monitoring and identification of crisis situations in information and communication systems, have big scientific and practical value. So, accurate definition of a set of the parameters removed as on network, and local level, will allow increasing efficiency of systems of protection and preventive means.

The management concept of business continuity (MBC) provides a number of stages, the most important among which is the analysis of influence on business, forecasting and identification of crisis situations (CS), response to CS, elimination of their consequences and restoration of the business processes interrupted with CS, and also documentary providing MBC systems. Any crisis situation is a consequence of set of incidents or attacks. Proceeding from this definition and formalization of key parameters which can be used for identification and identification of computer attacks, certainly, are an actual task.

For the effective prevention of CS in the sphere of IS it is necessary to develop a set of key parameters for forecasting and identification of attacks to ICS which under certain conditions can be the reasons of emergence of crisis. Thus, definition (formalization) of key parameters is the purpose of this work, value and which nature of change can define possibility of realization of this or that attack.

Definition of concrete CS and their characteristics in a bigger measure is subjective. Among the main reasons for emergence of CS the central place is occupied by incidents of IS and attack to ICS. Generally, in a context of this work, being based on the offered classification [11], practice of MBC EMS, statistics of CS and incidents of information security, it is expedient to allocate such types of attacks in ICS: DDos-attack, spam, scanning of ports, a computer virus (among which it is possible to allocate such subspecies as the net worm and the Trojan program) the programs blockaders (banners) which have been closely connected with concept of a phishing. Certain parameters (characteristics) are peculiar to each of these types of attacks, supervising which, it is possible to predict and identify them.

To predict possibility of realization of attack or to reveal it and to identify it is necessary to develop system which will make monitoring of network characteristics (traffic parameters) and local characteristics (parameters of computer system or a host), given in tab. 1. Considering that realization of CS can have as the predetermined and casual character, and ICS is in essence the weak formalized environment, the system should be based on special methods of the theory of indistinct sets [16] and consequently some of used parameters can be indistinct by the nature.

Table 1

Parameters for reviling and identification of attacks

Parameter	**DDos-attack**	**Spam**	**Scanning of ports**	**The computer viruses**		**Banner**	**Illegibility**
				Net worm (viruses)	**Trojan Horse**		
CPU	L	A	A	AA	AA	A	+
CNCh	VH	L	L	A/AA	AA	L/AA	+
UPr	Ab	Ab	Ab	P	P	P	-
STF	A	A	A	H	AA	A	+
OUP	P	P	Ab	P	P	P	-
MU	L	H/A	A/L	L	H/A	H/A	+
NEr	AA	AA	A	AA	AA	AA	+
ChSSF	Ab	Ab	Ab	P	Ab/P	P	-
NCC	H	A/AA	A/AA	A	A	A	+
DbR	L	A	L	A	A	A	+

VH – very high; H – high; AA – above an average; A – average; L – low; Ab - is absent; P –Is present.

Let's consider and will analyse the parameters supervised by system for forecasting, identification and identification of attacks in ICS:

1) Loading of the CENTRAL PROCESSING UNIT, CPU – a percentage indicator of the processor time allocated for performance of tasks. It is possible to determine by level of load how strongly the computer it is subject to harmful influences. The parameter is indistinct as its optimum (normal) value variously for different systems and, besides, does not give a definite answer about existence of the fact of attack.

2) Load of the network channel, CNCh. Monitoring of a traffic allows to fix data which are transferred on an Internet channel. Considerable increase of a traffic testifies to possible DDos-attack or other attack. And as it is almost impossible to define size of normal load of the network channel, the parameter is the indistinct.

3) Unusual processes, UPr. Watching number of processes, it is possible to define what process is new and can be harmful. The parameter is exact as the number of processes is limited, at the beginning of work the system of monitoring does a so-called picture of system and new processes always it is possible to see and list.

4) Size of temporary files, STF. The virus copy, or a reserve body of a virus can be stored in temporary files for automatic start. The parameter is indistinct because of that that too many different temporary files are created and removed in operating time of the computer and their size at normal functioning can be various.

5) Opening of not used ports, OUP. The parameter is accurate, in the beginning works of system of monitoring the system picture (open ports) becomes, and emergence in the course of work of new open ports can serve as a signal about attack to ICS.

6) Load of random access memory, MU. The parameter is indistinct as load of random access memory changes every second, its optimum (normal) value variously for different systems and besides does not give a definite answer about existence of attacks in ICS.

7) Number of failures and mistakes, NEr. This group includes a wide range of events from mistakes at authorization to failures at performance of certain processes or files. So big intensity of emergence of mistakes and failures testifies with some probability to possibility of realization of attacks. This parameter belongs to indistinct as mistakes very often are an element of normal work of system in ICS because of technical characteristics hardware and the software.

8) Changes of structure and size of files, ChSSF. This parameter is most important for identification of computer viruses as those very often change file structure, entering the body in the beginning, the end or the file middle, and structure of file system. It is accurate provided that processes of work of legal users are constantly supervised and are regulated by security policy rules in ICS.

9) Number of simultaneous connections, NCC. As practice for effective carrying out DDoS shows attraction of a large number of the sources participating in attack on the victim is necessary. Therefore, **the NCC parameter** at increase in number of connections to the server can be used as one of signs of the beginning of attack. The parameter is indistinct as at small values it is characteristic and for a condition of normal functioning and exact value which can testify to attack, it is almost impossible to define.

10) A delay between inquiries from one source, DbR. The parameter characterizes time between consecutive inquiries from one client connected to the server. Delay reduction between inquiries can testify to the DDoS-attack beginning. This parameter also is the indistinct.

The parameters considered in work create by analogy with [12, 17] a train of identification and identification of attacks:

DIA = <CPU, CNCh, UPr, STF, OUP, MU, NEr, ChSSF, NCC, DbR>.

Value of elements of this train give the chance to reveal attack in ICS and to identify it rather allocated types: DDos-attack, spam, scanning of ports, net worm (virus), Trojan program, programs blockaders (banners).

Conclusions

Thus, in this research value of parameters of a train of identification and identification of attacks of DIA which should be supervised by system for forecasting of attacks for ICS, their fixing and response to them is defined. Formalization of these parameters allows to consider features of attacks in ICS and to increase efficiency of preventive means and systems of protection of information resources. It also can be used for CS identification at an early stage of their development. In the following works the offered parameters and their train will be used as basis for creation of effective system of forecasting and identification of attacks and CS. Also we will note that number of revealed attacks in ICS and the list of parameters can be changed at system realization depending on requirements to its functionality.

References

1. Петренко С.А., Беляев А.В. Управление непрерывностью бизнеса. Ваш бизнес будет продолжаться / С.А. Петренко, А.В. Беляев. – М.: ДМК Пресс, Компания АйТи, 2011. – 400 с.

2. Van Bon Jan. ИТ СЕРВИС–МЕНЕДЖМЕНТ. Вводный курс на основе ITIL / Jan Van Bon. – Van Haren Publishing, по заказу ITSMF Netherlands, 2003. – 72 с.

3. Harris S. CISSP Certification All-in-One Exam Guide. – 5th edition. – Mc Graw-Hill Osborne Media, 2010. – 1216 p.

4. Гізун А.І. Сучасні підходи до захисту інформаційних ресурсів для забезпечення безперервності бізнесу / А.І. Гізун, В.О. Гнатюк, О.П. Дуксенко, А.О. Корченко // Матеріали X Міжнародної науково-технічної конференції «АВІА-2011». – К.: НАУ, 2011. – Т1 – с. 2.5-2.9.

5. Стасюк О.І. Базові характеристики та класифікація кризових ситуацій в ІТ-сфері / О.І. Стасюк, А.І. Гізун // Інфокомунікації – сучасність та майбутнє: Всеукр. наук.-практ. конф. 6-7 жовтня 2011 р. : тези доп. – Одеса: ОНАЗ, 2011. – С. 62-65.

6. Гізун А.І. Основні параметри для ідентифікації порушника інформаційної безпеки / А.І. Гізун, В.В. Волянська, В.О. Риндюк, С.О. Гнатюк // Захист інформації. – 2013. –№1 (58). – С.66-75.

7. Луцкий М.Г. Модели эталонов лингвистических переменных для систем выявления атак / М.Г. Луцький, А.В. Гавриленко, А.А. Корченко, А.А. Охрименко // Захист інформації. – 2012. –№2 (55). – С. 5-13

8. Корченко О. Г. Построение систем защиты информации на нечетких множествах [Текст] : Теория и практические решения / О. Г. Корченко. - К. : МК-Пресс, 2006. - 320 с.

9. Стасюк А.И. Базовая модель параметров для построения систем выявления атак / А.И. Стасюк, А.А. Корченко // Захист інформації. — 2012. — №2 (55) . — С. 47-51.

UDC 004.056.6 (045)

Z.O. Samosud, Postgraduate Student (National Aviation University, Ukraine, Kyiv)

BUGS SEARCHING DEVICE

This article adduces the analysis of the efficiency of existing methods of bugs searching. The main advantages and disadvantages between existing methods were marked out. Bugs detection device with the main principle of work to fix the distance to the object by the time of voice passing to this object was suggested.

Modern information technology and data transmission systems evolution requires ongoing monitoring of the security service market and opportune use of actual methods and tools of the information loss detection. Safe information security system composition requires the use of integrated approach considering all possible information loss variants.

There are a lot of technical channels of information loss can be organized to intercept the acoustic information that is a complex acoustic signal and measures in the frequency range from at least 20 Hz to 3,5 kHz [1]. To receive, develop and use acoustic signals special technical facilities of recording, transmission, amplification and reproduction of signals are used. Together these devices are powered by highly sensitive microphones that convert acoustic signal to electrical and called "bugs" [2]. This devices of acoustic signal interception are constantly being improved, becoming less and insensible, and methods of their detection more complicated.

Methods of bugs detection depends on several causes: their physical properties and classifications, characteristics of channels of information loss produced by them and principles of their installation. Principle of bugs work is based on the reception and transmission of informative signals from the source of their formation to the receivers that installed in remote or directly build in the bug's construction.

The main characteristics are: the output power signal, operating frequency range, modulation type, range of distribution of signals. The vast majority of devices can operate in the range closest to the speech signal (from 20 Hz to 20000 Hz), have some kind of sensitive to human speech with the lowest (under 60 mV/Pa) volume level microphone (from 20 dB) and hypersensitive conversion different types of surfaces to data signals devices [3, 4, 5].

Based on the main principles of bug's functioning, their physical characteristics and conditions of the installation the analysis of the main and most effective detections methods are conducted.

Bugs searching can be performed in several stages [6]. First of all investigated place is checked for the radio emission presence using radio monitoring that will determine the presence of bugs in it. The second step is to choose the most effective methods of interception devices localization. At this stage various methods of localization can be used.

Usually to lead searching large and expensive equipment are used (OSC-5000 ("Oscor"), CPM-700 ("Shark"), ST 031, ST 032 ("Piranha")) [7]. By simple counting the value of such equipment it is possible to analyze the demand of existing methods of searching improvement.

During bugs detection commonly test signal is used that can be tone. Difficulty arising from the use of tone signal in fact because the rooms were filled with furniture or other things there are “standing waves” that interfere with bugs localization. [9]. To get rid of “standing waves”pulse signal ranging method is used. This way is applied in one actual and effective bugs searching method – searching complex based on DigiScan EX program established for radiovawes searching and monitoring and also for information interception devices detection using scanning receivers AOR and ICOM. In modern terms, considering a large number of radio signals and noise, maximum efficiency of scanning receivers is achieved by using computer and DigiScan EX 1.6.

Bugs localization is scheduled on acoustic location principle, by measuring the sound delay that that comes out of the speakers to the computer receiver. Pulse is fed to the computer microphone and to the bug that is in the room with some difference in time.

If the rate and the distribution of the acoustic signal are known, the distance to the object can be determined. If the delay time multiplied by the speed of the acoustic wave the distance from acoustic system to the bug can be obtained. This applies to the usual formula for determining the length of delay distribution of the acoustic signal using the well-known value of speed of sound V_S = 340m/sec [8]:

$$\tau = \frac{\ell}{V_S} \qquad (1)$$

where ℓ – distance between speaker and bug.

Wherefrom the radius of acoustic waves distribution is determined as

$$\ell = \tau \cdot V_S \qquad (2)$$

Getting values of the delay of the acoustic signal from different points of the room (the coordinates of which are set in advance according to the room coordinates) it is possible to measure the radii of the circles that are formed as a result of acoustic signals sources at some point.

Knowing the distance between speakers program can determine the distance from the speakers to the bug. Measurements are taken in turns, for both left and the right speakers.

Measurements are made in semi-automatic mode using operator who observes pulse fronts on the waveform. Need to find and mark the impulse front on each oscillogram. It is very important that the distance from the speaker to the microphone was constant and consistent distance marked on the plan.

The main disadvantages of this method are:

- lack of precise and specific definition of the bug location, only the direction of possible locations;
- spend too much time on searching;
- large hardware structure and high cost of its main components.

The detection device with the main principle of work to fix the distance to the object by the time of voice passing to this object was suggested. As acoustic signal acts directly on microphone then bugs searching can be determined by the delay time of the acoustic signal or the time proportionally reflected in the distance.

The principle of the improved device operation (fig.1) that use examined method comprises [11]:

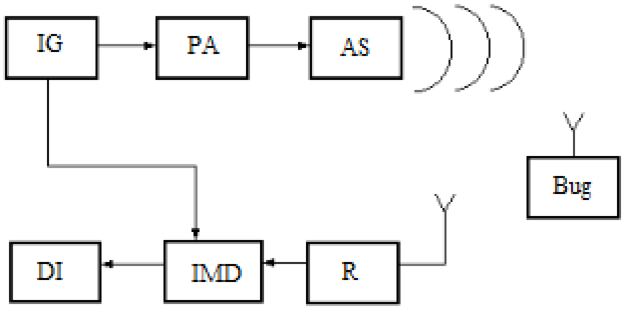


Fig.1. The flowchart of the bugs searching device

Impulse signal from the impulse generator (IG) using the power amplifier (PA) fed to acoustic system (AS) which distribute acoustic signal that reaches the bug and transmitted the receiver (R). Further the selected signal is fed to the acoustic impulse measuring device in voltage terms (IMD) that measures and displays acoustic signal voltage value on the delay indicator (DI) which depends on the delay time of the impulse.

Targeting bugs searching device in space and moving in the reducing the delay of the acoustic impulse the bug location can be determined. Reducing the volume (test signal level) searching will be more accurate.

There are many ways of bugs camouflage under different casual things and their construction which deeply complicates searching. But anyway bugs have a sensing element that responds to the effect of test acoustic signals.

Conclusions

The efficiency of existing methods of bugs searching analyzed. To form a clear direction and effective improvement of existing methods the main advantages and disadvantages were marked. The detection device with the main principle of work to fix the distance to the object by the time of voice passing to this object was suggested. As acoustic signal acts directly on microphone then bugs searching can be determined by the delay time of the acoustic signal or the time proportionally reflected in the distance.

Improving the components of the device by which the suggested method realized, helps resolve issues of mobility, reduces the cost and wasted time for searching. Suggested method of the bugs acoustic location may be more effective than searching methods by the electromagnetic radiation.

References

1. Торокин А.А. Основы инженерно-технической защиты информации. – М.: изд-во “Ось-89”, 1998. – 331 с.

2. Хорев А.А. Техническая защита информации: учеб. пособие для студентов вузов. В 3 т. Т. 1. Технические каналы утечки информации. – М.: НПЦ “Аналитика”, 2008. – 436 с.

3. Хорев А.А. Техническая защита информации: учеб. пособие для студентов вузов. В 3 т. Т. 1. Технические каналы утечки информации. – М.: НПЦ «Аналитика», 2008. – 436 с.

4. Энциклопедия промышленного шпионажа /Ю.Ф. Каторин, Е.В. Куренков, А.В. Лысов, А.Н. Остапенко/под общ. ред. Е. В. Куренкова. – С.-Петербург: ООО «Издательство Полигон», 2000. – 512 с., ил.

5. Каторин Ю.Ф., Разумовский А.В., Спивак А.И. Защита информации техническими средствами: Учебное пособие / под ред. Ю.Ф. Каторина – СПб: НИУ ИТМО, 2012. – 416 с.

6. НД ТЗІ 2.7-011-12 Захист інформації на об’єктах інформаційної діяльності. Методичні вказівки з розробки методики виявлення закладних пристроїв.

7. Конахович Г.Ф., Климчук В.П., Паук С.М., Потапов В.Г. Защита информации в телекоммуникационных системах. – К.: „МК-Пресс”, 2005. – 288 с., ил.

8. Фурдуев В.В. Электроакустика. – Ленинград: гос. изд-во техгико-теоретической литературы, 1948. – 516 с.

9. Журиленко Б.Є., Левандівська Л.І., Ніколаєва Н.К. Захист циркулюючої в приміщенні акустичної інформації тональним сигналом // Защита информации. – Киев: НАУ, 2007. – С. 36–39

10. Руководство пользователя. Программное обеспечение DigiScan EX для приемников AOR, ICOM версия 1.65. Редакция: Lite, Standard, Monitor, Professional, 2006 – 81 с.

11. Патент UA 86600 U Пристрій пошуку закладного пристрою за допомогою акустичної локації кл. G 01 S 7/52, 15/10 бюл. №1 опубл. 10.01.2014.

UDC 003.26:004.056.5 (045)

V.M. Kinzeryavyy, PhD, O.M Kinzeryavyy, Postgraduate Student
(National Aviation University, Ukraine, Kyiv)

METHOD OF TEMPLATE HIDING DATA IN VECTOR IMAGE STRUCTURE

To improve the efficiency of information hiding in the structure of vector images, the template method of data hiding is proposed in this work. Hiding data behind the template method performed by a gradual breakdown of Bezier curves segments, using preassigned table of correlations of different values of the template elements with different steps of Bezier curves. The proposed method is compared with the existing method of bitwise hiding data in vector images.

The development of digital technologies that is rapidly spreading in all spheres of human activity gives us a free opportunity to transfer and storage information on external media through the global network «Internet». But one of the important tasks of protecting information from unauthorized access arises upon the interaction with the network «Internet». You can protect your data by using steganographic methods of hiding information. Steganography is the science that studies the means and methods of hiding information in other inconspicuous objects – containers and based on the features of people's sense organs and structural properties of container construction [1]. The most perspective types of containers are media objects: text, sound, pictures and video. Method of bitwise hiding information in a vector image structure was proposed in the work [2], according to which, hiding of the secret message bits was going through the gradual separation of Bezier curves to visually identical totality of segments. The disadvantage of the method [2] is a significant increase in the size of the received steganocontainer (result-container) relative to the original container, owing to the growing number of control points required to represent a sequence of segments. The research that aimed at improving steganographic methods to hide information in vector images is an actual task.

The aim of this work is the improving efficiency of hiding information in vector image structure by the developing of method of template hiding data with the defined relation table of different values of the template elements with the different steps of Bezier curves that will make possible reducing the size of received streganocontainer. As you know, vector graphics, it is a type of computer graphics, where simple shapes, which defined by mathematical equations, is used for the construction of vector objects. Vector images are widely used in computer-aided design, web space and printing activity where you need to submit pictures of high quality. One of the key elements of vector graphics are Bezier curves, which are given by the following equation [3]:

$$B(t)=\sum_{i=0}^{n} b_{i,n}(t)P_i\ ,\ t=t+\Delta t\ ,\ t\in[0,1]\ ,$$

where, P_i – pivot points, $i\in\overline{0,n}$, i – pivot points index, n – procedure for determining Bernstein basis functions and polynomial curve segments, $n+1$ – pivot points number, t – parameter of curve structure, Δt – change of parameter t, $b_{i,n}(t)$ − Bernstein polynomials.

Bezier curves have the following properties [4]: 1) any Bezier curve can be divided and represented as a set of visually identical segments, where each segment of Bezier curve will be a curve of the same order as the original curve; 2) any Bezier curve is an invariant relative to affine transformations, which means that every Bezier curve can undergo the process of affine transformation, by which the position and distance between its points of reference are preserved and only their coordinates are changed.

On the basis of these properties in this work [2] a method of bitwise hiding information, resistant to affine transformations was proposed. Hiding by the method [2] was carried out by gradually splitting Bezier curves into segments with different values of the parameter $t = t + \Delta t$, $t \in (0,1)$ with predefined step (steganokey) Δt according to the following rules: If at some step t the bit «0» was hidden, then at this point Bezier curve is not divided into segments, and there was a transition to the next bit of the secret message and the next step t. If at some step t the bit «1» was hidden, then at this point Bezier curve was splitting into two segments by the de Casteljau algorithm [5]. Introduction of the next bit of the secret message received further in the second segment of the curve at the next step t.

To reduce the size of the resulting steganocontainer by the method [2] we suggest its improvement, where by the one separation of Bezier curve will be hide not one bit of secret information, but a block (series) of bits. This improvement will be achieved through the use of predefined table of correlations of different values of the template elements with different steps of Bezier curves. This table of template values will play the role of a steganokey, which used for hiding and reproduction information from a steganocontainer. Hiding data by the template method will occur by the following algorithm:

1.For each data block of template TB_x^k can defined one step $T\Delta t^k$ change in parameter t, where k – index of values of the template elements, $k \in \overline{1,2^x}$, x – the number of bits for one value of the template element.

2.Hidden message is divided into blocks $c = \{c_1^z, c_2^z, ..., c_m^z\}$, $z = n / m$, where z – the block size c_i^z, $i \in \overline{1,m}$, n – the size of hidden message, m – the general number of Bezier curves in vector image that will be hidden in a secret message, each of which is entered in D_i Bezier curve in vector image. Each message block is presented in the form $c_i^z = \{c_i^1, ..., c_i^q\}$, c_i^y – the part of message with x bit length, $y \in \overline{1,q}$, $z = q \cdot x$, q – the number of values of template elements in block. The resulting sequence of segments is indicated like $D_{P_v}^w$, where w – index of sequence of created curve segments D_i, $w \in N$, P_v – coordinates of pivot points, $v \in \overline{0,3}$.

3.Hiding of each block c_i^z of secret message is performing in curve D_i, $i \in \overline{1,m}$ by breaking it into segments with different values of the parameter t, $t \in (0,1)$:

3.1. Hiding of each element of the template TB_x^k from block c_i^z in a certain sense t occur by breaking the Bezier curve into two segments $D_{P_v}^w$ and $D_{P_v}^{w+1}$ by de Casteljau algorithm [5]. The subsequent introduction of the following template elements from the block c_i^z will occur with the following values $t = t + T\Delta t^k$, where the value $T\Delta t^k$ corresponds to hidden element TB_x^k on this step t, in the resulting second segment $D_{P_v}^{w+1}$ will start from the coordinates of partition point of the initial curve. Each partition of Bezier curve leads to an increase in the number of Bezier curves in a sequence of segments on $w = w + 1$.

3.2. By carrying out the hiding of block sequence c_i^z of Bezier curve D_i, it is replaced with visually identical sequence segments $D_{P_v}^w : D_i = D_{P_v}^0 \cup D_{P_v}^1 \cup ... \cup D_{P_v}^w$.

By carrying out data hiding (the size of 100-500 bytes) in a Bezier curve of Curveto type the vector image of SVG format [6] by the bitwise and template method we obtain the following results, which are presented in Table 1. Hiding data was carried out by using the following parameters [7]: 1) $CP_1 = 12$, where CP_1 – the maximum number of decimal places of fractional part of the coordinates of control points Bezier curves; 2) $CP_2 = 4$, where CP_2 – the minimum permissible length of Bezier curve relative to distances between the pivot points; 3) $CP_3 = 5$, where CP_3 – the maximum allowable error in the last number of decimal places of fractional part of coordinates of the reference points that arises in the process of playing back the original curve D_i of a sequence of segments $D_{P_v}^w$; 4) Step of the parameter t change by bitwise method was counted by the formula $\Delta t = 1/n$; 5) Values of the table of relationships for a template method were determined by the parameters $x = 8$ and $k = 256$.

Table 1

The results of hiding data in the SVG image structure

№	Size of hidden infor., byte	Container size «before», KByte	The bitwise method			The template method		
			Time for hiding, sec	Time for reprod., sec	Container size «after», KByte	Time for hiding, sec	Time for reprod., sec	Container size «after», KByte
1	100	19511	27,36	17,29	56,28	7,53	21,97	29,89
2	200	19511	43,35	33,56	93,05	14,80	40,42	40,07
3	300	19511	52,87	50,17	131,19	20,43	53,48	50,26
4	400	19511	68,14	67,07	169,68	28,74	73,13	60,46
5	500	19511	77,50	83,56	206,75	37,20	92,77	70,68

The diagram of Fig. 1 shows a comparison results of the obtained sizes of steganocontainers relative to the initial SVG images.

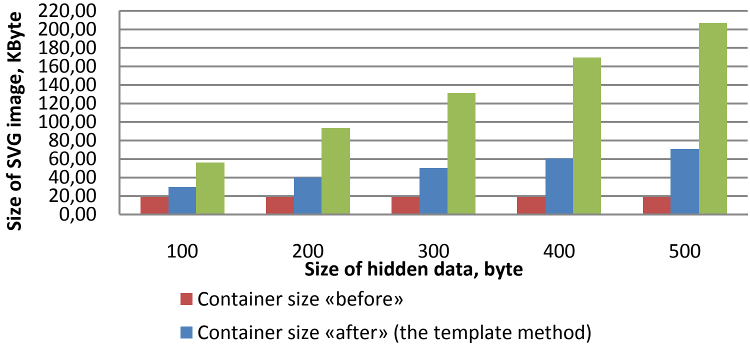


Fig. 1. Comparison of the obtained sizes of steganocontainers

The comparable results of time expenditure for hiding and extracting data by bitwise and template methods, that are presented in the diagrams on Fig. 2 and Fig. 3.

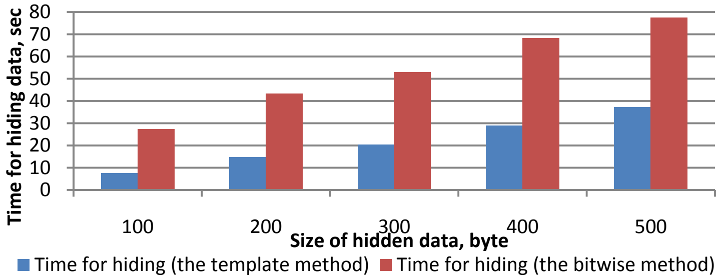


Fig. 2. Time expenditure for data hiding

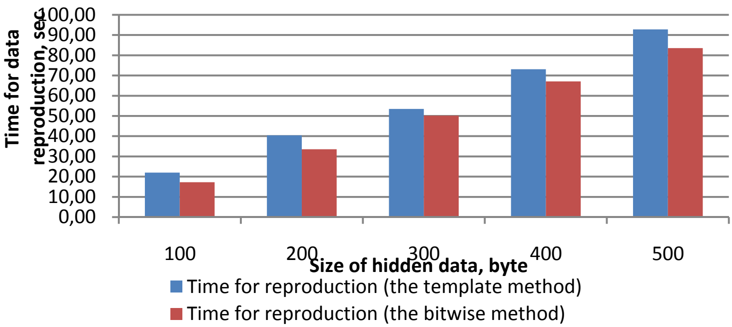


Fig. 3. Time expenditure for separation of hidden data

Conclusions

To improve the efficiency of information hiding in the structure of vector images, the template method of hiding data is proposed in the work. The experiment showed, that proposed method of template hiding data create the steganocontainer more than 2 times smaller and with smaller time expenditure for hiding data, than bitwise method, because for one Bezier curve partition, a block of secret message bits hide. But, using the template method lead to time increase for expenditure of hiding data from steganocontainer, because for the reverse process of gradual reproduction of the original curve from a summation of segments constantly we need to sort out all the values $T\Delta t^k$ of the template for finding the necessary value at which the merger of the last two sequence segments will take place.

References

1. Gribunin V.G. Digital steganography / V.G. Gribunin, I.N. Shackles, I.V. Juve. — M. : SOLON-Press, 2002. — 272 p.;

2. Kinzeryavyy O.M. Steganography method of hiding data in vector images / O.M. Kinzeryavyy, V.Y. Kovtun, S.O. Gnatyuk, V.M. Kinzeryavyy // theoretical and practical science journal «Bulletin of Engineering Academy of Ukraine». — 2013. — №3-4. — P. 66-68.;

3. Rodjers D. Mathematical Foundations of Computer Graphics : [tran. from English] / D. Rodjers, J. Adams. — M. : Mir, — 2001. — 604 p.;

4. Matsenko V.G. Computer Graphics : [tutorial] / V.G. Matsenko. — Ch. : Ryta, — 2009. — 343 p.;

5. Kunvu Lee. Basics CAD (CAO / CAM / CAE) / Lee Kunvu. — St.P. : Peter, — 2004. — 560 p.;

6. Dunaev V.V. HTML, scripts, and styles : [3rd edition] / V.V. Dunaev. — St.P. : BHV-Petersburg, 2011. — 816 p.;

7. Kinzeryavyy O.M. Experimental research of bitwise method for information hiding in vector images / O.M. Kinzeryavyy, V.Y. Kovtun // «Information Security». — 2014. — VOL. 20 №1. — pp. 66-70.

UDC 519.6:004.56 (045)

O.V. Gavrylenko, PhD (National Aviation University, Ukraine, Kyiv)
D.S. Matviiv, Postgraduate Student (National Aviation University, Ukraine, Kyiv)

CHOICE OF METHODS OF OPTIMAL SEARCH OF INFORMATION PROTECTING TOOLS FROM UNAUTHORIZED ACCESS TO COMPUTERIZED SYSTEMS

The authors offer a pre-selection preliminary choice of methods of optimal search of information protection tools from unauthorized access in computerized systems to ensure compliance with the existing requirements of the information protection in these systems in order to facilitate this choice and reduce development time of complex systems of information protection in AS.

Introduction. One of the major issues of development a modern security systems is search for the most efficient way of providing the required level of information security in its processing, transmission and storage in information (automated) and telecommunication systems (hereinafter - AS), in terms of information threats prevention or harm minimization from threats realization. [1, 2, 3].

Necessity for finding the most appropriate solution based on several criteria appears in many practical problems of complex protection systems design. Fairly common in practice is multi-criteria choice problems, where finite set of alternatives is given and these alternatives can be evaluated quantitatively and qualitatively [4]. What is more, set of alternatives can be very large in real problems the, that makes the task of decision making fairly complex, and therefore the greater importance get the role of the decision maker (hereinafter - DM).

Problem. This paper [10] is the generalized set of selection criteria for technical information protection from unauthorized access (hereinafter - UA) in different AS classes while integrated information security system (hereinafter - IISS) construction [10]. Getting summarized information about product (its features, functions, characteristics, destination) by using these criteria gives the opportunity for developer to simplify the IISS search that are necessary to ensure with existing AS protection requirements compliance [12]. In this case, the best result of finding the right product can be achieved by taking the optimal choice decision.

The aim is methods pre-selection for finding the optimal technical information protection from unauthorized access in AS. This selection is based on a brief analysis of the existing optimization [5, 6, 7] techniques guided by the proposed selection criteria [1, 3] with regard to their importance relative to each other.

The main part. Multi-criteria analysis and decision making methods are used in many areas of science and technology as well as in systems research. One of the branches of decision making theory is multipurpose (multi-criteria) methods. The complexity of multipurpose selection is primarily in objectives (criteria) contradiction [6]. Hence the necessity for some reasonable compromise scheme that allows improving the quality of decisions which made using all criteria and performance indicators arises. Exploring new approaches [5, 6, 7] for multipurpose tasks solving allows us to determine the following major classes of methods for multi-purpose optimization and decision making depending on the type of interaction with decision maker.

A priori methods are one of the most explored and developed methods. The main feature of these methods is that as a result of the use of method, multi-purpose task is reduced to a single-purpose. Depending on the selected method [5, 6] (eg, lexicographic (LM) [4]) only one Pareto-optimal resulting solution is found (*Pareto optimum* is choosing a optimal solution in multi-criteria system that cannot be improved by any criterion without worsening on other criteria). Otherwise under certain conditions decision is made by the decision maker. These methods require decision maker to determine the benefits in advance that can be problematic taking into account advantages of unlimited knowledge, based on the optimal objective. Method of targeted programming (GP) is an example of such a method.

Methods «with no advantages» [6]. For methods that do not take advantage, decision optimization performs DM. They can accept or decline the decision. This method is used in cases where the decision maker has no specific assumptions about decision. In this method, multi-purpose task conversion into a single-purpose optimization task is performed by minimizing the distance between certain defined benchmarks and result capabilities. Method of global criterion is an example of the method. The disadvantage of this method is the complexity of determination of acceptable values criteria. In most cases they are chosen subjectively. Therefore, if the criteria are equivalent, any of them can be selected as main, but it is better to choose the one for which is the most difficult to specify valid values. Note, that the solution obtained by this method will be always poorly effective.

A posteriori methods. These classic methods are often used in engineering sciences, as they provide many Pareto-optimal solutions, which are obligatory for decision maker. The role of DM is very important, because after finding the set of optimal solutions, he chooses one of them. The most popular approaches are : the method of weighted sums (weighted-sum method), the «ε-limit» method, a hybrid method.

Interactive methods [11]. DM takes an active role in solving the problems using interactive methods, which are promising for problems with many objectives. When while computations several optimal solutions are obtained, one of which satisfy the DM, it can be selected as optimal. Participation of DM in the computation process is required constantly, that cannot always be justified. For example, method of efficient solution in goal programming (ESGP), an interactive multi-linear programming (IMOLP), interactive simultaneous goal programming (ISGP), STEM method, evolutionary algorithms (EA).

Thus, taking into account the role of DM in the implementation of the considered classes of optimization methods it can be concluded that for the last two classes this role is crucial, while for the second class of methods it is minimal. In reference to the first class of methods (a priori) it can be concluded that decision maker is involved in the preparatory work and, where appropriate, in final stages.

So, the last two methods are the most time-consuming in relation to the DM, and therefore they can be considered less acceptable. While “No advantage” methods from this point of view, by contrast, seem to be the best. However, they do not take into account for distribution criteria over importance. The need for such a distribution is characterized by a priori methods, for which, as noted above, decision maker performs determination of criteria importance beforehand. Distribution of criteria over importance considered common for considered in [1] approach to the choice of information security tools from unauthorized access. In [1] the preliminary allocation criteria in descending order, to the author's opinion, according to degree of their importance in relation to performance by tool protection of information from unauthorized access by selected tool. Additionally, here are presented arguments concerning justification of such distribution. Criteria can be divided according to their content [1] into following groups:

The guidelines on the content of which depends providing a means of information protection (implemented functional profile protection class for AS [8, 9], which used a means of protection objects). The criteria that determine technical feasibility of using a tool in AS (compatibility with software requirements for technical support, requirements for technical protection of information, method of use, availability of technical and operational documentation for the tool).

The criteria that certify the quality and reliability of tool for guaranteeing protection (level of guarantees of functional security services realization, availability of conformance with regulatory requirements of technical protection of information). The value criterion that influence on its purchase ability (price category of the tool). The criteria that determine tool's versatility and convenience for further operation (operating conditions, method of implementation, primary purpose). This approach allows further considering of the problem of estimation of contribution of each criterion in determination their strengths to figure an optimal choice method. So, in terms of DM involving and taking into account the opportunity to determine the benefits between the criteria, that are confirmed by their division into groups by importance, it is proposed to consider a priori methods the most suitable method for solving the problem of choice of information protection tools from unauthorized access.

Conclusions

On the grounds of research of the basic techniques classes of multi-purpose work optimization, performed previous selection of a priori selection methods class of optimal search of technical protection of information from unauthorized access in AS needed to ensure the compliance with applicable requirements of protection. This choice creates prerequisites for improvement of the search facilities accuracy compared with the «no advantage» methods due to a priori assignment of benefits criteria in advance with minimal involvement of DM compared with other methods.

The proposed criteria allocation [1] according to their importance in groups, confirms the possibility of preferences setting on the selection of protection equipment proper to a priori methods.

References

1. Oleksiy Gavrylenko, Sergiy Gnatyuk, Dmytro Matviiv. Selection Criteria of the Tools of Information Security from Unauthorized Access into

Computer Systems of Different Classes. Journal of Computer Networks, 2014, Vol. 2, No. 2, 18-22. Available online at http://pubs.sciepub.com/jcn/2/2/3.

2. I.I. Simora, O.V. Gavrylenko, Classifier of tools of information security in informatively telecommunication systems, The 3rd international Scientific Conference ITSEC, National aviation university, 2013.

3. D.S. Matviiv, O.V. Gavrylenko. The system of choice of remedies in automated systems of different classes. The 3rd international Scientific Conference ITSEC, National aviation university, 2013.

4. N.V. Semenova, L.M. Kolechkina, A.M. Nagirna. Multicriteria problem of lexicographic optimization for fuzzy sets of alternatives. The report of the National Academy of Sciences of Ukraine, 2010, N6. [Online] Available: http://dspace.nbuv.gov.ua/bitstream/handle/123456789/29824/08-Semenova.pdf? sequence=1/.

5. V.V. Podynovsky, V.M. Gavrylov. Optimization by consistently applied criteria. M., 1975, 192 pages.

6. P.I. Bidjuk, O.P. Gozhyj, L.O. Korshevnuk. Computer decision support systems. [Online] Available: http://lib.chdu.edu.ua/index.php?m=2&b=313.

7. V. Podynovsky. Lexicographic optimization problem under uncertainty. «Proceedings of the USSR. Technical Cybernetics», 1973, N21.

8. Order number 22 of the Department of the special telecommunication systems and information security of Ukraine Service, ND TIS 2.5-005-99. Classification of AS and standard functional types of protected of the processed information is from an unauthorized access, 28 Apr 1999.

9. Order number 22 of the Department of the special telecommunication systems and information security of Ukraine Service, ND TIS 2.5-004-99. Criteria of estimation of protection of information are in the computer systems from an unauthorized access, 28 Apr 1999.

10. Order number 125 of the Department of the special telecommunication systems and information security of Ukraine Service, ND TIS 3.7-003-05. The conduct of work with a comprehensive security solutions in information and telecommunications system, 08 Nov 2005.

11. T. Schvarch, Interactive methods for solving multiobjective optimization. Russia, MGTY of Baumana, 2013. [Online] Available: http://technomag.edu.ru/file/out/589992

12. Position number 1299 about a technical information security in Ukraine, ND TIS 3.7-001-99. The methodical pointing is in relation to creating of requirement specification on creation of the system of information security of automated system, 27 Sep 1999.

UDC 004.056.5 (045)

Ya.B. Khanko, Postgraduate Student (National Aviation University, Kyiv, Ukraine)

MODERN ANALYTICAL FRAUD DETECTION SYSTEMS

This paper dedicates to research of leading world and domestic vendors of analytical fraud detection system (AFDS), on a set of parameters that characterize the performance of these systems and following comparison of AFDS basing on mentioned parameters.

Today in the banking industry of Ukraine, in remote banking sector, unauthorized thievery of customers' funds issues as relevant as ever. According to National Bank of Ukraine reports in 2013 (2012) it was detected 468 (139) facts of unauthorized thievery of customers' funds totaling $ 87 (116) mln UAH. In this regard, the relevance of identification and fraud prevention in e-banking systems is an urgent task. To date, published papers related to research in the field of fraud detection systems, mainly, conducted in the following three areas: network intrusion detection, detection of fraud related to payment cards and fraud detection in telecommunications. Lack of information in the area of fraud detection in e-commerce systems, both in domestic and foreign literature, most likely due to the secrecy and commercial interests in this direction.

Different papers [1,2] mainly concerned on questions of different analysis methods and models of fraud detection in telecom and payment card industry or provide a broad analysis of intrusion detection theory, describe main characteristics of network intrusion detection systems (NIDS) and its main construction principles. Another works disclose various methods and criteria for comparison of network IDS as well as the results of a comparative analysis selected IDS' according to selected criteria [3,4]. Standard NIST SP800-94 provides a comprehensive methodology and defines the basic criteria for testing NIDS. The most comprehensive review of commercial AFDS, its advantages and disadvantages provides Gartner in its analytical review Magic Quadrant for Web Fraud Detection. However, the methodology used and the criteria for analysis in this review were not disclosed.

In this context, the aim of this paper is to define a generic set of criteria for comparison the qualitative characteristics of AFDS, as well as to carry out a comparative analysis of commercial AFDS by means of selected criteria. It was examined nine commercial AFDS of different developers. Table 1 represents summary information about these systems.

Table 1

Modern AFDS Systems

Naming	**Manufacturer**	**References**
RSA Transaction Monitoring	RSA, Security Division of EMC	http://russia.emc.com/security/rsa-identity-protection-and-verification/rsa-transaction-monitoring.htm
FraudMAP Online	Guardian Analitics, USA	http://www.guardiananalytics.com/products/fraudMAP-online-banking-fraud.php
BIFIT Fraud	BIFIT, Russia	http://www.bifit.com/

monitoring		
Intellinx	Intellinx, США	http://www.intellinx-sw.com/
ThreatMatrix	ThreatMatrix Inc., США	http://www.threatmetrix.com/
CA RiskMinder	CA, США	ttp://www.ca.com/us/risk-based-authentication.aspx
NiceActimize Fraud Solutions	NiceActimize, США	http://www.niceactimize.com/
Behavior Piercing	NuData Security, Canada, Vancouver	http://nudatasecurity.com/
FraudWall	Frodex, Russia	http://www.frodex.ru/

Below is giving the list of basic parameters that was developed in the result of AFDS analysis and which are representing the qualitative characteristics of these systems:

1. Detection Mode (Time of detection-Td). Determines the ability of the system to collect, analyze and respond on events in real time (real time - Trt) or in near real-time (near-real time - Tnrt).

2. Suspicious behavior detection method (Detection method - DM). Method which is used to detect suspicious behavior is one of the key criteria of AFDS. It could be divided into the following subcategories: anomaly detection method (anomaly detection - DMAD), signature detection method (signature detection - DMSD) and method, which combines both of mentioned above – hybrid method of detection (hybrid detection - HD). Method which is used to detect suspicious behavior directly reflects the ability of AFDS to adapt to unknown types of fraud, which is a significant advantage.

3. Audit source (AS). Depending on the architecture, AFDS can receive information from a variety of sources. Data sources include two main and one extra. The main data sources are the network data (network data-ASNT) and host log files (host based data - ASHBD). As an additional source different developers use a centralized database (centralize data base - ASCDB), containing the typical models of attacks, fingerprints of compromised workstations, etc.

4. Threat counteraction (TC). There are three main types of threats to internet banking: authentication information thievery (TCAIT) - logins, passwords, certificates. This personal information is required for access to accounts in internet banking systems and execute the financial transactions. Man In the Middle (TCMItM). Mainly used for unauthorized substitution some fields in payment order directly before applying digital signature, in a manner transparent to the client. Remote control workstation (remote control - TCRC). By means of malware, fraudulent takes hold of client' PC and executes unauthorized financial transactions on behalf of a legal client.

5. AFDS response type (type of response - TR). Consider this characteristic from the following point of view: the passive mode (passive - TRP) - the operator receives the notification and basing on expert opinion blocks or allows transaction; active mode (active - TRA) – automatically response on suspicious transactions according to predefined rules or anomaly behavior and following notification of

operators (e.g. incorporating additional authentication factor like CAPTCHA to protect against bots).

6. System flexibility (flexibility - F). Ability of the system to add new parameters for analysis and identification of suspicious behavior, modify the values of the risks in evaluation etc. From this point of view consider the following types of flexibility. Black Box (FBB) – system does not allow to change any parameters manually, changing of values performs automatically of by service provider; moderate flexible (FMF) – system allows to change the values of know beforehand parameters; unlimited flexibility (full flexible - FFF) – system allows to change the weight/values and add new parameters which will be used in future calculation.

7. Mathematical model. Using one or another mathematical model can indirectly indicate the efficiency of the whole system and the ability to perform not only programmed sequence of predetermined operations, but also gives possibility to analyze incoming information, search and find patterns, make forecasting etc. These could include: neural networks, fuzzy logic, Bayesian network, Markov model, etc.

Table 2 shows the comparative analysis of AFDS according to defined above parameters.

Table 2

Analysis of AFDS Systems

Name	Type of detection		Detection method			Source			Threat counter-action			Type of responce		Flexibility			Mathematical model
	T_{rt}	T_{nrt}	DP_{AD}	DP_{SD}	DP_{HD}	AS_{NT}	AS_{HBD}	AS_{CDB}	TC_{MItM}	TC_{AIT}	TC_{RC}	TR_A	TR_P	F_{FF}	F_{MF}	F_{BB}	
RSA Transaction Monitoring	+	-	-	-	+	+	+	+	+	+	+	+	-	+	-	-	Bayesian network
FraudMAP Online	+	-	-	-	+	+	-	+	+	-	+	+	-	-	+	-	-
BIFIT Fraud мониторинг	+	-	-	-	+	+	+	+	+	+	+	+	-	+	-	-	-
Intellinx	+	-	-	-	+	+	-	+	+	-	+	+	-	-	+	-	-
Threat Matrix	+	-	-	-	+	+	+	+	+	-	+	-	+	-	+	-	-
CA Risk Minder	+	-	-	-	+	+	+	+	+	+	+	+	-	+	-	-	-
NiceActimize Fraud Solutions	+	-	-	-	+	+	+	+	+	-	+	-	+	-	+	-	Fuzzy logic
Behavior Piercing	+	-	-	-	+	+	+	+	+	-	+	-	+	-	-	+	-
FraudWall	+	-	-	-	+	+	+	-	+	-	+	-	+	-	+	-	-

Conclusions

In this paper, it was researched modern AFDS of various domestic and foreign manufacturers. On the basis of mentioned research it was developed basic set of parameters, which allow to determine main characteristics of AFDS. By means of these parameters it is possible to which it is possible to carry out comparative analysis of AFDS or to use to determine performance of such systems. Furthermore, these parameters can be used when developing new ACOM.

Further work will focus on compiling a list of identifiers that are required to successfully identify fraud, as well as choosing the most suitable mathematical apparatus for mapping and processing incoming data.

References

1. E. Aleskerov, B. Freisleben, and B. Rao, “CARDWATCH: A neural network based database mining system for credit card fraud detection”, in Computational Intelligence for Financial Engineering. Proceedings of the IEEE/IAFE, 1997, pp 220- 226. IEEE, Piscataway,NJ.

2. R. J. Bolton and D. J. Hand, “Unsupervised profiling methods for fraud detection”, in Conference on Credit Scoring and Credit Control 7”, Edinburgh, UK, 5-7 Sept., 2001.

3. Stefan Axelsson. Research in Intrusion-Detection Systems: A Survey. TR: 98-17. Department of Computer Engineering, Goteborg, Sweden, December, 1998.

4. Современные некоммерческие средства обнаружения атак Д.Ю. Гамаюнов, факультет Вычислительной Математики и Кибернетики, МГУ им. М. В. Ломоносова, Москва, 21 сентября 2002 г.

UDC 004.056.5 (045)

V.V. Kozlovskyi, Prof Dr Eng (National Aviation University, Kyiv, Ukraine)
A.V. Mischenko, PhD Assoc Prof (National Aviation University, Kyiv, Ukraine)

ECONOMIC COMPONENT OF INFORMATION SECURITY OF AVIATION INFRASTRUCTURE

In this paper authors proposed methods for research economic component of information security of aviation infrastructure as a complex system of information security of the state.

Scientific research is the main way to obtain new knowledge for the information security system of the state, the engine of progress. The methodology of scientific research of the economic component of aviation infrastructure information security as a complex system of information security, based on the theoretical foundations of economics and is based on a systems approach [1], is the essence of the profession of scientist and its basic position for the head is the basis for his ability to see the problem the problem of improving the efficiency of its object of responsibility, implement and manage scientific innovations on a scientific basis. Therefore, we consider the fundamental methods for implementing the basic principles of a systematic approach studies the economic component of information security aviation infrastructure.

Modern methodology of scientific and economic studies of the economic component of information security aviation infrastructure on the basis of the system approach says: object – ergodic "complex" system of the economic component of information security aviation infrastructure; purpose – to improve the research object – the economic component of information security aviation infrastructure; subject – object performance, as a measure of its perfection on the factors 'impact' – systemic signs; scientific problem – increasing (maximizing) the effectiveness of the object in the priority factor.

The purpose of the analysis is a comprehensive study of the object – the economic component of information security aviation infrastructure, namely (Fig. 1): clarify the system of the object (definition content "frame"); identification and assessment of properties of the object; determine the characteristics of the object [2] to evaluate its actual capabilities. The results of a systematic analysis of the economic component of the object information security aviation infrastructure used to develop mathematical (analytical) model dependencies to determine and assess system performance and to further formalize optimization problems organizing resource management system economic component of information security aviation infrastructure during its application.

The goal of synthesis is to create "desirable" economic component of the object information security aviation infrastructure, namely (Fig. 2): the definition of the desired content systemic signs; provision and evaluation required properties; ensure the values of the object to reach its required capabilities. The results of the synthesis system used to create the maximum system efficiency target economic component of information security aviation infrastructure. The purpose of "operational" study of the economic component of information security aviation infrastructure is just providing "economic-mathematical methods) to study the problems of analysis of system features, properties and characteristics of the object of research as a complex system ergatic economics of information security and their determination to synthesis problems.

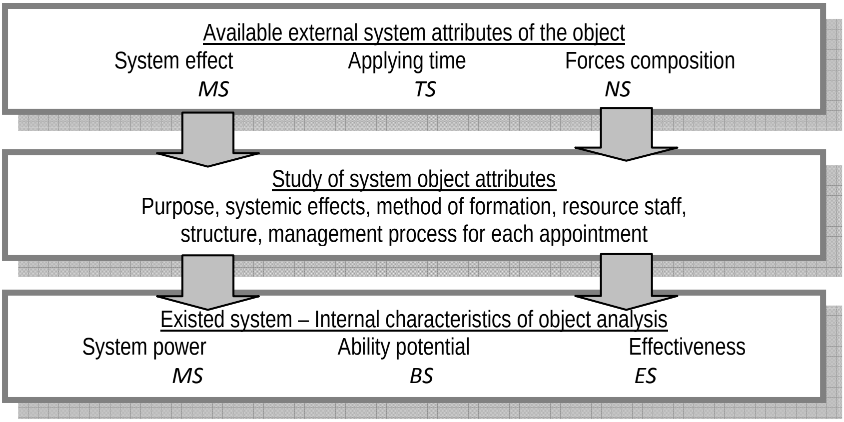


Fig. 1. Conception of analysis

The general concept of "operational research" facility economic component of information security aviation infrastructure "complex system" is explained by Fig. 3.

