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

"Safety in Aviation and Space Technologies"

Volume 1

September 21-23, 2010
Kyiv, Ukraine

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UDC 629.7.03:620.178.3(045)

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INFLUENCE OF THE METAL SAMPLES SURFACE MECHANICAL TREATMENT ON THEIR FATIGUE STRENGTH

This article includes results of analysis of mechanical treatment influence on fatigue strength property value, made based on data, found during metal samples trial.

Statistics and analysis of details and units of operating equipment service fractures show that more than 70-80% of them are caused by the influence of cyclic or cyclic and static stresses. In this conditions special meaning takes correct determination of fatigue resistance characteristics of already used and new materials, considering operating peculiarities of originating constructions. Unfortunately, under analysis and comparison of results of one and the same materials fatigue strength trial, published in periodical press, at times significant difference of fatigue data, found in the same trial conditions, becomes apparent. Found difference in many cases is caused, first of all, by statistic nature of trial material properties and by trial method peculiarities. However, one of its primary reasons relates to the samples or details production techniques and to the stress state formed at that in their surface layers. In this connection there is an urgent need of in-depth fatigue strength study of the samples, subjected to different modes of their surface finish treatment with different tools usage, as one of the most important reason of obtained results potential divergence.

Everybody knows, that residual stresses, emergent during mechanical treatment (cutting, abrasion, polishing) have significant influence on deformation and breaking material resistance. It is determined that during lathe turning with the fine cutting feeds in the surface layer residual compression stresses can emerge, and with the coarse feeds – considerable residual pulling stresses. In this connection, using favorable residual stresses in the surface layers, it is possible to significantly improve the breaking resistance; at the same time adverse factors, related to residual stresses, usually, lead to sharp decrement of breaking resistance. In that way, residual detail macrostresses at their rational distribution in the surface layers represent considerable reserve of the structural strength improvement. Nevertheless, studies of residual stresses influence, their distribution and resistance at construction materials cyclic load, are unfortunately, insufficient.

Due to the absence of recommendations, directed on samples production technique optimization for fatigue trials, there is a need to study its influence on obtained characteristics of construction materials fatigue strength. This work includes trial results of different mechanical treatment methods influence on residual stresses distribution and fatigue strength characteristics of samples made of foundry heatproof alloy EP539LM, used in transport GTE turbines working blades production. In their production common lathe turning equipment and standard tools were used.

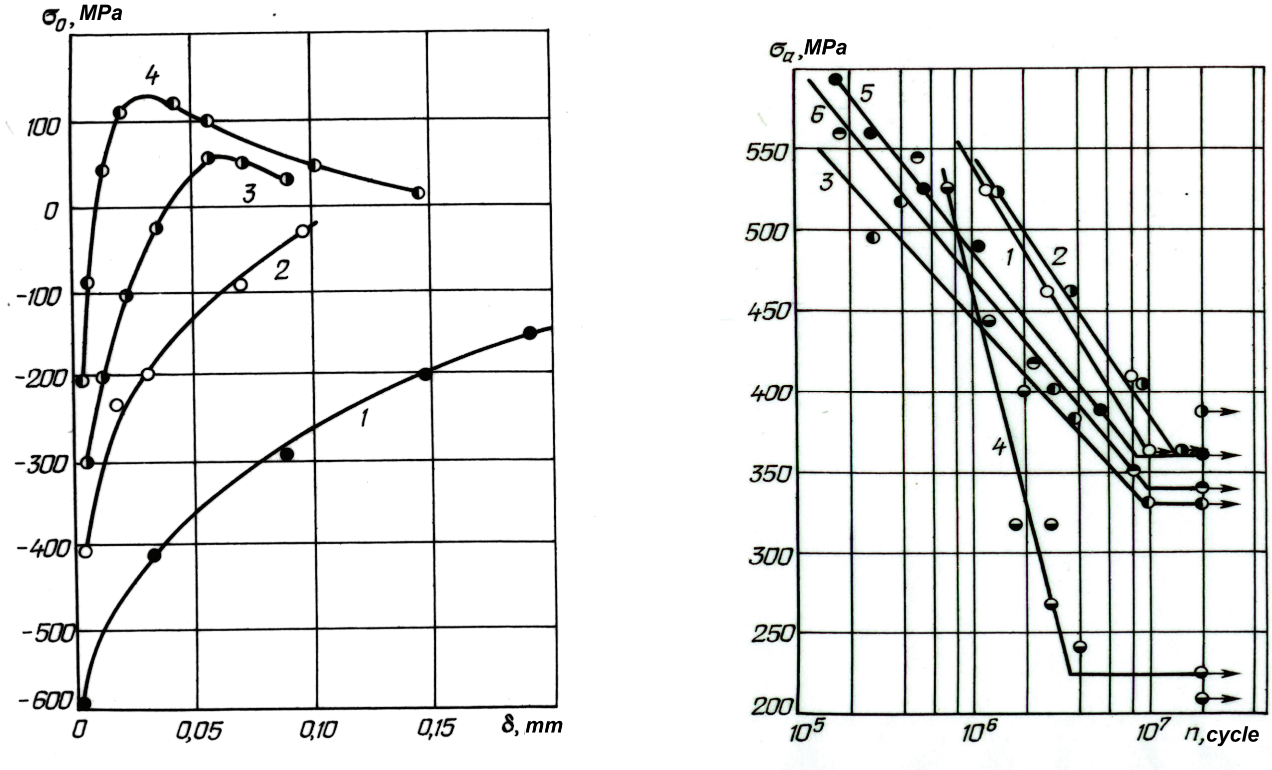
Samples for residual stresses and fatigue strength trial were produced of the same founding. Founded by investment patterns raw stocks of the samples were subjected to thermal treatment by the following mode: heating to 1343 K, 3-3.5-hour conditioning in argon, cooling to 973 K for 30 min. by the air blow-off with subsequent air cooling to ambient temperature. Accepted modes of every party samples surface finish treatment ensured different stress state of their surface layer with the same surface cleanness.

Finishing technique of the samples' working section after lathe turning to the final state included:

– for the first party – abrasion with abrasive papers;
– for the second party – abrasion with diamond disk and abrasive papers;

– for the third party – abrasion with SM-25 disk;
– for the fourth party – abrasion with EP disk and abrasive papers.

One-third of the fourth party samples (party 4^b) was subjected to annealing by the following mode: air heating to 1173 K, 4-hour conditioning. The second third of the fourth party samples (party 4^c) was subjected to annealing by the same mode, but in vacuum. Other fourth party samples (party 4^a) were not subjected to annealing.



a *b*

Fig. 1. Residual stresses' epures:
a – in the sample surface layer; *b* – alloy fatigue curves.

Results of residual stresses' trial, obtained in the samples working section by different methods of mechanical treatment and determined by mechanical method at circular layer-by-layer etch removal of the surface layers, are shown in the form of epures in Fig.1,a. Every curve of the stress distribution through the surface layer depth was build by the trial data of three samples. There were determined residual stresses of the first order.

As is evident from the figure, due to mechanical treatment considerable residual stresses emerge only in the thin surface layer.

Treatment of the first and the second party samples with lathe turning tool or diamond disk, due to the high diamond tool cutting capacity and its heat-transmission capacity, leads to that heating influence on residual stresses decreases, and the role of plastic deformation increases, causing in the sample surface layer residual compression stresses (curves 1, 2, see Fig.1,a).

Abrasion with EP disk of the fourth party samples (4^a) causes localized overheatings in the surface layer, and as a consequence, considerable thermotensions after the sample cooling, in which connection in the surface layer rather high residual pulling stresses are formed (curve 4). Somewhat smaller residual stresses emerge in the surface layer of samples after their treatment with SM-25 abrasive disk of the third party (curve 3).

In the samples of party 4^b and 4^c residual stresses were not found. As far as the samples of party 4^b were annealed outdoors and their working section was oxidized, it was again treated to needed roughness with abrasive paper.

Fatigue trial of samples was conducted on the UKI-type device at the temperature of 293 K and frequency of 50 Hz in conditions of pure circular bend.

Fatigue curve position (Fig.1,b) distinctively corresponds with the character of residual stresses' epures.

The most fatigue strength belongs to the first and the second party samples (curves 1 and 2) that have in the surface layer residual compression stresses, formed during lathe turning of their working section or its abrasion with diamond disk.

At the same time, in the surface layer of party 4^a samples (curve 4) rather high residual pulling stresses took place, in connection with what their fatigue endurance limit is in 1.5-1.6 times lower than of the other sample parties. Smaller decrease of fatigue endurance limit of the third party samples (curve 3) was obtained, in connection with smaller level of pulling residual stresses. At imposition on residual stresses of external cyclic load in conditions of pure circular bend they act similar to the constant load at asymmetrical loading, meanwhile pulling stresses decrease fatigue strength whereas compressing stresses increase it.

Samples of party 4^b and 4^c (curves 5, 6) had not residual stresses, and their fatigue endurance limits on the base of $2 \cdot 10^7$ cycles are respectively equal to 360 and 340 MPa. Some fatigue endurance limit decrease of party 4^c samples can be, presumably, related with that during EP disk abrasion on their surface burn marks are formed, which are not completely removed by vacuum annealing.

Working section of party 4^b samples after outdoor annealing was subjected to additional finishing with abrasive paper to remove oxidized layer, which exactly leaded to slight increase of this party samples fatigue endurance limit.

Resume

Fatigue breakings analysis of trial parties shows that in all trial cases samples with pulling residual stresses or, in their absence, fatigue crack source is positioned on the sample surface, whereas during the trial of the samples with significant residual compression stresses – on some depth. These findings correspond to results of works [1,2] and indicate the urgent need to analyze residual stresses (their sign and value), caused by different treatment techniques, explaining the findings.

Thereby, mechanical treatment of fatigue samples working section during their production has significant influence on residual stresses, formed in the surface layer in dependence of operating tool and mechanical treatment modes. This, in turn, determines and explains the value of fatigue strength characteristics of trial materials.

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DETERMINATION OF KINETIC CHARACTERISTICS AND WEAR ACTIVATION ENERGY "ШХ15" IN FUEL "TC-l"

Setup of the problem. The development of modern aircraft and military aviation, 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 mentioned above items as well as in their operation. Increased reliability, durability and cost-efficiency of these items depend on the surface durability of their individual units. In it is turn, the surface durability (wear-firmness) of structural materials of triboconnections cannot be increased and the antiwar properties of fuel and lubricants cannot be improved without conducting of tribotechnic al tests. But for conducting of such tests it's necessary to use universal, energy, integral and invariant criteria, at least in one of the value ranges of loads (P), speeds of sliding and temperatures. The criterion that meets all the above mentioned requirements is surface destruction activation energy, i.e. wear activation energy EP, which is the third stage of triboreaction [1]. This criterion is an energy criterion in fact, 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 EP for the fuel "PT" were also determined. Later the same characteristics were determined for the fuel "TC-1" that had been stored far a long time [2]. The characteristics obtained showed a degradation of antiwar properties of the fuel after the long-term storage. The following hypotheses were put forward with respect to this degradation: 1) this degradation may result from oxidation, contamination or from other processes connected with long-term storage; 2) this deterioration condition of the different antiwar properties of fuels "PT" and "TC-1", in spite of the interchangeability the permission to mix up these fuels in any correlation.

Aim of article - to put up the true causes of deterioration antiwar properties of the fuel "TC-1*" of long-term storage by means of realization of tribokinetic tests to determine the kinetic characteristics and EP of the fuel "TC-1", usually fresh and compare the obtained results, firstly with the value of EP then with the earlier value of EP for the fuel "PT" EPpt=21,278 kj/mol and the fuel " TC-1*" of long-term storage EPTC-1*=19,581 kl/mol.

Calculation - experimental part. For the achievement of aim of the tribokinetic tests, conducted under conditions analogous to the preceding tests to determine the kinetic characteristics and EP of fuel "TC-1*" of long-term storage, i.e. tribokinetic tests to determine the kinetic characteristics and EP of fresh fuel "TC-1" (DSTU 320.001249943.011-99), production of the Kremenchug oil - processing plant conducted on the friction machine "КИИГА-2" [3]. Both hard-phased elements were produced with ball-bearing steel "ШХ15" (ГОСТ 801-78). Tests have been conducted with axis load P=98,l H, speed of slide Vck=l,18 m/c without excess pressure in the cell, at two temperatures: T1=333°K and T2=303°K. Then, with the help of instrumental microscope "МИМ-7" at 70-divisible increment the diameter in two interperpendicular directions of the spot wear of every ball, was measured and the arithmetic value of diameters of the spots wear d, the mean value d of three of spots wear - dc and mean value dc of three or more tests were calculated. According to the method of carrying of tribokinetic tests, we calculated the value of wear of every ball, which segment is the geometric form of the ball, diameter the base of which is the diameter spot wear. The sum of the volume wear of third balls (summary volume wear of one test) and we calculated the arithmetic mean value of summary value wear of three or more tests Vc. Results of these tests we bring into table 1.

Table 1

Kinetic characteristics of the surface destruction – third of the stage triboreaction-wear

Temperature of the tests, T,°K	Time of the tests, ti, xlO3, s	Mean values of summary volumes of wear of the 3th tests, Vcxl0-3,mm3	Speed of wear for intervals of time, Δt×lO6, mm3/s	Order of wear NP for interval of time Δt	Constants of speed of wear KP×l0-3, s-1	Mean values KP KP×l0-3, s-1	Coefficient of deviation of the estimation of KP, w,%	Graphical value of KP
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 next stage of the tribokinetic experiment is to calculate the speed of reaction wear w:

$$w = \frac{\Delta V_c}{\Delta t_c} = \frac{V_{cti} - V_{cti-1}}{t_i - t_{i-1}} \qquad (1)$$

where V_{Cti} and V_{Cti-1} -mean value of the summary wear of the tree balls at moment of time t_i and t_{i-1} respectively.

The results of these calculations of w for every interval of time Δt1 are brought into table 1. The order of the reaction wear N^P was calculated for the initial Δt_1 and last Δt_3 interval of time using the next formule:

$$N^p = \frac{\lg \frac{w_1}{w_3}}{\lg \frac{V_{c1}}{V_{c3}}} \qquad (2)$$

where w_1 and w_3- speed of wear for interval of time Δt_1 and Δt_3 respectively;
V_{C1} and V_{C2} - mean of the three balls for intervals of time Δt_1 and Δt_3 respectively. The results of the calculation of the order of reaction of wear N^P are also brought into table 1. The constants of speed of wear KP we calculate with help of the final value of V_C in intervals of time Δt, i.e. using the formule:

$$K^p = \frac{\Delta V_c}{\Delta t * V_{cap}} = \frac{w}{V_{cap}} \qquad (3)$$

where V_{Cap} - mean arithmetic value of V_C at beginning and at the end of the interval Δt.

The results of these calculations we also bring into table 1. We also bring the mean arithmetic values of K^P and coefficient of deviation of the estimation of K^P-W, which is calculated according to method of the calculations of measurement errors of the physical quantity [4].

Thus, knowing the value of K^P at both temperatures T_1=333°K and T_2=303°K, according to the equation of Arrenius, the value of the activation energy of the surface destruction, i.e. wear calculated:

$$E^P_{TC-1} = \frac{R \cdot T_1 \cdot T_2}{T_1 - T_2} \cdot \frac{\ln(K^P_1)}{K^P_2} = \frac{1{,}9144 \cdot T_1 \cdot T_2}{T_1 - T_2} \cdot \frac{\lg(K^P_1)}{K^P_2} = \frac{1{,}9144 \cdot 333 \cdot 303}{30} \cdot \frac{\lg 0{,}9813}{0{,}4746} = 20{,}314 \ \frac{kj}{mol}$$

where R - universal gas constant.

For control of the correction determination of the kinetic characteristics of wear W, N^P, K^P, calculated by equations (1), (2), (3), along with the results of the tribokinetic tests we build the diagrams of the dependence of lg V_C from time of the tests (t) (fig.l). The linear dependence of lgV_C from t confirmed the order of the reaction $N^P \sim 1$ and set the value of K^P graphically, which is equal to the tangent of the angle of inclination of the straight line to the axis OX. This value of K^P is also brought into table 1. The results of the tests are brought into table 1 and on the figure 1 of the dependence of lgV_C from t.

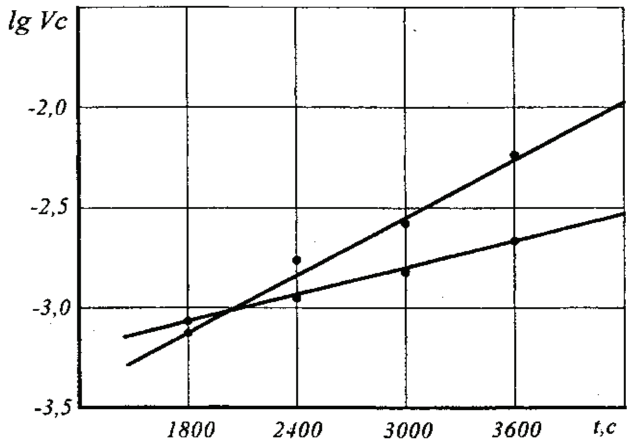

Fig.l. Diagram of the dependence logarithm of mean values of summary volumes of wear of three balls in three tests (lgV_C) from of the tests (t): 1 - at 333°K, 2 - at 303°K.

Conclusions

1. Using the obtained values of the kinetic characteristics and E^P_{TC-1}=20,314 kj/mol, place of the causes of the deterioration of antiwar properties was established of the fuel "TC-1*" of long-term storage: it is the consequence of the action of the processes of oxidization and other, which are connected with the length of storage.
2. In spite of full interchangeability and permission to mix up the fuels "PT" and "TC-1" in any correlation, antiwear properties, although insignificant, are yet distinguishable - in "PT" a little better (E^P_{PT}=21,278 kj/mol against E^P_{TC-1}=20,314 kj/mol), which was possible owing to the high accuracy of the determination of E^P.
3. Close values of E^P of the tree fuel ("RT", "TC-1" and "TC-1*" of long-term storage), for which we have determined the kinetic characteristics, confirm the invariation of E^P in diapason of normal mechanical-chemical wear, which correspond to the diapason of the structural-adaptation of the materials of the triboconnections.
4. The established value of E^P_{TC-1}=20,314 kj/mol in the fuel "TC-1" replenished the bank of data of wear-firmness of the steel "IIIX15" and antiwar properties of the fuel "TC-1" and matrixical energy - activation criterion of estimation of construction materials, antiwar properties of combustible - lubricant materials and combinations of these materials

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ARTIFICIAL INTELLECT AND HUMAN REASONING.

The subject of "artificial intellect" science is the human reasoning. The scientists grope for an answer to a question: how does the person think? The purpose of these researches – to create a model of human intellect and to realize it on a computer. (In other words: to learn the machine to think).

Artificial intellect (AI) is the program system simulating human reasoning on a computer. In order to create such system it is necessary to study the process of human reasoning, solving the certain problems or making decision in the concrete area, to specify the main steps of this process and to develop program means, reproducing them on a computer.

Hence, methods of AI suppose the simple structural approach to the development of complex decision-making program systems.

The artificial intellect gives the features of reason to a computer. Methods of AI simplify the combination of programs and give the possibility to put the ability of self-training and accumulation of new, useful in the future information in the system of artificial intellect. The person can accumulate knowledge without changing a way of reasoning and without forgetting already known facts. The system of AI works almost in the same way.

Methods of AI suppose a high degree independence of the program's separate parts, each of which realizes the certain step of the decision of one or several problems. Independent parts of the program can be compared with the separate blocks of the information in the human memory. Choosing the necessary information, the human brain automatically uses only facts concerning to the given task, not looking over all knowledge accessible to it.

One and the same program can be programmed using either traditional methods or methods of the human intellect. Applications of AI methods allow simplifying and accelerating essentially the development of the programs. AI programs have the special property, which is similar to the characteristic property of the human intellect, – changing of any, even a small part of the information does not influence on the structure of the program. Such flexibility gives to the process of programming more efficiency, it gives the possibility to create the programs, which are able "to understand", i.e. which possess by the features of reason.

Human reasoning.

The artificial intellect bases on the knowledge about the process of human reasoning. In order to have the possibility to speak about AI, the program system must have all the elements making the process of decision-making by the person – the purposes, facts, rules, mechanisms of the conclusion and simplification.

It is necessary to study the process of human reasoning solving the special problems or making the decisions in the concrete area, to define the basic steps of this process and to develop the software reproducing on a computer for creation of such system.

Purposes.

Reasoning is situated in the base of human activity.

When the alarm clock calls in the morning, the brain of the person gives a command to a hand to switch it off. It is not an automatic reaction – the decision of a concrete task demands the certain answer of a brain. The final result, on which the workings of the human mind are directed, is called the aim. As soon as the aim (to switch off a call) is reached, new aims for the person appear at once, for example, to brush the teeth, to dress, to have breakfast etc. Realization of all these aims leads to achievement of the main goal – to get to work in time. The ideas leading to the final result, are not usual, they are strictly proved. Each step on a way to the main goal has the local purpose. The brain always concentrates on the purpose without taking into account either the person performs simple physical work or solves a complex intellectual problem.

At designing of an expert system it is always necessary to remember about the aims for achievement of which it is intended.

The facts and rules.

The person stores a great knowledge. Generally the intellect can be represented as a set of the facts and rules of their use. Partially the aims are reached by means of rules of using of all known facts. An example:

Fact 1: Temperature of water boiling is 100 °C.

Rule 1: If the temperature of the process is less than 100°C, then water can be used for heating.

Rule 2: If the temperature of the process is more than 100°C, then the electro heater is used for heating.

Pay your attention, that all rules in the given example are expressed by the relative attitude in the view: IF … THAT …, i.e. if some condition is carried out, then some action follows.

Simplification.

When the human brain starts to solve even the simplest problem for the choice of the necessary actions, it has a huge volume of the information at the disposal. For example, the person crossing the street analyzes the speed and volume of the movement, the distance to the opposite side, the traffic-actuated signal. Simultaneously the brain processes the impressions, which do not have the direct connection with the crossing the street (for example, the color of the passing cars, the view of the trees and surrounding buildings, the people's clothes and etc.)

If the person analyzed all facts influencing on the aim before doing the first step, he would be standing on the sidewalk for a couple years. But human reasoning includes the complex system which controls the choice of the correct reaction to a concrete situation. Such choice is called simplification. The simplification mechanism blocks the facts and the rules which do not have the direct attitude to a solving at the given moment problem. The work of the simplification mechanism is schematically represented on fig. 1.

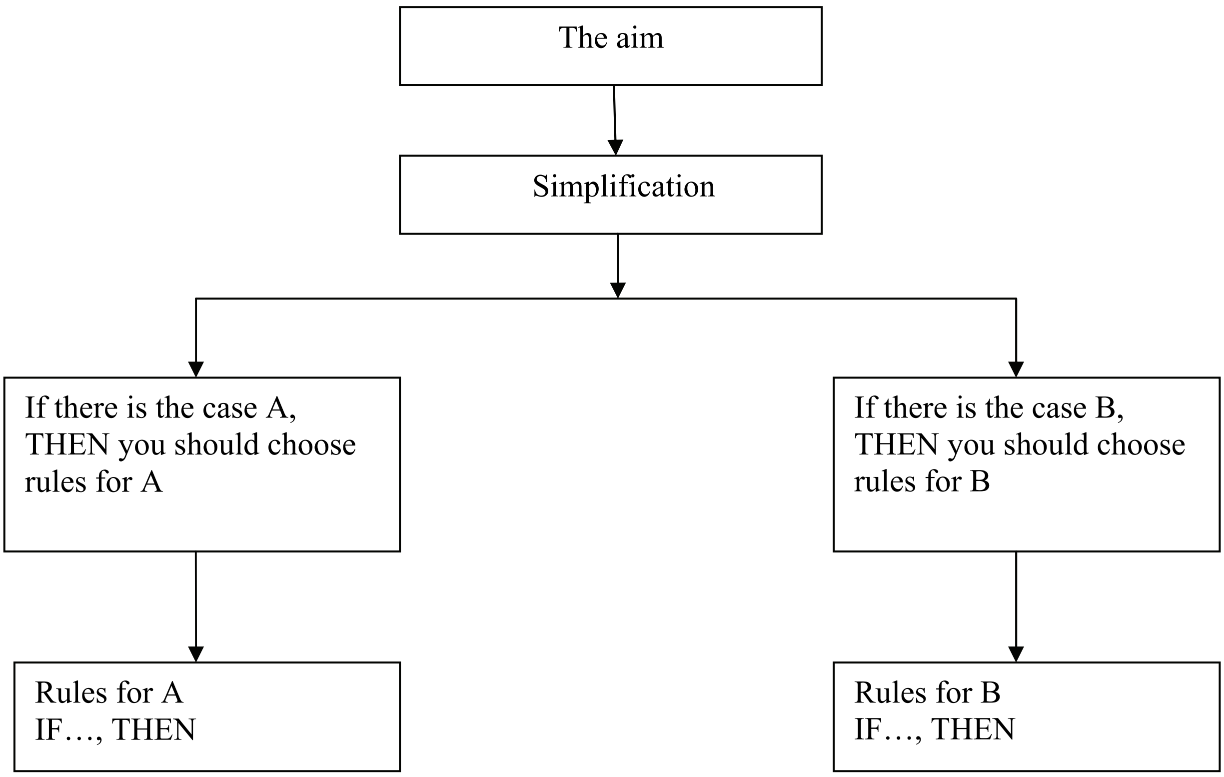

Fig.1. System of the simplification mechanism

Forward chaining mechanism.

Reaching the aim, the person not only comes to the decision of the given problem, but simultaneously he also acquires new knowledge.

The part of the intellect that helps to take out the new facts is called forward chaining mechanism.

An example:

Fact 1: Ann and Steve – Jon's parents.

Fact 2: Ann and Steve – Margaret's parents.

Rule 1: If the boy and the girl have the same parents, then these children – the brother and the sister.

The purpose: To define the family type of Jon and Margaret.

By means of available facts and rules, the purpose can be reached at once. Besides during the process of purpose achievement the new fact is received. New fact: Jon and Margaret – the brother and the sister.

There are many kinds of human activity which cannot be planned previously:

- writing music and making verses,
- theorem proving,
- literary translation from the foreign language,
- illness diagnostics and treatment,
- and others.

For example:

During playing chess the chess player knows rules of the game, he has the purpose – to win a game of chess. His actions are not programmed previously. They depend on the competitioner's actions, the position developing on a table, on the acumen and the personal experience of the chess player.

Computer as the executor carries out any work due to the program. Programs are written by the people, and the computer formally carries them out.

Developers of the artificial intellect systems try to learn the machine, similarly to the person, to build independently the program of its actions, taking into account the condition of a problem.

The aim of the computer transformation from the formal executor into the intellectual executor is put.

Any system of the artificial intellect works within the limits of the concrete subject (medical diagnostics, the legislation, mathematics, economy and etc.) Similarly to the expert, the computer should have knowledge in the given area.

Knowledge in the concrete subject, formalized in the definite order and incorporated in a computer memory, is called the computer knowledge base.

For example, you want to use the computer in order to solve the task connecting with geometry. There are 500 different content tasks in the book problems.

The expert on an artificial intellect will put knowledge of the geometry in the computer (as the teachers do). On the base of this knowledge and with the help of the special algorithm of logic reasoning the computer will solve any of 500 tasks.

The systems of an artificial intellect work on the base of the incorporated knowledge.

How is it possible to create intellectual system on a computer?

The human reasoning is based on two components: the stock of knowledge and the logic reasoning ability. Two main tasks appear during the intellectual systems creation on a computer:

 modeling of knowledge (development of the knowledge formalization methods for put them in computer memory as the knowledge base);

 modeling of reasoning (creation of the computer programs, which simulate the logic of human reasoning at the solving of different tasks).

Among the artificial intellect systems, which are widely introduced in the area of design autoimmunization, it is necessary to pay attention to the so called expert systems (ES), in basis of which there is an extensive reservoir of knowledge and expert estimations about a specific subject province.

Knowledge, which is owned by the expert in any province, can be possible to divide into formalized and not formalized. The formalized knowledge is formulated in the books, manuals, documents in the form of general and exact judgments (laws, formulas, models, algorithms, etc.). Not formalized knowledge is not usually got into the books and manuals, because of its specificity, subjectivity and approximate nature. Knowledge of such kind is a result of a long-term operational experience and intuition of the expert. They usually represent a set of empirical methods and rules. As a rule not formalized tasks possess by the incompleteness, inaccuracy, ambiguousness and inconsistencies of knowledge. Traditional programming as a basis for programs development uses algorithm, i.e. the formalized knowledge.

The expert systems do not reject and do not replace the traditional process of the programming. They differ from the traditional programs by the fact that they are focused on the decision of not formalized problems.

The person is called "expert" if he possesses a great volume of knowledge and experience in the specified area. Knowledge of such level is laid in the computer expert systems.

The function of the expert systems – consultations of the user, help in the decision-making.

The EXPERT SYSTEM uses knowledge, which it has in its narrow area in order to limit the search on a way to the decision of a problem. DENDRAL, is the first and the most successful expert system, it is based on the synergetic interaction between four types of knowledge, allowing narrowing a circle of an investigated organic molecules possible structures.

If the molecular formula C20H43N is only known, then 43 million configurations of atoms are mathematically possible.

However the knowledge of chemical topology, for example the valence of the carbon atom is equaled to four, narrows a circle of structures-candidates up to 15 million. The data about the molecule, received by means of weights (spectrometer), and also heuristic knowledge about what structures are more stable and more probable, limit the search yet more.

Finally, the data of the nuclear-magnetic resonance allow to the program DENDRAL to identify the structure of a molecule correctly.

Conclusions:

- The purpose makes the person to think;
- the human brain stores the huge number of the facts and rules of their usage, for the achievement of a definite aim it is necessary only to address to the necessary facts and rules;
- the simplification mechanism chooses quickly and effectively the facts and rules, necessary for the achievement of the nearest purpose;
- the forward chaining mechanism finishes the reasoning process, making the conclusions on the base of the rules selected by the simplification mechanism, and generating the new facts which are added to the person’s knowledge.

The help of the artificial intellect systems becomes especially important in the extreme situations, for example, at the technical failure, emergency situation, at the vehicles driving. The computer is not subjected to the stresses. It will find quickly the optimum and safe decision and it will offer it to the person.

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INVENTORY MANAGEMENT IN THE AIRCRAFT MAINTENANCE SYSTEM

Inventory management as one of the key competences acts the important part in providing of efficiency of the aircraft operation. In spite of the fact that improvement of the elements characteristic is very important reserve for rise in efficiency of the engineering system, it doesn't free them from faults in full. Therefore there are no doubts in needs of the spares for repair and prophylactic works, which extend the lifetime of the engineering systems.

Effective inventory management directly influences on the organization of airworthiness support of the aircrafts, where considerable role belongs to the spares and components. They must fully correspond to the production and technical parameters, which were set up and confirmed at the stage of the aircraft certification and production, and all processes must be identified. The largest problems arise at the planning stage. Therefore it must be provided both good statistic accounting of the components reliability and controlling their vital cycle. Inefficient organization of the delivery eventually doesn't allow to provide control of the flight safety and effective use of the assets. The the structure of the interaction between the air enterprises by delivery and using of the material resources structurally describes the process of fulfillment of the orders about the aircrafts spares delivery (fig. 1).

The central object in the models of the inventory management is the process Z(t) – amount of the spares, which are available in the moment t or inventory level. Process Z(t) decreases in accordance with consumption of the spares and increases at the expense of the completion. Consumption is specified as some random process (flow of needs), which by its origin corresponds to the failure flow. Completion is ordered in accordance with accepted policy of the management and delivered in accordance with financial rule of the fulfillment of the order. Management policy shows when and how many of additional products must be ordered, and the rule of the fulfillment of the order characterizes the gap between wishes to have these products as many as you want and real possibility to get them.

By fixing of all components above the model Z(t) becomes the fully definite random process. Its analysis, notably determination of the different characteristics - is one of the types of the task about inventory management. Special interest is represented by the calculation of the time distribution till exhaustion of this time (or probability of uninterrupted claims settlement), stationary distribution of inventory level, its average level, intensity of the order supply and other.

More specific tasks are related with choice of the management policy, which are optimal as to some criterion. On the one hand this criterion expresses the aspiration not to create the excessive inventory, and on the other hand to provide the satisfactions of needs in time, to avoid the deficits and, finally, to place the order as rarely as possible. There are both disputable and diverse aspirations among these ones, so their comparison represents the separate large problem. Consciously omitting it, it is entered the formal conception of the different expenditures. Penalty function f_i (i-integer) shows intensity of the expenditures, which are related either with keeping of the inventory on the determined level (by i>0) or its lack. Cost function of the order c (n) (n>0) shows how much will one order of the consignment with n products cost.

If all mentioned expenditures, which depend on dynamic of inventory and order supply are integrated along the trajectory Z(t) with finding of the time average, we will get the direct criterion of the efficiency, which requires the further minimization.

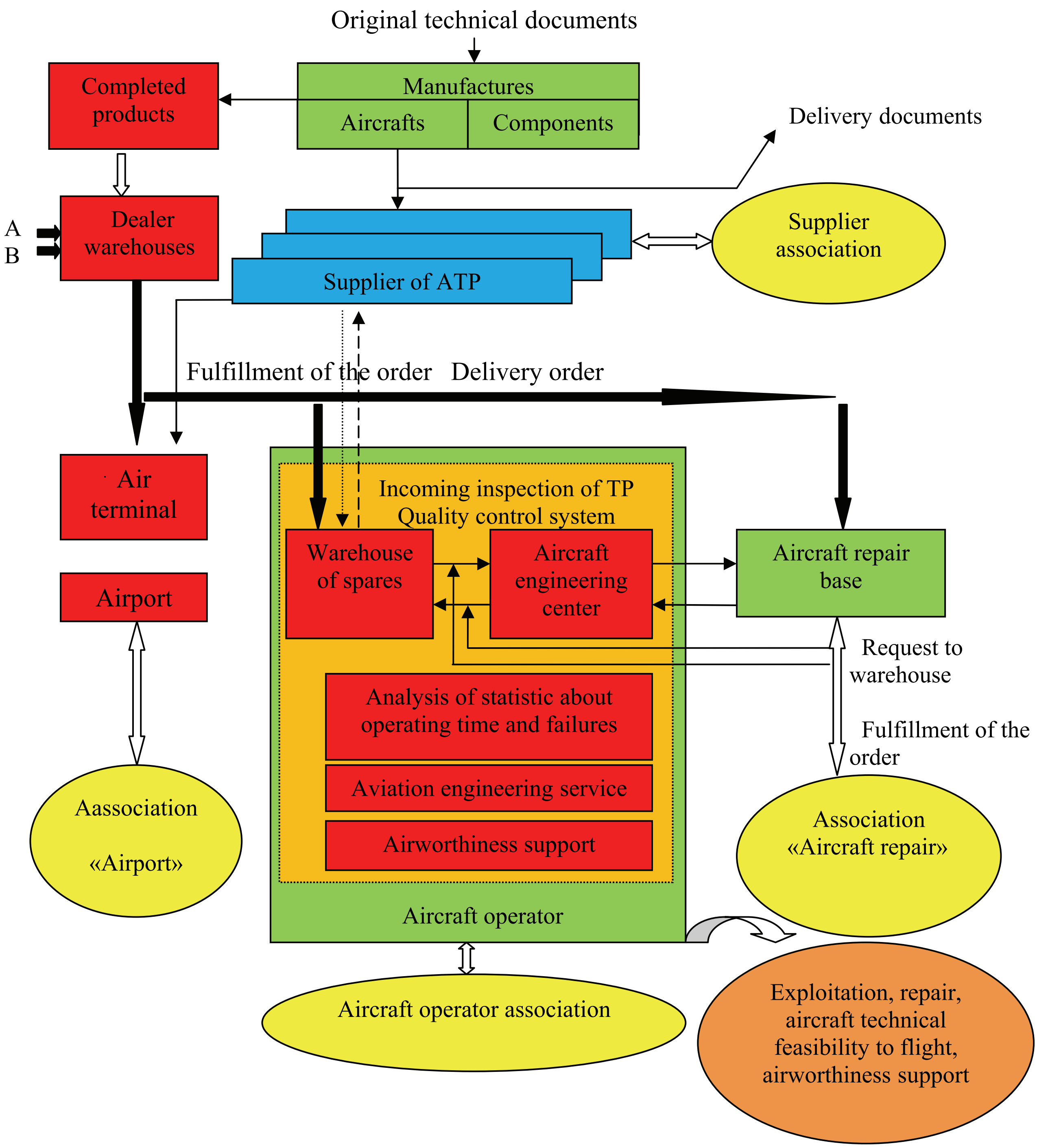

Fig. 1 Structure of the interaction between air enterprises by resources delivery

Notation conventions of operating and inspection delivery zones

⇨ Physical fulfillment of the order about delivery of ATP (Aircraft technical property)
→ Documentary fulfillment of the order (information exchange)
┈▸ Ordering with supplier
➡ **A** - exportation
➡ **B** – «grey dealers»

There are two main problems in the system of the inventory management. Sometimes it is previously restricted to some classes of the management policies, which depend on small amount of the parameters. Then the optimization problem is reduced to creation of the algorithms for determination of the optimum level of these parameters. But there are some doubts in such approach about existing more complex rules of the order supply, which transcends the considered class and provides less expenditures.

The tasks of the second type are based on the search of the conditions, when the simple management policies will be optimum in the global sense.

Nowadays, the important part of effective delivery and inventory management is using of the international standards and electronic attachments such as SPEC 2000. The main conditions of standards usage is conversion on the technology of e-business and gradual integration of the aircraft industry with world aircraft delivery industry and air transportation.

Designing and operation of the systems SPEC 2000 needs creation of the aircraft provider centers and location in the single database of the standard information about maintenance, repair and materiel support. The air provider must have the following rights and obligations:

- to co-ordinate on the informative level all participants of the delivery process (the central server and the central database);
- to generalize the gathered information and make analysis (diagnostics) of the state of the issues about the aircraft delivery;
- to report about the infringing and uncertificated delivery and usage of delivery objects;
- to organize the exchange of the standardize information between supplier and aircraft operator;
- to create for the interested self-regulated structures (associations, unions) the certification system of the logistic services, which are given by suppliers of ATP to the air companies and other participants of the high-technology market

Information system of the air provider at repair and maintenance consists of the four main databases, which allow the different companies to place in it all necessary information about their services and provide access for all interested participants:

- The central supply database. This database is mainly used by manufacturers and suppliers of the new spares, allowing providing the confidentiality of costs information.
- The central repair database. This database is used by air companies and repair plants, allowing providing the confidentiality of costs information.
- The accounting and redistribution system. This system is used by air companies and suppliers for accounting of components, engines, avionics, test equipment, consumed materiel and other. Access to the information in this system is not limited for all participants.
- The database at test, ground equipment and instrument. This database gives information about equipment to the specialized vehicle.

On basis of requirements, structure and architecture of SPEC 2000 construction, all supplier chains, which take part in the aircraft creation and operation, must have coordinated strategy, information technology of automatic identification of ATP.

To solve the problems above it is necessary to design the complex of the regulations, managerial procedure and program hardware of information supply, additional mechanism of the market control and interaction between participants of the production, delivery, operation and utilizing of ATP, both the civil and military aircrafts. It provides interaction of the plant facilities and the civil aviation with a glance of the level of the accepted risk.

Designing and operation of this system needs creation of the network of the electronic air providers at supply management. As the information logistic center, air provider must fulfill both the tasks of air authority inspection and the tasks of self-regulation on basis of the standard data exchange in the interests of air market participants.