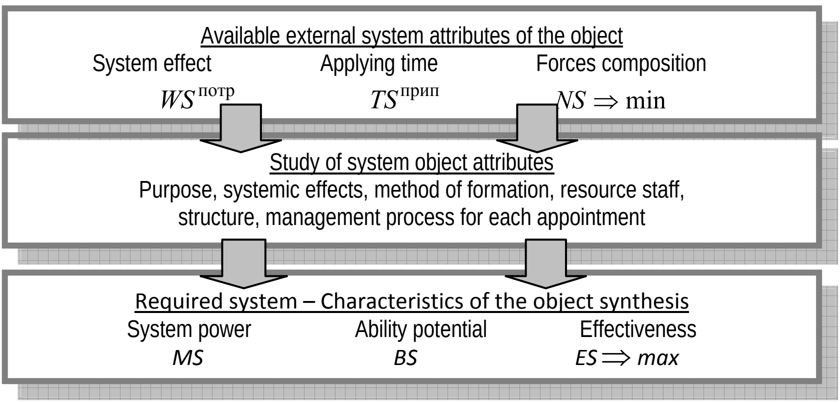


Fig. 2. Synthesis conception

The operating results of the study of the economic component of information security aviation infrastructure is to determine the optimal values of system parameters that maximize the effectiveness of the object "complex system" in the "real use" for a particular purpose. The methodology of scientific research "economic transactions" if it is based on the basic principles of "systems approach" and the appropriate method of implementation, provides versatility study (analysis) and the perfection of creation (synthesis) "complex" system of the economic component of information security aviation infrastructure. The fundamental principle of "maximum system efficiency" principles "priority" direction "completeness" and "completeness" of research involve the formulation and solution of basic scientific problem of synthesis of the economic component of information security aviation infrastructure resource methods and parametric optimization, between which there is a direct link.

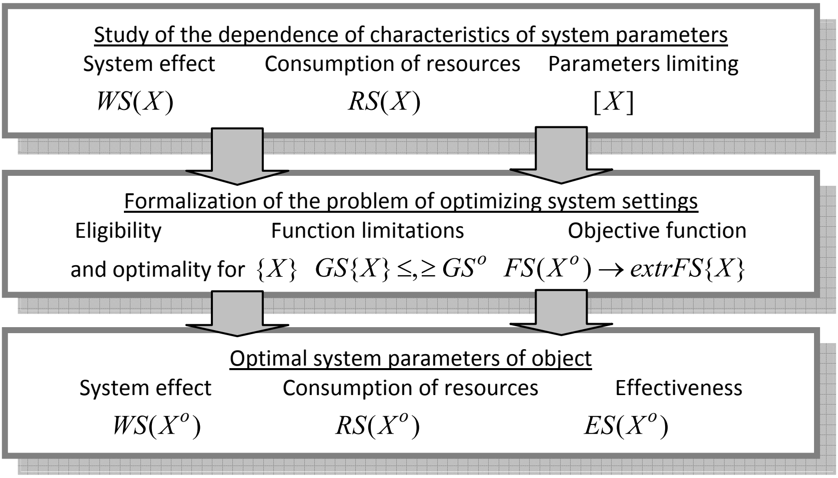


Fig. 3. The general concept of "operational research" component of the economic system of information security aviation infrastructure

Thus the methodology of scientific research specialty is the essence of professional scientist and that it determines the level of scientific results and potential effectiveness of science "information security" as a whole. Therefore, improvement and use of the theoretical foundations of the methodology of the economic component of information security aviation infrastructure on the basis of systematic approach is the key to maximum efficiency target of research.

References

1. Качинський А.Б. Безпека, загрози, ризик. Наукові концепції та математичні методи. Інститут проблем національної безпеки. Національна академія служби безпеки України. Київ, 2004. – 470 с.

2. Базилевич В.Д., Базилевич К.С., Баластрик Л.О. Макроэкономика. Учебник / Под ред. В. Д. Базилевича. — М.: 2008.

UDC 389.14:006.015.7

T.L. Scherbak, PhD (National Aviation University, Ukraine, Kyiv)

METROLOGICAL RELIABILITY OF TECHNICAL INFORMATION PROTECTION

The characteristic features of the functioning of technical protection of information. To ensure the effective and reliable operation of protection means proposed to carry out monitoring of the current and projected operation means of protection and determine their characteristics of metrological reliability.

Introduction. Scientific and technical information security problems are widely used in the information stage of terrestrial civilization. Many publications have noted that politics and economics, science and technology, industry sectors are using the methods, information technology hardware and software of information security. From the information security practices follows that information signals of different physical nature, including electromagnetic, electric, acoustic, vibroacoustic widely used for transmission of various information. To solve the problems of protection of data during transmission such signals using methods and technical means of protection. In normative documents integral information security criteria is to ensure its integrity, availability and confidentiality.

Practical use of a wide range of technical information protection of commercially generated by various organizations and firms allows you to create different variants of structures and architecture protection means adapted to the specific objects of protection and protection tasks required. Typically, such means are hardware and software means, wherein both combinations and ratios of hardware and software components of such agents have a wide range of variation.

Problem definition. To analyze the functioning of the technical information protection, and to note the characteristics of their work in solving problems of information security protection object. Substantiate the determination of the reliability of the characteristics of protection means for solving current and projected performance monitoring researched protection means.

Turn to the presentation of the results of research, using the results of publications on modern methods of information protection. Information Technologies and technical means of protection, as well as measuring instruments, including [1-6].

Research of the functioning of a technical device information security can be performed in two directions:

1. Measuring means, which in the functioning forms the primary measurement data for the tasks on information security;
2. Technical means for performing the tasks of information protection.

Therefore, at the beginning of the analysis of the functioning protection means as measuring means, which are formed primary measurement information as measurement data.

Such devices can be classified according to the principle of action transducers - sensors that convert physical fields studied in information signals. Examples of the most commonly used types of sensors on the practice of information security solutions are: radiowave; acoustic; seismic; barometric; ultrasonic; piezoelectric; magnetostrictive; electrical and others.

The question arises: what characteristics means of protection must be determined in the monitoring process that would more fully characterize its condition?

In this paper, based on the results of [1-6] proposed to consider the operation of the test as a means of non-standard operation of measuring equipment. The main characteristics of the process used to monitor the characteristics of metrological reliability means of protection. It enables to use [1-6]: theoretical foundations, techniques, information technology, hardware and software and information security systems; powerful theoretical apparatus of the theory of reliability and metrology; large volumes of test data operation of similar facilities and systems; development of modern information security, including mathematical and software, to conduct a study the functioning of similar means at all stages of their life cycle.

This line of research for monitoring the operation of technical protection of information is relevant and important, but also makes it possible to carry out the monitoring process in automatic (automated) mode.

Rationale for monitoring the operation of technical information protection proposed to be considered as a process of study of functioning means to assess their current and / or projected its states to ensure that the required protection functions. The main characteristics of the process used to monitor the characteristics of metrological reliability protection means.

Investigated protection of information is a non-standard measuring equipment, designed to measure, conversion, and problem solving of information protection of both hardware and software components of the object of information protection. When operating funds is observed as metrological and not metrological failures. The means refers to maintainable, reducing agent. Indicator of the reliability of such remedies should include the intensity of catastrophic failures, mean time between failures, operating time between failures, the probability of recovery, mean time to repair, availability factor and the coefficient of technical use. Change the values of metrological characteristics of protection over time due to aging, deterioration and accumulation of physical and chemical abnormalities in the nodes or elements of means caused by the interaction with the environment. It basically refers to the hardware components of means of protection. The rate of accumulation of incremental changes depends primarily on the used materials and technologies when instability of metrological characteristics of the time can have a direct impact on the correctness of decisions.

Indicators of metrological reliability means characterizes the one hand the value of the metrological characteristics, on the other - metrological serviceability of protection means in time by determining the likelihood that a given interval of time of use does not come metrological failure. In this case, the metrological characteristics as an indicator of reliability must be considered a random value - the value of the metrological characteristics of means of protection in fixed time and deliverables. Metrological failure occurs when the metrological characteristics reaches a limiting value of the normative and technical documentation on means of protection and determined the accuracy class.

Value indicators of metrological reliability depends on the type of connections between elements forming part of means of protection and its structure, characteristics of non-stationary random processes, change the parameters of these elements and tolerance in metrological characteristics. Metrological characteristics change occurs slowly, so the metrological reliability can be predicted. To solve the problems of metrological forecasting failures protection means necessary to identify the dependence of its metrological characteristics of changes in the physical characteristics of the means of protection, as well as influencing factors. For example, the ability to predict failure of metrology can be accomplished by monitoring the change of one of the parameters for which measurements can be carried out in the operation of means of protection [3,4] .

In the study of protection means as a means of measuring technology core components - the device is measuring channel. It is known that the measurement channel consists of a primary transducer (sensor) which converts the original action, as studied in the physical quantity measuring signals. Subsequent measurement channel converters perform various operations amplification, filtering, normalization of the output signal of the measuring sensor for the further execution of analog-to-digital conversion using the ADC, as the basic operation in converting the measurement signal its digital equivalent. Thus, we obtain a digital signal with discrete time and quantized levels of signal values. In the future, such a digital signal is a source of information for solving a variety and diverse tasks of information protection.

Proposal to consider the functioning of technical information protection as the operation of measuring devices is debatable. But such a proposal greatly increases the efficiency and reliability of protection means under:

– the development of modern information technology of information protection of critical facilities including aerospace, nuclear power plants, facilities and systems of a defensive nature;

– using the methodology of creating effective and reliable means of protection at all stages of their life cycle, from the design of the project, engineering and technological documentation, conducting a wide range of simulation, in most cases, computer experiments on measuring the development of different variants of the structure and architecture means a considerable amount of natural test;

– determining the metrological reliability of protection means that enables to take into account not only explicit element failures, power modules and means, but also "hidden" - not explicit metrological failures;

– presentation of high efficiency and reliability requirements of so-called "soft hardware" - which includes information support of mathematical, algorithmic and program maintenance;

– implementation methodology of the current and projected performance monitoring information security devices during operation, the repair and recovery operations, work on modernization.

Conclusions

On the basis of analyzing the functioning of technical information protection certain characteristics of such funds. In solving problems of protection on the first stage, transformation actions unauthorized access, as well as natural phenomena in the measurement signals and then solving the problems of protection of hardware and software components of the object of protection. To ensure the effective and reliable operation of protection means proposed to carry out monitoring of the current and projected the functioning of means of protection and determine their characteristics of metrological reliability.

References

1. Zhmerev V.S. Analysis of the relationship of metrological reliability and stability of the measurement signals / Zhmerev V.S., Malovik K.N., Sapozhnikov N.E., Yudin A.V. - Sevastopol: Collection of scientific works SNUYaUtaP, 2009. - pp. 106-111.

2. Zaitsev A.P. Technical means and methods of information security: the textbook / A.P. Zaitsev, A.A. Shelupanov, R.V. Mescheryakov: ed. A.P. Zaitsev and A.A. Shelupanov. - M.: Mechanical Engineering, 2009. – 508 p.

3. Malovik K.N., Yudin A.V. Development of nomograms for estimating the of metrological reliability measuring channels. - Ukrainian Journal of Metrology, 2010. - № 2. - pp. 45-47

4. Mishchenko S.V., Tsvetkov E.I., Chernyshev T.I. Metrological reliability of measuring instruments. - M.: Mechanical Engineering, 2001. – 96 p.

5. Lenkov S.V. Methods and tools for information security. In 2 volumes / S.V. Lenkov, D.A. Peregoudov, V.A. Khoroshko: ed. V.A. Khoroshko. - K.: Arius, 2008. - Vol.1. Unauthorized access to information. - 464 p. V.2. Information security. - 344 p.

6. Stogniy B.S. Basics monitoring in power. On the concept of monitoring / B.S. Stogniy, M.F. Sopel / / Technical electrodynamics. - 2013. - № 1. - pp. 62-68.

UDC 004.056.5 (045)

S.O. Gnatyuk, PhD Assoc Prof (National Aviation University, Kyiv, Ukraine)
V.M. Sidorenko, Postgraduate Student (National Aviation University, Kyiv, Ukraine)

CRITERIA FOR THE IDENTIFICATION OF CRITICAL INFRASTRUCTURES OF THE STATE

The problem of the lack of a common terminology in the field of critical infrastructure protection in Ukraine forced to turn to the experience of the world leading countries. This article presents an analytical research of the legal framework developed states in the world on identification basic assignment criteria of the elements to critical infrastructures. The obtained results will be useful for development of classifying methods of certain facilities to the critical information infrastructure.

A variety of variations using terms associated with critical infrastructures in different countries, determine their common features that can be used to determine the criteria for critical infrastructure. Analysis of the sources [1,4,5], which are devoted to the problems of critical infrastructure protection, pointed to an inconsistency of the laws of different countries, the lack of a clearly defined list of relevant facilities, imperfection of mechanisms for assigning objects to critical (main factor inhibition of strategies Infrastructure Protection) etc. Each state defines its critical infrastructure in terms of the criticality of individual sectors or the importance of certain services for the state's economy and security of society.

The main obstacle for standardization in the field of critical infrastructure protection is the specificity of each country, such as a variety of national needs and problems, depending on the region and level of development. However, among the number of definition variations, there is a common feature of the critical infrastructure of different countries in the world – it is crucial for the security of citizens, society and the state.

The absence of the concept of critical information infrastructure in the legislation of some countries can be explained by the fact that information component is included in the concept of infrastructure in general (i.e., critical infrastructure) and not allocated as separate link. However, it should be noted that the interpretation of the term in different countries has a clear analogy. For example, Australia, Canada, Netherlands, United Kingdom and the United States, according to [1] adopted a common point of view, describing the critical information infrastructure as «the information systems (software, hardware and data) and services that support one or more critical infrastructures and the disruption or outage of which causes severe damage to the functioning of that dependent critical infrastructure(s)»

Access to services that support certain standard of living, and access to effective relationship between state and citizen is crucial for the proper functioning and development of the modern state, society and economy. However, it is important not to confuse the inconvenience with criticality. Not all services, the humanity got used to, are crucial that's why their correct identification is critical. To this end, the criteria for identifying critical infrastructures have been specified in the EU

Directive [2]. According to which each state should identify potential critical infrastructure that meet two main groups of criteria - cross-cutting and sectoral.

Cross-cutting criteria should include**:**

1) Casualties criterion (assessed in terms of the potential number of fatalities or injuries);

2) Economic effects criterion (assessed in terms of the significance of economic loss and/or degradation of products or services; including potential environmental effects);

3) Public effects criterion (assessed in terms of the impact on public confidence, physical suffering and disruption of daily life; including the loss of essential services).

In Poland intersectoral criteria – a limit thresholds based on the severity of the impact of the disruption or destruction of a particular critical infrastructure [3]. They shall comprise the following: casualties, financial consequences, evacuation, loss of service, reconstruction time, international effect, uniqueness.

Sectoral criteria should take into account the characteristics of individual sectors of critical infrastructure. They define the characteristics or features of objects included in the critical infrastructure.

In the United States, according to [4], decided to divide the critical infrastructures to those which associated with international organizations (energy facilities, transportation, banking and financial systems, and telecommunications) and those that are not associated with them (water supply, emergency services, public administration).

Critical infrastructure objects that are connected and not connected with international organizations are divided into three categories:

- Vital (NPS, HPS, waterworks, objects of strategic storage of oil and gas, hazardous chemical and petrochemical production, warehouses of nuclear materials and ammunition);
- Extremely important (energy systems, underground, water supply lines, underground sewer systems, pipelines);
- Important (seaports, wastewater treatment plants, mainline buildings, major airports and communication centers).

In determining the elements of critical infrastructure, hierarchy of criteria include the following main groups [5]: economic security; life safety and health; national security and defense; national self-esteem and image of the state. Consider the construction of criteria for determining critical objects on the example of Russia, the criteria are grouped according to three parameters [6]:

<u>The criteria of significance of the object for the economy of the state:</u>

1. The annual cost of production output (mln);
2. The total number of personnel (thousands of people);
3. Carrying amounts of assets (mln);
4. Proportion of primary products produced by the object in the same type of products manufactured in the country (%).

<u>The criteria relating to reputational damage of the state:</u>

5. Violation of control of the state or region;
6. Harming to the authority of the state, including in the international arena;

7. Disclosure of state secrets, confidential scientific, technical and commercial information;

8. Violation of combat readiness and combat effectiveness of the Armed Forces;

9. Infringement stability of the financial and banking systems.

Potential threats for the population and territories:

10. The large-scale destruction of national resources (natural, agricultural, food, industrial, information);

11. The area of infection (contamination) in the event of an accident at the facility;

12. The population that could be affected in the event of an emergency at the facility;

13. Violations of life support cities and towns;

14. Massive violations of law and order;

15. Stopping continuous production;

16. Accidents and Disasters regional scale.

Critical infrastructure objects are divided by category repercussion on different areas and sectors: economy, finance, the environment, health and safety, technological environment, the duration of exposure.

Also criticality can be described by three general properties [7]: a critical proportion; critical time; critical quality.

The critical proportion includes aspects such as the number of items, assets, infrastructure nodes, number of clients served, number of service load and power of resources. Many sources are using criteria of influence such as number of victims, wounded, or economic loss. They all point to the same thing criterion, the critical part (fraction), expressed in different types of measuring impact.

Critical time summarizes all aspects related to time. These include the duration of the outage, the speed of adjustment, the average time to repair or restoring of functionality.

Critical Quality summarizes aspects such as the quality of the delivered services, and includes public confidence to the quality. The lack of quality or loss of consumer confidence in the product or service is one of the most important criteria for infrastructure.

All aspects of the criticality are pointing to the existence of a certain threshold; the overcoming of which is beginning to seriously effect the infrastructure system and other infrastructures or populations that are depends from it.

Many models and methodologies of critical infrastructure protection made considering available resources on the base of the criterion of "efficiency - cost". Most methodologies are include, in varying degrees, next elements [4]:

– Identifying important objects and identifying those of them that can be considered to critical infrastructures.

– Identification, description and assessment of threats;

– Assessment of the vulnerability of critical infrastructures from side of different specific classes of threats;

– Determine of the risk (i.e. the expected consequences of specific types of attacks on specific types of objects);

– Determining ways of reducing emerging risks;

– Determining of priorities in selecting measures to reduce risks on the base of own strategy.

Conclusions

Thus, in this work was carried overview of general criteria of identifying critical infrastructures in different countries. As result of analysis of regulations and scientific sources, in the approaches to the determination of the critical infrastructure of different countries, the key characteristics of critical infrastructures division by categories of importance and categories of consequences were detected and identified. Obtained results will be useful in future researches for developing sectoral criteria and methodologies of objects assignment to critical infrastructure.

References

1. International critical information infrastructure protection handbook 2008-2009 / Edited by A. Wenger, V. Mauer & M. Cavelty // Center for Security Studies, ETH Zurich, 2009.

2. On the identification and designation of European critical infrastructures and the assessment of the need to improve their protection: Council Directive 2008/114/EC [Електронний ресурс]. – Режим доступу: http://eur-lex.europa.eu.

3. National Critical Infrastructure Protection Programme adopted by the Council of Ministers[Електронний ресурс]. –Режим доступу: http://rcb.gov.pl/eng/?p=791

4. Цигичко В.Н., Смолян Г.Л., Черешкін Д.С. Забезпечення безпеки критичних інфраструктур в США. – 2006. – Т.27. – Труди ІСА РАН.

5. Бірюков Д.С. Стратегія захисту критичної інфраструктури в системі національної безпеки держави / Д.С. Бірюков, С.І. Кондратов // Стратегічні пріоритети. – 2012. – № 3 (24). – С. 107-113.

6. Гнатюк С.О. Критерії визначення елементів критичної інфраструктури держави / С.О. Гнатюк, В.М. Лядовська // «Інноваційний потенціал світової науки — XXI сторіччя»: матеріали XXIII всеукраїнської наук.-практ. конф., 10-15 грудня 2013 р. — Запоріжжя : Вид-во ПГА, 2013. — С. 55-57.

7. Fekete A. Common criteria for the assessment of critical infrastructures. International Journal of Disaster Risk Science. – 2011. – Vol.2. – №1. – P.15-24.

UDC 681.3.06 (045)

O.G. Korchenko, Prof Dr Eng (National Aviation University of Ukraine, Kyiv)
I.A. Terejkowski, PhD Assoc Prof (National Aviation University of Ukraine, Kyiv)

MODERN METHODS AND NEURAL NETWORK MODEL PARAMETER ESTIMATION OF INFORMATION SYSTEMS SECURITY

Analysis of modern methods and neural network models estimate the parameters of the security of information systems. Definitely their shortcomings. The ways of improvement.

In accordance with the results [2, 4], neural network methods and models for assessing the security settings of information systems (IS) is one of the basic directions of development of software modern information security systems. However, under the concept of IP security option we mean physical quantity characterizing associated with providing confidentiality, integrity and availability of information. Also note that a large number of false positives, and long term instability of training, lack of adaptation to the many features of the current state of IP significantly limit the practical value of these methods and models. So should urgently resolve the problem caused by the need on the one hand and prospects of using existing neural network recognition means, and on the other the lack of adaptability of modern methods and neural network models to the terms of use. Thus the **aim** of this work is to determine whether the modern methods and neural network models to the terms of use systems of information protection. In accordance with the specific purpose of works devoted to the analysis of the use of neural networks (NN) in mass recognition cyberattacks determine vulnerabilities and security settings management information systems. Here is a brief description of these works.

In [14] the method of determining the input parameters of neural network, designed to detect Dos-attacks on WiFi-networks that use standard protocols of IEEE 802.11. In applying the method provides a set of functions of the MAC level. The experimental study confirms the results of which improve the efficiency and accuracy of the neural network to recognize the attacks of the specified type.

[13] devoted to the use of additive neural network to recognize spam. We have promising applications of NN. The possibility of processing recognition results graphically.

In [11] The use of neural network to detect DDos-attack in the early stages of implementation. NN is used to determine the allowable transmission delay of packets in the network.

In [15] proposed a new methodology for training neural network designed to detect attacks on IP. Used NN enrolled by back propagation.

[12] devoted to the detection of malicious software by using neural network. A borrowed from bioinformatics method for determining the pieces of code that will be used as input parameters of NN.

Work [16] devoted to the development of Intrusion detection based on neural network adapted for training by back propagation. The results of the experiments confirm the effectiveness of the model in recognition of attacks signatures are presented in a KDD-99.

In [18] presented an approach intrusion detection type «SQL-injection" with NN. Proposed to consider the problem of determining malicious SQL-queries as a problem of time series prediction. Recurrent NN Elman’s and Jordan’s types was used. The results of experimental studies that were conducted on the basis of portal Php-Nuke, confirming the promise of the proposed approach.

In [17] examined the use of neural network to recognize butkitiv. Used NN from direct spread signal is trained by back propagation.

In [8] for solving the problem of detecting network attacks proposed to use a special binary NN that has two important properties: it is adapted to solve problems in which the input data is a complex multiply and fractal structure; teaching method is direct computational procedure and is not limited to finding a global extremum complex nonlinear function that does not impose any restrictions on the fundamental dimension of the problem. In this paper, there are no experimental data, which complicates comparative analysis.

In [4] considered an abstract mathematical model of DDoS-attacks (Distributed denial-of-service) such as SYN Flood and provides a method of identifying at an early stage, using mathematical tools of fuzzy NN. To formalize the expert knowledge about DDoS-attack was created five linguistic variables, each of which describes one of the components of the vector of parameters. Program with trained classifier showed good opportunity to detect SYN Flood-attack.

[10] devoted to research the possibilities of using hybrid neural structures like CounterPropagation to detect network attacks.

In [7] proposed a method for constructing cumulative IP traffic classifier for the classification of computer attacks. In the method used combining neural detectors, each of which is trained to recognize a particular type of attack. The detector is a three-layer NN, which the hidden layer as applied Kohonen network.

In [5] A method of constructing a model for training NN that is used to find networked computer attacks using software complex «Snort». Used multilayered perceptron. To optimize the structure used so-called "constructive algorithms", based on the method of dynamic allocation algorithm based on elements Barleta.

In [9] was established adaptive intrusion detection system based on teamwork Kohonen maps and multilayer perceptron performing the task of clustering and classification of data. Intrusion detection, which is carried out in several stages, made possible by the fact that in a database expert system paid in information about changes in the behavior of a particular item for some length of time. It is shown that the optimization of the architecture will improve the accuracy and efficiency of recognition. In [4] established a generalized model of computer attack and method of automatic detection for the monitoring of the behavior of distributed objects ICs and their interaction. Work aimed at improving the general theoretical approaches to detect network attacks and is somewhat an overview.

In [1] The process of recognition of network attacks using multilayer perceptron, Kohonen maps and radial basis function networks. Through numerical experiments determined that the best type of NN is Kohonen map. However, in the absence of a clear description of the optimization criterion and the experimental parameters NN cast doubt on the claimed results.

In the papers [2] to detect viruses is suggested to use the Kohonen map, which operates under the principles of artificial immune systems.

In [1] proposed methods for compressing feature space used in the NN to detect network attacks. The numerical experiments show that a positive result is to reduce the duration of NN learning process.

In [6] developed a method for determining the optimal type of architecture NN. Also, using numerical experiments, we prove that the optimization of the architecture will improve the accuracy and efficiency of recognition.

The analysis determined that the modern methods and neural network models may universally characterized by the following parameters:

P_1 - preprocessing of input parameters,
P_2 - optimization with one criterion of type of architecture,
P_3 - optimization with several criterions of type of architecture,
P_4 - optimization with one criterion architecture parameters,
P_5 - optimization with several criterions architecture parameters,
P_6 - optimization method of teaching,
P_7 - using of expert rules.

The values of the specified parameters exhibited by 3 point scale are given in Table 1. The parameter is -1 when not provided 0 - when provided indirectly and 1 - when provided directly.

Table 1

The values of the parameters characterizing neural network methods and models

Parameter / Source	P_1	P_2	P_3	P_4	P_5	P_6	P_7
[1]	1	0	-1	0	-1	-1	-1
[2]	0	1	0	0	-1	0	-1
[3]	0	0	-1	0	-1	-1	-1
[4]	0	-1	-1	-1	-1	0	-1
[5]	0	1	-1	0	-1	0	-1
[6]	0	0	-1	0	-1	0	-1
[7]	1	0	-1	-1	-1	-1	-1
[8]	1	0	-1	-1	-1	1	-1
[9]	1	0	0	0	0	1	-1
[10]	0	0	0	1	0	0	-1
[11]	1	0	-1	-1	-1	-1	-1
[12]	1	0	-1	-1	-1	-1	-1
[13]	1	1	0	-1	-1	-1	-1
[14]	1	0	0	-1	-1	-1	-1
[15]	0	-1	-1	-1	-1	1	-1
[16]	1	0	-1	0	-1	0	-1
[17]	-1	-1	-1	0	0	0	-1
[18]	1	1	0	1	0	-1	-1

Conclusions

Defined the parameters, the use of which allows us to estimate the main characteristics of modern neural network methods and models used in cyber attacks recognition systems, recognition of vulnerabilities and management of protective equipment.

References

1. Abramov E. S. Development and building Study methods of detection of attacks: dis. ... Candidate. Sc. sciences: 05.13.19 / E. Abramov Taganrog, 2005. 199 p.

2. Artyomenko A.V., Golovko V.A. Analysis of neural network pattern recognition methods of computer viruses / Materials breakout sessions. Youth Innovation Forum "Intro" - 2010. - Minsk: «BELISA", 2010. - 239.

3. Vasilyev V.I. Neural network detection of attacks on the Internet (for example, attack SYNFLOOD) / V.I. Vasiliev, A.F. Hafiz / / Neurocomputers in information and expert systems. - M.: Radio Engineering, 2007. P. 34 - 38.

4. Veselov V.V. Monitoring information system based on neural network technology / V.V. Veselov, O.A. Elmanov, I.N. Karels / / Neurocomputers in information and expert systems. - M.: Radio Engineering, 2007. P. 39 - 41.

5. Grishin A.V. Neural network technology in problems of detection of computer attacks / A.V. Grishin // Information technologies and computer systems - 2011. - № 1. - P. 53 -64.

6. Emelyanova Y. G. Analysis of problems and prospects for the creation of intelligent system to detect and prevent network attacks on cloud computing / Y. G. Emelyanova, V.P. Fralenko // Software Systems: Theory and Applications: electronic scientific journal - 2011. - № 4 (8). - P. 17-31. [Electronic resource]. URL: http://psta.psiras.ru/read/psta2011_4_17-31.pdf.

7. Komar M.P. The method of constructing classifier aggregate traffic information and telecommunication networks for hierarchical classification of computer attacks / M.P.Komar // System obrobki informatsiï. - 2012. - Preview Issue 3 (101), Volume 1 - P.134-138.

8. Magnitskii Y.N. Using binary neural network for intrusion detection resources distributed information systems / Y.N. Magnitsky // Dynamics of heterogeneous systems. - 2008. - P. 200-205.

9. Talalaev A. A. Development of the neural network module monitoring abnormal network activity / A. A. Talalaev, I.P. Tishchenko, V.P. Fralenko, V.M. Khachumov // Neurocomputers: development and application. - 2011. - № 7. - P. 32-38.

10. Hafiz A.F. Neural network intrusion detection system on WWW-server:

dis. ... Cand. tehn. Sciences: 05.13.11 / A.F. Hafiz-Ufa, 2004-172 c.

11. Chang-Lung Tsai, Chang A.Y., Huang Ming-Szu. Early Warning System for DDoS Attacking Based on Multilayer Deployment of Time Delay Neural Network // Intelligent Information Hiding and Multimedia Signal Processing, 2010, P. 704-707.

12. Chen Y., Narayanan A. , Shaoning Pang , Ban Tao. Multiple sequence alignment and artificial neuralnetworks for malicious software detection // Natural Computation, 2012, P. 261 – 265.

13. Du Toit T., Kruger H. Filtering spam e-mail with Generalized AdditiveNeural Networks// Information Security for South Africa. 2012., P.1-8.

14. El-Khatib K. Impact of Feature Reduction on the Efficiency of Wireless Intrusion Detection Systems // Parallel and Distributed Systems, IEEE Transactions on. – Volume:21, Issue: 8. – P. 1143 – 1149.

15. Jaiganesh V., Sumathi P., Mangayarkarasi S. An analysis of intrusion detection system using back propagation neural network // Snfjrmation Communication and Embedded Systems, 2013, P. 232 - 236.

16. Mukhopadhyay I., Chakraborty M., Chakrabarti S., Chatterjee T. Back propagation neural network approach toIntrusion Detection System // Recent Trends in Information Systems, 2011, P. 303-308.

17. Le-Tian Sha/Bootkit detection based on trusted computing andneural network // Management and Engineering, 2010, P. 117 – 121.

18. Skaruz J., Seredynski F. Recurrent neural networks towards detection of SQL attacks // Parallel and Distributed Processing Symposium, 2007, P. 1 – 8.

UDC 681.5:004.82(045)

Y. B. Artamonov, k.t.n.
(National Aviation University, Ukraine, Kiev)

SOFTWARE FOR AUTOMATED BOOKTEXT MANIPULATION

The basic concepts which have been used in the new program environment of texts editing "Intelligent book" were considered. The Primary goal of program environment is creation of electronic books with the content which automatically changes according to the level of information presentation depth. The basic mechanism of program work is settled on creation certain connections between text blocks, which allow to correct view of questions representation, which are revealed in the given text, automatically.

The problem of automated detection the text content is not new. For over than 30 years both separate scientists (Leont'eva N.M.) and scientific departments of number of institutes, primarily in Russia (The Institute of Linguistics of the Russian State Liberal University, The Institute of informatics problems of RAS, Russian SRI of Artificial Intelligence, The Kazan's state University [1] etc.) are engaged by this problem. The results of scientific researches became separate programmatic developments – Dialing, Politext, Galaxy-ZOOM, and even open-source projects (one of the most known is the Automatic text processing [2]).

But there is a task which has no decision until now – it is creation of adequate to the necessities of concrete user electronic variant of book product by the help of computer programs in the automatic mode. Even approaches to the decision of this scientific task are not enough formalized or take contradictory character until nowadays.

That, as soon as work reaches to recognition of text sense or even logical construction of connections between heterogeneous information in the book text, one have to use knowledge and ability of experts from the proper field of knowledge and bibliography. The necessity of personnel training, mediocre speed of information treatment, subjectivism, possibility of errors, and on the whole – a high cost of treatment the large volumes of text, does expedient development and use of software for automation of this process.

Exactly on crossing of these two directions – automatic text processing and development of bibliography-robot, – lies the idea of creation the software environment «Intelligent book».

The basic task of this software environment is creation of electronic books with content which automatically changes according to the level of information presentation depth. This product on nowadays design time needs «hand» tuning (what in course of time possibly will be transferable on automatic) and provides the performance of the followings objectives:

1. Creation of the book itself;

2. Determination of the complete plural of connections between the book's text and it' con-tent;

3. Filtration of the given information on the basis of the personal interest of user of questions which are lighted up in a book.

Conception of the «Intelligence book» software product construction

The given problem needs the decision of the followings two questions:

1) Correct fastening of text elements, what will allow to represent information both in a complete form and as an abstract; thus an abstract form must maximally pass the common content and, at a necessity, ex-pose the separate fragments of text, which can interest a reader;

2) Adjusting the flexible mechanism of watching the personal interest of reader, this will allow him to give the timely access to necessary information.

If the decision of the first question can be laid on the textbook author or group of experts which determine the richness of separate text elements content, the second question lies on the crossing of psychology and programming, where the basic task of programming is watching signs of the personal interest in text, among which are direct and sides signs.

The personal "interest" concept does not have a clear determination in psychology until now. There is a point of view, that attention is determined as an arbitrary or involuntary orientation and concentration of psychical activity on some object of perception. And this concentration does not appear in a "clean" kind.

Unlike cognitive processes (perception, memory, thought, etc.) attention does not have the special sense (determination); it appears as being inside of these processes and inseparably from them.

Basic properties of attention in this case are volume, concentration, firmness, oscillation, switching. The volume of attention is measured by the amount of objects which are perceived simultaneously. The objects incorporated according to their sense are perceived in a greater amount, than not incorporated. For the grown man the volume of attention is equal to 6-8 objects. Separately here distinguish involuntary and arbitrary attention [3].

First who made an attempt to expose the concept of attention from the mechanical point of view was Ribo in the motive theory of attention, and later this approach was developed in behaviorists and reflexologists. In this case attention is taken to the reflex options. The second attempt was related to the theory of Gestalt psychology and reduced the phenomenon of attention to the structures of the sensory field [7].

There can be no doubt that reflex options act substantial part in initial, most primitive forms of attention. It is well known that influence on the organism of some irritant usually cause organism to reflexly adapt to its best perception. Thus, for example, influence of sound on the ear-drum irritant cause a reflexive turn toward the source of sound. Obviously, that using this principle it is possible to watch and general signs of attention to the text for a reader. As basic elements for attention control were select:

1) Time of being on a page (only a middle area gets out, because a very rapid transition means absolute incuriosity, and large time of revision can mean the loss of the personal interest) is a basic parameter of control which relates to direct properties of attention. (In subsequent modifications of the system this parameter must change automatically, depending on the features of concrete user);

2) Motions of manipulator (for every reader there is a scenario of the interested transition – transition without the rapid returning on the page of content –

in which the set of motions enters by a manipulator during the revision of text). This parameter needs the special tuning on a user and relates to the second proper-ties of attention.

Technology of the correct text elements fastening

For the correct fastening of text elements, which will allow representing information both in a complete form and as an abstract, it was decided to present content of book text. There are three levels information presentations in the program. They are intended to grant the information to concrete user in the volume in which it is needed on the first stage of the personal interest.

The first level: it is a text without any reductions and treatments. This level is intended for use of readers who are only introduced the thematic of a book.

The second level: at this level the text of book passes certain processing (more detailed it is described below) which will allow the user with a shallow or middle knowledge of book subject to obtain most exact information, without a necessity to read what he already know.

The third level: information at this level passes the detailed treatment. User at this level has only a common picture of the book subject and requires just separate exact theorems and formulas without any explanations.

On each of these three levels it is necessary to give user the possibility of access to the searching sys-tem, which allows finding all necessary connections in a book, which could not get to the authors needed connections.

Inserting own semantic connections can be presented as a separate branch of the program development. But this mechanism will require not only grant permission for user to the management of semantic connections, but also requires creation of separate instrument for verification contradictory connections of absence.

Programmatic facilities of watching the personal interest by text contents

The question of watching personal interest of reader needs programmatic realization of such functions:

1) Control of time being on the page which automatically translates all elements of this page on the proper level of representation (also all elements of text, which are richly in content related to the elements of this page, get greater status);

2) Control of transitions between elements, which have rich in content copulas (this control requires the flexible extra charge of opening the separate text elements status marks);

3) Control of indirect user actions, such as manipulator moves, keys pressing, copying and insertion of text elements into other programs.

Obviously time have to be a basic control parameter, what reader outlays on an acquaintance with the text element. But even the book author cannot exactly present the expected time of reading the select group of text fragments.

That is why the next formula of nominal presentation time calculation of the group of selected for showing elements was selected as a standard measure:

$$T_N = \sum_{i=1}^{A}(K_i \cdot T_T) + \cdot T_F \cdot F + T_P \cdot P,$$

where T_N – is normative time for consideration of selected text fragment which consists of A indentions, F of formulas and P of pictures,

K_i – is amount of letters in an *i* indention,

T_T – is mean time on reading of single character,

T_F – is mean time on understanding of one formula,

T_T – is mean time for consideration of one picture.

For determination of mean values of T_T, T_F, T_T, which can be different for different users, is used program unit, at reading of text from screen, requires to push the button upon termination of reading, and at consideration of formulas and pictures – to answer question to them (time is taken into account only in the case of positive answers).

After determination of time, necessary for mastering of this text element, all elements related to him are opened for access and the additional opening marks begin to be counted for all connections of the first and second levels (after achieving the proper amount of total marks they also will open).

Thus user does not manipulate transitions from one level to other. But he gets possibilities to preliminary define the level of opening the text contents or specify on erroneous, according to his opinion, copulas.

As was said higher, user can get possibility of creation his own connections for adjusting of material opening procedure in obedience to own desires.

Conclusions

Potential of the use of similar software environment of books with internal semantic copulas is very high; in fact everyone would like to get necessary data quickly, without the considerable charges of time on an information retrieval, as in an ordinary book, and what is main – consistently.

Also a question of common acquaintance and receiving of the initial understanding of textbook or book content is important. Taking into account the large volume of information exactly the mode of acquaintance can be most used for work with materials of books in this software environment.

It is obviously expedient to consider possibility of application of this software product in the controlled from distance education at creation of electronic courses and books.

Certain application this program will also be able to get in works of bibliographies of scientific editions in matters of automation.

References

1. *Биряльцев Е.В.* Особенности лексико-семантической структуры наименований артефактов реляционных баз данных/ *Биряльцев Е.В., Гусенков А.М., Галимов М.Р.* // Тр. Казанской школы по компьютерной и когнитивной лингвистике TEL-2005, Казань: Изд-во Казан. гос. у-т, 2006, Вып.9. С.4-12.

2. Project of automated text process - www.aot.ru

3. *Вопросы* развития познавательных интересов учащихся в процессе обучения /Под общей ред. Д.К. Гилева.- Свердловск, 1970.–143с.

4. Світ психології - www.psychology.net.ru.

5. *Лингвистический процессор для сложных информационных систем* / Апресян Ю.Д., Богуславский И.М., Иомдин Л.Л. и др. - М: Наука, 1992. - 256 с.

UDC 004.78 (043.2)

I.F. Kashkevich, M.N. Duraid
(National Aviation University, Ukraine, Kiev)

ANALYSIS OF METHOD DEFENDS FROM DDOS ATTACK

In the article discusses methods for detecting and combating DDoS (Distributed Denial of Service) attacks.

A typical DDoS attack consists of amassing a large number of compromised hosts to send useless packets to jam a victim or its Internet connection or both. Internet has become the infrastructure of the modern society. The Internet architecture focuses on functionality and not the security. Inexperienced users leave their systems vulnerable to compromise. For example, using the vendor supplied default passwords, leaving auto-configure features in default settings, turning off firewalls, etc. makes it easy to gain root or administrator access.

And also very important here to guarding the net work by opening the firewalls with optimal plan by safely way to prevent Attack from another sites or hackers to avoid loss the important data in our Computers.

Distributed Denial of Service (DDoS) uses DoS as the basic building block. The main difference between DoS and DDoS attacks lies in its scale of attack and operation mode. This paper aims to provide an understanding of the existing

Attack methods: tools and defense mechanisms, so that a better understanding of DDoS attacks can be achieved. The goal of the paper is to simulate an environment by extending NS2, setting attacking topology and traffic, which can be used to evaluate and compare the methods of DDoS attacks and tools. Based on the simulation and evaluation results, more efficient and effective algorithms, techniques and procedures to combat these attacks may be developed.

One common method of attack involves saturating the target machine with external communications requests, so much so that it cannot respond to legitimate traffic or responds so slowly as to be rendered essentially unavailable. Such attacks usually lead to a server overload. In general terms, DoS attacks are implemented by either forcing the targeted computers to reset, or consuming its resources so that it can no longer provide its intended service or obstructing the communication media between the intended users and the victim so that they can no longer communicate adequately.

Denial-of-service attacks are considered violations of the Internet Architecture Board's Internet proper use policy, and also violate the acceptable use policies of virtually all Internet service providers. They also commonly constitute violations of the laws of individual nations.

The following are some proposed countermeasures that could apply to packet floods and congestion control exploits to detect, prevent, or counter attacks; a single defense could embody several mechanisms.

1. Path isolation – routers mark, sample or record packets to isolate traffic paths. Path information can be used to deploy filters on the path, or to perform fair sharing of resources.

2. Privileged customer – some customers obtain "passes" that allow privileged access to the critical resource, in form of capabilities, authorization to enter a dedicated overlay, knowledge of the server's identity, etc. A defense prioritizes traffic with "passes."

3. Traffic base lining – many traffic parameters are observed over time to learn their valid value ranges. During attacks, some parameter values will exceed their predicted range, which can be used to devise fine-grain filters or to isolate attack packets.

4. Resource multiplication – distributed resources are deployed (statically or dynamically) to sustain large attacks.

5. Legitimate traffic inflation – legitimate traffic is multiplied to enhance its Chances to win in the fight for the limited resource.

On the passive side, protect hosts from master and agent implants by using signatures and scanning procedures to detect them (essentially an IDS strategy).

Monitor network traffic for known attack messages sent between attackers and masters.

On the active side, employ cyber-informants and cyber-spies to intercept attack plans (e.g., a group of cooperating agents).

This line of defense alone is inadequate.

An after-the-fact response.

IP Trace back: Identifying actual source of packet without relying on source information.

– Routers can record information they have seen.

– Routers can send additional information about seen packets to their destinations.

– Infeasible to use IP Trace back.

– Cannot always trace packets' origins. (NATs and Firewalls!)

– IP Traceback also ineffective in reflector attacks.

– Nevertheless, it is at least a good idea and is helpful for post-attack law enforcement.

Performing DoS-attacks

A wide array of programs are used to launch DoS-attacks. Most of these programs are completely focused on performing DoS-attacks, while others are also true Packet injectors, thus able to perform other tasks as well. Such tools are intended for benign use, but they can also be utilized in launching attacks on victim networks.

Handling

Defensive responses to Denial of Service attacks typically involves the use of a combination of attack detection, traffic classification and response tools, aiming to block traffic that they identify as illegitimate and allow traffic that they identify as legitimate. A list of prevention and response tools is provided below:

Firewalls

Firewalls can be set up to have simple rules such to allow or deny protocols, ports or IP addresses. In the case of a simple attack coming from a small number of unusual IP addresses for instance, one could put up a simple rule to drop all incoming traffic from those attackers.

More complex attacks will however be hard to block with simple rules: for example, if there is an ongoing attack on port 80 (web service), it is not possible to drop all incoming traffic on this port because doing so will prevent the server from serving legitimate traffic. Additionally, firewalls may be too deep in the network hierarchy. Routers may be affected before the traffic gets to the firewall. Nonetheless, firewalls can effectively prevent users from launching simple flooding type attacks from machines behind the firewall.

Some stateful firewalls, like OpenBSD's pf packet filter, can act as a proxy for connections: the handshake is validated (with the client) instead of simply forwarding the packet to the destination. It is available for other BSDs as well. In that context, it is called "synproxy".

Switches

Most switches have some rate-limiting and ACL capability. Some switches provide automatic and/or system-wide rate limiting, traffic shaping, delayed binding (TCP splicing), deep packet inspection and Bogon filtering (bogus IP filtering) to detect and remediate denial of service attacks through automatic rate filtering and WAN Link failover and balancing.

These schemes will work as long as the DoS attacks are something that can be prevented by using them. For example SYN flood can be prevented using delayed binding or TCP splicing. Similarly content based DoS may be prevented using deep packet inspection. Attacks originating from dark addresses or going to dark addresses can be prevented using Bogon filtering. Automatic rate filtering can work as long as you have set rate-thresholds correctly and granularly. Wan-link failover will work as long as both links have DoS/DDoS prevention mechanism.

Routers

Similar to switches, routers have some rate-limiting and ACL capability. They, too, are manually set. Most routers can be easily overwhelmed under a DoS attack. Cisco IOS has features that prevent flooding, i.e. example settings.

Application front end hardware

Application front end hardware is intelligent hardware placed on the network before traffic reaches the servers. It can be used on networks in conjunction with routers and switches. Application front end hardware analyzes data packets as they enter the system, and then identifies them as priority, regular, or dangerous. There are more than 25 bandwidth management vendors.

IPS based prevention

Intrusion-prevention systems (IPS) are effective if the attacks have signatures associated with them. However, the trend among the attacks is to have legitimate content but bad intent. Intrusion-prevention systems which work on content recognition cannot block behavior-based DoS attacks.

An ASIC based IPS may detect and block denial of service attacks because they have the processing power and the granularity to analyze the attacks and act like a circuit breaker in an automated way.

A rate-based IPS (RBIPS) must analyze traffic granularly and continuously monitor the traffic pattern and determine if there is traffic anomaly. It must let the legitimate traffic flow while blocking the DoS attack traffic.

DDS based defense

More focused on the problem than IPS, a DoS Defense System (DDS) is able to block connection-based DoS attacks and those with legitimate content but bad intent. A DDS can also address both protocol attacks (such as Teardrop and Ping of death) and rate-based attacks (such as ICMP floods and SYN floods).

Like IPS, a purpose-built system, such as the well-known Radware DefensePro, can detect and block denial of service attacks at much nearer line speed than a software based system.

Blackholing and sinkholing

With blackholing, all the traffic to the attacked DNS or IP address is sent to a "black hole" (null interface or a non-existent server). To be more efficient and avoid affecting network connectivity, it can be managed by the ISP.

Sinkholing routes traffic to a valid IP address which analyzes traffic and rejects bad packets. Sinkholing is not efficient for most severe attacks.

Clean pipes

All traffic is passed through a "cleaning center" or a "scrubbing center" via various methods such as proxies, tunnels or even direct circuits, which separates "bad" traffic (DDoS and also other common internet attacks) and only sends good traffic beyond to the server. The provider needs central connectivity to the Internet to manage this kind of service unless they happen to be located within the same facility as the "cleaning center" or "scrubbing center".

Conclusion

Internet has not significantly changed in recent years. Network resources remain limited and susceptible to consumption attacks, and systems still contain vulnerabilities, new and old, that either remain un-patched or are patched in a less than timely manner. Internet management is distributed, and each network is run.

Attack Detection and Filtering by two phases:

1) DDoS Attack Detection: Identifying DDoS attack packets.

2) Attack Packet Filtering: Classifying those packets and dropping them. (Overall performance depends on effectiveness of both phases.)

Effectiveness of Detection:

a) FPR (False Positive Ratio): No. of false positives/Total number of confirmed normal packets

b) FNR (False Negative Ratio): No. of false negatives/Total number of confirmed attack packets

And must be know that both metrics should be low!

References

1. Shabtai, A.; Fledel, Y.; Kanonov, U.; Elovici, Y.; Dolev, S.; Glezer, C. (March–April 2010). "Google Android: A Comprehensive Security Assessment". IEEE Security & Privacy Magazine 8 (2): 35–44. doi:10.1109/MSP.2010.2

2. "DDoS: A Threat That's More Common Than You Think". Tatacommunications.com. 2011-09-07.

UDC 519.872 (075)

O.M. Dyshliuk, k.p.-m.s.
(National Aviation University, Ukraine, Kiev)

MODEL WIRELESS NETWORKS AS A QUEUEING SYSTEM WITH FLOW OF DEMANDS OF A COMPLEX STRUCTURE

The features of the capacity of wireless networks are studied. A problem of queueing system with a complex arrival process in systems of random complex calls is considered. The conditions for equivalent replacement of a system with complex calls with a system with simple calls have been found.

Wireless networks have been immediately implemented into our everyday life and took their sound position in network infrastructure of enterprises and organizations. Depending on the range of action and communication provided, all wireless networks can be divided into the following categories: wireless personal area networks, local area wireless networks, wireless metropolitan area networks and wireless wide area networks. Such networks use radio-frequency and light signals, which transmit information through air.

Considering the features of wireless networks, we indicate their capacity as a significant feature, which reflects their performance and efficiency. For example, analyzing the features of the capacity of wireless wide area networks (WiMAX), we can draw a conclusion about complex structure of the request, which comes to service [1]. Thus, in models of assessing the capacity of a wireless channel, the request, in contrast to the classical queuing theory, has a complicated structure. It consists of separate parts and each requires an appropriate service. Such multiplicity of servicing requests is typical of the processes of service in wireless networks at the expense of the discontinuity of signals coming through a wireless channel and transmission of the information from the source to the receiver.

Operation of a wireless interface in its access to network is complicated, as unsteady features of wireless channel increase significantly the values of delay and error probability in packet transmission. In wireless networks with such requests there might be different radio-frequency interferences, while servicing different parts of the same request. However, the process of modeling such system, is much more complicated than in the case of simple requests. could a system with complex requests be replaced by the equivalent one with a simple requests in the sense of some criteria? that the equivalent change is possible with the implementation of the corresponding condition of temporary separation of requests. This greatly simplifies the modeling algorithm.

Every queueing system in abstract representation is a random operator, which converts the incoming arrivals in some function of time, which characterizes the queueing system work.

Let us denote $X(t)$ the number of requests, received by the system at the interval $(0,t)$ for $t>0$ and minus the number of requests at the interval $(t,0)$ for $t\le 0$. Suppose, for example, $W(t)$ is a virtual waiting time at the moment *t* (i.e., if at the time t an imaginary request enters, then its waiting time is equal to $W(t)$). As a result, $W(t) = A_t[X(s), -\infty < s \le t]$. Here A_t is an operator, which transforms one function to another (or more precisely, the value of this second function at the moment t). This is a random operator, since $W(t)$ does not depend only upon the flow, but also upon the service time of the requests received.

Let us give a mathematical definition. Suppose we have queueing system, characterized by the process $W(t)$ (this is not necessarily waiting time), as an operator of the arrival $X(t)$.