Creation and development of the network of the air provider centers are related with holding of the air industry restructuring, providing exchange both business (economic) and technical information between air operator, manufactures and suppliers. The new possibilities of common usage of the resources on basis of the flexible, multilevel scheme are opened for all participants of the air market and others, which interact with it (fig. 2). Network provides effective combination of the functionality, efficiency and flexibility, and as a result - safety

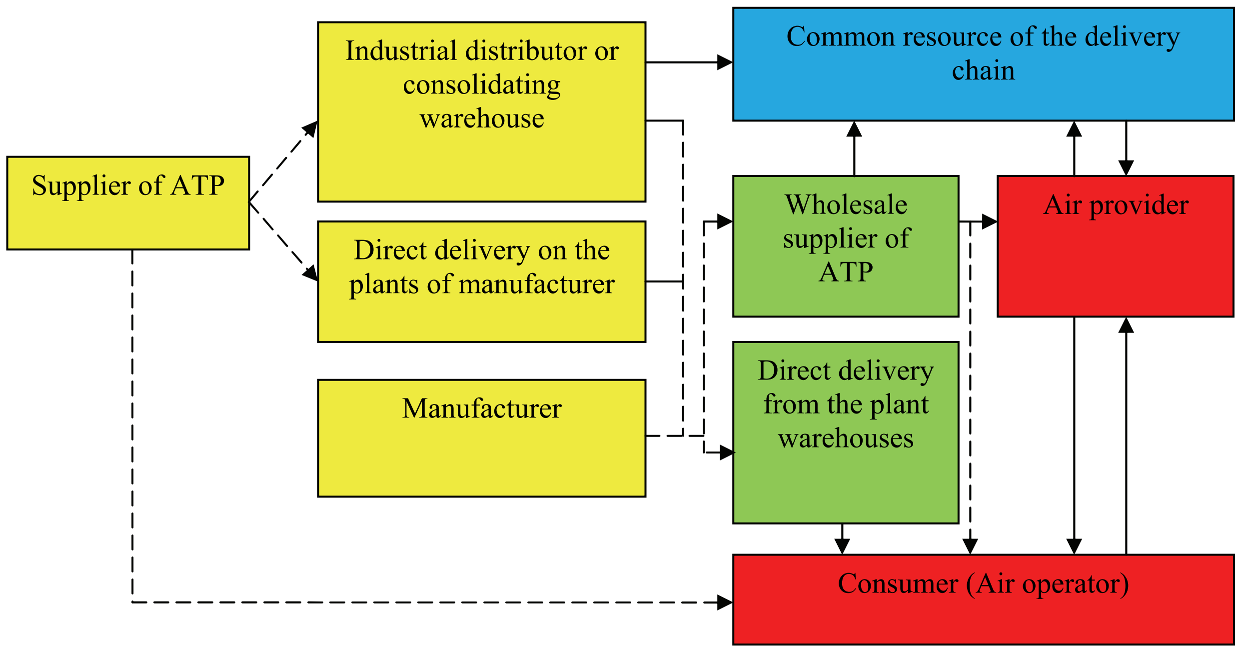

Fig. 2 Flexible multilevel delivery system

- - -► Traditional delivery channels

——► Optimized channel through "Air provider"

Conclusion

The above allows affirming, that nowadays the effective functioning of the aircraft industry is possible only on conditions of the system organization of works of all enterprises, which take part in designing, production and maintenance of ATP.

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FORMING OF STRUCTURE AND TRIBOTECHNICAL PROPERTIES OF ELECTRIC-SPARK COATING ON THE BASIS OF TiB_2-SiC

It is studied peculiarities of steel 30ХГСА surface structure modified by electric-spark alloying. It depends on the content of metal binding in electrodes ТБКНХ. There are established tribotechnical characteristics and studied the wear mechanisms of received coatings in the conditions of sliding friction without lubricant in comparison with steel and electric-spark coating ВК-6.

Introduction

Solution of the problem of reliability and aviation engineering components operating time increase is inseparably connected with increase of durability of movable contacting pairs and increase of construction elements structural strength. The most effective method of difficult technical problems solution is creation of wear resistant coatings on the surface of the machine parts of constructive materials. The combination of high firmness with plastic properties is of great importance for the coatings, so composition ceramics are prospective as basis of coatings because make possible to control the phase composition and structural effect. It allows constructing of the surface with necessary operation properties.

In Francevich Institute of material science problems of National Academy of Sciences of Ukraine there were developed cermets ТБКНХ on the basis of TiB_2-20%SiC with metal binding Ni-20%Cr that have high wear resistance in aggregate with steel at sliding friction without lubricant [1]. It was found out that oxides TiO_2, B_2O_3, SiO_2 are formed on the surface of cermets ТБКНХ in the process of friction. These oxides get bound in amorphous film that has low inclination to adhesion interaction with steel, so they protect surface from damages [2, 3]. It is expedience to investigate the electric-spark steel strengthening by electrodes ТБКНХ for studying the opportunity of creation of wear-resistant coatings on the basis of the developed cermets. Among the number of directions of strengthening technologies the electric-spark method is characterized by the possibility of application of any conducting materials, refractory metals and compounds, by high adhesion of strengthening layer and base, by possibility of local coating without visible deformation of details. Besides, electric-spark method is appropriate technology that is characterized by low power intensity, process simplicity and small overall dimensions of equipment [4, 5].

Thus, the **purpose of this research scientific work** is investigation of the peculiarities of forming of structure and tribotechnical properties of coatings applied on the steel 30ХГСА by electric-spark method with using of the electrode materials on the basis of titanium boride and silicon carbide.

1. The objects and methods of investigation

The electric-spark-coatings were applied on the steel 30ХГСА with using of developed electrode materials ТБКНХ on the basis of refractory component TiB_2-20%SiC with 20, 30, 40 % (mass) of metal binding Ni-20%Cr. Electrodes ТБКНХ were obtained by the method of sintering at temperature 1650 ^oC in furnace СВШ during one hour. Electro-spark steel alloying was carried out on installation ALIER-50 that has seven modes. Due to this the coating thickness can be varied. In the conditions of experiment electric-spark coating was applied during eight minutes on sixth mode (amplitude value of impulse current I=200 A, impulse energy E_{im}=2,52 J, impulse duration t_{im}=700mcs) in order to provide the major thickness (till 200mcm).

Tribotechnical investigations of developed electric spark coatings were performed in the conditions of sliding friction without lubricant on installation МТ-68 according to scheme shaft-bush in the wide velocity ranges and loadings. A steel 65Г was used as opposite body. For comparison electric-spark coating on the basis of ВК-6 and steel 30ХГСА were tested at the same conditions.

Composition and structure of coatings and secondary phases that were formed at friction process were studied with electronic micro analyzer «Camebax SX-50». Microhardness was measured with micro hardness gauge ПМТ-3 at loading 0,1 N.

2. The results of investigations and their discussion

The modified layer with thickness 150-200 mcm is formed in the result of electric-spark alloying by cermets ТБКНХ. Phase composition of alloyed layer essentially differs from the composition of electrode because of interaction of materials in the process of electric-spark alloying. Heterophase structure is formed on steel in the process of electric-spark alloying by electrode materials ТБКНХ. It represents matrix from solid solution of silicon, nickel, and chrome in steel (Fe-Ni-Cr-Si), that is disperse strengthened by inclusions of titanium boride (Fig. 1).

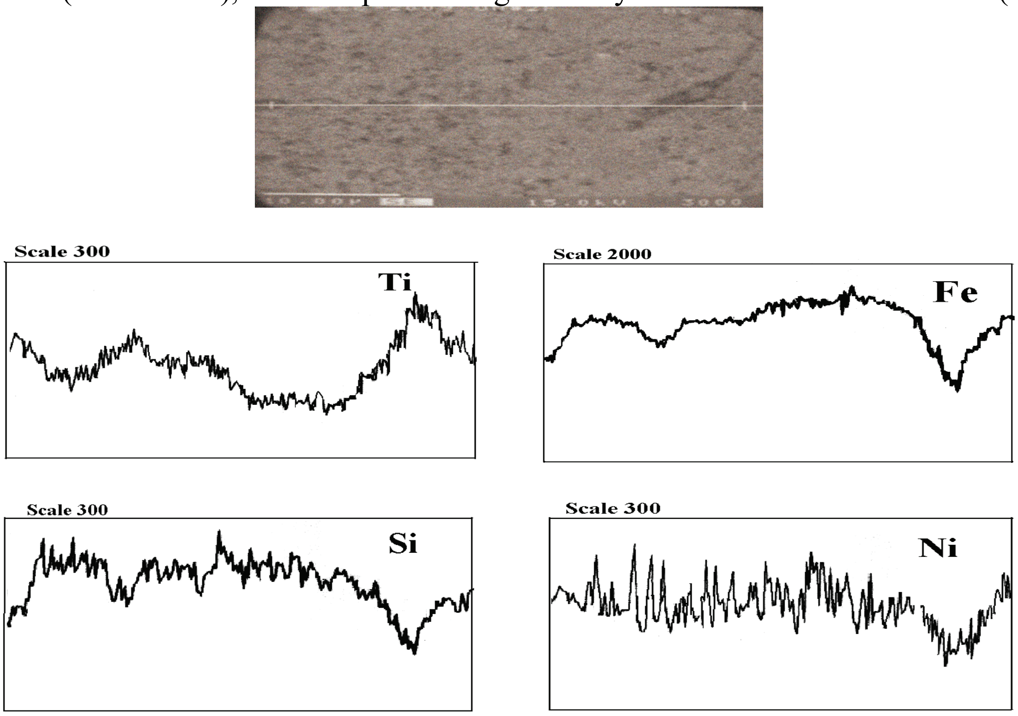

Fig. 1. Structure of steel electric-spark layer on the basis of composite material ТБКНХ30

Dispersion of titanium boride inclusions in the coating material depends from the amount of metal binding in electrode: with increase of metal binding from 20 up to 40% the size of TiB_2 inclusions decreases per 4…1 mkm. Because the size of titanium boride grains in ТБКНХ30 and ТБКНХ40 cermets averages 6-8 mkm, probably breaking up of the electrodes components happens in the process of electric spark alloying in the issue of mechanical and thermal influence of spark discharge.

There is not sharp interface between steel and the coating. It acknowledges the formation disperse strengthened layer with the depth 300-400 mkm like compositional material with matrix structure. Micro hardness change by the thickness of alloyed steel layer on the basis of cermets ТБКНХ with 20, 30 and 40% of metal binding has the identical character: H_μ on the surface is 21-23 GPa and gradually decreases in the direction of steel basis up to H_μ=4.8-4.6 GPa.

Formation of modified alloyed layer on the steel surface has the number of advantages in comparison with classic coating: in the conditions of friction under the action of contact loadings coating can break off and exfoliate in the issue of insufficient adhesion with the basis, and uniform electric spark layer with highly dispersed structure must provide high operational properties through all the specimen surface. Besides, because at sliding friction without lubricant high temperatures arise in contact area, it is important that coefficient of thermal expansion will not have the sharp change through the depth of modified layer.

Tribotechnical investigations in the conditions of sliding friction without lubricant showed that developed electric spark coatings on the basis of ТБКНХ have considerably smaller wear intensity and friction coefficient in comparison with steel 30ХГСА (Fig.2).

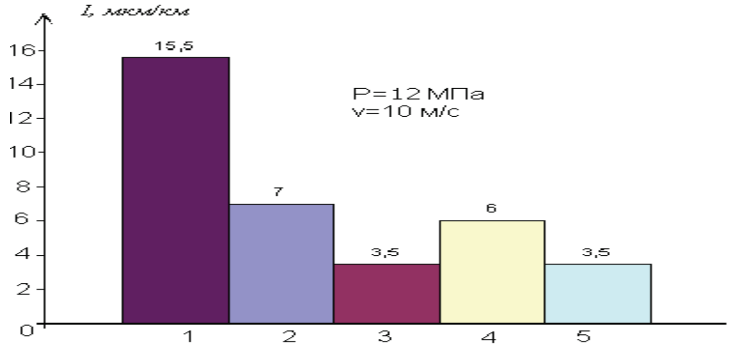

Fig. 2. Wear intensity at dry sliding friction (P=12 MPa, v=10 m/s): 1 – steel 30ХГСА; 2 – electric-spark coating ТБКНХ20; 3 – electric spark coating ТБКНХ30; 4 – electric-spark coating ТБКНХ40; 5 – electric-spark coating ВК-6

In the conditions of test (P=12 MPa, v=10 m/s) the lowest values of wear intensity are typical for electric-spark surface ТБКНХ30 (I=3,5 mkm/km) and electric-spark coating ВК-6 (I=3,5 mkm/km). At this coatings on the basis of ТБКНХ have better antifriction properties than steel 30ХГСА (f=0,33-0,38) and coating ВК-6 (f=0,2-0,34); the lowest friction coefficient of electric spark surface ТБКНХ30 is f=0,18-0,22.

In the issue of the complex of physicochemical and mechanical processes on the electric spark surfaces the superficial electric spark layers change. These changes regularities and character are defined by the structure of surface layer on steel and friction mode. In the cause of these transformations the secondary structures as dense oxide films on the basis of TiO_2, SiO_2, B_2O_3, Fe_2O_3 form on the contact surface of electric-spark coatings (Fig. 3).

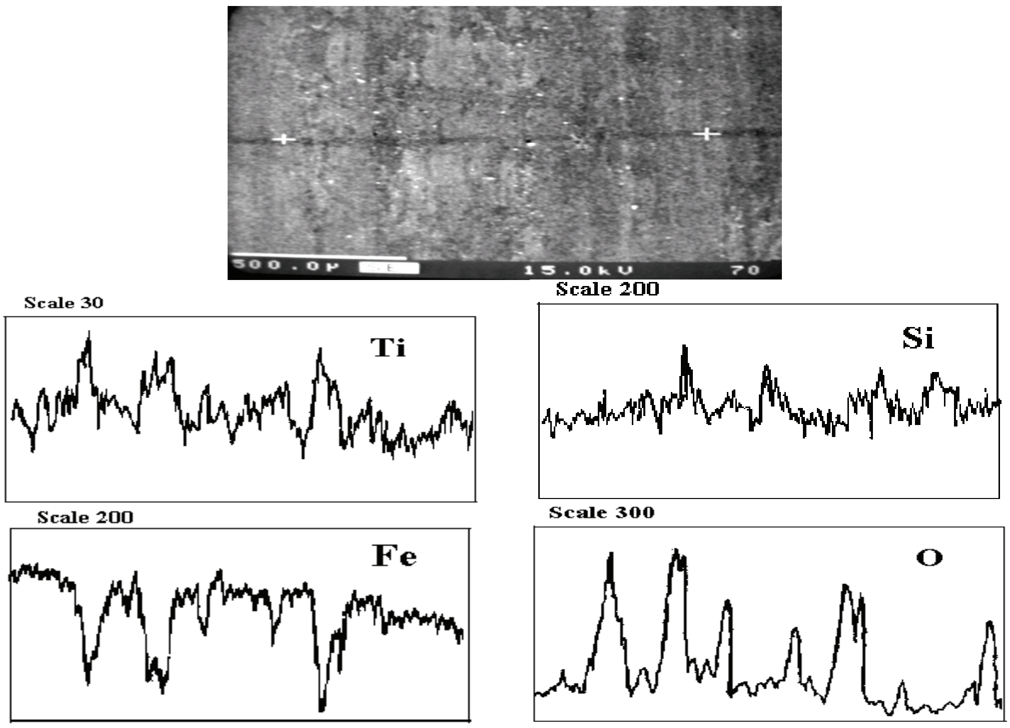

Fig. 3. Friction surface of ТБКНХ30 coating after tribotechnical test at sliding friction (v=10 m/s; P=12 MPa)

The films take contact loadings at the friction and prevent adhesion interaction with control body that provides high tribotechnical characteristics of electric-spark coatings in the conditions of sliding friction without lubricant.

Intensity of secondary structures in the form of protection oxide films formation depends on the quantity of metal bindings in electrode material and from surfaces structure. Oxide films on the surface of electric-spark coating ТБКНХ30 are denser and placed more uniformly than on the surface of ТБКНХ20 coating. The friction surface of ТБКНХ30 coating does not undergo considerable damages in the process of friction, and only traces of direct flexible deformation without obvious adhesion interaction signs are observed. Coating on the basis of ТБКНХ40 is also characterized by oxide film formation in the process of friction, but the traces of adhesion interaction with steel control body are detected on the surface.

Conclusions

Thus, it was determined that heterophase structure is formed in the process of electro-spark alloying of steel 30ХГСА by ТБКНХ electrodes on the basis of compositional material (TiB_2-20%SiC) with 20, 30, 40% of binding (Ni-20%Cr) content. It represents matrix Fe-Ni-Cr-Si that is strengthened by boride titanium grains.

Deposition of protection coatings on steel 30ХГСА with materials ТБКНХ leads to substantial improvement of tribotechnical properties. Tribotechnical characteristics of developed electric-spark surfaces depend on the quantity of metal binding in alloyed electrode. Application of electric-spark coating ТБКНХ30 is optimal at the sliding friction without lubricant because it increases steel wear resistance in 4-4,5 times and decreases friction coefficient till f=0,18-0,21. Wear mechanism of developed coatings can be determined by the processes of secondary structures in the form of borosilicate films on the basis of TiO_2, SiO_2, B_2O_3, Fe_2O_3 formation in the area of tribological contact. They act as solid lubricant and reduce friction coefficient.

According to the properties of electric-spark ТБКНХ coatings the developed cermets can be used as electrodes for strengthening of machines steel parts that operate at the friction without lubrication at velocities till 10 m/s and loadings till 12 MPa.

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SITUATION CONTROL OF COMPLEX OBJECT IN CONDITIONS WITH FUZZY SOURCE INFORMATION

In an article the problem of management a complex object is examined in the conditions of fuzzy source information. The automatic classification method is considered of the states of complex object. This method based on the algorithm of clustering fuzzy c-average values and on the algorithm of situation logical deduction for control in conditions with fuzzy source information.

One of distinctive descriptions of complex objects (CO) is a presence of plenty of independent entry and output parameters, characterizing the state of the system ambiguous appearance. The construction of adequate model at plenty of entrance variables requires high-cube base of knowledge, the amount rules of products in which exponentially increases with the increase of entrances the model, that reduces quality of fuzzy logic intervening.

In this case on the stage of generation base of knowledge, consisting of fuzzy logical rules, it is expedient to operate the concrete not parameters of the system, but classes of its states. It, in most cases results in diminishing of volume the base of knowledge, and accordingly to the increase of management exactness.

Consequently management of complex objects must be carried out not on it parameters, but on the states [1]. Thus, in system of automatic management (SAM) CO there is a task of authentication of the state of complex object of management on it looked after parameters.

Fuzzy situations. Let $Y = \{y_1, y_2, ..., y_p\}$ great number of signs, the values of which are describe the state of object of management, environment and control the system. Every sign of $y_i (i \in I = \{1,...,p\})$ is described the proper linguistic variable $< y_I, T_i, D_i >$, where $T_i = \{T_1^i, T_2^i, ..., T_m^i\}$ is a therm-great number of LP y_i (set of linguistic values of sign), m_i – is a number of values of sign; D_i – is a base great number of sign of y_i. For description of therms $T_j^i (i \in L = \{1, 2..., m_i\})$, proper values of sign of y_i, fuzzy variables are utilized, $< T_j^i, D_i, \widetilde{C}_j^i >$, value T_j^i – described a fuzzy great number $\widetilde{C}_j^i$ in the base great number of D_i.

$$\widetilde{C}_j^i = \{< \mu_{C_j^i}(d)/d >\}, \; d \in D_i$$

Then a fuzzy situation is named [2] a fuzzy set of the second level

$$\widetilde{S} = \{< \mu_S(y_i)/y_i >\}, \; y_i \in Y,$$

$$\mu_S(y_i) = \{< \mu_{\mu_S}(T_j^i)/T_j^i >\}, \; T_j^i \in T_i,$$

where $Y = \{y_1, y_2, ..., y_p\}$ great number of signs, characterizing the state of the system, and to every sign of y_i (Y is put in accordance linguistic variable $< y_I, T_i, D_i >$), where $T_i = \{T_1^i, T_2^i, ..., T_m^i\}$ the therm-great number of LS y_i, D_i – is a subject scale.

Fuzzy situations are set the states, which a management object, environment and informative system of SAM, are in, at creation of the up-diffused bases of fuzzy knowledge.

Classification of the states. Let the state of object or subject domain can be described the values of some signs or parameters. If the great number of the states of object possesses general properties, or values of signs description of the states, it is talked about the presence the class of the states object.

Under procedure of forming of classes, classification, understand organization of the states of object on their likeness [3].

When the state of object can be presented as a vector of numbers, determining the geometrical location of consisting space the coordinates of which are signs description of the state, it is talked about the clusterization of the state [4].

The group of the states of object, formative in space descriptions compact in a manner area, is named a cluster. Realization of method of clusterization in the intellectual system (IC) is determined the mutual spatial location of clusters in space. If set about clusters, proper different classes, far enough from each other, it is possible to take advantage of classification on some from birth-certificates. Among the great number of algorithms of clusterization most known algorithm of ISODATA and algorithm of maxmin distance [5]. During work with complex objects clusters can be recovered and have the washed out scopes, which takes a place as a result of incomplete or fuzzy information about the state of object. The methods of breaking up the space of problems, operating concepts theories of fuzzy sets, are used in this case [6].

Situational intervening. For determination of the state of management object it is necessary to compare an entrance fuzzy $\widetilde{S}_0$ situation to every logic situation from some set of model fuzzy situations of $S=\{\widetilde{S}_1,\widetilde{S}_2,\ldots,\widetilde{S}_N\}$. As a measure for determination degree of closeness $\widetilde{S}_0$ fuzzy situation of fuzzy situation $\widetilde{S}_i \in S(i \in K=\{1,2,...N\})$ can be utilized degree of the fuzzy including of fuzzy situation $\widetilde{S}_0$ in an fuzzy situation $\widetilde{S}_i$; degree of fuzzy equality $\widetilde{S}_0$ and $\widetilde{S}_i$; degree of fuzzy community $\widetilde{S}_0$ and $\widetilde{S}_i$; and also other measures of closeness. The choice of measure of closeness is determined the features of management object and organization block of making a decision in intellectual system.

Let $\widetilde{S}_i=\{<\mu_{Si}(y)/y\}$, $\widetilde{S}_j=\{<\mu_{Si}(y)/y\}$ $(y \in Y)$ there are some situations. Then the degree of including situation $\widetilde{S}_i$ in a situation $\widetilde{S}_j$ [3] is designate the size of $\nu(\widetilde{S}_i,\widetilde{S}_j)$, determined expression:

$$\nu(\widetilde{s}_i,\widetilde{s}_j)=\underset{y\in Y}{\&}\nu(\mu_{S_i}(y),\mu_{S_j}(y)),$$

where $\nu(\mu_{Si}(y),\mu_{Sj}(y))$ is calculated as follows:

$$\nu(\mu_{S_i}(y),\mu_{S_j}(y))=\underset{l\in L}{\&}(\mu_{\mu_{Si}}(T_i^l)\rightarrow\mu_{\mu_{Sj}}(T_j^l))$$

Here is $\nu(\mu_{Si}(y),\mu_{Sj}(y))$ the degree of including fuzzy set $\mu_{Si}(y)$, in a fuzzy set $\mu_{Sj}(y)$.

It is considered that a situation $\widetilde{S}_i$ unexpressly joins in a situation, $\widetilde{S}_j$, $\widetilde{S}_i \subseteq \widetilde{S}_j$ if degree of including $\widetilde{S}_i$ in $\widetilde{S}_j$, some not less threshold of including of $t_{inc} \in [0.6;1]$, management determined terms, $\nu(\widetilde{S}_i,\widetilde{S}_j) \geq t_{inc}$.

Existence of two mutual including of situations $\widetilde{S}_i$ and $\widetilde{S}_j$, means that at the threshold of including t_{inc} situation $\widetilde{S}_i$ and $\widetilde{S}_j$ approximately identical. Such likeness of situations is named fuzzy equality, and degree of fuzzy equality $\mu(\widetilde{S}_i,\widetilde{S}_j)$, situations $\widetilde{S}_i$ and $\widetilde{S}_j$ determined as follows:

$$\mu(\widetilde{S}_i,\widetilde{S}_j)=\vee(\widetilde{S}_i,\widetilde{S}_j)\,\&\vee(\widetilde{S}_j,\widetilde{S}_i).$$

It is possible to get after transformations

$$\mu(\widetilde{S}_i,\widetilde{S}_j)=\underset{y\in Y}{\&}\mu(\mu_{S_i}(y),(\mu_{S_j}(y))$$

where $\nu(\mu_{Si}(y),\mu_{Sj}(y))$ calculated as follows:

$$\mu(\mu_{S_i}(y),(\mu_{S_j}(y))=\underset{l\in L}{\&}((\mu_{\mu_{S_i}}(T_i^l)\rightarrow\mu_{\mu_{S_j}}(T_j^l))\,\&\,(\mu_{\mu_{S_j}}(T_i^l)\rightarrow\mu_{\mu_{S_i}}(T_j^l))).$$

It is considered that situations $\widetilde{S}_i$ and $\widetilde{S}_j$, unexpressly equal $\widetilde{S}_i \approx \widetilde{S}_j$, t ([0,6; 1], where $\mu(\widetilde{S}_i, \widetilde{S}_j) \geq t$, $t_{inc} \in [0.6;1]$ is some threshold of fuzzy equality of situations.

Fuzzy $(p-q)$ - situations such likeness of situations is named [3], when the fuzzy values of all of signs in situations are unexpressly equal, except for fuzzy values no more, than q signs. If situations $\widetilde{S}_i$ and $\widetilde{S}_j$, described p signs, for their $(p-q)$ there is enough fuzzy equality OF $(p-q)$ signs from a great number.

If signs which a management object is described through do not interdependent, from some situation it is possible to pass to any situation having $(p-q)$ with a situation, by application no more than q of local (operating on the value of only one sign) managements.

Let $\widetilde{S}_i = \{< \mu_{Si}(y)/y\}$ $\widetilde{S}_j = \{< \mu_{Si}(y)/y\}$ $(y \in Y)$ there are fuzzy situations. Then degree $(p-q)$ of $k_{p-q}(\widetilde{S}_i, \widetilde{S}_j)$ situations $\widetilde{S}_i$ and $\widetilde{S}_j$, determined expression:

$$k_{p-q}(\widetilde{S}_i, \widetilde{S}_j) = \underset{y \in Y \setminus Y_q}{\&} \mu(\mu_{S_i}(y), \mu_{S_j}(y)),$$

here $|Y_q \leq q|$ the sign of y_k belongs Y_q, if $\mu(\mu_S(y_k), \mu_S(y_k))$

At $Y_q = \varnothing$ situations $\widetilde{S}_i$ and $\widetilde{S}_j$, unexpressly equal.

It is considered like determination of fuzzy equality, that situations $\widetilde{S}_i$ and $\widetilde{S}_j$, have $(p-q)$, if $k_{p-q}(\widetilde{S}_i, \widetilde{S}_j) > t$.

Let the great number of the possible states of management object be set of S of standard fuzzy situations. It is assumed that great number of standard situations of S is full. To every fuzzy situation $\widetilde{S}_i \in S$ on the basis of expert information the managing decision $r_i \in R$, where R is a great number of managing decisions, in-use for a management an object. A fuzzy situational intervening is taken to recognition of entrance fuzzy situation $\widetilde{S}_0$, describing current status of management object, and delivery proper it managing decision from the great number R. For recognition of fuzzy situation it is possible to offer two methods:

- method of "next-door neighbour" in the space of standard fuzzy situations;
- delivery of managing decisions taking into account all of standard situations.

For this purpose some measure of likeness of fuzzy situation of S_0 must be utilized by standards from a great number $\widetilde{S}$.

As a measure of likeness fuzzy situations the degree of the fuzzy including of fuzzy situations and degree of fuzzy equality is most preferable. Both these measures consist of calculation of degree of likeness in an interval $[0;1]$. Not very big degree of likeness is equal to 1, the least – 0. Degree of likeness 0,5 means a complete vagueness.

For the estimation of equality or inequality fuzzy situations, including or not including the thresholds of fuzzy equality and fuzzy including of t are entered from an interval $[0.6;1]$. It is considered that a fuzzy situation $\widetilde{S}_0$ is unexpressly included or unexpressly equal to the fuzzy situation $\widetilde{S}$, if

$$\nu(\widetilde{S}_0, \widetilde{S}) > t;$$

$$\nu(\widetilde{S}_0, \widetilde{S}) \& \nu(\widetilde{S}, \widetilde{S}_0) > t \quad \text{accordingly.}$$

It is considered on the method of "next-door neighbour", that a management object is in a standard situation $\widetilde{S}_i \in S$, having a most degree of likeness with a fuzzy situation, and on the object of management the managing decision r_i must be worked $r_i \in R$.

On the second method resulting managing influence of r is determined the association of all of managing decisions of $r_i \in R$, modified in accordance with the degree of likeness of standard situations with a current situation $\widetilde{S}_0$.

Multicriteria problems have a characteristic feature, the above all difference of which consists in that no single point of view is, and there is the great number of effective decisions, or decisions optimum on Pareto. On Pareto such alternatives which in transition from one alternative to other the values of one or a few criteria can not become better without worsening of even one criterion will be optimum. Determination of great number on Pareto narrows the initial great number of decisions, that it diminishes vagueness. If some additional information about a task is absent, the subsequent narrowing of great number of Pareto by formal methods is impossible.

If criteria and their values get out taking into account a cooperatively, as a result general interest of group of criteria is put higher than interests of every separate criterion, the choice is optimum on Pareto [7].

For the grant of evenness influencing each of criteria on the final value of integral criterion it is necessary to level turn-downs values of criteria by the down-scaling and taking them to the range [1; 0].

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

For realization of process control of change properties and descriptions objects of exploitation it is necessary to define the possible managers of influence and to optimize organization of their leadthrough at the set limitations for the receipt of the required values of output vector $T_i = \{T_1^i, T_2^i, ..., T_m^i\}$ at minimum operating costs.

It should be noted that in the known models of optimization of plenitude and periodicity of prophylactic measures on the management by the state of difficult objects of exploitation development poliparametric method of optimization not is completed until now.

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ESTIMATION OF DYNAMIC PROPERTIES OF HYDROMECHANICAL FOLLOW-UP DRIVES BY USING THEIR DYNAMIC STIFFNESS CHARACTERISTICS

Various dynamic characteristics of hydromecanical follow-up steering drives of aircrafts' control systems have been studied. Based on the analysis of drive's dynamic stiffness characteristics, the impact of drive's kinematics on its stability and antiflutter properties is estimated. The advantages of drives with the so-called "inverse kinematics" are demonstrated.

The topicality of the research.

Hydromechanical follow-up drives are widely used in control systems of modern aircraft (AC) as steering drives of aerodynamical control surfaces. They are characterized by a limited stiffness of their bearing support and relatively small damping forces that in connection with mass (inertial) loads often results in loss of drive's stability or occur of weakly damped oscillations in the power circuit of the AC control system. The above-mentioned phenomena are especially inherent in booster control systems of airplanes [1, 2, 4, 5]. Thus, when developing control systems of airplanes, it is essential to provide the hydromechanical follow-up steering drives (boosters) with an appropriate stability margin. To do it, in some cases a special damping device can be installed in the power circuit of the airplanes control system [1, 3]. But, this method of providing stability has an essential disadvantage due to the increase in complexity of the whole system and its weight; besides, it is difficult to ensure a required stability of steering drives in case of failure of a damping device. Taking into account of the aforesaid, today the required stability margin of steering drives is being achieved by choice of an appropriate kinematic diagram of the drive and optimization of its basic parameters.

Another important task to be solved when developing airplanes booster control systems is the flutter oscillation damping of aircraft control aerodynamic surface by using dynamic properties of the steering drive itself.

Findings of the research.

The design experience of airplanes booster control systems has shown that the stability of a hydromechanical follow-up steering drive and its antiflutter properties can be most fully characterized by drive's dynamic stiffness to be determined experimentally.

The dynamic stiffness of the steering drive $G(S)$ can be determined as a ratio of Laplace image of force disturbance $R(S)$ that effects drive's output link and the motion image of point of force $y(S)$ generated by the aforesaid force disturbance: $G(S) = \frac{R(S)}{y(S)}$ where S is the Laplace operator.

Thus, the dynamic stiffness characteristics of the steering drive shall be detrmined by a ratio of a return transfer function of the drive to the load applied to its output link.

It should be noted that the steering drive (РП) installed on the bearing supports of a limited stiffness is an element of the elastic system "steering surface – steering drive – drive's bearing support", which has an internal energy source, namely a hydrosupply from the airplane's hydraulic system.

The antiflutter properties of the drive are dependant on its ability to dissipate the energy of torsional oscillations of the steering surface.

The work absorbed by the elastic system, which is ossilating under the impact of an external sinusoidal load, can be detrmined as a product of the force amplitude and the travel at $\sin\varphi$, where φ is a phase shift between the disturbing force and the movement of the point of its application.

The aforesaid work is positive when $\varphi > 0$ (the force advances the travel) – it correspondes with the energy dissipation in the system. In this case the elastic system is passive. When $\varphi < 0$, the elastic system performs the work against the disturbing force and can be called active. The latter is possible only in that case when the system has an internal energy source. If $\varphi = 0$, the elastic system works as an ideal spring that accumulates the energy of an applied force.

To analyse the influence of the kinematic diagram of the steering drive (SD) on its antiflutter properties, two diagrams of single-channel SDs that have been widely used in the control systems of the most modern aircraft were studied (Fig. 1).

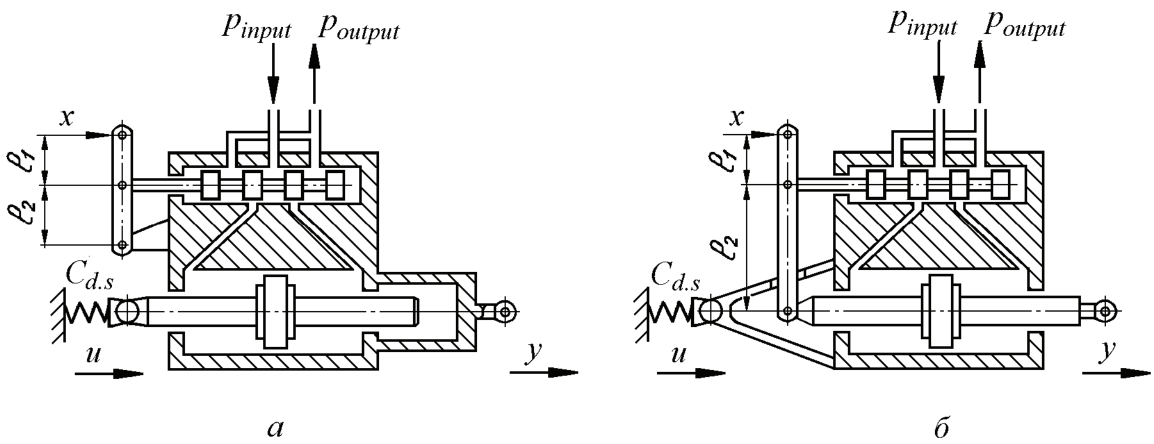

Figure 1. The Kinematic diagrams of hydromechanical follow-up steering drives; *a* – the steering drive with a hydraulic distributor in a movable rod; *б* – the drive with the “inverse kinematics”.

The table below contains some design ratios that can be used for the calculation of kinematic coefficients of drives’ diagrams under review.

Table

Parameters of kinematical coefficients

Parameters	**Steering drive diagrams**	
	Diagram “*a*”	Diagram “*б*”
The feedback factor k_{fb}	$l_2/(l_1+l_2)$	$l_1/(l_1+l_2)$
The transmission coefficient k_{tr}	+1	$-l_2/l_1$
The coefficient of influence of the deformation of drive’s bearing support on the mismatch value of the sliding valve k_{def}	0	+1

Based on the analysis of the dynamic model of the steering drive presented in [1], we can get the following simplified analytic expression for the estimation of the dynamic stiffness of the single-channel hydromechanical follow-up drives of the kinematic diagrams under review:

$$G(S)=G_0\frac{T_1S+1}{T_2S+1}\approx G_0\frac{TS+1}{\frac{G_0}{G_\infty}TS+1}, \quad (1)$$

where G_0 – static stiffness of the drive; T_1 and T_2 – the constants having a time dimension; $T=1/D$ – the time constant of the drive (D – the quality factor of the drive); G_∞ – the amplitude component of the drive's dynamic stiffness at a forcing frequency of $\omega\to\infty$.

The value G_∞ for the steering drives of the kinematic diagrams under review can be characterised by the stiffness of drive's bearing support $C_{d.s}$, the reduced stiffness of the power control drive $C_{c.d}$ and the hydraulic stiffness of drive's actuating hydraulic motor C_h, which takes into account the elasticity of working fluid in chambers of the hydraulic cylinder and is independant on the steering drive kinematics:

$$G_0=\frac{1}{\frac{k_{Qp}+k_{leak}}{k_{Q\varepsilon}k_{fb}F}+\frac{k_{def}}{k_{fb}}\frac{1}{C_{d.s}}+\frac{1}{C_{c.d}}}=\frac{1}{\frac{T}{B}+\frac{k_{def}}{k_{fb}}\frac{1}{C_{d.s}}+\frac{1}{C_{c.d}}}, \quad (2)$$

where k_{Qp} – the amplification coefficient of the discharge characteristic of the SD sliding piston-type selector valve in terms of pressure; k_{leak} – the interchamber leakage coefficient of the SD hydraulic motor; $k_{Q\varepsilon}$ – the amplification coefficient of the SD sliding piston-type selector valve in terms of consumption; B – the stiffness coefficient of the drive's load characteristic.

As follows from the analysis of the above expression (1), $\lim\limits_{\omega\to\infty}G_\infty(j\omega)=C_\Sigma$, i.e., in the high-frequency range the steering drive works as the ideal spring.

The correlation of the time constants T_1 and T_2 defines the the characteristic of the drive as an elastic system. If $T_1\succ T_2$, the drive has the damping features, when $T_1=T_2$, it posesses the features of an ideal spring, and if $T_1\prec T_2$, it has the features of an active system, i.e., the system, which introduces into the elastic system "steering surface – steering drive – drive's bearing support" an additional energy.

In order to ensure the flutter oscillation damping, the first condition should be filfilled, which in case of an absolutely inflexible (positive) drive has been always met (liquid – incompressible, the bearing support – absolutely inflexible), when $C_\Sigma\to\infty$; in this case $T_2\to 0$. Suffice it to meet the condition $C_\Sigma\succ G_0$ by decreasing the coefficient B (by using a sliding valve or introducing interchamber flow-overs in the drive's hydraulic motor) because usually it is difficult to succeed in a sufficient increase of C_Σ. A decrease in slope of the sliding valve's discharge characteristic (coefficient $k_{Q\varepsilon}$), in order to increase the time constant T, resultes in reduction of precision and operation speed of the booster control system, thus it cannot be recommended as an assential method for increasing the SD damping properties.

To determine analytically the value of phase shift between the external load $R(S)$ and the travel of drive's output link $y(S)$, the following formulas can be used [3]:

$$\varphi(\omega)=-\operatorname{arctg}\frac{G_0}{G_\infty}T\omega+\operatorname{arctg}T\omega \qquad \text{when } G_0\succ 0$$

or

$$\varphi(\omega)=-180^\circ-\operatorname{arctg}\frac{G_0}{G_\infty}T\omega+\operatorname{arctg}T\omega \qquad \text{when } G_0\prec 0.$$

The carried out analysis has shown that the dynamic stiffness characteristics of the steering drive depends substentially on its kinematic diagram [2]. The reason for it is that in case of a static or a dynamic load of the output link the deformation of the SD bearing support is being transmitted through the kinematic feedback system, or by other way, to the sliding valve, while on sliding valve a corresponding additional mismatch is being built $\Delta\varepsilon$, which is to be respat by the drive. Depending on the SD kinematic diagram the above-mentioned influence is equivalent to an additional positive or negative feedback in terms of load and has a considerable impact on the dynamic stiffness characteristics of the drive.

Figure 2 shows standard logarithmical frequency dynamic stiffness characteristics of steering drives of the kinematic diagrams under review.

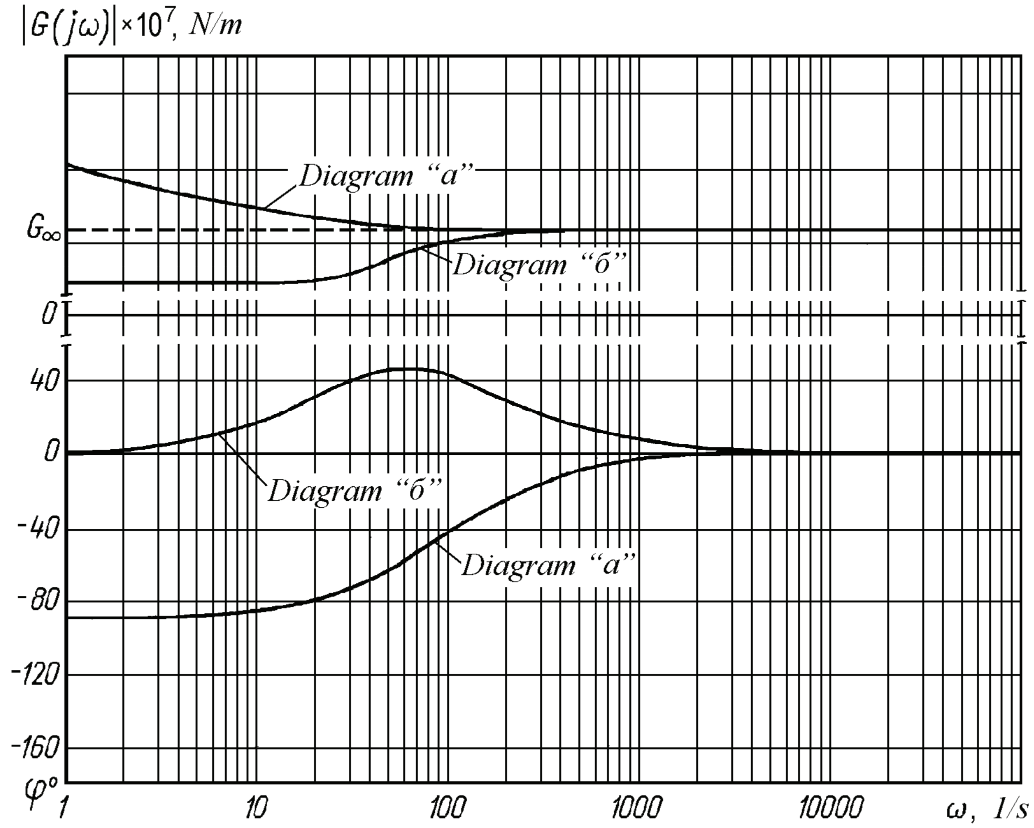

Figure 2. Standard logarithmical frequency dynamic stiffness characteristics of single-channel steering drives of various kinematic diagrams.

The analysis of the above-mentioned characteristics has shown that steering workdrivers with an "inverse kinematics" (Diagram "б" shown on fig. 1) demonstrate the maximum stability and the best antiflutter properties because only such drives have a phase-frequency characteristic of the dynamic stiffness in the range of positive values of phase shift between the external load $R(S)$ and the travel of the drive's output link $y(S)$, so they can be used for flutter oscillation damping of the steering surface without application of special correction links. The steering workdriver РП-56 of the control system of the Ту-154 airplane and also other drives used in rudder's control systems of modern aircraft are carried out according such a layout. An analytical influence of the drive's kinematic diagram on its dynamic stiffness can be determined by the ratio k_{def} / k_{fb}, which has an assential impact on the workdriver's statical stiffnes G_0. As follows from the table and the expressions (1), (2), only the drives with an inverse kinematics meet the condition $(k_{def} / k_{fb}) \succ 1$

that reduces the value G_0. With increasing the bearing support's stiffness C_o the antiflutter properties of the steering drives with the inverse kinematics are reducing.

According to the findings of the studies there is a univocal correspondence between the dynamic stiffness characteristics of the steering workdriver and its stability. The steering drive is stable if its static stiffness $G_0 > 0$ and the following condition is met:

$$\frac{G_\infty}{G_0} \succ 1 - \frac{h^\bullet}{mD}, \qquad (3)$$

where $h^\bullet$ – an equivalent coefficient of viscous frictions in the power circuit of the booster control system; m – a weight of the steering surface reduced to the drive's output coordinate, D – the quality factor of the drive.

The analysis of the SD stability conditon (3) confirms the conclusions made up in the works [2, 4] of a higher stability of steering drives with an "inverse kinematics". Their application may help to solve the stability problem of the SD booster control systems working under conditions of significant inertial loads and a low proper damping of steering surfaces.

Summery.

The following conclusions may be drawn from the studies carried out:

1. To ensure required antiflutter properties of the booster control system, the highest possible stiffness of the power circuit, i.e., "steering surface – steering drive – drive's bearing support" should be provided. To meet this condition, the power circuit system of aircraft booster control system should be designed with an appropriate static stiffness G_0, but in this case the SD stability problem due to considerable inertial loads on its output link is to be solved.

2. In order to solve the stability problem of the steering drive fully and to reduce the flutter oscillations, it is advisable to use in the power circuit of the booster control system steering drives with an inverse kinematics (s. Diagram "*б*"), to increase the stiffness $C_г$ of the hydraulic spring of the drive as much as possible (e.g., by minimizing "dead" volumes of liquid in its cavities and by application of other appropriate constructive decisions), and also to decrease the static stiffness G_0 of the drive, taking into consideration the maximum permissible sagging of the aircraft steering surface under aerodynamic loads during the flight.

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AEROTHERMODYNAMIC OPTIMIZATION OF AERO-JET ENGINES FOR MIDDLE AND LONG RANGE AIRCRAFT

Abstract

The main objective of the present study is to perform aerothermodynamic optimization of aero-engines for middle and long range commercial aircraft. For solving optimization problem a new software program is developed in MATLAB programming language, while objective function is determined for minimizing the specific fuel consumption. The input variables included the fan pressure ratio (π_f) and the bypass ratio (α).As a conclude software program developed can successfully solve optimization problems at $1.2 \le \pi_f \le 2$ and $2 \le \alpha \le 10$ with aircraft cruise flight Mach number ≤ 0.8.

Keywords: *High Bypass Turbofan Genetic Algorithm, Fan, Bypass Ratio*

INTRODUCTION

For making aero-jet engines applicable for all types of aircraft, the following development goals were being pursued:

- Higher overall efficiency
- Larger-power-output engines
- Larger ratios of power output to engine weight, volume, and frontal area
- Greater service life, endurance, and reliability
- Reduced noise

Highest possible thermodynamic and propulsive efficiencies of aircraft propulsion systems led to the following engine characteristics:

- Very high compressor pressure ratios
- Very high turbine inlet temperature
- Very high bypass ratios

The advantages of the turbofan engines for long and middle range aircraft can be summarized as follows:

- High overall efficiency, resulting in long flight range
- Lower jet velocity, which leads to great noise reduction
- Increase in thrust
- Low specific fuel consumption, which reduces chemical emissions

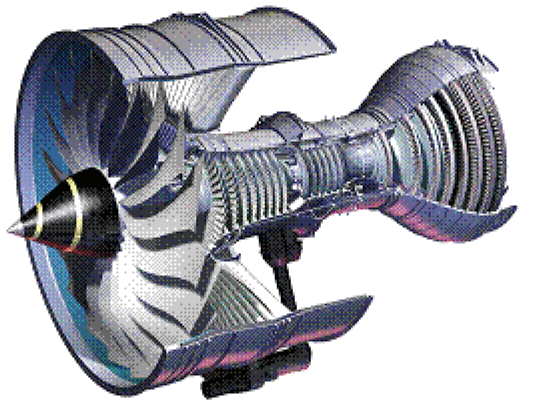
In this paper, we report the development of a modular aircraft high bypass turbofan engine simulation in the MATLAB (Matrix Laboratory) environment. A new software program was developed for multi-design point optimization of a high bypass turbofan engine. Newly developed software program is TURBOGENf (Turbofan Genetic Fan). It can search optimum thermodynamic points of a high bypass turbofan engine couple with elitism-based Genetic Algorithm method (EBGA) for minimum specific fuel consumption (Turan, 2008).

AERO-JET ENGINE MODELLING

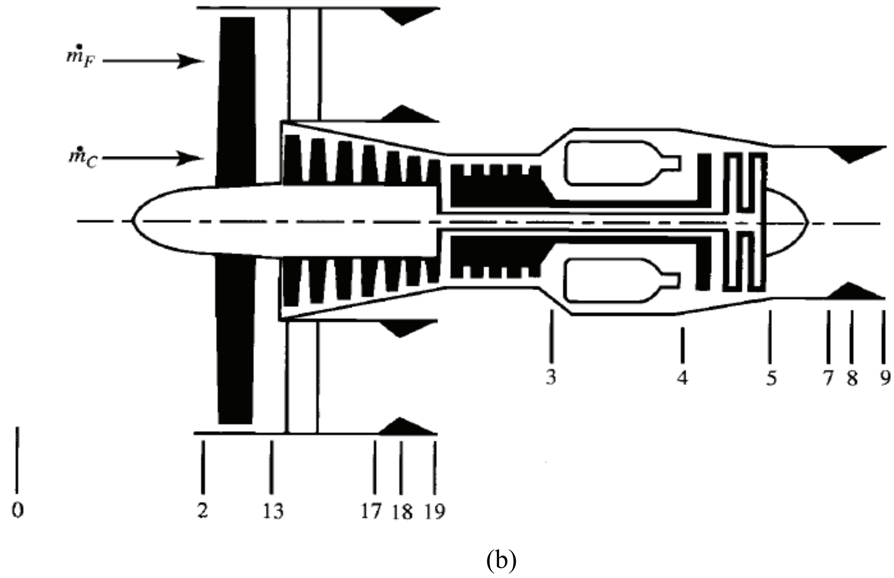
In the following, we focus on a particular type of jet engine: the separated flows and non afterburbing turbofan. With the current level of technology, this one has revealed to be the optimum configuration for high subsonic commercial aircraft (Cumpsty, 2000).

The assumptions for the analysis of the turbofan engine cycle with losses are as follows:

- Perfect gas upstream of main burner with constant properties γ_c, R_c, C_{pc}
- Perfect gas downstream of main bumer with constant properties γt, Rt, Cpt
- All components are adiabatic (no turbine cooling)
- The efficiencies of the compressor, fan, and turbine are described through the use of (constant) polytropic efficiencies e_c, e_f, and e_t, respectively.



(a)



(b)

Figure 1. a) *Aero-jet engine b) station numbering of aero-engine (Mattingly, 1996)*

Parametric cycle equations are given from Mattingly (1996). In these cycle analyses, specific thrust is shown in Eq.1.

$$\frac{F}{\dot{m}_0} = \frac{1}{1+\alpha}\frac{a_0}{g_c}\left[(1+f)\frac{V_9}{V_0} - M_0 + (1+f)\frac{R_t T_9 / T_0}{R_c V_9 / a_0}\frac{1-P_0/P_9}{\gamma_c}\right] +$$

$$\frac{\alpha}{1+\alpha}\frac{a_0}{g_c}\left(\frac{V_{19}}{V_0}-M_0+\frac{T_{19}/T_0}{V_{19}/a_0}\frac{1-P_0/P_{19}}{\gamma_c}\right) \tag{1}$$

Specific fuel consumption can be also seen Eq.2.

$$SFC=\frac{\dot{m}_f}{F}=\frac{f}{(1+\alpha)F/\dot{m}_0} \tag{2}$$

ELITISM-BASED GENETIC ALGORITHM METHOD

Genetic algorithms, introduced by John Holland (1975) are being more and more employed to solve problems involving search and optimization operations, mainly due to the robustness and simplicity they offer. Genetic algorithms are computational models that simulate the natural processes of selection and evolution originally found in the nature, where the more apt individuals have higher probability to survive, to reproduce and to transmit their genetic characteristics to next generations. Genetic algorithms allow performing elegant and robust searches and they also allow applying optimization methods, which are specially useful to find answers in complex or poorly understood search spaces.

In genetic algorithms, each potential solution existing in the search space is considered as an individual. An individual is represented by a string of symbols, called a chromosome. Each symbol in a chromosome is called a gene, which is the part of a chromosome that codifies a specific characteristic of the individual. The literature present several ways to encode the individuals in chromosomes for a variety of applications, but there are no previous attempts to encode individuals aiming similarity search.

Starting from an initial population, the genetic operators of selection, crossover and mutation are cyclically applied, creating new generations of individuals (Goldberg, 1989). At the end of the evolution process, the answer will be the individuals in the population having the best fitness.

In the nature, the selective pressure is exerted by the ambient. In the computational context, it is simulated by the application of an objective function that evaluates each individual's fitness. Usually genetic algorithms have two problem-dependent components: how to encode the solution space as chromosomes, and how to define the objective function (Whitley, 1994).

The main genetic operators are:

Selection: this operator is applied after calculating the fitness, selecting individuals from the current population

for reproduction;

Crossover: the crossover operator creates new individuals recombining genetic characteristics from its parents;

Mutation: this operator randomly modifies an individual's genetic code. It is a random movement in the search space, required to guarantee genetic diversity of the population and to avoid the algorithm to stuck at a local, partial solution.

The genetic algorithm is executed until a stop condition is satisfied. An usual condition is to set a maximum amount of time to execute the query, so when the time is up the execution ends.

One of the most common technique used to perform selection is the roulette wheel technique, where the space occupied in the roulette by each individual (and thus its chance to be selected) is proportional to its fitness. Therefore, individuals not well-fitted for the answer tend to extinguish, while the more apt tend to reproduce and maintain their characteristics in future generations.

The mutation operator modifies an individual's genetic code. The probability of occurring a mutation is controlled by the user-defined parameter , usually set to a small value. When a mutation happens, a gene is randomly modified in the individual's chromosome. Mutations prevent search stagnation, enabling the exploration of search space's areas that could not be reached with crossover operator, depending on the initial population. After executing the three genetic operators, a new population is generated and a new cycle begins. Fig. 2 presents the general scheme of a elitism-based genetic algorithms.

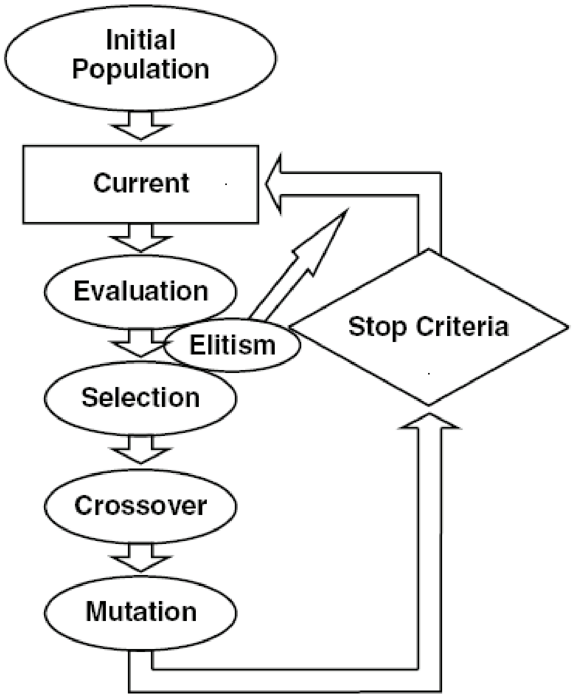


Figure 2. *Outline of execution of the elitism-based genetic algorithm*

ELITISM-BASED GENETIC ALGORITHMS IN TURBOGENF

TURBOGENf is a software program developed by Turan (2008) in MATLAB programming environment. It covered three distinct part. First of it is parametric calculation section of a high bypass turbofan engine. The second section covers elitism-based genetic algorithm and the last one is 3-D color scaled performance curves of the commercial turbofan engine.

Aim of the current study is minimizing *SFC*, which is objective function in TURBOGENf. It can be show in Eq. (3) as follows:

$$Min(SFC)_i = \frac{f_i}{(1+\alpha)_i (F/\dot{m}_0)_i}, \quad \mathrm{i} = 1,2,...,\mathrm{Gn} \tag{3}$$

Population of each generation is constituted two decision variables: fan pressure ratio (π_f) and bypass ratio (α). Flowchart of the TURBOGENf can be shown in Fig.3.

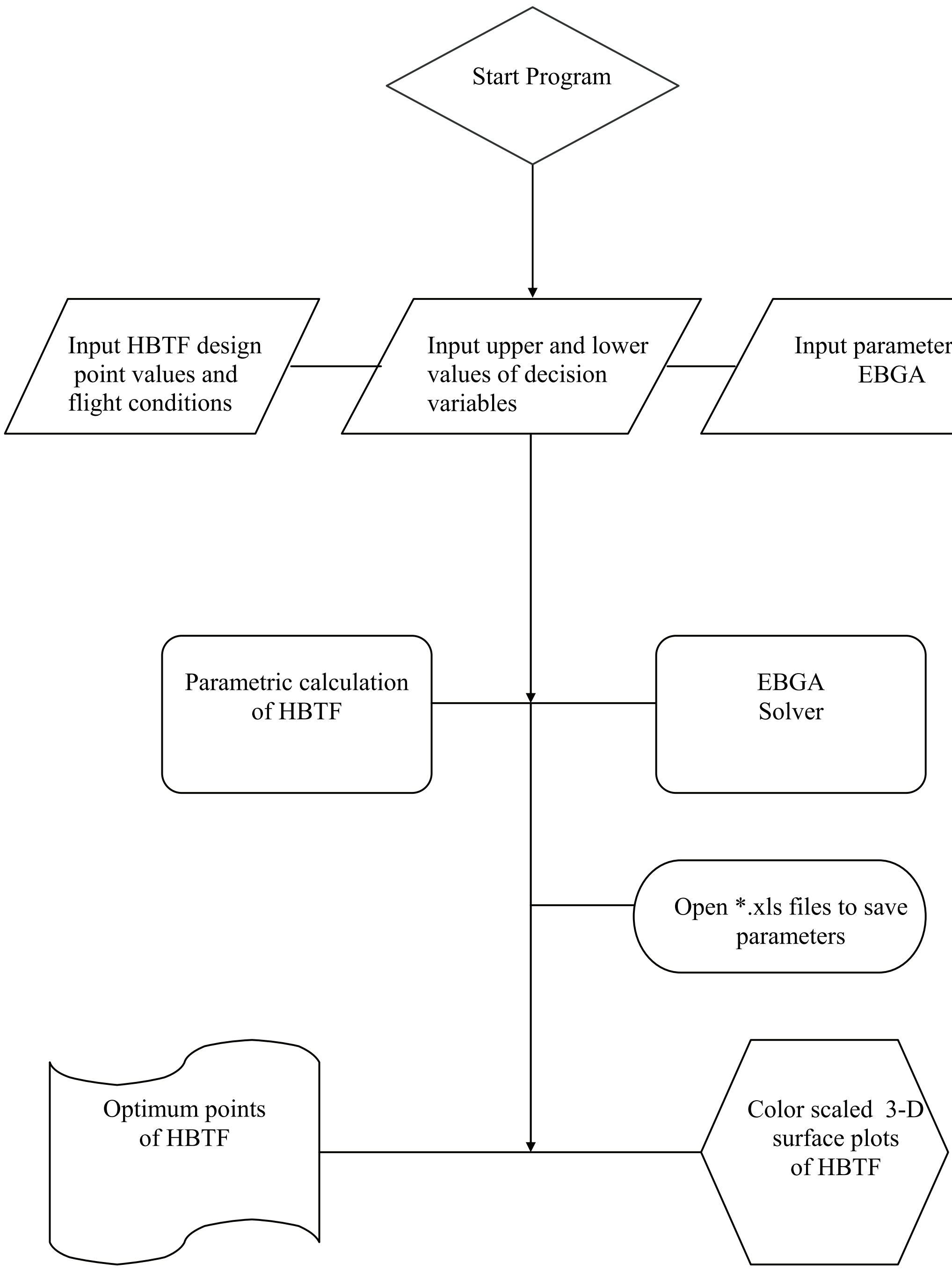


Figure. 3 *Flowchart of TURBOGENf*

TURBOGENf is a software program developed in MATLAB programming environment which analyses parametric cycle of a non afterburning, separate exhaust flows turbofan engine at different design points in SI unit and get optimum design points at different flight conditions and design criteria via elitism-based genetic algorithm simultaneously. Main purpose of TURBOGENf is minimizing specific fuel consumption of a high bypass turbofan engine under different design criteria . Decision variables of TURBOGENf are fan pressure ratio and bypass ratio. It is possible to see some 3-D performance curves of an engine in TURBOGENf. TURBOGENf can be able to draw 3-D color scaled counter plot corresponding to specific fuel consumption coupled with decision variables such as fan pressure ratio and bypass ratio. Table 1 and Table 2 consists of design points of an example turbofan engine and genetic algorithm's parameters for computer experiment respectively. Objection function is also shown in Fig.4 in this experiment.

Table 1. *Flight conditions and design-point parameters of TURBOGENf*

M_0	T_0 (K)	h_{PR} (kJ/kg)	π_c	T_4(K)	Cpc kJ/(kg.K)	Cpt kJ/(kg.K)	γ_c	γ_t
0.8	220	43100	15	1500	1.00488	1.147	1.4	1.33
p_{t4}/p_{t3}	p_{t19}/p_{t13}	e_c	e_f	e_t	η_b	η_m	p_0/p_9	p_0/p_{19}
0.99	0.99	0.90	0.89	0.89	0.99	0.99	0.90	0.90

Table 2 .*Genetic algorithm parameters of TURBOGENf*

$(\pi_f)_{min}$	$(\pi_f)_{max}$	has_{π_f}	α_{min}	α_{max}	has_α
1.2	2	0.1	2	8	0.1

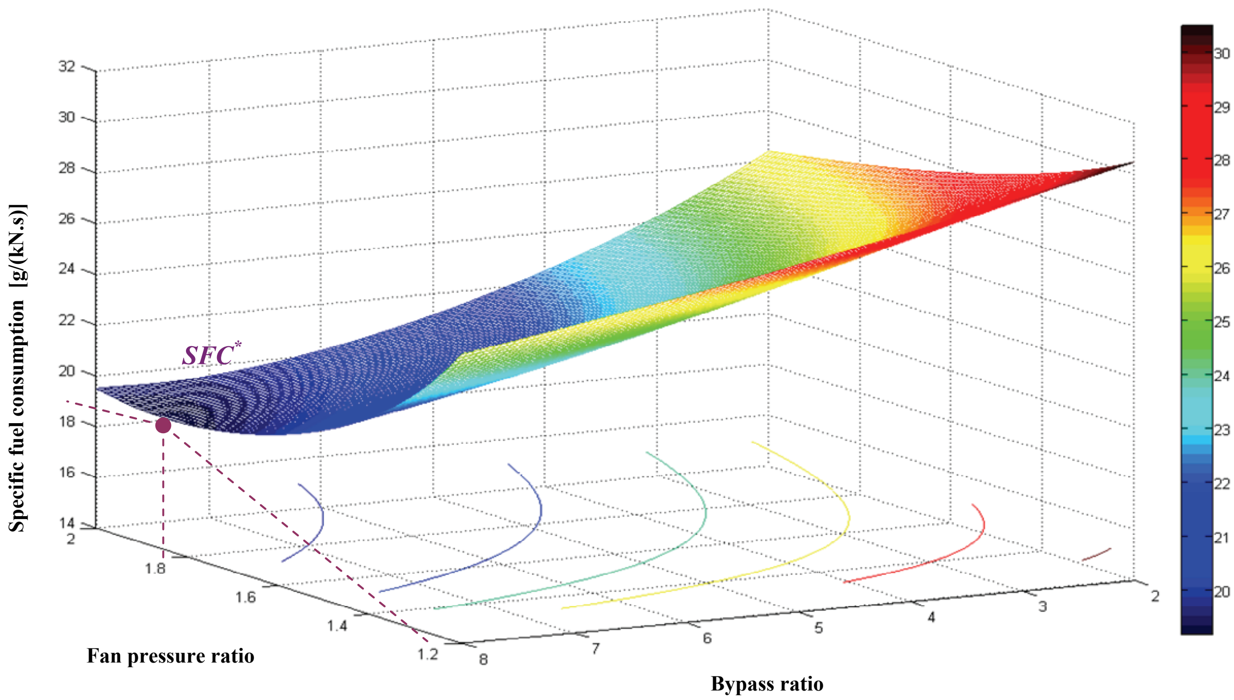


Figure 4. *Specific fuel consumption -fan pressure ratio-bypass ratio 3-D curves in TURBOGENf*

CONCLUSION

In this study, elitism-based genetic algorithm method was applied for minimum specific fuel consumption of high bypass turbofan engine in the conceptual design phase. In this regard, TURBOGENf software program was developed. Decision variables in this software were fan pressure ratio and bypass ratio. The main conclusions drawn from the results of the present study may be listed as follows:

a) Depending on the application, it can be seen that elitism-based genetic algorithm method is successful tool for solving this optimization problem. The ability of a elitisim-based genetic algorithm to provide a family of optimal solution to this particular problem has been demonstrated.
b) Optimization problem was solved easily in TURBOGENf.

c) TURBOGENf can successfully solve optimization problems at $1.2 \le \pi_f \le 2$ and $2 \le \alpha \le 10$ with $M_0 \le 0.8$.

d) 3-D color scaled surface performance plots of a high bypass turbofan engine can be drawn easily from TURBOGENf.

e) It can be observed that Gn>200, Pn>300 and Mr=0.003 are sufficient for yielding optimum points in TURBOGENf.

However, it has to be realized that the proposed application is rather academic. First, constrained problem could be considered. Then, additional effects, such as the weight, noise, exergy efficiency and thrust of the commercial engine or its pollutant emmissions should be introduced in the model to define new figures of merit.

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ENERGY ANALYSIS OF PISTON-PROP AIRCRAFTS AT VARIOUS ALTITUDES

Summary

This study deals with investigating the effect of varying altitude values on energy efficiency in a typical four cylinder, naturally aspirated, spark ignited reciprocating engine. In this regard, the minimum and maximum energy efficiency values are calculated to be 11.41% and 23.64% in altitudes of 3000 m and 500 m, respectively. The maximum energy efficiency is obtained at a maximum engine power and rated power setting.

Introduction

Piston-prop aircraft is a combination of a reciprocating engine and a propeller. This type of aircraft has been widely used around the world. A half of the flight operation is operated in this type of aircraft. Naturally aspirated-spark ignited reciprocating engines have been generally applied to this system.

Because of the naturally aspirated inlet air, the mass flow into the engine is directly affected by the outside air density (altitude, temperature, and humidity) and intake manifold pressure. This problem can be dissolved by using a supercharging system in an engine. At an altitude of 6000 m, a piston engine has less than half of its sea-level horsepower [1].

$$\mathrm{HP} = \mathrm{HP_{SL}}\left(\frac{\rho}{\rho_0} - \frac{1-\rho/\rho_0}{7.55}\right) \tag{1}$$

The horsepower is a critical parameter for energy analysis. So, it is important to determine that how much horsepower aircraft has at an indicated altitude.

Besides, an engine power is rated in a control panel. This helps in designating an engine power and hence fuel consumption. Cruising is done at a rated power setting between 65% and 75%. While a rated power setting of 75% is called a performance cruise, that of 65% is called the economy cruised [2].

Energy analysis

During a steady-state process, the total rate of mass entering the control volume is equal to the total rate of mass leaving [3]:

$$\sum \dot{m}_{in} = \sum \dot{m}_{out} \tag{2}$$

the total energy content of a control volume remains constant during a steady-state process as follows [3].

$$\dot{E}_{in} = \dot{E}_{out} \tag{3}$$

$$\dot{Q}_{in} + \dot{W}_{in} + \textstyle\sum_{in} \dot{m}\left(h + \frac{V^2}{2} + gz\right) = \dot{Q}_{out} + \dot{W}_{out} + \textstyle\sum_{out} \dot{m}\left(h + \frac{V^2}{2} + gz\right) \tag{4}$$

where the subscripts in and out represent inlet and output states, respectively. While $\dot{Q}$ denotes the heat rate, $\dot{W}$ the work rate, $\dot{m}$ the mass flow rate, h the specific enthalpy, *V* the velocity, *g* the gravitational acceleration and *z* the elevation of the center of gravity of a system relative to some arbitrarily selected reference level [3]. Here, the work value for the design altitude or motor performance rates is found using Equation (1).

Energy input rate to a control volume is obtained from the lower heating value, H_u and mass flow rate of fuel, $\dot{m}_{fuel}$, changes with altitude as follows:

$$\dot{E}_{fuel} = \dot{m}_{fuel} H_u \tag{5}$$

Energy efficiency of the control volume is defined as the ratio of the net work rate to the fuel energy input rate as follows:

$$\eta = \frac{\dot{W}}{\dot{E}_{fuel}} \tag{6}$$

Results and discussion

In this study, we calculated energy efficiency changes with altitute for a typical four cylinder, naturally aspirated, spark ignited reciprocating engine. The results are obtained using a mathematical program in MATLAB. Energy efficiency is directly affected by the altitude, power setting and engine power.

As shown in Figure 1, while energy efficiency reduces 7.88 to 7.76 at a fixed power setting rating, it decreases 0.35 to 0.23 at a fixed engine power in an altitude of 500 m.

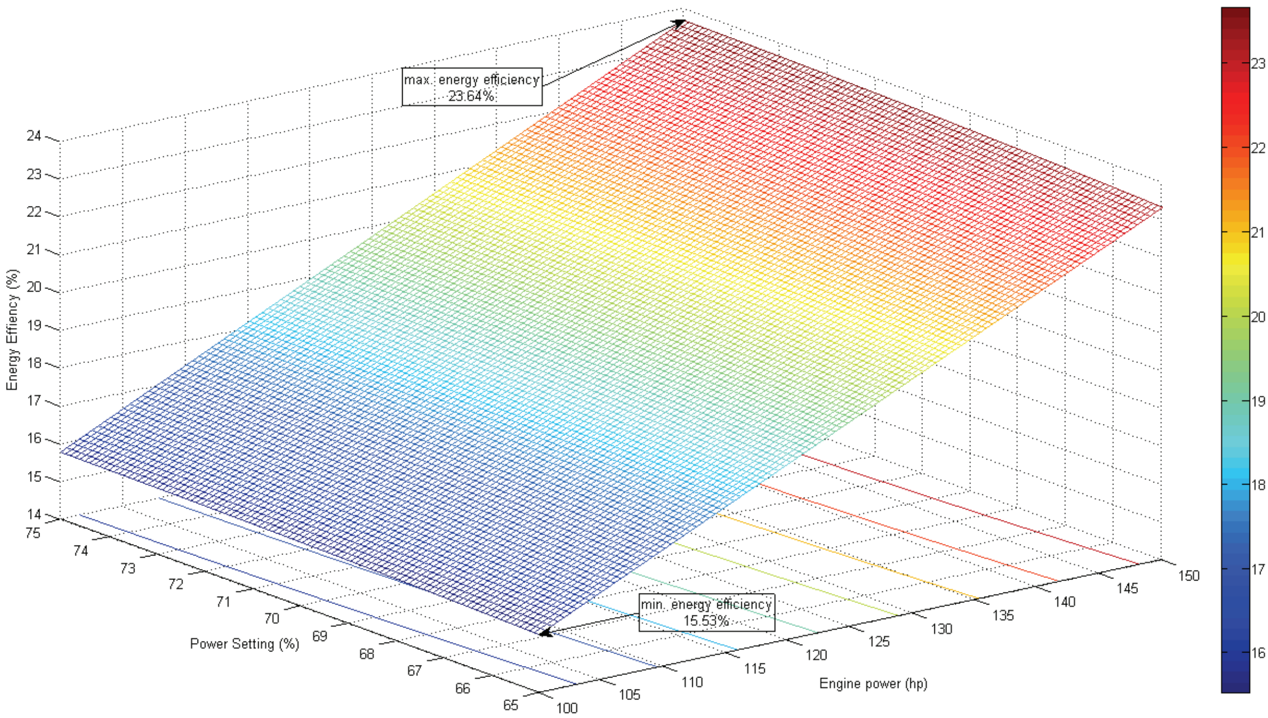

Figure 1. Energy analysis changes with engine power and power setting at 500 m altitude.

While energy efficiency decreases 7.43 to 7.31 at a fixed power setting rating, it declines 0.34 to 0.22 at a fixed engine power in an altitude of 1000 m (Figure 2).

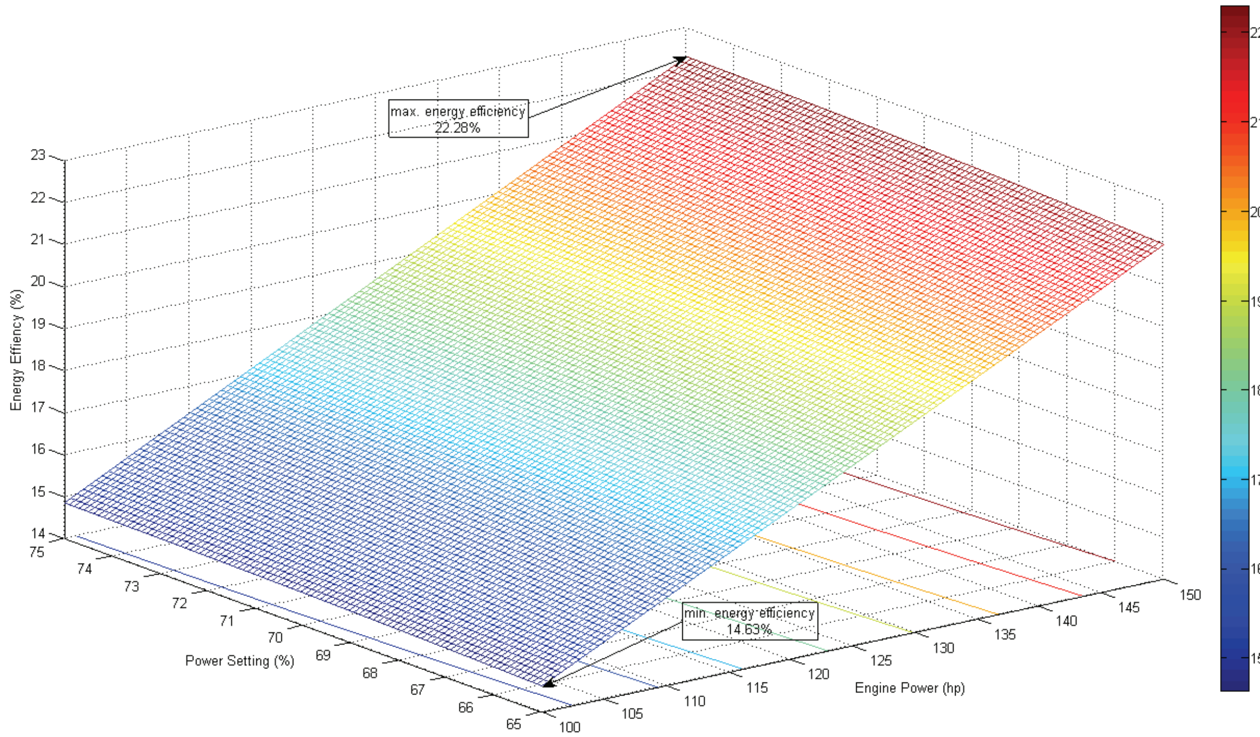

Figure 2. Energy analysis changes with engine power and power setting at 1000 m altitude.

While energy efficiency is dropped 6.58 to 6.47 at fixed power setting rating, it lowers 0.3 to 0.19 at a fixed engine power in an altitude of 2000 m (Figure 3).

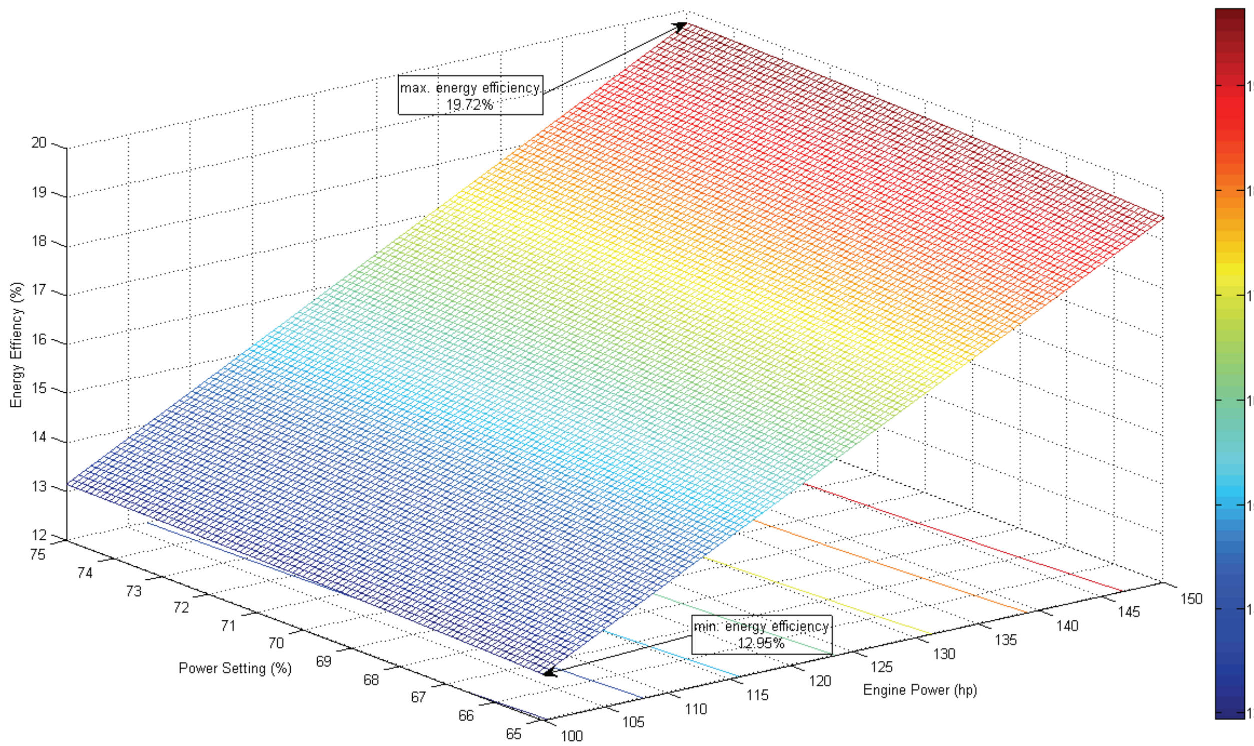

Figure 3. Energy analysis changes with engine power and power setting at 2000 m altitude.

While energy efficiency drops 5.79 to 5.7 at a fixed power setting rating, it decreases 0.26 to 0.17 at fixed engine power in 3000 m altitudes (Figure 4).