Let us denote $L_X[W(t)]$ the distribution law *W(t)* (i.e., the set of finite-dimensional distributions) of the random process $W(t)$ for the given trajectory of the process $X(t)$.

Definition 1. Queueing system will be called as a system with the τ-renewal pulses , if for any trajectories $X_1(t)$ and $X_2(t)$ of the process $X(t)$, coinciding for $t_0 - \tau \le t \le t_1$, the equality $L_{X_1}[W(t)] = L_{X_2}[W(t)]$ takes place for finite-dimensional distributions, related to the values of the process $W(t)$ at the interval $t_0 \le t \le t_1$.

As an example, let us consider the system of the type *G*/*G*/*n*/0 with an inverted order of service and the displacement of requests. One has the arrival and service time distribution of the most general form. Requests waiting is not allowed. Suppose, that at some moment t a request arrived, and $n(t) = n$, i.e., all the channels are busy. Then the new request displaces the request, that has come before everyone else, and takes its channel, and that one gets a refusal. This order of service is typical for some information processing systems: "fresh" information is more valuable than the earlier one. Assume, that equality $L_{X_1}[W(t)] = L_{X_2}[W(t)]$ is fulfilled. Then it also will be queueing system with the τ-renewal pulses ; at the moment t_0 only those requests are served, which received after $t_0 - \tau$, but nothing depends upon the rest ones.

Definition 2. Queueing system, which is not queueing system with the τ-renewal pulses , no matter what $\tau > 0$ is, will be called queueing system with the τ -unrenewal pulses.

The definition of the system with the τ-renewal pulses itself suggests that operating such systems is much simpler, since at the limited interval (of the length of τ) only a finite number of events can occur. But the question arises: what is the reserve of systems with this property? There are many such systems and among them interesting for the practice systems of information processing. Here are some examples.

Let us consider queueing system of the type *G*/*G*/∞. The system has an infinite number of channels, the arrival $X(t)$ and service time distribution of the most general form.

Let us denote $B(t)$ the distribution function of service time of one request and assume, that $B(\tau) = 1$. The described system fits our definition, if instead of

$W(t)$, $n(t)$ — the number of busy channels at the moment *t,* will be taken. On the basis of $L_{X_1}[W(t)] = L_{X_2}[W(t)]$, it is obvious that on the interval $[t_0, t_1]$ there are no longer those requests, that have been received before the moment $t_0 - \tau$.

A similar ground can be given for a system of the type *G/G/∞* with the limited time of residence of requests in it, suggesting that this time is permanent or occasional, but does not exceed x.

Let us introduce the concept of the τ-equivalence of flows.

Definition 3. Two pulse flows, finite-dimensional distributions of which coincide on the intervals of the length not more than x, will be called the τ-equivalent.

Let us formulate the theorem about the τ-equivalence of the flow of multiple pulses and flow of single pulses.

Theorem 1. Let X be a Poisson steady flow of multiple pulses with the parameter λ. In every multiple pulse there is a random number ν of single pulses with the finite mathematical expectation $\overline{\nu}$. Single pulses, which enter one multiple pulse, begin in intervals, greater than $\tau + \tau_1$, and the lifetime of any single pulse is not larger than τ_1.

Under these conditions, the flow X is τ-equivalent to a Poisson flow of single pulses with the parameter $\lambda\overline{\nu}$. The distribution function $B(t)$ of the pulse length of equivalent flow is connected with the characteristics of the initial flow X by the following formula: $B(t) = \frac{1}{\overline{\nu}} \sum_{\nu=1}^{\infty} p_\nu \left(B_{\nu 1}(t) + B_{\nu 2}(t) + \ldots + B_{\nu\nu}(t)\right)$, where p_ν is probability of partial value ν, $B_{\nu k}(t)$ is a distribution function of the k-th single pulse in the multiple pulse, which includes ν single pulses.

Conclusions

The question of statistical modeling of the functioning of queueing system with complex arrival process is investigated. The conditions for equivalent replacement of a system with complex calls with a system with simple calls have been found. The results enable significantly to simplify the simulation algorithm of the operation and analysis of a complex system.

References

1. Shahnovich I., The network architecture WiMAX: basic principles and elements, *Pervaia milya*, 2009, No. 1.

2. Koba E.V., Dyshlyuk O.N. Renewal type queues with a complex arrival process, *Journal of Automation and Information Sciences*, No. 42(8), 48-55.

3. Koba E.V., Dyshlyuk O.N., Estimating the overlapping probability for complex demands in queuing systems, *Kibernetika i sistemnyi analiz*, 2010, No. 3, 175-180.

UDC 004.7(045)

Y.B. Artamonov, O.O. Zholdakov, G.N. Kremenetskiy
(National Aviation University, Ukraine, Kiev)

COMPUTER APPLIANCE IMPLEMENTATION OF LOAD DISTRIBUTION IN NEURAL-LIKE SYSTEMS

This article is devoted to actual problems of a computer appliance implementation of neural-like systems in the context of specialized computer networks. The article proposes the expansion of the minimal interaction zone in the surface layer with gradual clustering – froth-method. The method considered in growing networks, using the algorithms of cellular structures and the growing neural gas.

Introduction.

The problem of neural-like systems development is not one decade. Special note this approach deserves in the context of special computer systems development that are designed and operate based on the rules and methods of artificial neural networks. The need for computer appliance implementation of neuron-like systems is caused by the low performance of software implementation and the absence of specialized hardware solutions [1-3].

For tasks, that require a minimum time of the decision, implementation on programmable logic integrated circuits (PLIC) and move to the release of neurochips leads to significant increase of the system performance.

The aim of this article is to present the principles of the computer appliance implementation of the neural-like systems on PLIC using Java Hardware Development Languege (JHDL)

The design of the neural computing systems.

It is expedient to use JHDL for the of neuron-like systems design. The development process using JHDL consists of the following stages: description of the device on Java using JHDL classes; compiling device classes using the standard Java compiler; debugging and simulation device in a Dynamic Test Bench (DTB); generating device descriptions in Electronic Design Interface Format (EDIF); EDIF conversion to firmware bitstream using software manufacturer PLIC (for Xilinx can be Alliance or Foundation)

When developing PLIC, you can use existing modules: drives, multipliers, counters, delay lines, decoders, multiplexers, dividers, comparators, adders, etc.

Hierarchical implementation of devices is possible due to a matrix structure PLIC, consisting of configurable logic blocks (CLB), as elementary cells .

Creation of the scheme of the neural network starts with the mathematical description and schematic diagram of the main cell – formal neuron (FN) (Fig. 1) [3]

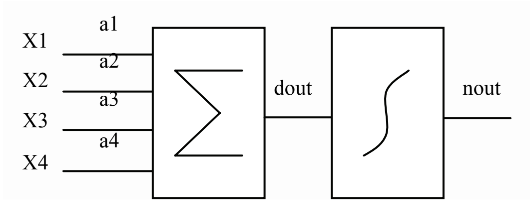


Fig. 1. Schematic representation of the formal neuron

Or mathematically:

$$dout = \sum_{i=1}^{4} a_i X_i \ , \tag{1}$$

$$nout = f(dout), \tag{2}$$

the expression (1) is the transformation of inputs TN, (2) is the transfer function FN.

In DTB expression (1) is as follows (Fig. 2).

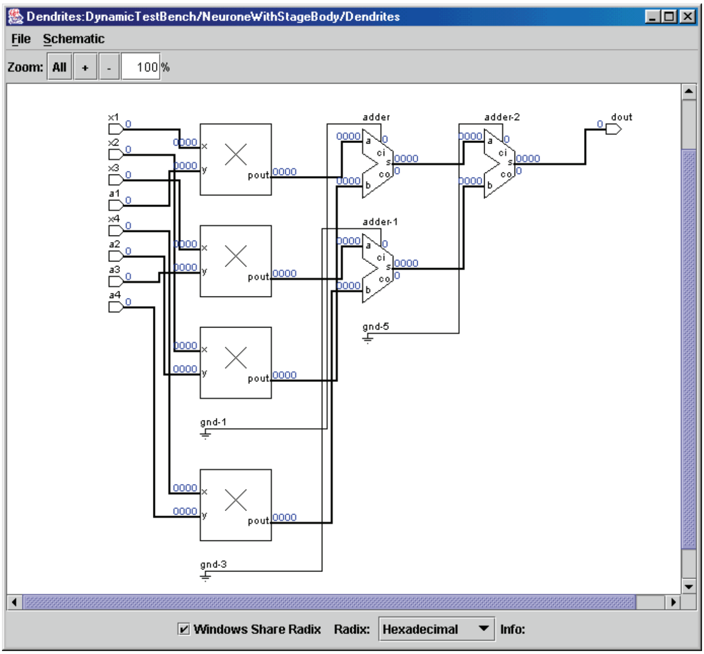


Fig. 2. The scheme of transformation of inputs TN presented in DTB

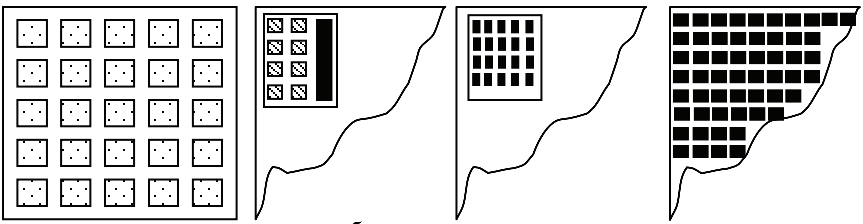
For the design of very large scale integrated circuits (VLSIC) of neurochips it is advisable to use a package system modeling System View of the Elanix company. Using this system is being worked full structural scheme of the system at the algorithmic level, are calculated for a variety of temporal and spectral characteristics; noise immunity is analised, taking into account characteristics of the real distribution of signals, depending on the type of the designed system.

Given matrix structure PLIC, consisting of configurable logic blocks (CLB), both of elementary cells on a chip, you can build a hierarchical blocks of higher levels of organization, such as adders, consisting of CLB. On the basis of adders then formed multipliers of multipliers – individual neurons and neuronal built fragments of the neural network. The principle of forming a hierarchical fragment of a neural network is illustrated in figure 3.

Initial array of elementary CLB allows on the basis of available libraries arithmetic units (adders, multipliers, Comparators and, ultimately, neurons) create a more complex structure with a high degree of parallelism of computational process and an extremely high performance due to the use of multi-level pipelining.

Using the PLIC to build the neural computer network

Programmable logic integrated circuits XILINX on a single chip enable you to build a rather large number of multipliers running simultaneously on a large frequency (up to 166 MHz).



а б в г

Fig. 3 Principle of the creation of neural network fragment on a XILINX PLIC: **а** – fragment of a neural network on a XILINX PLIC (– one neuron); **б** – the topology of a single neuron-on-chip PLIC XILINX (- multiplier); **в** – topology of a single multiplier on-chip PLIC XILINX (- parallel adder); **г** – topology of a parallel adder-on-chip PLIC XILINX (- CLB)

If we combine a large number of external conclusions PLIC, developed structure of high-speed interconnects, increased rate of exchange between crystals (200 MHz), it allows to create on the basis of PLIS finished fairly regular fragment of a neural network, and then, implementing cascading PLIC simple connection specified for hardware cascading conclusions, to build the national Assembly of any configuration and complexity.

On one PLIC chip, you can create a fully integrated neural system functioning as a whole, or part of a neural network with broad opportunities cascading. For the design of the national Assembly on the basis of PLIC Xilinx there are several stages (Fig. 4).

On the basis of the available libraries, which includes such parts as multipliers of various performance, capacity, structures, adders arbitrary capacity, implementation of various functions of activation and, ultimately, the neurons of different architecture and performance, you can build the regular segment of the neural network, for example, part of the layer with a fixed dimension of the vector of input parameters.

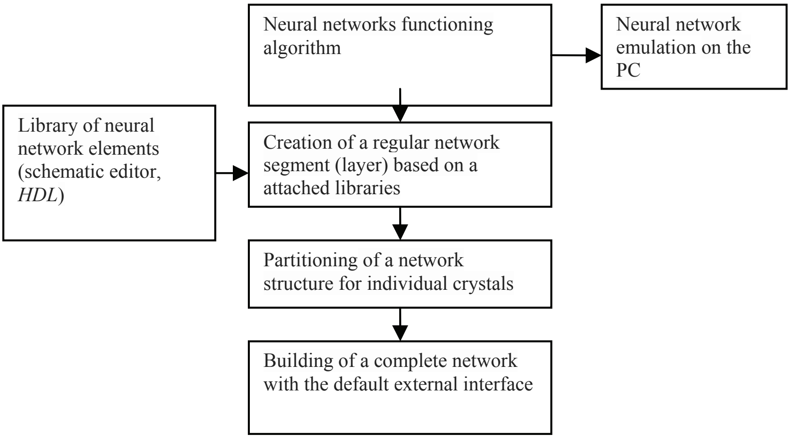


Fig. 4. The sequential stages of creation of a neural network on a *Xilinx* PLIC

The next step is based on the known dimensions of a network to make the layout of individual segments on PLIC chips (choice PLIC is determined by the required performance, cost, ability cascading etc) and to determine the interconnect. Here it is necessary to determine the structure of the controller that controls the process of learning network (in the General case it can be distributed in all PLIC) and the General process of loading and unloading data and standard network interface with external devices.

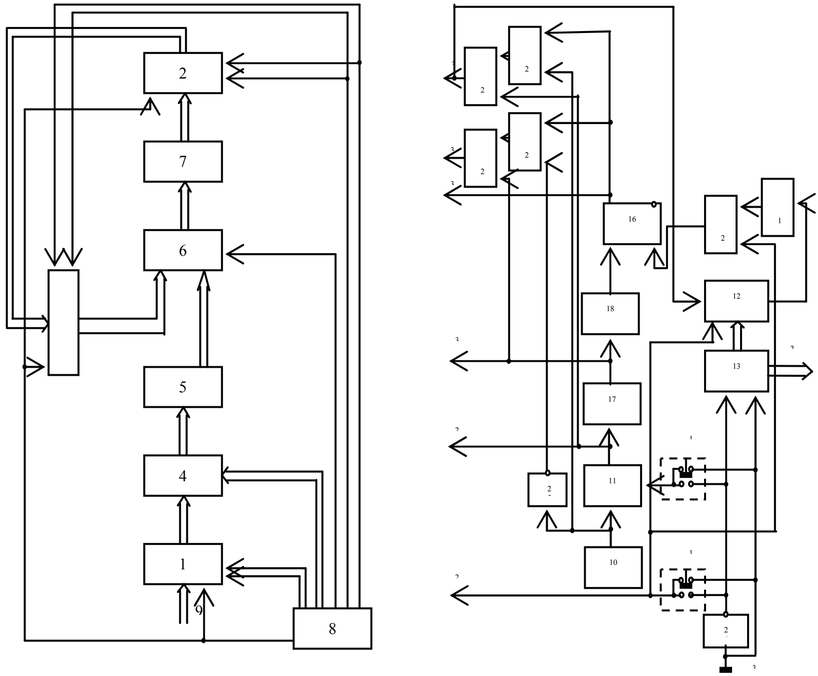
Hardware implementation of the compute the exponential function

To improve computing performance of neuron activation function like

$$OUT = \frac{1}{1+e^{-NET}}$$

where NET is the signal, which is fed to the input neuron, OUT - the output signal has been proposed algorithm, and submitted the application for the invention of a device calculate the exponential function.

In Fig. 5,a presents the structural scheme of the device for calculating the exponential function, as in Fig. 5,b - control unit.



a b

Fig. 5. The structural scheme of the hardware implementation of computing the exponential function: a - device computing, b - control unit

The device for calculating the exponential function works in the following way. The initial state of the device is determined by 14 key, that can be made in the form of push-button, 8th management unit. A signal is a logical zero tyres 34 block 8 management generates signal logical units at the entrance of the item HE 26, key 14 and the first output 27 block 8 of management, which comes on the installation inputs registers 1-3, setting them to zero status. The output signal of the item HE 26 through key 14 enters through the element OR 22 on the reset input trigger 16, setting it to zero state.

The algorithm of the device work is described by the following expression

$$y = e^{-x} \approx (1 - 2^{-m} x)^{2^m}, \qquad (6)$$

where ‘x’ is the value of the argument, ‘m’ is given as an integer constant.

The constant ‘m’ is selected in accordance with the required accuracy of calculation of the exponential function y(x) on the interval changes arguments [0; 1].

Program implementation of a load balancing method

Program implementation of load distribution method consists of several parts: a server, the agents and client modules. Software modules are implemented in the Java 1.4 programming environment, so you can use them on many hardware platforms on many operating systems: Windows (2000, XP, 7), Linux, Unix, MacOS, BeOS. This provides an opportunity to organize calculations in the network with a variety of equipment [2].

Software implementation operates as follows. Through certain intervals from each computing node, the agent sends a UDP packet to the server with information about the load. The latest information is stored on the server. If the client needs to perform some task, it sends a set of specific parameters of this task on the server. The server takes this set to the input of the neural network and sends information about the load, which were received from the agent of the computer. This process is repeated for i=1..N, where 'N' is the number of computers in the network. Output network received the predicted time of the task for each of N computers, select the lowest value of time, and send the number of the computer, as well as the unique number of tasks to the client. After receiving information from the server, the client sends a challenge to the specified computer. Upon completion of the task the computer on which it is executed, sends a packet with the received number of tasks and data on the time of execution. The server performs a cycle of training of neural networks with the use of these data.

Communication between modules is organized using Fast Ethernet 1 (physical) and 2 (channel) layers of the OSI model, IP 3 (network) TCP and UDP 4 (transport). This allows to use the developed modules in the Internet.

Special agents gather information about the load of computer. The main component of the agent package is ua.kiev.geos.LoadMeter. This package has classes that are responsible for the loading of the agent, perform the procedures of collection, and respond to requests of the server about a load. The interaction between the server and the agent is using TCP/IP. The server sends an XML document to the agent that processes the document, and sends the response as an XML document. The request has the following form:

<REQUEST><LOAD ID=”1’ CLASS=”ua.com.cadis_east.LoadMeter.CCPUmeter”/>
<LOAD ID=”2” CLASS=”ua.com.cadis_east.LoadMeter.CRAMmeter”/>
<LOAD ID=”3” CLASS=”ua.com.cadis_east.LoadMeter.CNETmeter” DestAddress=”193.108.121.35”/></REQUEST>

Solving limitations of neural network computing power

The problem of limited computing power can be solved by parallelization, but it is necessary to solve two problems:

1) the spatial organization of the neural network - that is how to distribute the neurons between the compute nodes while minimizing traffic;

2) the choice of learning algorithms and transfer functions for the cluster.

Also there are limitations in speed of communication channels [5]. Therefore, the main task is to solve the question of how to divide (cluster) the specialized computer network and minimize the data flows between clusters.

Adapted algorithm split multi-layer neural network with the possibility dynamic host clustering.

For an explanation of the approach to the construction of algorithm for separation of the neural network, which is caused by the limitations or speed channels, or the capacity of the nodes and provides dynamic host clustering computer network, on the basis of which created a neural network. Consider the example of foam on boiling milk.

Boil milk is rapid and transient in connection with the contents couple of bubbles under the mammary film. After the break through film milk foam fills all space and cascades on, forming a related substance.

Based on the above example boiling milk with the formation of the milk foam introduced a new name for this method - froth-method (froth - eng. 1) foam, 2) foaming; boil) [5].

Consider two algorithms that will be used in the froth-method of the network partitioning:

1) Adapted to the multi-layer neural network algorithm growth;

2) the Algorithm of monitoring restrictions and migration sites in froth-method

Algorithm growth adapted to the multi-layer neural network

1. Will train the existing sample. If the error is above an acceptable level, then go to p. 2, otherwise to complete the algorithm.
2. Search in a network neuron q with the greatest mistake

$$q = \arg\max_{c \in A} E_c\ .$$

3. Add to this layer node r.
4. Add link between r and neighboring q.
5. If the there is a connection in network (a, b), the weight of which exceeds the specified value ‘wmax’, add a new layer ‘lc’ between layers ‘la’ and ‘lb’ so that each node in ‘lb’ answered site in a new layer ‘lc’.
6. Add link between ‘la’ and new ‘lc’ layer so that the nodes in the new layer have the same regard, as appropriate nodes ‘lb’.
7. Add link between the new layer and ‘lb’ so that nodes descendants ‘lb’ had connections with hosts ‘lb’.
8. Add link between the new layer and ‘lb’ so that the nodes are heirs of nodes with minimal error had connections with other nodes layer ‘lb’ with a fairly small error.
9. Remove connection with coefficients less certain wmin .
10. If the number of iterations less than set, return to paragraph 1.

The algorithm of monitoring restrictions and migration nodes in froth-method

1. If $L^{c_i} \geq L^{Nd_k}$ or $V^{r_{ij}} \geq V^{Ch_l}$, go to p. 2, otherwise exit.
2. Select the layer with the highest level of growth l_y:

$$l_y = \arg\min[avg(A)], A\{age_l\}, \forall l = 1..L.$$

3. Choose the most active areas of growth in the layer j_y:

$$j_y = \arg\min[avg(A)], A\{age_{lj}\}, \forall j = 1..J$$

4. Form clusters, which is limited to the selected nodes:

$$C_k = \{n_{ij}\}, \forall i = l_y..L, \forall j = j_{y-1}..j_y$$

5. Set neural network adapters [4].

6. Roaming clusters in available computing nodes with free communication channels Nd_k.

Conclusions

In this article computer appliance implementation of load balancing in parallel computation networks was developed. It differs from the known models of the neural networks that allows distributing the load in parallel computation networks with less error of the task.

During the program implementation of this approach class library created: for computing the input values of the neuron, symmetric linear activation function, symmetric rigid step hyperbolic tangent, neural network training and classes that implement the proposed algorithm.

Developed protocols for communication between servers that collect data about the tasks and the load of computational nodes, and server load balancing.

For solving problems of separation of the specialized computer network and minimize data flows between clusters in case of the network growth, froth- method of dynamic growth area network is used.

References

1. V. Shirochin 'Architectonics of thinking and neurointellect'. – K.: Publisher Junior, 2004. – p. 560.

2. O. Palagin, V. Opanasenko, V.Saharin 'Verification systems based on reconfgurable devices // Mathematical machines and systems. – 2004. – № 2. – p. 100 – 113.

3. V. Kruglov, V.Borisov 'Artificial neural network. Theory and practice'. – 2 publication. – M: Hot line-Telecom, 2002. – p. 382

4. Clustering in modular neural networks / H. Kremenetskyi // Journal of computational and applied mathematics. – C,- №3(99). – p. 57-62.

UDC 519.6:532.516.5 (043.2)

Glazok O.M., c.t.s. (National Aviation University, Ukraine, Kyiv)

COMPUTATIONAL MATHEMATICAL METHOD OF FLUID DYNAMICS PROBLEMS SOLVING

A mathematical method of solving of systems of nonlinear equations, produced by the numeral model of hydrodynamic problem, is offered. For the difference scheme on a rectangular calculation mesh it is suggested to utilize the iteration-based method of solving, based on the construction of auxiliary target function, the value of which characterizes the norm of discrepancy of the system.

Software applications and packages which perform various types of hydrodynamic calculations are widely utilized in modern scientific and design practice. For research of turbulent motion of liquids and gases, modern software complexes of hydrodynamic calculation are equipped with the sets of models of turbulence of different levels of complication [1].

Modern approaches for mathematical modeling of laminary turbulent and flows are mainly based on the supposition about acceptability of the Navier-Stokes equations description of flows and prognostication of their characteristics. (For turbulent flows statistical properties of flows ensembles, at identical from the macroscopic point of view external conditions, are examined). Numerous researches have been performed, – for example, described in the sources [2, 3], – which, in the opinion of their authors, confirm the supposition about adequacy of this model.

Direct Numerical Simulation (DNS), Large Eddy Simulation (LES), Reynolds-averaged Navier-Stokes (RANS) and some derived methods are the most common methods of hydrodinamic numerical simulation. There are also combined approaches, which combine those or other features of the DNS, RANS and LES, for example, the Detached Eddy Simulation method (DES).

Direct Numerical Simulation includes solution of complete Navier-Stokes equations, that allows to get instantaneous characteristics of a turbulent flow. In addition, statistics, got as a result of DNS performing, can be utilized for development and research of models of processes of turbulent transfer, development of methods for controlling turbulent streams, and others like that [4, 5].

Because of the limited possibilities of measuring technique, DNS can be used as an additional source of experimental data; for example, at research of such characteristics of flow as pulsations, pressure, vorticity, speed of dissipation of turbulent energy, and also for visualization of instantaneous picture of flow.

Obstacles to the wide use of methods of numeral modeling in practice are related to contradiction between high requirements to the calculation schemes and descriptions of initial and boundary conditions, on one side, and limited computing resources, on the other side. Solving typical modern engineering problems that include aero- and hydrodynamics calculation require the months of work of computer clusters. Application of such methods, as RANS, LES et al, allows to shorten the volume of calculations to a certain extent, in comparison with DNS, but yet does not lead to the ultimate solution of the problem.

Thus, development of such methods and approaches to the solution of the mentioned tasks which would allow to decrease the amount of necessary calculations is the actual scientific problem.

Let us consider a two-dimensional hydrodynamic task, described with the Navier-Stokes equations of the following form:

$$\frac{\partial U_x}{dt}+\frac{\partial}{\partial x}(U_xU_x)+\frac{\partial}{\partial y}(U_yU_x) =-\frac{1}{\rho}\frac{\partial P}{\partial x}+v\left(\frac{\partial^2 U_x}{\partial x^2}+\frac{\partial^2 U_x}{\partial y^2}\right); \tag{1}$$

$$\frac{\partial U_y}{dt}+\frac{\partial}{\partial x}(U_xU_y)+\frac{\partial}{\partial y}(U_yU_y) =-\frac{1}{\rho}\frac{\partial P}{\partial y}+v\left(\frac{\partial^2 U_y}{\partial x^2}+\frac{\partial^2 U_y}{\partial y^2}\right); \tag{2}$$

$$\frac{\partial U_x}{\partial x}+\frac{\partial U_y}{\partial y}=0\,, \tag{3}$$

where $U_x = U_x(x,y)$ and $U_y = Uy(x,y)$ are components of the velocity vector along the *x* and *y* coordinates, accordingly; $P = P(x,y)$ is pressure; v is the viscosity of the liquid; ρ is the density of the liquid.

For the compactness of record, let us introduce the denotations:

$$U_x(x,y)=f(x,y);\quad U_y(x.y)=g(x,y)\,. \tag{4}$$

Taking into account the denotations (4), let us write down the difference scheme for the system (1) – (3) on a rectangular mesh:

$$2f_{i,j}\frac{f_{i+1,j}-f_{i,j}}{\Delta_x}+g_{i,j}\frac{f_{i,j+1}-f_{i,j}}{\Delta_y}+f_{i,j}\frac{g_{i,j+1}-g_{i,j}}{\Delta_y}+\frac{1}{\rho}\frac{P_{i+1,j}-P_{i,j}}{\Delta_x}-$$
$$-v\frac{f_{i+1,j}-2f_{i,j}+f_{i-1,j}}{\Delta_x{}^2}-v\frac{f_{i,j+1}-2f_{i,j}+f_{i,j-1}}{\Delta_y{}^2}=0\ ; \tag{5}$$

$$g_{i,j}\frac{f_{i+1,j}-f_{i,j}}{\Delta_x}+f_{i,j}\frac{g_{i+1,j}-g_{i,j}}{\Delta_x}+2g_{i,j}\frac{g_{i,j+1}-g_{i,j}}{\Delta_y}+\frac{1}{\rho}\frac{P_{i+1,j}-P_{i,j}}{\Delta_x}-$$
$$-v\frac{g_{i+1,j}-2g_{i,j}+g_{i-1,j}}{\Delta_x{}^2}-v\frac{g_{i,j+1}-2g_{i,j}+g_{i,j-1}}{\Delta_y{}^2}=0\ ; \tag{6}$$

$$\frac{f_{i+1,j}-f_{i,j}}{\Delta_x}+\frac{g_{i,j+1}-g_{i,j}}{\Delta_y}=0\ , \tag{7}$$

where $f_{i.j}$, $g_{i,j}$, $P_{i,j}$ are values of the functions $f(x,y)$, $g(x,y)$, $P(x,y)$ in the point of calculation mesh under the number (i,j) ; Δ_x and Δ_y are the steps of calculation mesh along the coordinates *x* and *y* accordingly. In equations of the system (5)–(7) the order of indexes corresponds to the alphabetical order of variables (the first index corresponds to the x coordinate, the second – to the y coordinate).

It is proposed to utilize the iteration-based method of solving of the system of equations (5)–(7), based on the construction of special-purpose auxiliary function. Let us present the system (5)–(7) in the generalized form:

$$\lambda_1(H)=e_1\,;\ \lambda_2(H)=e_2\,;\quad \dots\quad \lambda_k(H)=e_k\ , \tag{8}$$

where λ_* – generalized operators which correspond to the left-part functions of the difference equations;

$H=\{a_1,a_2,\dots,a_n\}$ is a set of the generalized arguments, the elements of which are unknown values of the functions $f_{*,*}, g_{*,*}, P_{*,*}$ in the points of the calculation mesh;

e_* are the values in the right parts of equations which do not depend on the generalized arguments a_* ;

k is the general quantity of equations of the system;

n is the general quantity of the generalized arguments.

Let us build an auxiliary function the value of which characterizes the norm of discrepancy of the system (8) at the intermediate (current in the iterative process) values of generalized arguments, found on the current step of iteration process:

$$V=\sum_{i=1}^{k}\left(\lambda_1(\dots)-e_1\right)^2\ . \tag{9}$$

Let us introduce auxiliary differential equation which sets a condition on speed of convergence of the iteration process:

$$\dot{V}+cV=0\ . \tag{10}$$

where $\dot{V}=\dfrac{\partial V}{\partial t}$; c – constant value – a parameter of quality of dynamic process of solution search; t – a relative (calculation) time, related to the amount of iterations of calculation process.

In the process of calculation the generalized arguments a_i change, and, in the case of convergence of the process, they approach the exact solutions of the system of equations (5–7). Therefore, there is an indirect dependence of the function V (9) on the relative time t , as a result of presence of dependences $a_i(t)$. Taking that into account, it is possible to write down:

$$\dot{V}=2\sum_{i=1}^{k}\left[\left(\lambda_i(\dots)-e_i\right)\frac{\partial\lambda_i(\dots)}{\partial t}\right]=2\sum_{i=1}^{k}\left[\left(\lambda_i(\dots)-e_i\right)\sum_{j=1}^{l}\left[\frac{\partial\lambda_i(\dots)}{\partial a_j}\dot{a}_j\right]\right]$$

and the auxiliary equation (10) gets the form:

$$\sum_{i=1}^{k}\left[\left(\lambda_i(...)-e_i\right)\sum_{j=1}^{l}\left[\frac{\partial\lambda_i(...)}{\partial a_j}\dot{a}_j\right]\right]+c\sum_{i=1}^{k}\left(\lambda_1(...)-e_1\right)^2=0 .$$

Also, the auxiliary conditions can be used in the form of a system of equations:

$$\dot{P}_i=-\varepsilon\frac{\partial V}{\partial P_i},\ \varepsilon=cV,\ i=1..k .$$

Conclusions

A mathematical method of solving of systems of nonlinear equations, derived from the numerical model of a hydrodynamic task, was offered. The offered method is based on the use of an auxiliary function and contains the parameter of quality of dynamic process of search of solution, that allows to manage speed of convergence of the system. The offered approach allows the further diminishing of dimension of the search space, and organization of solution calculation problem on the multiprocessor or distributed computing system.

Possible directions of subsequent researches are: study of calculation efficiency of realization of the offered method in the case of two-dimensional and three-dimensional problems; optimization of expressions which are used for reduction of dimension of space of search, with the speed of approaching to the exact decision as a criterion; optimization of information processes of data exchange between blocks in the multiprocessor or distributed system; a study of possibility of application of the proposed method to the problems set on irregular meshes..

References

1. Jiyuan Tu. Computational Fluid Dynamics, Second Edition: A Practical Approach //Jiyuan Tu, Guan Heng Yeoh, Chaoqun Liu. – Butterworth-Heinemann, 2012. – 456 pages.

2. Лойцянский Л.Г. Механика жидкости и газа /Л.Г. Лойцянский. – М.: Наука, 1987. – 840 с.

3. Липанов А.М. Теоретическая гидродинамика ньютоновских сред /А.М. Липанов. – М.: Наука, 2011. – 551 с.

4. Moin P. Direct numerical simulation. A tool in turbulence research /P. Moin, K. Mahesh // Annual Review of Fluid Mechanics. – 1998, V.30.. – P. 539-578.

5. Липанов А.М. Численный эксперимент в классической гидромеханике турбулентных потоков / А.М. Липанов, Ю.Ф. Кисаров, И.Г. Ключников. – Екатеринбург: Изд-во УрО РАН, 2001. – 160 с.

UDC 004.623:004.922 (043.2)

Glazok O.M., c.t.s.; Khodchenko F.S. (National Aviation University, Ukraine, Kyiv)

AN ALGORITHM FOR INFORMATION PROCESSING IN IMPLEMENTATION OF LANDSCAPE DATA DYNAMIC LOADING

The use of Continious Level of Detail (CLoD) approach for visualization of flight over the huge landscape is considered. Foe the tasks of visualization of aircraft flight, it is necessary to provide acceptable performance at high speed of movement. In order to achieve this goal, the algorithm of phased processing of chunks of the landscape is offered.

Multiresolution modeling, or multiresolution visualization, is a process that allows for adjusting the level of detail (LoD) of the presented scene, while maintaining a constant (or at least appropriate) frame rate and assuring interactivity to the user [1]. Multiresolution visualization has become a matter of interest for the last dozen of years, with development of various real-time applications, such as computer and video games, virtual reality and scientific simulation. As these applications require rendering of complex models for realism, graphics rendering engines include multiresolution modeling techniques, which have become widely used.

The multiresolution modeling techniques presented in the literature are classified by the criterion of the two main approaches to managing level of detail (LoD): Discrete LoD (DLoD) and Continuous LoD (CLoD). The DLoD approach manages a small number of independent levels of detail (LoDs), where each approximation or LoD represents the original object using a different number of faces. CLoD is introduced as an alternative which provides a wide range (virtually a continuous range [2]) of different approximations, such that the LoD can be adapted to the application requirements with a high degree of accuracy. CLoD has been extended to provide view-dependent LoDs, which is sometimes considered as a third approach.

There are some substantial differences between the two approaches (CloD and DLoD) on the stages of model construction, data loading, and run-time rendering. Let us consider them in the application to a practical problem – to perform a visualization of the global landscape with the view from the unmanned aerial vehicle (UAV). Based on the scales and detalization, this problem may be classified as the problem of loading and rendering of the "huge terrain". The "huge terrain" is the terrain that is many times greater that its part that can be viewed from any point of view, available for the system, and has the amount of information many times greater that the available space in the operative memory of the computer system.

It is quite obvious that for loading and rendering of a huge terrain its data should be divided into parts (chunks). Complete loading of the terrain is not possible due to the memory space and time limitations. At the same time, if one tries to process the whole data set, the speed of processing will be too low for real-time interactivity. The fact that such terrains are always seen partially also leads to the idea of partial processing. Such an idea got the name Chunked Level of Detail [3], also abbreviated as CLoD, and is a subclass of LOD [2].

Basically, the landscape is divided into the rectangular (or square) parts. This promotes coordination and visibility determination operations.

After the division, the algorithm of visible parts determination should be applied. The simplest visibility criterion is distance. In this case, one should define maximal distance from which an object can be visible. In case of flight visualization, it is possible also to chop off the parts which do not get in the angle of visibility. Because any flying object can turn only with limited angular velocity, there is no sense to load memory objects located behind that angle (except for the necessity of reflection of back view). As a softer variant, it is possible to decrease distance of visibility for the objects that lay outside of the angle of visibility.

At flight visualization, the higher the flying vehicle is, the more distant the horizon line. In other words, the radius of visibility increases with the height increase. At large values of heights, there may be necessity to render quite a large piece of terrain. At the same time, distant parts will have little angular sizes and, therefore, their exact rendering has no sense. As a consequence, one should introduce and apply a special factor for the level of detalization of parts. This factor should also be taken into account as a correction factor at visibility determination.

There may be two variants of algorithm of detalization change. The first one requires that every element of a landscape had several models (resources) of different detalization levels. The models should be loaded as needed. The second way is creation of a certain quantity of separate elements in every part of a landscape separate some number of separate detalizing elements. Every element will be represented only at the certain range of detalization levels (while a level of detalization is given as a numerical factor). It is possible also to unite these elements hierarchically. The first method requires more memory, while the second method is more difficult in realization. There is also a possibility to combine these two methods.

The data loading algorithm is important factor of system productivity. Every resource before its rendering passes the two stages: downloading from hard disk into the main memory, loading and construction from the main memory into the videomemory. Also, in the process of load, can be present information cashing (placing it into a temporal storage), which will accelerate downloading from a hard disk. For example, cache may help to avoid the stage of recoding of an image, or to hold a necessary file in the pre-loaded state). Cache operations may be considered as the third stage.

It is possible to pass all of the stages at once, as soon as there arises a necessity to display an object. However, such an approach will substantially complicate loading and movement on a map; in many cases it will lead to place jerks (usually called “popups”). It is possible to enter the factor of safety, connected with the object sizes, and load less critical information in a separate stream (with lower priority), then the elements of a map will be loaded beforehand, as possible. But efficiency of this approach will be small, if there is a lot of parts and information which must be loaded, which is just the case for the flight visualization problem.

The second approach is to pass the stages beforehand and gradually. This approach is referred to as phase processing [4, 5]. In this approach it is needed to enter the two factors: the main memory radius and the cache radius. These radiuses are numerical characteristics that determine the necessity of specific pieces of data loading. At this approach, each chunk of data is classified as the chunk belonging to one of the three areas (Fig.1). All the data that are outside the radius of cashing should be kept on a hard disk as basic data. All the data that gets inside the radius of cashing should be processed: the data that come from outside the system should be buffered in memory; the data that come from within should be written down in a hard disk cache. Such approach allows to promote the productivity and smoothness of loading, but at the same time it increases the expense of memory.

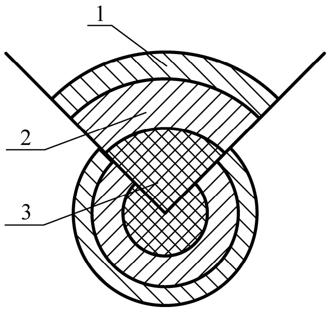


Fig. 1. The three areas of data chunks location. 1 – cache area; 2 – memory area; 3 – visible area.

Let us consider an example design of the system on the basis of all considered before. For the sake of simplicity, we will suppose that the information to load is the bitmap images of a map. Let us use the sequential (stage-by-stage) algorithm of loading, and limit detalization to the multilevel model detalization.

The program keeps metadata about every part of a map. The metadata include the size, position and reference (path, name) to the file with the loaded information. Consequently, we should have a "Map element" object, which will keep metadata. Because the subsystem of the map resources of card will be engaged in loading, metadata will contain references to the "Resource unit" object, in which the information necessary for loading will be kept.

The elements of landscape may be kept in a simple list. There is no sense to create a hierarchy. Using a list allows to perform quick check for visibility of the stored elements.

The resources subsystem consists of the list of resource elements. The "Resource unit" object keeps the unit state (current stage of processing) and pointers to the "Resource" objects for every stage, such as "File resource", "Cache resource", "Memory resource" and "Visible resource". The "File resource" object exists permanently and stores the path to the necessary file. The other objects can be created and deleted during work. Each object includes a function of creation of an object of the next stage. At transition to the next level, unnecessary objects are deleted, and corresponding pointers get the null values.

At each iteration of the cycle all parts of the landscape are checked for belonging to the cache, memory and visibility areas. Depending on the area found, the proper processing stage and the level of detalization are determined for each piece of terrain data.

The procedure of determination of belonging to an area is done as following: at first each vertex is checked for presence in the view angle (using the scalar product of the vector of direction of a camera and the vertex vector). According to the results, the verification radiuses of visible and invisible areas are corrected. Here, the radiuses for visible areas may be enlarged and the radiuses for invisible areas may be made smaller if necessary. Then the distance from a camera to the element (rectangle) is calculated. Next, the obtained distance is compared with the verification values of the areas. At this stage the level of detalization may be determined.

Conclusions

The base algorithm of data processing for flight visualization over a huge landscape has been proposed. It is further possible to perfect and optimize them for minimization of expenses of memory and increase of the productivity. It is possible also to obtain a greater smoothness utilizing multithreading and MPI (Message Passing Interface). Provided the due optimization is done, the proposed approach is capable to provide the high performance of load at high-speed flights. The basic lack of this approach is a high consumption of main memory.

A method can be applied in navigational complexes, visualization software of simulators and research projects. It perfectly fits for parallelizing and work over a network.

References

1. Ribelles J. An Improved Discrete Level of Detail Model Through an Incremental Representation./J. Ribelles, A. Lopez, O. Belmonte. – Proceedings of TPCG. – 2010. – Pp. 59-66.

2. Luebke D. Level of Detail for 3D Graphics /David P. Luebke. – Morgan Kaufmann Publishers, 2003. – 390 p.

3. Thatcher U. Rendering Massive Terrain Using Chunked Level of Detail Control /Ulrich Thatcher. – Режим доступа: http://tulrich.com/geekstuff/sig-notes.pdf

4. Lindstrom P. Visualization of large terrains made easy /P. Lindstrom and V. Pascucci. – IEEE Visualization 2001 Proceedings. – Oct 2001. – Pp. 363-370.

5. Hansen C. The Visualization Handbook /Charles D. Hansen, Chris R. Johnson. – Academic Press, 2004. – 984 p.

UDC 004.7 (043.2)

O. Dyshliuk, k.f.-m.n.
(National Aviation University, Ukraine, Kiev)
G. Kvita, k.e.n.
(Kyiv national university of technologies and design, Ukraine, Kiev)

METHODS MODELING CONTROL PROCESSES COMPLEX ECONOMIC SYSTEMS

The models and methods of economic cybernetics, which are used in the process control of complex economic systems. Author determined specific software for the realization of economic and mathematical modeling techniques.

To solve the economic problems in order to obtain quantitative estimates and models in decision-making for the development of modern enterprises is to use tools that combines mathematical methods and solve certain classes of problems in economic cybernetics, in particular the problem of economic-mathematical modulation.

Methods of economic cybernetics focused on knowledge of advanced positions in the adaptation and application of new quantitative methods developed in other fields. Implementation of forecasting methods, mathematical modeling, neural networks and information theory is relevant and modern economic cybernetics task. The assets of their own methods of economic cybernetics important are systemic and system-approach, general systems theory applied to a new class of objects-economic systems and economic modeling, econometrics and economic forecasting. An important contribution to the development of economic cybernetics made work of a number of eminent scientists. An important contribution to the development of economic cybernetics made work of a number of eminent scientists: V. Glushkov, N. Viner, S. Bir, V. Nemchinov, O. Lang, G. Grinevsky and others. The classic approach to the ideas of cybernetics is general systems theory and systems analysis, which focuses on coordination, interaction of the system with the formation of the structure as a whole [1].

Based on analysis of software implementation methods for economic cybernetics, you can select the optimization model and simulation, as well as models and forecasting methods.

In the simulation model the variables making model is the input - output result of a process model to simulate the objective function value that corresponds to this input variable value solutions.

Note that the application of simulation modeling are universal and specialized. By the universal software include programming languages with which you can build your own model. Examples of universal modeling languages are SLAM II, SIMSCRIPT II.5, SIMAN, GPSS/H, GPSS/PC, PC-MODEL, RESQ, application Simulink to the package MatLab and others. Specialized software, for example MAP/1 and SIMFACTORY, used for modeling specific manufacturing systems. As a specialized software for modeling the process of a production are tools that allow you to specify the number of work centers, their description, the intensity of the receipt, processing times, lot sizes, volume of work in progress, available resources, and more. In addition, these programs allow the analyst to observe the production process of animated presentation and monitor the process of modeling in quantitative terms, and flows in the system [2].

Simulation models are mostly built for predicting in terms of instability and uncertainty factors that determine the operation of the facility forecasting, in the absence of relationships between factors.

In addition to the simulation models to modulate mathematical economic models include models and forecasting methods. The main purpose of this type of model - a researcher to provide information about the object of study in the future. In modern conditions in developing forecasts important to the further development and improvement of forecasting methodology.

Note that expert forecasting methods used in the cases when is not possible to take into account many factors influence the considerable complexity of object prediction; presence of high uncertainty information, or in the absence of information about the object prediction. By the classification of forecasting methods include: methods of peer review, formalized methods (math and logic) [3].

Methods of peer reviews allows you to create prognosis group of experts, based on their experience, intuition, creativity and imagination. In what experts are selected by a special technique. Expert methods of separation of individual and collective. The individual expert assessments includes the following methods: survey methods in the form of interviews and analytical method. Methods collective peer review include: the method of the "round table" method of "brainstorming".

Formal methods are based on actual current information about the object and predicting its past development. By the logic most often referred historical analysis and a comprehensive method based on scenario approach.

The scenario approach – coherent description of the process of change in a cut-and-time object prediction, based on the situation that has developed. Description scenarios is considering time estimates.

The historical analogy is that the idea of the prospective state of object prediction is based on the model, is the last stage of development, to be held object prediction.

From the set of mathematical models used in predicting the trend, econometric and simulation models.

Trend model – mathematical model that describes the change in the projected rate depending only on time. It is represented as a linear function of one variable. It is not nothing but a prediction of the behavior of an object by extrapolating the trends of the object you are forecasting, revealed last.

Econometric model is different from the trend in that it addresses the changes in not only on time but also other factors. It is represented as a linear function of several variables.

Simulation models are mostly built for predicting in terms of instability and uncertainty factors that determine the operation of the facility forecasting, in the absence of relationships between factors.

Adapted forecasting methods are based on the fact that the process of implementation of them is to compute successive time values predicted my index with regard to the degree of influence of previous levels. These include naive models, methods fluid medium and exponential smoothing, which provide continuous adjustment of extrapolation formula according to new data from the actual value of the index whose value predicted.

Note that the software implementation of existing models and methods that can occur with the use of various software tools. In particular, the optimization model and simulation modeling can be used by software such as Minitab, MatLab, POMWIN, MS Excel, Project Expert, SLAM II, SIMSCRIPT II.5, SIMAN, GPSS/H, GPSS/PC, PC-MODEL, RESQ and others. For models and forecasting methods – Minitab, MatLab, MS Excel, STATISTICA, SPSS, SAS.

Conclusions

The paper considers models and methods of economic cybernetics, which are used in the process control of complex economic systems. Point-but software tools, which are designed to implement optimizations and simulation-port models and forecasting.

References

1. Lisenko Y.G., Egorov P.V., Ovechko G.S., Timohin V.N., Economic cybernetics [in Russian], Donetsk, Yugo-Vostok, 2004.

2. Ruban V.Y., Shikovec K.O., Kvita G.M. and others, Cybernetic modeling [in Ukrainian], KNUTD, Kiev, 2005.

3. Grabovecklу B.E., Economic forecasting and planning [in Ukrainian], KNUTD, Kiev, Center for textbooks 2003.

4. Kvita G.M., Shikovec K.O., Panenko V.V., Economic modeling of business processes Universities, *Visnik Kyivskogo nacionalnogo universitetu technologyi ta disaynu*, KNUTD, Kiev, 2012, No 4(66), 390-397.

UDC: 004.78 (045)

O.S. Vasyliev (Economic Co.Ltd "Vesta", Ukraine)
O.O. Belyakov (National Aviation University, Ukraine)

ANALYTICAL OPTIMIZATIONS TECHNOLOGIES FOR RECOGNITION OF AERIAL PHOTOS

In this article method of recognition system is defined using RGB-format. Using facilities of Microsoft Visual Studio represented methods on aerial photo. And analyze .NET technology for the optimization of programming code.

Introduction

Analytical technologies in the first place are needed people who make important decisions - managers, analysts, experts and consultants. Company profit in most cases depends on the quality of those decisions - the accuracy of forecasts, optimally chosen strategies.

The question of pattern recognition is relevant past 40 years and relevance does not decrease so far. So when developing software to control unmanned aerial vehicles (UAV) pattern recognition problem faced in the development of autopilot.

Pattern recognition has a wide range of use in the autopilot:

1) problem of determining the location of the UAV;
2) search certain objects on the ground, and so on;
3) patrolling moving objects;
4) analysis of area.

As test data we use an arbitrary image area. It should be images of acceptable quality and resolution. But given that arbitrary image, you need to take into account the uncertainty analysis. As a model for search you must select a unique part of the picture. This object has characteristics very well and clearly visible to the human eye.

1. Description of method.

With the image selected sample of size 375x300 pixels. This size is not significant and is equal to the size of fields in program analysis. Data Format - 32 bits per pixel in RGB-format. This format allows you to submit any color as three components (red, green, blue). This format is used for many sources of color are light sources such as screens monitors, TVs and more.

Software tools can track each color separately in 8 bit format. This can significantly reduce the required memory for storing images.

Also, depending on the character set can be present such as setting transparency. Length - 8 bits. The lower the number - the transparent image.

To start, load an image and draw a complex component that is a decimal display format code in RGB. This means Microsoft Visual Studio let us operate image as an array of points. For simpler processing transform each pixel in the array, because array access faster than taking the color of each pixel. Thus we get an array of colors for each point on the screen. For the first attempt selected image areas of road junction (Fig. 1), and the search is performed on the image of the road (Fig. 2).

The way a simple search of both arrays, we compare the full image of an image search. The comparison is for an integrated color value of the point.

Since the color format consists of 24 bits, according have 2^{24} colors. It is 16 million colors. The human eye does not distinguish neighboring colors. And even colors with a difference of 10 is also difficult to distinguish. Therefore, there is the first option - sensitivity.

Fig. 1. Original image

Fig. 2. Search image

It appears first "reef." For example, the colors # 969600 and # 96960A with a difference of 10. But this difference is actually blue. In decimal form this number 9868800 and 9868810 respectively. But if you take the colors # 969600 and #909600 is a significant difference in the concept of decimal 9,868,800 and 9,475,584. The difference of 400 thousand, but a difference of 6 units of red. Thus, we can conclude that the need process each color separately. Etalon has options 27x54 points. It is 1458 points for comparison. Original image has 375x300 points. To find the right bulkhead will need about 140 million cycles. Even with modern methods of computer technology it is very bulky volume and process.

Having considered the color values of neighboring pixels can be seen that they are very similar. And after 2 or 3 pixels color is not significantly changed. So should not conduct an analysis of each area, such as every second or third. This will increase the speed to 2 or 3 times, respectively.

Can we expect 100% match in this case? Of course not. But we get some suspicious sites and rate increases at times.

Fig. 3. Result of searching

Thus we have 35 million plus 109 checks on suspicious similarity plots. All areas are in close proximity to the original and may be the correct result.