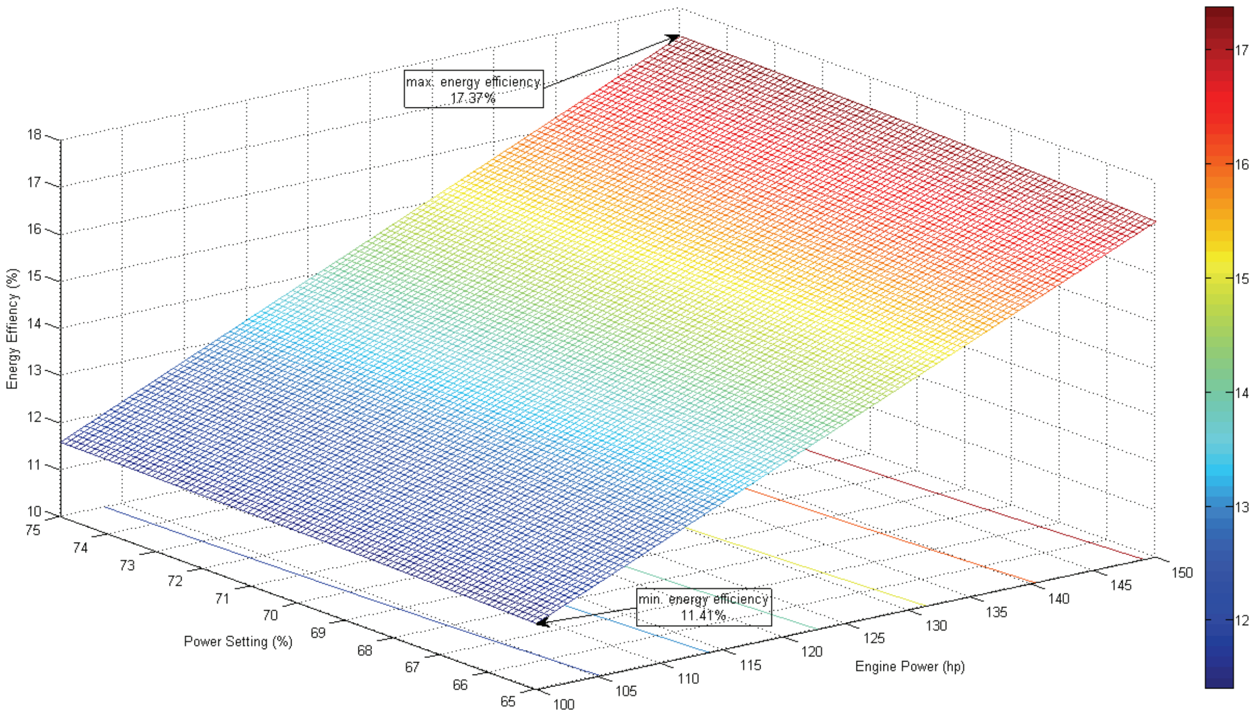

Figure 4. Energy analysis changes with engine power and power setting at 3000 m altitude.

All parameters studied are shown in Table 1.

Table 1. Energy efficiency variations with altitude.

Altitude (m)	**Energy Efficiency (%)**			
	Maximum		***Minimum***	
500	23.64	*150 HP engine power and 75% rated power setting*	15.53	*100 HP engine power and 65% rated power setting*
1000	22.28		14.65	
2000	19.72		12.95	
3000	17.37		11.41	

Conclusion

While the maximum energy efficiency is obtained to be 23.64% at an engine power of 150 HP and a rated power setting of 75% in 500 m, the minimum energy efficiency is found to be 11.41% at an engine power of 100 HP and a rated power setting of 65% in 3000 m. Energy efficiency decreses with three parameters, increasing altitudes, decreasing engine power and decreasing rated power setting. If the best energetic flight is desired, the flight altitude is preferred in its lower border.

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RELATIONAL DATABASE MODEL FOR STORAGE OF STATISTICAL DATA AND DIAGNOSIS OF GTE WITH THE HELP OF PARAMETERS THAT ARE REGISTERED AT OPERATING CONDITIONS.

Paper is devoted to the problem of aeroengines monitoring. Deviations from operating parameters of GTE being the evidence of some damage or engine fault, and data collection and processing technology has discussed for different combination of the various parameters changes of engine АИ-25 operation

Problem of input data choosing

The theoretical solution of the problem of diagnosing gas turbine engine (GTE) 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.

Creating automated systems for technical diagnosis improves the uptime of facilities due to early detection of conditions conducive to failure, which will significantly reduce costs in the operation and management of gas turbine engine.

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 difficult to account for factors that influence the technical condition of the 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 point 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. Such initial input parameters as air pressure, temperature in different engine sections, rotors speeds and fuel consumption, which will be transformed in more useful parameters such as pressure ratio – π_k, rotors work – L_{lpc}, L_{hpc} and efficiency η and others, are more helpful and precise in estimation of engine diagnosis.

The input data:

1. Temperature after LPC, HPC, LPT
2. Pressure after LPC, HPC, LPT
3. Fuel consumption
4. LPC and HPC rotor speeds

Registered values of АИ-25 engine which correspond to normal condition, which are used, are given in table 1.

Table 1

Registered values of АИ-25 engine

Controlled parameter	Engine modes			
	Idle	0,4 Nominal	0,6 Nominal	0,85 Nominal
Nhpc, rpm	8920	12870	14030	15020
Nlpc, Rpm	3700	6140	7410	8580
Gf, kg/hr	193	280	392	487
Te, K	288	288	288	288
Pe, kg/cm^2	1,03	1,03	1,03	1,03
Thpc, K	283	287	291	294
Phpc, kg/cm^2	1,09	1,24	1,35	1,44
Tc, K	333	438	500	546
Pc, kg/cm^2	1,76	3,35	4,29	5,18
Tt, K	685	650	677	721
Pt, kg/cm^2	1,05	1,12	1,17	1,24

Typical operational faults and damages of GTE flow part are: inlet duct clogging, erosion of inlet duct, LPC blades clogging, extension of radial gaps in LPC, LPC blades nicks, LPC rotor RPM limit exceed, first and last stages HPC blades clogging, HPC blades erosion, extension of radial gaps in HPC stages, HPC rotor RPM limit exceed, burnout, cracks in combustion, carbonization or clogging of fuel injectors, corrosion of HPT and LPT blades, carbonization of HPT and LPT blades, nozzle shape deformation.

Database Input Data

The input data is represented as a set of numerical values which correspond to values given in Table 1. The table is created in database, where fields are named as parameters (P_e, T_{hpc}, etc.) Each row of the table represents the reference value of parameter at each engine mode. The reference table is shown below (table 2).

Table 2

Reference table

Id	nhpc	nlpc	Gf	Te	Pe	Thpc	Phpc	Tc	Pc	Tt	Pt	Regimes
1	8920	3700	193	288	1,03	283	1,09	333	1,76	685	1,05	Idle
2	12870	6140	280	288	1,03	287	1,24	438	3,35	650	1,12	0,4 Nominal
3	14030	7410	392	288	1,03	291	1,35	500	4,29	677	1,17	0,6 Nominal
4	15020	8580	487	288	1,03	294	1,44	546	5,18	721	1,24	0,85 Nominal

Parameters have relations which have logical connection in database. Series of tables with data and relational connections between them generate the architecture of the database, which is shown on fig.1.

Before entering parameters user must choose the engine mode. Once it is chosen, user can enter the data in necessary fields, after filing all fields the save button has to be clicked. Clicking this button will automatically enable this data to be saved in table called by the name of chosen engine mode. Then user has an opportunity to fill a new set of fields and also change it using bottom control buttons. This is only a first stage of diagnostics, called data entry.

Once we've created tables, it is more preferable to create a visual form for entering parameters, taken from sensors. A main window for data entry is shown on figure 2.

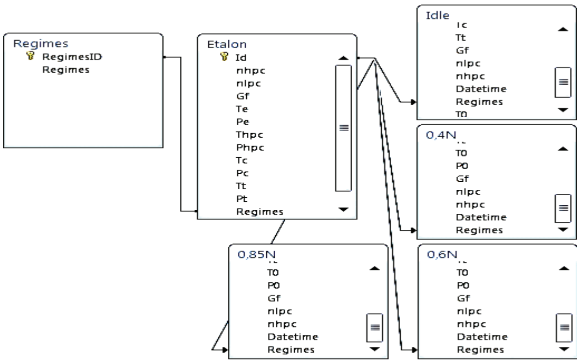

Figure 1. Architecture of the database

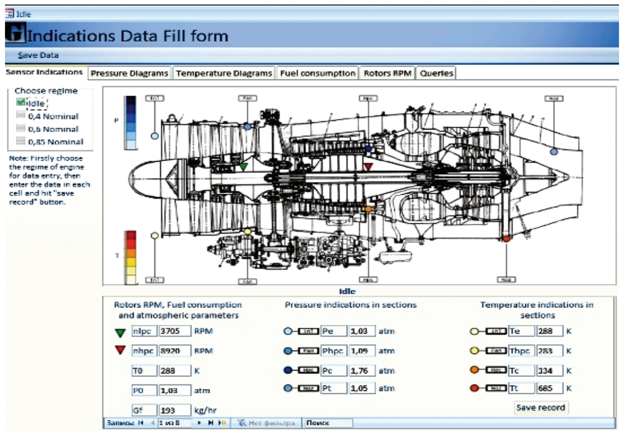

Figure 2. Database interface

Building queries

Queries are built on the basis of table's content. It is a very powerful instrument for data sorting and calculating. Our queries will be designed in such way, that for every engine part (inlet duct, LPC, etc) will be considered each engine mode with necessary parameters.

Figure 3 represents a query for inlet duct at idle engine mode.

This query consists of three related tables, and each is necessary for inlet duct diagnosis estimation.

Using query

Now let's consider the last tab of the database form which is called "Queries". This is the most important tab, where knowledge base and queries are stored. This tab can give the full information about engine faults, defects and provides search of faults in whole database (figure 4).

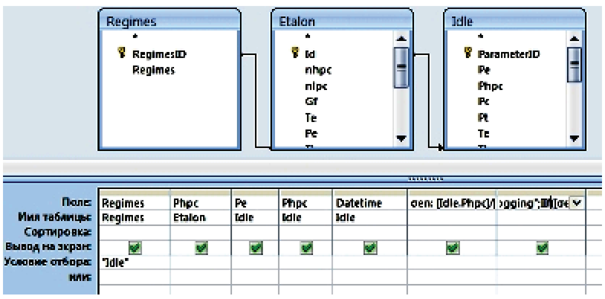

Figure 3. Query for inlet duct diagnosis at idle mode

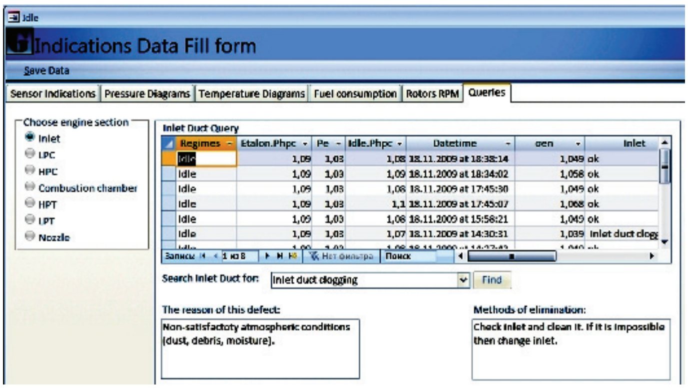

Figure 4. Query tab view

In this tab user should choose engine part (in our case Inlet duct is selected) then in a field which is called "Search inlet duct for:" user have a possibility to choose one of several faults which Inlet Duct should be searched for. While user is selecting the possible fault, two windows below will automatically filled with tips for fault elimination and possible reasons of fault occurrence. This event uses knowledge base which is divided on two parts. First part consists of database table with possible faults of chosen engine part, which is related to search combo box. And a second part consists of VBA (Visual Basic for Applications) programming code, which is implemented in search combo box and include tips and reasons inside itself.

Logical expressions and functions construction for diagnosis estimation

Consider a parameter $\boldsymbol{\sigma_{en}}$ which was calculated in inlet duct query for idle mode. It is called total pressure coefficient, which equals to $\frac{P_{hpc}}{P_e}$. According to this parameter we can make a conclusion about Inlet duct condition. Let's consider inlet duct clogging and inlet duct erosion. Clogging of inlet duct appears due to non-satisfactory atmospheric conditions (dust, debris, moisture), when small particles stick to the surface of inlet duct. And erosion may be caused by mechanical effects on a surface of inlet (friction, scratch, etc). Now the main question is – how to get query field to be calculated and to estimate a diagnosis of the inlet duct on the basis of $\boldsymbol{\sigma_{en}}$ parameter? The fact is that query fields may not only represent a table data, but they can make calculation (figure 5).The expression: $\boldsymbol{\sigma_{en}}$:[Idle.Phpc]/[Idle.Pe] means that every value from table "Idle" of "Phpc" field must be divided by "Pe" field value of same table. And the field name will be $\boldsymbol{\sigma_{en}}$. The function IIf is a special control function, which has three output bytes, they are: IIf("expression";"true part";"false part"), the "expression" means a mathematical expression which shows a condition, function or a value. In our case it shows that if $\boldsymbol{\sigma_{en}}$ is less than value of 1,04 then write text "Inlet duct clogging" – this condition is executed if it is true. This was the true part. The false part: if condition that $\boldsymbol{\sigma_{en} < 1{,}04}$ is not true, we consider next condition that means the same, but it has the value $\boldsymbol{\sigma_{en} < 1{,}048}$ and if it is satisfied then "Erosion of inlet duct surface" text will be written. These conditions represent faults of inlet duct because the ratio $\frac{P_{hpc}}{P_e}$ is too low for accepting the fact of normal inlet duct operation. For example the reference value of $\frac{P_{hpc}}{P_e}$ is $\frac{1{,}09}{1{,}03} = 1{,}0582$ but when pressure behind LPC (it is called P_{hpc} because it is on inlet to the HPC) is 1,07 which tells us about abnormal inlet duct condition because pressure is less that a clean inlet duct has. We can make a conclusion that something prevents inlet duct for normal operation. It may be clogging. So according to these reservations we have to use a range of permissible values for inlet duct or other engine part to estimate whether its normal condition or abnormal. Next we have a condition again that if $\boldsymbol{\sigma_{en} < 1{,}048}$ is false then if $\boldsymbol{\sigma_{en}}$ lies between values 1,048 and 1,16 - it may be considered as normal operation condition. And then in other cases if nothing else satisfy our conditions (means that the value more than 1,16) – write that "Pressure limit exceeded" which is impossible for idle mode operation. This means that our control levers have faults in their inclination degree setting and they must be regulated because it is no longer an idle mode.

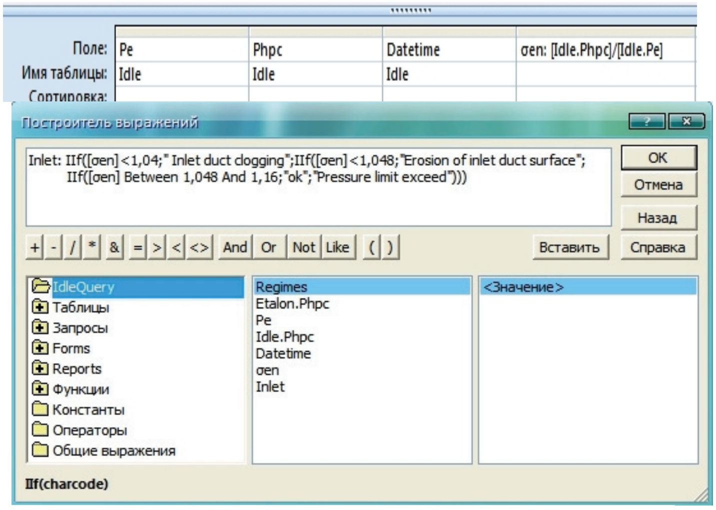

Figure 5. Representation of calculated query field, based on logical operations

Conclusion

Computer Information and Communication Technologies became a necessary aid applied for different purposes in the area of aerospace systems. Knowledge-Based Systems become more and more popular for the decision making support purposes

The most important aspect of a knowledge base is the quality of information it contains. The best knowledge bases have carefully written articles that are kept up to date, an excellent information retrieval system (search engine), and a carefully designed content format and classification structure.

Some knowledge bases have an artificial intelligence component. These kinds of knowledge bases can suggest solutions to problems sometimes based on feedback provided by the user, and are capable of learning from experience.

Databases provide data storage, replenishment, sort and easily manipulate with numerical, text, graphical information. Including knowledge base can expand possibilities of learning, predicting and diagnose GTE faults in our case. Also it decreases time, spent on manual data sort and solution on different problems helps rapidly in search of necessary information and reduce costs on GTE diagnostics.

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RESEARCH OF INFLUENCE OF THERMAL RESISTANCE OF ELEMENTS OF TRYBOSYSTEM ON WEARPROOFNESS OF FRICTION UNITS

Annotation
In the paper the results of the research of trybosystem the specimen's thermal resistance influence on wear resistance of friction units under boundary lubrication

Introduction

The reliability of equipment widely used in petrochemical, gas-processing, power, aerospace and other industries is largely determined by the resource of trybosystems, which operate in the conditions of the high mechanical and temperature loading including the conditions of aggressive environments. The increased wear rate of trybosystems results in the considerable financial and technical expenditures [1].

In this respect, the new school of engineering of friction surfaces is being developed intensively over the last few decads, within the framework of which the search of new untraditional ways of increase of trybosystems' wear resistance based on the modern understanding of self-organization of the open thermodynamic systems, first discovered by Ukrainian school of B.I. Kostetsky, is conducted [2]. Self-organization processes may run in a trybosystem for some materials at certain conditions. Wear particles migrate repeatedly from one friction surface onto another always remaining in the friction zone. The selective transfer mode is a wearless process per se.

The assumption that there is the possibility of transition of trybosystems to minimum wear rate (wearless mode) because of the purposeful action from outward (thermal stream, power, radiation and other) is the basis of this school of knowlege.

Therefore the study of influence of trybosystem specimen's thermal resistance on wear resistance of friction units under boundary lubrication is a topical question that will allow the programming of operating properties of trybosystems at the design stage.

Materials and Research Methods Applied

Two pairs of specimens made of 30ХГСА steel and ЛС-62-1,5 brass have been prepared. М10Г2К (ГОСТ- 8581-78) used as a lubricating environment (expense of working liquid - 1,2 l/hour). Testing of specimens was performed with the help of the automated trybodiagnostic complex [1] according the "plane-plane" scheme in line with the certified methodology of wear test with the constant loading.

Speed of rotation of the friction machine transmission shaft was approximated to the condition of modeling units operation, and it was equal to 400 rpm. The loading was equal to 1000 N. The choice of testing pattern, loading, materials and lubricating environment was conditioned by the design of axialpiston hydraulic machines used in modern aviation. At the experimental stage of the researche the friction coefficient and average temperature of surface of trybology contact were registered simultaneously. Mass wear was measured by periodical weighing, and linear wear was determined with the help of micrometer.

Experimental Research

In accordance with the results of experiments held earlier [2,3,4], a thermal stream spreads from a more heated specimen of friction pair to a colder specimen of friction pair at the least thermal resistance. Thus thermal resistance of specimens is calculated according to the following inequality:

$$\frac{\delta_c}{\lambda_c F_c} + \frac{\delta_o}{\lambda_o F_o} \neq \frac{\delta_L}{\lambda_L F_L}, \tag{1}$$

where δ_c – thickness of the steel specimen;

λ_c – coefficient of steel heat-conduction;

F_c – area, through which a thermal stream is conducted or the area of friction of the steel specimen;

δ_o, λ_o, F_o – thickness of friction contact of steel and brass specimens, coefficient of friction contact heat-conduction, area of friction respectively;

δ_L, λ_L, F_L – thickness, rate of heat-conduction and area of brass specimen respectively.

For the selected trybosystem, the left part of inequality (1) is equal to 4,19 K/W, and the right part to 0,75 K/W. Thus, the thermal stream which is mainly generated in the brass specimen will not spread through friction contact to the steel specimen as their sum total thermal resistance is considerably higher, than thermal resistance of the brass specimen. This implies that the warmth will disperse to the environment through the brass specimen. It results in "additional" loading of the brass specimen from the thermal stream and, thus, to the increase of its wear rate in comparson with the steel specimen.

The results of testing of the base trybosystem – 30ХГСНА steel – ЛС62 - 1,5 brass – are illustrated in fig.1. As it can be noticed the wear rate of the brass specimen reaches $3\cdot10^{-9}$ м^3/g, and the steel specimen – $0,6\cdot10^{-9}$ м^3/g; it means that for this trybosystem the steel specimen is less loaded. For "additional" loading of the steel specimen, without changing sliding velocity and loading, it is necessary to send a thermal stream from the brass specimen through friction contact toward the steel specimen. For this purpose, it is necessary to increase the thermal resistance in the right part of the inequality (1), i.e. the thermal resistance of the brass specimen.

Mechanically it can be fulfilled by arranging plates on the friction surface of the brass specimen or applying coating. To exclude the influence of material structure on wear resistance, the 1 mm width ring (plate) was cut from the brass element, and fixed on the end surface mechanically. This way the same brass specimen with one layer was obtained, it had material structure identical to the base friction specimen.

The calculation of thermal resistance was done according to the following inequality [3,4]:

$$\frac{\delta_c}{\lambda_c F_c}+\frac{\delta_o}{\lambda_o F_o}\neq\sum_{i=1}^{n}\frac{\delta_i}{\lambda_i F_i}+\sum_{i=1}^{k}\frac{\delta_k}{\lambda_k F_k}+\frac{\delta_л}{\lambda_л F_л} \quad (2)$$

where n – number of plates;

δ_i, λ_i, F_i – thickness, rate of heat-conduction and area of friction respectively;

k – number of transitions between plates;

δ_k, λ_k, F_k – thickness, rate of heat-conducting and contact area between plates respectively;

The calculation of the trybosystem thermal resistance according to (2) for the brass specimen with one brass plate, and further with two and three plates, gave the following results brass – one brass plate on the brass basis – 4,19 K/W>2,06 K/W; brass – two brass plates on the brass basis – 4,19 K/W>3,37 K/W; brass – three brass plates on the brass basis – 4,19 K/W<4,68 K/W.

According to the calculations, adding the first plate considerably increases the thermal resistance of the brass specimen compared to the base trybosystem, and, thus, a part of thermal stream toward the friction contact. However, the thermal resistance of the friction contact and the steel specimen is twice as high, and the thermal stream is as in "reservation" in the plate, which is represented by the increase of temperature from 70 °C to 95 °C (fig.1) only without the change of loading, sliding velocity, materials and lubrication.

The results of the experimental testing (fig.1) show that the wear rate of the immobile brass specimen was reduced from 3·10-9 м3/g to 1·10-9 м3/g, and the wear rate of the steel specimen increased from $0,6\cdot10^{-9}$ м^3/g to $1,8\cdot10^{-9}$ м^3/g.

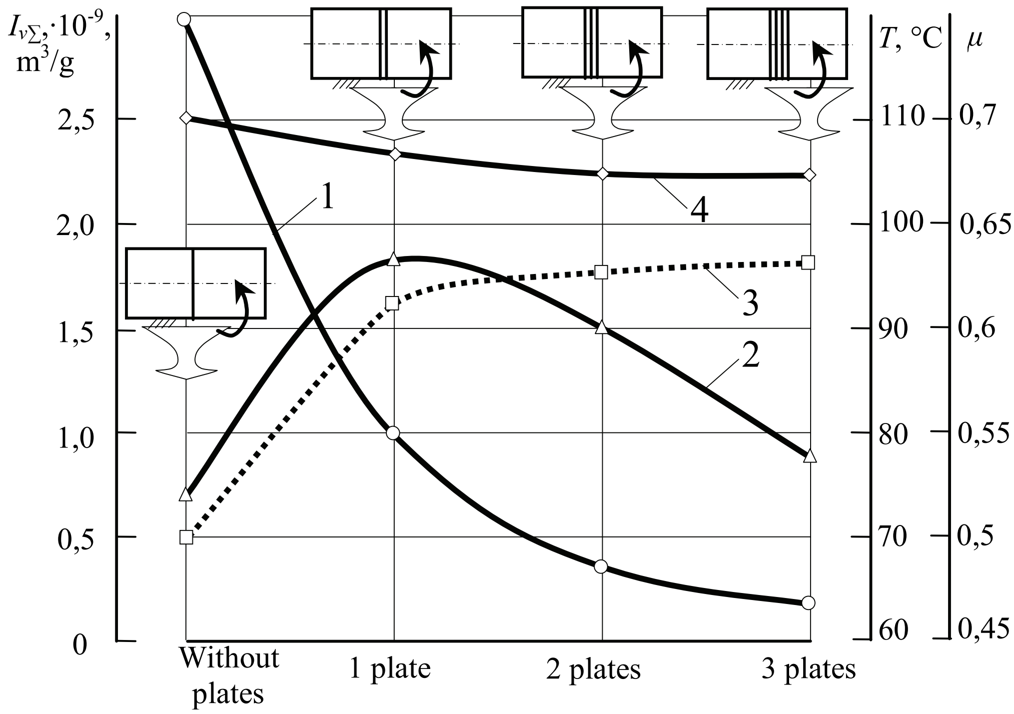

Figure. 1. Dependence of volumetric wear rate (Iv) in trybosystems of 30ХГСНА steel – ЛС-62-1,5 brass: 1 - immobile brass specimen; 2 - mobile steel specimen; 3 - temperature (T); 4 - friction coefficient (μ)

Adding two brass plates to the brass specimen reduced the wear rate of the brass specimen to $0{,}4\cdot10^{-9}$ м^3/g, yet, the character of the dependence of the steel specimen wear rate changed, and the wear rate started diminishing. Adding three brass plates provided a change in thermal resistances. The thermal stream which was generated in the first working brass plate was transferred through the friction contact to the steel specimen and simultaneously dispersed in the environment. This resulted in the increase of temperature in the working brass plate, as a result of "reservation" of thermal stream, and moreover, the wear rate of brass and steel specimens went down simultaneously, see fig.1.

Results of Chemical and Cractographical Research

The chemical analysis of friction surfaces revealed that on the friction surface of the brass specimen, as a result of the application of plates, content of copper reduced from 62% to 58%, but the content of zinc increased from 35% to 45% (table 1). The phenomenon of mass transfer of copper and zinc from the brass specimen to the steel specimen was observed. The research of the steel surfaces after tests allowed to indentify copper on the steel surface to 7,3% zinc to 5,4%. For the base trybosystems (without plates) the transference of copper and zinc to the steel surface was not detected.

It may be explained by the fact that when the plates were added, temperature of the first plate increases considerably (fig.1). Thus the thermal stream was left "reserved" in the first working plate and dispersed to the environment through the friction contact and the steel specimen. The high temperature facilitates the rapid flow of trybochemical reactions on the friction surfaces of specimens, diffusion processes, segregation of elements and mass transfer.

Table 1

Chemical Composition of Brass-steel Trybosystems

Mode of friction	Specimen	Chemical composition on the friction surface %				
		Cu	Fe	Zn	Pb	S
Before testing, primary friction surfaces	30ХГСНА	-	94	-	-	-
	ЛС-62-1,5	62	0,2	35	1,5	-
After testing, base tribosystem without plates	30ХГСНА	0,1	94	0,1	0	0,1
	ЛС-62-1,5	62	0,2	36	0	0,03
After testing, with three plates	30ХГСНА	7,3	94	5,4	0,2	0,6
	ЛС-62-1,5	58	0,04	45	0	0,06

The results of the Fourier-analysis show that the change in thermal stream direction leads to the decline of principal vector of tension both in the steel and in the brass specimens in accordance with the sliding direction vector. Thus, the level of anisotropy of structure subblocks in trybosistem with plates almost doubled, which indicates that the tribosystem has passed to the new, higher level of organization.

Conclusions

The research conducted allows us to draw a conclusion, that it is possible to operate thermal streams by changing thermal resistance of trybospecimens. It is possible to apply the adding of plates or coatings on the base material as the structural elements which increase thermal resistance. According to the research, the application of thin plates from material identical to the base specimen (plates from ЛС- 62-1,5 brass were secured on the immobile specimen from ЛС- 62-1,5 brass) has positive effect on the operation of thermal streams and diminishing of wear intensity.

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DEVICE FOR TEMPERATURE CHANGE REGISTRATION BY FERRIMAGNETIC CRYSTAL

This report is devoted to development and description of highly sensitive device for temperature change registration, the basis of which is dependence of passing light polarization plane rotation angle in a sensitive element on a temperature

There are plenty of types of devices for temperature measurement, including devices for minor temperature change registration, using for transformation of temperature to the measureable signal thermocouple, thermistor, optoelectronic, piezoelectric resonator and other operating principles [1-3]. Main description of device, which registers the temperature change, is a sensitiveness of used method.

In [4] a device for small differences of temperatures detection is described, which is a differential multijunction thermocouple with sensitiveness up to 0.1 °*K*. In [5] the temperature field irregularity detection method is described, the work of which is based on dependence of voltage drop value on a *p-n* junction on a temperature, providing sensitiveness to the temperature field gradient no less than 0.01 °*C*. Temperature measuring error of optoelectronic sensors, operating principle of which is based on dependence of value and density spectral distributing of object radiation energy on a temperature does not exceed 0.1 °*C* in 0 – 100 °*C* range [1, 6].

In this report for temperature change measurement (registration) is suggested to use an yttrium garnet ferrite crystal $Y_3Fe_5O_{12}$, placed in the magnetostatic field and magnetized to the saturation as a detecting element. For temperature change registration dependence of passing light polarization plane rotation angle in a crystal on a temperature is used. The polarization plane rotation is registered by photopolarimeter with Faraday cell based on yttrium garnet ferrite crystal (fig. 1) [7, 8]. The Faraday cell consists of polycrystal *7* and yttrium garnet ferrite crystal *6*, placed in the magnetic field and form the closed core. A light stream passes through the yttrium garnet ferrite crystal, in which the additional excitation of light polarization plane is takes place.

The garnet ferrites of rare-earth elements spontaneous magnetization behavior substantially differs from normal "weiss" law: besides the Curie point $Tc \approx 560$ °*K*, there is another point, where the spontaneous magnetization of matter is equal to the zero [9].

For spin resonance, when it is possible to consider with some approaching, that a medium has one magnetic sublattice, the gyromagnetic Faraday Effect is [10]:

$$\alpha_F = \frac{2\pi\sqrt{\varepsilon}}{c}\gamma I_S, \qquad (1)$$

Where α_F is a polarization plane rotation angle; ε is an permittivity; γ is a gyromagnetic ratio; I_S is a magnetic saturation.

From (1) the change of passed light polarization plane rotation angle will be determined by the equation:

$$\Delta\alpha_F = \frac{2\pi\sqrt{\varepsilon}}{c}\gamma\frac{dI_S}{dT}\Delta T\,. \qquad (2)$$

The maximal sensitiveness of temperature change registration will be:

$$\Delta T = \frac{\Delta\alpha_F}{\frac{2\pi\sqrt{\varepsilon}}{c}\gamma\frac{dI_S}{dT}} \qquad (3)$$

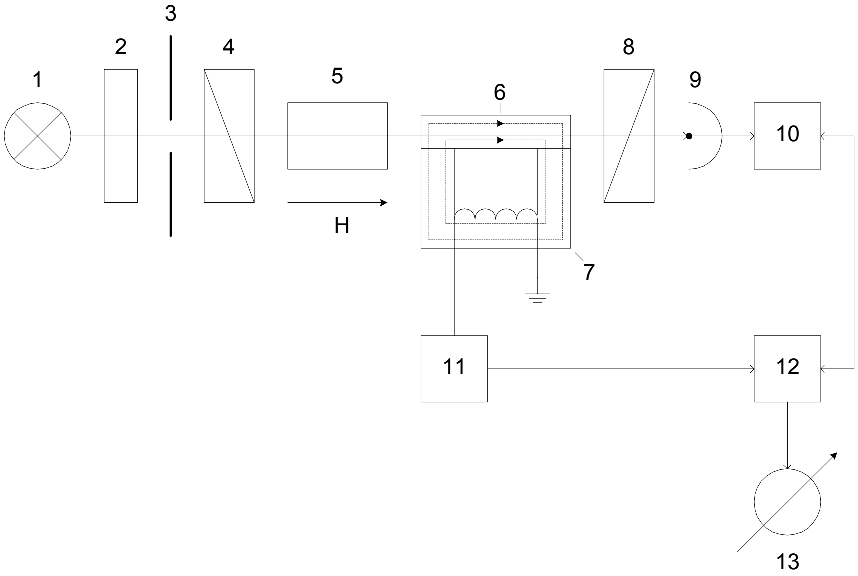

Fig. 1. Flow-chart of device
1 – Source of light; 2 – filter; 3 – diaphragm; 4 – polarizer; 5 – detecting element; 6, 7 – Faraday cell; 8 – analyzer; 9 – photodetector; 10 –amplifier; 11 – audio-frequency oscillator; 12 – synchronous detector; 13 – microammeter (indicator)

On a fig. 2 dependences of light polarization plane rotation angle and its derivative $\frac{\partial \alpha_F}{\partial T}$ on temperature are represented.

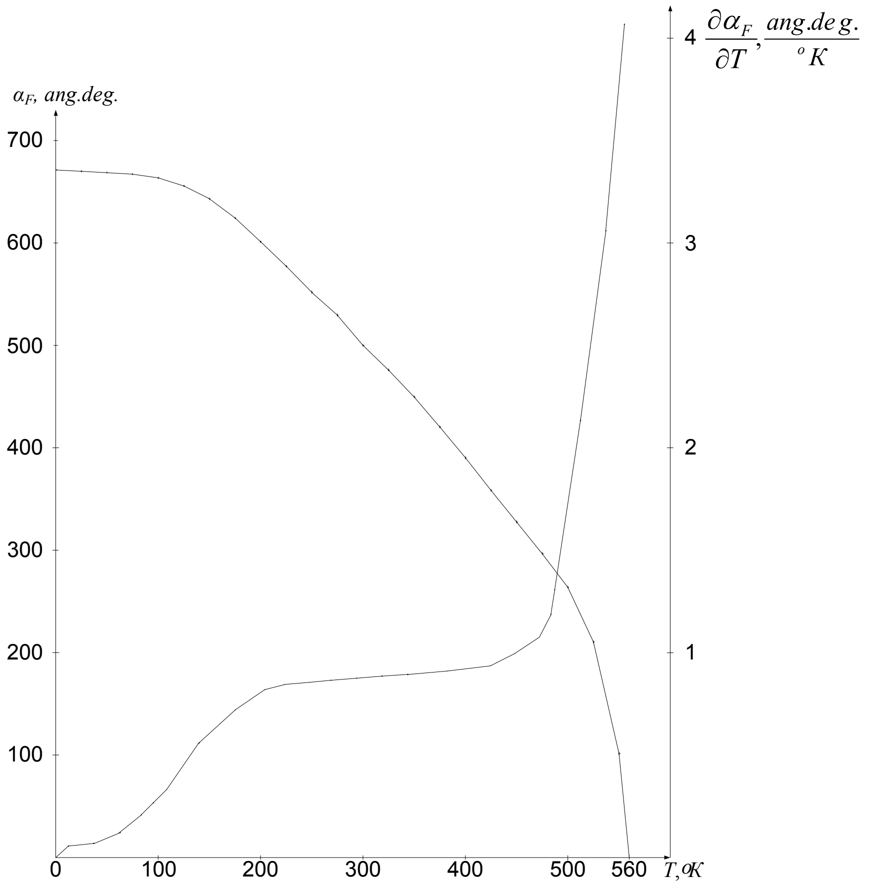

Fig. 2. Dependences of light polarization plane rotation angle α_F and its derivative $\frac{\partial \alpha_F}{\partial T}$ on temperature

Dependence $\alpha_F(T)$ is built taking into account results, received in article [11], where it was shown that due to the multiple reflection of light beam from detecting element walls it is succeeded to obtain the big values of polarization plane rotation angle.

On the most flat area of $\frac{\partial \alpha_\Phi}{\partial T}(T)$ curve in 200÷400 °*K* temperature range a derivative takes 0.81÷0.92 *ang.deg/°K* values. The maximal slope of the $\frac{\partial \alpha_\Phi}{\partial T}(T)$ curve is observed in 500÷560 °*K* temperature area. On this area derivative values are equal to 1.7÷4.06 *ang.deg/°K*.

Sensitiveness of photopolarimeter polarization plane rotation angle measurement, described in [8] is 0.0005 *ang.deg*. The least temperature change, registered with the help of this photopolarimeter in 200÷400°*K* temperature range is 0.00048°*K*, in 500÷560°*K* area – 0.00011°*K*.

It should be noted that with the use of crystal which except for the Curie point has another point, where the spontaneous magnetization of matter is equal to the zero it is possible to obtain the greater sensitiveness of temperature registration because there is a jump of the $\alpha_F(T)$ curve in the compensation point.

Summary

The received results show that the using of the described device allows to considerably increase the sensitiveness of medium temperature change measurements, to 0.00048°*K* in an area of room temperature, and during work in a temperature area, where slope of $\frac{\partial \alpha_F}{\partial T}(T)$ is maximal, a sensitiveness is increased up to 0.00011°*K*.

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AUTOMATIC DIAGNOSTIC SYSTEMS OF POWER EQUIPMENT IN THE AEROSPACE INDUSTRY

Actuality of the theme. Operation of power plants and electrical of aerospace systems networks is impossible without damage and not normal mode. The most dangerous are the short-circuit (SC), overload and damage of insulation. Short-circuits can appear because of breakdowns or slab insulation, wire breakage, the erroneous actions of the staff and the other reasons.

In most cases in place of short-circuit occurs the arc, the thermal effect of which can lead to the destruction of live parts, electrical apparatus and insulators. During a short circuit to the place of injury occur large currents, the currents can be thousands of amperes, which heat current-carrying parts and can cause additional damage. Simultaneously, the electrical network linked to the injury site, where is a significant decrease in stress, can lead to stopping of electric motors and a violation of the stability of parallel generators. In most cases, prevent to the development of the accident can quickly disable the damaged part of the electrical installation or a network using special automatic devices operating on the circuit breaker, and dubbed the relay protection.

The action of the switch element of the damaged electric arc goes out, the passage of current of short-circuit is terminated and restored power to the undamaged part of the electrical installation or network. This greatly reduced or completely prevented damage to equipment, which arose short-circuit, as well as restored normal operation of electrical equipment intact. It can be concluded that the main purpose of relay protection is to identify the place of the short-circuit and quickly automatically disconnect switch of damaged equipment.

The second purpose of relay protection is to detect violations of normal modes of the equipment, which subsequently could lead to an accident and filing alarm personnel, or disable the equipment with time delay.

According to the rules of technical operation (RTO), power equipment of power stations, substations and electrical networks must necessarily be protected from short circuits and abnormal operating modes of relay protection devices and electroautomatics (RPE).

A brief historical sketch of the relay protection history.

At the end of the IXX century began to use fuses to protect equipment from short-circuits.