Increase the sensitivity and reduce the chance to match: We have 208 squares, half of which are obviously untrue and have a very low coefficient of coincidence. Hence we can conclude that the increase in step with decreasing test sensitivity and threshold matching can speed up the algorithm and reduces the probability of the result.

All systems for pattern recognition with a rate coefficient as a false alarm and failure rate.

Coefficient of wear - the ratio of false positives to the total number of inspections. For the first case it is 0, the second - 0, for the third $3 * 10^{-6}$. It is supposedly good, but believe that some nuances not taken into account as it complexity image and an array of test images is small.

Bounce rate - the ratio of failures to the total number of inspections. In all three cases, it is 0. This indicates a lack of the original.

In practical problems the system has some standards. This may be the faces of people, photos of products, objects on the map. Man thinks images. This enables identification of different shape, parameters. For each group of products is desirable to find the model parameters. For example, a set of lines.

One measure is the difference brightness points. When the point of equal brightness with the background, it merges with the background. Therefore, the difference brightness or color, we can build a model of standards.

Creating an album of samples increases stability, but increases the rate of false positives. A large number of elements of the album considerably slows down the algorithm is a generalized model is to simplify the search.

To investigate polygons it is recommended another system, for example neurosystem.

Proposed method is a method of pre-processing data to recognition on another system.

Code optimization

All data stored in the system database, than we need to analyze how much impact the use of built-in tools programming environment on the performance.

The ability to create triggers on .NET platform in a general development environment (CLR) allows to take advantage of object oriented programming in MS SQL Server. Using CLR allows you to create database objects in languages VB .NET, C #, J #, C ++ environment .NET Framework, which increases the efficiency of development.

To test the standard means .NET platform to create database tables triggers a program that evaluates the performance of trigger, standard features built platform .NET, and compares its performance with triggers that are built by means of MS SQL Server and database work on the side. The program provides for analysis of three triggers: UPDATE, INSERT and DELETE.

The software application consists of the following components:

1) database with tables that contain a certain number of records;

2) customized triggers in the environment of MS SQL Server;

3) triggers that are implemented by means of platforms .NET;

4) The instrument automatically run scripts to perform operations on tables database;

5) module to calculate the average processing time of each operation;

6) reporting forms to the study.

The program is developed for Windows with the use of Microsoft Visual C#.

The program implemented two groups triggers to database tables, each of which carried three triggers (INSERT, UPDATE, DELETE).

General view window on startup (Fig. 4). Each group triggers different method of creating and storing. The first group was developed and preserved by means of platforms .NET, second group - the means of MS SQL Server.

This window contains three groups of values that include placing the results of 100 operations add, update and delete for tables with different number of records.

After executing the event handler for the component Button1 (this component is responsible for handling events Clicking the "Run query") is processing all created triggers and count the execution time of each operation.

The module contains a counting time the following code:

```
System.Diagnostics.Stopwatch w = new Stopwatch ();
        w.Start ();
        command.ExecuteNonQuery ();
        w.Stop ();
```

This code runs the system timer before starting to execute the request and stops it after processing the request. After counting, the data are transmitted to the relevant fields that are placed on the form (Fig. 4).

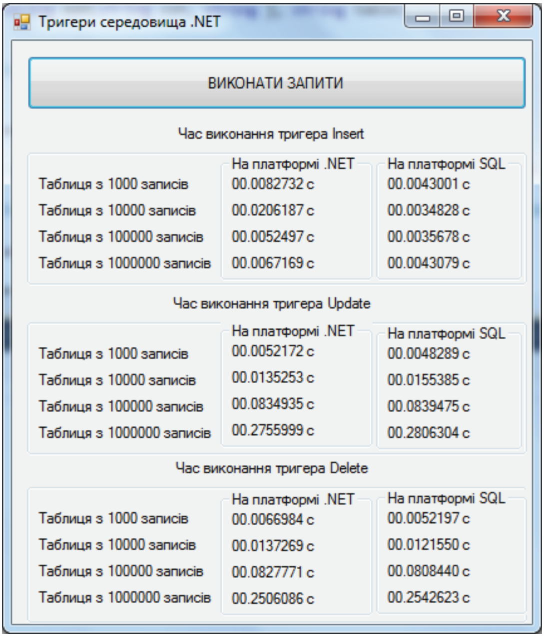


Fig. 4 - The window you start the trigger

Tables by which studied the performance triggers .NET compared to SQL triggers have the same structure to prevent impact on the performance of individual processing time records, and differ only in the number of records (1000, 10000, 100000 and 1000000).

Table 1

Summary results of processing speed triggers database

Type of trigger	Number of records in the table	Performance platform based .NET, ms	Performance platform based MS SQL Server, ms
INSERT	1 000	2,27	0,63
	10 000	2,31	0,72
	100 000	2,35	0,77
	1 000 000	2,41	0,84
UPDATE	1 000	1,71	1,42
	10 000	1,92	1,71
	100 000	5,1	5,01
	1 000 000	6,5	6,34
DELETE	1 000	2,5	2,02
	10 000	7,01	6,91
	100 000	7,13	7,01
	1 000 000	8,11	8,04

For all table triggers are executed according to an algorithm that checks the operation that was performed on the table (INSERT, UPDATE and DELETE), calculated a trigger, and before the end of the algorithm test condition further involvement manipulation operations on the table.

To obtain reliable data for reporting form filling conducted 100 operations that caused each of the flip-flops, and calculated the average time the relevant transaction. These values were presented in the main window.

Window to the data in Fig. 4 shows the results for one run programs after multiple runs of the program was obtained average values of each of the operations (Table. 1).

Conclusions

Using full-color images requires significant memory and performance. The shorter operands for comparison, the more operations are compared. But analyzing the results must take into account data representation format #RRGGBB and highlight the prevailing color in this type of image.

Determination of sensitivity is determined by external conditions and the experimental method. Step movement of the image is greater than unity - this will increase performance. But the maximum value should be set up according to the image. In this experiment used a 1/10 of the sample. Lowering the percentage of matches with the standard gives false results, but allows you to define the image of some disabilities or differences. But a simple neurosystem can complete this method for powerful instrument in UAV-software.

Experiments have shown that the use .NET platform does not affect the performance trigger, but simplifies their writing and subsequent processing while updating software applications.

References

1. *Айзерман М. А.*, *Браверман Э.М.*, *Розоноэр Л. И.* Метод потенциальных функций в теории обучения машин. М., «Наука», 1990.

2. *Андерсон Т.* Введение в многомерный статистический анализ. М., Физматгиз, 1993.

3. *Фисенко В.Т.*, *Фисенко Т.Ю.* Компьютерная обработка и распознавание изображений: Учебное пособие. - СПб.: СПбГУ ИТМО, 2008. - 192 с.

UDC 004.724.5

V. Klobukov (National Aviation University, Ukraine, Kiev),
S. Volhonskiy (National Aviation University, Ukraine, Kiev),
D. Samofalov (National Aviation University, Ukraine, Kiev)
V. Ryabokon (National Aviation University, Ukraine, Kiev)

BASIC PRINCIPLES OF THE E-GOVERNMENT

This article provides basic information about the organization and technological support of the concept of e-government. Basic technological and administrative challenges of introducing the concept e-government in Ukraine

In 2010, the Cabinet of Ministers of Ukraine was approved by the concept of e-government in Ukraine [1].

As noted in this order, one of Ukraine's priorities is the development of the information society, which can be defined as a people-oriented, open to all and aimed at fostering innovative model of development, high-tech society in which every citizen has the ability to create and store information and knowledge, have free access to them, enjoy and share to allow each person to realize their potential for personal and social development and quality of life.

The purpose of implementing e-government in Ukraine is the development of e-democracy to achieve European standards of electronic public services, openness and transparency in government for human and civil, civic organizations and business.

The main objectives of e-governance are:

• improving the quality and availability of public services for the person and the citizen, simplifying procedures and reducing administrative costs;

• improving the quality of administrative and management processes to ensure control effectiveness of activity of state and local governments while ensuring an adequate level of data security;

• ensuring transparency of information about the activities of state and local government, access to it and to allow direct involvement of human and civil rights and civil society in the preparation and review of draft decisions taken at all levels of government.

The ordinance also emphasizes that the main component of e-government is e-government - the only automated information infrastructure of interagency cooperation of state and local government together, citizens and business entities.

The definition of e-government experts formulated on the basis of different principles [2]. Some authors prefer the descriptive nature. Others choose the applied aspect and just list the different application components. There is also a short technical definitions focus only on applied technological solutions and specific software; economic - focused on maximum efficiency of governance and so on.

Further we consider the definition of e-government as described in [2], namely, as an organization of public administration based on electronic processing, transmission and dissemination of information, provision of public services of all branches of power to all categories of people by electronic means, the same means of informing the population on the work of public authorities.

This definition of e-government in itself involves the use of advanced information and information and communication technologies for the processing and transfer of information, its preservation, protection of databases used in public administration Internet technologies.

For data and information and communication technology, which should ensure the effective functioning of e-governance should include products that are based on proven industrial technology, using proven security model and provide:

• Computer infrastructure (network, telecommunications, software, information, organization, etc.);

• integration of data into a single information space based on client-server technology;

• license purity;

• organization of collective work of employees;

• regulated access to information resources of over LANs and the Internet;

• e-mail;

• Dissemination and sharing of information;

• electronic document;

• implementation of specialized applications;

• management of corporate knowledge;

• Managing workflow (workflow);

• Integration of relational databases;

• the possibility of modifying software applications;

• sending instant messages;

• conducting conferences in real time.

The development of e-government - is a complex process that takes a lot of material, intellectual and financial resources and requires the solution of complex legal, organizational, technical and technological problems, and e-government - is not partial technological solution, and the concept of governance, which is essential large-scale transformation of the information society.

Organizational and technological foundations of e-government.

Organizational and technological foundations of e-government should provide [3]:

• the development and widespread adoption of means to provide remote access to information about the activities of state and local governments;

• providing electronic public services using centers (points) to provide services based on single infrastructure automated information interagency communication and cooperation between state agencies, local governments and individuals and legal entities;

• Creation of a secure system of interagency electronic document;

• implementation of departmental information systems planning and reporting, and a unified system of monitoring the effectiveness of the executive;

• Formation of the regulatory framework governing the order and procedures for collecting, storing and providing data contained in public information systems, as well as control over the use of government information systems.

The main unresolved problems of implementing e-government.

As noted in [1], despite the rapid development in the last decade, information and communication technologies and their widespread use in government, remain unresolved following problems:

• lack of a national system of indicators (parameters) evaluating the state of e-government;

• lack of uniform standards and regulations of the system of electronic document using a digital signature, and maintenance of state information resources, adapted to international;

• inadequate regulatory and methodological framework that makes it possible to state and local governments, citizens and economic function in the information society;

• unregulated by law question of administrative services and appeals to state agencies and local governments through the Internet;

• lack of integrated national information resources and information interaction of state and local governments;

• limited access of citizens and businesses to information resources of state and local governments;

• poor quality and lack of administrative services provided to individuals and entities using electronic means;

• inadequacy of existing Government portal websites of state and local governments that do not provide the interactive mode of operation and the provision of administrative services in a "one stop shop";

• limited opportunities for electronic document management systems of state and local governments;

• lack of common formats and protocols, digital signature;

• low awareness of civil servants, local government officials and citizens on the merits and benefits of e-government;

• information slowness of libraries, archives and museums, which can lead to a deepening of "digital divide";

• lack of necessary financial and material resources and inefficient use.

Analysis of the existing list of unsolved problems suggests that a prerequisite for the application of new information and information and communication technologies in public administration are required streamlining of the current government. Without this preliminary arrangement governance application of new information technologies is possible only for informational certain of its functions.

With a certain conventionality fate unresolved problems can be split into groups, namely, those related to:

1 imperfection regulatory and methodological framework;

2 insufficient ordering of state power;

3 insufficient level of training of governmental officials from the perspective of understanding the essence of e-government, seeing it only as a posting on the Internet information and services;

4 lack of integrated national information resources and information interaction of state and local governments; limited possibilities of electronic documents of state bodies, local authorities, government agencies, organizations and other entities that form the national information resources.

References

1. The Cabinet of Ministers of Ukraine Resolution of 13 December 2010 p. № 2250-r, Kyiv, on approval of the concept of e-government in Ukraine.

2. National Centre for e-governance, nc.gov.ua.

3. The concept of e-government in Ukraine / O. Baranov, M.S. Demkova, S.V. Dziuba, A.V. Efanov, I.B. Zhyliaev, E.L. Klepets, Yu.Misnykov, O.Arvo, T.V. Popova, I.A. Ruban, A.I. Semenchenko, S.A. Chukut. Ed. A.I. Semenchenko, 2009. - 16 s.

UDC 004.724.5

S. Volhonskiy, D. Samofalov, L. Klobukova, O. Zykov
(National Aviation University, Ukraine, Kiev)

ELECTRONIC DOCUMENTS MANAGEMENT SYSTEMS OF HIGHER EDUCATION INSTITUTIONS AS A COMPONENT OF E-GOVERNMENT

This publication describes the basic questions of electronic document management system of higher education institutions as part of the concept of e-government

Consider the university as a great organization (corporation) that is stable diversified geographically distributed structure that contains all necessary management support system and operates on the principles of decentralized management.

Main characteristics university as a corporation mainly typical representative of a family of large organizations and interest in that capacity:

1 The scale and distributed structure.

2 A wide range of activities that are subject to automation:

• office automation and control of orders and decisions;

• financial management, accounting, budget accounting, payroll / scholarships, tuition accounting, logistics;

• HR management, automation of accounting and management of personal affairs staff, faculty, students and graduates;

• support the organization and management of educational process;

• support and organization of distance education;

• automation of libraries, support electronic library catalogs;

• registration and management of research activities, including project management system;

• information and analytical support strategic decision making by senior management of the organization for the purposes of strategic management, including through the application of quality management systems.

3 Complex organizational and management structure.

4 Variety park computational tools, network equipment, and especially basic software.

5 A large number of special-purpose applications based on different software.

In view of the above it can be argued that the university information system should be a corporate management information system (CIS), which would not only ensure the integration of all key business processes of the organization and then transferred them to the level of computer technology, but also had the opportunity to integrate with other systems, including systems and e-government. It is important to note the fact that this system was the "status" of a collective work, as e-government, and it is the collective work in an integrated information space.

If we analyze the composition of tools which ensure the effective functioning of e-governance and composition of fixed assets for the operation of corporate information systems, it is obvious that they are almost identical.

Implement basic functions listed above and build an effective management information system university can only be provided when the core of the CIS, its systems forming element, which provides information for the initial system is such a system that is able to unite together under a single system, the above technology and provide them with a completely new quality.

In other words, the core of the CIS should be powerful modern automation systems management processes built on technology platforms, which integrates all the basic tools for collaboration.

The problems of creation and implementation of integrated enterprise, information systems management tools university as the collection, processing, storage and analysis, which operates in an environment of high school, and perhaps should be considered in a broader plane, namely, national, and consider such systems as local subsystem national system of e-governance.

As such it is advisable to consider the electronic document management system because their composition and includes all the major means to ensure efficiency CIS.

Electronic documents management systems in the broadest sense - is the organizational and technical systems that support the creation, management, access and dissemination of electronic documents in computer networks, and provide control over the flow of documents within the organization.

Currently, the company's software developers offer a wide selection of EDS, designed for different institutions and organizations. This boxed system with different functionality, a unique and powerful set based platforms (IBM Lotus Notes / Domino, IBM FileNet, Microsoft SharePoint, Oracle, EMC Documentum etc.), development of Custom hybrid systems - are based on customizing boxed systems (adaptation of finished products for specific user applications) and others.

These systems projects for banks of authorities, businesses, industries, insurance companies and many other institutions and organizations, given the fact that each institution has its defining performance indicators, their types of documents to be implemented in EDS.

For example, in the executive branch there are more than ten types of EDS, which represent different classes: electronic office systems scale of distributed SED others.

But as universities (and other research institutions), the vast majority of the SED, which are suitable for use in organizations, trade and industry, is inapplicable because the specifics of the university generates a large number of types and types of documents that are not used in other categories of organizations (eg, scientific and technical reports, research papers, reports on scientific achievements, patents, etc.)..

Based on the analysis of existing EWS can be argued that universities need systems that are flexible and open architecture allows you to create your own types and categories of documents and routes of their movement.

University systems of electronic document can be system-forming constituents only if they are based on information platforms that have become de facto and de jure standards for information systems, means collective work.

Suppliers of basic platforms must have a stable position in the Ukrainian market. Only under these conditions can act as EDS systems - forming part of corporate management information system university.

At the current time on the world market, there are quite a large number of EDS that deserve attention and provide a means for automation of workflow. However, to use the system, not localized, and does not have enough support in Ukraine, it is impractical. The main manufacturers present at the Ukrainian market that meet these requirements include systems: Microsoft SharePoint, IBM / Lotus / Content Manager, Documentum, Humminbird.

All listed products - are open systems that are just platforms for application development. Moreover, on the basis of each of these different companies have developed a sufficient number of applications, including the electronic document management systems that can be used in the creation of complex systems. But it should be noted that today there is no single ideal platform for the introduction of workflow. Any solution will require additional efforts not only to develop a set of applications, but also to supplement the basic tools provided platform.

Considering the existing SED can also make even a very important conclusion, namely, despite many developments and implementations, agencies and institutions, including universities, in terms of a single information space, still isolated from each other, and performance single institution is lost in the general system of interdepartmental workflow, where complicated process control and analytical data collection, handling external documents.

Therefore, creating SED for higher education (and general and executive bodies) should consider them not only as internal workflow automation, and as one of the most important and fundamental components of management e-governance, which should provide information link between universities and state agencies, local governments and others. Only such an approach will be to create a single integrated information space, a single automated information infrastructure of interagency cooperation of state and local governments together and universities.

Prerequisites for implementing e-government. Higher education as a medium for the preparation of specialist managers to work in integrated corporate information environment.

A prerequisite for the effective implementation of e-governance is the ability of managers to work in an environment of new information technologies, the ability to both independently and together with others to analyze complex situations that are waiting for their resolve and for which it is necessary to make specific decisions, develop different versions of decisions to think about their benefits and disadvantages, make and justify appropriate management decisions.

And in this case should not talk about computer literacy users in the narrow sense, and the ability of managers to work in integrated environments of information systems collaboration and decision making.

Unfortunately, most managers or have no experience in such areas if their experience is limited knowledge of office applications, Internet search engines and e-mail.

Towards solving this problem may be different - that the creation of scientific-methodical, consultative, teaching centers for the implementation, development and application of e-government, this organization of training centers companies integrators knowledge of information technology and business solutions etc. But it should be noted that students of these centers are primarily specialists, managers of state structures and institutions, most of them lack knowledge of basic concepts, principles and means of collaboration in an integrated information environment.

Therefore, one of the feasible directions to solve this problem is to train specialists in universities other than previously competencies as required by the course taken by the Government to a radical technological modernization of the Ukrainian economy. Their formation, in turn, can be achieved only if the HEIs themselves become powerful sources of innovative ideas and technologies. And one way traffic of higher education in this direction is the transformation of the organizational model of high school, implementation of corporate forms of management, implementation of new principles of management, transfer and adaptation of corporate governance principles in the management system of universities and the like. Universities have become a kind of polygons in the training of personnel who must master the skills of teamwork in an integrated corporate information environment.

Conclusions

1 Problems creation and implementation of integrated enterprise, information systems management universities should be considered not only from the perspective of gathering, processing, storage and analysis, which runs on universities, but also in a broader plane, namely, national, and consider systems such as local subsystem national system of e-governance.

2 As corporate systems creating integrated, management information systems should be considered university of electronic documents because, on the one hand to them includes all the basic tools that provide efficiency CIS, on the other hand, the same tools used in electronic systems governance.

3 Design, creation and implementation of electronic document management systems of higher education institutions must be performed to the extent that they are part of e-governance. Therefore, such systems should be based on information platforms that have become de facto and de jure standards for information systems, means collective work.

4 Higher education institutions should become polygons preparation specialist managers, who must master the skills of collaboration in integrated corporate information environments.

References

1. Cabinet of Ministers of Ukraine Resolution of 13 December 2010 p. № 2250-r, Kyiv, on approval of the concept of e-government in Ukraine, National Center for Electronic Governance, nc.gov.ua.

2. The concept of e-government in Ukraine / O. Baranov, MS Demkova, SV Dziuba, AV Efanov, IB Zhyliaev, EL Klepets, Yu.Misnykov, O.Arvo, TV Popova, IA Ruban, AI Semenchenko, SA Chukut. Ed. AI Semenchenko, 2009. - 16 p.

3. Kozin IV, Dr., Professor, Bashtannyk OI, Lecturer, Zaporizhia National University. Information model of educational process of high school.

UDC 004.724.5

V. Klobukov (National Aviation University, Ukraine, Kiev),
S. Volhonskiy (National Aviation University, Ukraine, Kiev),
D. Samofalov (National Aviation University, Ukraine, Kiev)
V. Ryabokon (National Aviation University, Ukraine, Kiev)

REQUIREMENTS FOR INFRASTRUCTURE ELECTRONIC DOCUMENT MANAGEMENT SYSTEMS IN HIGHER EDUCATION INSTITUTIONS

The article deals with the requirements for infrastructure electronic document management systems (EDS), namely, engineering infrastructure, as a combination of hardware, software and technology sites that provide information and analytical support core activities of higher education institutions (HEIs), analyzes the components of infrastructure SED . It is concluded that EDS infrastructure should create an integrated collaboration environment, to provide complete solutions (organizational, architectural, communications, software, etc.) in the area of collaboration, allow technology to solve complex problems at any organizational level.

The specific higher education institution (HEI) defines its main activities, namely, educational. We shall consider university as a large organization (corporation) that is stable diversified geographically distributed structure that contains all necessary management support system and operates on the principles of decentralized management.

The predominant characteristics university as a corporation are:

1 The scale and complex distributed structure.

2 A wide range of activities that are subject to automation:

- support the organization and management of educational process;
- registration and management of research activities;
- support and organization of distance education;
- automation libraries, support electronic library catalogs;
- office automation and control of orders and decisions;
- financial management, accounting, budget accounting, payroll / scholarships, tuition accounting, logistics;
- personnel management, automation of accounting and management of personal affairs staff, faculty, students and graduates;
- information and analytical support for strategic decision making by senior management of the organization for the purposes of strategic management, including through the application of quality management systems.

3 Companies and organizations as part of the corporation have certain autonomy in formulating and carrying out their own technical policy automation.

4 Variety park of computational tools, network equipment, and especially basic software.

5 A large number of software and hardware applications for special purposes, created based on various underlying software.

In view of the main characteristics of universities as corporations can be argued that the effective management of such a complex system is impossible without providing information - analytical support of all components, which in turn requires an effective, well designed and planned information system management, and more precisely, corporate information management system (CIS).

Without going into terminological definition of such systems, we emphasize that the infrastructure CIS should include tools for building corporate network communication software documentation for management, promoted domains, means of organizing collective of employees and so on.

With this particular, it follows, first, that the requirement for CIS should be the ability to integrate a large number of hardware and software that, in general, are operating on different technology platforms and protocols from different vendors and developers.

And secondly, subjects to applicate of new information and information communication technology, and these are used to create the CIS, should be only ordered system processes and organizational structures. Appropriate to computerise are only those procedures and management activities who's content is objectively necessary and reasonable from the standpoint of a scientific approach and system analysis requirements.

Thus, considering the problems of creation and implementation of corporate information systems management universities as tools for collecting, processing, storage and analysis, which runs on universities, it is advisable to determine what should be the core of the CIS, its systems forming element which determines the basic requirements for an infrastructure of the CIS and will provide initial information for the entire system, will be able to create a single, integrated information environment of the university.

At the heart of any process (industrial, academic, educational, etc.) is the set of regulations and documents governing the individual components of the process. Only thanks to regulatory documents, strict adherence to guidelines and step by step documentation of processes can achieve high-quality results.

With this in mind, natural, clear and defensible system-forming an organizational element, the core building CIS consider electronic document management system (EDS) that, first, run all the streams of documents, performing in some sense the role of the compiler of the organizational structure of the institution through the formalization of business processes and second, significantly affect CIS infrastructure requirements in terms of technical, communication, software and organizational tools that provide performance EDS and CIS as a whole.

Therefore, creating EDS for higher education (and general and executive bodies) should consider them not only as internal workflow automation, and as one of the most important and fundamental components of management e-governance, which should provide information link between universities and state agencies, local governments and others. Only such an approach will be to create a single integrated information space, a single automated information infrastructure of interagency cooperation of state and local governments together and universities.

Requirements for infrastructure SED.

According to the classical definition of infrastructure (from the Latin - infra-below under the structure - building, location.) Is a set of components of any object with a subordinate (sub) nature and provide conditions for normal operation of the object as a whole.

In the broadest sense, the infrastructure of electronic document probably be seen as a linked set of regulatory, legislative, educational materials, organizational solutions and mechanisms, engineering, technical, programmatic and technological objects that ensures adequacy technology used for electronic interaction between the recognition of an electronic document legal fact, and provides information security and conflict resolution between the parties to electronic documents.

Infrastructure EDS form as existing in the organization of technical and software, and so those that actually added to the CIS for the functioning of the EDS.

Analysis of theoretical positions allows structured electronic document and detail the functional tasks of infrastructure and formulate basic requirements for it, namely, infrastructure EDS should:

1. create an integrated collaboration environment, to provide complete solutions (organizational, architectural, communications, software, etc.) in the field of collaboration, allow technology to solve complex problems at any organizational level;
2. provide all the organizational and technological solutions for the creation and development of EDS, based on general architectural, technological principles and standards on information platforms that have become de facto and de jure standards for information systems, means collective work;
3. provide performance applications that are built on technology platforms (Lotus Notes, SharePoint, etc.) that allow to automate work with complex structured data and formalized dynamic processes;
4. support object-oriented architecture systems;
5. ensure scalability of the system;
6. provide flexibility (the system should not require a radical readjustment in the structural reorganization of the institutions and processes of change documents);
7. ensure openness (ability to add new applications to the SED, functions, improve existing and organize data exchange with other systems);
8. to ensure smooth operation of database servers and applications, multi-protection;
9. provide guaranteed power supply, physical protection equipment;
10. provide information security (providing users with multi-database access, application of encryption and digital signatures, data integrity during transmission over computer networks);
11. to ensure consistency (the system should be focused on the implementation of all tasks electronic document from document preparation, registration and control of the issuance to reports, document search and storage);

12 provide a remote access to documentary information through telecommunication systems and the Internet;

13. provide the necessary bandwidth computer network;

14. have the necessary margin of safety which takes into account the strategy of the institution;

15. provide the ability to integrate with other systems.

The components of the infrastructure of electronic documents universities.

As part of infrastructure of electronic documents universities there are two main components are relatively independent.

The first - a corporate network (CN), which is a system of centralized communications and computer infrastructure reflects the organization. It is the basis for integrating functional subsystems and fully defines the technical properties of an information system, that is important to its successful operation. Requirements for it are uniform and standardized, and its construction methods are well known and repeatedly proven. CN is based on two main pillars, namely: CN - strategic support system of the corporation; CN - effective system of centralized communications of the corporation.

The second component - interrelated functional subsystems that provide problem solving of the university. The second component is based entirely on the basis of the first and adds to the information system application functionality. Requirements for it are complex and in many cases contradictory, as put forward by experts from different domains. However, this component is ultimately important for the functioning of the organization, because on it, in fact, built the entire infrastructure.

Conclusions

1. The development of corporate information systems and implementation of EDS should be started with the construction of computer infrastructure (corporate network) as a fundamental component of creating systems that is based on proven industrial technology.

2. Success in building the corporate information system depends on the quality and reliability of system-technical base, which lies at its core. It is important to first examine the possibility architecture (system and technical infrastructure) and then proceed to build application-specific functionality on a holistic foundation. Further, computer infrastructure and system functionality should be built parallel to the maximum extent to ensure variability level application-specific functionality.

3. systems forming an organizational element, the core building CIS should be considered EDS which, first, run all the streams of documents, performing in some sense the role of the compiler of the organizational structure of the institution through the formalization of business processes, and secondly, significantly affect CIS infrastructure in terms of requirements engineering, communications, software, organizational tools that provide performance SED and CIS as a whole.

4. Infrastructure of the EDS must create an integrated collaboration environment, to provide complete solutions (organizational, architectural, communications, software, etc.) in the field of collaboration, allow technology to solve complex problems at any organizational level.

References

1. D.A. Pokryshen, 2012. Information technology and learning tools. 2012. №4 (30). Access the journal: http://www.journal.iitta.gov.ua.net.

2. Ladyzhenskyy G.M. Architecture of the corporative information systems. St .: BHV, 2006. - 410c.

3. Martin Fowler. Architecture the corporate software applications. 2006 - 544p. Access: http://www.booksgid.com/programmer/4642-martin-fauler.-arkhitektura.html.

UDC 004.724.5

V. Klobukov, V. Ryabokon, O.Zykov, L.Klobukova
(National Aviation University, Ukraine, Kiev)

THE BASIC PRINCIPLES OF AUTOMATED SYSTEMS DEPLOYMENT INSIDE CONTAINERS VIRTUALIZATION SOFTWARE IN A PROJECT

In the article described the Docker - platform for developers and sysadmins to develop, ship, and run applications.

Docker is an open platform for developing, shipping, and running applications. It is designed to deliver applications faster. With Docker applications can be separated from infrastructure. It combining a lightweight container virtualization platform with workflows and tooling that help manage and deploy applications.

Docker provides a way to run almost any application securely isolated in a container. The isolation and security allow to run many containers simultaneously on one host. The lightweight nature of containers, which run without the extra load of a hypervisor, gives the ability to get more out of the hardware.

Docker itself is the tooling and a platform which can perform several tasks:

- getting applications (and supporting components) into Docker containers;
- distributing and shipping those containers to developer teams for further development and testing;
- deploying those applications to the production environment, whether it be in a local data center or the Cloud.

Docker's architecture

Docker uses a client-server architecture. The Docker client talks to the Docker daemon, which does the heavy lifting of building, running, and distributing Docker containers. Both the Docker client and the daemon can run on the same system,or a Docker client can be connected to a remote Docker daemon. The Docker client and daemon communicate via sockets or through a RESTful API.

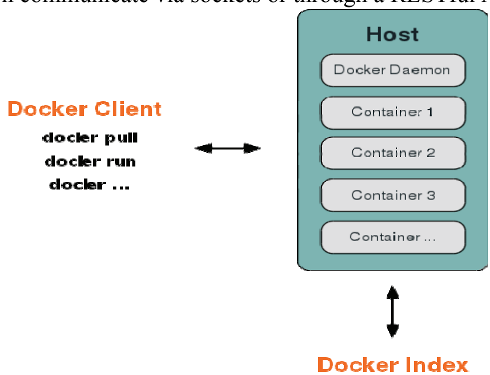


Figure 1 Pic. 1 Docker's architecture

The Docker daemon.

The Docker daemon runs on a host machine. The user does not directly interact with the daemon, but instead through the Docker client.

The Docker client.

The Docker client, in the form of the docker binary, is the primary user interface to Docker. It accepts commands from the user and communicates back and forth with a Docker daemon.

Docker's internals

There are three Docker components:

Docker images

A Docker image is a read-only template. For example, an image could contain an Ubuntu operating system with Apache and a web application installed. Images are used to create Docker containers. Docker provides a simple way to build new images or update existing images, or it is possible to download Docker images that other people have already created. Docker images are the build component of Docker.

Each image consists of a series of layers. Docker makes use of union file systems to combine these layers into a single image. Union file systems allow files and directories of separate file systems, known as branches, to be transparently overlaid, forming a single coherent file system. When someone change a Docker image—for example, update an application to a new version— a new layer gets built. Thus, rather than replacing the whole image or entirely rebuilding, as you may do with a virtual machine, only that layer is added or updated. Now it is not necessary to distribute a whole new image, just the update, making distributing Docker images faster and simpler. Every image starts from a base image, for example ubuntu, a base Ubuntu image, or fedora, a base Fedora image. It is possible also to use images of user's own as the basis for a new image, for example if there is a base Apache image it is possible to use this as the base of all user's web application images.

Docker images are then built from these base images using a simple, descriptive set of steps called instructions. Each instruction creates a new layer in image. Instructions include actions like:

- run a command.
- add a file or directory.
- create an environment variable.
- what process to run when launching a container from this image.

These instructions are stored in a file called a Dockerfile. Docker reads this Dockerfile when you request a build of an image, executes the instructions, and returns a final image.

Docker Registries

Docker registries hold images. These are public or private stores from which images can be uploaded or downloaded. The public Docker registry is called Docker Hub. It provides a huge collection of existing images. These can be images created by community or individual users. Docker registries are the distribution component of Docker. The Docker registry is the store for the Docker images. Once user build a

Docker image it can be pushed to a public registry Docker Hub or to user's own registry running behind firewall.

Using the Docker client, it is possible to search for already published images and then pull them down to the Docker host to build containers from them.

Docker containers

Docker containers are similar to a directory. A Docker container holds everything that is needed for an application to run. Each container is created from a Docker image. Docker containers can be run, started, stopped, moved, and deleted. Each container is an isolated and secure application platform. Docker containers are the run component of Docker.

A container consists of an operating system, user-added files, and meta-data. As we've seen, each container is built from an image. That image tells Docker what the container holds, what process to run when the container is launched, and a variety of other configuration data. The Docker image is read-only. When Docker runs a container from an image, it adds a read-write layer on top of the image (using a union file system as we saw earlier) in which your application can then run.

Docker container can be run by using the docker binary or via API. The Docker client tells the Docker daemon to run a container. For example:

$ docker run -i -t ubuntu /bin/bash

In this command the Docker client is launched using the docker binary with the run option telling it to launch a new container. The bare minimum the Docker client needs to tell the Docker daemon to run the container is:

- what Docker image to build the container from, here ubuntu, a base Ubuntu image;
- the command, must be run inside the container when it is launched, here /bin/bash, to start the Bash shell inside the new container.

To execute this command, Docker does the following:

- pulls the Ubuntu image: Docker checks for the presence of the Ubuntu image and, if it doesn't exist locally on the host, then Docker downloads it from Docker Hub. If the image already exists, then Docker uses it for the new container;
- creates a new container: once Docker has the image, it uses it to create a container;
- allocates a filesystem and mounts a read-write layer: the container is created in the file system and a read-write layer is added to the image;
- allocates a network/bridge interface: creates a network interface that allows the Docker container to talk to the local host.
- sets up an IP address: finds and attaches an available IP address from a pool.
-executes a process specified: runs application, and;
- captures and provides application output: connects and logs standard input, outputs and errors for user to see how the application is running.

There is now a running container. It can be managed, application inside can be interacted, and then, when finished, container can be sopped and removed.

The underlying technology

Docker is written in Go and makes use of several Linux kernel features to deliver its functionality.

Namespaces

Docker takes advantage of a technology called namespaces to provide the isolated workspace called the container. When user runs a container, Docker creates a set of namespaces for that container.

This provides a layer of isolation: each aspect of a container runs in its own namespace and does not have access outside it.

Some of the namespaces that Docker uses are:

- The pid namespace: used for process isolation (PID: Process ID).
- The net namespace: used for managing network interfaces (NET: Networking).
- The ipc namespace: used for managing access to IPC resources (IPC: InterProcess Communication).

The mnt namespace: used for managing mount-points (MNT: Mount).

The uts namespace: used for isolating kernel and version identifiers. (UTS: Unix Timesharing System).

Control groups

Docker also makes use of another technology called cgroups or control groups. A key to running applications in isolation is to have them only use the resources you want. This ensures containers are good multi-tenant citizens on a host. Control groups allow Docker to share available hardware resources to containers and, if required, set up limits and constraints. For example, limiting the memory available to a specific container.

Union file systems

Union file systems, or UnionFS, are file systems that operate by creating layers, making them very lightweight and fast. Docker uses union file systems to provide the building blocks for containers. Docker can make use of several union file system variants including: AUFS, btrfs, vfs, and DeviceMapper.

Container format

Docker combines these components into a wrapper called a container format. The default container format is called libcontainer. Docker also supports traditional Linux containers using LXC. In the future, Docker may support other container formats, for example, by integrating with BSD Jails or Solaris Zones.

UDC 004.415.2 (045)

Sidorov N.A., Doct. of sciences
(National aviation university, Kiev)

GREEN SOFTWARE LIFE CYCLE MODEL

The approach to development the software life cycle models for satisfaction of green and sustainable software requirements was proposed. The approach based on three parts of software life cycle model. Aspects of greening software are looked. The software life cycle model is importance part of software engineering and greening of model is importance action for green and sustainable software engineering.

Introduction

The effect of software on sustainable development is the hot topic now-a-days in Green Computing [1, 2]. Sustainable development refers to resource use for meeting the needs of humans while taking into account the ecological, economic, and societal impacts. Software has an direct or indirect effect on the environment by operating and managing the information systems. This paper focuses on green and sustainable software by building a green software life cycle models. Green Software is the software whose direct and indirect negative impacts on economy, society, human beings, and environment that result from development, deployment, and usage of the software are minimal. The Green Software is the sustainable software that it has a positive effect on sustainable development.

Researches and publications

Some publications are focused on building green software, some design software processes to aid all stakeholders in building green software products [3]. Others efforts are focused on building software tools that measure the greening of software and are used in building green software products [4]. In general software solutions include virtualization, closing applications no longer in use, efficient algorithms by writing a compact design of codes and data structures, reduction of parallelism overhead by developing efficient load balancing algorithms, fine grained green computing, and creating energy allocation algorithms for routing data [5, 6]. However, there are publications focused on all software development processes [7, 8]. For example, a conceptual reference model named GREENSOFT Naumann prooposed [7]. The four parts of the model cover a life cycle model, - metrics, procedure models, and recommendations and tools. The parts of model supports software developers, administrators, and software users in creating, maintaining, and using software in a green manner. Shenoy and Earatta also provide a green development model in which they suggest steps that may lead to lower carbon emissions in the software life cycle stages [8]. Mahmoud and Ahmad proposed green software development model which consist of two levels. The first level represents how to obtain a green and sustainable software product. On this level, the green product analysis after system testing in software life cycle model is added.

Green software processes in software life cycle phases was included. For example, the risk analysis in terms of energy efficence in requarements specification phase was added. The second level of green model indicates how software tools can play a major role in having energy efficient use of software applications thus promoting green computing [8]. The level represents the five categories for software tools and concepts that authors define.

Green and sustainable software life cycle model

We proposed the green software life cycle models based on three parts of classical model [9]. The essence of the software life cycle phase consists in fulfillment of processes with the help of resources (methods, means, tools, staff) and developing software product (Fig.1). According to the ISO/IEC 12207:1995 standard, a software life cycle model is a framework containing processes, activities, and tasks involved in the development, operation, and maintenance of a software product, spanning the life of the software system from the definition of its requirements to the termination of its use.

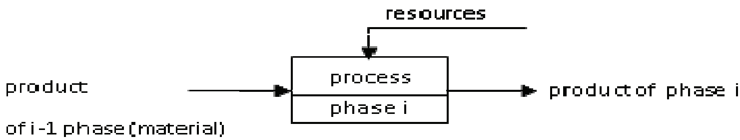


Fig.1. Basic components of the software life cycle

Therefore, the software life cycle model consists of the following basic components: processes, products, resources. The green software life cycle model is created by including the “greening” components in classical software life cycle model (Fig.2.)

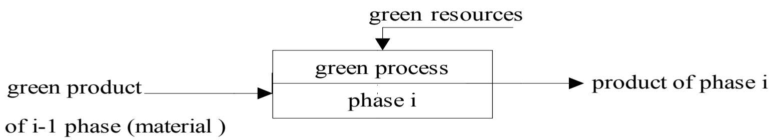


Fig.2. Basic components of green the software life cycle

A process can be defined as a sequence of actions or operations. An operation (action) usually has an expected duration, cost and resources. We will use the following definition. The process is a sequence of interdependent actions during which the source product, with the help of the resourses, is transformed into another (output) product. The IEEE 1074 standard defines the following processes and actions: choice of the software life cycle model, project management, preliminary development, development, post development, integration, the 17 subprocesses and 65 actions. There are vertical (for example, coding) and horizontal (for example, quality management) processes. In green software life cycle models the processes include additional greening phases. For example, requirement specification process includes phase of risk analysis in terms of green and sustainable software or design/construction processes include reusing and effective programming style. All processes of green software life cycle model reduce wastes.

The software life cycle processes are fulfilled with the help of the recourses. There are the following resources: tools, methods, implementers (performers). There are the following types of tools: separate, integrated. The separate tools are used to realize one process of the software life cycle. For example, the separate tools are used for: creating human-computer-interfaces (HCI builder), data base management (DBMS), specifying the requirements (specificators), domain analysis (DAT), coding (translators), testing (testers), documentation (documentators), maintenance (analyzers), restructuring (restructurs). The integrated tools are used to realize all or some processes of the software life cycle. For example, the integrated tools are used for the following: analysis and design (CASE-Analysis Design); project management (CASE-Project Management); quality control (CASE-Quality Control); reversing engineering (CARE). The tools of green software life cycle model use the Green Performance Indicators, the metric IT Hardware Power Overhead Multiplier. Software tools can be built to reduce waste, identify, and limit the amount of energy, keep the memory and CPU-time.

There are two types of software products: result of the software life cycle is software systems (software product); results of the processes of the software life cycle are work products. A green and sustainable software product ideally meets three conditions: the software is produced in a way that meets green and sustainability requarements; the software product has minimal negative social, economic and environmental impacts during its usage; the software functionality reinforces green and sustainable development or at least has no negative impacts on the society or environment. Product Sustainability summarizes the effects of software product on other products (information systems) and services (applications).Green and sustainability criteria and metrics for software products are used in green software life cycle model. In this context, there are the following tasks: To define a green software product, To define green criteria, and To develop metrics for green software and engineering For decision these tasks, it is necessary to provide additional tools and methods.

Conclusion

The approach to development the software life cycle models for satisfaction of green and sustainable software requirements was proposed. The approach based on three parts of software life cycle model. Aspects of greening software are looked. The software life cycle model is importance part of software engineering and greening of model is importance action for green and sustainable software engineering.

References

1. L.M. Hilty,W. Lohmann AN ANNOTATED BIBLIOGRAPHY OF CONCEPTUAL FRAMEWORKS IN ICT FOR SUSTAINABILITY In:ICT4S

2013: Proceedings of the First International Conference on Information and Communication Technologies for Sustainability, ETH Zurich, February 14-16, 2013, p. 288-300.

2. Sidorov N.A., Software ecology – Software engineering- No. 1.-2010.- p.53-61.

3. T. J Good Beautiful Software - In Search of Green Software Quality Factors. CEPIS UPGRADE XII (4):22–27.-2011.

4. Shojaee H Rules for Being a Green Software Engineer. Ship Software OnTime! The blog that helps you build great software. http://ships of software on time.com/2007/12/24/rules-for-being-a-green-software-engineer/. Accessed 26 Jul 2011.

5. Zapico, J. L., Brandt, N. ,Turpeinen, M. Environmental Metrics: The Main Opportunity from ICT for Industrial Ecology. Journal of Industrial Ecology 14 (5) 2010, P.703-706.

6. Kocak SA Green Software Development and Design for Environmental Sustainability. In: 11th International Doctoral Symposium an Empirical Software Engineering (IDOESE 2013). October 9, 2013, Baltimore, Maryland.- 2013.

7. S. Naumann, M. Dick, E. Kern, T. Johann, "The GREENSOFT Model: A reference model for green and sustainable software and its engineering", Sustainable Computing: Informatics and Systems, vol. 1, no. 4, **(2011)**, pp. 294-304.

8. S. Mahmoud,I. Ahmad A Green Model for Sustainable Software Engineering. International Journal of Software Engineering and Its Applications Vol. 7, No. 4, July, 2013.

9. Sidorov N. Software engineering - NAU.- 2005.- 140 p.

UDC 004.62

Chystiakova I.S. (Institute of Software Systems National Academy of Sciences, Ukraine, Kiev)

METHODOLOGIES FOR ONTOLOGY CREATION

This paper is devoted to the problem of ontology creation. A brief overview of the main existing methodologies of ontology creation is proposed within the component of ontology engineering.

Introduction

Ontologies are the key aspect of the development of the Semantic Web. There are several fundamental definitions of ontologies for the different fields of science. We consider it as a formal, explicit specification of conformed conceptualization [1]. Any domain, any subject area can be represented as a set of concepts and relationships between them. Thus, you can create some structured, machine-readable and machine-processed set of basic concepts and their definitions, which allows experts to share information within the subject area, and computer agents to process semantically uniform information. Ontologies are gaining wide popularity not only in the fields of artificial intelligence, but also in the areas of knowledge engineering, natural language processing, database design and data integration, e-commerce, information extraction, bio-informatics, etc. The question arises: why do we need to create an ontology?

In [2], there is a set of the following reasons:

1) To share common understanding of the structure of information among people or software agents. For example, there are two resources that contain information of the same domain. If they use the same ontology to define common terms in the domain, the computer agents use information of both resources for response to the user requests, or as input data to the external application.

2) To enable reuse of domain knowledge. Ontology implements the "open world" conception, that is, with the passage of time and the emergence of new, previously unknown entities within a domain can be easily added to an existing model, without re-designing the conceptual framework. It is also possible to create an extensive ontology from several existing, which describe the different parts of a large domain, as well as to create a common ontology (for example, UNSPSC), which can be reused to create their own arbitrary domain ontology.

3) To make domain assumptions explicit. If domain knowledge changes, the expert should be able change them explicitly, without being a specialist in creation and programming the ontologies.

4) To separate domain knowledge from the operational knowledge. We have an opportunity to create some product from the parts of other products of certain specifications. In this case it will be completely independent of its components. For example, we create a car, the parts of which are the engine, steering wheels, seat belts, etc.

5) To analyze domain knowledge. When we reuse and extend an existing ontology, it is important to analyze its declarative specification, in order to avoid duplication of data and their contradictions.

Such a rapid development of ontologies has led to a new field of science - ontology engineering.

Ontology engineering in computer science is a discipline that studies methods, methodologies and tools for building and using ontologies.

Ontology engineering methodologies describe methodological process of ontology development. It often provides a set of guidelines or transactions, which have to be performed in sequence. Today there are many different methodologies. Some of them are offered only as a theory; some of them based on practical results. Publication [3] provides a detailed overview of 15 different methodologies. We shall consider only the three most important from our point of view.

1) The Enterprise Ontology methodology [4].

2) METHONTOLOGY [5].

3) Ontology Development 101 [6].

The Enterprise Ontology methodology

The authors of this methodology were the first who realized the need to provide developers with some general workflow to develop ontologies. It represents a set of guidelines and their sequence, but does not describe the specific tools of execution. It is based on the practical experience of creating ontology of enterprises (Enterprise Ontology), which is a collection of terms and definitions relating to business enterprises.

The proposed methodology consists of several stages. Each of them has a description. We offer a summary of the ideas presented in this paper.

<u>Stage 1. Identify Purpose</u>.

Like any other methodology, the first step is to define the goal, why create an ontology, who (or what) will use it, what scope does it have, whether it will be reused, etc.

<u>Stage 2. Building the Ontology</u>.

It is divided into several sub-stages, each of which has its own set of characteristics.

2.1) *Ontology capture*. First of all, here may be included everything, that regards to knowledge extraction. At this stage the analysis of domain of building ontology takes place. Today there is a whole field of research devoted to the knowledge extraction of different sources of subject areas. However, we will not consider this issue within this publication. We present only definition of the authors of methodology itself.

By ontology capture they mean:

- identification of key concepts and relationships in the domain of interest;
- production of precise unambiguous text definitions for such concepts and relationships;
- identification of terms to refer such concepts and relationships;
- agreeing on all above.

2.2) *Coding*. Author of the methodology considers coding as an explicit representation of the conceptualization of all data determined in "capture" step by means of a formal knowledge representation language.

According to [7], the stage of 'capture' and coding should be present in any methodology. The author considers the question of unification of these steps into one. For this purpose methodology should fundamentally explain the existence of circumstances (and which), whereby this union possible.

2.3) *Integrating existing ontologies*. During the previous two stages we discussed the use of already existing ontologies to create a new one. We explored the problems of interaction with other ontologies within domain and communication between communities that use these ontologies. Therefore, at this stage, the establishment of agreements about how the ontology will be used in the future takes place.

<u>Stage 3. Evaluation</u>.

The authors of the methodology refer to work [8], fully defining this stage as follows:

"…to make a technical judgment of the ontologies, their associated software environment, and documentation with respect to a frame of reference…The frame of reference may be requirements specifications, competency questions, and/or the real world." [8] It is also noted that before the estimation of ontology it should be first seen which methods of assessment used in knowledge-based systems, and then adapt it to ontologies.

<u>Stage 4. Documentation</u>.

Any user of ontology wants to have detailed instructions of usage, which will vary depending on the type and purpose of the ontology. The authors of the methodology note that the lack of quality documentation is a serious obstacle to effective knowledge sharing. Therefore, all important assertions of the ontology should be documented, including the major concepts and primitives that are used to express the definitions of ontology.

Methontology

It was proposed as a methodology for developing ontology from scratch. Unlike the previous one, METHONTOLOGY describes in detail the sequence of actions and techniques of construction. It presents an evolving prototype as lifecycle ontology. It includes activities such as specification, formalization, integration and implementation. It is presented in parallel very important activities, such as knowledge extraction, evaluation, integration and documentation, running throughout the whole life cycle. The methodology has been tested on different ontologies multiple subject areas (chemistry, pollution, etc.)

The authors present METHONTOLOGY in the form of recommendations on the life cycle of the ontology that allows declaring it as a universal methodology for ontology development "from scratch."

The process of ontology development is defined as a list of actions that are required to build their own ontologies, without the order of these actions. The list contains the following components:

1) Planning (tasks, time, resources).
2) Specifying (goal and objective of creating ontology, domain, end users).
3) Knowledge detection (list of sources of knowledge extraction).
4) Conceptualizing (creation of an ontology conceptual model).
5) Formalization (creation a formal model of a conceptual model using descriptive logics or frame-based representation systems).
6) Integration (use of existing ontologies).
7) Implementation (ontology representation in some formal language).
8) Evaluation (estimate the correct description).
9) Documentation (detailed user manual).
10) Maintenance (detailed guidance on the management of ontology)

The life cycle of ontologies is defined as a sequence of steps that ontology passes during the lifetime. It goes through the following stages: specification, conceptualization, formalization, integration, implementation, support. Knowledge acquisition, documentation and evaluation are tasks that executed throughout the ontology life. As the creator of ontologies should define requirements that will be its core before creating an ontology, it follows that the life cycle of ontologies is much closer to the classical software life cycle, than life cycle of knowledge-based systems. Therefore METHONTOLOGY is based on the evolutionary model (from software engineering) because it allows you to modify, add and delete definitions in the ontology at any time that is most appropriate for the creation and development of the ontology.

Methodology consists of the following phases.

1) Specification. The goal is to create an informal, semiformal or formal ontology specification, written in natural language. It should include the following: the purpose of creation (as well as the intended use, end users, etc.); level of formality (highly informal, semi-casual, semi-formal and strictly formal); scale (set of terms that will be presented, features, detail).

2) Knowledge acquisition. It means identification of sources (books, experts, guides, etc.), knowledge extraction techniques (brainstorming, analysis of texts, special tools, etc.), and their combination.

3) Conceptualization. The goal is to create a conceptual model. The first step is to create a glossary of terms, which includes concepts, instances, verbs and properties. If the first phase was formed a good document of specifications, many terms have already been defined in it. Later they will be determined during the process of creation and should be included in the glossary. This includes the definition of the basic concepts, attributes and properties, creating the hierarchy between them and defining interactions with each other.

4) Integration. Starting create ontology "from scratch", you should always use the definitions, which are already exist in the finished ontologies. This can include both the use of meta-ontologies, and other existing ontologies of the domain.

5) Implementation. The result of this phase is an ontology written in some formal language (C + +, Prolog, Ontolingua, etc.)

6) Evaluation. At this stage technical evaluation of created ontology, software environment and documentation of each phase of the life cycle is held. It includes verification and validation.

7) Documentation. There are no uniform guidelines for documenting ontologies, because there are few methods of building ontologies. Existing documentation about ontology creation process is often include comments in the source code of ontology, natural language text, which is attached to the formal definition, articles on ontologies, conferences, etc. METHONTOLOGY offers use a set of documents that have been formed at the end of each stage of the life cycle as documentation on the ontology.

Ontology Development 101

It is an iterative methodology based on several fundamental rules applied during the ontology development process. It describes all phases of the process, including such as the definition of the hierarchy of classes, properties, and instance creation. As an explanation example it was taken the wine ontology using Protégé 2000 tool. Lifecycle model is absent.

The methodology is based on three fundamental rules [6]:

1) There is no one correct way to model a domain— there are always viable alternatives. The best solution almost always depends on the application that you have in mind and the extensions that you anticipate.

2) Ontology development is **necessarily** an iterative process.

3) Concepts in the ontology should be close to objects (physical or logical) and relationships in your domain of interest. These are most likely to be nouns (objects) or verbs (relationships) in sentences that describe your domain.

Steps of creation ontology.

Step 1. Determine the domain and scope of the ontology.

Before proceeding the creation of ontology it should be clearly defined the subject area, its scope, degree of detail, what, who and how will use the ontology. Answers to these questions may change during the ontology design process, but in any given time interval, they help narrow the scope of the model.

Step 2. Consider reusing existing ontologies.

It should always be considered an opportunity to improve or extend an existing ontology. This may be the initial requirement if your system should be able to interact with other applications that have already interacted with specific ontologies or controlled vocabularies. There are many ontologies available on electronic resources, and their formalism does not play a significant role since as knowledge representation systems are able to import and export ontologies. Even if the system can operate with only one clearly formalism, the task of translation is not such a complex.

Step 3. Enumerate important terms in the ontology.

Because step is described very briefly, we have expanded the definition of this step to improve readers` understanding. It needs to build a glossary of terms (terms of concepts, properties, relations, etc.) with the provision of their definitions in natural language and an indication of their synonyms, acronyms, and other characteristics. Initially, it is important to get a complete list of terms, without having to worry about crossing the concepts they represent, about relations between the terms, about the possible properties or notions about what the concepts are -

classes, properties or relations. Definition of terms provides a solid basis for unambiguous understanding of the domain being modeled by all persons participating in the creation and use of ontology.

Step 4. Define the classes and the class hierarchy.

There are three possible approaches to the development of the class hierarchy.

1) "From top to bottom". First the more general concepts are defined, with their subsequent specialization and specification down to more concrete concepts.

2) "Bottom-up". First the most specific concepts ("leaves" of the hierarchy) are defined and followed by grouping them into more general.

3) Combined. It contains both of the approach above. First the most notable concepts are marked and then they summarized and detailed simultaneously.

Neither of these approaches is better nor worse than another. Their use depends on the given problem, the domain representation and imagination the subject area by the developer. The concepts of ontology primarily selected from those identified in step 3.

Step 5. Define the properties of classes.

Initially, it is given the author's understanding of the definition of properties. Here you need to identify and clearly define the set of properties (attributes, characteristics) that characterize each entity. It is required the selection set required/non required properties and properties that identify the entities. It should be specified the range of permissible values of properties and other restrictions on property values. In other words, the properties may also have properties (required identifying, range, type, capacity).

According to [6], there are several kinds of object properties.

1) “Intrinsic”. As property values range serves some type of data.

2) “Extrinsic”. As the range value is performed other class or its subset.

2) «Внешние». В качестве диапазона значение свойства выступает другой класс или его подмножество.

3) Relationship between individuals of classes.

Properties are inherited. If the parent class has this property, then the descendants will also possess them.

Step 6. Define the facets of properties.

Because this issue is devoted to a large part of [6], here we present our understanding of the processes taking place at this stage. In this step identification and clear definition of other arbitrary binary relationships between concepts occurs, indicating what type of relations they relate (equivalence, part/whole, aggregation, association, cause and effect, etc.). You should specify the capacity of the end of communication (1:1, 1: M, M: N) and their optional (mandatory, optional). Binary communication may also have reflexivity, transitivity and symmetry properties. Thus thesaurus is constructed. Note that bonds themselves may also have a taxonomic structure (for example, the relationship between man and organization "to be employed" is a generalization of communication "is a senior researcher.")

Step 7. Create instances.

The final step is the creation of one (or even several) copies of the ontology. This involves the creation of instances of entities (classes) with the values of all properties of the entity, as well as all the necessary connections between them.

Conclusions

The ontology development process is a difficult task, so there are many different methodologies to create them. All of them rely on their own terms and practical evidence, but none of them is fully mature.
In this paper we presented a brief overview of the three main methodologies for developing ontologies. It was given their short description and key components.

References

1.T. R. Gruber. “A Translation Approach to Portable Ontologies”. Knowledge Acquisition, 5(2):199–220, 1993.

2.Natalya F. Noy and Deborah L. McGuinness. “Ontology Development 101: A Guide to Creating Your First Ontology”. Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880, March 2001.

3.Iqbal, R., Murad, M.A.A, Mustapha, A., Sharef, N.M., (2013), "An Analysis of Ontology Engineering Methodologies: A literature review", Research Journal of Applied Sciences, Engineering and Technology, 6(16): 2993-3000

4.Uschold, M. and M. King. Towards a methodology for building ontologies. Proceeding of the Workshop on Basic Ontological Issues in Knowledge Sharing, 1995, pp: 74.

5.Fernández-López, M., A. Gómez-Pérez and N. Juristo, 1997. Methontology: From ontological art towards ontological engineering. Proceeding of the Spring Symposium on Ontological Engineering (AAAI), pp: 33-40.

6.Natalya F. Noy and Deborah L. McGuinness. ``Ontology Development 101: A Guide to Creating Your First Ontology''. Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880, March 2001.

UDC 004.4:004.738.5(045)

Kolisnichenko R.A.
(National Aviation University, Ukraine, Kyiv)

METHOD OF FLIGHT SIMULATOR DEVELOPMENT

Methodology development of IT-infrastructure of flight simulator is proposed. Methodology is based on principles of IT Infrastructure Library. An example of the use of method is presented.

Introduction

Flight simulators (FS) are used for studies to aviating, working off flying hours by pilots. With the increase of complication of the airborne systems, FS become more difficult. For the construction of modern FS it is necessary to develop new methodological approaches that allow rationally in the compressed terms with a maximal economic effect to execute development of the facilities and software FS. For effective work of FS it is necessary to provide the concerted work of heterogeneous constituents of the system, integrate software, work out the problems of management networks, by Computing resources (CR) to the complex, process-oriented managements of the information telecommunication system (ITS) [1]. For the proper functioning of ITS, that forms and supports the business processes of FS, it is necessary to create the IT-infrastructure that gives an opportunity effectively to use CR of the system; minimize influence of human factor; promote a return from capital investments. Such approach it is expedient to use for the construction of difficult domain-driven real-time systems one of that and there is FS.

Method

Initial development phase of IT-infrastructure time is determination of IT-services through the processes of activity (business processes) [2] what must provide FS. There is a task to define and describe architecture of IT-services that FS will give, work out methodology of construction service model (SM) IT-services, taking into account the features of FS domain. The generalized architecture of FS consists of: CR; communication net; console of instructor (CI); cockpit (CP); imitator of noise (IN); systems visualization of flight (SVF); motion platform (MP). These parts depending on FS have different after an amount and complication run-time systems. CI intended for setting initial conditions of flight, control quality of aviating, management the imitation refuses of airplane. CR is needed for maintenance and deployment of software that manages work of FS. Communication net provides the exchange of data between CR of FS. CP is intended for the acquaintance of pilots from CP of the real airplane. IN provides voice accompaniment in CP. SVF in FS used for visualization surrounding of airplane at flight. MP creates the imitation of gravitational influence during implementation of flights.

The basic business processes of FS are: realization of flight education by pilots; studies of aviating, navigation, then that (the table 1). The participants processes of activity are a crew of airplane and instructor. After determination processes of activity it is necessary to divide them into a business-function with the separation of business-functions for pilots and instructor. Pilots in FS meet from CP of the real airplane, get skills on the use of control system and equipment.

Table 1.

Basic processes of activity and business-function of FS are for the pilots of airplane

Processes of activity	Business-function
Pre-flight studies	An acquaintance of crew is with a cockpit, devices, custom controls and equipment in the booth of airplane
	Studies to all set operations, verifications and controls onboard airplane, that executed before flight
	Implementation studies of management power-plants, by the systems of airplane, electronic equipment, their verifications
Studies technique of aviating	Training of launching is of airplane in normal and extreme terms
	Training implementation of the guided events on an instrument-landing and landings manoeuvres depending on the specific terms of the air field
	Studies aviating is in normal and difficult terms
	There is training of flights en-route with the use of radiotechnical facilities and communication means
	Training actions of crew is in case of occurring on wing of different refuses and unforeseen situations

The use of FS to the pilots gives an opportunity to work off a flying task; watch the parameters of flight; perceive visual surroundings and voice accompaniment during aviating; feel gravitational influence.

IT-services target at certain business-functions. In this case it is IT-services that is based on the application systems: support functions of CP; providing functioning of IN; visualization of flight; management of MP. Processes of management and control studies: task of initial conditions to flight; monitoring of aviating; estimation and discussion of errors. In a table 2 the brought list over processes of activity and business-functions for an instructor. The instructor of FS has a workplace (CI) – an automated workstation (AW) with the hardwarily-programmatic providing. Thus, IT-service that supports the business-functions of instructor there are organization and support functioning AW instructor of FS.

Table 2.

Processes of activity and business-function of FS of instructor

Processes of activity	Business-function
Pre-flight studies	Choice of flight task
	Setting of initial conditions of flight
Studies aviating of pilots	An imitation cooperation of pilots is with an air-traffic controller
	Management the imitation refuses of airplane

Forming of reports is on working off a flying task	Receipt values of parameters with fixing of them on paper or electronic transmitters for control of aviating and analysis errors of aviating

Determination and development of IT-services are part of IT-processes (Service Level Management, Service Design) libraries of ITIL (IT Infrastructure Library). On recommendation of ITIL the structure IT-service is described SM [3]. Development SM IT-services [3]: selection IT-services; determination resources of IT-service; development of software metrics and indexes of quality of IT-processes and services. Forming of SM, allows to present the model of IT-service that describes composition and intercommunications configuration of units (CU) – elements of IT-infrastructure.

Creation of SM will bring around to the example of IT-service "Providing functioning of IN". An imitation of voice surroundings is in the booth of FS [4] provides auditory information about the modes operations of airplane. At beginning is developed the generalized architecture of IN. In accordance with her SM IN is built FS. Visualization structure of SM is executed by means of graphic reflection of model levels from a top in a bottom, determining CU and connections (Fig. 1) that will give an opportunity to realize IT-service through the elements of IT-infrastructure and functional equipment (FE). Realization SM of IT-service is a process transference of model on a hardwarily-programmatic platform and integrations of her from FE. At the choice of CR, the equipments of information telecommunication net and FE take into account requirements to IN. OS must optimally use software, present resources of IN. The application software of IN must be developed for every model to FS, using experience developers of software for FS, for example [4, 5].

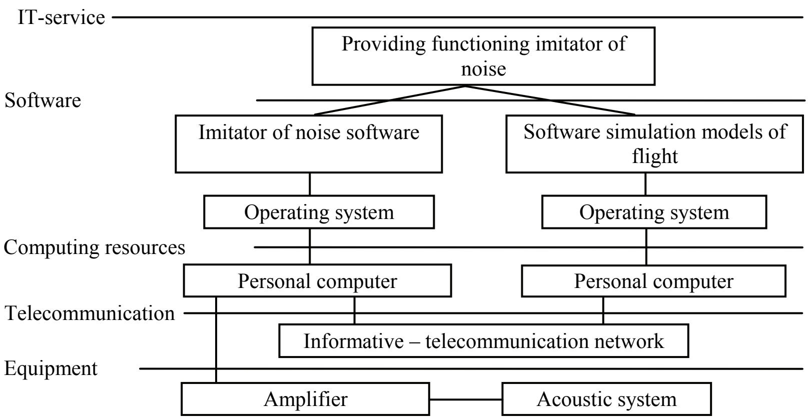


Fig. 1. Service model of IT-service "Providing functioning of IN"

The structure of other IT-services is like developed for the construction IT-infrastructure of FS. The worked out outline elements IT-infrastructure of FS is erected in a table 3.

Table 3

Hhierarchic structure configuration units IT-services of FS

IT-service / Level SM	Support functions of CP	Providing functioning of IN	Visualization of flight	Management of MP	Providing workstation of instructor
Software	Software of CP, Software of object communication device, Software model of FS, OS	Software of IN, OS	Software of SVF, OS	Software of MP, OS	Software of CI, OS
CR	PC, PLK	PC	PC	PC	PC
Telecommu nic-ation	Local network, network concentrator, server				
FE	Object communication device, devices, environment	Amplifier, audio system	Projector, projection screen	Hydraulic booster, hydraulic actuator	

Chart of IT-infrastructure [1, 6], depending on business-logic can have a different amount of hierarchical levels. Taking into account the features subject domain of FS, the four-level chart of IT-infrastructure of FS, that is totality of ITS, auxiliary personnel, users of services and FE. ITS consists of the IT-system, communication net, software, CR. The level of cooperation of networks (I level) is intended for access of users to all CR. The level of CR (II level) provides a basis for functioning of FS. The level of universal services (III level) includes services communication of data, signals of management and also software that is not appointed to the users, but necessary for work FS. The level of business application (IV level) provides cooperation of the systems and facilities management of software. Control system of IT-infrastructure (CSI) promotes efficiency work of FS through automation management of ITS, concordance of work constituents of ITS, integration of software. The consumers of IT-services of FS are pilots and instructor. Basic service that gives IT-infrastructure to the instructor this "Providing workstation of instructor". Services that is given by IT-infrastructure of FS to the pilots "Support functions of CP", "Providing functioning of IN", "Visualization of flight", "Management of MP".

Thus, the generalized architecture of modern FS is described. Determination of basic business processes, decomposition of them is executed on business-functions and setting of IT-services for pilots and instructor. The executed development structure IT-services of FS is by means of SM. Built generalized chart IT-infrastructure of FS.

References

1. Ролик А.И. Концепция управления корпоративной ИТ-инфраструктурой / А.И. Ролик // Вісник НТУУ «КПІ». Інформатика, управління та обчислювальна техніка: Зб. наук. пр. – К.: Век+, – 2012. – № 56. – С. 31-55.
2. Андерсен Бьёрн. Бизнес-процессы. Инструменты совершенствования / Пер. с англ. С.В. Ариничева / Науч. ред. Ю.П. Адлер. – М.: РИА «Стандарты и качество», 2003.- 272 с, илл.
3. ITIL Service Strategy, – Norwich, UK: TSO, 2011. – 359, 453 p.
4. Сидоров Н.А. Реинженерия программного обеспечения информационно-моделирующих тренажерных комплексов. / Сидоров Н.А., Недоводеев В.Т., Хоменко В.А., Сердюк И.П. // Управляющие системы и машины. – К. – 2008. – № 4. – С.68-74.
5. Stefan Burger, Oliver Hummel, Matthias Heinisch, Airbus Cabin Software, IEEE Software, January/February 2013, IEEE Computer Society.
6. Ролик А.И. Тенденции и перспективы развития управления информационными технологиями / А.И. Ролик // Вісник НТУУ «КПІ»: Інформатика, управління та обчислювальна техніка. – К.: «ВЕК+», 2012. – № 55. – С. 81–109.

UDC 004.4:004.738.5(045)

M.M. Kostiv
(National aviation university, Ukraine, Kiev)

EFFECTIVE PROGRAMMING STYLE

The task of creation of style of effective programing and tool for analyses of text of the application is considered, the results of experimental research for creation of the recommendations are represented.

Inroduction

In connection with the distribution of engineering methods of the software development, reuse, and extreme programming in a corporate software development, the use of programming styles when writing programs is attached a great significance [1, 2].

In the modern world due to the increasing complexity of applications software developers need to pay attention on performance, create appropriate technologies, styles and methods for developing large programs.

The use of efficient programming style helps make the application faster at the stage of writing the code [3], enhance the performance of the application using existing resources without addition or replacing the hardware, reduce the minimum hardware requirements and losses.

For Web - applications the speed is very important factor, because with the appearance of the technology WEB 2.0 applications became interactive and accessible to millions people around the world.

The styles, which are focused on the effectiveness, are still represented only as opinions of some authors about writing effective programs. For example, B. Stroustrup defines which data structures can be used more efficiently for solving certain tasks and provides recommendations [4].

Method

The growth of the speed of the application can be performed in two ways. First, other algorithms can be selected, and secondly, the checking of code of the application for compliance with rules of style of effective programming [5]. The creation of this style is described by the programming language PHP in the work.

Scheme for creation of style of effective programming is shown in the model of the scientific technique (Figure 1).

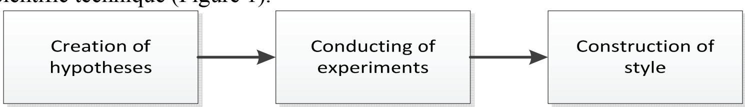


Fig.1.The schema of efficient style of programming

Algorithm for creation of hypotheses is divided into two parts: solving of the tasks in the chosen domain and formation of hypotheses on the basis of solved tasks (Fig. 2).

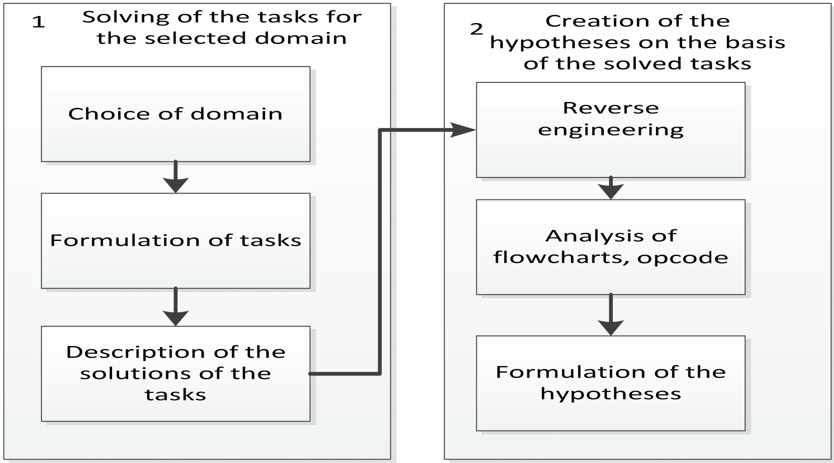


Fig.2. Algorithm for creation of hypotheses

First, the constructions for solving tasks are defined, which are related to a specific domain and occur in Web programming (Table 1).

Table 1.

Possible tasks, which are grouped by domain

Domain	Task
Searching in arrays	Checking the array for emptiness
	Checking the existence of an element in the array

For each task the algorithms for its solution are created and implemented in PHP as constructions.

Constructions are grouped by the common tasks they solve - two constructions into one group (Table 2).

Table 2.

Classification of the constructions

	Task	The first construction	The second construction
1	Checking the array for emptiness	$items = array(); if (empty($items)){}	$items = array(); if (count($items) == 0){}

2	Checking the existence of an element in the array	$array = array('a' => 1,'b' => 2); if(isset($array['a'])){}	$array = array('a' => 1, 'b' => 2); if(array_key_exists('a', $array)) {}

The hypotheses for each task in the group should be formulated theoretically for determining the faster construction in the same group, improvement of understanding of style and better explanation of the rules of style in teaching people effective programming style.

Theoretical confirmation or refutation of hypotheses will be performed through the execution of reversing engineering. In reverse engineering, the opcode is used, which obtained from a PHP script by means of a tool Vulcan Logic Disassembler [6]. The analyses of opcode and creation of flowcharts must be performed for each construction in the group during execution of reverse engineering.

Figure 3 shows a flowchart for the first construction, and in Figure 4, respectively, flowchart for the second construction for the task "Checking the array for emptiness" is shown from the table. 2.

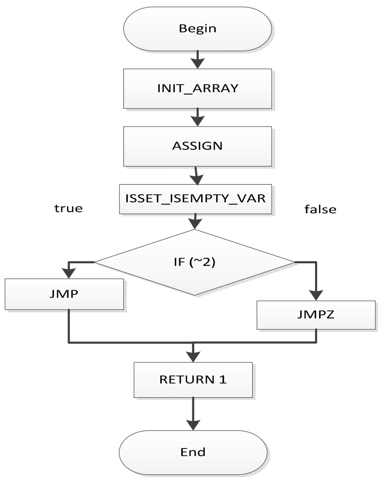


Fig.3. The flowchart for the first construction

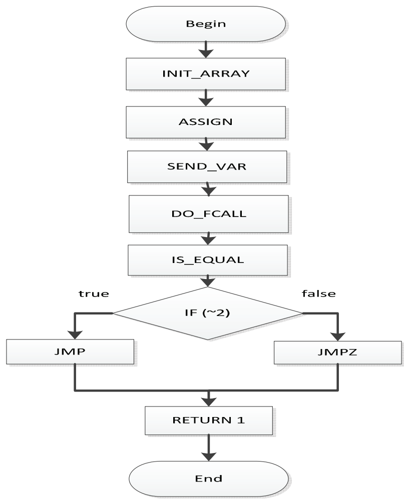


Fig.4. The flowchart for the second construction

During analyses of flowcharts, the hypotheses are created and create and substantiated.

Flowchart for the first construction contains seven processes, and for the second, respectively, contains nine processes. The hypothesis can be created, that the first construction will be determined as fast, and the other - as slow.

Tool

For the experimental confirmation or refutation of the hypothesis, it is necessary to create a tool that measures the execution time of each construction in the group and creates different evaluations of speed.

The results of the experiment for the constructions from the group with common task "Checking the array for emptiness", given in Table 3. These data indicate that the first construction is faster than second in 3.5 times. Thus, the hypothesis is confirmed experimentally.

Table 3.

The results of the experiment

Test	Construcioncode	Min execution time	Max execution time	Average time of execution	Percent of min	Percent of max	More than min	Less than max	Execution time
11.2	if (empty($items)) {}	0.0010	0.0011	0.0010	0.0000	28.5714	1.0000	3.5000	
11.1	if (count($items) == 0) {}	0.0029	0.0046	0.0035	250.0000	100.0000	3.5000	1.0000	

After completing all the previous steps for the other groups with constructions, the style of effective programming can be developed, which includes recommendations for improvement the speed of the program. For example, use the following recommendation when writing programs in the programming language PHP:

•check the array for emptiness use the construction void if (empty ($ array)) {} instead of if (count ($ array) == 0) {}.

The tool analyzes the code in the selected project and identifies those lines of code that contain ineffective constructions that violate the rules of style. The result of the analysis of the code is displayed in a table where in the first column file with code is displayed, and the second contains rules of style for improvement the highlighted lines of code (Figure 5).

CodeSniffer.php

File content	Comments
`echo "Registering sniffs in the $standardName standard... ";`	Don't use variable in double quotes, use concatenation.

Fig.5 The analyses of the text of the application

Conclusions

In the work the creation of style and technique of effective programming is considered with the programming language PHP, which can be used in the development of Web-applications. The developed style of effective programming can be improved and expanded by adding new tasks and constructions. By means of developed technique the style for other languages of programming can be created.

Using of style of effective programming increases performance of the application with existing resources without addition or replacing the hardware.

References

1.Сидоров Н.А. Стилистика программного обеспечения // Проблемы программирования. − 2006. − № 2−3. − С. 245 − 255.

2.Sidorov N.A. Software stylistics. // Вісник НАУ. -№2. -2005. – С.98-103

3.Крамар Ю. М. Применение стилей программирования в конструировании программного обеспечения // Освіта та інженерія програмного забезпечення. – К.: НАУ, 2011.

4.B. Stroustrup: Software Development for Infrastructure. Computer, vol. 45, no. 1, pp. 47-58, Jan. 2012, doi:10.1109/MC.2011.353.

5.Сидоров М.О., Костів М.М. Створення стилю ефективного програмування \\ Інженерія програмного забезпечення. - № 3 (15). - 2013. - С. 7 – 12.

6.Vulcan Logic Disassembler [Электронный ресурс]- режим доступа: http://pecl.php.net/package/vld

UDC 004.415.2 (045)

E.M. Sidorov, Ph.D
(National aviation university, Ukraine, Kiev)

LOSS IDENTIFICATION METHOD IN LEAN SOFTWARE DEVELOPMENT

Below is the proposed method of loss identification in the lean software development. The application of the method is illustrated by the example of losses at task switching. The examples include types of activity leading to losses, and the types of losses.

Introduction

Sustainable development implies lean development of software whose major task is to reduce costs or waste [1, 2, 3]. Presumptions of possible waste in the development process can be proved by way of *in vivo* experiment. However, *in vitro* testing will help better understand the reasons for losses; will enable their identification and qualitative assessment. The article offers the method for such testing. The method is illustrated by the example of losses at task switching [2].It is not infrequent that the developer runs several active projects at a time. For example, the intention to engage the staff at all stages of agile development leads to engagement of the same people in various projects. In this case the projects can be implemented simultaneously implying task switching among them. Such implementation method is criticized because it leads to longer implementation periods and losses [2].

There are no research works studying the influence of task switching on the software development process, but there are similar studies in other industries. Thus, research work [4] studies the problem of task switching as a whole. Research work [5] considers the switching aspects (environment, reasons, and strategies) in the context of “man-computer” interaction. Research work [6] presents, as part of the experiment, the results of the study of task switching during a working day of an office employee (meetings, telephone calls, e-mail). Research work [7] offers the notion of “activity scheme” as the means of [presentation and understanding of complex work microstructure. Though such studies prove the existence of losses caused by task switching, the software engineering requires their identification and assessment.

Method

The method is based on the hypothetic-deductive model of the scientific method, and thus has two major components. The first one is the supposition of loss in lean software development. The second on is the experiment to prove the supposition. The experiments imply the review which allows loss identification.

Hypothesis

The developed working and software products are marked by considerable volume of information (program code, specifications, decisions made, development and testing plans). When switching between projects a worker needs the time to digest (recall, renew) this information. Let us formulate three assumptions.

Hypothesis 1- switching between projects is time consuming, therefore task switching projects *ceteris paribus,* will be completed later that the same projects without switching. Then $\mathrm{T(n)} > \mathrm{T'(n)}$ where T(n) stands for the time spent by the participant on the performance of tasks with switching; n stands for the category of task complexity; T'(n) stands for the time spent on the performance of the same tasks, but consecutively. The margin of T(n)–T'(n) stands for the time lag caused by switching. The percentagewise loss of time is as follows: $\mathrm{S(n)} = \frac{\mathrm{T(n)} - \mathrm{T'(n)}}{\mathrm{T(n)}} 100$

Hypothesis 2 – the scope of works required for project implementation depends on its complexity, therefore there is dependence between losses on switching among projects and project complexity.

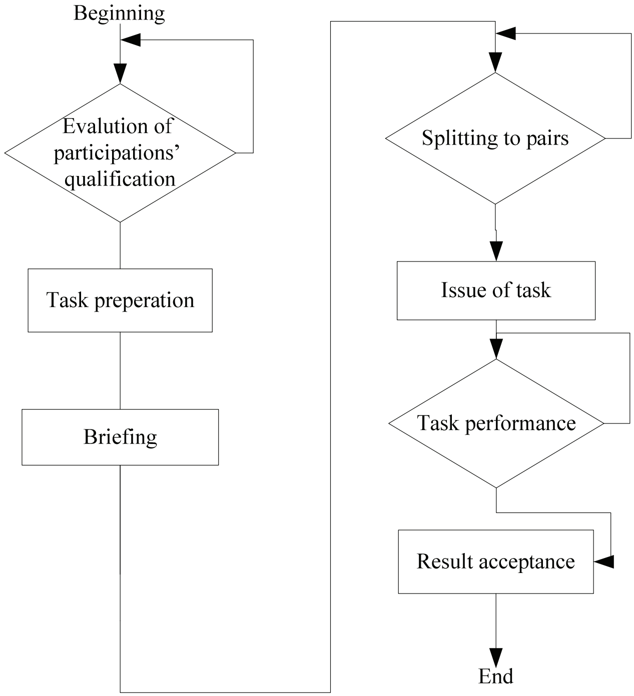
Hypothesis 3 – there is correlation between task complexity and time loss caused by switching, namely, if $\mathrm{n_1}$ >n_2, then $\mathrm{S(n_1)} > S(\mathrm{n_2})$ Higher task complexity means more time needed to switch between tasks.

Experiment

Purpose. The experiment scheme is shown on pic. 1. The purposes of the experiment in the context of switching are: finding time loss, identification and evaluation of losses. The first goal is attained by way of comparison of successive work on several projects and work implying switching among projects. The second goal is attained based on the attainment of the first goal by means of review and qualitative assessment of losses.

Participants. In order to carry out the experiment *in vitro* to test the hypothesis and identify and evaluate the time loss the participants may be represented by, for example, senior students, familiar with program development. The qualification of the participants shall be checked in advance and must be roughly equal. The qualification can be evaluated by way of testing. It is desirable that the number of participants oddly even.

Task preparation. Before starting the observer prepares the tasks differing in complexity. Such tasks however must not excessively differ within one category. The minimal number of categories is three, e.g. easy, medium, and difficult. The complexity of tasks shall be determined by experts. The easy category may include tasks the performance whereof takes 1 to 3 hours (realization of an individual function of the program). For example, realization of line maintenance algorithm in a file. The medium category includes tasks requiring half or the whole day for their performance (realization of an individual application function). For example, realization of the saving dialogue box building program with the possibility of choosing and allocation of coding and file. In the difficult category the performance of tasks takes several days (small application). For example, writing of the text editor program like Notebook.



Pic. 1. Experiment scheme

Briefing. The participants must keep to the experiment scheme and meet its requirements. Therefore they shall be briefed as to the correct count of actual time of work, and the importance of holding on tight to the experiment scheme. The tasks performed within unreal periods of time shall not be considered. The participants may be asked to assess the margin of error at time count. This will improve the assessment quality. The participants must be also advised of the proper process structure. For example, a participant using the Test - Driven Development method can obtain better result through test writing but it may affect the total time of performance and contort the outcome if the other participant in the pare has not performed the test at all.

Pairs. The participants shall be divided into pares. It is important for the observer to be aware of the each participant's qualification prior to the beginning of the study. If one pare comprises the lamer programmer and a programmer with certain practical experience, chances are that the experience programmer will spent less time on the task even with switching between tasks. That is why it is advised to ensure the equal qualification level of participants both within a pair and in the complexity category; and divide the participants randomly.

Issue of tasks. Each pare shall be given two tasks of the respective complexity. One person in the pare shall perform the tasks consecutively, the other one – with certain intervals between tasks. The switching interval shall be chosen based on the total duration of the task. It is desirable that the number of such switches was the same for each complexity category. When choosing the interval duration one should consider the duration of the easy task.

Task performance. The participants should count the time spent of task performance.

Acceptance of results. The quality of tasks performed may be checked by means of formal acceptance tests functioning in the black-box mode, or the observer's assessment. The tasks whose quality does not conform to certain minimal level shall be rejected.

Activity presentation and loss identification

To present the activities one can use the activity schemes [7], which are proposed to be enhanced with the additional item "Projects" (pic.2). The scheme can help present and analyze the complex activity types, for example, activity duration, complexity, interruption rate by the activity type.

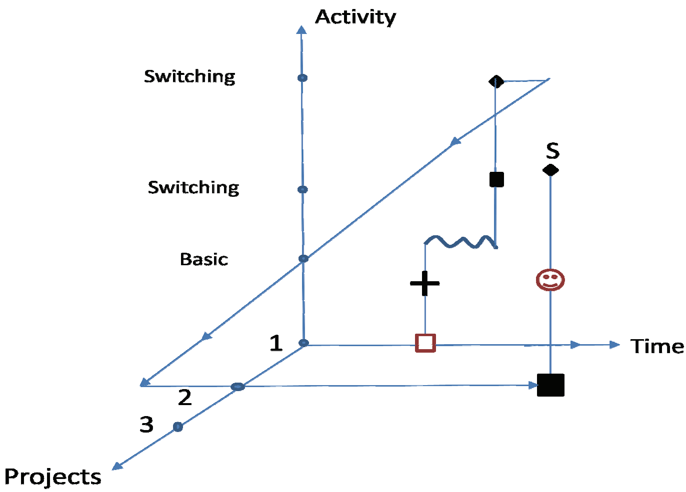


Рис.2 Activity scheme

The experiment results allow identification of certain activity types which lead to the loss in any processes during software development (table 1) [3].

The experiments made it possible to identify the losses (table 2) [1, 8].

Table 1.

Activity types leading to the loss

Item No. п/п	Denomination on the scheme	Activity type	Essence of the activity
1	□	Calendar	Monitoring, fillingin
2	■	Email	Reading, writing
3	☺	Conversation	Dialogue, conference
4	S	Self-switching	Scheduled, random
5	E	External interruptions	Device, colleagues, visitor, activity
6	◆	Interruption	Any interruption
7	—	Meeting (conference)	Onsite (outside)
8	+	Paper	Text preparation
9	~	reading	Reading of documents

The activity types provided in Table 1 lead directly to the loss of time, but they are also linked to other loss types (table 2).

Table 2

Loss types

Item No.	Loss type	Loss nature
1	Temporal	Timeout, waiting, schedule breakdown
2	Material	Paper, cartridge, fuel, water
3	Power	Electric power, heat
4	Financial	Expenditures on the activity leading to losses (table 1)

Conclusion

At present, seven loss types have been identified which can be found in the software development processes [2]. However none of them has undergone any study. The method proposed in the research work may be applied not only for the study of shift losses (which include switching between tasks), but also to other loss types.

References

1.Sidorov N.A. Software ecology – Software engineering- No. 1.-2010.-p.53-61.

2.M.Popendyk, T.Popendyk, Software lean development - Williams- M.–2010.-256 C.

3.E.M.Sidorov, Classification of waste for software development. //E.M.Sidorov – Bulleting of V.Dal South-Ukrainian National University.-No.3.-2013.-p.20-23.

4.S.Monsell Task switching.-TRENDS in Gognitive Sciences.- v.7.-n.3.-2003.-p.134-140

5.O.Bondarenko. Task switching in Detail: Task Identification, Switching Strategies and Influencing Factors.-Eindhoven Univ.of Techn.-2004.-11P.

6.M.Czerwinski, E.Horvitz, S.Wilhite. A Diary Study of Task Switching and Interruptions. - Microsoft Research.-2001-12 P.

7.M.J. Muller. Activity Graphs of the Microstructure of Complex Work. IBM Research.-2004.-3 P.

8.G.Mark., D.Gudith., U.Klocke. The Cost of Interrupted Work: More Speed and Stress. University of California.-2005.-5 P.

UDC 004.415.2 (045)

Sidorova N.M, Kramar Y.M. (Ph.d)
(National aviation university, Ukraine, Kiev)

ONTOLOGY OF PROGRAMMING STYLE

Tthe application of style in software development is introduced. The task of using programming style is considered. The use of style in programming requires observance of its rules when writing the program texts. In order to minimize the scope of work associated with the use of style, one should apply new means. In this article, the application of ontologies is described.

Introduction

Style in programming runs through all processes of software creation. It is represented by the set of rules, expressed with the use of language means, and reflects existing technical and cultural experience. The use of style in programming improves software development and maintenance efficiency.

The use of style in programming requires observance of its rules when writing the program texts. In order to minimize the scope of work associated with the use of style, one should apply new means. In this article the application of ontologies is described.

Researches and publications

Application of style in software development is old, but not often investigated problem. The first results of research style have been presented in work [10], The results of following researches are presented in works [11; 12], I.V.Velbitsky has introduced graphic style of programming [13] A.P. Ershov considered style as fundamental professional property of the programmer, marking the role of educational process in purchase of style property and the role of industrial requirements in its preservation [14], I.V. Pottosin describes requirements which the "good" program should satisfy [15], Works [16; 17] reflect the results of researches of modern aspects of the style which are mainly connected, with the use of designs of object-oriented programming languages.

Ontology of programming stylistics

Let's define stylistics of programming as a section of the software engineering [1; 2] which subject is application of style in programming. *The analysis of* literature [3-7; 9-19] shows, *that in programming* there is no satisfactory definition *of* style. *Likewise,* there exists no definition *of* other spheres of human activity that could be used in programming. As a basis of reasoning on style we shall take the definition of style as means of expression of some ideology or an idea in human activity [8J. Thus, considering style, it is necessary to consider two measurements: one reflects a set of ideologies and ideas, and the other is a set of types of human activity. Defining style of human activity, first of all it is necessary to identify ideology or idea which it expresses, and then, projecting them on human activity to define other concepts connected with it in *this activity. Obviously, defining style, which* has found application in different areas of human activity, description of characteristic features or attributes of corresponding ideology or idea is enough. Then this description will represent style as a domain-independent concept. Considering style from ontological positions, as object ("essence", "thing"), possessing properties it is necessary to specify essential properties of style and its communication with other objects of the domain. We shall define style - "essence" (class) as a system of three following properties (fig. 1): to express some ideology or idea; to have the period (time) of existence; to have connection with human activity.

«style denotation»: style
Idea (ideology) = «any» Existent time = «some time» Action = «no»

Fig. 1. Class-style

For style as domain-dependent concept all three properties are essential. The first and second properties remain essential always, that are qualities of style as domain-independent concept. Importance of the third property leads to the domain-dependent concept of style of human activity. Thus, to style, as to domain-independent concept, there corresponds essence (means) expressing any period of time, some ideology or idea, the way which has not been connected with specific human activity. As a matter of fact, style represents the basis on which styles of various human activities are constructed. Considering stylistics of programming as a subject domain, for representation of its ontology, we shall use both computer and mathematical approaches [18]. Application of the first approach will be shown by means of UML-diagrams, and for the second we will use the axiomatic method widespread at the description of subject domains of databases. Representation of style within the limits of the second approach can look like St = <A, S, D>, where A - set of own axioms of style not depending on an essence of expressed ideology, S and D - sets of the axioms describing characteristic features of ideology of style in static and dynamics. The last sets can be used for description of style of programming. Set A may contain such axioms [19]:

-. uniqueness of style: if exists ideology I and style, based on it, then there are no styles that are also based on this ideology $\forall \mathrm{ISt(I)} \sim \begin{pmatrix} \overline{\mathrm{St}}(\mathrm{I}) = \\ \mathrm{St(I)} \end{pmatrix}$;

-existence of style of human activity: if there exists ideology I, style St, based on it, and human activity P, then exists style of human activity St_P(St (I), P), based on the style St(I) $\forall \mathrm{ISt(I)} \sim \forall \mathrm{PSt_p}(\mathrm{St(I)}, \mathrm{P})$;

- reflexivity: every style is the substyle of itself $\forall \mathrm{St}(\mathrm{St} = \mathrm{St})$*;*

- antisymmetiy: substyle (style, which is derived from some style) can't be a style for a style, it was based on it $\forall \mathrm{St_1}\ \forall \mathrm{St_2}\ \left(\mathrm{R}(\mathrm{St_1}, \mathrm{St_2}) \sim \mathrm{R}(\mathrm{St_2}, \mathrm{St_1})\right)$*;*

- transitivity: if style St_2 is substyle of some style St_1 and style St_3 is substyle of St_2, then St_3 is substyle of St_1 $\forall St_1, \forall St_2, \forall St_3 \left(R(St_1, St_2) \sim (R(St_2, St_3) \sim R(St_1, St_3)) \right)$

Axioms of static S describe peculiarities of condition of the style in definite domain of human activity. Usually in description of style, multiple essences and relations between them are used. Description of their conditions is description of static. Axioms of dynamics D describe changes that occur during style existence time. For example, axiom that describes property, is called "time of style existence": if exists style St, then it exists during some finite period of time: $\forall StT\left(St, (t_1, t_2)\right) \sim (t_1 < t_2)$.
For description of dynamics of changes in domain, it is possible to use modal logic. We may obtain different classes of human activity by assigning different values to the property "human activity" in class "style" (fig. 2).

«programming style denotation»: programming style
Idea = «any» Existent time = «some time» Action = «programming»

Fig.2. class-programming style

Thus, programming style is the style that is used in human activity (domain), whose essence consists in programming.

We are able to construct a model of the "programming" domain while considering in human activity (domain) three essences (subject, tool and product), and taking into consideration that in programming such essences are programmer, programming language and program (fig. 3).

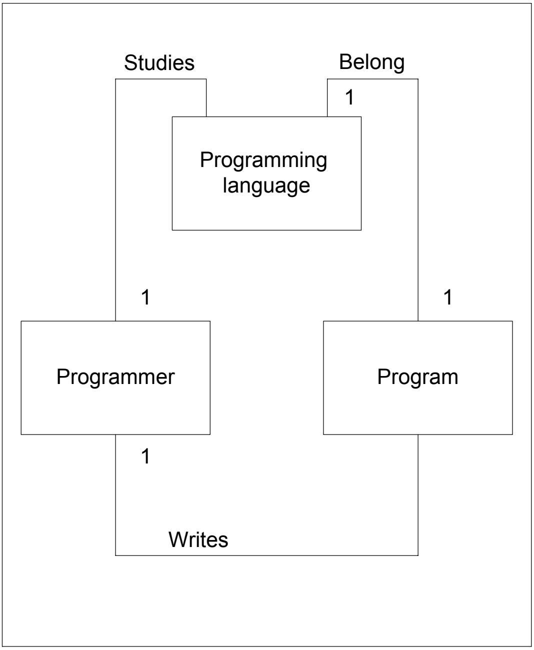


Fig. 3. Programming domain

Considering connection of essences, mentioned above, with style of human activity, we may define such conceptions, as style of a subject, style of a tool and style of a product. For "programming" domain, they correspond to such conceptions, as: programmer's style, style of programming language and style of program. A fragment of model of "programming" domain, that takes into consideration influence of style, is represented by three classes - style of programming language, programmer and program (fig. 6) [19]. Usually, in style of programming language, some subset of programming style is realized. Support must be realized in the form of means, providing representation of corresponding style in the context of programming language means. As a rule, programming style expression doesn't exceed the limits of vocabulary and syntax of programming language and is provided automatically. But it is necessary to keep to style of programming, that's why it's necessary to provide tools, controlling programming style, just as the way controlling syntax. It will provide obligatory realization of style property of the program in the context of the given style of a programming language. It is possible to realize control over the programming style by means of empirical methods and tools, in particular - measurements and measuring devices. Style of programmer is the acquired quality of programmer to be acquainted with definite style of programming and apply it in programming. Acquirement of this quality is performed by studying the style of programming language. In the strict sense, style of programmer must be his professional quality, like the ability to paint for an artist and must be acquired while training skills [14]. Style of programmer is connected with processes of motivation of training, retraining and application of programming style.

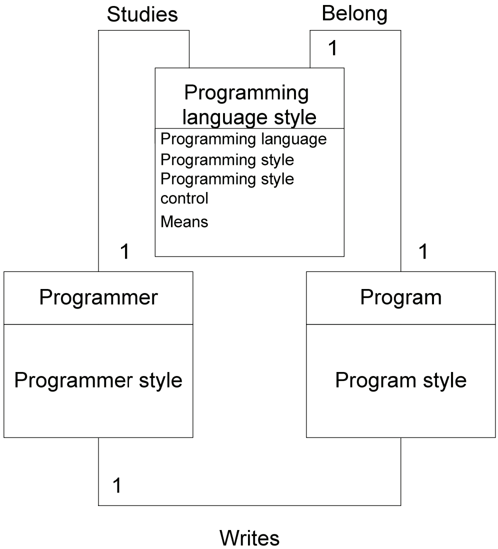


Fig. 6. Programming domain and style

Style of a program is the ability of a program to satisfy requirements of the programming language. Incomplete satisfaction of the requirements of programming language leads to stylization of a program. For example, many programmers use stylization to Hungary notation. Thus, the main system-generative factor for style is ideology or idea.

Scheme of rules of programming styles systematization

Modeling of object domain includes the description of objects, their features and relations between objects. Object of the subject domain is rules representing the style.

The following features have been revealed: rules have an author and pattern of use; descriptions of software objects, to which the rules are applied, are considered on the levels of encapsulation and make up a program; a program can be considered as a construction of software objects descriptions. By analyzing rules and relations between them and other objects of subject domain, we systematize the rules by the use of five criteria: pattern of a rule application, object of rule application, level of encapsulation of objects to which a rule is applied, and the author of a rule.

Pattern of a rule application. The rules which observance is compulsory are selected, for example, “all designations should be composed in English”, and rules which are recommended for use, for example, “do not use short identifiers”. We shall distinguish two types of rules: directives and recommendations.

Object of rule application. Rules are considered concerning software objects (for example, variable, expression, subprogram) or in various aspects of program (for example, commentation, designations). We shall define the type of objects of rules application as a systematization sign.

Level of objects encapsulation. Description of software construction often depends upon which software construction of higher level it is encapsulated into. For example, certain style rules are applied for the subprogram if it is a procedure, function or macro. Other rules are applied if the same subprogram is a class method. In the first case it is recommended to apply the rule “do not use global variables in a subprogram”. As far as there is no notion of global variables when describing a method, one should follow the rule “take the description of method body out of class description scope”. All software constructions can be considered on the lexical, operational, subprogram, modular and class levels of encapsulation. We shall systematize the rules by the level of encapsulation of objects to which a rule is applied.

Author of rule. Analysis of rules shows that certain rules are proposed by organizations-developers, for example, «use upper and lower cases during the composition of identifiers» («Camel», Microsoft). The other rules – by individual software engineers, for example, “use a prefix for indication of variable values type” (Hungarian notation, Charles Simonyi). Yet the other rules are connected with certain software tools, for example, presentation of identifiers in the form “Commmand1, Command2, label1, …” (Delphi). The major part of them does not have an author. We systematize the rules by the pattern of author in the following way: rules of organizations, private rules, rules of tools and general (“public”) rules.

In order to implement a model of subject domain in the form of ontology, it is required to systematize rules, as well as to develop the presentation of rules. Verbal description of rules in the form of natural language sentences (which are usually examples and explanations) is the most widely used. Each rule we shall describe by a relation tuple with a scheme $Sch = (D, F)$, where D – is a documentary part of rule presentation, and F – is a factual part (systematizing patterns) (table 1). At the same time, $D = (d_1, d_2, d_3)$, where d_1 – is a description of rule, d_2 – explanation or commentary to the rule, d_3 – exclusion, and $F = (f_1, f_2, f_3, f_4, f_5)$, where f_1 – nature of a rule, f_2 – object of rule application in the software aspect, f_3 – object of rule application in the object aspect, f_4 – level of encapsulation of objects to which a rule is applied, f_5 – rule authorship.

Table 1

Form and example of presentation of programming style rule

Documentary part of rule presentation *D*			Factual part of rule presentation F (systematizing patterns)					Programming style
Description of rule	Explanation of rule	Exclusion of rule	H_A	P_A	O_A	I_A	W_A	
d_1	d_2	d_3	f_1	f_2	f_3	f_4	f_5	*SP*
Variables that have a small operation scope, should be described by short designations	Short designation of variable informs of the fact that the variable is temporal, is introduced for the storage of intermediate values or performance of auxiliary functions	–	R_AV	N_AV	V_AV	S_AV	C_AV	U_V

Remark: attributes: H_A – nature of recommendations, P_A – software aspect, O_A – object aspect, I_A – encapsulation level, W_A – authorship, and values of attributes: R_AV - recommendation, N_AV – designations, V_AV – variable, S_AV – subprogram, C_AV – general, U_V – style of “structural programming” paradigm.

Conclusion

Usually, in style of programming language, some subset of programming style is realized. Support must be realized in the form of means, providing representation of corresponding style in the context of programming language means. In order to minimize the scope of work associated with the use of style, one should apply new means. In this article the application of ontologies is described. Modeling of object domain with the help of ontologies includes the description of objects, their features and relations between objects. Object of the subject domain is rules representing the style. Form of presentation of programming style rule for ontologies was proposed.

References

1. *Соммервил И.* Инженерия программного обеспечения.- М.: Вильямс 2002. - 620 с.

2. *Сидоров Н.* Повторное использование, переработка и восстановление программного обеспечения. УсиМ. -1998.-№3.-С.74-84

3. *Knuth D.E.* Literate are programming // Computer Journal. - 1984. - Vol. 27, N 2. - P. 42-44.

4. *Weisen M.* Source Code // Computer. - 1987. Nov. P. 66-73.

5. Goldberg A. Programmer as Reader.-IEEE Software *-1987. Sept.-P. 62-70.*

6. *Robson D.J., Bennett K.H., Cornelius B.J., Munro M* Approaches to Program Comprehension // J.Systems Software. - 1991. - Vol. 14, N. 2. - P. 79-84.

7. *Software* cultures and evolution // V. Railich, N. Wilde, M. Buckellew et. al. Computer. - 2001. - Sept. - P. 25-28.

8. *Соколов А.Н. Теория стиля* -М., 1968. -210 с.

9. *Bosch I.* Design and use of software architectures.

- Addison-Wesley, 2000. - 325 p.

10. *Тассел В.* Стиль, разработка, эффективность, отладка и испытание программ. М.: Мир, 1980. - 280 с.

11. *Керниган Б.,Плоджер Ф.* Элементы стиля программирования. М.: Радио и связь, 1984. - 160 с.

12. *Боровин Г.К.* Ошибки – ловушки при программировании на Фортране. М.: Наука, 1987. -144 с.

13. *Be.ribduiiKiiu KB.* TexHOJiorwa nporpaMMHpoBa- ннн. - K.: TexHina, 1984. - 274 p.