- Since 1901 appear first induction current.
- In the years 1905-1908 the differential current principle was developed.
- In the first half of the 20-ies the first distance protection were released.
- In the 1923-1928 years are beginning to develop security-based electronics, in particular the high frequency currents, transmitted by wire shielded line.
- In 1932 the Soviet Union developed a distance protection on the tubes.
- In the 70's began to be widely used in relay protection needs of electronic devices. (PLP-70, MTZ-M, BAURPN, FTE-1636, FIP-1, FIP-2, ART-1H, DPGs, KRZA and many others).
- In the 80-ies started using relay devices based on integrated circuit (YARE, BDE, SHDE, LIFP, FIS, AVZK, AK-80, ANCA, AVPA, EOP, and many others).
- There is a real technological revolution associated with the transition to a new generation of devices RPA - microelectronic and microprocessor technology
- (Ukrainian production: "Diamond", MRSA-05)
- (Russian-made: "Sirius", UGA-10, TEMPO).

Nowadays, more widespread becomes microprocessor Protection (MPP) of electrical equipment, which are replacing electro-mechanical and microelectronic relay. MPP does not change the principles of relay protection and automatics, but they extend the functionality, reducing the number of the relay, simplify maintenance and ultimately reduce its cost. Features of MPP are quite high:

1. Microprocessor protection is faster, what in certain cases, plays an important role.
2. Return coefficient of measuring is around 0.96 – 0.97.
3. Microprocessor protection or microprocessor terminals are multipurpose ones. What brings together in one terminal functions of different (perhaps even not identical) systems of protection.
4. Unmoving parts increases reliability of devices.
5. Power consumption at a level 0.1 – 0.5 VA.
6. Error is 2 – 5 %.

Microprocessor terminals (the same as MPP) are equipped with different, quite unexpected, but very handy devices such as a storage digital oscilloscope for a number of emergency events.

Digital microprocessor protection and automation device appeared relatively recently. But at power objects, they begin to be implemented fairly well. Producing microprocessor terminals in a wide range of programs for different class of voltgei from 0.4 to 750 kV. World leaders in the manufacture of devices RPA are European concerns ABB, SIEMENS, ALSTOM. Common to them is the shift to digital technology. MPP of these firms has high cost. Much cheaper are domestic terminals, such as MRSA-05 production enterprise "Kievpribor".

MPP of the type MP3C-05 can be described as:

- high-performance 16-bit microprocessor system;
- fully digital processing of measured values;
- full galvanic isolation of internal circuits;
- simple management via the control panel buttons or by connecting a PC to the RS232 connector software to work with the menu;
- storage of messages and injuries;
- continuous monitoring, as measured quantities and technical software;
- communication with the central control unit via a serial interface RS485.

On the basis of MPP automated diagnostic systems are built which can conduct a preliminary analysis of incoming data, organize them, to hold its preliminary estimation and provide results in a convenient form for further expert estimation of the hardware (the current parameters, the parameters for the period, trends, etc.).

The main problem to be solved in the construction of this system:

- docking of the diagnostic system with the existing automated systems;
- selection a mathematical model describing the condition of the equipment;
- development of software environment for processing and displaying information.

Docking is not currently so complicated problem. All systems are able to provide information in a standardized form - OPC-server protocols Modbus, IEC 870-5-101/104 format of waveforms is Comtrade, etc. The mechanisms of information transmission are open (there are descriptions of the principles of data) and can be used to transfer data to a database of a diagnostic system.

For most types of electrical equipment mathematical models of their state are developed. It is needed to adapt them for use in the diagnostic system taking into account the number of parameters which diagnostic system can receive and the principle of operation of the system.

The environment program should first of all provide all necessary data in convenient to the user way and have the ability to input the initial and additional information (data correction after the repair of equipment, etc.).

Let's consider the algorithm of the program for diagnostic of high voltage switches technical state.

During the development of high-voltage switches diagnostic program prototype the mathematical package MathCad is used. This allows to work out the basic data processing operations without the cost of specialized software creating, which is appropriate to create already on the basis of established algorithms operation.

It is assumed that the main impact factors influencing the technical condition of high-voltage switches are switched current and the number of commutations. In normal operation without switching the electrical parameters, as a rule, does not exceed the manufacturer's nominal parameters and residual life is not reduced. In this case, is supposed to use data from two automated systems - robot system (counting the number of switching) and the registration system of emergency event (as defined dial-current).

The figure shows the number of outages for circuit breaker BB/TEL-10-20/1000 [3].

In this case, to get by means of the starting points the mathematical functions of allowable trips number cubic spline interpolation is used.

Consumotion of switching resource for one trip of current I is equal to the inverse of the allowable number of disconnections under this current:

$$\rho_{0I} = \frac{1}{n_{0I}},$$

where ρ_{0I} – cof switching resource under current I;
n_{0I} – allowable number of disconnections under current I.

After each switching of the residual resource of the switch $R_{\text{ост}}$ the flow of switching resource for one trip is subtracted, and thus the current switch resource:

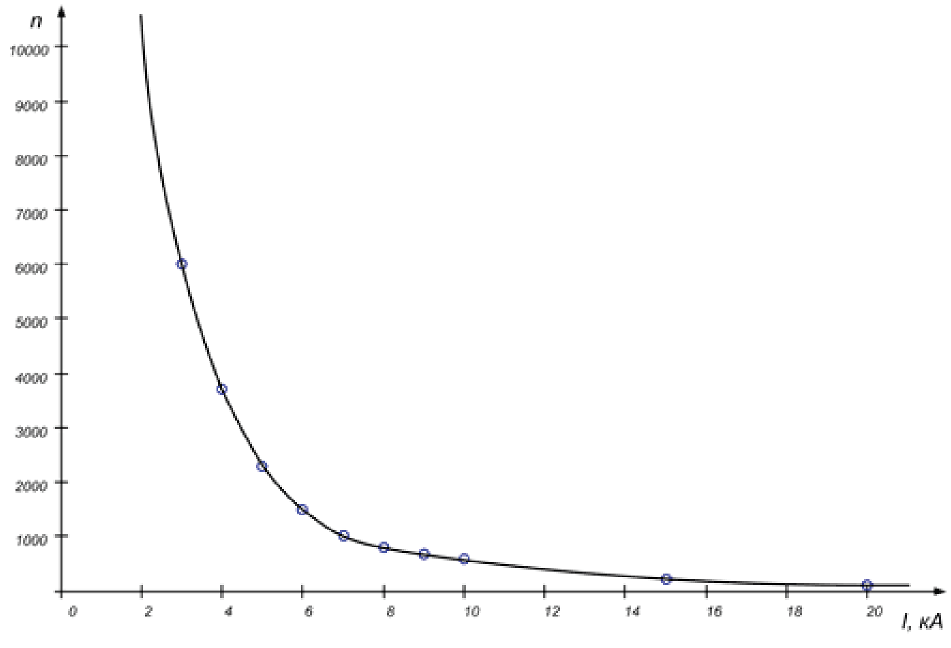
$$R_{\text{ост.т}} = R_{\text{ост}} - \rho_{0I},$$

where $R_{\text{ост.т}}$ – is the current switch resource (taking into account the disconnection);
$R_{\text{ост}}$ – residual resource of the switch (before the disconnection).

The condition of the output switch to the repair:

$$R_{\text{ост.т}} < \frac{1}{n_{0\min}},$$

where $n_{0\text{мин}}$ – allowable number of disconnections at the highest current, possible in place of the switch installation.



Dependencies of trips permitted number of the switch from dial-BB/TEL-10-20/1000 current.

Based on the statistics of disconnections (number of cycles on / off, current disconnections), which is made in the program of diagnostics, it is possible to make a prognosis and recommendations on the time duration of the next repair.

Conclusions

Thus there is an opportunity at minimal cost to create at aerospace complex the electrical equipment diagnostic systems (from simple to fairly serious condition monitoring systems, transformers and generators). Systems for "simple" equipment are able to produce their own forecast, the system for sophisticated equipment are less accurate in forecasting, but can provide information for further expert analysis of the state of electrical equipment.

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MECHANISM OF DETECTION OF DISCONTINUITIES IN PIPELINES BY ULTRASONIC GUIDES WAVES

The paper deals with the features of detection of discontinuities in welded pipelines, with which low-frequency guided waves of longitudinal and torsional modes interact during their propagation in the form of a circular wave through the pipe cross-section.

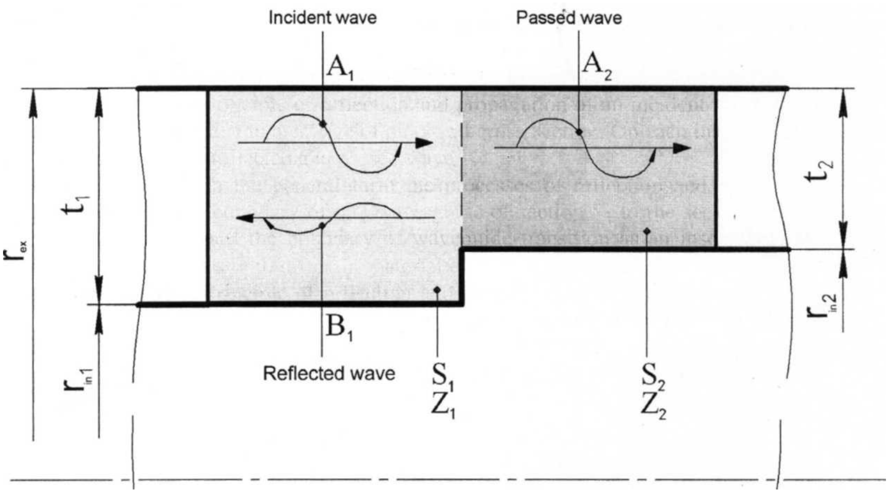
Introduction

Extended welded pipelines are characterized by the presence of various discontinuities in them, related to the change of material density and/or cross-section of pipe walls on their joint boundary and/or along the pipe length. The main pipeline discontinuities are defects of metal loss in pipe section, resulting from corrosion damage and erosion wear of pipe wall. Such defects leading to pipe wall thinning, are the interfaces, which influence the transmission of ultrasonic low-frequency guided wave during its propagation along the pipeline as an extended wave guide. Influence of pipe wall defects as interfaces on ultrasonic wave propagation is exactly what forms the base for the mechanism of defect detection by low-frequency guided waves.

Interaction of guided wave with pipe defects.

Interaction of guided wave with pipeline defects is based on the principle of reflection and propagation of an incident ultrasonic wave on each interface, which is due to a change of pipe wall cross-section. On each interface the incident wave is divided into the reflected and passed wave.

Let us analyze in the general form the processes of reflection and passing of guided waves on the transition boundary of one wave guide of section Si to the second wave guide of section S_2. We will regard the boundary of waveguide transition as an inseparable absolutely rigid contact of two pipes with different material constants ρ_1, E_1 and ρ_2, E_2 for guided mode of the longitudinal wave. Principle of reflection and passing of guided waves on the boundary of wave guides of different cross-sections is shown on a pipeline fragment with different inner diameters of pipes, which is given in the Figure, where t_1, r_{in1} and t_2, r_{in2} are the wall thicknesses and inner radii of the first and second pipe, respectively; r_{out} is the pipe outer radius.



Principle of reflection and passage of guided waves on the boundary of pipe section change

If a square-wave pulse with sinusoidal filling of the required frequency is excited at one end of the pipeline, then ultrasonic wave of amplitude A_1 will propagate through pipe wall thickness along the pipeline longitudinal axis. Propagating along waveguide section with cross-sectional area S_1 incident wave of amplitude A_1 comes across another waveguide, the cross-sectional area of which is equal to S_2. The incident wave is transformed into a reflected wave, amplitude B_1 of which depends on the degree of change of pipe cross-section, and into passed wave with amplitude A_2, which propagates further along the pipe section.

As reflected wave formation occurs in a section of change of pipe cross-sectional area, consideration of the processes of acoustic wave propagation in waveguides is performed using the concept of mechanical impedance Z , dependent both on waveguide parameters (its cross-sectional area S), and on the medium properties, namely velocity of sound C and density ρ. Mechanical impedance is an important parameter of an extended pipeline medium. In pipe zones without defects, the controlled pipeline has finite mechanical impedance. Change of mechanical impedance is related both to a change of pipe cross-sectional area due to its corrosion damage and erosion wear, and to a change of wave impedance of welded joint medium and its cross-sectional area, because of the presence of various discontinuities. Therefore, mechanical impedance, essentially is a measure of pipe resistance to propagation of guided ultrasonic waves. The Figure shows the simplest case of transition from the first pipe with mechanical impedance $Z_1 = \rho_1 C_1 S_1$ to a sufficiently long pipe with mechanical impedance $Z_2 = \rho_2 C_2 S_2$.

Coefficients of reflection R and passage W of guided wave from the jump of mechanical impedance on the interface of the two media are found from the following expressions:

$$R = \frac{Z_2 - Z_1}{Z_2 + Z_1}; \quad W = \frac{2Z_2}{Z_2 + Z_1}. \tag{1}$$

Product of ρC in expressions for mechanical impedance is the specific acoustic impedance of the medium and represents the wave impedance of the medium. Wave impedance characterizes the reflecting properties of the medium and determines the conditions of sound reflection and passage on the boundary of the two media. If .wave resistances of the media are equal, the coefficients of reflection and passage of the guided wave will depend on the change of the pipe wall cross-section.

Proceeding from that, according to the Figure, coefficients of reflection R and passage W of low-frequency ultrasonic wave from the jump of mechanical impedance of pipe medium will be determined by the following expressions:

$$R = \frac{S_2 - S_1}{S_2 + S_1}; \quad W = \frac{2S_2}{S_2 + S_1}. \tag{2}$$

As guided wave propagation occurs in the direction of reduction of pipe cross-section $(S_2 < S_1)$, a reversal of the phase of the reflected wave relative to the incident wave is observed. Passed wave has the same phase as the incident wave. Depending on values of S_2 and S_1, reflection coefficient R will have a negative or positive value. At positive R the phase of the reflected signal does not change. Frequencies of the incident and reflected waves are equal in all the cases, this greatly facilitating solution of the problem of guided wave reflection.

Assessment of reflected signal amplitude.

Let us assess the dependence of the amplitudes of the reflected and passed wave on the degree of change of the pipe cross-sectional area, because of the presence of defects along the pipe length. On each interface the incident wave will split into one reflected and one passed wave, which results in these waves forming a sequence of completely separated and independent from each other individual pulses. Each passed wave will be smaller than the incident wave by amplitude after the interface. In the section of the last defect along the pipe length incident wave of amplitude A_{in} is transformed into reflected wave of amplitude B_{in} and passed wave of amplitude A_{end}, which is reflected from the end of pipe with amplitude B_{end}. In the absence of attenuation of a low-frequency guided wave in the pipeline final section, amplitudes of passed wave A_{end} and reflected wave B_{end} will be equal. Therefore, the following dependence of the amplitudes of the passed and reflected from defect waves will be in place in the entire tested pipeline section:

$$\begin{aligned} &B_1 = A_1 - A_2; \\ &B_2 = A_2 - A_3; \\ &\dots\dots\dots\dots\dots \\ &B_n = A_n - A_k; \end{aligned} \tag{3}$$

Amplitudes of each of the pulses of the reflected and passed waves can be calculated, if we apply formulas (2) to each individual process of guided wave reflection and passage on the interface. Sound pressure of the pulse sequence will decrease each time, as a result of the next splitting.

Taking into account expressions (2) for determination of coefficients of reflection R and passage W of the guided wave on the boundary of the change of pipe wall cross-section, amplitudes of reflected B_1 and passed A_2 waves will be determined by formulas of the following form:

$$B_1 = R \cdot A_1 = \frac{S_2 - S_1}{S_2 + S_1} A_1, \tag{4}$$

$$A_1 = W \cdot A_1 = \frac{2S_2}{S_2 + S_1} A_1. \tag{5}$$

From expression (4) it is seen that the value of reflected wave amplitude is proportional to the difference of areas $S_2 - S_1$, i.e. depends on the dimensions of corroded cross-sectional area of the pipe wall. This means that the low-frequency guided wave is sensitive to metal losses in pipe cross-section. From expression (4) it also follows that the coefficient of reflection by amplitude, due to a jump of pipe cross-section because of the presence of a defect, is much smaller than the cross-sectional ratio $\frac{\boldsymbol{S}_2}{\boldsymbol{S}_1}$. Therefore, the guided wave propagates further along the pipe and only its small part is reflected from the jump of the pipe cross-section.

Assuming that the cross-sections in the defect location differ only by two times, i.e. $\boldsymbol{S}_2 = \frac{1}{2\boldsymbol{S}_1}$, reflected wave amplitude B_1 will be equal to:

$$B_1 = \frac{S_2 - S_1}{S_2 + S_1} A_1 = -\frac{S_2}{3S_2} A_1 = -\frac{1}{3} A_1. \tag{6}$$

In this case, the amplitude of passed wave A_2 will be equal to:

$$A_2 = \frac{2S_2}{S_2 + S_1} A_1 = \frac{2S_2}{3S_2} A_1 = \frac{2}{3} A_1. \tag{7}$$

Let us assess the faction of excited wave energy which is reflected at section ratio $S_2 = 1/2S_1$. It is known [1] that the coefficient of reflection R_e of incident flat sound wave on the boundary of cross-sectional change of an object with the same material constants evaluated in terms of energy, is equal to:

$$R_э = \left(\frac{S_2 - S_1}{S_2 + S_1} \right)^2. \tag{8}$$

In the general case it means that only a small fraction of sound wave energy is reflected back from the defect, whereas a considerable part of energy propagates further along the pipe. For ratios of pipe sections $\boldsymbol{S}_2 = \frac{1}{2\boldsymbol{S}_1}$ from expression (6) value of sound wave reflected energy will be equal to:

$$\left(\frac{B_1}{A_1}\right)^2 = \left(\frac{1}{3}\right)^2 = \frac{1}{9}. \qquad (9)$$

From expression (9) it follows that if the sections of a sound and defective pipe differ by two times, only 1/9 of incident energy is reflected back. According to [2], the law of conservation of energy is satisfied. This law states that the difference of energies of the incident and reflected wave should be equal to the passed wave energy. As energy density is proportional to the square of amplitude, the following relationship is fulfilled:

$$S_1(A_1^2 - B_1^2) = A_2^2 S_2. \qquad (10)$$

Although only a small fraction of sound wave energy is reflected back from the defects, the reflected echo-signal amplitude is the main parameter, which forms the base of the mechanism of detection of defects of corrosion damage and erosion wear of pipe wall, as the value of echo-signal amplitude corresponds to the degree of pipe cross-section variation.

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EMPIRICAL MODE DECOMPOSITION IN SIGNAL ANALYSIS

The use of the empirical mode decomposition in polyharmonical with irrational frequency rate signal analysis is discussed. Computer simulations are used to present capabilities and to determine limitations of this method.

Introduction

A new nonlinear technique, referred to as Empirical Mode Decomposition (EMD), has recently been pioneered by N.E. Huang for adaptively representation nonstationary signals as sums of zero-mean AM-FM components [1]. Although it often proved remarkably effective [1, 2], the technique is faced with the difficulty of being essentially defined by an algorithm, and therefore of not admitting an analytical formulation which would allow for a theoretical analysis and performance evaluation.

EMD basics

The decomposition is based on the simple assumption that any data consists of different simple intrinsic modes of oscillations. Each intrinsic mode, linear or nonlinear, represents a simple oscillation, which will have the same number of extrema and zero-crossings. Furthermore, the oscillation will also be symmetric with respect to the “local mean.” The result is the final complicated data. Each of these oscillatory modes is represented by an intrinsic mode function (IMF) [1] with the following definition:

- in the whole dataset, the number of extrema and the number of zero-crossings must either equal or differ at most by one
- at any point, the mean value of the envelope defined by the local maxima and the envelope defined by the local minima is zero.

An IMF represents a simple oscillatory mode as a counterpart to the simple harmonic function, but it is much more general: instead of constant amplitude and frequency, as in a simple harmonic component, the IMF can have a variable amplitude and frequency as time functions.

With the above definition for the IMF, any function can be decomposed as follows: take the test data $U(t_j)$, where t_j - discrete time variable with period of discretization $T_d = 0.01$ sec, $j \in N,$ as given in Figure 1; identify all the local extrema, and then connect all the local maxima by a cubic spline line to make the upper envelope. Repeat the procedure for the local minima to produce the lower envelope. The upper and lower envelopes should cover all the data between them, as shown in Figure 1. Their mean is designated as $m_{1\,1}(t_j)$, also shown in Figure 1, and the difference between the data and $m_{1\,1}(t_j)$ is the first proto-IMF $h_{1\,1}(t_j)$:

$$h_{1\,1}(t_j) = U(t_j) - m_{1\,1}(t_j)$$

In accepted designations first index is a number of IMF, second index – the number of proto-IMF. Described operation is called sifting. Sifting is applied several times but in next step $h_{1\,1}(j)$ is treated as data:

$$h_{1\,2}(t_j) = h_{1\,1}(t_j) - m_{1\,1}(t_j),$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$h_{1k}(t_j) = h_{1(k-1)}(t_j) - m_{1k}(t_j).$$

Sifting process is repeated up to *k* times, until $h_{1k}(t_j)$ fits to IMF definition. Then first IMF defined as $c_1(t_j)$ is accepted as $h_{1k}(t_j)$ (more information about stopping criteria can be found in [1]).

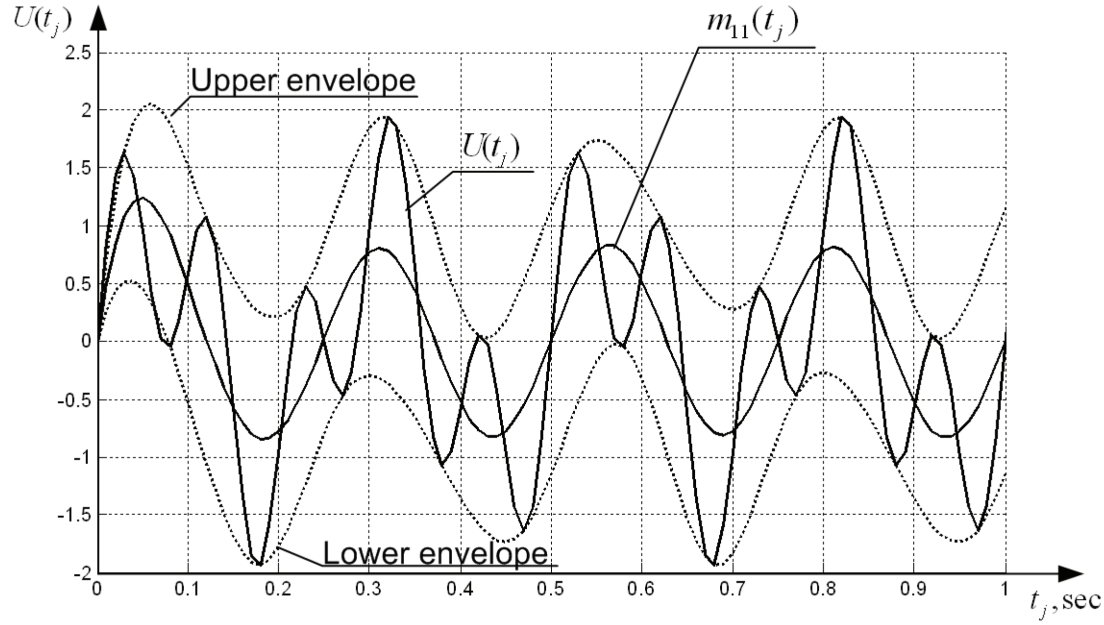

Figure 1: Data, upper and lower envelope defined by local maxima and minima, and the mean value of envelopes.

Obtained IMF $c_1(t_j)$ is subtracted from the initial data and residue $r_1(t_j)$ is obtained. Residue is used as initial data in next series of sifting:

$$r_1(t_j) = U(t_j) - c_1(t_j),$$
$$r_2(t_j) = r_1(t_j) - c_2(t_j),$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$r_n(t_j) = r_{n-1}(t_j) - c_n(t_j).$$

Thus we obtain *n* IMFs and last residue that could be monotonic mean trend or constant:

$$U(t_j) = \sum_{l=1}^{n} c_l(t_i) + r_n(t_j)\,.$$

This method is intuitive. It has a posteriori-defined basis and high level of adaptability. It is important to mention that results usually have direct physical meaning. It perfectly fits to nonstationary and nonlinear data analysis. Also it could solve problem of analyzing polyharmonical signals in case of irrational frequencies proportion of its components. For example we need to get phase characteristics for the signal with next form:

$$U(t_j) = \sin(2\pi 3t_j) + \sin(2\pi\sqrt{28}t_j) + \sin(2\pi\sqrt{111}t_j)\ . \qquad (1)$$

Analysis of such signal with Fourier-based algorithm will lead to fake results. But application of EMD for it gives us more correct results.

Hilbert analysis

Decomposition of (1) leads to obtainment of cyclical signals $c(t_j)$. One of the most informational characteristics of these signals is their phase characteristic. The task of it`s acquisition could be solved by applying Hilbert transform (HT). As usual HT is used to represent signal in complex form. According to this transform real signal $c(t_j)$ is associated with complex signal [3,4]:

$$\dot{c}(t_j) = c(t_j) + jc_H(t_j) = C(t_j)e^{j\varphi(t_j)},$$

where $c_H(t_j)$ is conjugated to $c(t_j)$ signal, $i = \sqrt{-1}$. These signals are connected to each other with direct and inverse discrete HT. Hilbert image obtainment allows us to get following signal characteristics:

- amplitude characteristic:

$$C(t_j) = \sqrt{c^2(t_j) + c_H^2(t_j)};$$

- phase characteristic:

$$\varphi(t_j) = \arg \dot{c}(t_j) = \operatorname{arctg}\frac{c_{\text{н}}(t_j)}{c(t_j)} + \frac{\pi}{2}\{2 - \operatorname{sign} c_{\text{н}}(t_j)(1 + \operatorname{sign} c(t_j))\}.$$

Last expression allows us to obtain partial phase characteristics on $[0, 2\pi)$ interval. To obtain full phase characteristic we must unwrap partial phase characteristic [4].

Simulation

As example polyharmonic signal EMD is discussed. Such tasks are very important in different signal processing and scientific research fields. If we analyse polyharmonical signals with rational frequencies proportion we could use Fourier transform methods. But if that proportion is irrational such methods won`t be effective. That's why we use empirical mode decomposition, and then apply Hilbert analysis to received IMFs.

Let`s analyse previously mentioned polyharmonical signal $U(t_j)$ (1) shown on figure 2.

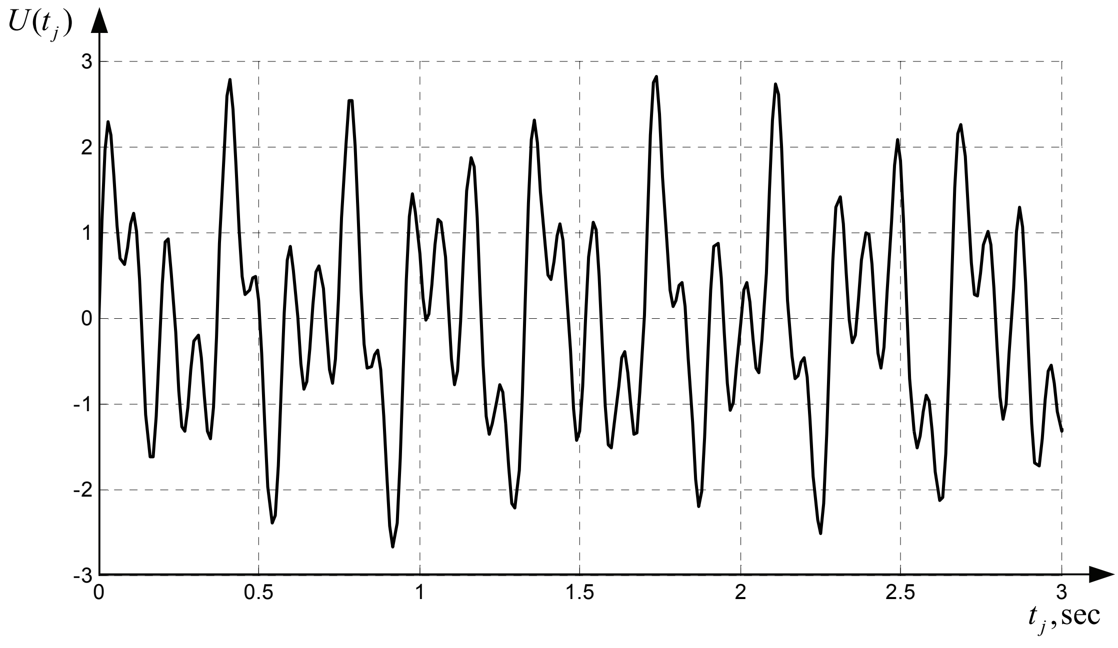

Figure 2 Analysed signal $U(t_j)$.

It is sum of three sine functions: $U_1(t_j) = \sin(2\pi 3 t_j)$, $U_2(t_j) = \sin(2\pi\sqrt{28}t_j)$, $U_3(t_j) = \sin(2\pi\sqrt{111}t_j)$ with frequencies 3, $\sqrt{28}$ and $\sqrt{111}$ Hz as follows. These components are shown on figure 3.

The result of EMD is shown in figure 4. As you can see first IMF $c_1(t_j)$ is representing signal component with highest frequency $(U_3(t_j))$ and the third, $c_3(t_j)$ – with lowest $(U_3(t_j))$. The analysis of these plots shows that amplitude characteristics of IMF`s are a little different from amplitude characteristics of appropriate signal components. This error is maximal on the beginning of analysed interval.

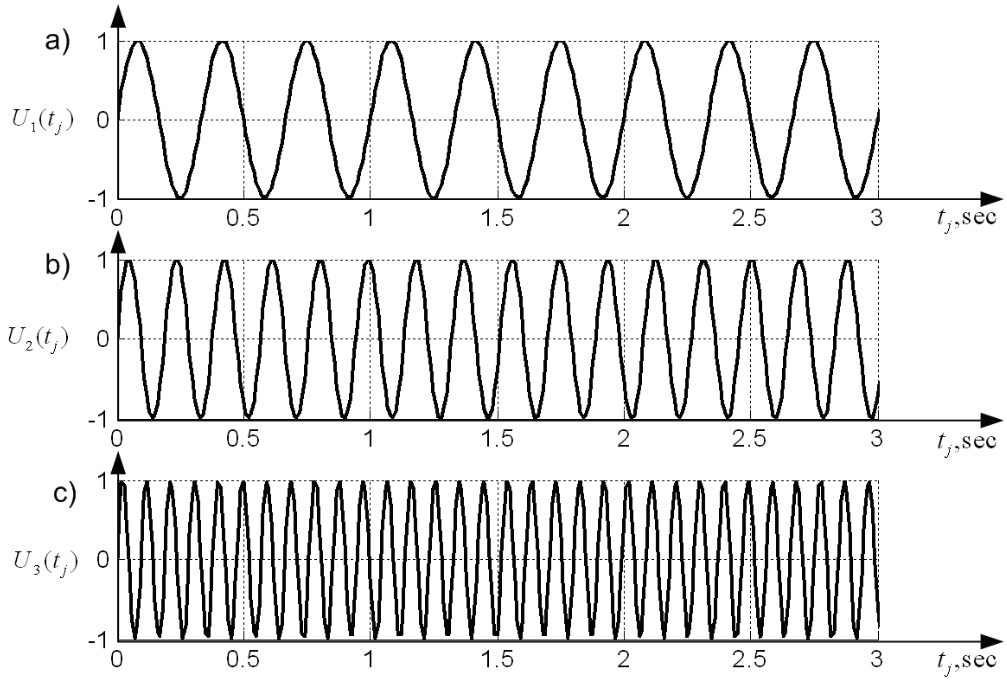

Figure 3. Components of analysed signal

a) $U_1(t_j) = \sin(3t_j)$, b) $U_2(t_j) = \sin(\sqrt{28}t_j)$ c) $U_3(t_j) = \sin(\sqrt{111}t_j)$

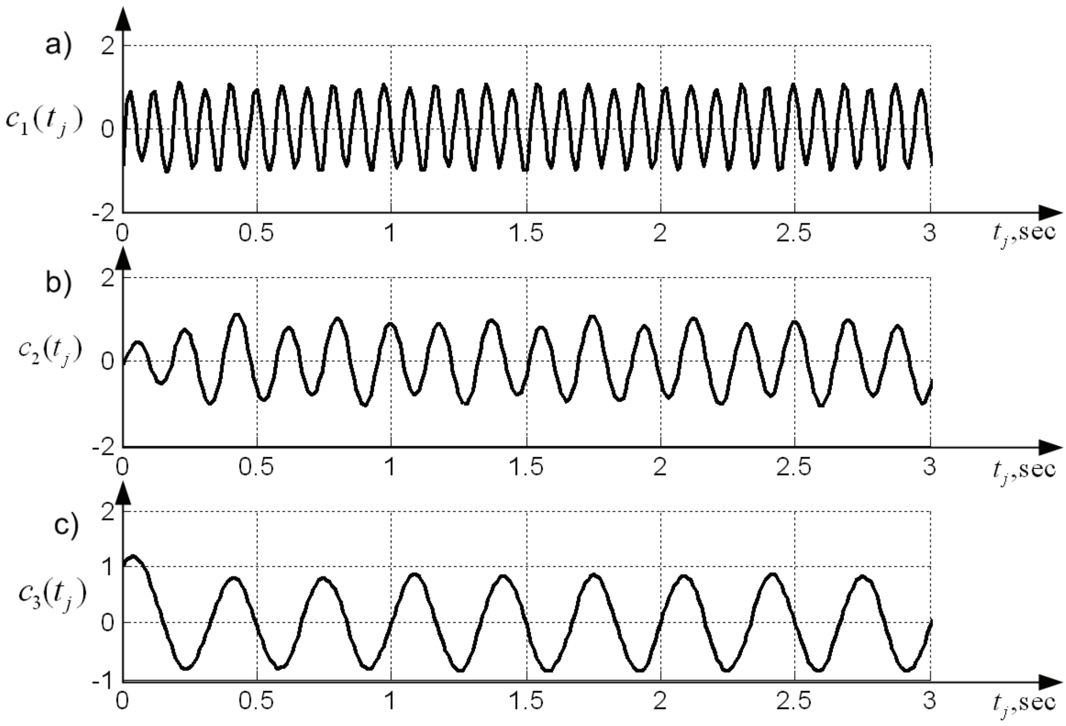

Figure 4. Intrinsic mode functions representing components of signal

a) $c_1(t_j)$, b) $c_2(t_j)$ c) $c_3(t_j)$

Partial phase characteristics can be obtained with the help of HT (shown on figure 5). Phase characteristic error was treated as absolute difference between phase characteristic of $U_3(t_j)$ and phase characteristic of $c_1(t_j)$ for example. The maximal error was also at the beginning of analysed interval and set 0,713 rad. Average phase characteristic obtainment error set less than 0,05 rad, that allows us to draw a conclusion about EMD as useful instrument in polyharmonic signal analysis.

Obtained phase characteristics: $\varphi_1(t_j)$, $\varphi_2(t_j)$, $\varphi_3(t_j)$ can be used to calculate other characteristics such as component frequencies, rate of frequency change, frequency deviation etc.

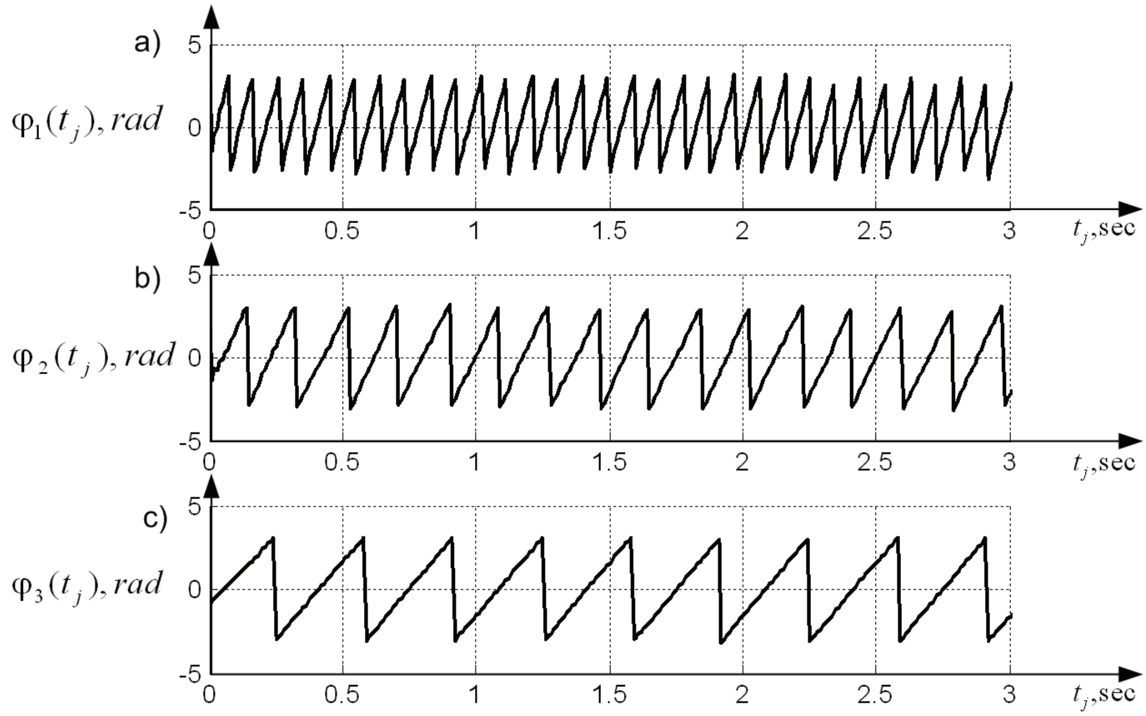

Figure 5 Partial phase characteristics:
a) $\varphi_1(t_j)$, b) $\varphi_2(t_j)$, c) $\varphi_3(t_j)$

Conclusion

In this paper the application of empirical mode decomposition to polyharmonic signal with irrational frequency rate analysis is discussed. Suggested method is quite useful in numerous complicated tasks of digital signal processing and signal analysis as discussed earlier. Although real purpose of empirical mode decomposition is in analysis of nonstationary and nonlinear data, it could be useful in achieving characteristics of polyharmonic signals. Average phase characteristic obtainment error set less than 0,05 rad. As for limitations of this method could be added that frequencies of signal`s components must be differed at least by 2 Hz.

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CIRCULAR DATA SIMULATION

Simulating algorithms of circular data distributions are presented. Probability density functions diagrams and random angles distributions circular histograms are modeled with usage of different scale types. Received results can be applied in statistical analysis of circular data.

1. Introduction

Circular measuring is the impotent scientific and technical part of the measurement theory. Random circular data generation [1] is the impotent stage of data origination for random circles statistical experiment. The paper introduces algorithms of different distributions random circular data simulating.

A one-dimensional random circles simulation problem is forming in the following way. The probability density function $f(\theta)$ for continuous random quantity $\theta \in (0,2\pi)$ for the Uniform distribution, the von Mises distribution, the Wrapped Normal distribution and the Wrapped Cauchy distribution are given. The selective random circles data array of the dimension $1 \times J$ has to be formed. Problem solution is oriented to application Matlab software, which is widely used in science and technical tasks.

2. Simulation

Simulation algorithms are based on application of the next statistical random circles characteristics:

– sample trigonometric moment of the first kind

$$T_1 = \frac{1}{J}\sum_{j=1}^{J} e^{i\cdot\theta_j} = a_1 + ib_1 = \frac{1}{J}\sum_{j=1}^{J}\cos(\varphi_j) + \frac{i}{J}\sum_{j=1}^{J}\sin(\varphi_j) = r_1 e^{i\mu_1} ;$$

– sample mean resultant length $r_1 = \sqrt{a_1^2 + b_1^2}$, $r_1 \in (0,1]$;

– sample mean direction μ: $\cos\mu = a_1/r_1$, $\sin\mu = b_1/r_1$;

– sample circular standard deviation $\sigma = \sqrt{-2\ln r_1}$.