14. *Ершов А.П.* Предварительные соображения о лексиконе программирования // Кибернетика и вычислительная техника.- М.: Наука, 1985.- Вып. 1 . - С . 199-210.

15. *Поттосин И.В.*»Хорошая программа»: попытка точного опредиления понятия //Программирование.- 1997.-2.-С.3-17.

16. *Нуквист Е* Правила хорошего тона для программирования на С++.К.: Наук.думка. -1994. - 85 с.

17. *Мейерс С.* Эффективное использование С++.-М.: ДМК. -2000.-325с.

18. *Клещев А.С., Артемьева И.А.* Математические модели онтологий предметных областей. Ч.1. Существующие подходы к определению понятия «онтология»// НТИ. Сер.2. Информационные процессы и системы. – 2001.»2. – С. 20-27

19. *Sidorov.N.* Software stylistics.-Proceedings of the NAU.-2005 № 2. P. 98-102.

UDC 004.413 (043.2)

O.O. Grinenko, Senior Lecturer
(National Aviation University)

MATHEMATICAL MODEL OF SOFTWARE ECOSYSTEM

The mathematical model of software ecosystem is considered using set theory, proposition logic and real-time process algebra (RTPA)

Introduction

Software ecology is said to be a new branch of software engineering today. The software creates organizational and technical systems that appear, evolve and degrade like natural biosystems. Software Ecology is a term that affects the industry of researches of the properties, behavior and laws of software systems and their impact on enviroment and human activities. A key role in studies of the ecology and software ecosystems is played by software. Researches of software ecosystems may be associated with the identification and formalization of ecosystem types of software, creation their models, development of recommendations for development and maintaining the software ecosystems and so on.

Software Ecosystem Model

Definition and the formal description of the software ecosystem is very important today. Researches into software ecosystems are represented by several works [1], [3], [4], [5], [6], [10], [11], [12]. Software ecosystem is a complex that includes the software, environment of its development, operation, maintenance and utilization associated with each exchange of software and intelligence. A software products and services, producers of products and services, customers, contacts are the main elements of ecosystem. It is important to create models of software ecosystems. At the ecosystem approach of studies the key role is played by programs that create system and developed, accompanied and operate in a socio-technical environment. Social and technical environment of the software ecosystem includes hardware, developers, suppliers, users, state, standardization companies, and others. It is possible to select the software interaction with other elements of the ecosystem:

– other software;
– hardware;
– user;
– organizations and social groups;
– artificial objects;
– natural objects and processes.

The studies of ecosystems consist of the analysis and construction of representations. The complexity of software ecosystems and the diversity goals of stakeholders determine the presence of many points of view. With the concepts of ecosystem properties that are useful for considering large software systems, such as the complexity of isolated, decentralized control, unpredictable effects, the complexity of monitoring and evaluation, competition in niches, stability, adaptability, stability and viability. These features, as well as the composition of the ecosystem itself are opened to examine it from the point of view of the system (System of a System).

System of system in is defined as the set of ordered systems that interact to provide a certain performance. The loss of any part of the system reduces the performance of the whole system.

System of Systems is any system composed of systems that are themselves autonomous. Under the system we mean any group of interacting or interdependent entities forming purposeful unity. Under autonomy refers to the ability to exercise independent action or decision. Operational, management and evolutionary independence and emergent behavior arise from autonomy of the components of the systems [2].

All of the above makes it possible to consider the software ecosystem as a system of systems, autonomous components of which are:

1. Software (technical abstract system S_1).

2. Hardware (technical material system S_2).

3. Objects and processes (natural system S_3).

4. State, standardization organizations, vendors, software users (economic system S_4).

5. Developers and managers, social communities (social system S_5).

Thus, in an ecosystem of software systems, we mean a system formed by the interaction of autonomous open systems technical, natural, social and economic origin to ensure specified performance.

Based on algebra of systems [13], you can submit the software ecosystem as a result of algebraic operations of conjunction of autonomous components of the system:

$$ES = \coprod_{i=1}^{n} S_i \;, \; n = 5 \;, \quad (1)$$

where ES – software ecosystem, S_i – systems, which are parts of software ecosystem, $\coprod$ – conjunction of systems.

Since the elements of ecosystems are open systems software, we will file it as a tuple:

$S = (C, R^C, R^i, R^O, B, \Omega, \Theta)$,

where C is a non-empty set of system components, $C = \{c_1, c_2, ..., c_n\}$;

$R^C \subseteq C \times C$ is a set of internal relations;

$R^i \subseteq C_\Theta \times C$ is a set the external input relations;

$R^O \subseteq C \times C_\Theta$ is a set the internal output relations;

B is a set of behaviors (or functions), $B = \{b_1, b_2, ..., b_p\}$;

Ω is a set of components of structures, conditions of relations, the scope of behavior, $\Omega = \{w_1, w_2, ..., w_q\}$;

Θ is an environment of non-empty set of components C_Θ, $C_\Theta \cap C = \varnothing$.

Given introduced notation, we can rewrite equation (1) as:

$$ES = ES(\cup_{i=1}^5 C_i, \cup_{i=1}^5 R_i^C \cup_i \Delta R_j^C, \cup_{i=1}^5 R_i^i, \cup_{i=1}^5 R_i^O, \cup_{i=1}^5 B_i \cup_j \Delta B_j, \cup_{i=1}^5 \Omega_i, \cup_{i=1}^5 \Theta_i) \quad (2)$$

where $\cup$ is a conjunction of sets;

$\Delta R^C, \Delta B$ is a new internal relations and behavior;

$j = C_n^2 = \dfrac{n!}{2!(n-2)!}$ is a number of systems, which are included in the software ecosystem.

To describe formally every set of tuple is proposed by using the following theories:

- for C, Θ – set theory and algebraic operations on them;
- for R – theory of relations. In this case, be sure to check that the properties of asymmetry and reflexivity (in case when at least one of the properties can not be done, tuple can not be considered as a system);
- for B, Ω – propositional logic and real-time process algebra (RTPA) [13]. It should be noted that the behavior of a software system is divided into static and dynamic.

General formal description of software ecosystem

System S_1 "software".

$S_1 = (C_1, R_1{}^C, R_1{}^i, R_1{}^O, B_1, \Omega_1, \Theta_1)$ is an open technical abstract system, where

$$C_1 = \{c_{ij} \mid c_{ij} \in \bigcup_{j=1}^{m} P_j,\ i = \overline{1,n},\ j = \overline{1,m},\ m, n \in N\},$$

P_j is a set of software subsystems,

c_{ij} is subsystems components.

Let's consider C_1. For example, software is a system for the collection of information in the form of responses of experts and / or users with further processing. Then the set of components of the system can be as follows:

$$C_1 = \{c_{ij} \mid c_{ij} \in \bigcup_{j=1}^{3} P_j,\ i, j \in N\ \},$$

where P_1 - subsystem „Web-module”;

P_2 - subsystem „Data Base”;

P_3 - subsystem „Main Application”;

c_{i1} ={files *.jsp, Web-browser, TomCat WebServer}, $i = \overline{1,7}$;

c_{i2} ={tables}, $i = \overline{1,18}$;

c_{i3} ={ libraries, executable component }, $i = \overline{1,16}$.

General number of system components – 41.

$R_1^c = \{\rightarrow\}$, where $\rightarrow$ - relation of base dependency.

$$(\forall c_{ij} \in P_j,\ i = \overline{1,n},\ j = \overline{1,m},\ i, j \in N)$$

$$((c_{11} \rightarrow c_{nm}) = \rightarrow (c_{11}, c_{nm}) \text{€} (c_{nm} \xrightarrow{\varphi} c'_{nm}) \Rightarrow (c_{11} \xrightarrow{\psi} c'_{11})),$$

where φ, ψ – transformation "change component".

For structure (tuple) to be really a system, it is important to check the properties of reflexivity and asymmetry for a given relation. In this case, the relation of reflexivity is obvious. Property asymmetry is also performed as:

$$(\forall c_{11} \in P_1)(\forall c_{22} \in P_2)(c_{11} \neq c_{22})[c_{11} \rightarrow c_{22} \not\Rightarrow c_{22} \rightarrow c_{11}]$$

R_1^i = {Integration (reusable software components, software components); development and maintenance (developers, software components); functioning (hardware, software components); development of normative base (standards bodies, software components); defense of intellectual property rights (government, software components)}

R_1^O = {Exports (software components, other software); functioning (software components, hardware); providing solutions and services (software components, users); supply (software components, independent software vendors); impact on the environment (software components, natural processes)}

Θ_1 = {Hardware, natural objects, social system, economic system, other software ecosystem}

B_1 = {Set of behaviors (functions) of the system}.

As already mentioned, the behavior of a software system is divided into static and dynamic and easily described using real-time process algebra.

Conclusions

In this paper, we provided a mathematical model of software ecosystem, bases on set theory, propositional logic and real-time process algebra. This model describes software ecosystem as a system of system, which are systems of different nature. It is given also an example of description of system “software”.

From new software ecosystem perspectives, future work is related to identifying properties of each system, to describing them, to understanding dependences of these systems on themselves, to finding characteristics for monitoring of software ecosystems and to developmenting of recommendations for development and maintaining the software ecosystems

References

1. Сидоров Н.А. Экология программного обеспечения / Николай Сидоров //Інженерія програмного забезпечення. – Київ. – 2010. – № 2. – С. 1–9.
2. Сидоров Н.А., Луцкий М.Г., Гученко И.В. Системная инженерия програмного обеспечения / Николай Сидоров, Маким Луцкий, Инна Гученко // Інженерія програмного забезпечення. – №4. – 2010. – с. 13-25.
3. Grinenko O. Models of software ecosystems / Olena Grinenko // The Fifth World Congress “Aviation in the XXI century”. – Kiev, 2012. – P. 1.10.23 – 1.101.27.
4. Grinenko O.O. Software Ecosystems / Olena Grinenko // Journal of the National Transport University. – Kiev: National Transport University. – 2012. – Vol. 26. – P. 508 – 512.
5. Sidorov N.A., Grinenko O.O. Software Ecosystem Modeling / Nikolay Sidorov, Olena Grinenko // Journal “Software Engineering”. – Kiev: National Aviation University. – 2013. – Vol. 2 (14). – P. 38 – 48.
6. D.G. Messershmitt, C. Szyperski. Software Ecosystems: Understanding an Indispensable Technology and Industry. – London: MIT press, 2003. – 233 p.
7. L. Webber, M. Wallance. Green Tech: thow two and to plan implement sustain – able IT solutions. – FBACOM. – 2009. – 29 p.
8. Y. Velye, A. Velye, R. Elsenpeter. Green IT: Rednee your Information systems Environmental input while adding to the bottom line. – 2008.
9. G. Schulz. The Green and Virtual Data Center. // Taylors Francis G. – 2009. – 218 p.
10. Jansen S, Bosch J. Understanding Software Ecosystems: A Strategic Modeling Approach. // Proceedings of the Workshop on Software Ecosystems 2011. – P. 65 – 76.
11. Jansen S., Finkelstein A., Brinkkemper. A sense of community: A research agenda for software ecosystems // 31th International Conference on Software Engineering, New and Emerging Research Track. –2009. – P. 12 – 16.
12. Duinkerken W. Transaction Cost Economics in Software Ecosystems: some empirical evidence. – April 20, 2009. – P. 22 – 37.
13. Wang Yingxu. Software engineering foundations: a software science perspective. – Auerbach Publications, 2008. – 1420 p.

UDC 004.413

Nagornyak T.V. (National Aviation University, Ukraine, Kyiv)

METHODS OF CODE OPTIMIZATION ON THE CRITERION OF MINIMUM ENERGY CONSUMPTION

Aspects of the energy-saving approach in the information systems development are reviewed. Methods of code optimization on the criterion of minimum energy consumption are described. Recommendations for developers to write programs that ensure the optimal use of the information systems electricity are given.

Introduction

Information systems (IS) are of great importance for modern society. Without them it is impossible productive activity in any industry. However, their use has costs and affect the environment. That is why the modern IS should be green.

The greenness of information systems is reached by minimizing the consumed electric power, and also used computer resources. Aspects of green information systems are:

- reduction of harmful impacts on the environment hardware IS;
- implementation of energy saving technologies;
- provision of «greenness» data centers [10].

The main object of this article is the second aspect green information systems. It is energy saving. In information systems this can be achieved in two ways.

The first way is reducing energy consumption by improving the design of the hardware components of the information system.

The second way is using to reduce power consumption software (SW) information system. [9]

The aim of this article is examining aspects reduction of energy consumption IP through the use of energy-saving and review of modern methods of code optimization on the criterion of minimum energy consumption.

1. The main sources of energy consumption

When the application starts, there are two main sources of energy consumption - CPU and memory.

The power consumption of the processor. For measuring this component of the energy consumption of the developed model of energy consumption level instructions.

There are two main components of these models:

- basic energy costs - costs that are associated with the underlying processing necessary to execute the statement. Consumption is estimated as the average current is spent executing one cycle of processing multiple instances of the same instructions;
- overhead energy is obtained due to the switching action in the schema processor and indirect additional costs of energy resulting from the fulfillment of related instructions (recalculation indexes cycles and calculating memory addresses).

To measure the average current in this case used a sequence of specialized instructions [3].

Energy costs for memory. According to the typical model of energy consumption of the energy consumed in the operation of memory access, and its flow is directly proportional to the number of accesses, size and number of ports I / o memory, power supply, and production technologies [3].

2. Code optimization

When developing software, we can save energy through efficient use of computing resources and avoid repeating work, for example, recompiling [6].

Here is an overview of modern methods of code optimization on the criterion of minimum energy consumption through efficient use of computing resources.

Selection of efficient algorithms for software development

The study of the problems and the right choice of architecture, design, algorithms and data structures that will help to create software that will provide better performance while consuming less energy.

A better algorithm or data structure for this task depends on many factors. For a specific task stack can be better than all, and B-tree can be better than a binary or hash function. But when the choice of the algorithm it is necessary to note that the movement of data in the program code requires energy, so you select an algorithm that should ensure data movement to a minimum [1].

Multithreading

Multithreading is a property of the platform (for example, operating system, virtual machine, and so on) or application, which is that the process is generated in the operating system may consist of multiple threads running in parallel, that is, without the prescribed order in time[8].

The experiment carried out in [4] showed that parallelization of tasks can significantly reduce the energy consumption of the processor.

Using vector instructions

One way to optimize the code is code vectorization - replacement use scalar C-code with advanced instructions such as SSE4.x, AVX1 or AVX2. These instructions help perform commonly used actions faster and with less power requirements. [2]

In [1] was an experiment that was what took 2 different audio decoding algorithm and optimized using Intel ® Advance Vector Extensions (Intel AVX). In accordance with this method was on and off function AVX and measured performance and average power of audio decoding. When AVX is enabled, the work is done much faster - on 1.65X and 1.34X with huge energy savings.

Reducing the number of system calls

For example, preferably using the Windows API "EnterCriticalSection()" to synchronize data between threads in user space instead of "WaitForSingleObject()", running in kernel space, it saves more than 60 % of the energy [5].

Reducing memory usage

Minimize memory usage is achieved by eliminating unnecessary casts of graphics format caching frequently used data structures, limiting the number of moves data between kernel space and user space[2].

Using libraries

Energy efficiency can also be improved through the use when writing code libraries that contain already optimized implementation of General algorithms in areas such as audio, video, imaging, cryptography, speech recognition, and signal processing for execution. An example of such a library is Intel® Integrated Performance Primitives and Kernel Library Intel® Math provided by Intel [1].

3. Recommendations

On the basis of the material presented can be formulated recommendations for software developers:

- to avoid duplicate work, for example, recompiling;
- to implement programs to choose an algorithm that reduces the data movement to a minimum;
- actively to use a threaded organization code;
- when writing code to use modern vector instructions, such as SSE4.x, AVX1 or AVX2;
- to reduce the number of system calls;
- to exclude from the program code unnecessary format conversion charts;
- to use caching frequently data structures used;
- when writing code to use the catalogue of the libraries that contain already optimized implementation of General algorithms.

In addition to the above recommendations, you can reduce the time in privileged mode and replace cycles standby Sleep(0) Pause() function [2].

Conclusions

Described in the article modern methods of code optimization on the criterion of minimum energy consumption, and data based on the review recommendations software developers design programs allow for more efficient use of the information systems computing resources. Reducing energy consumption of the information systems is relevant direction and requires further development.

References

1. Energy-Efficient Software Guidelines [Електронний ресурс] / Intel inc. – Режим доступа: http://software.intel.com/ru-ru/articles/partner-energy-efficient-software-guidelines – 03.02.2014 г.

2. Снижение энергопотребления приложений [Електронний ресурс] / Intel inc. – Режим доступа: http://software.intel.com/ru-ru/articles/conserving-active-power – 01.02.2014 г.

3. Проектирование и анализ программного обеспечения с низким энергопотреблением с помощью программных метрик энергоэффективности [Текст] / *А.В. Юрченко.* – Режим доступа: http://technomag.bmstu.ru/ doc/511596.html - 1.01.2013

4. Анализ энергопотребления при выполнении операций ввода/вывода дисковой подсистемы [Електронний ресурс] / Intel - Режим доступа: https://software.intel.com/ru-ru/articles/power-analysis-of-disk-io-methodologies - 3.04.2012

5. Оптимизация кода почтового программного приложения на платформе Apple iOS по критерию минимума энергопотребления [Текст]/*И.Б. Туркин, А.В. Вдовитченко*.-Інженерія програмного забезпечення №1, 2014

6. Green Software: Greening What and How Much? [Текст] / *Krzysztof Sierszecki, Tommi Mikkonen, Michaela Steffens, Thomas Fogdal, Juha Savolainen* - *IEEE Software*, vol. 31, no. 3, pp. 64-68.

7. Повышение эффективности энергопотребления для приложений [Текст] / *Ш. Фараг, Б. Сроур* – Режим доступа: http://blogs.msdn.com/b/b8_ru/archive/2012/ 02/15/improving-power-efficiency.aspx – 10.01.2014.

8. *Рихтер Д.* CLR via C#. Программирование на платформе Microsoft .NET Framework 2.0 на языке C#, Питер, 2007 г, 656 с., с.573-607.

9. *Сидоров Н.А.* Зелёные информационные системы и технологии. - Інженерія програмного забезпечення №3, 2011.

10. *Toby Velte, Anthony Velte, Robert Elsenpeter*. Green IT [Электронный ресурс]: McGraw-Hill Prof Med/Tech, 2008, p. 45-62. Режим доступа: http://books.google.com.ua/books?id=xPQZqKrJN7oC&printsec=frontcover&hl=ru&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

UDC 004.4:629.735.072.8:004(043.5)

Y. Ryabokin, PhD (National Aviation University, Ukraine)

THE DOMAIN-ORIENTED TOOL FOR CONSTRUCTING SOFTWARE

In the article considers problems of reducing the cost of software development for complex domains. The domain-oriented tool for constructing software of instructor consoles for flight simulators various types is proposed.

In conditions of limited financing and difficulties associated with the development of domain-oriented software special importance is the question of reducing the cost of software development, while maintaining the quality and reliability of software and improve productivity software.

Constructing is important part of the process of software development. Depending on the size of the project is allocated at constructing 30-80% of the total running time.

Constructing software this is a stage of life cycle software development, following the designing, which aims at building a working code [1-2]. That is, constructing is a process of conversion artifacts created by human in the previous stages life cycle, in artifacts, which understandable for computer via tools and programming languages. The result of constructing is a programming code.

Take into account the complexity of some domains (flight control, the activities of the bank, instructor console for flight simulator, etc.), and the importance and high cost of stage constructing software is appropriate to create a domain-oriented software tool for constructing software for such domains. In article is proposes the creation of a domain-oriented applications (software environment) for constructing software of instructor consoles for flight simulators various types.

Software environment this is a set of software tools, by means of which is realized design programs. In article, environment is proposed to create through systematic asynchronous reuse by method of domain engineering. Thus, the environment and the software is domain-oriented.

Domain engineering – activities, that aimed at collecting, systematizing and preserving past experience in building systems or parts of systems in a particular domain in the form of reusable resources (assets, resources), and providing appropriate means for reuse of resources (ie, search, distribution, adaptation, assembly) when creating new systems [3].

Domain engineering is designed to improve the quality of developed software products through the reuse of software artifacts. As a result, through the use of domain engineering, the company can maximize profits; reduce the time of launch of new product on the market, using concepts (concept) and the implementation of previous systems, applying them to the target system [3, 4].

There are two approaches for organize the software environment [5]: adaptive and composite. In article, is proposed to use an adaptive approach, the essence of which is consists in the use of predefined reusable architecture and set of reusable components to fill the vacant seats in architecture by them. By using the domain engineering creates not only a set of reusable components (R), but also reusable architecture of domain-oriented application (A):

$$S = (R, A),$$

where S – software environment; R – repository of reusable components; A – reusable architecture of domain-oriented application.

Components of environment are created based on the experience that has accumulated in the domain and have formalized an image that consists of ontologies – graphical and analytical notation, mathematical models of domain entities, code templates. The components are stored in the repository environment.

Repository is a storage of reusable components, including interface elements, parameters, and programs of flight, which is inherent formalized image in form a ontology.

Architecture of domain-oriented application this is a structure that contains the relationship between application parts that is filled reusable components in the constructing of software (Fig. 1).

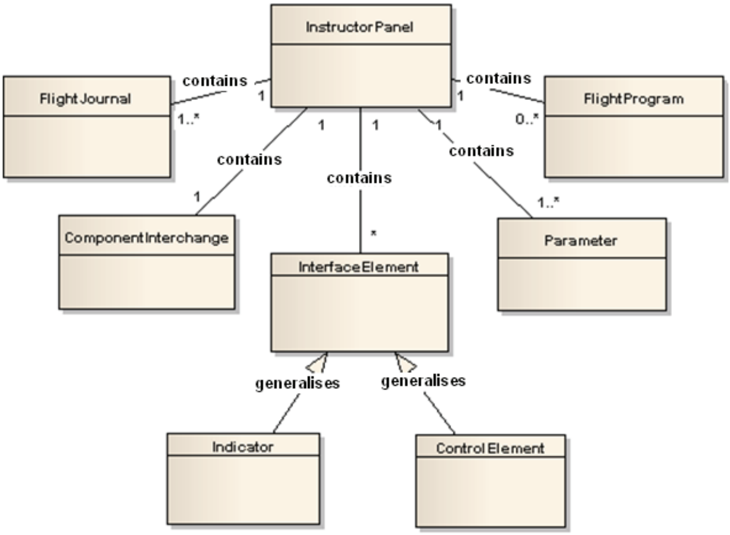


Fig. 1. Architecture of domain-oriented application

The panel of instructor console is the main compositional class (InstructorPanel), which includes the following classes: InterfaceElement (interface element), Parameter (parameter), FlightJournal (journal of flight), FlightProgram (program of flight). In addition, the panel includes an element – component of the exchange parameters (ComponentInterchange), intended for two-way exchange of parameters between the instructor console and flight simulator by UDP-protocol. He is represented by classes UDPClient – a client who sends the message and UDPServer – server receiving the message.

Each reusable component (RC), depending on its type (interface element, parameter, program and journal of flight), in the environment represented deuce of the form: $RC = (t_i, e_i)$, where t_i – template of program that provides a visual representation of the object (V_i); e_i – editor of reusable components.

Each editor is presented in two zones. Zone «A» this is a display of visual images interface element, zone «B» – setting structure and establish a visual image element by filling the field values, that indicate specific parameters element. Editing of reusable components is setting the templates of software code reusable components that is realized via editors.

The interface of reusable component is described using language XML, in the form of XML-specifications. Templates of code reusable component is represented using XML-tags that are created for each type of reusable components. Between these tags indicate the values of components that together form the XML-specification. These descriptions are stored in XML-files.

Generation of reusable components this is integration of visual and functional images of components and transformation them into code. To ensure of working the generator by language C# is proposed to create software modules designed to integration and transformation XML-specifications, in accordance with the rules of transformation, in objects of classes programming languages C# and vice versa. The module contains methods that describe the conversion algorithm. When converting XML-specifications on object of a certain class of languages C# each attribute of XML-tag is transformed in the property of the relevant class. The received code of reusable components is saved to the file, which combines image software of elements instructor console.

Conclusions

The proposed in the work domain-oriented environment for constructing software allows to create software for instructor consoles of flight simulators different types, which significantly reduces the time and cost of software development.

References

1.Software Construction by SWEBOK. [Electronic resource]. – Access: :http:// http://swebok.sorlik.ru/

2.Sameting J. Software Engineering with Reusable Components / J. Sameting // Springer-Verlag. – 1997. – 285 p.

3.Alana E. Domain engineering methodologies survey / E. Alana, A. Rodriguez // GMV AEROSPACE AND DEFENCE S.A. – 2007. – 38p.

4.Simos M., Creps D., Klinger C., Levine L Lockheed Martin Tactical Defunse Systems. Organization Domain Modeling (ODM) Guidebook: Version 2.0 Manassas: STARS-VC-A025/001/00. – 1996. – 509p.

5.Sidorov N. Introduction to Software Engineering / N. Sidorov// NAU, 2010. – 82 p.

UDC 330.33

A.O. Antonova, Cand. Tech. Sc., (National Aviation University, Ukraine, Kyiv)

NECESSARY CONDITION FOR EXCITATION THE OSCILLATIONS IN GOODWIN'S MODEL OF BUSINESS CYCLE

We investigate the necessary condition for excitation of long-periodic Goodwin's oscillations and short-periodic sawtooth oscillations in the Goodwin model of the business cycle with fixed delay in the induced investment and in the consumption.

Introduction

In [1] Goodwin proposed a business cycle model in the form of the neutral delay differential equation with fixed delay in investment

$$\varepsilon\dot{y}(t) = -(1-\alpha)y(t) + \varphi(\dot{y}(t-\theta)) + A(t). \tag{1}$$

Here $y(t)$ is income, $\varphi(\dot{y})$ is induced investment, A is the autonomous investment, $\varepsilon > 0$ and $\theta > 0$ are the time-lag of the dynamic multiplier and the time-lag between the investment decisions and the resulting outlays, α is the marginal propensity to consume, $0 \le \alpha \le 1$, and $\dot{y} = \dfrac{dy}{dt}$. Values of y, φ and A are expressed in billions of dollars per year, t is time in years. The function $\varphi(\dot{y})$ satisfies the conditions:

$$\varphi(\dot{y}) \ge 0; \quad \varphi(0) = 0; \quad \varphi'(0) = r;$$
$$\varphi(\dot{y}) \to \varphi_c \text{ if } \dot{y} \to \infty; \ \varphi(\dot{y}) \to \varphi_f \text{ if } \dot{y} \to -\infty,$$

where r is the acceleration coefficient (in years), φ_c and φ_f are the Hicksian ceiling and floor (in billions of dollars per year). Also an initial function $y(t) \equiv \Phi(t),\ t \le 0$ for the delay differential equation (1) needs to be specified.

It was shown in [2] by the analog simulation, that Eq. (1) has many solutions. One of them is similar to the long periodic Goodwin's oscillation [1]. Other solutions are the short periodic sawtooth oscillations with periods $T_n \approx \dfrac{\theta}{n},\ n = 1, 2, \ldots.$ These results are confirmed by a numerical simulation performed in [3].

Recently Matsumoto and Szidarovszky [4] have proposed Goodwin's model with a fixed delay in investment and in the consumption. This model has the following form:

$$\varepsilon\dot{y}(t) = -y(t) + \alpha y(t-\gamma) + \varphi(\dot{y}(t-\theta)) + A(t), \tag{2}$$

where γ is the consumption delay time.

We have performed numerical simulations of Eq. (2) and have showed that this model also generates the long oscillation as well as the short periodic ones.

Problem statements

In this paper we obtain the necessary condition for the excitation of Goodwin's oscillations and the sawtooth oscillations for model with delays in the induced investment and in the consumption.

Analysis of the linearized Googwin equation

If $A(t)=0$, Eq. (2) has a stationary solution $y_s=0$. We are interested in the stability of this solution. Variational equation for Eq. (2) takes the form

$$\varepsilon\dot{y}_L(t)=-y_L(t)+\alpha y_L(t-\gamma)+r\dot{y}_L(t-\theta). \tag{3}$$

To investigate its stability, we seek its solution in the form $y_L(t)=y_0e^{\lambda t}$, where λ is the eigenvalue. Substituting $y_L(t)=y_0e^{\lambda t}$ into Eq. (3) and rearranging terms, we obtain the corresponding characteristic equation:

$$r\lambda e^{-\lambda\theta}+\alpha e^{-\lambda\gamma}-\varepsilon\lambda-1=0. \tag{4}$$

First recall some basic facts concerning the properties of solutions of Eq. (4). For the roots with $|\lambda|\to\infty$ Eq. (4) can be replaced by an approximate equation $r\lambda e^{-\lambda\theta}-\varepsilon\lambda=0$. From this equation we obtain $\lambda_n\theta=\ln p+2i\pi n,\ n=\pm1,\pm2,\ldots$, where $p=r/\varepsilon$. If $r>\varepsilon$, then all high modes with frequencies $\omega_n\approx 2\pi n/\theta,\ n=1,2,\ldots$ are unstable for any value of θ.

We now consider the dependencies of the roots of Eq. (4) on the parameter *r*. There were chosen the following parameters [1]: $\alpha=0.6,\ \varepsilon=0.5,\ \theta=1$. The numerical results given in Table 1and in Table 2 for γ=0 and γ=1 respectively.

Table 1. Roots of Eq.(4) as functions of *r* for α=0.6, ε=0.5, θ=1 and γ=0 .

r	λ_0	λ_1	λ_2
0.5	-0.1870+0.8453i	-0.0076+6.4074i	-0.0020+12.6296i
0.6	-0.0903+0.8218i	0.1713 +6.4069i	0.1794 +12.6296i
0.7	-0.0084+0.7943i	0.3226+6.4063i	0.3328 +12.6295i
0.8	0.0625+0.7641i	0.4537 +6.4058i	0.4657 +12.6294i
1.0	0.1810+0.6985i	0.6729+6.4046i	0.6878+12.6292i
1.2	0.2776+0.627i	0.8520+6.4034i	0.8692+12.6291i
1.4	0.3593+0.549i	1.0036+6.4023i	1.0226+12.6289i
1.6	0.4299+0.4620i	1.13491+6.401i	1.1555+12.6288i
1.8	0.4922+0.3595i	1.25016+6.400i	1.2727+12.6286i
2.0	0.5478+0.2204i	1.35452+6.399i	1.3776+12.6285i

Table 2. Roots of Eq.(4) as functions of r for α=0.6, ε=0.5, θ=1 and γ=1 .

r	λ_0	λ_1	λ_2
0.5	-0.7506+0.4333i	-0.0288+6.4010i	-0.0079+12.6287i
0.6	-0.5947+0.5666i	0.1452 +6.4290i	0.1721 +12.6441i
0.8	-0.3662+0.6602i	0.4205 +6.4624i	0.4561 +12.6630i
1.0	-0.2004+0.6779i	0.6345 +6.4811i	0.6764 +12.6741i
1.2	-0.0708+0.6659i	0.8096 +6.4926i	0.8564 +12.6814i
1.4	0.0353 +0.6385i	0.9578 +6.5001i	1.0086 +12.6864i
1.6	0.1250 +0.6013i	1.0863 +6.5052i	1.1405 +12.6901i
1.8	0.2027 +0.5568i	1.1997 +6.5088i	1.2568 +12.6929i
2.0	0.2710 +0.5056i	1.3013 +6.5113i	1.3609 +12.6951i

We see, that the stability switch for λ_0 depends strongly on γ.

At any stability switch $\mathrm{Re}\,\lambda = 0$ and hence $\lambda = i\omega$. Substituting $\lambda = i\omega$ into (5) and separating the real and imaginary parts, we have

$$r\omega \sin \omega\theta + \alpha \cos \omega\gamma = 1,$$

$$r\omega \cos \omega\theta - \alpha \sin \omega\gamma = \varepsilon\omega$$

which is equivalent to

$$\varepsilon\omega \sin \omega\theta - \cos \omega\theta + \alpha \cos \omega(\gamma - \theta) = 0, \tag{5}$$

$$r = \varepsilon \frac{1-\alpha \cos \omega\gamma}{\cos \omega\theta - \alpha \cos \omega(\gamma-\theta)}. \tag{6}$$

We have the following claim. Equation (4) has purely imaginary roots if and only if

$$r = r_k = \frac{1-\alpha \cos \omega_k\theta}{\omega_k \sin \omega_k\theta},$$

where ω_k is a root of (5).

From Eqs. (5) – (6) it follows that if delay γ increases, then the frequency ω_0 decreases and the threshold r_0 increases. The numerical solutions of Eqs. (5) - (6) for $\varepsilon = 0.5,\ \alpha = 0.6,\ \theta = 1$ are shown in Figure 1 by solid lines.

For small $\omega_0\theta$, $\omega_0(\gamma)$ and $r_0(\gamma)$ can be approximated by the following formulas

$$\omega_0 \approx \sqrt{\frac{2(1-\alpha)}{2\varepsilon\theta + \theta^2 - \alpha(\gamma-\theta)^2}}, \tag{7}$$

$$r_0 = \varepsilon + \alpha\gamma + \frac{(1-\alpha)\theta}{2}. \tag{8}$$

Dependencies (11) and (12) are shown in Figure 1 by dashed lines.

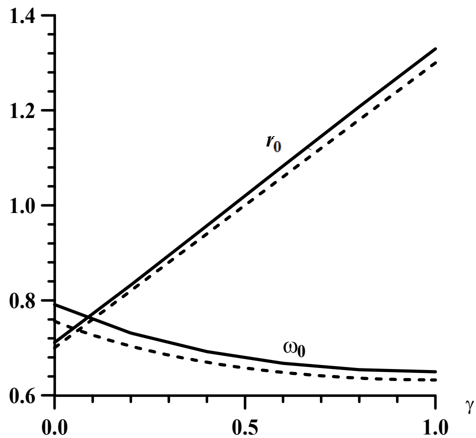


Fig. 1. The functions $\omega_0(\gamma)$ and $r_0(\gamma)$ for α=0.6, ε=0.5, θ=1. The solid lines correspond to the numerical solution of Eqs. (5) - 6). The dashed lines correspond to the formulas (7)-(8).

Conclusions

We have shown that if $r > \varepsilon$, the unstable high modes

$$\omega_n \approx \frac{2\pi n}{\theta}, \ n = 1, 2, \ldots$$

always exist. To excite Goodwin's mode the accelerator must exceed the certain minimum value r_0. We have found an approximate expression for r_0:

$$r_0 = \varepsilon + \alpha\gamma + \frac{(1-\alpha)\theta}{2}.$$

In the range $\varepsilon < r < r_0$ the Goodwin's mode does not excite. It should also be noted that in reality the excitation threshold of Goodwin's mode lies higher than r_0. This is due to the fact that, as seen in Table 2, only when $r \geq 1$ the growth rate of Goodwin's mode will be comparable with the growth rate of the first mode.

This confirms the results of the numerical solution of Eq. (3), which are shown in Figure 2. They show that there is a threshold $\gamma_{cr} \approx 0.61$: if $\gamma < \gamma_{cr}$, then the steady state solutions have the form of the long periodic Goodwin oscillations. If $\gamma > \gamma_{cr}$, then the steady state solutions have the form of sawtooth oscillations.

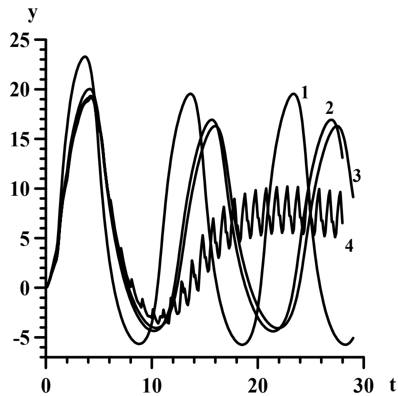


Fig. 2. Solutions $y(t)$ of Eq. (2) with α=0.6, ε=0.5, θ=1, r=2, Φ(t)=0, and $A(t)=10te^{-t}$. The lines 1, 2, 3 and 4 correspond to γ=0.05 , γ=0.5, γ=0.6 and γ=0.625.

$$\varphi(\dot{y}) = \varphi_c\left[1 - \frac{\varphi_c - \varphi_f}{\varphi_c - \varphi_f e^{\rho\dot{y}}}\right], \quad \rho = r\frac{\varphi_f - \varphi_c}{\varphi_c \varphi_f}, \text{ and } \varphi_c = 9, \varphi_f = -3.$$

Acknowledgments

The author would like to thank Dr. S. Reznik for stimulating discussion and his assistance in carrying out the computations.

References

1. R.M. Goodwin, Econometrica 19, 1–17 (1951).

2. R. H. Strotz, J.C. McAnulty, J.B. Naines, Econometrica 21, 390-411(1953).

3. A. O. Antonova, S. N. Reznik, and M. D. Todorov, "Analysis of types of oscillations in Goodwin's model of business cycle" in Application of Mathematics in Technical and Natural Sciences - AMITaNS' 12, AIP Conference Proceedings 1301, edited by I. Christov and M. D. Todorov (American Institute of Physics, Melville, NY, 2010), pp. 188–195.

4. A. Matsumoto, F. Szidarovszky, "Nonlinear Multiplier-Accelerator Model with Investment and Consumption delays", in Discussion Paper N 227 (Institute of Economic Research, Chuo University, Tokio, 2014), pp.1-19.

UDC 621.3.011:31.004

V.P. Denysiuk, Dr. Phys.-Math. Sc., L.V. Rybachuk, Cand. Phys.-Math. Sc.
(National Aviation University, Ukraine, Kyiv)

METHOD OF IMPROVEMENT OF THE CONVERGENCE OF TRIGONOMETRIC INTERPOLATING POLYNOMIALS

This paper considers the method of phantom nodes to improve the convergence of trigonometric interpolating polynomials, based on the compression of a segment of interpolation and adding a certain number of phantom nodes to the sequence of a function values. The results of test calculations correspond with the theory and demonstrate the efficiency of the considered methods.

Trigonometric polynomials are applied as mathematical models of physical processes in many scientific and technical problems. When information about a process is given as a discrete equidistant sequence of values of a function, trigonometric interpolation polynomials are applied [1]. It is easy to see that the interpolation trigonometric polynomials have the same disadvantages as the well known Fourier series. To improve the rate of convergence of these polynomials we propose the method which is called the method of phantom nodes [2, 3].

It is known that classic construction of an interpolation trigonometric polynomial is realized in such way. One should choose a number N, $N = 2n+1$, ($n = 1, 2, ...$) of interpolation nodes and define the net $\Lambda_N = \{t\}_{i=1}^{N}$, $t_i = \frac{2\pi}{N}(i-1)$ on the segment $[0, 2\pi]$. Calculating the values of the function $f(t)$ at the nodes of the net $\Lambda_N = \{t\}_{i=1}^{N}$, one will construct a trigonometric interpolation polynomial $T_n(t)$.

Let's make a following remark. Generally speaking, an interpolation trigonometric polynomial $T_N(t)$ interpolates a function $f(t)$ at the N points given on the segment $2\pi - h$, $h = \frac{2\pi}{N}$. At the point 2π the value of this polynomial is defined by virtue of periodicity. Therefore we will consider the interpolation polynomial $T_N(t)$ only on the segment of interpolation $2\pi - h$.

The method of phantom nodes consists in following. We add to the sequence of interpolation nodes a set of $2k$, $(k = 1, 2, \dots)$ phantom nodes on the right side; the values at these phantom nodes may be chosen in one way or another. Note that we take an even number of phantom nodes only to keep the total odd number of interpolation nodes.

It is easy to see that in this way we receive $N + 2k$ interpolation nodes on the segment $[0, 2\pi]$; therefore the order of interpolation polynomial is now equal to $n + k$.

It is evident that the segment $2\pi - h$ of interpolation of the function $f(t)$ is compressed and becomes equal to $2\pi - h_1(2k+1)$, where the step of net now equals $h_1 = \dfrac{2\pi}{N+2k}$.

As a result of application of the method of phantom nodes an error of interpolation of the function $f(t)$ is essentially decreased in all cases considered.

When applying the proposed method of phantom nodes it is important to choose the values of interpolation sequence at phantom nodes in an appropriate way. Although in some cases this choice does not offer any essential problem, generally these values may be chosen applying the Hermitian polynomials which are constructed on the values of function and values of divided differences of corresponding order.

To select the values of the interpolation sequence at phantom nodes authors also applied the method of direct selection of values on the basis of criteria of minimal error; this was done to determine the potential of the method of phantom nodes.

To illustrate the proposed method of phantom nodes the test examples for some smooth functions on the segment $[0, 2\pi]$ were considered. On this segment N interpolation nodes were defined and values of the function were calculated in these nodes. Further, for these nodes a trigonometric interpolation polynomial was constructed and the error of interpolation was calculated. Then two phantom nodes were added. Values at these nodes were calculated by different methods. For the received sequence of $N+2$ points an interpolation trigonometric polynomial was constructed and the error of interpolation was calculated again. Then similar calculations were conducted for four phantom nodes.

The results of comparison of these errors are given in the tables 1-6.

Comparison of error of interpolation for function $y = t+1$, $x \in [0, 2\pi)$ without phantom nodes to the error of interpolation with 2 phantom nodes

Table 1

Number of interpolation nodes	Continuity of function	Continuity of function and its first derivative	Continuity of function and its first two derivatives	Values are selected
5	2.5	7.6	7.6	35.2
9	3	8,7	18.3	36.7
13	3.2	9.4	9.4	35.5

Comparison of error of interpolation for function $y = t+1$, $x \in [0, 2\pi)$ without phantom nodes to the error of interpolation with 4 phantom nodes

Table 2

Number of interpolation nodes	Continuity of function	Continuity of function and its first derivative	Continuity of function and its first two derivatives	Values are selected
5	3.4	15.8	41.3	208
9	4.5	20.6	61.1	1153.8
13	4.8	22.9	71.1	1159.4

Comparison of error of interpolation for function $y = \sin\frac{3}{4}t$, $x \in [0, 2\pi)$ without phantom nodes to the error of interpolation with 2 phantom nodes

Table 3

Number of interpolation nodes	Continuity of function	Continuity of function and its first derivative	Continuity of function and its two derivatives	Values are selected
5	.73	1.5	4.8	10.6
9	5.8	50	84.6	220
13	4.4	23.1	60	133.3

Comparison of error of interpolation for function $y = \sin\frac{3}{4}t$, $x \in [0, 2\pi)$ without phantom nodes to the error of interpolation with 4 phantom nodes

Table 4

Number of interpolation nodes	Continuity of function	Continuity of function and its first derivative	Continuity of function and its first two derivatives	Values are selected
5	.58	1.4	10	597.82
9	3.14	14.6	53.7	1264
13	8	70.6	282.4	3428.6

Comparison of error of interpolation for function $y = .02\exp t$, $x \in [0, 2\pi)$ without phantom nodes to the error of interpolation with 2 phantom nodes

Table 5

Number of interpolation nodes	Continuity of function	Continuity of function and its first derivative	Continuity of function and its first two derivatives	Values are selected
5	1.5	2.75	5.5	16.9
9	1.8	13.75	15.7	23
13	2.1	5.2	12.1	27.1

Comparison of error of interpolation for function $y = .02\exp t$, $x \in [0, 2\pi)$ without phantom nodes to the error of interpolation with 4 phantom nodes

Table 6

Number of interpola-tion nodes	Continuity of function	Continuity of function and its first derivative	Continuity of function and its first two deriva-tives	Values are selected
5	1.6	5.2	8.9	49
9	2.2	7.9	22	407
13	2.1	8.1	8.9	506

Conclusion

The method of improvement of convergence of interpolation trigonometric polynomials, based on the preliminary compression of segment of interpolation and adding an even number of phantom nodes to the sequence of interpolation nodes, is proposed; values at these phantom nodes are calculated by means of Hermitian polynomials or chosen in a predetermined manner. Test calculations were conducted applying both methods; results of these calculations confirm efficiency of the proposed method. There are strong reasons to suppose that in the case of matched phantom nodes we get polynomials that are close enough to polynomials of the best approximation.

References

1. Денисюк В.П. Сплайни та сигнали. – К.: ЗАТ «ВІПОЛ», 2007. – 228 с.
2. Денисюк В.П. О некоторых методах улучшения сходимости тригонометрических рядов Фурье и интерполяционных тригонометрических многочленов//Journal of Qafqaz University, Mathematics and Computer Science, Number 33 (2012), http://journal.qu.edu.az
3. Метод покращення збіжності рядів Фур'є та інтерполяційних многочленів по ортогональних функціях//Наукові вісті НТУУ "КПІ".–2013. – №4. – С.31-37.

UDC 519.254:620.179.1(045)

V.G. Demydko, Cand. Tech. Sc. (National Aviation University, Ukraine, Kyiv),
V.I. Mamchuk, Cand. Tech. Sc. (National Aviation University, Ukraine, Kyiv)

MATHEMATICAL PROCESSING OF THE RESULTS OF NON-DESTRUCTIVE TESTING

For quality control elements of aviation technology that uses radiation, ultrasonic, vortex-current, and other methods. Probability of detecting defects in the different methods are not the same and depends on the different causes of defect formation. Thus objectivity control depends on the awareness of methods of non-destructive tests, which are considered in this work.

Providing quality aircraft parts is performed on the stages of the production and operation of the various methods of non-destructive testing. In most cases, the construction of the aircraft is such that it does not give the possibility of comprehensive access for non-destructive testing of its most critical elements. Therefore, the certification of aircraft uses stripped-down information that does not fully cover the quantitative quality assessment elements in their construction.

As a result of this evaluation, the elements of aviation technology have probabilistic nature that gives a base for interpretation of the condition of objects to test their uncertainty and quantitatively evaluate it through the entropy, $H(K)$, where K is the state of the object after testing.

The amount of information, I, from the transition of testing the object from state A (before testing) to state K(after testing) is calculated by the formula (**1**):

$$I = H(A) - H(K), \tag{1}$$

where $H(A)$ is initial entropy, i.e. the degree of uncertainty before non-destructive testing (NDT).

The initial entropy state of the object to test can be estimated using known information about it. For example, if it is known that an event A has a probability $p(A)$ to occur, and inversely, the event $\overline{A}$ with a probability of $p(\overline{A}) = 1 - p(A)$, then the entropy $H(A)$ of the event A is equal to:

$$H(A) = -p(A)\, log_2\, p(A) - p(\overline{A})\, log_2 p(\overline{A}) \quad . \tag{2}$$

If the event A is denoted as the presence of unallowable defects in construction; then the event B is denoted as the detection of defects (authentic signal from the defect or irrelevant signal from an extraneous source), which is then fixed with a non-destructive method of testing, then the initial entropy is determined by (**2**). Thus when a monitored object, about which there is no information about the possibility of the presence of unallowable defects $p(A)$, then to calculate the entropy $H(A)$, it is accepted that the probability $p(A) = p(\overline{A}) = 0{,}5$. Entropy evaluation of the state of the object after testing depends on the probability of $p(B)$, that the signal will be recorded, from the probability of the inverse event, $p(\overline{B})$, and the conditional probability, $p(A/B)$ and $p(A/\overline{B})$.

The probability of event B that the signal will be recorded (reliable or false), in accordance with the formula of total probability is equal to:

$$p(B) = p(A)\cdot p(B/A) + p(\overline{A})\cdot p(B/\overline{A}). \qquad \mathbf{(3)}$$

The conditional probability $p(A/\overline{B})$ is presence of defect when there is no signal, is found by the Bayes' Formula:

$$p(A/\overline{B}) = \frac{p(A)\cdot p(\overline{B}/A)}{p(\overline{B})}, \qquad \mathbf{(4)}$$

where $p(\overline{B}/A)$ is the probability of events inverse to (B/A).

Conditional entropy state of object after testing $H(A/B)$, that in the construction, there is the presence of an unallowable defect and the recorded signal comes from the defect itself; and $H(A/\overline{B})$, that the design defect is present but the recorded signal is not present, are in accordance with the formula (**2**).

Entropy state of the object after the conducted testing depends on the conditional entropy and is equal to:

$$H(K) = p(B)\cdot H(A/B) + p(\overline{B})\cdot H(A/\overline{B}). \qquad \mathbf{(5)}$$

The volume of information about the state of the object after the non-destructive test is found by formula (**1**).

The dependence of the amount of information on the reliability of existence of the defect, i.e., the probability $p(A/B)$ is shown on Fig. 1. For curve 1: the conditional probability of an incorrect signal $p(B/\overline{A}) = 0$; the probability of the presence of an unallowable defect in the design $p(A) = 0,9$ and the likelihood of receiving a signal from the defect $p(B/A) = 0,95$. For curve 2: $p(B/\overline{A}) = 0,2$; $p(A) = 0,5$ and $p(B/A) = 0,9$.

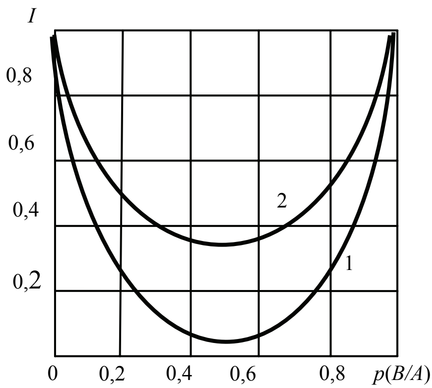


Fig.1

For example, on the basis of statistical data, it is known that in 40% of aircraft AN-26, during maintenance after 30 thousand hours, the subzygomic beams have cracks of critical sizes. When using the vortex-current method of non-destructive testing, the probability of obtaining a credible signal of the presence of a crack is equal to 0.9, and the probability of a false signal (not cracked) is equal to 0.2. For example, the probability of the presence of defects, $p(A) = 0,4$; and the probability of the inverse event (absence of defects) $p(\overline{A}) = 0,6$. Conditional probability associated with the presence of a credible signal during vortex-current method of testing is equal to: $p(B/A)$ = 0,9 and $p(B/\overline{A})$ = 0,2. When calculating the initial entropy $H(A)$ should take into account the information about the object that is subject to testing. That is, if it is known from statistical research that $p(A)$ = 0,4; however for a particular subzygomic beam, which was not tested by any method, then we assume that $p(A)$ = 0,5. Statistical data will be used in formulas (3) and (4). Therefore, according to formula (2), entropy event A is equal to $H(A) = -\log_2 0{,}5 = 1$.

The probability of event B, that a signal was recorded, according to formula (3) is equal to:

$$p(B) = 0{,}4 \cdot 0{,}9 + 0{,}6 \cdot 0{,}2 = 0{,}48 \Rightarrow p(\overline{B}) = 1 - 0{,}48 = 0{,}52.$$

According to formula (4), to find $p(A/\overline{B}) = \dfrac{0{,}4\,(1-0{,}9)}{0{,}59} \approx 0{,}068$.