2.1. The uniform distribution *CU*

If the total probability is spread out uniformly on the circumference of a circle, we get the Circular Uniform (CU) distribution with the constant density $f(\theta) = 1/2\pi$, $0 \le \theta < 2\pi$ [2].

All the directions are equally likely and hence this is also known as isotropic or random distribution. Its trigonometric moments $\alpha_\rho = 0$, $\beta_\rho = 0$, $\rho \ge 1$. Since the length of the first trigonometric moment $\rho = 0$ in this case, this distribution has no well-defined mean or preferred direction μ. Circular dispersion $\delta \to \infty$. The distribution function is $F(\theta) = \theta/2\pi$, $0 \le \theta < 2\pi$.

Method of simulation [3]:

1) Set pseudo-random uniform number u_j, $u_j \in U$, $U[0,1]$, $j = \overline{1,J}$; 2) Than $\theta_j = 2\pi u_j$.

Figure 1 shows the polar axes histogram of random uniform angles distribution for $J = 500000$.

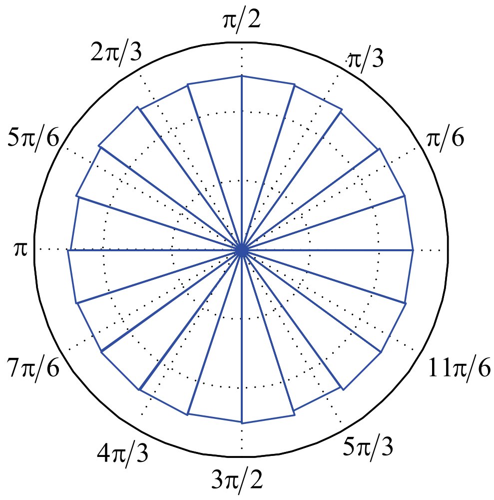

Figure 1. Polar axes histogram of random uniform angles distribution.

2.2. The von Mises distribution $VM(\mu,k)$

The von Mises distribution or a Circular Normal (CN) distribution is a symmetric distribution which is the most common model for unimodal circular data samples. Its probability density function is [4,5]

$$f(\theta)=\left[2\pi I_0(k)\right]^{-1}\exp\left[k\cos(\theta-\mu)\right],\ 0\le\theta<2\pi, \tag{1}$$

where $0\le\mu<2\pi$ and $0\le k<\infty$ are parameters, $I_0(k)$ – is the modified Bessel function of the first kind and order zero and is given by

$$I_0(k)=(2\pi)^{-1}\int_0^{2\pi}\exp\left[k\cos(\phi-\mu)\right]d\phi=\sum_{r=0}^{\infty}(k/2)^{2r}(1/r!)^2\,. \tag{2}$$

The distribution function is [6]

$$F(\theta)=\left[2\pi I_0(k)\right]^{-1}\int_0^{\theta}\exp\left[k\cos(\phi-\mu)\right]d\phi\,. \tag{3}$$

By the symmetry of the cosine function, this density is seen to be symmetric about the direction μ (as well as $\mu+\pi$). Since the cosine function has maximum value at zero and minimum value at π, the Circular Normal density is maximum at $\theta=\mu$, i.e., μ is the modal direction with the maximum value

$$f(\mu)=e^{k}\big/2\pi I_0(k) \tag{4}$$

and the minimum density, when $\theta=(\mu\pm\pi)$, is

$$f(\mu\pm\pi)=e^{-k}\big/2\pi I_0(k)\,. \tag{5}$$

From equations (4) and (5): $f(\mu)/f(\mu\pm\tau)=e^{2k}$. As $k\to 0$, the distribution converges to the uniform distribution CU; as $k\to\infty$, the distribution tends to the point distribution concentrated in the direction μ.

Modulation algorithm is described below [3]:

The values of parameters μ and k are known. On the preparation stage auxiliary parameters are computing: $a=1+\sqrt{1+4k^2}$, $b=[a-\sqrt{2a}]/(2k)$, $r=(1+b^2)/(2b)$.

1. Set $z=\cos(\pi u_1)$. Calculate $f=(1+rz)/(r+z)$ and $c=k(r-f)$.
2. If $c(2-c)-u_2>0$ go to 1.
3. If $\log(c/u_2)+1-c<0$ go to 4.
4. $\theta=sign(u_3-0.5)\cos^{-1}(f)+\mu\ \ [\mathrm{mod}\,2\pi]$.

u_1, u_2, u_3 are pseudo-random uniform numbers from $U[0,1]$ new each time step 1,2 or 4 is executed.

Figure 2 shows the circular distributions of three independent von Mises samples for $J = 10000$ angles with the next parameters: for Θ_1: $\mu = \pi/2$, $k = 50$; for Θ_2: $\mu = \pi$, $k = 10$; for Θ_3: $\mu = 3\pi/2$, $k = 50$. The each distribution VM_1, VM_2, VM_3 value area is divided for 15 intervals for histogram plotting.

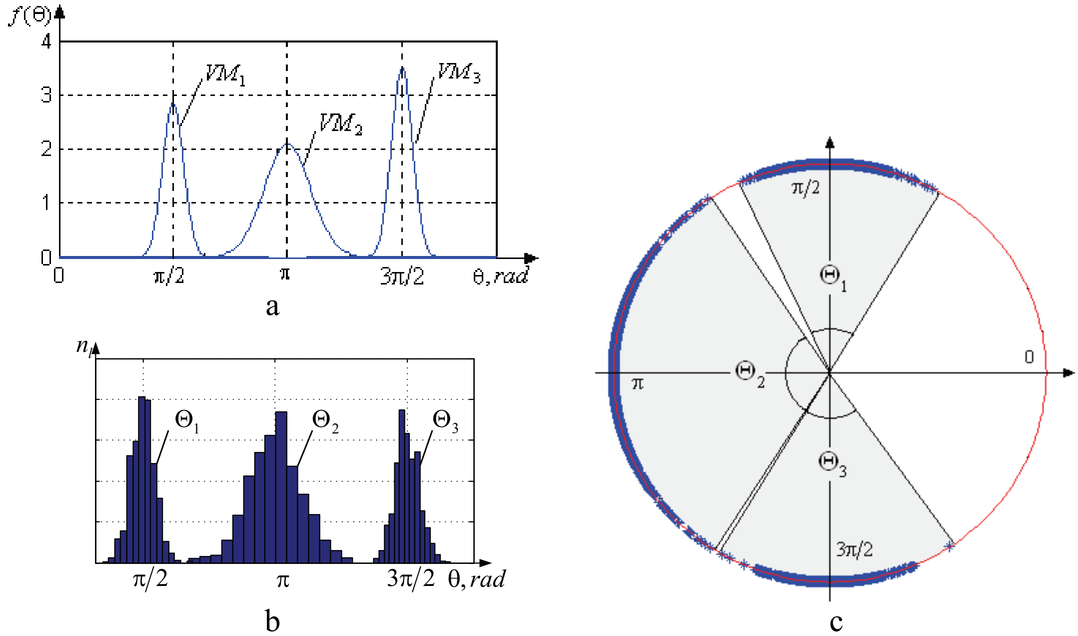

Figure 2. Circular distribution of three independent von Mises samples VM_1, VM_2 and VM_3: a – probability density functions; b – histograms, where n_l – amount of specified distribution values in the l-th interval; c – distributions on circumference of a circle.

Many random circular distributions are approximated to the von Mises distribution. The table of quantiles of the von Mises distribution for various concentration parameters and cumulative probabilities is obtained for confidence interval estimation. The cumulative von Mises distribution function with mean directions π and various concentration parameters k is presented on Figure 3. For each sample $J = 500000$. k points are 0, 0.5, 1, 2, 4, 8.

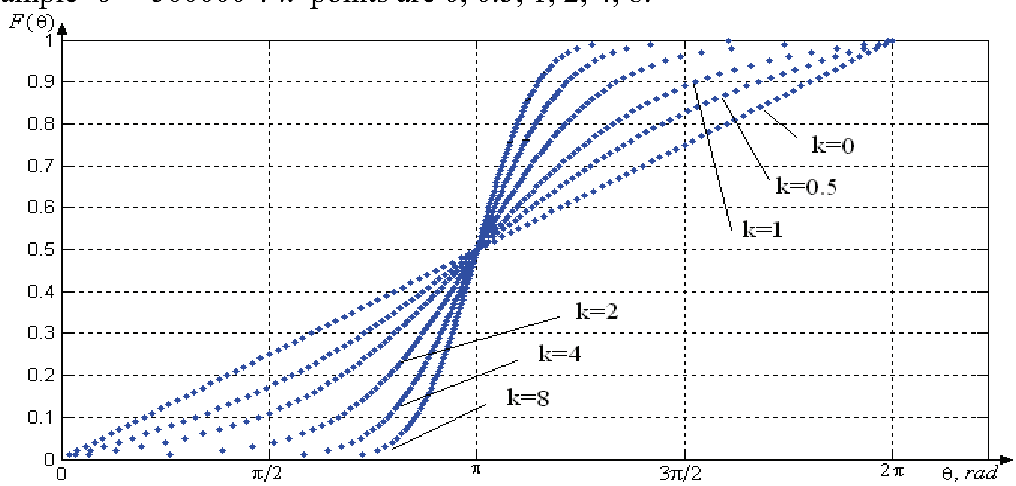

Figure 3. The cumulative von Mises distribution functions for $\mu = \pi$ and various concentration oparameters k .

Table of von Mises distribution quantiles is concidered for the next confidence probabilities: $P_c = 0.8$, $P_c = 0.9$, $P_c = 0.95$, $P_c = 0.99$.

Table 1. Quantiles of the von Mises distribution.

k	P_c							
	0.8		0.9		0.95		0.99	
	θ_{min}, rad	θ_{max}, rad	θ_{min}, rad	θ_{max}, rad	θ_{min}, rad	θ_{max}, rad	θ_{min}, rad	θ_{max}, rad
0	0.6284	6.2203	0.3142	5.9690	0.1570	6.1261	0.0314	6.2517
0.5	1.0132	6.1731	0.5379	5.7453	0.2738	6.0094	0.0550	6.2282
1	1.4901	6.0684	0.9336	5.3496	0.5170	5.7662	0.1078	6.1754
2	2.0886	5.4525	1.7236	4.5596	1.3488	4.9344	0.4878	5.7954
4	2.4617	4.4581	2.2550	4.0284	2.0651	4.2183	1.6452	4.6395
8	2.6764	4.0062	2.5407	3.7425	2.4205	3.8627	2.1763	4.1069

Example 1. Confidence interval determination for the von Mises circle distribution centered on $\mu = 1 \;\; rad$, $k = 2$ and $P_c = 0.9$ with Table 1 data application.

Confidence interval limits for specified parameters k, P_C and $\mu = \pi$ are $\theta_{min} = 1.7236 rad$ and $\theta_{max} = 4.5596 rad$. Expanded uncertainty is $U = 0.5(\theta_{max} - \theta_{min}) = 0.5(4.5596 - 1.7536) = 1.418 rad$.

The result determines as $(\mu \pm U) \mod 2\pi = (1 \pm 1.418) \mod 2\pi$. Thus confidence interval limits $\theta'_{min} \cong 5.8652$ and $\theta'_{max} \cong 2.418$ are shown on Figure 4 b.

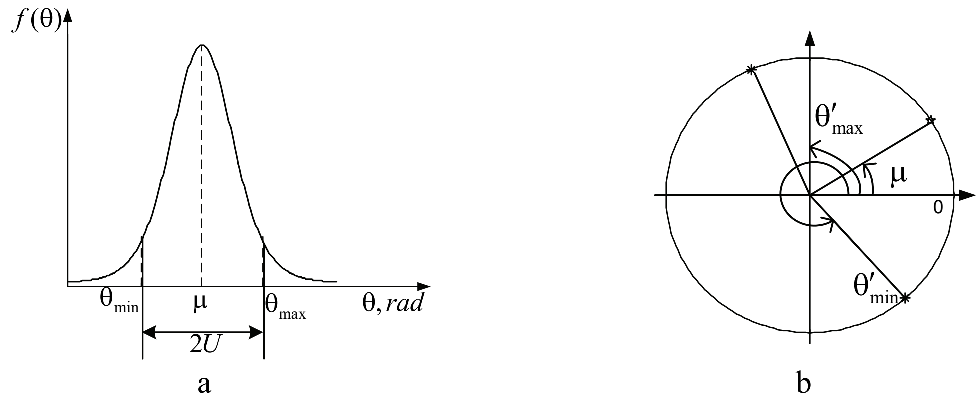

Figure 4. Example 1.

2.3. The Wrapped Normal distribution $WN(\mu, \rho)$

The Wrapped Normal distribution [2] is a symmetric unimodal two-parameter distribution which can be obtained by wrapping the Normal or Gaussian distribution (on the line) around the circle. Its probability density function is

$$f(\theta) = 1/2\pi \left(1 + 2\sum_{\rho=1}^{\infty} \rho^{\rho^2} \cos \rho(\Theta - \mu) \right), \; 0 \le \theta < 2\pi, \; 0 \le \rho \le 1, \tag{6}$$

where μ is mean direction, $\delta = (1 - \rho^4)/(2\rho^2)$ – circular dispersion. As $\rho \to 0$, the distribution converges to the uniform distribution CU; as $\rho \to 1$, the distribution tends to the point distribution concentrated in the direction μ. Distribution function is obtained by straightforward integration of (6).

Algorithm of simulating [3] includes following steps:

1) calculating $\sigma = \sqrt{-2 \ln \rho}$, $x = 0.25 \cdot (1.715528 \cdot (u_1 - 0.5)/u_2)^2$;

2) checking the condition $x \le 1 - u_2$: in true case go to 5;

3) checking the condition $\ln(c/u_2) + 1 - c < 0$: in true case go to 5; 4) returning to 1;

5) finding $x = \sigma z + \mu$, when z is pseudo-random value from $N(0,1)$;

6) obtaining a pseudo-random value from $WN(\mu, \rho)$ as $\theta = x \;\; [\mod 2\pi]$.

u_1, u_2 are pseudo-random uniform numbers from $U[0,1]$ new each time step 1 is executed.

On Figure 5 polar axes histogram shows the random Wrapped Normal distribution of two samples Θ_1, Θ_2 for $J = 10000$ angles with the parameters: for Θ_1: $\mu = \pi$, $\rho = 0.95$; for Θ_2: $\mu = \pi/6$; $\rho = 0.7$.

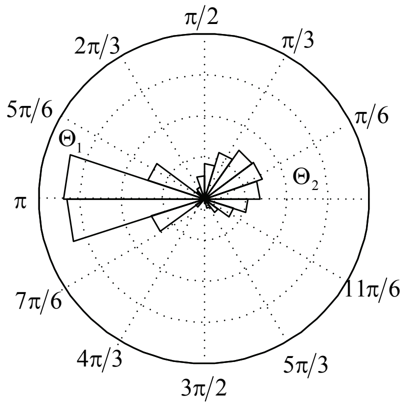

Figure 5. The Polar axes histogram of random Wrapped Normal distributions Θ_1 and Θ_2.

2.4. The Wrapped Cauchy distribution $WC(\mu, \rho)$

The Wrapped Cauchy distribution is a symmetric unimodal distribution which can be obtained by wrapping the Cauchy distribution (on the line) around the circle. Its probability density function is

$$f(\theta) = (1/2\pi)(1-\rho^2/1+\rho^2 - 2\rho\cos(\theta-\mu)),\ 0 \le \theta < 2\pi,\ 0 \le \rho \le 1 \tag{7}$$

The distribution function is

$$F(\theta) = (1/2\pi)\cos^{-1}\left(((1+\rho^2)\cos(\theta-\mu) - 2\rho)/(1+\rho^2 - 2\rho\cos(\theta-\mu))\right), \tag{8}$$

where μ – mean direction. As $\rho \to 0$, the distribution converges to the uniform distribution CU; as $\rho \to 1$, the distribution tends to the point distribution concentrated in the direction μ.

Algorithm of simulation [3]:

1. Set pseudo-random uniform number u_j, $u_j \in U$, $U[0,1]$, $j = \overline{1,J}$;
2. $V = \cos(2\pi u_j)$, $c = 2\rho/(1+\rho^2)$;
3. $\theta = \cos^{-1}((V+c)/(1+cV)) + \mu$ $[\bmod 2\pi]$ – pseudo-random value from $WC(\mu,\rho)$.

Modeled probability density functions WC_1, WC_2 and WC_3 are shown on Figure 6 a: WC_1 has $\mu = \pi$, $\rho = 0.2$; WC_2 has $\mu = 7\pi/6$, $\rho = 0.8$; WC_3 has $\mu = 5\pi/6$, $\rho = 0.5$. Sample Θ_1 for $J = 100000$ angles is also shown as a polar histogram on Figure 6 b.

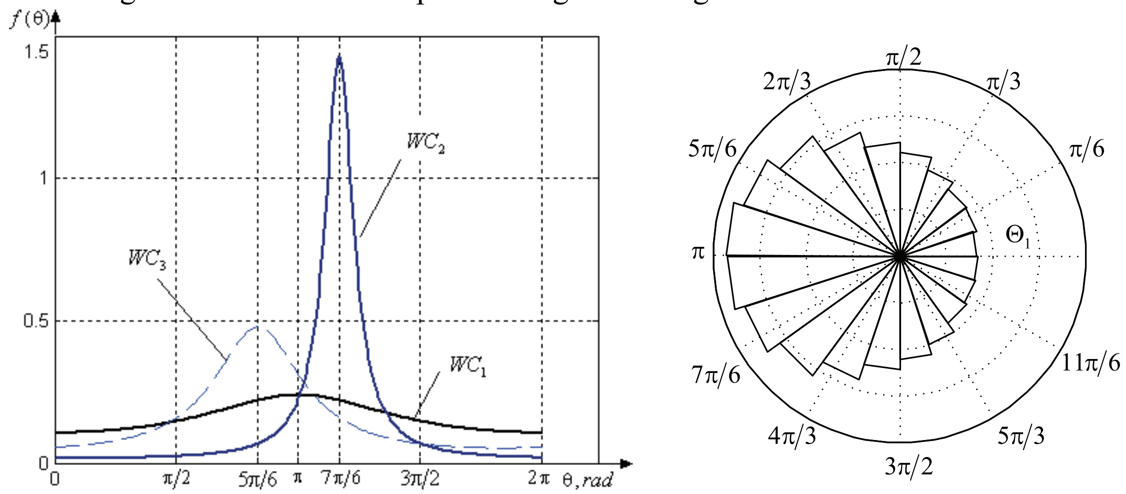

Figure 6: a – probability density functions of the Wrapped Cauchy distributions WC_1, WC_2 and WC_3; b – Θ_1 polar histogram.

Simulated circular distributions confirm reasonableness of executed methods of simulation. These methods can be applicated while random circular data computer experiments.

3. Conclusions

1. The basic random circular data distributions as the Uniform distribution, the von Mises distribution, the Wrapped Normal distribution and the Wrapped Cauchy distribution are described.

2. The algorithms of different probability densities random circular data simulating are considered. Simulation data can be used for further circular statistical analyses in different areas of science and technique.

3. The table of quantiles of the von Mises distribution for variable concentration parameter and confidence probabilities is given. It can be applied for random circular data measurement results accuracy ranking.

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ACOUSTIC EMISSION WITH NONLINEARITY OF DEFORMATION AND THRESHOLD CHANGE OF DESTRUCTION RATE OF COMPOSITE MATERIAL

Signals of acoustic emission taking into account nonlinearity of a composite deformation and threshold type of change of fibers destruction speed in a critical area are described using relaxation model of composite material destruction.

Introduction

Acoustic Emission (AE) is one of the methods of composite materials diagnostics. Theoretic and experimental research, directed to establish of acoustic radiation, are used for development of control methods and danger criteria assess of processes, developing in structure of a composite material. From this point of view theoretic research with development of models of AE signals are very important.

Analysis of destruction process of composite materials, in conditions of uniaxial tension and shear, is based on usage of fiber bundle model [1-3]. According to the model we can assume that the fibers are independent and destruction of them happens in consecutive way when reaching the threshold value of strength (deformation). Such assumption is true under the following conditions. First, matrix is elastic or it is less strong than the bunch (fibers). Then the destruction of it does not conduce to destruction of the material because the bunch can stand external load. Second, matrix is stronger than the bunch. When the deformation is elastic destruction starts from destruction of a bunch (fibers). Then gradual accumulation of destructed fibres or sub-micro (micro) cracks brings to complete destruction of the material. In both cases destruction of the bunch is examined as the basic process that leads to the loss of bearing capacity and destruction of the material. Under such conditions properties of the bunch, influence of the surface of part matrix-bunch and interaction between separate fibers under destruction of the composite material are not examined.

Model of the bunch of fibers was used for description of AE signals radiation process in conditions of tension [4, 5]. Interaction between intensity of AE energy radiation with the speed of destruction of fibers when approaching the complete destruction of the material was thus achieved. Such limit was connected with the fact that uncertainty (tendency of functions to infinity) appeared when the process of destruction and AE radiation in the moment of complete destruction of the material was being described. It makes the description of the forming AE signal impossible.

Analytical expressions for AE signals during destruction of the composite material in conditions of shear load were achieved in works [6, 7], for the case of a uniform distribution of probability density of tension and bending deformation. Kinetic regularity of the destruction process [8] and nonlinearity of stress changes on the fibers during destruction of them [9, 10] were taken into account. Research made in [7], showed nonlinearity of changes of AE signals characteristics when the speed of loading is being geared up. Such nonlinearity can be connected with both nonlinearity of stress changes on the fibers and peculiarities of the destruction process – threshold character of destruction.

Regularities of AE signals changes accounting threshold character and exponentially increasing speed of destruction in critical sphere approaching the relaxation model will be shown in the article. The fact that stress on the fibers changes non-linearly in the sphere before the beginning of destruction will be taken into consideration.

Results of Researches

Nonlinearity of stress changes on the fibers that appears in the process of destruction during stretching and bending [9, 10], in general can be described by the polynomial as

$$\sigma(\varepsilon) = E\varepsilon - E\zeta\varepsilon^2 - E\zeta_1\varepsilon^3........, \tag{1}$$

where E – modulus of fiber elasticity; $\zeta, \zeta_1,....$– parameters.

If the modulus of elasticity is a unit (E=1) and to limit only by the second member of decomposition in (1), accounting threshold deformation ε_0 , that meets maximum stress σ_0 , and consider, that deformation of the material is uniform ($\varepsilon = \alpha t$), dependence of the stress from deformation will be the following

$$\sigma(t) = \sigma_0 + \sqrt{1-4\sigma_0\zeta}\,\alpha\tau - \zeta\alpha^2\tau^2, \tag{2}$$

where σ_0 – threshold stress of destruction; ζ – dimensionless parameter; α – speed of deformation; $\tau = t - t_0$; $t > t_0$ and $\tau > 0$; t_0 – beginning of destruction.

As it seen from (1), non-linearity of stress change on the fibers in the critical area is connected with both characteristic ζ and α .

Taking into consideration the expression for speed of remaining fibers [4, 5] changes, threshold character of destruction that starts at the time moment t_0, and also the kinetic of the process with a speed increasing by exponential law, expression for the quantity of non-destructed fibers will be the following

$$N(\tau) = N_0 e^{-\upsilon_0 \int\limits_0^{\tau} e^{r[\sqrt{1-4\sigma_0\zeta}\,\alpha\tau - \zeta\alpha^2\tau^2]} d\tau} . \tag{3}$$

Results of modeling $N(\tau)$, according to (3), for the case of constant value α and different ζ , and also for constant value ζ and different α , are shown in fig.1 and fig. 2 in relational units. All the parameters used in (3) are brought to dimensionless values. When modeling it was taken: $\tilde{\sigma}_0$=0,00497, $\tilde{t}_0$ =0,0005, $\tilde{\upsilon}_0$ =100000, r =10000. For fig.1 α =10, and values ζ were: ζ =1,37, ζ =1,39 and ζ =1,41. For fig. 2 ζ =1,37, and values α changed in the range of values from 10 to 50. The time of beginning of fibers destruction for the given $\tilde{\alpha}$ is: for $\tilde{\alpha}$ =10 - $\tilde{t}_0$ =0,0005; for $\tilde{\alpha}$ =20 - $\tilde{t}_1$ =0,00025; for $\tilde{\alpha}$ =40 - $\tilde{t}_0$=0,000125; for $\tilde{\alpha}$ =50 - $\tilde{t}_0$ =0,0001.

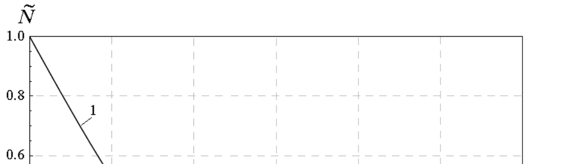


Fig. 1 – Time dependence of the quantity of non-destructed fibers. $\tilde{\alpha}$ =10, $\tilde{\upsilon}_0$=100000, g=0,1, r =10000, $\tilde{t}_0$ =0,0005, $\tilde{\sigma}_0$=0,00497. Curves 1, 2, 3 were achieved according to (3) for the following values ζ : 1 - ζ =1,37; 2 - ζ =1,39; 3 - ζ =1,41

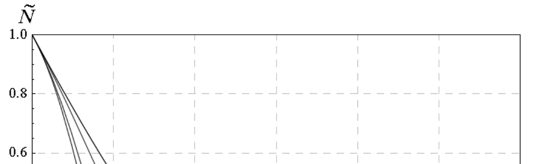


Fig. 2 – Time dependence of the quantity of non-destructed elements, according to (3), when ζ =1,37, $\tilde{\upsilon}_0$=100000, r =10000, $\tilde{\sigma}_0$=0,00497, g=0,1. For curves 1-4 $\tilde{\alpha}$ possesses the value: 1 – $\tilde{\alpha}$ =10; 2 – $\tilde{\alpha}$ =20; 3 – $\tilde{\alpha}$ =40; 4 – $\tilde{\alpha}$ =50

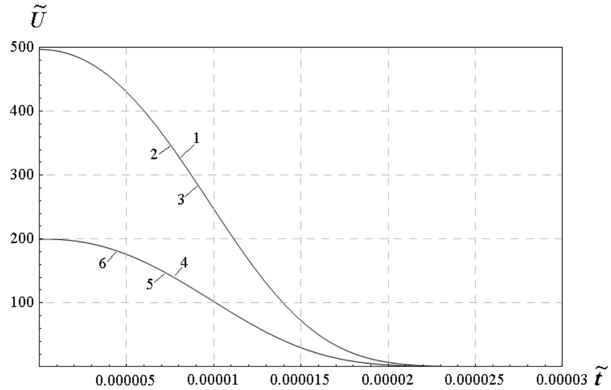
From fig.1 it can be seen that time dependence of the quantity of non-destructed elements does not depend on the change of value ζ made by us. But all the curves in the fig.1 match each other. At the same time when increasing $\tilde{\alpha}$ the speed of destruction increases too. As a result you can see increase of fall slope of curves quantity of the remained elements and decrease of the time of destruction process (fig. 2).

Taking into account the assumptions taken in [6, 7] (destruction of each fiber brings to formation of single impulse of disturbance that spreads without attenuation, its duration δ is less than the time of the whole process of destruction and amplitude depends on tension of destruction), expression for the AE signal will be the following

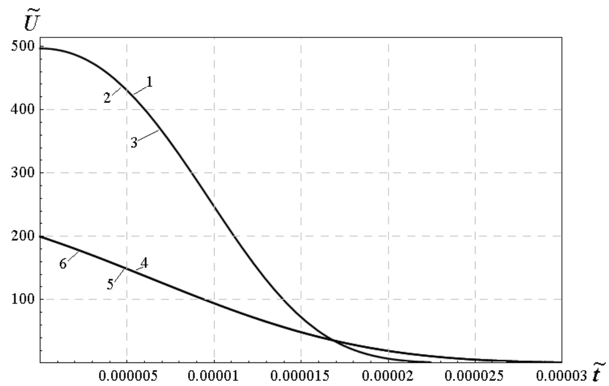
$$U(t) = u_0 \upsilon_0 [\sigma_0 + \sqrt{1 - 4\sigma_0 \zeta \alpha \tau - \zeta \alpha^2 \tau^2}\,] e^{r[\sqrt{1 - 4\sigma_0 \zeta \alpha \tau - \zeta \alpha^2 \tau^2}\,]} e^{-\upsilon_0 \int_0^{\tau} e^{r[\sqrt{1 - 4\sigma_0 \zeta \alpha \tau - \zeta \alpha^2 \tau^2}\,]} d\tau}, \quad (4)$$

where υ_0, r – constants, that depend on physical-mechanical characteristics of the material; $u_0 = N_0 \beta \delta_S$; δ_s – average duration of a single impulse of disturbance; β– coefficient of proportionality.

Results of AE signals modeling according to (4), in form of graphs $\widetilde{U}(t) = U(t)/u_o$ in relative units for values of the parameters as in fig.1 are shown in fig.3, *a* (curves 1, 2, 3). In fig.3, *a* (curves 1, 2, 3) it can be seen that accounting the given value of α and different values of ζ you can observe no changes in parameters of the forming AE signals. Undoubtedly the initial amplitude of AE signal will depend on threshold stress $\widetilde{\sigma}_0$. The less $\widetilde{\sigma}_0$, the less the initial amplitude of AE signal, it can be seen in the results of modeling shown in fig. 3, *a* (curves 4, 5, 6). AE signals in fig. 3, *a* (curves 4, 5, 6) were achieved for the same values of the parameters as in fig. 3, *a* (curves 1, 2, 3), and $\widetilde{\sigma}_0$ is decreased in 2,5 times. The results show that the form of AE signals does not depend on values ζ and $\widetilde{\sigma}_0$. AE signal according to its form is a signal of relaxation type. At the same time when decreasing the threshold stress and constancy of material characteristics you can watch the increase of destruction process time or duration of AE signals that cannot be seen in the obtained results (fig. 3, *a*). Such discrepancy can be explained in the following way: decrease of $\widetilde{\sigma}_0$ for the taken material, means increase of dispersion of firmness characteristics, so it brings to decrease of value *r* in (3) and (4). It is shown in fig. 3, *b* graphs of AE signals with the same value of the parameters as in fig. 3, *a*, but for curves 4, 5, 6 value *r* is decreased in 2 times. Such decrease of *r* with taken $\widetilde{\sigma}_0$ practically brings only to increase of AE signal duration.



a



b

Fig. 3 –Temporal move $\widetilde{U}(\tau)$ for AE signals that were achieved using (16) with $\widetilde{\alpha}$=10, $\widetilde{\upsilon}_0$=10^5. Values of the parameter $\widetilde{t}_0$: 1, 2, 3 - $\widetilde{t}_0$=0,0005; 4, 5, 6 - $\widetilde{t}_0$=0,0002. Values of the parameter ζ : 1, 4- ζ =1,37; 2, 5 - ζ =1,39; 3, 6 - ζ =1,41. For (*a*): r=10000; curves 1, 2, 3 - $\widetilde{\sigma}_0$=0,00497; curves 4, 5, 6 - $\widetilde{\sigma}_0$=0,00025. For (*b*): curves 1, 2, 3 - $\widetilde{\sigma}_0$=0,00497; r=10000; curves 4, 5, 6 - $\widetilde{\sigma}_0$=0,00025; r=5000

According to fig.2 faster destruction of the fibers of compositional material happens with increase of $\widetilde{\alpha}$.

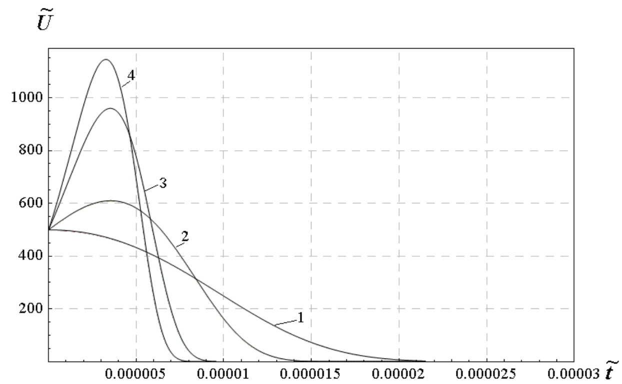


Fig. 4 – Temporal move $\tilde{U}(\tau)$ for AE signals, that were achieved using (16) with ζ =1,37, $\tilde{\upsilon}_0$=10^5, r=10^4, $\tilde{\sigma}_0$=0,00497. Values of the parameter $\tilde{\alpha}$:1 – $\tilde{\alpha}$ =10; 2 – $\tilde{\alpha}$ =20; 3 – $\tilde{\alpha}$ =40; 4 – $\tilde{\alpha}$ =50

It brings to increase of the amplitude, decrease of duration and transformation of AE signals form that is shown in fig. 4. Graphs of fig.4 are normalized similarly to the graphs of fig. 3 and they were achieved with the values of the parameters in accordance with fig.2. The result that was achieved coordinates with the facts given in work [7]. But initial leap of AE signals amplitude $\tilde{U}(\tau = 0)$, as for the values of fig. 3, is defined by value of the threshold stress $\tilde{\sigma}_0$ and does not depend on the speed of load.

Conclusion

Results of the research showed that with threshold change of destruction speed of composite material fibers, nonlinearity of stress changes on the fibers does not influence on form and amplitude of the forming AE signals. It was proved that the change of threshold stress of destruction brings to decrease of amplitude parameters of AE signals. But one must take into account the change of dispersion of compositional material characteristics in firmness that influences on the change of AE signals duration. It is also shown that in relaxation model accounting threshold destruction character, physical-mechanical characteristics of fibers and speed of compositional material load (it is given by external conditions) influence on parameters and form of AE signals. Increase of amplitude, decrease of duration and transformation of AE signals form happens with increase of load speed.

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MATHEMATIC MODELS OF AIRCRAFT STRUCTURAL RELIABILITY CALCULATION

The mathematic models of damageability under static and cyclic loadings are researched. The parameters of damageability and endurance are considered necessary for the calculation of long-term durability exhaustion at the low-cycle and high-cycle fatigue, thermocyclic endurance and creep, as well as general models, taking into account the multiaxis and multicomponent loadings. The models of damageability at loading range, the probabilistic models of endurance and accumulation of damages at random influence are given. Probabilistic criteria for calculation of service life making and their connection with accumulated damageability are researched.

Problem statement

For the constructive elements having long periods of latent damage accumulation, it is expedient to evaluate the operational condition on the basis of individual service life calculation depending on the stressing during the operation period.

In the process of designing and finishing the choice of the rational constructive and engineering solutions, which allow to increase the reliability of specific component, is always a result of the analysis and the compromise between features of various aspects of stressing, an calculation of probability for possible types of destructions, its consequences, an engineering and economic ground of the appointed service life. Such approach to service life calculation can be implemented by means of the rated-experimental methods providing comparison between parameters of operational loading of components with the experimental performances of their durability considering the influence of main factors of actual loading processes.

1. Models of components damaging during static and cyclic loading

During the calculation of service life of crucial constructive elements of airframe and gas-turbine engines (GTE) at a design stage and while in service, the concept of material damaging is used.

Damaging is understood as the process of irreversible changes developing in a material under the influence of stresses, strains and temperatures, and leading, finally, to destruction.

From the physical point of view the development of this process is the irreversible changes of material structure, which cause the violations of material integrity (a macrocracks, form change, a warping, etc.), defined by character of: the static, the long static, the multicyclic, the low-cycle, the thermocyclical operating loading.

Material damageability is estimated by the parameters which describe behavior of a material on the basis of mechanics methods of a continuous solid state.

The material damageability rate of a component is estimated by relative value D, which varies within limits 0÷1. Its value on an initial intact condition equals zero ($D=0$), and at the moment of reaching a limiting condition equals one ($D=1$).

For the evaluation of long static damage under the condition of monoaxial loading the conditional principle of linear damage summation in the form of relative endurance is used.

$$\mathrm{D}_s = \int_0^{\mathrm{t}} \frac{d\mathrm{t}}{\tau_{dur}(\sigma_{st}, \mathrm{T})},$$

where

$\tau(\cdot)$ – characteristics of long durability

Multiaxis loading is considered as one of four equivalent loadings which are a combination of the principal loadings σ_1, σ_2 и σ_3 ($\sigma_1 \geq \sigma_2 \geq \sigma_3$):

$$\sigma_{e1} = \sigma_1$$
$$\sigma_{e2} = \frac{1}{\sqrt{2}}\sqrt{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}$$
$$\sigma_{e3} = \frac{1}{2}(\sigma_{e1}+\sigma_{e2})$$
$$\sigma_{e4} = (\sigma_1+\sigma_3)$$

For the description of performances for long durability $\tau_{\text{dur}}(\cdot)$ at fixed temperature or exponential dependences of time before destruction t^* from equivalent stress σ_e are used:

$$t^*(\sigma_e) = C\sigma_e^{-n}$$
$$t^*(\sigma_e) = A\exp(-\alpha\sigma_e)$$

where

C, n, A, α − material constants

At variable temperature the generalized performances of the long durability are used $\lg(t^*) = \tau(\sigma, T)$, three types of the these equations describe dependences with accuracy for alloy ЖС26ВСНК (Fig.1) look like [11].

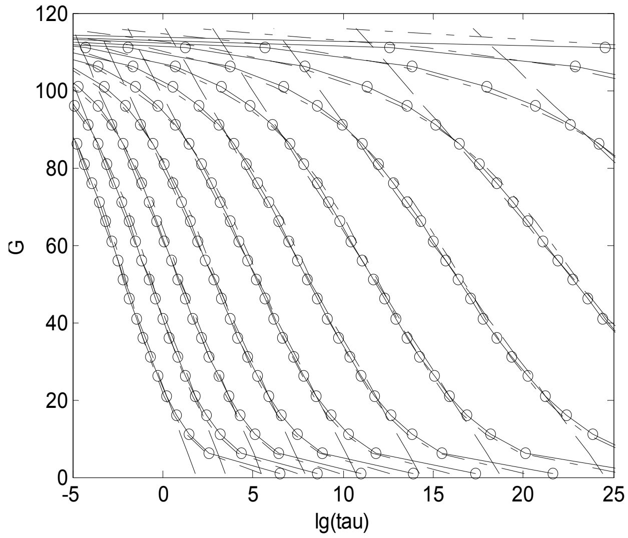


Fig. 1. Types of long-term durability curves of alloy MAR (ЖС26ВСНК)

$$\lg(\text{t*}) = -20 + (36537.33 - 9082.95\lg(\sigma) + 4180.43\ \lg(\sigma)^2 -$$
$$1569.85\ \lg(\sigma)^3 + +341.732/(\lg(\sigma) - 2.08))/\text{T})$$
$$\lg(\text{t*}) = -20 + (35273.76 - 21806.17\lg(\sigma) + 2383.192\ \lg(\sigma)^2)/(1 - 0.466814\ \lg(\sigma))/\text{T}$$
$$\lg(\text{t*}) = -20 + 30004.82/T - 106.8396\sigma / \text{T}$$

where

σ − component loading in kg/mm^2;

T – component temperature °K.

The way of estimating the fatigue ratio is the same:

$$D_c = \int_1^N \frac{dN}{N(\sigma_a, T)},$$

where

$N(\cdot)$ − endurance performances.

In case of multicomponent loading for calculation of components damageability such criteria of destruction as strength, time and deformation are applied [9,10]. These criteria are based on both linear and nonlinear ways of damage calculation.