Conditional entropy evaluations of an object if there are cracks based on credible and false signals are equal to:

$$H(A/B) = -\,0{,}9\,\log_2 0{,}9 - 0{,}1\,\log_2 0{,}1 \approx 0{,}469;$$

$$H(A/\overline{B}) = -\,0{,}068\,\log_2 0{,}068 - 0{,}932\,\log_2 0{,}932 \approx 0{,}035.$$

So after the conducted testing, entropy $H(K)$ condition of the lining of shell structures of the subzygomic beams, according to (5) is equal to:

$H(K) = 0{,}48 \cdot 0{,}469 + 0{,}52 \cdot 0{,}035 \approx 0{,}243$.

Comparing with entropy $H(A)$, we see that the NDT reduces the degree of uncertainty, therefore quality control costs become justified. The difference in entropy before testing and after testing will measure the volume of information received (**1**):

$$I \approx H(A) - H(K) = 1 - 0{,}243 = 0{,}757.$$

The main parameter that determines the probability of detecting defects is the signal to noise ratio. For example, in radiography this ratio is equal to [1]:

$$k = \frac{\Delta D}{\sigma} = f\,\frac{|\gamma - \gamma_1|}{\gamma}\,\Delta x\sqrt{S}, \qquad \textbf{(6)}$$

where ΔD is the added density of the darkening picture, which is caused by the presence of the defect; σ - standard deviation of the density of the darkening picture; f is a detection factor which depends on the radiographic mode; γ, γ_1- density of the tested material and the material containing defects, respectively; Δx - the radial size of the defect; S- area of the defect image in the picture. For gas pores, the ratio is equal 1 since $\gamma >> \gamma_1$. For slag inclusions, the ratio is reduced to 0,7; and for tungsten inclusions, the ratio grows up to 1,49.

Thus, for the same geometrical sizes of the defect, the larger the value of the signal to noise ratio, the greater the probability of having a tungsten inclusion.

To assess the reliability of defects during ultrasonic testing (UT), the results of UT data are compared with destructive or other non-destructive methods of testing. When processing data from UT and its concurrency against the examination results, reliability testing matrices are used (table 1).

Table 1

$P_t = 1 - (\alpha_0 + \beta_0)$ $P_f = \alpha_0 + \beta_0$	Examination	
	Defect exists	Defect does not exist
Echo signal occurred Echo signal did not occur	$P_в = 1 - \beta_0$ β_0	α_0 $1 - \alpha_0$

Where α_0 – relative frequency of false signals; β_0 - relative frequency of non-detected defects; P_c - relative frequency of correctly detected defects; P_t- relative frequency of correct decisions about the presence or absence of defects; P_f - relative frequency of false decisions.

The relative frequency of correct decisions about the presence or absence of defects, using 100% of UT results with a limited number of other tests to detect defects is calculated by:

$$P_t = 1 - (\alpha_0 + \beta_0);\ \alpha_0 = n_f/(n_s - n_д);\ \beta_0 = \frac{n_{nд}}{n_д},$$

where n_f- number of trials which had taken place during false signals; $n_s = \frac{L_0}{l_д}$ - the total number of measurements using UT for each production unit; $n_д$ - the number of defects discovered during destructive tests; $n_{nд}$ is the number of measurements, which contained missed defects, L_0 is the length of the tested object; $l_д$ – the width of the chart in the ultrasonic detector.

For example, when $\alpha_0 = 0,05$ and $\beta_0 = 0,15$ the reliability testing matrix will look like (table 2):

Table 2

$P_t = 0,8$ $P_f = 0,2$	Examination	
	Defect exists	Defect does not exist
Echo signal occurred Echo signal did not occur	$P_c = 0,85$ $\beta_0 = 0,15$	$\alpha_0 = 0,05$ 0,95

Conclusions

On the basis of the proposed mathematical model used to calculate the volume of information received *I*, of the non-destructive test, as quality control elements of aviation technology. The main parameters that affect the objectivity of NDT were defined. The benefits of using NDT to reduce the degree of uncertainty, which, subsequently justify quality control costs were illustrated.

References

1. *Троицкий В.А., Радько В.П., Демидко В.Г.* Дефекты сварных соединений и средства их обнаружений. К.: Вища школа, 1983.-144 с.

2. *Демидко В.Г., Бабко А.І.* Інформативність неруйнівного контролю елементів конструкцій авіаційної техніки. Львів:ФМІ, 2008 с.233-237.

UDC 536.23

B.P. Golovnya, Dr. Tech. Sc. (National University, Ukraine, Cherkasy)

SOME SYSTEMATIC MISTAKES IN NEAR-WALL TURBULENCE MODELING AND POSSIBLE WAY TO OVERCOME THEM

All near-wall models of turbulence do not reproduce the cascade energy transfer. In the author opinion, models poorly take into account the structure of near-wall turbulence. Therefore these models can not reproduce correctly all processes in turbulent boundary layer. Traditional correction terms can not be regarded as physically reasonable solution of the problem. This paper presents a possible explanation of difficulties encountered in the development of turbulence models for the calculation of the boundary layer. A technique to overcome these difficulties is presented.

Introduction. Almost all modern models of turbulence are based on the equation of turbulent energy transfer. If such model is reckoned as universal then it must answers the three questions. First – where does the turbulent energy originate? Second – what happens to this energy later? Third – how does the energy dissipate? Otherwise there are certainly exists such flow that this model can not reproduce.

Kolmogorov's theory of cascade energy transfer answers these questions. By this reason results of simulations by high-quality models must be in agreement with this theory.

It is known that the RANS and LES type models do not reproduce the basic features of cascade energy transfer in simulations of the boundary layer. Main reason – these models poorly take into account the structure of near-wall turbulence.

Physical effects not taken into account in modern models. Following [1], let us briefly consider the mechanism of periodical flow renewal in a turbulent boundary layer.

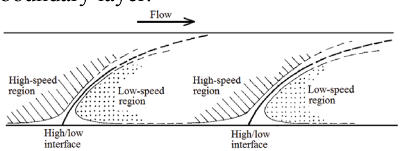


Fig. 1. Long-scaled quasi-ordered vortex structures in turbulent boundary layer.

Main role in a turbulent boundary layer is played by long-scaled quasi-ordered vortex structures. Their schematic representation is shown in Fig. 1 (see [2]). Structures move along the flow. After passing the boundary that closes this structure, intense high-frequency fluctuations of velocity etc. are observed and there occur jet ejections of decelerated liquid from the wall and invasion of accelerated to the wall region. Experiments show that these jet ejections of liquid are accompanied by the long-scaled vortexes deceleration. All this is one cycle of a turbulent boundary layer renewal.

Very thin longitudinally oriented vortexes are formed from these ejections. These vortexes form so called horseshoe vortexes, see Fig. 2. This intertwining of horseshoe vortexes is observed as comprehensive whole. We will call it a medium-scale structure. However, this structure really consists of thin vortexes. Such

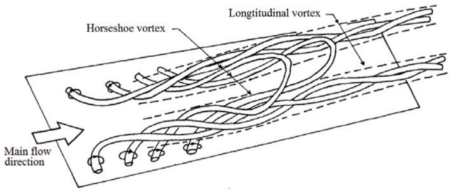


Fig. 2. Longitudinally oriented and horseshoe vortexes

vortexes dissipate very rapidly. So, the rate of dissipation in the medium-scale structure must be very high. Also, thin vortexes create very small turbulent viscosity.

Simulations [4] show that medium-scale structures have noticeable turbulent energy. It can be estimated as $\Delta k_{+} \approx 0.25 \div 0.28$.

The hypothetical graph of the spectral function in some cross section of the layer which is placed very close to the wall is shown in Fig. 3b. Fig. 3a and 3b differ very markedly. Form of the Fig. 3b is determined by two factors. First, main part of the graph corresponds to the cascade process theory. This part of the graph is in agreement with Fig. 3a. Second, the ejection is presented in the graph at high wave numbers. It is determined by existence of the medium-scale structures in the layer. Let's move the cross section from the wall. At some distance from the wall the effect of these structures must start to decrease with increase of the distance, i.e. size of the ejection in Fig. 3b must decrease also. On the boundary of layer Fig. 3a and 3b must coincide.

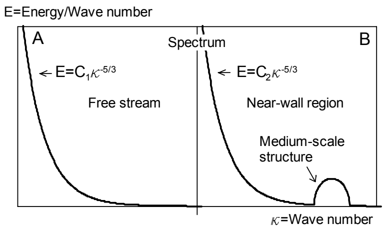


Fig. 3. Spectral function in two points of the flow.

Any sufficiently general model of turbulence must be agreed with such behavior of turbulence. This means that model must answer the following questions. 1) From the point of view of the theory of cascade process Fig. 3 violates the energy conservation law. Indeed, the cascade process guarantees that if the wave number increase then the turbulent energy decreases. Growth of the turbulent energy in the cascade process is impossible. 2) As it was said above, the experiments show that the jet ejections of the liquid are accompanied by deceleration of the long-scaled structures. Because the medium-scale structures appear from these ejections it is natural to assume that some part of the braking energy is used on production of the medium-scale structures. So, it can be said that direct energy transfer from the long-scale to the medium-scale structures exists in the layer and this transfer occurs without any involvement of the cascade process. It is not clear how to introduce this mechanism into the model, especially if this model is in agreement with the cascade process. 3) At turbulence modeling fluctuation flow is averaged. As a result very strange formation appears on location of the medium-scale structure. It has sufficiently large sizes $(L_{+} \approx 100)$, noticeable turbulent energy, dissipate very rapidly, and create vanishingly small turbulent viscosity.

All authors of models of turbulence in fact attempt to correspond to third item of this list. That means that all models of turbulence have the following properties. 1) The calculated turbulent energy is equal to the sum of the energies of the long-scale and medium-scale structures. 2) The calculated dissipation rate in the near-wall region is sufficiently high. This simulates the rapid dissipation of the medium-scale structures. 3) The calculated turbulent viscosity in the near-wall region is strongly suppressed. This simulates the fact that the medium-scale structures have not effect on the turbulent viscosity.

These properties are obtained by introducing into the model of the complex correction functions. Unfortunately these corrections effect on the long-scaled structures also. As a result the model looses all original positive qualities of the models without corrections and can not simulate the cascade process.

New approach to turbulence modeling. The author offers a radically different approach. From an engineering point of view the main problem of the turbulence modeling is to provide correct simulation of the mean flow. In its turn, this is guarantees by quality reproduction of the turbulent viscosity. But as stated above, the medium-scale structures create vanishingly small turbulent viscosity. So their influence can be neglected.

The medium-scale structures can be eliminated in the following way. Let k be the total turbulent energy, k_0 – the energy of the long-scale structures, and k_1 – the energy of the medium-scale structures. Neglecting the energy of interaction of structures we get $k = k_0 + k_1$. Denote $f_0 = k_0 / k$ or $k_0 = f_0 k$.

Schematically the equation of total turbulent energy transfer can be written as $Dk/Dt = Diff(k) + P - \varepsilon$. Here $Diff$ – operator of diffusion transfer, P – rate of turbulent energy production, ε - rate of k dissipation. Multiplying (1) on function f_0 we obtain

$$\left\{ f_0 \frac{Dk}{Dt} = f_0 Diff(k) + f_0 P - f_0 \varepsilon \right\} = \left\{ \frac{Dk_0}{Dt} = Diff(k_0) + f_0 P - \varepsilon_0 \right\} \qquad (1)$$

Here $\varepsilon_0 = f_0 \varepsilon$ - dissipation rate in the long-scale structures. Major result – the production term is multiplied on additional function. Transformation $f_0 Diff(k) = Diff(f_0 k) = Diff(k_0)$ is the model of turbulent diffusion.

All these calculations are not rigorous and are needed only to clarify the origin of the equation (2). The same result can be obtained strictly on the base of equations of fluctuation components transfer.

Now, taking into account equation (1), let us introduce corrections into the model. The resulting system has the following form

$$\frac{Dk_0}{Dt} = \frac{\partial}{\partial x_k}\left(\nu + \frac{\nu_t}{C_k} \right) \frac{\partial k_0}{\partial x_k} + f_0 P - \varepsilon_0 - E_k, \qquad (2)$$

$$\frac{D\varepsilon_0}{Dt} = \frac{\partial}{\partial x_k}\left(\nu + \frac{\nu_t}{C_\varepsilon} \right) \frac{\partial \varepsilon_0}{\partial x_k} + \frac{\varepsilon_0}{k_0}\left(C_1 f_0 P - C_2 \varepsilon_0 \right) - E_\varepsilon \qquad (3)$$

$$\nu_t = C_\nu F_\nu \frac{k_0^2}{\varepsilon_0} \qquad (4)$$

Here E_k and E_ε are the corrections assigned to balance the diffusion on the wall.

To close model (7)-(9) it must first be supplemented by the expression for the function f_0. The results of it calculations are given in Fig. 4.

The following approximation was obtained for the function f_0:

$$f_0 = \left(1-\exp\left(-\mathrm{Re}_{y0}/5.5\right)\right)\left(1-\exp\left(-2.4\,y/L_{\varepsilon 0}\right)\right)$$

where $\mathrm{Re}_{y0} = \sqrt{k_0}\,y/\nu$, $L_{\varepsilon 0} = k_0^{3/2}/\varepsilon_0$.

Test calculations have shown that the expressions

$$E_k = \left(1-f_0\right)\frac{\partial}{\partial x_k}\left(\nu+\frac{\nu_t}{C_k}\right)\frac{\partial k_0}{\partial x_k},\ E_\varepsilon = \left(1-f_0\right)\frac{\partial}{\partial x_k}\left(\nu+\frac{\nu_t}{C_\varepsilon}\right)\frac{\partial \varepsilon_0}{\partial x_k}$$

are good approximation for the wall corrections.

Final form of model equations

$$\frac{Dk_0}{Dt} = f_0\frac{\partial}{\partial x_k}\left(\nu+\frac{\nu_t}{C_k}\right)\frac{\partial k_0}{\partial x_k} + f_0 P - \varepsilon_0,$$

$$\frac{D\varepsilon_0}{Dt} = f_0\frac{\partial}{\partial x_k}\left(\nu+\frac{\nu_t}{C_\varepsilon}\right)\frac{\partial \varepsilon_0}{\partial x_k} + \frac{\varepsilon_0}{k_0}\left(C_1 f_0 P - C_2\varepsilon_0\right)$$

By the results of test calculations for the function F_ν we obtained the following approximation: $F_\nu = \left(1-\exp\left(-\mathrm{Re}_{y0}/45\right)\right)\left(1-\exp\left(-2.4\,y/L_{\varepsilon 0}\right)\right)$.

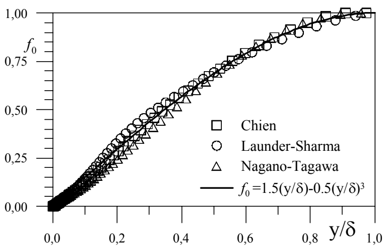


Fig.4. Results of calculation of the function f_0.

The constants and the boundary conditions are: C_ν=0.09, C_ε=1.3, C_k=1, C_2=1.45, C_1=0.9C_2. y=0 - k_0=ε_0=0, $y\to\infty$ - k_0=k_e, ε_0=ε_e.

Here we show only the simplest $k-\varepsilon$ model. On the base on this approach there are developed the model of temperature fluctuations transfer, the model of turbulent stresses and heat fluxes transfer, several ASM – models; were performed simulations of bypass transition, flow with laminarization and relaminarization, cascade process, separated flow, etc. Some results are shown in the attached figures.

References

1. *Репик Е.У., Соседко Ю.П.* Турбулентный пограничный слой. - М.: - Физматлит – 2007
2. *Nakagawa H., Nezu I., Matsumoto N.* Structure of space-time correlations of bursting phenomena in an open-channel flow // Mem. Fac. Eng. Kyoto Univ. – 1980 - V.42 - № 1 - P. 85-124.

3. *Utami T., Ueno T.* Experimental study on the coherent structure of turbulent open-channel flow using visualization and picture processing // J. Fluid. Mech. – 1987 - V. 174 - P. 399-440.
4. *Zhang Z., Lilley G.M.* A Theoretical Model of the Coherent Structure of the Turbulent Boundary Layer in Zero Pressure Gradient. // В кн. Turbulent Shear Flows 3, Springer-Verlag - 1982 - P.60-72.
5. *A.E. Samuel, P.N. Joubert.* A boundary layer developing in an increasingly adverse pressure gradient, J. Fluid Mech. 66 (3) (1974) 481–506.
6. *B.E. Roach, D.H. Brierley.* The influence of a turbulent free-stream on zero pressure gradient transitional boundary layer development, in: O. Pironeau et al. (Eds.), Numerical Simulation of Unsteady Flows and Transition to Turbulence, C.U.P., New York, 1992, pp. 319–347.
7. *G. Comte-Bellot*, Ecoulement turbulent entre deux parois paralleles, Publ. Sci. Tech. Ministere de l'Air (419) (1965).
8. *T. Tsuji, Y. Nagano,* Turbulence measurements in a natural convection boundary layer along a vertical flat plate, Int. J. Heat Mass Transfer 31(1989) 2101–2111.
9. *R. Cheeswright, E. Ierokipiotus,* Velocity measurements in a turbulent natural convection boundary layer, in: Proc. 7th Int. Heat Transfer Conf., Munich, vol. 2, 1982, pp. 305–309.
10. *A.G. Kirdyashkin*, Structure of Thermogravitational Fluxes near Heat TransferSurface, Ph.D. Thesis, Institute of Thermophysics, Siberian Branch of the USSR Academy of Sciences, Novosibirsk, 1975.
11. *J. Kim, S.J. Kline, J.P. Johnston*, Investigation of a reattaching turbulent shear layer: flow over a backward-facing step, ASME J. Fluids Eng. 102 (1980) 302–308.
12. *Golovnya B.P.* Modelling of the fluctuating component in the form of the sum of an infinite number of random quantities. Part 1. k–ε Modeling// Int.J. of Heat and Mass Transf. - V 52 - 2009 - pp.5218-5228
13. *Golovnya B.P.* Modelling of the fluctuating component in the form of the sum of an infinite number of random quantities. Part 2. Model of transfer of turbulent stresses and turbulent heat fluxes// Int.J. of Heat and Mass Transf. - V. 52 – 2009 - pp. 5229-5240.

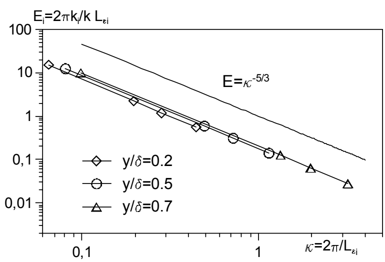


Fig. 5. Discrete spectrum of turbulent energy in three cross sections of the boundary layer.

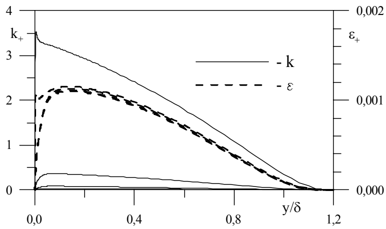


Fig. 6. Turbulent energy and dissipation rate at three steps of cascade process.

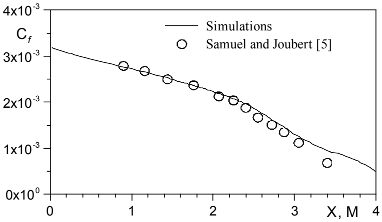


Fig. 7. Friction coefficient in the flow with laminarization and relaminarization.

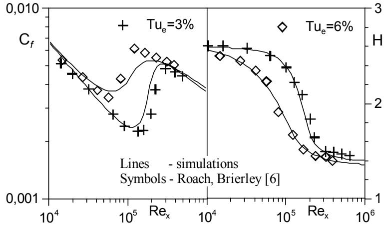


Fig.8. Bypass transition in the boundary layer. Friction coefficient and form parameter.

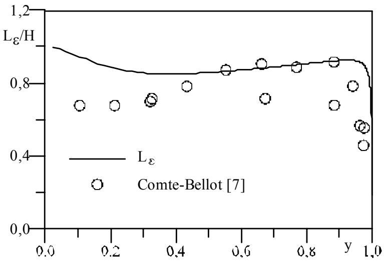


Fig. 9. Dissipative scale in channel at a distance X=118H.

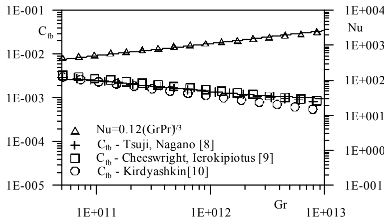


Fig. 10. Natural convection on vertical flat plate

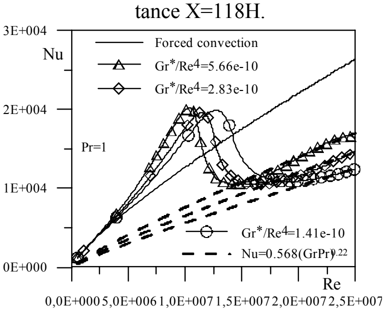


Fig.11. Heat transfer at opposite mixed convection on vertical flat plate.

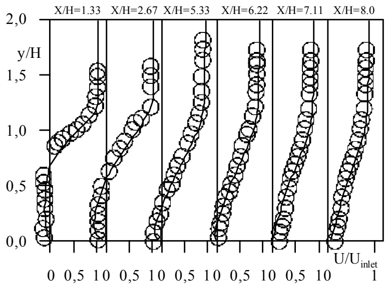


Fig. 12. Flow past a backward-facing step. Longitudinal velocity. Symbols - [11]

UDC 517.5

O.V. Karupu, Cand. Phys.-Math. Sc. (National Aviation University, Ukraine, Kyiv)

ON INTEGRAL MODULI OF SMOOTHNESS OF CONFORMAL MAPPINGS

We consider some estimates for integral moduli of smoothness of arbitrary order for the function realizing conformal mapping of the unit disk onto the domain bounded by the smooth Jordan curve and for the function realizing conformal mapping between the domains bounded by the smooth Jordan curves.

Suppose that G is a simply connected domain in the complex plane bounded by a smooth Jordan curve Γ, $\tau = \tau(s)$ is the angle between the tangent to Γ and the positive real axis $s = s(w)$ is the arc length on Γ. Suppose $w = \varphi(z)$ is a homeomorphism of the closed unit disk $\overline{D} = \{z : |z| \le 1\}$ onto the closure $\overline{G}$ of the domain G, conformal in the open unit disk D.

The aim of this paper is to receive information about connection between the function $\tau = \tau(s)$ and the functions $w = \varphi(z)$ in terms of the uniform integral moduli of smoothness of arbitrary order.

Kellog in 1912 proved the theorem in which it had been established that if $\tau = \tau(s)$ satisfies Holder condition with index α, $0 < \alpha < 1$, then the derivative $\varphi'(e^{i\theta})$ of the function $\varphi(z)$ on ∂D satisfies Holder condition with the same index α. Afterwards this result was generalized in works by several authors: S.E. Warshawski, J.L. Geronimus, S. J. Alper, R.N. Kovalchuk, L I. Kolesnik .

P. M. Tamrazov $[1]$,$[2]$ obtained solid reinforcement for the modulus of continuity of the function $\varphi(z)$ on $\overline{D}$. Some close problems were investigated by E.P. Dolzenko.

In particular, results in the terms of the uniform curvilinear, arithmetic, local and integral moduli of smoothness of arbitrary order were received by author (more detailed see $[1]$, $[3]$ and $[5]$). Some estimates for the integral moduli of smoothness of arbitrary order were considered by author in $[3]-[7]$.

Let $\omega_{k,z}(f(z),\delta)$ be a noncentralized local arithmetic modulus of smoothness of order k $(k \in N)$ of the function $w = f(z)$ at a point z on the curve γ. Then the integral modulus of smoothness of order *k* for the function $w = f(z)$ on the curve γ is introduced by the formula

$$\omega_k((z),\delta)_p = \left\{ \int_\gamma \left[\omega_{k,z}(f(z),\delta)\right]^p d\lambda(z) \right\}^{1/p}, \ 1 \le p < +\infty, \ k \in N,$$

where $\lambda = \lambda(z)$ is the linear Lebesgue's measure on the curve. This integral modulus is the special case of integral moduli of smoothness introduced by P. M. Tamrazov in 1977. He defined integral moduli of smoothness as averaging on arbitrary measure on the curve of the respective local moduli of smoothness. Difference between these moduli and traditional integral moduli of smoothness, introduced as the least upper bound of averaging absolute values of finite differences, is that the operators of averaging and taking of least upper bound are applied in reverse order.

Theorem 1. ($[4]$). Let $\tau(s) \in L_{pk}[0,l]$, $1 \le p < +\infty$, $k \in N$. Let integral modulus $\omega_k(\tau(s),\delta)_{pk}$ of smoothness of order *k* for the function $\tau = \tau(s)$ satisfy condition

$$\omega_k(\tau(s),\delta)_{pk} = O[\omega(\delta)](\delta \to 0),$$

where $\omega(\delta)$ is normal majorant satisfying the condition

$$\int_0^l \frac{\omega(t)}{t} dt < +\infty .$$

Then integral modulus of smoothness of order *k* of the derivative $\varphi'(e^{i\theta})$ for the function $\varphi(z)$ on ∂D satisfies condition:

$$\omega_k(\varphi'(e^{i\theta}),\delta)_p = O[\nu(\delta)](\delta \to 0),$$

where

$$\nu(\delta) = \int_0^l \frac{\omega(x_1)}{x_1\left(1+\left(x_1/\delta\right)^k\right)} dx_1 +$$

$$+\sum_{j=1}^{k-1}\sum_{r_1=1}^{j-1}\cdots\sum_{r_j=1}^{r_{j-1}-1}\delta^{k-r_1}\int_0^l\cdots\int_0^l x_{j+1}^{r_{j-1}}\left(1+\int_{x_{j+1}}^l \frac{\omega(y)}{y_j^{r_j+1}}dy\right)\left(1+\left(\frac{x_{j+1}}{x_j}\right)^{r_{j+1}1}\right)\times$$

$$\times\prod_{p=1}^{j}\left(1+\int_{x_p}^l \frac{\omega(t_p)}{t_p^{r_{p-1}-r_p+1}}dt_p\right)\left(1+\left(\frac{x_p}{x_{p-1}}\right)^{r_{p-1}}\right)^{-1} x_p^{r_{p-1}-r_p-1}dx_1\ldots dx_{j+1} .$$

In partial case when integral modulus of smoothness $\omega_k(\tau(s),\delta)_p$ of order k for the function $\tau(s)$ satisfies Holder condition $\omega_k(\tau(s),\delta)_p = O(\delta^\alpha)(\delta \to 0)$, $0 < \alpha < k$, then the integral modulus of smoothness $\omega_{k,\theta}(\varphi'(e^{i\theta}),\delta)_{pk}$ of the same order k for the derivative $\varphi'(e^{i\theta})$ of the function $\varphi(z)$ on ∂D satisfies the condition $\omega_k(\varphi'(e^{i\theta}),\delta)_{pk} = O(\delta^\alpha)(\delta \to 0)$ with the same index α.

Theorem 2. ([5]) If integral modulus of smoothness of order k of the m-th derivative of the function $\tau = \tau(s)$ satisfies Holder condition with index α, where $m \in N$ $(m < k)$ and $0 < \alpha < k$:

$$\omega_k(\tau^{(m)}(s), \delta)_p = O[\delta^\alpha](\delta \to 0),$$

then integral modulus of smoothness of order k of the $(m+1)$-th derivative of the function $\varphi(e^{i\theta})$ satisfies Holder condition with the same index α:

$$\omega_k(\varphi^{(m+1)}(e^{i\theta}), \delta)_{pk} = O(\delta^\alpha)(\delta \to 0).$$

If integral modulus of smoothness of order k of the m-th derivative of the function $\tau = \tau(s)$ satisfies condition

$$\omega_k(\tau^{(m)}(s), \delta)_p = O\left(\delta^k \log\frac{1}{\delta}\right)(\delta \to 0),$$

then integral modulus of smoothness of order k of the $(m+1)$-th derivative of the function $\varphi(e^{i\theta})$ satisfies condition

$$\omega_k(\varphi^{(m+1)}(e^{i\theta}), \delta)_{pk} = O\left(\delta^k \log\frac{1}{\delta}\right)(\delta \to 0).$$

Theorem 3. If nonzero continuous derivative $\varphi'(z)$ of the function $\varphi(z)$ exists on $\overline{D}$ and on ∂D $\varphi'(e^{i\theta})$ integral modulus of smoothness of $\varphi'(e^{i\theta})$ satisfies Holder condition with index α, where $0 < \alpha < k$:

$$\omega_k(\varphi'(e^{i\theta}), \delta)_{pk(k+1)/2} = O(\delta^\alpha)(\delta \to 0),$$

then integral modulus of smoothness of the same order of the function $\tau = \tau(s)$ satisfies Holder condition with the same index α:

$$\omega_k(\tau(s), \delta)_p = O(\delta^\alpha)(\delta \to 0).$$

Let G_1 and G_2 be the simply connected domains in the complex plane bounded by the smooth Jordan curves Γ_1 and Γ_2. Let $\tau_1(s_1)$ be the angle between the tangent to Γ_1 and the positive real axis, $s_1(\zeta)$ be the arc length on Γ_1. Let $\tau_2(s_2)$ be the angle between the tangent to Γ_2 and the positive real axis, $s_2(w)$ be the arc length on Γ_2. Let $w = f(\zeta)$ be a homeomorphism of the closure $\overline{G_1}$ of the domain G_1 onto the closure $\overline{G_2}$ of the domain G_2, conformal in the domain G_1.

Theorem 4. ([7]) Let integral moduli of smoothness $\omega_k(\tau_1(s_1), \delta)_{pk}$ and $\omega_k(\tau_2(s_2), \delta)_{pk}$ of order k $(k \in N)$ for the functions $\tau_1(s_1)$ and $\tau_2(s_2)$ satisfy Holder condition $\omega_k(\tau_1(s_1), \delta)_{pk} = O\left(\delta^\alpha\right)(\delta \to 0)$ and

$\omega_k(\tau_2(s_2),\delta)_{pk} = O\left(\delta^{\alpha}\right)(\delta \to 0)$ with the same index α, $0 < \alpha < k$.

Then integral modulus of smoothness $\omega(f',\delta)$ of the derivative of the function $f(\zeta)$ on Γ_1 satisfies Holder condition $\omega(f',\delta) = O(\delta)(\delta \to 0)$ with the same index α.

Theorem 5. Let integral moduli of smoothness $\omega_k(\tau_1(s_1),\delta)_{pk}$ and $\omega_k(\tau_2(s_2),\delta)_{pk}$ of order k $(k \in N)$ for the functions $\tau_1(s_1)$ and $\tau_2(s_2)$ satisfy conditions

$$\omega_k(\tau_1(s_1),\delta)_{pk} = O\left(\delta^k \log\frac{1}{\delta}\right)(\delta \to 0)$$

and

$$\omega_k(\tau_2(s_2),\delta)_{pk} = O\left(\delta^k \log\frac{1}{\delta}\right)(\delta \to 0).$$

Then integral modulus of smoothness $\omega(f',\delta)$ of the derivative of the function $f(\zeta)$ on Γ_1 satisfies Holder condition

$$\omega(f',\delta) = O(\delta \log\frac{1}{\delta})(\delta \to 0).$$

References

4. *Тамразов П. М.* Гладкости и полиномиальные приближения. Наукова дум-ка. Киев. 1975.-274 с.
5. *Тамразов П. М.* Конечно-разностные тождества и оценки модулей гладко-сти суперпозиций функций. Препринт Ин-та математики АН УССР, 77.5, К., 1977, 24 с.
6. *Карупу О. В.* О модулях гладкости конформных отображений.//Укр. матем. журн., т. 30, №4, 1978, с.540-545.
7. *Карупу О. В.* Про деякі властивості модулів гладкості конформних відо-бражень //Праці Ін-ту математики НАН України, Київ, 2000, т. 31. – с.237-243.
8. *Karupu O. W.* On properties of moduli of smoothness of conformal mappings. In: Complex Analysis and Potential Theory, *Proceedings of the Confertence Satellite to ICM 2006*, World Scientific, Singapore, 2007. – p. 231-238.
9. *Karupu O. W.* On some properties of integral moduli of smoothness of confor-mal mappings // Bulletin de la société des sciences et des lettres de Łódź. Recherches sur les déformations, 2012, vol. LXII, no. 2. – P. 111-116.
10. *Каруру О. В.* Властивості інтегральних модулів гладкості конформних відображень однозв'язних областей //Збірник праць Ін-ту математики НАН України, Київ, 2013, т.10, №№ 4–5. – с. 565 – 569.

UDC 517.9

O. Karpenko, Cand. Phys.-Math. Sc.
(National Aviation University, Ukraine, Kyiv)
M. Bohner, Dr. Phys.-Math. Sc.
(Missouri University of Science and Technology, Rolla, MO, USA)
O. Stanzhytskyi, Dr. Phys.-Math. Sc.
(Taras Shevchenko National University of Kyiv, Ukraine, Kyiv)

ON THE RELATION BETWEEN OSCILLATORY SOLUTIONS OF SECOND-ORDER DIFFERENTIAL EQUATION AND CORRESPONDING DIFFERENCE EQUATION

In this paper we establish the conditions for oscillations of the solutions of linear second order differential equations, provided the solutions of the corresponding difference equations oscillate. We also establish the converse result, namely, when the oscillation of the solutions of difference equations implies the oscillation of the solutions of the corresponding differential equations.

Introduction. The focus of the present work is a linear second order differential equation and corresponding difference equation. Difference equations are important objects of study from both theoretical and practical points of view. Difference schemes arise in numerical integration of differential equations. Besides, they are convenient mathematical models of objects whose evolution has discrete character. A good example of such a model is the model of a financial market with the change in prices of risky assets at discrete points of time. In the simplest case, the function that describes the total capital of an investor at this market satisfies a linear difference equation. Since the change in value of shares (risky asset) is of oscillatory nature, so is the evolution of the total capital. Therefore, oscillatory solutions become especially important in such models.

Oscillatory properties of solutions of difference equations were studied by numerous authors, e.g. [1,10,11], to name only a few. For corresponding equations on time scales, the notion of a generalized zero of a solution and oscillation of solutions were investigated in, e.g. [2,5], again to name only a few.

The qualitative properties of solutions of ordinary differential equations and corresponding difference equations, provided the step size $h > 0$ goes to zero, are of particular interest (see, e.g. [7] and references therein). The works [6,8] investigate the relation between existence of attractors in systems of differential equations and corresponding difference equations.

The papers [9] establish the existence of bounded solutions of differential equations on the axis, provided the corresponding difference equations have such solutions, and vice versa.

It is well known (see, e.g. [7, p. 114]) that on finite time intervals, solutions of difference equations behave essentially the same as solutions of corresponding differential equations for small step sizes $h > 0$, and the error at the nodal points is proportional to h. However, this error estimate does not guarantee that oscillatory properties of solutions are preserved.

The question of the relation between oscillation of the solutions of linear difference and the corresponding differential equations was considered in the works [3,4,12]. The aforementioned works study oscillation of a fixed solution of some Cauchy problem for a difference equation, given that the solution of the Cauchy problem with the same initial data for the corresponding differential equation has such property, and vice versa. In this approach, the step size $h > 0$ depends on the initial data, and the coefficients have certain smoothness requirements which are somewhat artificial for such equations. The natural question which arises is whether there exists a universal step size $h > 0$, independent of the choice of the initial conditions, which would guarantee the oscillation properties uniformly in the initial data. In this work, our main result establishes the existence of such step size h. Besides, we provide several generalizations of the results in [12]. In particular, we study oscillation properties of linear functional second-order difference and differential equations. We also remove the technical smoothness conditions on the coefficients, replacing them with a more natural Lipschitz condition.

Problem statements. Consider the linear second-order differential equation

$$\ddot{x} + p(t)\dot{x} + q(t)x = 0 \tag{1}$$

The following equations are called the functional difference equation and the difference equation, corresponding to (1), respectively:

$$\Delta^2 x(t) + hp(t)\Delta x(t) + h^2 q(t)x(t) = 0 \tag{2}$$

$$\Delta_k^2 x(t_0) + hp(t_0+kh)\Delta_k x(t_0) + h^2 q(t_0+kh)x(t_0+kh) = 0 \tag{3}$$

Here

$$\Delta x(t) = x(t+h) - x(t)\,,\ \Delta^2 x(t) = \Delta(\Delta x(t)) = x(t+2h) - 2x(t+h) + x(t)\,,$$

$$\Delta_k x(t_0) = x(t_0+(k+1)h) - x(t_0+kh)\,,\ \Delta_k^2 x(t_0) = \Delta_k(\Delta_k x(t_0))\,.$$

Denote by $x_k^h = x(t_k)$ the solution of (3), where $t_k = t_0 + kh$.

*Definition 1.*We say that the solution x_k^h of (3) changes sign at t_k if either one of the following conditions holds:

1) $x_k^h x_{k+1}^h < 0$;

2) $x_k^h = 0$ and $x_{k-1}^h x_{k+1}^h < 0$.

Definition 2. A solution x_k^h of (3) is called oscillatory on some interval if it has at least two changes of signs on this interval.

We study (2) under conditions that ensure continuity of its solutions. Thus, we have the usual concept of a zero for solutions of (2), and the notion of oscillation of its solutions is essentially the same as for solutions of (1).

In this work, we present conditions ensuring the existence of a (universal) step size $h > 0$, for which oscillation of solutions of (1) follows from oscillation of solutions of (2) and (3). We also obtain the converse result. We focus our attention on the oscillatory properties of the solutions of equations in the form

$$\ddot{x} + p(t)x = 0 \tag{4}$$

Assume that the following conditions hold:

$$p(t) \geq 0, t \in (0, a); \tag{5}$$

p be Lipschitz on $[0, a]$. (6)

The difference equation corresponding to (4) is

$$\Delta_k^2 x + h^2 p(kh)x(kh) = 0 \tag{7}$$

Main results. Let present the main results about the relation between oscillation of solutions of (1), (2), (3), (4) and (7). These equations are equivalent to the systems:

$$\begin{cases} \dot{x} = y, \\ \dot{y} = -p(t)y - q(t)x, \end{cases} \tag{8}$$

$$\begin{cases} x(t+h) = x(t) + hy(t), \\ y(t+h) = y(t) - h(p(t)y(t) + q(t)x(t)), \end{cases} \tag{9}$$

$$\begin{cases} x_{k+1}^h = x_k^h + hy_k^h, \\ y_{k+1}^h = y_k^h - h(p(t)y_k^h + q(t)x_k^h), \end{cases} \tag{10}$$

The solutions of (9) are uniquely determined by the initial functions $x = \varphi(t), y = \psi(t)$, $t \in [0, h]$ which satisfy the coherence condition

$$\begin{cases} \varphi(h) = \varphi(0) + h\psi(0), \\ \psi(h) = \psi(0) - h(p(0)\psi(0) + q(0)\varphi(0)), \end{cases} \tag{11}$$

Theorem 1. Let p and q in (1) be Lipschitz on $[0, a]$. Then there exists $h_0 > 0$ such that for all $h \in (0, h_0]$, the following assertion holds: if x is a solution of (1) which starts at $t_0 \in [0, h]$ and has at least three zeros on $[t_0, a)$, then the corresponding solution of the difference equation (3) oscillates on $[t_0, a)$.

Consider now (2), or the equivalent system (9).

Theorem 2. Let p and q in (2) be Lipschitz on $[0, a]$. Then there exists $h_0 > 0$ such that for all $h \in (0, h_0]$, the following statement holds: every solution of (9) with the initial functions $\varphi, \psi \in C(0, h]$ satisfying (11) has oscillatory first component on $(0, a)$, provided that there exists $t_0 \in [0, h]$ such that the solution of (1) with the initial data $x(t_0) = \varphi(t_0), \dot{x}(t_0) = \psi(t_0)$ has at least three zeros on (t_0, a). The following theorem describes the relation between oscillation of the solutions of (1) and (7).

Theorem 3. Let p satisfy (5) and (6). Then there exists h_0 such that for all $h \in (0, h_0]$, the following assertion holds: if x_k^h is a solution of (7) which has at least three changes of sign on $(0, a)$, then the corresponding solution of the differential equation (2) oscillates on $(0, a)$.

References

1. R.P. Agarwal, M. Bohner, S.R. Grace, and D. O'Regan, Discrete Oscillation Theory, Hindawi Publishing Corporation, New York, 2005.

2. R.P. Agarwal, M. Bohner, T. Li, and C. Zhang, Oscillation of third-order nonlinear delay differential equations, Taiwanese J. Math. 17(2) (2013), pp. 545–558.

3. A.M. Ateiwi, Oscillatory properties of the solutions of differential equations and their stability. PhD thesis, Kyiv, 1997.

4. M. Bohner, O. Karpenko, O. Stanzhytskyi, Oscillation of solutions of second-order linear differential equations and corresponding difference equations, J. Difference Equ. Appl. 20(7) (2014), pp. 1112–1126.

5. M. Bohner and S.H. Saker, Oscillation of second order nonlinear dynamic equations on time scales, Rocky Mountain J. Math. 34(4) (2004), pp. 1239–1254.

6. B.M. Garay and K. Lee, Attractors under discretization with variable stepsize, Discrete Contin. Dyn. Syst. 13(3) (2005), pp. 827–841.

7. L. Gru¨ne, Asymptotic behavior of dynamical and control systems under perturbation and discretization, Lecture Notes in Mathematics, Vol. 1783, Springer-Verlag, Berlin, 2002.

8. L. Gru¨ne, Attraction rates, robustness, and discretization of attractors, SIAM J. Numer. Anal. 41(6) (2003), pp. 2096–2113 (electronic).

9. O. Karpenko and O. Stanzhytskyi, The relation between the existence of bounded solutions of differential equations and the corresponding difference equations, J. Difference Equ. Appl. 19(12) (2013), pp. 1967–1982.

10. W.G. Kelley and A.C. Peterson, Difference Equations: An Introduction with Applications, 2nd ed., Harcourt/Academic Press, San Diego, CA, 2001.

11. O. Ocalan, Oscillation of nonlinear difference equations with several coefficients, Commun. Math. Anal. 4(1) (2008), pp. 35–44.

12. M.A. Skalkina, On the oscillations of solutions of finite-difference equations, Izv. Vyssˇ. Ucˇebn. Zaved. Matematika 1959 (6(13)) (1959), pp. 138–144.

UDC 519.9

Oksana.I. Kovtun, Associate Professor
(National Aviation University, Ukraine, Kyiv)
Oleg.V. Pereguda, Associate Professor
(Taras Shevchenko National University of Kyiv, Ukraine, Kyiv)

RESEARCH OF THE COMPLETE ENERGY OF MECHANICAL SYSTEM UNDER RANDOM PERTURBATION

Behaviour of complete energy of the stochastic mechanical system is the subject of this investigation.

For today actual it remains in the problems of treatment of the signals of decision question of working to information with white noise.
In aviation industry this question decides after traditional approaches, so on the basis of stochastic equations of Iтo.
In the present paper, we investigate the behavior of the total energy in the case where fluctuations of the "white-noise" type in the Ito form act under a certain angle to the vector of phase velocity of system differential equations.

A mechanical system without friction is called the simplest conservative system with one degree of freedom if its motion is described by the following differential equation of the second order:

$$\ddot{u}(t) - f(u(t)) = 0, \quad u(0) = u_0, \quad \dot{u}(0) = \dot{u}_0, \tag{1}$$

Where u_0 and $\dot{u}_0$ are the initial position and the initial velocity of the system $\left(f^2(u_0) + \dot{u}_0^{\,2} > 0 \right)$, $u(t)$ and $\dot{u}(t)$ are the position and velocity of the system at time $t > 0$, $f(z)$ is a continuously differentiable function. [1].

Equation (1) is equivalent to the following system of differential equations of the first order:

$$\begin{cases} \dot{x}_1(t) = x_2(t), \\ \dot{x}_2(t) = f(x_1(t)), \end{cases} \quad x_1(0) = u_0, \quad x_2(0) = \dot{u}_0 . \tag{2}$$

In the Cartesian coordinate X_1OX_2, the state of the mechanical system at time $t > 0$ is represented by a point M with coordinates $(x_1(t), x_2(t))$ that moves along the phase trajectory (level lines of the total energy of the system), the phase velocity is represented by the vector $b(x(t)) = (x_2(t), f(x_{1(t))})$, $x(t) = (x_1(t), x_2(t))$, and the total energy of system (2) has the form

$$E(t)=\frac{x_2^2(t)}{2}-\int_0^{x_1(t)} f(z)dz .$$

It is known [2] that, under random perturbation, system (2) to replace by of the system stochastic differential Ito equations

$$dx(t)=a(t,x(t))dt+\sigma(t,x(t))dw(t) , \qquad (3)$$

where $w(t)$ is a one-dimensional Wiener process defined on the probability space (Ω, F, P), $a(t,x)=(a_1(t,x), a_2(t,x))$ are nonrandom vector functions, and

$\sigma_1(t,x)=g_1(t,x)x_2-g_2(t,x)f(x_1)$, $\quad \sigma_2(t,x)=g_1(t,x)f(x_1)+g_2(t,x)x_2$,

$x^0=(x_1^0, x_2^0)$, $\quad x_1^0=u_0$, $\quad x_2^0=\dot{u}_0$.

Consider an open domain $D\subseteq R^2$. assume that We also use

$I_1(t,x)=(b^{\perp}(x), a(t,x))+\frac{1}{2}\left[-f'(x_1)\sigma_1^2(t,x)+\sigma_2^2(t,x)\right]$,

$I_2(t,x)=(b^{\perp}(x), a(t,x))+\frac{1}{2}g_1^2(t,x)\left[-f'(x_1)x_2^2+f^2(x_1)\right]$,

$G(x)=\frac{x_2^2}{2}-\int_0^{x_1} f(z)dz$, $\quad (E(t)=G(x(t)))$,

$(\cdot,\cdot)$ is a scalar product, $\nabla G(x)=\left(G'_{x_1}(x), G'_{x_2}(x)\right)$.

Note that, the curve $G(x)=G(x^0)$, $x\in D$, are local phase trajectories of Eq. (2).

The function $G(x)$ is twice continuously differentiable. Therefore, according to the Ito formula for the process $G(x(t))$, where $x(t)$ is a solution of Eq.(3), the following equality holds with probability 1 for all $t\geq 0$:

$$E(t)=E(0)+\int_0^t \{(\nabla G(x(s)), a(s,x(s)))+\frac{1}{2}\left[G''_{x_1x_1}(x(s))\sigma_1^2(s,x(s))+\right.$$

$$\left.+2G''_{x_1x_2}(x(s))\sigma_1(s,x(s))\sigma_2(s,x(s))+G''_{x_2x_2}(x(s))\sigma_2^2(s,x(s))\right]\}ds+$$

$$\int_0^t (\nabla G(x(s)), \sigma(s,x(s)))dw(s)= E(0)+\int_0^t I_1(s,x(s)ds)+\int_0^t g_2(s,x(s))|b(x(s))|^2 dw(s) .$$

Equality (4) yields the following statements:

Theorem 1. If $g_2(t,x)=0$ in the domain $[0,\infty)\times D$, then the following inequality holds with probability 1:

$\int_0^{\tau_1} m(s)ds\leq E(\tau_t)-E(0)\leq \int_0^{\tau_t} M(s)ds$, where

$m(t) = \inf_{x \in D} I_2(t,x),\ M(t) = \sup_{x \in D} I_2(t,x)$.

Indeed, if $g_2(t,x) = 0$ in the domain $[0,\infty) \times D$, then equality (4) takes the following form for $t = \tau_t$: $E(\tau_1) - E(0) = \int_0^{\tau_1} I_2(s, x(s))ds$.

Theorem 2. Suppose that the following equalities hold in the domain $[0,\infty) \times D$:

(i) $g_2(t,x) = 0$;

(i) $I_2(t,x) = \alpha(t,x)G(x)$, where $\alpha(t,x)$ is a continuously differentiable function.

Then the following equalities holds with probability 1:

$$E(\tau_t) = E(0)\exp\left\{ \int_0^{\tau_t} \alpha(s, x(s))ds \right\}.$$

Corollary 1. With probability 1 the following assertions are true:

(a) *if* $\left| \int_0^t \alpha(s,x)ds \le C \right|$ in the domain $[0,\infty) \times D$, then $|E(t)| \le |E(0)| \exp\{C\}$ for all $t \ge 0$;

(b) *if* $\lim_{t\to\infty} \int_0^t \sup \alpha(s,x)ds = -\infty$ in the domain $[0,\infty) \times D$, then $E(t) \to 0$ as $t \to \infty$;

(c) *if* $\lim_{t\to\infty} \int_0^t \sup \alpha(s,x)ds = -\infty$ in the domain $[0,\infty) \times D$, then $E(t) \to 0$ as $t \to \infty$.

Theorem3. Suppose that, in Eq.(3), $g_i(t,x) = g_{i,}(x)$ $a_i(t,x) = \dot{a}_i(x)$, the functions $g_i(x)$ are continuously differentiable in domain D, and $\sigma_1^2(x) + \sigma_2^2(x) > 0$. Then there exists a function $G(x)$ twice continuously differentiable in the domain D and such that if the vector $a(x)$ satisfies the equality

$$(\nabla G(x), a(x)) + \frac{1}{2}\Big[G''_{x_1x_1}(x)\sigma_1^2(x) + 2G''_{x_1x_2}(x)\sigma_1(x)\sigma_2(x) + \\ + G''_{x_2x_2}(x)\sigma_2^2(x)] = 0\Big] \qquad (4)$$

in the domain D, then $G(x(t)) = G(x^0)$, $\forall t < \tau_D(x^0)$

Proof. The statement of Theorem 3 means that, for $x^0 \in D$, the curves $G(x(t)) = G(x^0)$ are locally invariant curves of Eq.(3). It is know [2] that, in order that there curves be locally invariant for all $x^0 \in D$, it is necessary and sufficient that equality (4)

$$(\nabla G(x), \sigma(x)) = 0 \qquad (5)$$

be true in the domain D. Equality (5) means that the function $G(x)$ is a local (in the domain D) general integral of the differential equation

$$-\sigma_2(x)dx_1 + \sigma_1(x)dx_2 = 0$$

i.e., this is an exact differential equation, i.e.,

$$G'_{x_1}(x) = -\sigma_2(x), \qquad G'_{x_2}(x) = -\sigma_1(x).$$

However, in this case, the equality

$$(-\sigma_2(x))'_{x_2} = (-\sigma_2(x))'_{x_1}$$

Must be true in the domain D. If this equality is true, then Theorem 3 is proved. If this equality is not true, then, as is known, under the condition $\sigma_1^2(x) + \sigma_2^2(x) > 0$ there exists an integrating factor $\mu(x) \neq 0$ continuously differentiable in the domain D and such that the equation

$$-\mu(x)\sigma_2(x)dx_1 + \mu(x)\sigma_1(x)dx_2 = 0 .$$

is an exact differential equation. Thus, there exists a twice continuously differentiable function $G(x)$ such that, in the domain D, we have $G'_{x_1}(x) = -\mu_2(x)\sigma_2(x),$ and $G'_{x_2}(x) = \mu(x)\sigma_1(x)$ and, hence, equality (9) is true. Theorem 3 is proved.

References

1. A.A.Andronov, A.A.Vit, and S.E. Khaikin, Oscillation Theory [in Russian], Nauka, Moscow(1981).
2. G.L. Kulinich and O.V. Pereguda, “Phase picture of the diffusion processes with the degenerate diffusion matrices,” Rand. Oper. Stochast. Equat., 5, No. 3, 203-216 (1997).
3. G.L Kulinich “Qualitative analysis of the influence of random perturbation on the phase velocity of the harmonic oscillator,” Rand. Oper. Stochast. Equat., **3,** No. 2, 141-152 (1995).
4. I.I. Gikhman and A.V. Skorohod, Stochastic Differential [in Russian], Naukova Dumka, Kiev (1968)

UDC 532.526

Yu. Krashanitsa, Dr. Tech. Sc.
(National Aerospace University "KHAI", Ukraine, Kharkiv)
Ye. Shkvar, Dr. Tech. Sc. (National Aviation University, Ukraine, Kyiv)
Peng Yue, postgraduate
(National Aerospace University "KHAI", Ukraine, Kharkiv)

MATHEMATICAL MODELS OF FLOW OF BODILY PROFILES LIMITED STATIONARY VISCOUS INCOMPRESSIBLE FLUID FLOW

On the basis of the apparatus of vector- tensor analysis summarizes integral representations of the solutions in the form of combinations of surface integrals of potential type not only the primary challenge of vector analysis for the surface vortices distribution and intensity used sources of mass, but also the full Navies - Stokes equation for flow past an arbitrary system threads bodily Profile viscous incompressible fluid flow and also near the interface.

Introduction

In the aerodynamics, problem of the increasing efficiency of the aircraft and transport associated with the theoretical and experimental studies of relevant aerodynamic characteristics, the rationale of existing and new principles of formation and management of forces, which should ensure that the technical and economic requirements for safe operation.

Implementation of such a merger will allow obtaining high values of fluidic characteristics defining, in combination with high speeds, the level of efficiency of vehicles; will contribute to the solution of some problems takeoff - landing aircraft stability, control and safety devices, moving in large and small distances from the boundary.

Research problem statement

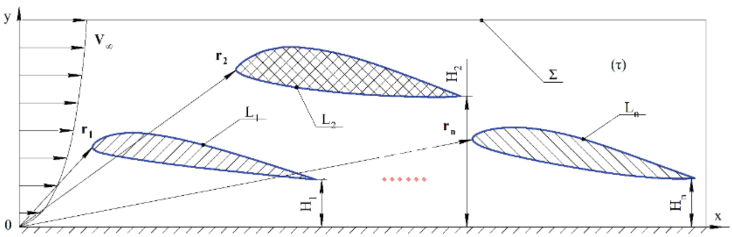


Fig. 1. System of the solid profiles at steady viscous flow near the partition surface, $L_1, L_2, ..., L_n$ – boundary of the profiles; Σ – boundary of the control volume; $H_1, H_2, ..., H_n$ – height of the profiles; $\mathbf{r_1}, \mathbf{r_2}, ..., \mathbf{r_n}$ – provisions vectors of the profiles; $\mathbf{V}_\infty$ – velocity vector or flowing around stream.

A solution to the problem of the study of flow of an arbitrary system of airfoils in the bodily form of a flat area (τ) the actual flow of an incompressible medium (Fig. 1). Due to the possible presence of a plane interface at takeoff / landing field flow velocity $\mathbf{V}_\infty$ is considered significant twist.

It must be emphasized that current research problem and sought after problems in continuum mechanics and, in particular, aerohydrodynamics, based on the development of functional devices [1] and vector-tensor analysis [2 – 4], which is fully exploited and effectively promotes numerical methods for solving the entire spectrum of tasks demanded aerohydromechanic. Application of Functional Analysis in fluid mechanics and gas due to reflection of the fact that in reality, it is usually impossible to measure the value of a physical quantity at the point, and it is possible to measure only the average values in a small neighborhood of the point. Thus, the technique of generalized functions is convenient and appropriate apparatus to describe the distributions of various physical quantities [1].

Boundary conditions in the flow problem of corporal airfoils in a bounded domain

It is known that the mathematical models of processes or phenomena in aerohydromechanic nonconductor environment are a complex system of differential conservation laws (1, 2) for steady flow of the viscous incompressible fluid and the initial and boundary conditions, due to the experimental observations [5, 6].

$$(\nabla,\mathbf{V})=0; \tag{1}$$

$$(\mathbf{V},\nabla)\mathbf{V}=-\frac{1}{\rho}\nabla p+\nu\Delta\mathbf{V}, \tag{2}$$

where, p – the internal hydrostatic pressure within the environment; ρ – density of the medium; $\nu=\frac{\mu}{\rho}$ – the kinematic viscosity coefficient, a μ – the dynamic viscosity coefficient.

Differential law of conservation of momentum (2) in the case of stationary traffic, nonconductor and incompressible medium can be written in conservative form:

$$\left(\nabla,\left(\mathbf{VV}+\mathbf{I}\frac{p}{\rho}+\nu[\mathbf{I},\mathbf{\Omega}]\right)\right)=0, \tag{3}$$

where $\mathbf{VV}$ – dyad and vortices in the plane case is calculated by the formula $\mathbf{\Omega}=[\nabla,\mathbf{V}]=\mathbf{k}\omega=\mathbf{k}\left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)$ [6].

When the boundary conditions for pressure p на Σ_0 and $\Sigma_{вер}$ (fig. 2) form:

$$p(x)=-\frac{2\nu\rho}{H^2}V_\infty x+p_\infty, \tag{4}$$

the boundary conditions for the velocity vector

$$\mathbf{V}\big|_{L_i}=\mathbf{0}, \tag{5}$$

and its components:

$$u\big|_{\Sigma} = \begin{cases} u\big|_{x=0,y\in(0,H)} = -\dfrac{2V_{\infty}}{H^2}\left(\dfrac{y^2}{2} - yH\right); u\big|_{y=0,x\in(0,\infty)} = 0; \\ u\big|_{y=H,x\in(0,\infty)} = V_{\infty}; \end{cases} \qquad v\big|_{\Sigma} = 0, \qquad (6)$$

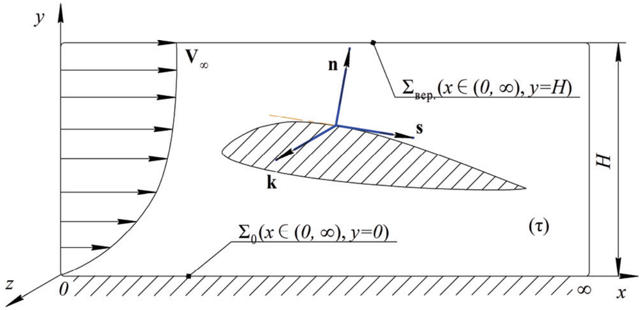


Fig. 2. The boundaries of the viscous medium.

In addition, there must highlight the classical fact that the velocity vectors **V** and vorticity **Ω** are addressing the major challenges of vector analysis [2 – 4]:

$$(\nabla, \mathbf{V}) = q; \ (\nabla, \mathbf{\Omega}) = 0, \qquad (7)$$

where q - the intensity of the possible sources / sinks of mass and energy parameters of mechanization.

The fundamental solution of the main problem of vector analysis

Classical Cauchy-Riemann conditions [2, 5] in vector forms:

$$\nabla\varphi = [\nabla, \mathbf{k}\psi]; \ \nabla\psi = -[\nabla, \mathbf{k}\varphi], \qquad (8)$$

where the functions φ and ψ – conjugate analytic functions – known Laplace equation [2, 5]:

$$\varphi = \frac{1}{2\pi}\ln|\mathbf{r} - \mathbf{r_0}|; \quad \psi = \frac{1}{2\pi}\operatorname{arctg}\frac{y - y_0}{x - x_0}. \qquad (9)$$

It follows that the tensor

$$\mathbf{\Gamma} = \mathbf{I}\varphi - [\mathbf{I}, \mathbf{k}\psi], \qquad (10)$$

is conservative and potential [2, 5]:

$$(\nabla, \mathbf{\Gamma}) = 0, \ \ [\nabla, \mathbf{\Gamma}] = 0. \qquad (11)$$

In addition, it can be argued that the tensor **Γ** is the fundamental solution of the differential operator of second order:

$$\nabla(\nabla, \mathbf{\Gamma}) = \Delta\mathbf{\Gamma} + [\nabla, [\nabla, \mathbf{\Gamma}]] = \mathbf{I}\Delta\varphi. \qquad (12)$$

Thus, the main problem for the vector analysis [2 – 4], represented in the form of second order:

$$\nabla(\nabla, \mathbf{V}) = \nabla q; \quad \nabla(\nabla, \mathbf{\Omega}) = 0, \qquad (13)$$

tensor **Γ** (10), by definition [1, 2], is a fundamental solution.

Integral representation of the solutions

Integral representations of solutions of boundary value problems of mathematical physics for differential equations, in this case, the second order are constructed by integrating the combination of operators (12), (13) for an arbitrary vector and with the necessary differential properties and tensor $\mathbf{\Gamma}$ field on (τ), using the classic process of allocating singular point, based on the known properties of the double layer potential $\frac{\partial \varphi}{\partial n}$ [1]:

$$\mathbf{a} = -\iint_{(\tau)} (\nabla q, \mathbf{\Gamma}) d\tau + \oint_{\Sigma L_i + \Sigma} \left\{ \left(\frac{\partial \mathbf{a}}{\partial n}, \mathbf{\Gamma} \right) + \left(\left[\mathbf{n}, [\nabla, \mathbf{a}] \right], \mathbf{\Gamma} \right) \right\} d(\sigma + 1) -$$

$$- \oint_{\Sigma L_i + \Sigma} \left(\mathbf{a}, \frac{\partial \mathbf{\Gamma}}{\partial n} \right) d(\sigma + 1). \tag{14}$$

In the simplest case of an incompressible heat-conducting fluid in the absence of mass sources in the area, we have the integral representation, for example, the velocity vector:

$$\mathbf{V} = \oint_{\Sigma L_i + \Sigma} \left\{ \left(\frac{\partial \mathbf{V}}{\partial n}, \mathbf{\Gamma} \right) + \left(\left[\mathbf{n}, [\nabla, \mathbf{V}] \right], \mathbf{\Gamma} \right) \right\} d(\sigma + 1) - \oint_{\Sigma L_i + \Sigma} \left(\mathbf{V}, \frac{\partial \mathbf{\Gamma}}{\partial n} \right) d(\sigma + 1), \tag{15}$$

Then the integral representation of the vorticity (15), with the basic formulas of vector-tensor analysis [2 – 4], has the form:

$$\mathbf{\Omega} = 2 \oint_{\Sigma L_i + \Sigma} \left(\left[\frac{\partial \mathbf{V}}{\partial s}, \nabla \psi \right] - \left[\frac{\partial^* \mathbf{V}}{\partial n}, \nabla \varphi \right] \right) d(\sigma + 1), \tag{16}$$

$$\omega = 2 \oint_{\Sigma L_i + \Sigma} \left(\left(\frac{\partial^* \mathbf{V}}{\partial n}, \nabla \psi \right) + \left(\frac{\partial \mathbf{V}}{\partial s}, \nabla \varphi \right) \right) d(\sigma + 1), \tag{17}$$

where $\mathbf{s} = [\mathbf{n}, \mathbf{k}]$ – tangent vector at the boundaries (fig. 2).

Expressions for determining the aerodynamic forces and moments

Building Formulas for determining vectors full aerodynamic force and moment [6], in our case based on the laws of conservation of momentum

$$\rho (\mathbf{V}, \nabla) \mathbf{V} + \nabla p - \mu (\nabla, \nabla) \mathbf{V} = 0, \tag{18}$$

and the angular momentum

$$\left[\mathbf{r}, \left\{ \rho (\mathbf{V}, \nabla) \mathbf{V} + \nabla p - \mu (\nabla, \nabla) \mathbf{V} \right\} \right] = 0. \tag{19}$$

Thus, by definition, complete the aerodynamic force acting on the solid surface of the previous expressions, we have

$$\mathbf{R}_i = \oint_{L_i} \left\{ \mathbf{n} p + \mu [\mathbf{n}, \mathbf{\Omega}] \right\} dl; \ \mathbf{M}_i = \oint_{L_i} \left[\mathbf{r}, \left\{ \mathbf{n} p + \mu [\mathbf{n}, \mathbf{\Omega}] \right\} \right] dl. \tag{20}$$

The coefficients of aerodynamic forces and moments on each individual profile calculated by the standard formulas [6]:

$$C_x = 2\frac{(\mathbf{i},\mathbf{R})}{\rho V^2 \pi ab}; C_y = 2\frac{(\mathbf{j},\mathbf{R})}{\rho V^2 \pi ab}; m_z = 2\frac{(\mathbf{k},\mathbf{M})}{\rho V^2 \pi bc} \tag{21}$$

Conclusions

Thus, a great practical and theoretical interest is the solution of the problem of flow studies bearing elements of aircraft, in order to determine the actual aerodynamic characteristics, as well as ways to optimize the processes of energy saving in the transport sector by means of mathematical modeling [7]. Besides the presented approach allows you to explore plausible physical processes of vortex formation in the vicinity of the carrier elements, their spatial interaction and influence on the aerodynamic characteristics of the aircraft.

References

1. *V.S. Vladimirov*. Equations of mathematical physics. - M.: Science, 1981. – 512 p.
2. *Yu. Krashanitsa*. Method of boundary integral equations for fluid applications. Saarbrücken, Germany: Lambert Academic Publishing, 2013. – 244 p.
3. *B. Pobedrya*. Lectures on Tensor Analysis. - M.: Publishing house MSU, 1979. – 223 p.
4. *Yu. Krashanitsa, Peng Yue.* Some generalizations of the operations of the vector-tensor analysis. K.: AATT (2/109), 2014. – P. 29 – 32.
5. *Yu. Krashanitsa, Peng Yue.* Integral representation of the solution of the problem of flow of bodily profiles restricted flow of a viscous medium. K.: AATT (3/110), 2014. – P. 63 – 69.
6. *L. Loytsyanskiy*. Mechanics of liquid and gas. M.: Science, 1970. – 904 p.
7. *Shkvar Ye.O., Kozlova T.V., Kravchenko V.V. & others.* Novel technologies of energy saving, based on methods of vortical structure control in turbulent flows / "Energy and Automation." – 2012. – № 2 (12). – P. 112-124. – Mode of access: www.nbuv.gov.ua/e-Journals/eia/2012_2/index.htm

UDC 532.526.4

V. Movchan, Dr. Phys.-Math. Sc. (National Aviation University, Ukraine, Kyiv),
Ye. Shkvar, Dr. Tech. Sc. (National Aviation University, Ukraine, Kyiv)

MATHEMATICAL MODELS OF TURBULENT VISCOSITY COEFFICIENT FOR WALL SHEAR FLOWS

The basic principles together with modern approaches and tendencies of mathematical modeling of turbulent wall shear flows are described, discussed and analyzed. Several perspective concepts of turbulent viscosity coefficient mathematical representation for both typical and special modeling cases, proposed and developed by authors are presented together with their advantages demonstrating.

Introduction

In the study of wide range of different environmental problems, the process of mathematical models constructing is based on physical model, which is creating with the use of available experimental results, obtained for the investigating class of problems. In this case it is necessary to correctly apply the process of schematization and idealization, consisting of taking into accounts only the most essential features and rejecting the minor ones. So any mathematical model is always simplification of the real more complicated situation and therefore the measure of simplification corresponds to different levels of approximations. For example, such unreal quantities as blocks frictionless, weightless non-stretching threads, inviscid fluid have been introduced in classical applied mathematics. These concepts are the abstractions and elements of idealization that was proposed by the authors of corresponding models. After schematization the procedure of the obtained result transferring into the language of mathematical concepts and values together with postulating correlations between the most significant properties is applying.

General concept of development of modern theoretical investigations is wide application of mathematical modeling methodology in analysis and getting the solution of problems, important for different spheres of practical activity together with assessment of consequences and influences of this activity on the environment.

In the process of mathematical models constructing the methods of similarity and dimensionality have received considerable applicability.

Mathematical model of the process, phenomenon, object is a mathematical scheme that reproduces, imitates, reflects the principles of their functioning, certain properties and features and can replace them in the cognitive process in order to obtain new or extend the existing knowledge.

Any mathematical model has two components: mathematical and problematic, based on a specific science whose problem is the subject of studying.

Although the mathematical model due to simplification, idealization is not identical to studying phenomenon or process, but this replacement allows to formulate the considering problem as mathematical one and use a universal mathematical methodology for its investigating.

Mathematics gives the possibility to describe a wide range of facts and results of observations, make their detailed qualitative and quantitative analysis, predict forming the analyzing process under different conditions and thus forecast the results of its development. Forecasting is an important and difficult task and predictions that come true are particularly valuable.

The most of practically interesting processes are so complex that even now it is rarely possible to create their universal models, which are valid throughout the whole period of time and at all stages of the process development. Therefore, using the results of experiments or observations it is important to distinguish correctly the dominating factors that influence and control the process development at the considering stage or during a given period of time. Their correct selection allows to reject less significant factors for the actual set of conditions and build on this base the corresponding mathematical model.

The most difficult situation occurs when our knowledge of the phenomenon is not enough. In this case the construction of a mathematical model requires making some additional assumptions, which are treated as hypotheses. The conclusions obtained with the use of hypothetical models application are arbitrary. They are correct in so far as valid assumption. For their verification it is necessary to compare the results obtained on the base of the proposed model with all available information concerning the phenomenon. The level of agreement between calculated and experimental results indicates whether the hypothetical model together with accepted assumptions are qualitative or false.

Turbulence is one of the most complicated natural phenomena. First quantitative description of turbulent motion was given by O. Reynolds. According to his suggestion, the values of all the hydrodynamic variables can be presented as a sum of averaged (regular) and pulsating (irregular) components and then study the averaged flow properties. Pulsating components greatly intensify the process of moving media mixing. Turbulent mixing is a reason of significant increase of resistance in pipe flow, flows around buildings, aircrafts, missiles, ships, cars, etc. and energy losses in turbines or compressors. Growth frictional resistance in turbulent motion is equivalent to increase of the viscosity coefficient from ten till thousand or even more times.

The first significant progress on the way of building a model representation of the turbulent exchange coefficients, as it is well known, was implementation of Prandtl idea (1925) on their ability to be determined by local characteristics of the shear flow. Later this model been improved by a lot of authors for the purpose of correct reproduction of turbulent flow structure. The first author of this paper, V. Movchan, has proposed the following basic universal form model of turbulent viscosity coefficient ν_t [1]:

$$\nu_t = \nu_{tout} \tanh \frac{\nu_{tin}}{\nu_{tout}}, \qquad (1)$$

where ν_{tout}, ν_{tin} – values of ν_t in external and internal regions respectively.

Depending on the applied methods of ν_{tout} and ν_{tin} mathematical description the corresponding model for ν_t can have algebraic or differential structure.

Basic algebraic model can be presented by the following modified form of (1):

$$\nu_t = \gamma \nu_{tout} \tanh\frac{\nu_{tin}}{\nu_{tout}},$$

where γ – intermittency factor. Internal region has the following structure of its mathematical description: $\nu_{t\ in} = lD_m$, $l = \kappa y \sqrt{\tau^+} \upsilon_*$,

$$D_m = \tanh\frac{\sinh^2[\kappa_0 y^+(1+\kappa_3 \,|\, y^+ - 30 \,|)\sqrt{\tau^+}\,] \tanh[\sinh^2(\kappa_2 y^+ \sqrt{\tau^+})]}{\kappa y^+ \sqrt{\tau^+}}.$$

Linearization of the argument of the function $\sinh^2[\kappa_0 y^+(1+\kappa_3 \,|\, y^+ - 30 \,|)\sqrt{\tau^+}\,]$ transforms the damping factor D_m to the following simplified form:

$$D_m = \tanh\frac{\sinh^2(\kappa_1 y^+ \sqrt{\tau^+}) \tanh[\sinh^2(\kappa_2 y^+ \sqrt{\tau^+})]}{\kappa y^+ \sqrt{\tau^+}}$$

that allows to obtain the approximate-analytical solutions for velocity profile within viscous and buffer sublayers of boundary layer.

External region can in frames of algebraic level of modeling be presented by the formula $\nu_{tout} = \chi U_H \delta^*$, $\chi = 0.0168$.

Here and above κ_0, κ_1, κ_2, κ_3, κ, χ – model coefficients; $y^+ = y\upsilon_*/\nu$ – normal to wall coordinate y, dimensionless according to wall law; ν – kinematic viscosity coefficient; $\upsilon_* = \sqrt{\tau_w/\rho}$ – shear velocity; $\tau^+ = \tau/\tau_w$ – dimensionless shear stress by its value on a wall τ_w, that depends on pressure gradient parameter $p^+ = \dfrac{\nu}{\rho\upsilon_*^3}\dfrac{dp}{dx}$ as follows: $\tau^+ = 1 + p^+ y^+$ for $p^+ \ge 0$ and $\tau^+ = (1 - p^+ y^+)^{-1}$ for $p^+ < 0$; p – averaged pressure; ρ – density; U_H – velocity on the external free boundary of a wall shear flow; δ^* – displacement thickness, using as a linear scale in external region of boundary layer.

Modeling of near-wall effects of control. In case of necessity to account the influences of micro-riffling and/or polymeric additives that, despite on different physical mechanism, have similar effect of velocity profile shifting in semilogarithmic coordinates. As it has been shown by Ye. Shkvar, effective results in frames of Movchan's turbulence model can be found on the base of generalization and implementation of I. Rotta approach for roughness accounting. This approach requires modifying the normal coordinate y^+ into y_1^+ in the following way: $y_1^+ = 0$ for $s \le 0$ and $y_1^+ = s$ for $s > 0$, where $s = y^+ + \Delta y^+_{rough} - \Delta y^+_{pol}$; Δy^+_{rough} – generalized parameter, accounting both irregular and regular roughness influence; Δy^{+}_{pol} – additional parameter that similarly to previous one describes the influence of polymeric additives injecting in near-wall region of a water boundary layer. Fig. 1 illustrates the comparison between experimental (circles) and calculated (lines) laws of friction for rough pipe flow $\lambda(\mathrm{Re})$, $\mathrm{Re} = UD/\nu$ for different values of relative parameter R/h, R – pipe radius; $D = 2R$, h – roughness height.

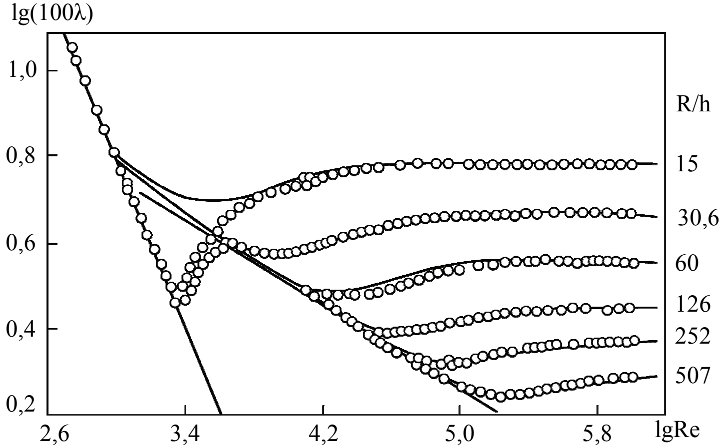


Fig. 1. Law of friction for rough pipe flow $\lambda(\mathrm{Re})$

Modified algebraic model of turbulent viscosity. This modification effectively combines the described above set of dependencies for internal region ν_{tin} together with well known and popular in turbomachinery Baldwin-Lomax approach for external region ν_{tout}, namely:

$$\nu_{t\ out} = \chi C_{cp} F_{wake}\,;\ C_{cp} = 1.6\,;\ F_{wake} = \min\left(y_{max} F_{max}; C_{wk} y_{max} \Delta U^2 / F_{max}\right);$$

$$C_{wk} = 0.25\,;\ \Delta U = |U_{max}| - |U_{min}|\,;\ \gamma = F_{Kleb} = \left[1 + 5.5\left(C_{Kleb} y / y_{max}\right)^6\right]^{-1};$$

$$C_{Kleb} = 0.3\,;\ F(y) = y\left|\frac{\partial u}{\partial y} + \frac{\partial \upsilon}{\partial x}\right| D_m\,;\ F_{max} = \max\left[F(y)\right];\ \ y_{max} = y(F_{max})\,.$$

The results of comparison of experimental data for distributions of friction coefficient $C_f(x)$, momentum thickness $\delta^{**}(x)$, formfactor $H(x) = \delta^{*}(x)/\delta^{**}(x)$, obtained by H. Moses (id. 3800 – Fig. 2) H. Ludwieg & W. Tillmann (id 1100 – Fig. 3) for nonequilibrium flows, forming under adverse pressure gradient, with corresponding numerical predictions, made by Ye. Shkvar by using the basic (smooth lines) and modified (dashed lines) variants of algebraic models, demonstrate good level of agreement in general.

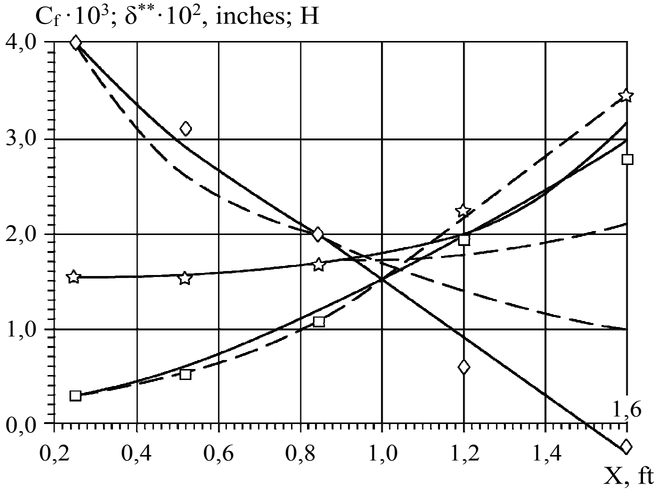


Fig. 2. Comparison of flow parameters numerical predictions and corresponding H. Moses experimental data (id. 3800): $C_f(x)$ – rhombs, $\delta^{**}(x)$ – squares, $H(x)$ - stars

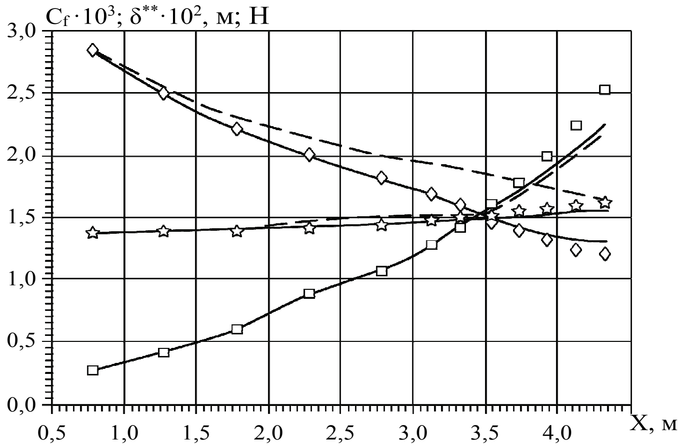


Fig. 3. Comparison of flow parameters predictions and H. Ludwieg & W. Tillmann experimental data (id. 1100): $C_f(x)$ – rhombs, $\delta^{**}(x)$ – squares, $H(x)$ - stars

Hybrid algebraic – one-parametric differential model of turbulence. This is the next step of turbulence models elaboration, joining both algebraic and differential approaches for internal and external regions respectively. The turbulent viscosity coefficient is presented as a function of kinetic energy of turbulence k: $\nu_{t\ out} = \chi_k \Delta \sqrt{k}$. This approach requires for determination of k solving the corresponding transport partial differential equation, that makes it more universal and exact for wider range of modeled types of boundary layers. Here $\Delta = U_H \delta^* / \upsilon_*$. Comparison of calculated values of dimensionless turbulent viscosity coefficient $\nu_t / \delta\upsilon_*$, obtained on the base of this level of modelling for $\Delta/\delta = 3{,}875$, $\chi_k = 0{,}0085$ (smooth line) and Klebanov's (circles) and Townsend's (crosses) experimental data (Fig. 4) demonstrates a good correlation. Here δ – boundary layer thickness.

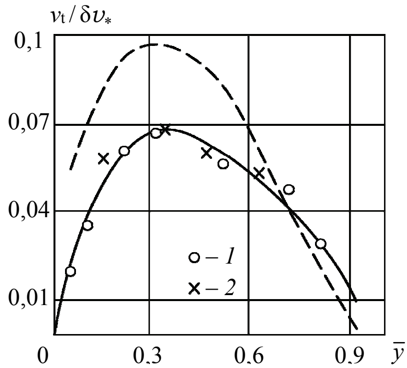


Fig.4. Turbulent viscosity coefficient distribution

Hybrid algebraic – two-parametric differential model of turbulence. Here we demonstrate one more modification of basic turbulent viscosity mathematical description (1) for external region – two-parametric $k-\varepsilon$ approach: $\nu_{t out} = C_\mu k^2/\varepsilon$, $C_\mu = 0{,}09$, where ε – dissipation rate of k. Simplification and adopting of the constructed model for internal region allows to determine the profiles $k(y)$, $\varepsilon(y)$ and Reynolds stresses $\tau(y)$. For viscous and buffer sublayers these distributions in dimensionless form have the following structures:

$$\bar{k} = \frac{k}{\upsilon_*^2 \tau^+} = \frac{1}{C_0} \tanh(\kappa_1 y^+ \sqrt{\tau^+}) \sqrt{\tanh[\sinh^2(\kappa_2 y^+ \sqrt{\tau^+})]};$$

$$C_0 = 0{,}16[1 + \tanh(0{,}13 y^+ \sqrt{\tau^+})];\ k^+ = \frac{y\sqrt{k}}{\nu};$$

$$\bar{\varepsilon} = \frac{\varepsilon\nu}{\upsilon_*^4 \tau^{+2}} = \frac{\tanh^2(\kappa_{11}\sqrt{k^+})}{\cosh^2(\kappa_{11}\sqrt{k^+})} \tanh[\sinh^2(\kappa_{22}\sqrt{k^+})] + D_\varepsilon;$$

$$D_\varepsilon = 0{,}0316 \frac{\bar{k} D_0}{k^+};\ D_0 = 1 - \tanh[0{,}5\sqrt{k^+}(\sqrt{k^+} - 4{,}3)];$$

$$\bar{\tau} = \frac{-\overline{u'\upsilon'}}{\upsilon_*^2 \tau^+} = \tanh^2(\kappa_{11}\sqrt{k^+}) \tanh[\sinh^2(\kappa_{21}\sqrt{k^+})].$$

In logarithmic zone the corresponding dependencies have simpler structures:

$$\overline{k} \cong 1/C_0\ ;\ \overline{\varepsilon} = 1/(\kappa_{01}k^+)\ ; \quad \overline{\tau} \cong 1\ ,$$

where κ_{01}, κ_{11}, κ_{21}, κ_{22} – model coefficients.

Figures 5-8 illustrate good enough agreement of calculated distributions of k, ε and $\overline{\tau}$ in the internal region (continuous lines) in comparison with experimental results (symbols) and approximations of different authors (lines).

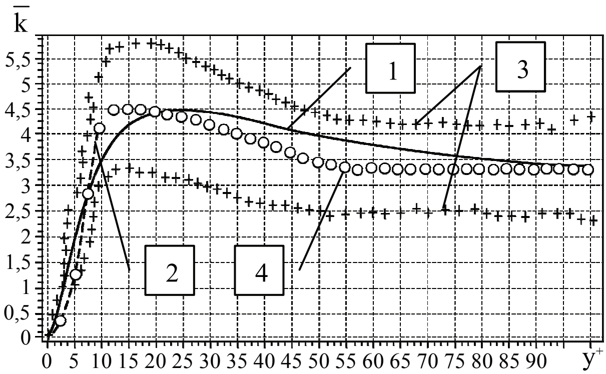


Fig. 5. Distribution of $\overline{k}(y^+)$ in the vicinity of a wall: 1 – predictions by the authors approach; 2 – approximation $\overline{k} = 0{,}05(y^+)^2$; 3 – D. Coles experimental data (1978); 4 – *Patel*, *Rodi* and Scheuerer experimental data (1985)

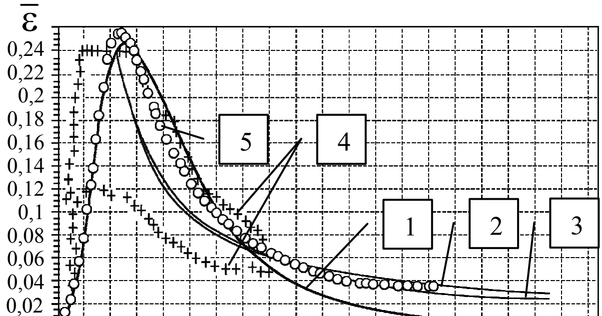


Fig. 6. Distribution of $\overline{\varepsilon}(y^+)$ in the vicinity of a wall: 1 – predictions by the authors approach; 2 – approximation $\overline{\varepsilon} = 1/(\kappa_{01}k^+)$; 3 – approximation $\overline{\varepsilon} = 1/(\kappa y^+)$; 4 – D. Coles experimental data; 5 – J. Laufer experimental data

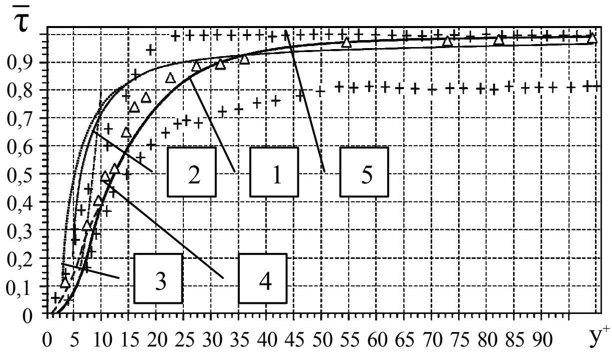


Fig. 7. Distribution of $\overline{\tau}(y^+)$ in the vicinity of a wall: 1 – predictions by the authors approach; 2 – approximation $\overline{\tau} = 1 - 1/(k_0 y^+)$; 3 – approximation $\overline{\tau} = 1 - 1/(\kappa_{01} k^+)$; 4 – P. Abbrecht experimental data; 5 – D. Coles experimental data

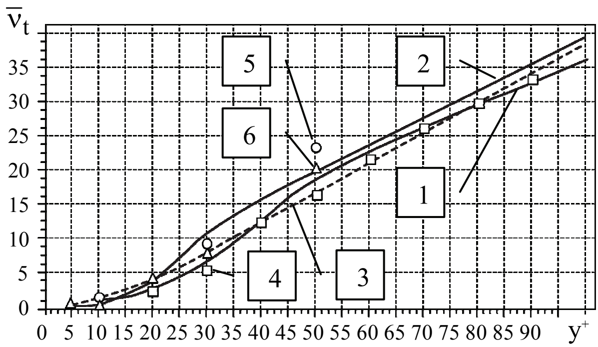


Fig. 8. Distribution of $\overline{\nu}_t(y^+)$ in the vicinity of a wall: 1 – predictions by the proposed hybrid algebraic – one-parametric differential model of turbulence; 2 – predictions by the Movchan's basic algebraic model of turbulence; 3 – predictions by the Van-Driest damping function; 4 – G. Shubauer experimental data; 5 – J. Laufer experimental data; 6 – P. Abbrecht experimental data

Conclusions

The proposed family of different-level approaches for semiempirical turbulence modeling demonstrated the correctness of the applied hypotheses and flexibility for wide range of wall shear flows types.

References

1. Mathematical models of near-wall turbulence / M.S. Kulik, V.T. Movchan, Ye.O. Shkvar // – Kyiv: NAU, 2012. – 356 p.

UDC 519.6

S.V. Choporov, Ph.D., A.O. Lisnyak, Ph.D.
(Zaporizhzhya National University, Ukraine, Zaporizhzhya),
D.V. Akimov
(Yuzhnoye State Design Office, Ukraine, Dniepropetrovsk)

DISCRETE MODELS GENERATION FOR LAYERED SHELLS OF A SPACECRAFT

The report describes the problem of discrete models generation for layered shells of spacecrafts. In obtained discrete models layers of finite elements correspond to layers of shell material. Proposed in the report technique explicitly model the discontinuous nature of the material.

Composite materials (composites) and layered materials are one of the great technological advances of a modern engineering. By the term layered materials we usually refer to materials that are combinations of two or more organic or inorganic layers. Layered materials allow to optimize some physical and mechanical properties of constructions. Layered shells are widely used in spacecraft's engineering.

In computational and numerical analysis of solids, two main approaches have been adopted to simulate layered materials [1]:

1) techniques which explicitly model the discontinuous nature of the material;

2) techniques which use equivalent continuum model of the material.

The first approach includes the Discontinuous Deformation (Displacement) Analysis (DDA) [2] and the Discrete Element Method (DEM) [3,4]. The Finite Element Method (FEM) or the Finite Difference Method (FDM), which utilize layers topology, interfaces or contact technology, also included in the first approach. The Discontinuous Deformation Analysis and the Discrete Element Method are common used in rock mechanics, simulation of granular materials and the micro-dynamics of powder flows. These techniques provide a more accurate description of layered material nature. However, they are complex. The FEM based software requires meshes which elements topology correspond to material's layers topology.

The second approach includes the FEM and FDM equivalent continuum model. In the equivalent continuum technique the discrete material is replaced by a homogeneous continuum. E.g., in Cosserat theory, one of the mathematical models describing the mechanics of general micropolar continua, each point of the continuum is associated with independent rotational degrees of freedom in addition to translational degrees of freedom. The basic kinematics variables of Cosserat theory are the displacements, the first-order displacement gradients, the microstructural rotations, and the rotation gradients. Higher-order displacement gradients are not considered [1]. However, in general case for complex solids implementation of this approach is hard.

Thus, the aim of the present report is to develop approach for finite elements meshes generation. Obtained meshes should approximate layers borders by finite elements edges (or faces in 3D case).

The FEM-simulation of spacecrafts layered shells includes five steps (fig. 1).

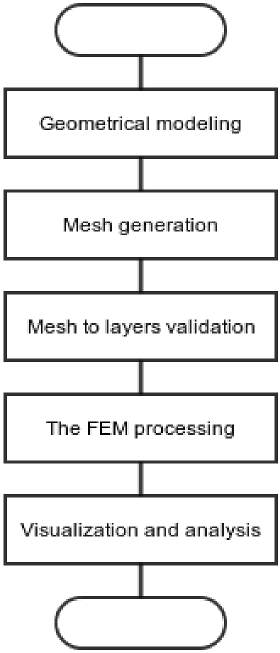


Fig. 1. Layered solids simulation flowchart

1. Geometrical modeling of a solid. One from representation schemes [5] is used for geometrical modeling. Boundary representation, Constructive Solid Geometry (CSG) and functional representation are commonly used to represent geometrical object in computer.

2. Mesh generation is a process of a geometrical object discretization into user-defined shape finite elements. Triangles (tetrahedra in 3D) and quadrilaterals (quadrilaterally-faced hexahedra in 3D) are commonly used types of finite elements. Obtained on this step meshes are block-structured or unstructured.

3. Mesh to layers validation is a process of refinement. We can use correction of a node position or element subdivision techniques for layers boundaries approximation by finite elements edges (faces in 3D).

4. The FEM processor should use for each layer corresponded mechanical constants. Corresponding between material layers and finite elements layers is obtained on third step.

5. In the final, obtained displacements (deformations) or stresses are visualized and processed.

Developed during the research approaches are used in software for computer-aided modeling (CAM). For this software developed domain specific language

(DSL) for geometrical modeling of layered solids.

E.g., fig. 2, layered discrete models of the front and back frame of the spacecraft's module. Finite elements layers correspond to material layers.

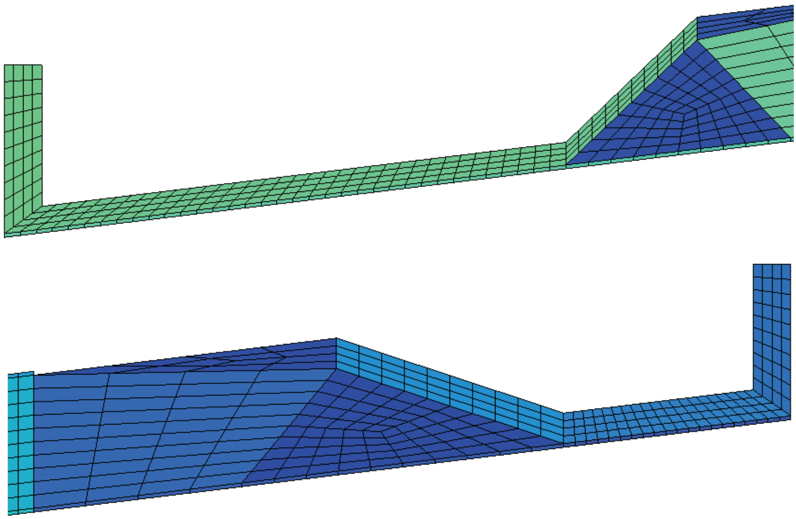


Fig. 2. Finite elements layers

Three-dimensional discrete model of spacecraft module can obtained by rotation of 2D-mesh:

$$\lfloor x_{ij} \quad y_{ij} \quad z_{ij} \rfloor = \lfloor h + x_i \quad (k + y_i)\cos\varphi_j \quad (k + y_i)\sin\varphi_j \rfloor,$$

$$\varphi_j = \frac{2\pi j}{M}, 1 \le i \le N, 0 \le j \le M,$$

where N – nodes count; (x_i, y_i) – 2D-mesh node coordinates; M – elements layers count in rotation body model; (h,k) – initial coordinates for rotation (translation). E.g., fig. 3 presents rotation of discrete 2D-model of the spacecraft's module.

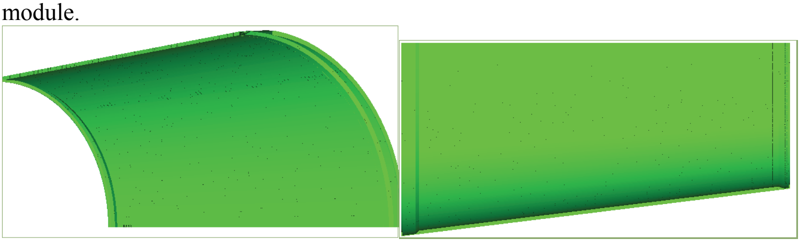


Fig. 3. Spacecraft's module model

Thus, this approach process layered shell of spacecrafts as a three-dimensional solid. Such approach requires a lot of computer resources because obtained models have big number of finite elements. However, it allows to build models of shells with complex topology of layers.

References

1. Riahi A. Full 3D finite element Cosserat formulation with application in layered structures / A. Riahi, J.H. Curran // Applied Mathematical Modelling. – 2009. – 33. – P. 3450-3464.

2. MacLaughlin M.M. Review of validation of the discontinuous deformation analysis (DDA) method. / M.M. MacLaughlin, D.M. Doolin // International Journal for Numerical and Analytical Methods in Geomechanics. – 2006. – Volume 30, Issue 4. – P. 271-305.

3. Pande G.N. Numerical methods in rock mechanics / G.N. Pande, G. Beer, J.R. Williams. – Chichester: Wiley, 1990. – 327 p.

4. Williams J.R. Discrete element simulation and the contact problem / J.R. Williams, R. O'Connor // Archives of Computational Methods in Engineering. – 1999. – Volume 6, Issue 4. – P. 279-304.

5. Requicha A.G. Representations for Rigid Solids: Theory, Methods, and Systems / Ari G. Requicha // Computing Surveys. – 1980. – Volume 12, Issue 4. – P. 437-464.

UDC 539.3

V.Z. Gristchak, D.Sc., S.I. Gomeniuk, D.Sc., S.N. Grebeniuk, Ph.D.
(Zaporizhzhya National University, Ukraine, Zaporizhzhya)
I.F. Larionov, P.G. Degtiarenko, V.N. Sirenko, D.V. Akimov
(Yuzhnoye State Design Office, Ukraine, Dniepropetrovsk)

AN INVESTIGATION OF A SPACECRAFT'S PROPELLANT TANK'S SHELL'S BEARING STRENGTH

This report describes an approach for numerical simulation of nonlinear stress-strain state for the propellant tank's shell of the spacecraft. The finite element method was used in computer simulation, basing on 3D shell model.

Modern software is commonly used for numerical simulation of constructions, engines, shells, etc. The report describes how to use CAE-software «MIRELA+» [1] and FORTU [2] for numerical simulation of the propellant tank. These software are based on the finite element method (FEM). CAE «MIRELA+» uses the moment finite-element scheme [3]. The propellant tank has two pieces and stringers (fig. 1). The propellant tank used under internal pressure. Internal pressure can break the tank. An experimental value of ultimate tensile strength was obtained. However, an experimental investigation is very complex and too much expensive. Thus, development of CAE-software for tensile strength is urgent.

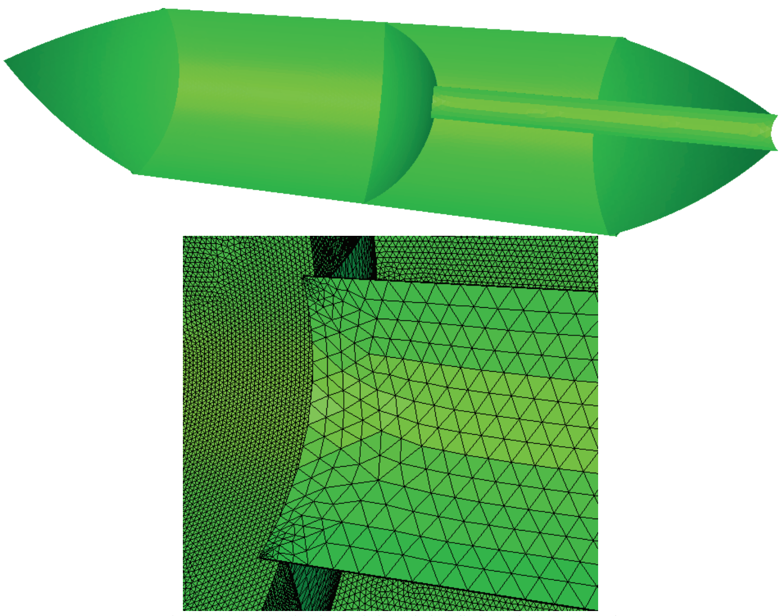


Fig. 1. Geometrical model and the finite-element mesh

Stress-strain state of the propellant tank is nonlinear. Thus, the nonlinear stressing process should be simulated. Figure 2 shows the non-linear stress-strain curve for dilatation of the material. Deformations model development for nonlinear stress-strain state is urgent problem. Consider a solution of this problem as combination of linear solutions with dynamic moduli (mechanical properties dynamically change during deformation process). The elastic modulus is function of deformation speed. The value of elastic modulus can be obtained using the stress-strain curve in iterative process of stressing (fig. 2). Suppose the Poisson's ratio is 0,3.

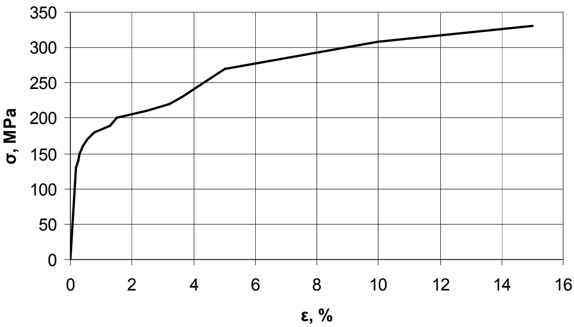


Fig. 2. The stress-strain curve

Ultimate tensile strength of the shell is 340 Mpa. If stress value is greater than tensile strength then the propellant tank damaged.

Obtained in FEM-numerical simulation values of tensile strength by CAE «MIRELA+» and by CAE FORTU are corresponded with experimental results. Stress-strain state of the propellant tank is plotted with a gray-scale map (fig. 3).

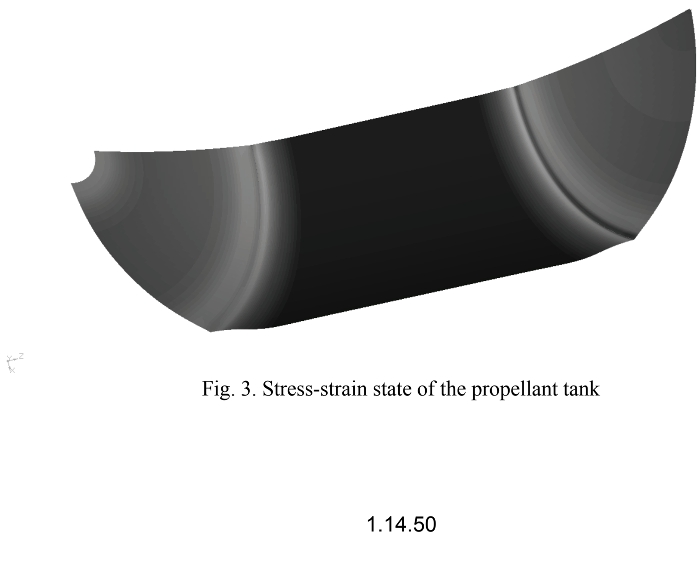


Fig. 3. Stress-strain state of the propellant tank

Thus, CAE «MIRELA+» and by CAE FORTU allow FEM simulation of spacecraft's stress-strain state. Obtained by «MIRELA+» and by FORTU tensile strength value placed on a cylindrical part of the shell.

References

1. Метод конечных элементов в вычислительном комплексе «МІРЕЛА+». Киричевский В.В., Дохняк Б.М., Козуб Ю.Г., Гоменюк С.И., Киричевский Р.В., Гребенюк С.Н. – К.: Наук. думка, 2005. – 392 с.

2. Гоменюк С.И. Объектно-ориентированные модели и методы анализа механических процессов. – Никополь: Никопольская коммунальная типография, 2004. – 316 с.

3. Киричевский В.В. Метод конечных элементов в механике эластомеров. – К.: Наук. думка, 2002. – 655 с.

CONGRESS SECRETARIAT
National Aviation University,
1, Kosmonavta Komarova ave.,
Kyiv, 03058, Ukraine
Tel: +380 44 406-71-56
Fax: +380 44 406-79-21
e-mail: congress@nau.edu.ua
www.congress.nau.edu.ua