2. Damage models of components by loading range

The components of glider and power plant are usually under the influence of changing stress with different maximum stress values σ_{max}. A loadong range is a stress frequency of various intensity. Changing laoding with different maximum stress values σ_{max} are usually acting on the air frame and engine components during the flight. Let's analyze a range of stresses occurring from bending moment which affects wing components caused by atmospheric turbulence. The work reveals the analysis of flight stressing ratio of different aircraft. It shows that the range of its amplitudes complies with the logarithmic law $\sigma_a = f(\ln(N_\sigma))$ and lies within the same range with changes [2]. The loading range can be stated as the ratio σ_f / σ_c, where σ_f is the current stress value and σ_c is the average stress value in flight and it characterizes the flight conditions. The loading continuous range for limiting the stress can be replaced by the step function that greatly reduces an accounting system. The range is divided into 10 degrees with maximum value σ_1 / σ_c=1,6 and minimum σ_{10} / σ_c=0,222 (Table 1)

Table 1

Discrete stresses range

σ_i / σ_c	1,6	1,50	1,30	1,15	0,995
n_σ	1	2	5	18	52
σ_i / σ_c	0,84	0,685	0,530	0,375	0,2220
n_σ	152	800	4170	34800	358665

Maximum laoding of the final two stages and corresponding stress intensity factors (SIF) for the crack resistance analysis are lower than the level of the saturation intensity threshold coefficient K_{th}. That is why they are not taken into account. The lower part of the Tab. 1 shows corresponding to this loading cycles n_σ, of a given level which is within the prescribed limits. In this block maximum stress appear once, while minimum ones appear 4170 time per every 5200 loading cycles.

It's obvious that

$$\sigma_{\max} = \sigma_c + \sigma_a ;$$
$$\sigma_{\min} = \sigma_c - \sigma_a .$$

Cycle asymmetry factor:

$$r = \frac{\sigma_{\min}}{\sigma_{\max}}$$

Figure 2 shows maximum and minimum stresses of range loadings by given midvalue of the laoding σ_c = 70 MPa

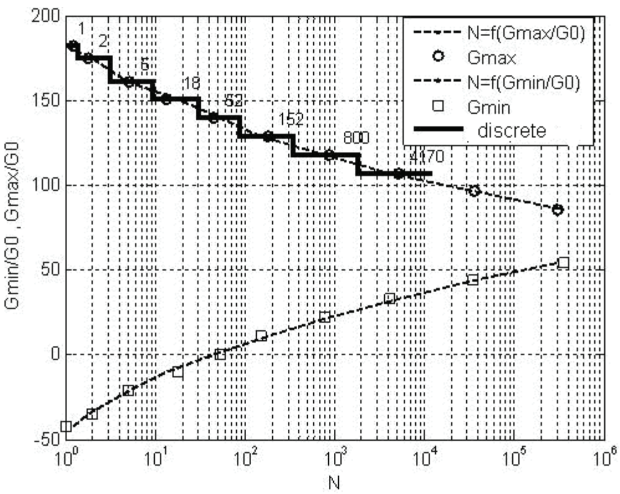


Figure 2. Continuous and discrete laoding range.

The equations of the curves for maximum and minimum stresses range by $\sigma_c = 70$ MPa look like:

$\lg(N_{\max i})$=0.0003477 $\sigma^2_{\max i}$ -0.14892 $\sigma_{\max i}$ +15.669;

$\lg(N_{\min i})$=0.0003477 $\sigma^2_{\min i}$ +0.05155 $\sigma_{\min i}$ +1.6357;

where

$$\sigma_{max\ \mathrm{i}} = \sigma_{\mathrm{c}}(1+\frac{\sigma_{\mathrm{i}}}{\sigma_{\mathrm{c}}});\ \sigma_{min\ \mathrm{i}} = \sigma_{\mathrm{c}}(1-\frac{\sigma_{\mathrm{i}}}{\sigma_{\mathrm{c}}})$$

Load program is based on the formation of particular ranges that in their turn are formed by main range by exclusion of its particular components: the first one, first two ones, etc. Meanwhile each range characterizes stressing conditions during particular flight. When there is a full range - similar flight conditions occur in a turbulent atmosphere (storm), in other cases – in less dangerous situations. Occasional order of the laoding range choice and programming allows us to simulate flight conditions close to real ones.

According to the linear damage summation hypothesis damage extent is proportionate to the relation of cycle number $n_{\sigma i}$ to the limit number of cycles $N_{lim\,i}(\sigma_{\max \mathrm{i}})$ for a given i^{th} stress $\sigma_{\max i}$. The discrete loading range has *k* levels, and the continuous one has loading cycles, the part of which depends on stress level that changes from $\sigma_{\max 1}$ to $\sigma_{\max k}$.

Let's call general number of loading cycles a full cycle, obtained damage – a damage range, and total accumulated damage – a damage per one full stress cycle. Due to this the formulae for calculation of accumulated damage per *m* full laoding cycles in the discrete and continuous variant look like:

$$\mathrm{D_m} = \sum_{\mathrm{l=1}}^{\mathrm{m}}\sum_{\mathrm{i=1}}^{\mathrm{k}}\frac{\mathrm{n}_{\sigma i}(\sigma_{\max \mathrm{i}})}{\mathrm{N_{lim i}}(\sigma_{\max \mathrm{i}})}; \qquad (1)$$

$$\mathrm{D}_m = \sum_{\mathrm{l=1}}^{\mathrm{m}}\int_{\sigma_{\max 8}}^{\sigma_{\max 1}}\frac{\mathrm{n}_\sigma(\sigma_{\max})d\sigma}{\mathrm{N_{lim}}(\sigma_{\max})}, \qquad (2)$$

where damage ratio is $D_m > 1$.

In general case the quantity $n_{\sigma i}$ defines only that part of cycles that corresponds to a given stress level $\sigma_{\max i}$; that is why it can be non integer. In a given example of the loading range the maximum stress appears only 10 times per 40 000 flights [2], that is why while calculating the damage for one flight $n_{\sigma i}$ =1/4000.

Taking into account a complicated nature of actual component laodng ranges and integration kind of resistance properties when computing the value of integrals, it is appropriate to use quadrature formulae – the Simpson one and the Newton-Cotes one of the 8th degree. But for some cases there are end design formulae of damage model per full loading cycle of the component:

The first model along with linear range dependence and limit stresses from $\lg(N)$:

$$\mathrm{D_{FC}} = \int_{v_1}^{v_2}\frac{\mathrm{n}_\sigma(\sigma)d\sigma}{\mathrm{N}(\sigma)} = \int_{v_1}^{v_2}\frac{10^{\mathrm{c+d\sigma}}}{10^{\mathrm{a+b\sigma}}}d\sigma = \frac{10^{(\mathrm{c\text{-}b_{0+v_2}}(d-b_1))} - 10^{(c-b_{0+v_1}(\mathrm{d\text{-}b_1}))}}{(\mathrm{d - b_1})ln(10)}$$

The second model along with quadratic range dependence and the linear one of limit loading from lg*(N):*

$$D_{FC}=\int_{v_1}^{v_2}\frac{n\ (\sigma)d\sigma}{N(\sigma)}=\int_{v_1}^{v_2}\frac{10^{c+d\sigma+q\sigma^2}}{10^{a+b\sigma}}d\sigma=\begin{pmatrix}-\frac{1}{2}erf\left(\frac{1}{2}\frac{qv_2ln(100)+ln(10)(d-b_1)}{\sqrt{-qln(10)}}\right)+\\ \frac{1}{2}erf\left(\frac{\frac{1}{2}qv_1ln(100)+\frac{1}{2}ln(10)(d-b_1)}{\sqrt{-qln(10)}}\right)\end{pmatrix}\times$$

$$\times\exp\begin{pmatrix}ln(10)(q(c-b_0)-\\ \frac{1}{4}\frac{-d(d-2b_1)-b_1^2)}{q}\end{pmatrix}\Bigg/\sqrt{-\frac{qln(10)}{\pi}}$$

The third model along with range degree dependences and limit loading:

$$D_{FC}=\int_{v_1}^{v_2}\frac{n_\sigma(\sigma)d\sigma}{N(\sigma)}=\int_{v_1}^{v_2}\frac{A\sigma^m}{B\sigma^n}d\sigma=\frac{A\left(-v_2^{-n+m+1}+v_1^{-n+m+1}\right)}{B(n-m-1)}$$

The fourth model along with strength-exponential range dependence and limit loading:

$$D_{FC}=\int_{v_1}^{v_2}\frac{n_\sigma(\sigma)d\sigma}{N(\sigma)}=\int_{v_1}^{v_2}\frac{A\sigma^m c^\sigma}{B\sigma^n b_1^\sigma}d\sigma=\frac{-A\begin{pmatrix}C_{v1}^{22}n-C_{v1}^{22}m+C_{v2}^{11}n-C_{v2}^{11}m-\\ -C_{v1}^{21}n+C_{v1}^{21}m-C_{v2}^{12}n+C_{v2}^{12}m+\\ +C_{v2}-C_{v1}\end{pmatrix}}{((-ln(c)+ln(b_1))B)},$$

where

$$C_{v1}^{22}=v_1^{-n+m}d_1^{\,n-m}\gamma(-n+m,d_1);$$
$$C_{v2}^{11}=v_2^{-n+m}d_2^{\,n-m}\Gamma(-n+m);$$
$$C_{v1}^{21}=v_1^{-n+m}d_1^{\,n-m}\Gamma(-n+m);$$
$$C_{v2}^{12}=v_2^{-n+m}d_2^{\,n-m}\gamma(-n+m,d_2);$$
$$C_{v2}=v_2^{-n+m}c^{v2}b_1^{-v2};$$
$$C_{v1}=v_1^{-n+m}c^{v1}b_1^{-v1};$$
$$d_1=v_1(-ln(c)+ln(b_1));$$
$$d_2=v_2(-ln(c)+ln(b_1));$$

$\Gamma(\alpha),\ \gamma(\alpha,x)$ – full and partial range of functions.

The continuous line of Fig.3 shows the stresses range (SR) and limit stresses (LS), and the dot line shows damage range per one full stress cycle for 1 model:

SR: $\lg(N_S)$ = -0.554125 $\sigma_{\text{мах}}$ +9.7235455;
LS: $\lg(N_{D1})$= 12.294422-0.275464 $\sigma_{\text{мах}}$.

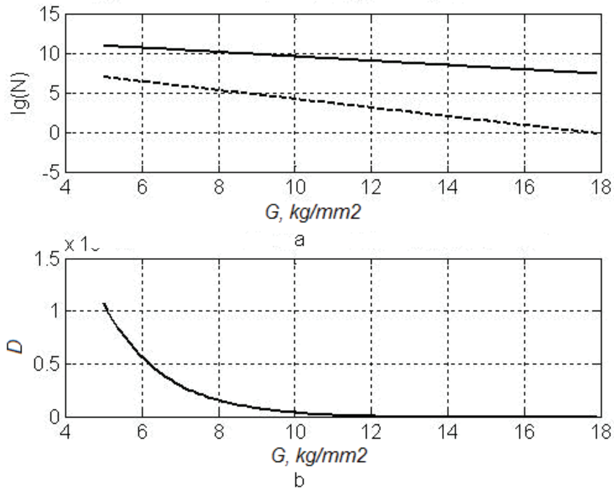


Figure 3. The first model characteristics per full cycle: − stresses range and durability characteristics $\lg(N) = f(\sigma) + S_{\sigma,}$ b − damage range of a full cycle $D = f(\sigma) + S_{\sigma}$

Figure 4 shows the same characteristics for quadratic range – $\lg(N_S)=0.03477\sigma_{max}^{2}$ - $1.4892\sigma_{max}$ +15.669) and limit stresses $\lg(N_{D2})=23.4151-5.6135\ln(\sigma_{max})$, calculated with a help of numerical method. The quantities of accumulated damage per one full cycle equal: first model - D_1 = 0,0014, second model - D_2=0.0001151.

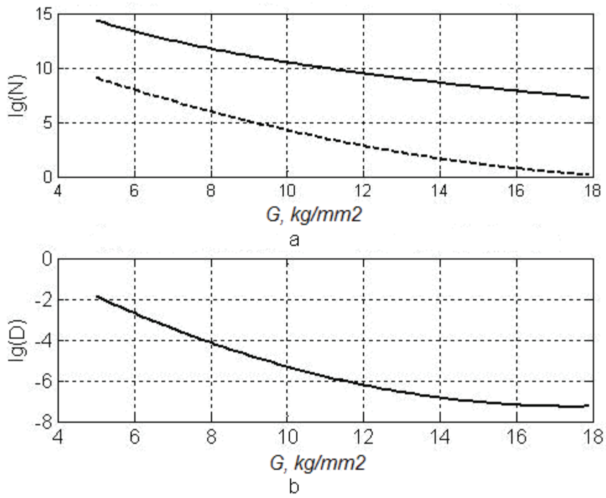


Figure 4. Characteristics of the second model per full cycle: a − loading range and durability characteristics $g(N) = f(\sigma) + S_{\sigma,}$ b − damage range of a full cycle $D = f(\sigma) + S_{\sigma}$

3. Probabilistic damage models under static and repeated loading

Let's consider several possible components damage accumulation process models during the flight.

The random lumped loadings which are slowly varying in accordance with the function are acting on components. (Figure 5):

$$(t)=\sigma_0+\chi(t), \qquad 6)$$

where

σ_0 − random variety, distributed in accordance with ordinary law with following parametes $M[\sigma_0]=0$, $D[\sigma_0]=S^2_0$;

$\chi(t)$ - determinate function.

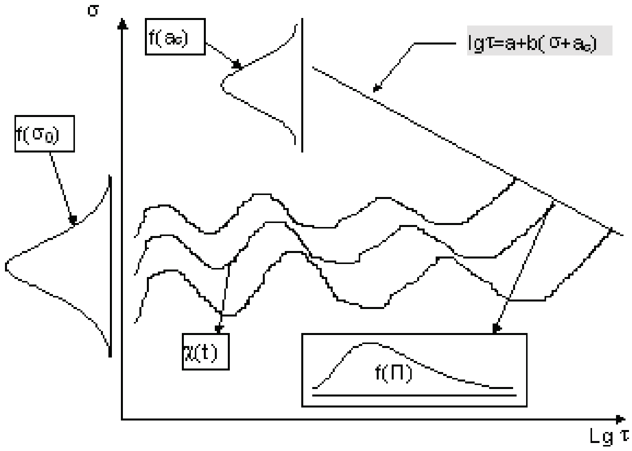


Figure. 5. The damage progress model under random stressing

It is physically the rejection of the fact that acted on the component in flight stress rates during the entire flight will differ by the constant value from the average values for these modes. For example, this may be due to changing weather conditions, arrangements and other external factors of the flight.

Structural behavior of components material under the influence of static or slowly varying loadings and constant temperature can be described by stress rupture curve, which is valid for exponential law of relationship between destructive stress σ_n and time for failure.

In the probabilistic interpretation this curve has the following structure:

$$g\tau = a + b(\sigma + a_\sigma), \qquad (7)$$

where

a_σ − featured probabilistic material properties variable;

$M[a_\sigma]=0$, $D[a_\sigma]=S^2_a$.

According to linear hypothesis of static damage summation the level of damage accumulated in the material components of damage D during the time of laoding t^* is defined by the formula:

$$D\left(t^*\right) = \int_0^{t^*} \frac{dt}{\tau(\sigma(t))}.$$

Substituting expressions (6) and (7) in this formula, we obtain

$$D = \int_0^{t^*} \frac{dt}{exp(a + b(\sigma(t) + a_\sigma))} = \frac{\gamma\left(t^*\right)}{exp(a + b(\sigma_0 + a_\sigma))} = \varphi(\sigma_0 + a_\sigma) \qquad (8)$$

where

$$\gamma\left(t^*\right) = \int_0^{t^*} \frac{dt}{\exp(b\chi(t))}$$

$\gamma(t)$ − determinate function.

Random variety of damageability rate per flight D in expression (8) is connected with random variety σ_0 and steady exponential dependence a_σ. To determine the distribution damage density $f(n)$ we use the formula

$$f_D(D) = f_\nu(\Psi(D))|\Psi'(D)|, \qquad (9)$$

where

$f_\nu(\cdot)$ − distribution damage density of the sum of normal independent random variable σ_0 and a_σ; $M[\nu]=0$; $D[\nu]=S^2_\nu=S^2_a+S^2_\sigma$;

$\Psi(D)$ - inverse function in relation to $\varphi(\cdot)$.

According to the expression (9)

$$\Psi(D) = \nu = (\gamma(t^*) - \ln D - a)/b;$$

$$|\Psi'(D)| = 1/bD.$$

Returning to the formula (9), we have

$$f_D(D) = \frac{1}{\sqrt{2\pi} S_0 bD} \exp\left(-\frac{\left(\ln D - \ln \gamma(t^*) + a\right)^2}{2(bS_\nu)^2} \right).$$

Integrating the resulting expression, we determine the damage distribution law per flight:

$$F_D(D) = \int_0^D f_D(D) dD = \Phi\left(\frac{\ln D - \ln \gamma(t^*) + a}{bS_\nu} \right),$$

where

$\Phi(U)$ − probability integral:

$$\Phi(U) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{U} \exp\left(-\frac{t^2}{2} \right) dt$$

Thus, for this model, the damage per a flight is a lognormal random variable with a constant value damage logarithm dispersion $D[\ln D] = b^2(S^2_a + S^2_\sigma)$

and dependent on the operating time of damage logarithm expectation $M[\ln D] = \ln\gamma(t^*) - a$.

From computational point of view the simplicity and the clarity of the model due to the possibility of separation in the expression (8) random and non-steady components of the loading is obvious.

Let's consider a damage model under the condition of low-cyclic fatigue.

The rotor elements of compressors and turbines which are installed on modern aviation engines work under the variable temperature modes within the material elastoplastic limits i.e. at the non-isothermal low-cyclic fatigue condition that causes plastic deformations and yield flow.

The destructions due to low-cyclic fatigue are typical for rotor discs, turbine blades, shafts and other rotor elements.

Non-elastic deformations change the dimensions of the elements and influence the material property of resisting repeated laodings.

Yield deformations influence on loading redistribution in the elements even in case of insignificant plastic deformations. That's why these deformations should be taken into account during elements strength calculation.

In design practices the most popular methods of plasticity and yieldability analyzing are the theories of deformation, yield flow ability and hardening.

Low-cyclic non-isothermal loading of the gas-turbine engine hot section elements is caused by the frequent engine starts and cutoffs, modes transition during the engine operation cycles which are accompanied by the time-exposure at the different flight modes under the continuous loadings and temperatures. The calculation of material ability to resist low-cycle fatigue by means of direct experiment method at such complex loading program is practically impossible. That is why it is more reasonable to modify the loading calculation programs to simpler equivalent low-cycle modes of loading for which typical experimental characteristics of material endurance to low-cyclic loadings can be derived. Isothermical deformation characteristics are the limits of schematization.

Prior to acting loading $\sigma(t)$ changing operational program reduction to equivalent one it should be decomposed into low-cyclic $\sigma_m(t)$ and static $\sigma_{st}(t)$ components. Cyclic components $\sigma_m(t)$ can be subtracted by the method of complete cycles, "fall of rain" or another method starting from the initial cycle in which stress changes from zero to absolute maximum σ_{Max} which corresponds to the full strength engine operation mode. Besides, the initial cycle by the method of "fall of rain" can determine elementary cycles with their minimal and maximal values (amplitude and average) of loadings in cycle.

Damages in every elementary cycle are estimated independently and than are summarized. In this case according to the linear hypothesis of damage summation the general damage accumulated during the flight can by calculated by the formula

$$D_{CC} = \frac{1}{N_{des}} + \sum_{i=1}^{m} \frac{1}{N_{desi}} = \frac{1}{N_{des}(T_{max}, \sigma_m, \Delta\varepsilon)} + \sum_{i=1}^{m} \frac{1}{N_{desi}(T_{max}, \sigma_m, \Delta\varepsilon_i)}$$

where N_{des} N_{desi} − number of cycles till distraction of the base and elementary cycles;

m − number of elementary cycles in the base cycle set.

Elementary damage at one loading cycle for the simplest case of components stressing by the random cyclic loadings σ_i which are governed by the same law of distribution $F(\sigma)$ according to linear hypothesis can be calculated by the formula

$$D = \frac{1}{N(\sigma, \alpha_\tau)}$$

where

σ − random loadings which arise during the flight cycle ($M[\sigma] = \overline{\sigma}$, $D[\sigma] = S_\sigma^2$);

α_τ − centered random variable which characterizes material dispersion properties ($M[\alpha_\tau] = 0$, $D[\alpha_\tau] = D_{\alpha\tau}^2$);

$N(\cdot)$ − Material endurance function by means of which number of cycles made before element destruction under the continuous cyclic loadings σ can be determined.

Quasistatic destruction takes place due to accumulation of one-side plastic deformations which are resultant of low-cyclic loading. Such deformations are equal to the single loading static deformations.

Destruction with cracks formation occur due to the accumulation of fatigue damages.

If local operational loadings in the construction caused by strength loading are determined experimentally or by salvation of elastic or elastoplastic problem, than according to fatigue destruction criteria (rigid-type stressing) and regardless of steel cyclic properties the loadings σ_a^* destructive amplitudes for the construction with given number of cycles before destruction N can be determined by the Manson's formula [1,8]

$$\sigma_a^* = \frac{E}{4 \cdot N^{m_p} + \frac{1+r^*}{1-r^*}} ln \frac{100}{100-\Psi} + \frac{\sigma_{-1}}{1 + \frac{\sigma_{-1}}{\sigma_B}\left(\frac{1+r}{1-r}\right)} \qquad (12)$$

where

E – modulus of elasticity;

m_p – index of strength – steel characteristic;

r^*, r − steel ratio coefficient of elastic and actual loading conditions correspondingly;

Ψ − relative reduction of investigated sample cross section area;

σ_{-1} − endurance limit at the symmetrical cycle of loading (tension-compression);

σ_B − ultimate loading limit.

Endurance curve (12) may be expressed with respect to number of cycles before destruction by the following way:

$$N = \left(\frac{a_0}{\sigma_a^* - a_1} - a_2 \right)^{-1/m_p}, \qquad (13)$$

where:

$$a_0 = \frac{1}{4} E \ln\left(\frac{100}{100-\Psi}\right);$$

$$a_1 = \frac{\sigma_{-1}}{1+\frac{\sigma_{-1}}{\sigma_B}\left(\frac{1+r}{1-r}\right)};$$

$$a_2 = \frac{1}{4}\left(\frac{1+r^*}{1-r^*}\right).$$

In order to make probability description of strength characteristics it is necessary to add to the abovementioned model (13) parameters α_τ which characterize possible material properties.

In case of stress low relation of mathematical expectation dependence between cycle numbers and loading (13), the material endurance stochastic characteristics can be described by means of three regularities:

$$N = \left(\frac{a_0}{\sigma_a^* + \alpha_\tau - a_1} - a_2\right)^{-1/m_p} \qquad (14)$$

$$N = \left(\frac{a_0}{\sigma_a^* - a_1} - a_2\right)^{-1/m_p} \cdot e^{\alpha_\tau} \qquad (15)$$

$$N = \left(\frac{a_0}{\sigma_a^* + \alpha 1_\tau - a_1} - a_2\right)^{-1/m_p} \cdot e^{\alpha 2_\tau} \qquad (16)$$

Introduce S_α^2. In equation (14) this parameter determines uniform diffusion of strength characteristics around the stress logarithm $\ln(\sigma_a)$, and in model (15) – around the logarithm of cycle number ln*(N)*. Strength characteristic model (16) in general case includes two dependent random variable with different dispersions $S_{\alpha 1}^2$, $S_{\alpha 2}^2$ and $\mathrm{M}[\alpha 1] = \mathrm{M}[\alpha 2] = 0$ determines the characteristics of diffusion around the endurance curve.

General scheme of component's loadings is described on fig.14.

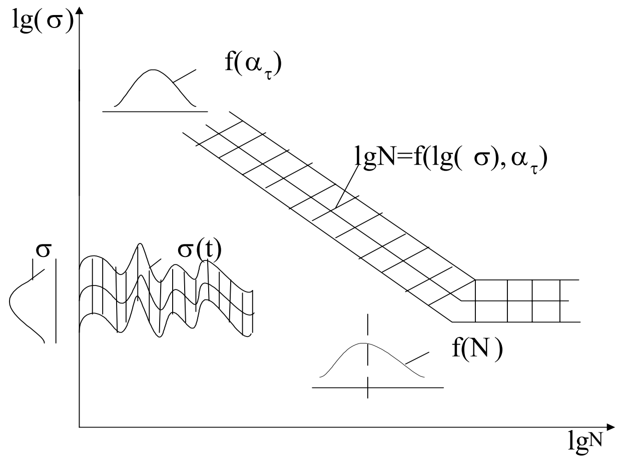


Fig. 6. General scheme of component's stressing and probability strength characteristics.

Endurance curve $\sigma_a(N)$ for the element made of material 08X18H10T under the symmetrical loading cycle and endurance probability model $\sigma_{a1}(N,\alpha_\tau)$, $\sigma_{a2}(N,\alpha_\tau)$ − constructed in accordance with the formulas (6), (7) is shown on fig. 15.

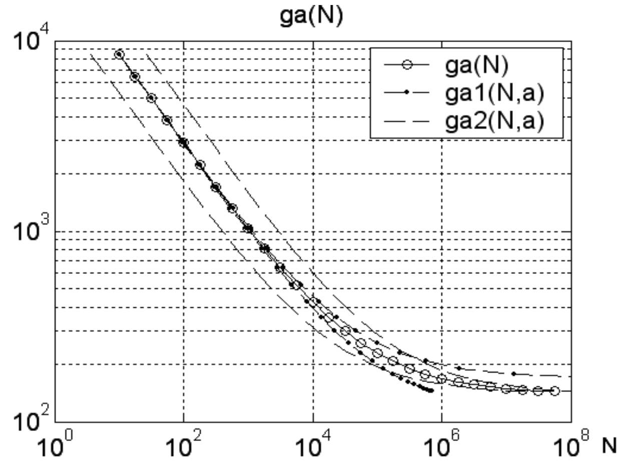


Fig. 7. Endurance characteristics probability model of steel 08X18H10T

Curves $\sigma_{\alpha 1}(N)$ и $\sigma_{\alpha 2}(N)$ − correspond to fractals $\overline{\sigma_a(N)} \pm 3S_\alpha^2$.

Steel characteristics and loading cycle parameters correspond to the manufacturer calculation: *E*= 205000 MPa,

Ψ =42,5, σ_B = 491 MPa,

$\sigma_{-1} = 0{,}4\sigma_B$ =196 MPa,

$r^* = r = \dfrac{\sigma_{\min}}{\sigma_{\max}}$ =0.

In more simple case for different material function $N(\cdot)$ can be described by strength-low relations

$$N = \begin{cases} C(\sigma + \alpha_\tau)^m, & \sigma > \sigma_{-1} \\ \infty, & \sigma <= \sigma_{-1} \end{cases}, \qquad (17)$$

or

$$ln(N) = \begin{cases} C_1 + m\, ln(\sigma + \alpha_\tau) & \sigma <= \sigma_{-1} \\ \infty, & \sigma <= \sigma_{-1} \end{cases}, \quad 18)$$

where $C_1 = \ln(C)$

$$N = \begin{cases} C\,\sigma^m e^{\alpha_{\tau 2}}, & \sigma > \sigma_{-1} \\ \infty, & \sigma <= \sigma_{-1} \end{cases}, \qquad (19)$$

$$N = \begin{cases} C(\sigma + \alpha_{\tau 1})^m e^{\alpha_{\tau 2}}, & \sigma > \sigma_{-1} \\ \infty, & \sigma <= \sigma_{-1} \end{cases}. \qquad (20)$$

Within the error limit corresponding models (14)-(15) and (16)-(20) are approximately equal (fig.8). The results of calculation are shown on fig.9.

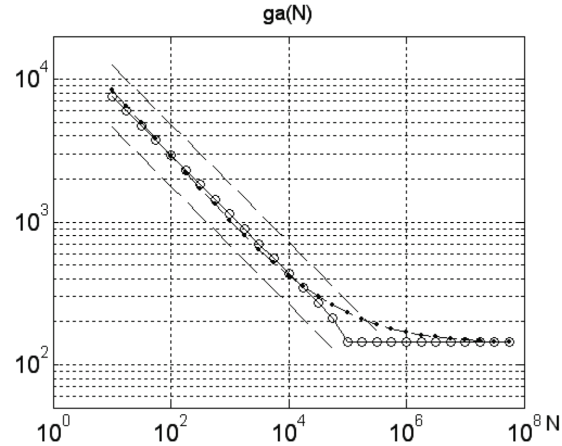
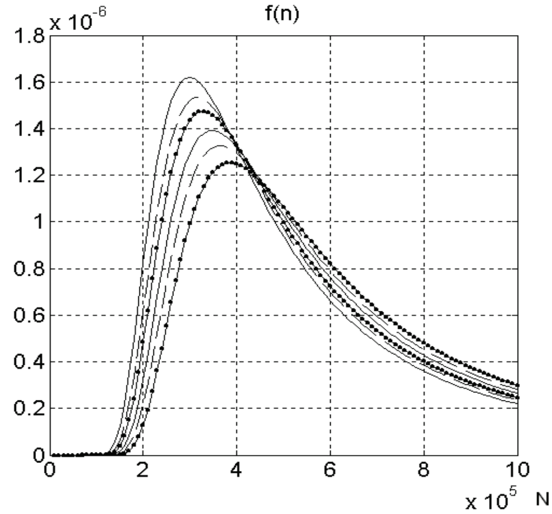
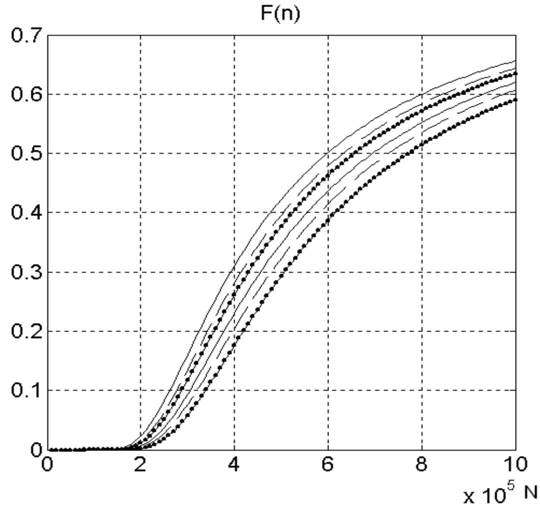


Fig. 8 General and linear fatigue endurance model of steel 08X18H10T



a)



b)

Fig. 9. Densities (*a*) and distribution function (*b*) of cycle number before element destruction.

4. The definition of probabilistic characteristics for loading and capacity of turbine engine components service life

The most profitable way of using the airframe is the exploitation of the actual condition.

Service life of the actual condition allows using more complete configuration's included stock performance components and will provide benefits while maintaining high reliability in service.

Design safety margins of the engine vital parts, which include rotating blades and blast wheels, compressor's and turbine's wheels, rotor shafts, are the initial basis for evaluating the permissible operating time in any way of establishment a service life (fixed, differential). The calculation of depletion and monitoring service life and other strength integrity characteristics executes in basis of loading characteristics envisage of structural elements on all modes of turbine engine operating cycle and using standard characteristics of constructional material strength (such as durability, high-cycle and low-cycle fatigue) through the accumulated damage characteristics.

For the comparative envisage of turbine engine parts structural strength we use determine strength factors which determine their strain, deformability, carrying capacity and longevity. For strength envisage factors of safety k are compared with the lowest bearable factors of safety $k_{\min}$ and in the case of inequality $k > k_{\min}$ the strength margin for the concerned parameter meets the strength standards.

One of the major criterions of turbine engine's part structural strength envisage is the strength factor.

$$k_\sigma = \frac{\sigma_{\lim}}{\sigma_{eq}},$$

where

σ_{lim} − limit load, which characterizes limit part's material properties; σ_{eq} − equivalent net loads.

The limit and operating loads envisage is depending on the part's job conditions. The ultimate load σ_B is taken as σ_{lim} and the highest tensile loadings $\sigma_{\max}$ are taken as σ_{eq} under static loadings.

In the case of complex load lumped stresses are calculated by one of the strength model [3,6]. The long-term strength σ_{dur} is taken as the limit load under service conditions at high temperatures and constant or slowly varying loads when material properties change continuously, and for variable symmetric cyclic loads it is the fatigue point σ_{-1}.

In this case the expressions for the strength factors have the following structure:

$$k_{\sigma dur} = \frac{\sigma_{dur}}{\sigma_{eq}}, \quad k_{\sigma a} = \frac{\sigma_{-1}}{\sigma_{eq}}.$$

The durability is chosen appropriate to the time t and temperature T and the fatigue point is chosen appropriate to the number of cycles N and temperature T.

Strength factors are expressed in complex formulas for the joint action to re-static and high mechanical and thermal-cycle stresses or their pair wise repertories [10]. These coefficients are in better agreement with experimentation but their application is connected with necessity to conduct special researches.

Besides strength factors for the stress to assess the structural strength of turbine engine parts we use the safety margin of longevity

$$k_\tau = \frac{\tau(\sigma_{eq})}{t}, \tag{21}$$

where

$\tau(\cdot)$ − time to failure at load equal to the equivalent σ_{eq};

t − load operating time.

Turbine engine vital parts factors of safety are related on basis of the correlation of design and experimental values to obtained from the operation values in engineering practice. Specified supplies are usually set for blades, which are designed to operate in certain conditions and produced from this material. In this case the factors of safety are peculiar similarity criteria of parts and can be set depending on the results of parts tests of this type.

The strength factor and durability factor are considered under service condition as dynamic characteristics which vary depending on operating time and previous load history.

Monitoring of these stress characteristics is better to envisage through the damage part characteristics using the linear hypothesis of static damage summation by bringing stressing capabilities to an equivalent operation.

Let's consider the theory of determine rate definition $k_{\sigma\,dur}$ and k_τ under operation.

Every j engine operating mode is characterized by some levels of acting loading in structural element σ_j and temperature T_j. The long-term static damage rate of structural elements on j operation according to the linear hypothesis of static damage summation equals relative operating period on this operation

$$D_j = \frac{t_j}{\tau(\sigma_j, T_j)}, \tag{22}$$

where

D_j - operation's damage;

t_j − operation's durability;

$\tau(\cdot)$ − material life characteristics.

For the equivalent operation with parameters t_{ej}, σ_e, T_e the damage D_{ej} could be found by a similar formula

$$D_{ej} = \frac{t_{ej}}{\tau(\sigma_e, T_e)}. \qquad (23)$$

According to the equivalence condition $D_j = D_{ej}$ equivalent operation must make the same damage as the current. Therefore equivalent operation durability can be determined by the ratio

$$t_{ej} = \frac{t_j \tau(\sigma_e, T_e)}{\tau(\sigma_j, T_j)}. \qquad (24)$$

The total equivalent operation durability for some i^{th} flight is determined by the expression

$$t_{ei} = \sum_{j=1}^{m_i} t_{ej}, \qquad (25)$$

where

m_i − the number of loading segments in the i flight.

For n flights accumulated equivalent operation durability is expressed by the sum

$$t_e = \sum_{i=1}^{n} t_{ei}. \qquad (26)$$

As an equivalent operation one of the most intense operating mode is usually chosen. It's the maximum engine operating mode for the turbine blades.

According to the equation of the set of stress rupture curves of material structural elements $\tau(\sigma_e, T_e)$ using the equivalent time amount t_e to applicable temperature T the equivalent long-term strength $\sigma_{eD}(T_e, \sigma_e)$ can be found and the accumulated equivalent durability factors of strength are determined by the formula

$$k_\sigma = \frac{\sigma_{eD}(T_e, t_e)}{\sigma_e}. \qquad (27)$$

In order to obtain practical formula for k_σ it is necessary to provide possibility of solution for equation of strength curve family with respect to stress and durability variables. Otherwise equivalent long-term-strength limit should be calculated by iterative method. Exponential and strength equation can be solved by direct calculation method. For such equations we'll consider the methodology of long-term-strength safety factors determination.

When material long-term-strength characteristics are described by means of exponential expression

$$lg\,\tau = A(T) + B(T)\sigma, \qquad (28)$$

according to formula (27) the strength safety factor can be calculated in the following way:

$$k_\sigma = \frac{lg\ t_e - A(T_e)}{B(T_e)\sigma_e}, \qquad (29)$$

where

$A(T), B(T)$ − temperature function.

Taking into account expressions (22)...(29), the strength safety factor can be express in terms of accumulated element damage D_n during n flights

$$k_\sigma = \frac{lg \sum_{i=2}^{n} \sum_{j=1}^{m_i} \frac{\tau(\sigma_e, T_e)}{\tau(\sigma_j, T_j)} t_j - A(T_e)}{B(T_e)\sigma_e} = 1 + \frac{\ln D_n}{\eta}, \qquad (30)$$

where

$$D_n = \sum_{i=1}^{n} D_i = \sum_{i=1}^{n}\sum_{j=1}^{m_i} D_{ij}\,, \qquad (31)$$

$\eta = \ln(10)B(T_e)\sigma_e$.

Using the following strength characteristics

$$lg\tau = A(T) + B(T)lg\sigma\text{, (or } \tau = C(T)\sigma^{B(T)}\text{,}$$

where

$$C(T) = 10^{A(T)}\text{)}$$

dependence of strength safety factor k'_σ on accumulated damage is expressed by the formula

$$k'_\sigma = \frac{1}{\sigma_e}\left(\frac{1}{C(T_e)}\sum_{i=1}^{n}\sum_{j=1}^{m_i}\frac{\tau(\sigma_e, T_e)}{\tau(\sigma_j, T_j)}t_j\right)^{\frac{1}{B(T_e)}} = D_n^{\frac{1}{\vartheta}}, \quad (32)$$

where

$$\vartheta = B(T_e).$$

Using the expressions (21), (22), (31), the equivalent durability capacity which is determine as a variable opposite to accumulated damage can be find

$$k_D = \frac{1}{D_n}. \qquad (33)$$

Taking into account expressions (30), (32) and (33) at the equal level of accumulated damages the dependence between minimal normalized durability safety factors $k_{D\min}$ and strength $k_{\sigma\min}, k'_{\sigma\min}$ can be established:

$$k_{\sigma\min} = 1 - \frac{\ln k_{D\min}}{\eta}, \qquad (34)$$

$$k'_{\sigma\min} = (k_{D\min})^{-1/\vartheta}. \qquad (35)$$

Equalities (34) and (35) normalize and reduce to common criteria of critical safety factor values for stresses or durability for different types of strength characteristic description.

For investigation of quantitative regularity of element material long-term strength reduction process during the time in operational practices the life reduction factor is often used. This factor is also assumed as proportional to equivalent working time of an element or number of flight cycles n:

$$k_B = \frac{n}{n_{cr}}100\%,$$

where

n_{cr} – critical number of flight cycles before full life exhaustion.

When k_D is used as a criteria of strength than life reduction factor will be proportional to the accumulated damage:

$$k_{BD} = \frac{k_{D\min}}{k_D}100\% = k_{D\min}D_n 100\%.$$

In this case for the critical number of cycles before full life exhaustion we can write the following

$$n_{cr0} = \frac{n}{k_{BD}}100\% = \frac{n \cdot k_D}{k_{D\min}} = \frac{n}{k_{D\min}D_n}.$$

Conclusions

In this research models and damage calculation methods for damaging, remaining durability, airframe structural elements and engine life time exhaustion in accordance with the criteria of long-term durability, low-cycle and high-cycle endurance, also for elements with cracks under the one-sided, multi-sided and multi-component loading are investigated in determinate and probable variants under continuous loading and various stress conditions.

Suggested models can be used during the calculation of possible types of destruction probability, choose of optimal constructive and technological works which permit to increase components stress resistance capacity. This, as a rule, is a result of analysis and compromise between different types of loading and also difficulties from its result and life time technically and economically grounded.

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METHODICAL ASPECTS OF ALLOY D16AT DEFORMATION RELIEF REGISTRATION UNDER CYCLIC LOADS

In this paper was described methodical aspects of alloy D16AT deformation relief registration by means of optical inteferometric profiler. The surface of alclad in the stress concentrator effective range on flat specimen from constructional alloy D16AT was investigated under cyclic loads. The model based on the parameters of deformation relief description for the remaining fatigue life estimation was suggested.

In the end of the 20th century the general approaches to aircraft structure health monitoring (SHM) implementation have begun developed [1]. SHM assumes installation of various sensors on aircraft, allowing to register impacts of different factors on structure elements strength during operation (moistness and an ambient temperature, static and dynamic loadings) and also to control damages occurrence [2].

For elements of an aircraft structure the most typical damage is fatigue failure. According to a principle of fail-safe design the crack should not propagate to critical dimensions during operation between visual inspections [3]. However for some elements of a design crack initiation is inadmissible, especially if access to a place of a crack initiation is complicated. This circumstance causes application of monitoring methods which allow to estimate a condition of an element of a design at a stage before crack initiation.

As the indicator of the cumulative fatigue damage it is possible to use a condition of a surface of an al-clad by which constructional duralumin alloys is clad. During metal fatigue the damageability process that is connected with dislocation structure formation and evolution, is occurred and arise on a surface [4]. Thus the estimation of a surface condition, for example on a saturation of a deformation relief (DR), can be considered as a method for fatigue damage diagnosing and exhaustion of bearing capacity of a structure in whole [5].

In the soviet and the post soviet union aircraft industry sheet of aluminium alloy D16AT with a thin surface layer (3 … 4 % of sheet thickness) of high purity technical aluminum is widely used. On a clad surface during load cycling there is the local plastic deformation accompanied by DR formation and propagation. There are some approach for fatigue damage estimation by DR saturation [6,7]. Practically features of DR propagation in a direction, perpendicular to a surface are not studied. The present work is devoted to development of methodical maintenance of such investigation.

For fatigue tests were used the flat specimens from D16AT sheet with 4 mm diameter hole stress concentrator in centre, that modelling rivet holes in aircraft skin. The part of a specimen surface, adjoining to concentrator, was polished with diamond paste. The experiments were performed using servo-hydraulic fatigue test machine BiSS Bi00-202V.

DR changes were monitored on a control area with a dimension 225×170 micron located in the stress concentrator effective range. DR on a surface of al-clad of alloy D16AT was investigated with use of technical possibilities of optical interferometric profiler “Micron-Alpha” [8]. The profiler allows to register the optical image of a surface with DR markings, to make digital processing of the received image, and also to define topography of an investigated surface. It is established that two-dimensional DR appearance on a surface completely corresponds to its three-dimensional topography (fig.1). Procedure of critical DR parametres definition consist in the following.

Parametre of DR saturation D. The Procedure of DR quantitative estimation on al-clad surface with use of parametre D is described in [9]. Local microplastic deformation leads to the topography of the polished surface changes and change its relief by means of formation of slip bands, extrusions, etc.

During surface monitoring in microscope mode in places with DR marks there is a change of dispersion of light that is developed in the form of dark zones on an optical picture. By means of a digital camera of monitoring surface snapshots became.

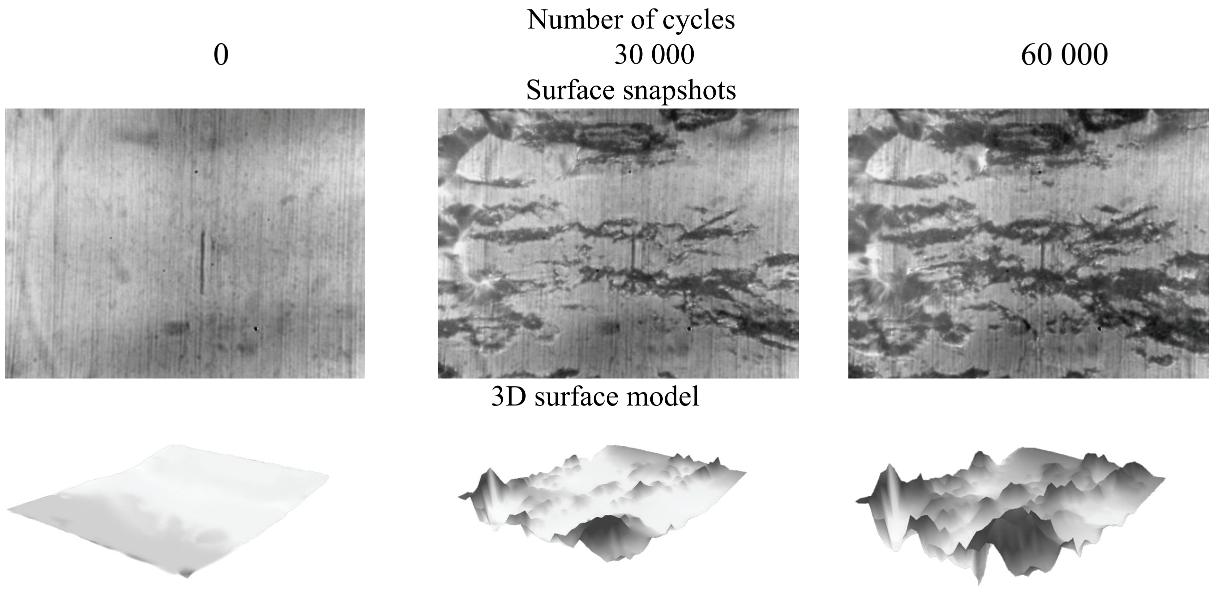
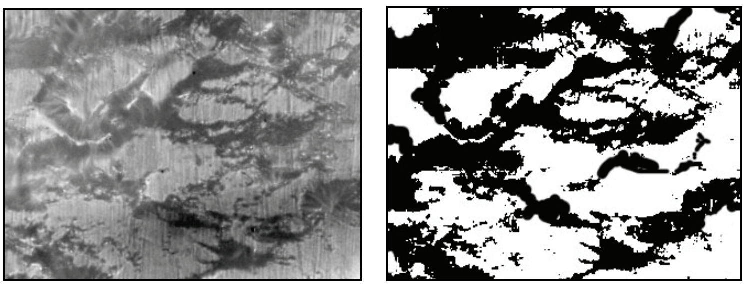


Fig.1. Changes on the surface under cyclic loads

Than, snapshot is rectified in monochrome (black-and-white) image (fig.2) on which in an automatic mode the total area of dark zones **S** (the area occupied by DR marks) is defined [9].



a b

Fig. 2. Representation of the surface as photo (microscope x 500) (a)
and the monochrome image (b)

The relation of this area to the total area of controllable surface **A** defines the quantitative characteristic – parameter of DR saturation **D** [9]:

$$D = \frac{S}{A} \qquad (1)$$

Parameter $\mathbf{D_Y}$ is the relation of area with DR marks (**S**) to the area without DR marks (**A-S**) and related to parameter DR saturation as

$$D_Y = \frac{S}{A - S} = \frac{D}{1 - D} \qquad (2)$$

For next parameters estimation is used information about surface topography that was obtained in optical profiler mode. Controlled area represents data file with matrix 320×240 points. All points of this matrix have the value that estimate the height of a surface relief. For specimen with absolutely even surface the height in each point will be identical.

Parameter of roughness $\mathbf{R_a}$**.** arithmetic average of roughness deviation was chosen as value which shows surface relief changing. Surface roughness is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form and is a value of arithmetic average of roughness deviation that is found from the formula

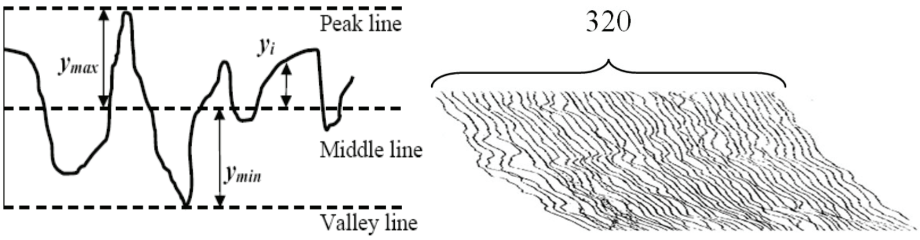
$$R_a^{/} = \frac{1}{n}\sum_{i=1}^{n}|y_i| \tag{3}$$

$|y_i|$ – an absolute deviation of a profile from an average line, μm;

n - number of points by which the parameter is defined.

Controllable area consists of 320 lines and average value of roughness parameter will be (fig.3):

$$R_a = \frac{\sum_{j=1}^{320} R_{a\,j}^{/}}{320} \tag{4}$$



a b

Fig. 3. Surface roughness parametres (a) and representation of analytical model for area roughness controls (b)

The increment of roughness value in relation to initial (before load cycling) will be equal to

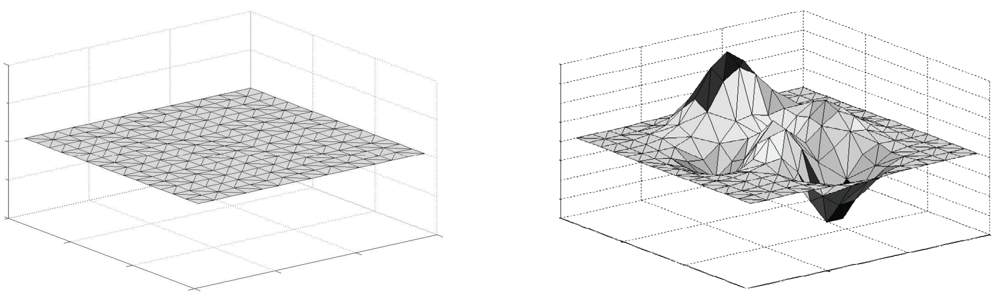
$$\Delta R_a = R_a^i - R_a^0 \tag{5}$$

R_a^i - roughness of a controllable area with i number of cycles, μm

R_a^0 - an initial roughness of a controllable area, μm.

Irreversible surface strain ε_a. It has been established [6] that DR formation under load cycling the sample to be accompanied by increase in the surface area (fig. 4). Change of the area of a surface concerning a reference value can be described irreversible plastic deformation:

$$\varepsilon_a = \frac{\Delta A}{A_0} \tag{6}$$



a b

Fig. 4. Change of the surface area with number of cycles: an initial condition (a) and after load cycling (b)

It is necessary to notice that between parameters D_Y and ε_a there is a direct linear relation. Thus the line slope angle of ε_a=f (D_Y) depends on the stress level (fig. 5). For development multiple regression models for the relative operating time estimation parameters was used the program of mathematical and statistical analysis StatGraphics Plus V5.1. The model is based on the parameters of DR.

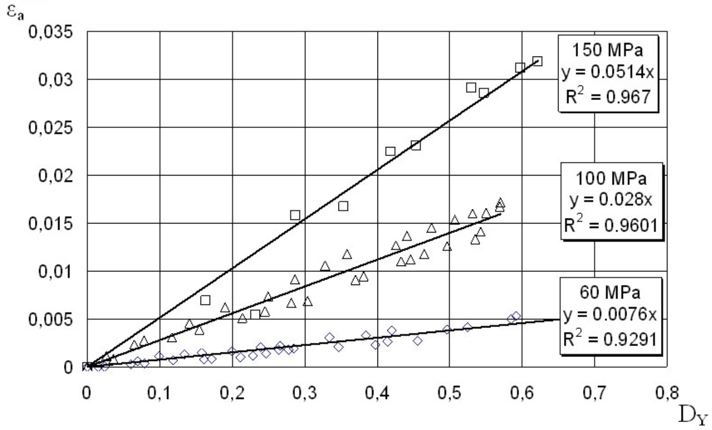


Fig. 5. ε_a=f (D_Y) subjections for different stress levels

During results investigation analysis was obtained model:

$$\overline{N} = 0{,}0056 + 1{,}2335\, D + 0{,}709322\, D_Y + 3{,}89\, \varepsilon_a - 0{,}0038\, \Delta R_a \qquad (7).$$

The value of R-square is 83,6105%.

Conclusions

The carried out researches have confirmed possibility of the information about DR use, obtained by means of inteferometric profiler and microscopy, i.e. with use of non-destructive control for aircraft skin residual fatigue life estimation.

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NON DESTRUCTIVE OPTICAL METHOD UNDER FULL-SCALE AIRCRAFT TESTING AS A METHOD OF FATIGUE LIFE PREDICTION

Approximate procedure for aircraft fatigue monitoring under full-scale testing and in operational conditions is presented. The new way for estimation of aircraft accumulated fatigue damage are described. The diagnostic parameters for alclad aluminium alloys are the intensity of deformation relief and fractal demansion. Special software for the extrusion/intrusion images processing with damage parameter and fractal dimension calculation has been developed.

Introduction

Taking into consideration the importance of the aircraft fatigue problem, a set of International Civil Aviation Organization (ICAO) documents, as well as European Joint Aviation Regulations (JAR), US Federal Aviation Regulation (FAR), Airworthiness Regulations of Russia and Ukraine consider the aircraft fatigue analysis as a mandatory procedure for providing aircraft reliability and service life. Components that fail by fatigue usually undergo three separate stages of damage: a) initiation of a fatigue crack; b) propagation of the fatigue crack; c) final sudden failure. It is obvious that the quicker you reveal the initial stage of fatigue the less probability of disastrous failure is.

Fatigue analysis includes a set of theoretical and experimental procedures, but taking into account the complicated character of aircraft loading during operation and the stochastic nature of metal fatigue, one may assume that at present only reliable and adequate instrumental diagnostic of actual accumulated fatigue damage can prevent unexpected failure of structural components.

There are two approaches to instrumental estimation of accumulated fatigue damage: a) application of fatigue indicators (sensors, specimen-witnesses) [1]; b) direct material state diagnostic.

A set of diagnostic methods use fatigue indicators, mounted on the surface of the object to be inspected. Such devices are often called fatigue sensors or specimen-witnesses [1]. The indicators subjected to the spectrum of operating cyclic loads, change their state or may be even destroyed and in such a way indicate the degree of damage in the tested structural element.

Direct inspection may be performed by applying non-destructive methods, such as acoustic emission testing, high frequency ultra sonic, penetration of liquid, eddy current test methods, etc.

At the presented report the new way for the estimation of aircraft accumulated fatigue damage at the early stage of fatigue destruction are described. This method is based on the possibility of quantitative analysis of extrusion/intrusion structures of metal surface. Proposed approaches have been verified by fatigue test of real aircraft parts in the loading conditions close to operational.

New method background

One of the most stressed parts of the aircraft structure is skin. For a skin of civil aircraft, aluminum alloys D16 and V95 are widely used in Ukraine and Russia, which are almost analogous to 2024T3 and 7075T6, according to AISI-SAE designation. The main alloying components of D16 and 2024T3 are copper and magnesium, while V95 and 7075T6 contain about 5% of zinc.

In order to reduce the possible corrosion process, some sheets of mentioned alloys are often covered with a layer of pure aluminum (for D16 and 2024 T3) or with a layer of Al with 1,0 % of Zn (for V95 and 7075 T6). The thickness of clad layer is ranging from 4 to 7% of the total sheet thickness.

Aluminium and some of its alloys, which may be used for cladding, are considered to be so called persistent slip bands (PSBs) type materials, because when they are subjected to cyclic loading, PSBs appear and develop on their surfaces [3].

It’s well known that the surface state plays an important role in the metal fatigue. Damage evolution in cyclic straining starts predominantly on the surface of the materials and is represented by the surface relief formation. Persistent slip bands on the surface and exstrusion/intrusion structure formate the deformation relief.

One of the diagnostic parameter for alclad aluminium alloys is the intensity of deformation relief, i.e. the ratio of the area with extrusions/ intrusions to the total checked area in the observed field [4].

The search of the additional criteria for deformation relief at quantitative description leads to fractal geometry [5], which is wildly used nowadays at solving the material science problems. So, in the paper [6] some examples of fractal geometry application for the description of the processes of slip lines initiation and propagation on the single-crystals surface are presented. Nowadays there are a lot of methods of the fractal dimensions calculation for nature objects. One of the most widespread is a “box counting” [6]. This method allows to calculate definite types of fractal dimension.

The first possible type of fractal dimension is fractal dimension of the relief clusters boundaries. Fractal dimension of the clusters boundaries is designated as $D_{p.}$

For some fractals the most informative parameter is a fractal dimension of the ratio of perimeter to area. It is known, that this ratio characterizes the shape of objects, and for the regular geometrical figures this parameter is constant value and doesn’t depend on the object size.

As the paper [7] shows such kind of dimension describes the shape of clouds.

Correspondent fractal dimension for the clusters of deformation relief will be further called Dp/s. For the data processing automatization the special software has been developed [9].

Fractal dimension $D_{p/s}$ with the application of geometrical method was estimated as a doubled absolute value of the tangent of the slope angle of the middle part of the fractal graph in its linear approximation in log-log coordinates [7].

Fractal dimensions of the deformation relief clusters contours as well as the fractal dimensions determined by the ratio of perimeter to area exceed topological dimension of the line and are within the range of 1 to 2.

The procedure of accumulated fatigue damage estimation used in the research includes the application of digital images of the deformation relief observed by the light microscope.

The design of specially constructed test machine allows to carry out optical observation of the specimen surface after initial several cycles of loading. Damage parameter D and fractal dimension Dp/s were selected as the main diagnostic parameters.

Experimental procedure

The laboratory specimens have been loaded with the wide range of stresses at frequency 25 Hz. The surface was polished with diamond paste. The specimens had a hole in the center in order to induce fracture localization. Such stress concentrator indicates the point for optical investigation as well. The thickness of the specimen is 1 mm and the diameter of the hole is 1 mm.

Deformation relief intencity depends on the stress level, distribution of the stress near the stress concentrator and number of cycles. Metallographic investigation of the chosen metals was performed by using the recommendation [8].

The procedure for accumulated fatigue damage estimation used in the research includes the application of digital images of the deformation relief observed by the light microscope.

The images of cyclically loaded specimen surfaces have been processed by special software [9]. The developed program saves the surface images and gives the possibility to determine the proposed damage parameter D and fractal dimension Dp/s.

A set of experimental curves that express the dependence of accumulated damage parameters on the number of cycles have been obtained. As example, the result of fatigue test of D16 specimen and damage monitoring under the maximum stress: 1) 234,5 MPa, 2) 173,0 MPa, 3) 147 MPa are presented. They express the relationship of damage parameter D (a) and fractal dimension Dp/s (b) and current number of cycles N, fig. 1.

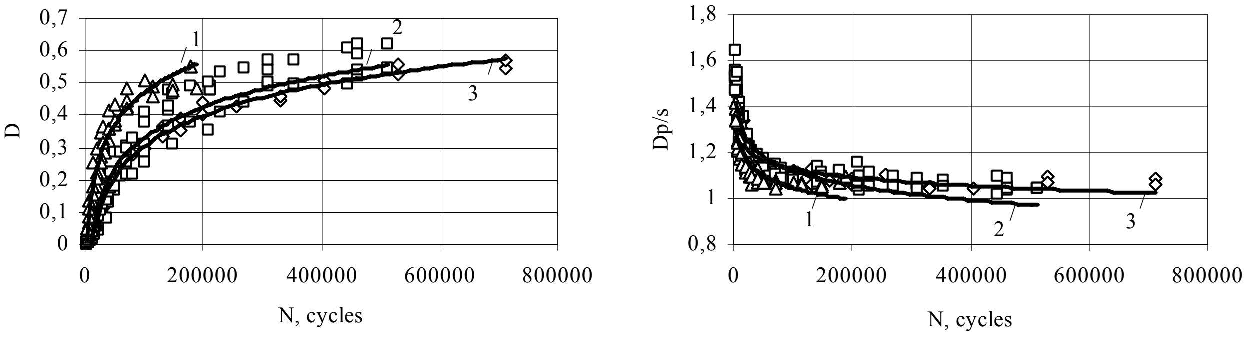

Fig. 1. The dependence of damage parameter D and fractal dimension Dp/s on the number of load cycles N

The influence of maximum stress on intensity of accumulated fatigue damage at the first stage of deformation rekief evolution is presented on fig. 2.

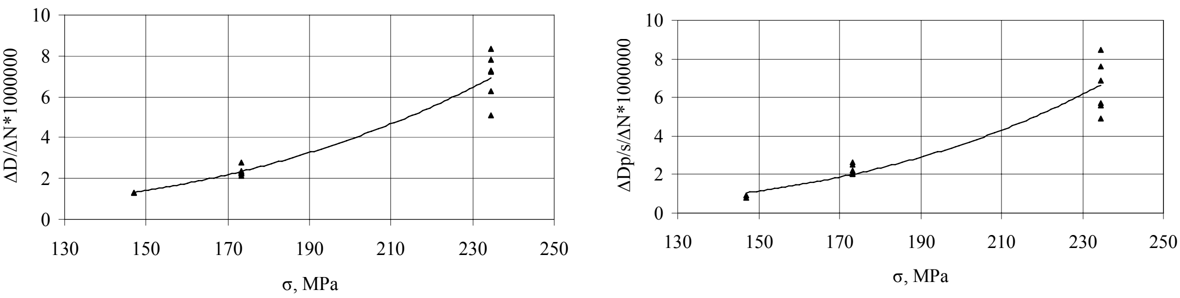

Fig. 2. The dependence of rate of change the damage parameter D and fractal dimension Dp/s on the maximum stress.

As it is seen, the rate of change of damage parameters depends on maximum stress level. So, these parameters are maximum stress-sensitive. Thus, the first stage of deformation relief evolution is more informative for accumulated fatigue damage estimation and for residual life prediction.

The tests were finished after the nucleation of fatigue crack of 1.0 mm length, so a crack length of 1.0 mm has been accepted as the critical state condition.

The aim of presented test is to justify experimentally the possibility of quantitative estimation of accumulated fatigue damage by the saturation parameters and fractal dimensions of deformation relief, that is forming under fatigue on the alclad alloys surface.

Experimental results

In this connection we can apply multiple correlation models in the life prediction process. In such way both parameters of the deformation relief should be taken into account.

Dispersion and regression analysis made with module "ANOVA" of the "Statgraphics Plus" has shown the possibility of the multiple correlation model application: $N_{res.}$,%=228,252– 385,169 D – 69,067 $D_{p/s}$, where: D – damage parameter; $D_{p/s}$ – fractal dimension; $N_{res.,\%}$ - residual number of cycles, %. Correspondent value of the R^2 equals 92,2851%. Standard error is 6,48. Analysis performed proves the significance of both considered models parameters: damage parameter D and fractal dimension $D_{p/s.}$

As a result of scheduled researches, the following exemplary program for aircraft fatigue analysis might be proposed:

1. Load operating range, load distribution along the structure, and material characteristics are determined. According to recommendations of International Civil Aviation Organization (Doc. 9051-AN/896, ICAO, 1987) the load range must be based on statistic tests data obtained by generalized load researches for the particular airplane type, and in case of insufficient data - with

the help of supposed use of aircraft.

2. Structure parts to be investigated are determined. The location of possible damage can be determined by analysis or on the basis of endurance tests of the whole structure or its separate elements.

3. Laboratory fatigue tests of structure elements (specimens) with monitoring of intrusion/extrusion structures are carried out to create data bank. The data bank (atlas) must contain test results on different load levels, different sequences of load application, etc. For each regime of loading multiple regression models that describe the relationship between D – damage parameter, $D_{p/s}$ – fractal dimension and $N_{res.}$,% - residual number of cycles, %, are calculated.

4. Monitoring of fatigue process of aviation structures is performed by means of inspection of skin clad coating in areas determined according to requirements of item 2.

5. The analysis of an inspected part of a structure is conducted by estimation of damage parameter D and fractal dimensions and calculation of the residual fatigue life by the use of corresponding multiple regression models.

Conclusion

Intrusion/extrusion structures on the surface of single-crystal and polycrystalline aluminium indicate the level of accumulated fatigue damage.

A set of experiments have proved close correlation between parameters of surface intrusion/extrusion pattern and number of cycles for fatigue crack initiation.

Proposed approach can be applied in single-crystal fatigue sensors concept and under direct monitoring of aircraft units fatigue.

The new approach may be recommended for indication of more dangerous points of aircraft structures and for the prediction of fatigue crack under full scale test of aircraft structures as well as for residual service life estimation.

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INVESTIGATION OF HEAT-PROOF COMPOSITE ALLOYS WEAR PROPERTIES AT CONDITIONS OF HIGH TEMPERATURE FRETTING CORROSION

Present work solves a task of gas turbine engines rotor blades durability increase. Tribotechnical tests of a set of composite powder and cast alloys at conditions of high temperature fretting-corrosion have been conducted. Also a mechanism of low-porosity powder alloys with high content of filler agent is explained.

Introduction. Physical environment and loading conditions of gas turbine engines (GTE) rotor blades are characterized by high level of acting static and dynamic load, broad range of operating temperatures alternation, high rotational velocities, and as a result they are subjected to high vibrational load. According to a general tendency to overhaul and operating life increase, we determine a challenge to increase thrust and power properties of contemporary gas turbine engines. This leads to further increase of load-carrying capacity and operating temperature of rotor blades.

For decreasing of vibrational load rotor blades they are supplied with middle shrouds in their tip part which have zigzag shape. Nevertheless even in nominally fixed joints vibrodisplacements originate an intensive erosion of middle shrouds contact surfaces as a result of fretting-corrosion. All this causes an increased wear and leads to premature elements failure [1]. In addition turbine blade dovetail part is also subjected to intensive wear due to fretting-process.

Research task was to find such a material, which at elevated operating temperature will have higher surface strength and wear resistance in comparison with reference alloy (alloy # 1).

It is known that one of the most important factors which define material's wear resistance are it's structure, mechanical properties, mutual arrangement, volume ratio and character of interaction of structural components [2,3]. Large value have processes, which flow on the friction surface of materials. As an example we can take a well-known method of alloys tribological properties improvement through realization of Sharpi-Bochvar principle. It points on the necessity to get a structure with heterogeneous distribution of mechanical properties Such materials consist of a soft and plastic matrix with hard inclusions disposed inside. Just that very principle was used while developing alloys for solving the task of research. We used powder alloys with high content of carbide phase because of impossibility to get a cast alloy of such composition as well as Cobalt matrix has not enough moistening properties towards TiC.

Table 1

Composition of composite alloys

№	Co, %	TiC, %	NbC, %	Porosity,%	Type of alloy
1	80	----	20	----	cast
2	70	30	----	----	cast
3	70	30	----	25	powder
4	50	50	----	28	powder
5	50	50	----	3,1	powder

Experimental techniques. For tribotechnical tests we used installation MFK – 1. To provide required temperature mode It was additionally equipped with annular electrical furnace, thermocouple and milliamperemeter (Fig. 1).

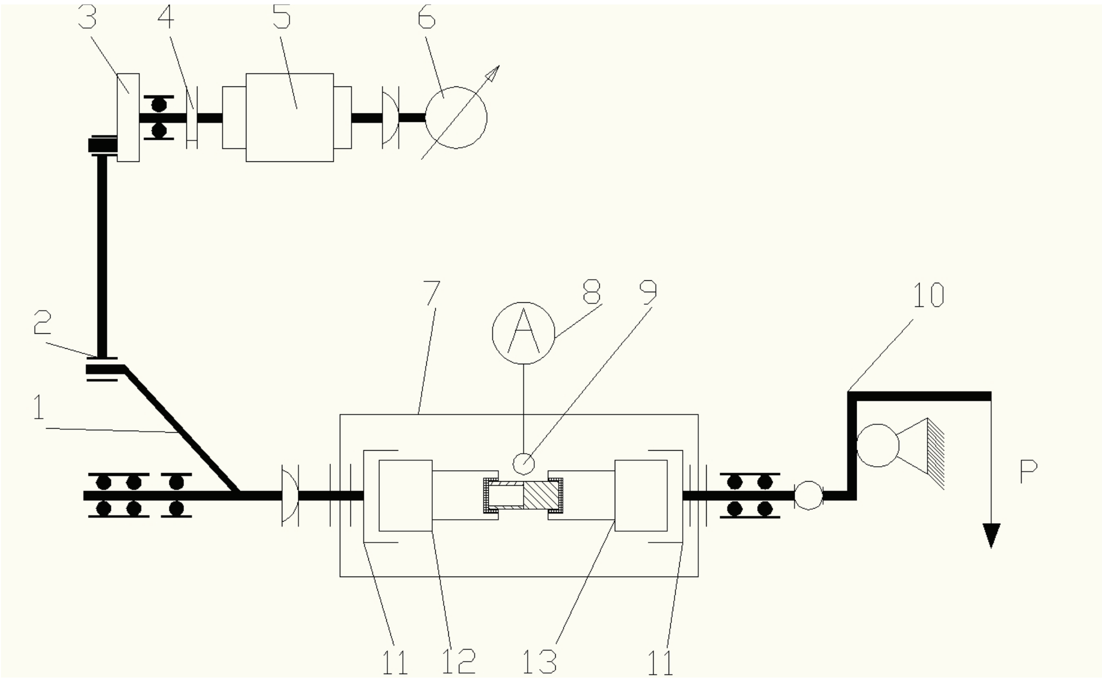

Fig. 1. – Functional diagram of installation MFK – 1:
1 – horizontal link; 2 – vertical link; 3 – adjusting eccentric ; 4 – coupling;
5 – electrical motor; 6 – tachometer ; 7 – annular electrical furnace; 8 – milliamperemeter;
9 – thermocouple; 10 – lever-type load-applying unit; 11 – collet; 12 – movable specimen;
13 – immovable specimen.

Working couple (Fig. 2) is a movable specimen with circular recess to which a bush is mounted helping to with a high-temperature sold. The bush contacts with immovable specimen. Immovable specimen is produced in the same way. MFK installation allows to conduct test at fretting-corrosion condition at frequency range 10 – 30 Hz, normal load up to 40 MPa, amplitude of vibrodisplacement - 0,001 – 2,5 mm. The magnitude of vibrodisplacement of movable specimen is set by adjusting eccentric. Precise tuning of fretting-process amplitude with accuracy 0 - 0,015 mm is performed with a special screw.

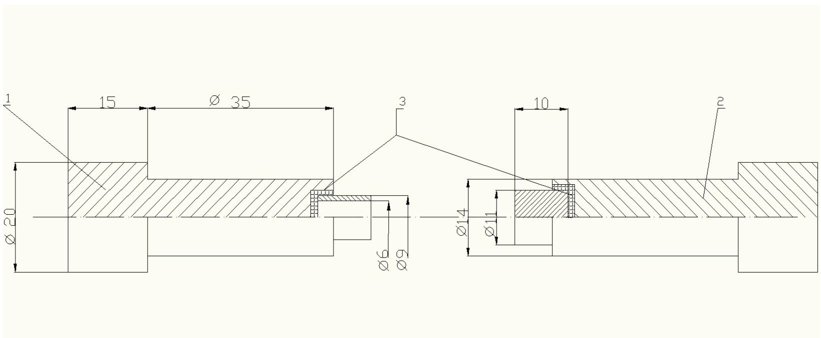

Fig. 2. – Specimens used for a test:
1 – movable specimen; 2 – immovable specimen; 3 – solder

The magnitude of vibrodisplacement may be measured with a microscope at stroboscopic lighting or using an inductive transducer. Heating of specimens allows to conduct tests at temperature up to 800°C. Elongated specimens and furnace with opened sides allows to keep stable working temperature inside, at the same time at the area of openings it is not higher then 300°C, that's why we don't need any cooling system.

Before test specimens are drawn into collet jaws and after this installation is loaded. In this way they are aligned and finally fixing. During heating the installation is unloaded to eliminate seizure.

Installation loading is accomplished through lever-type load-applying unit which allows to employ high specific loads. After test average linear wear was measured (Fig. 3). For this we used an optimeter. Round surface of a specimen was divided into 8 equal sectors, on friction tracks we performed 5 measurements and determined a mean line of a working face. In the same way we determined a mean line of reference surface. The difference of these two lines levels was accepted as an average linear wear.

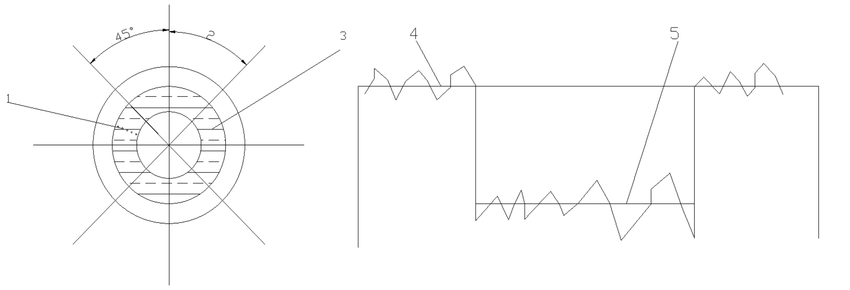

Fig. 3. Linear wear measurement circuit:
1.- points of measurement; 2- sector; 3- friction track; 4- mean line of reference surface.; 5 - mean line of a working face .

Tribological test was carried out at the following conditions of vibrational load:

Specific contact load – P=30 MPa;

Amplitude of vibrodisplacement – A=120 mkm;

Vibration frequency – υ=30 Hz;

Number of cycles – $5 \cdot 10^6$.

Environment temperature – 650 °C;

Results of tribotechnical tests are presented on Fig. 4.

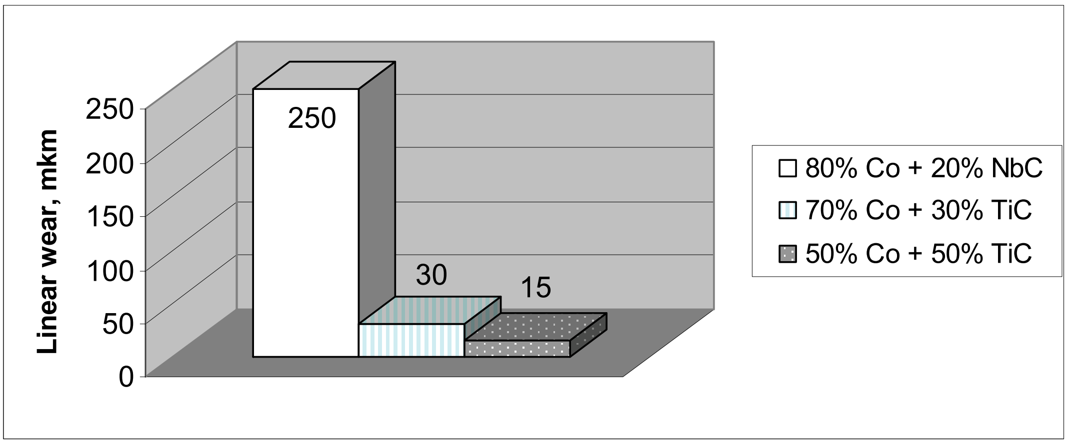

Fig. 4. Results of tribotechnical test of composite alloys at condition of high temperature fretting – corrosin.

During investigation it became impossible to estimate wear resistance of composite powder alloys with high porosity. (#3 i #4). At the initial time of friction we observed oscillations of friction force in a range of 15-20% with a frequency 8-10 sec. After $2 \cdot 10^6$ cycles we stated destruction of movable specimens into several fragments or separation of immovable specimen. This can be explained by poor ability of porous material to relaxation of internal stress. As a result in in surface layer a net of cracks is formed, they grow into depth of the material.

Reference alloy #1 during friction is liable to chipping. On its surface a thin oxide film is formed, but it is instable and rapidly deteriorates thus opening broad areas of juvenile metal which also subjected to increased wear. The same behavior is intrinsic to alloy #2, though higher content of TiC significantly improves its tribotechnical properties. In both cases conditions of secondary structures formation and strength are broken thus causing deterioration of alloy surface layers.

Alloy #5 according to results of a test has the highest wear resistance. This may be explained by high volume content of TiC and low porosity. The last factor prevents formation and development of cracks inwards of material. It is known [4], that structurally nonuniform alloys are worn as a whole. In course of friction specific load is redistributed: it is increased for wear resistant inclusions and decreased for less wear proof. Particles of TiC are mostly located on areas of real contact and prevent destruction of protective oxide films. This film has porous structure. These pores in initial stage of friction accumulate wear products which act as solid lubricant. All these conditions provide stabilization of friction process and high wear resistance. It is evident that material worked exactly in a range of of loads, parameters of vibrodisplacement when on surface of alloy formed a dissipative structure, which is very efficiently disperses energy supplied to tribosystem.

Conclusions

1. Alloys with high porosity can not hold proposed loading conditions and are failured due to fatigue processes and are destructed in the initial phase of tribotest.
2. Alloys with low content of carbides in course of friction form thin oxidized film, which is quickly deteriorated and clear metallic surface is also subjected to increased wearing. In addition these alloys are inclined to chipping.
3. Powder alloy with high volume content of TiC forms porous oxide film, which accumulates wear products which act as solid lubricant thus helping to friction process stabilization. Carbide phase been located on areas of real contact and receives major part of load and prevents oxide film destruction. This alloy is prospective for further investigations and may be applied for gas turbine engines turbine rotor blades restoration by method of soldering-on of compensation layer on worn surface, as well as during their manufacturing.

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MODEL OF THE ELASTIC INDENTATION OF A HALF-SPACE BY A NON-IDEAL BERKOVICH INDENTER

Elastic indentation of a half-space by a non-ideal Berkovich indenter is simulated by means of a boundary element method. Paper accounts for tangential displacements which are usually neglected in analysis of indentation data. A simple expression is derived for the impact of the tangential displacements on the values of the reduced Young's modulus determined due to the Oliver-Pharr technique

Introduction. Depth-sensing indentation is a widely used technique in the study of mechanical properties of materials [1]. It yields information about hardness and elastic modulus and is also applicable for determination of yield stress and strain hardening exponent. Depth-sensing measurements at penetration depths of tens or hundreds of nanometers are referred to as nanoindentation [2; 3], is particularly well suited to the characterization of coated and other surface-engineered systems [4–6].

One of the more commonly used methods for extracting hardness and elastic modulus from nanoindentation load–displacement data is that of Oliver and Pharr [7–9]. It has an advantage that difficult measurements of the contact area at the nano-scale are not required, since it is calculated from the contact depth. Thus, the accuracy of the Oliver-Pharr technique depends on how well it predicts the contact area. The most possible factors distorting the value of the contact area are the roughness of contacting surfaces [10], non-ideal shape of indenters [11; 12], pile-up or sink-in [9; 13] and tangential displacements [14]. In the present investigation we refine on the Oliver-Pharr method by allowance for the non-ideal shape of the indenter tip (rounding) and for the tangential displacements.

The Oliver-Pharr method does not account for the tangential displacements. The method is based on the Bulychev-Alekhin-Shorshorov (BASh) relation [8; 15; 16] which is restricted to frictionless contact between elastic bodies and smooth surfaces and considers only the normal displacements on the surface of solids. Neglect of the tangential displacements leads to the incompatibility of strains in the area around the contact [14]. Moreover, the tangential displacements themselves at the boundary of the contact region can achieve approximately 22 % of the indentation depth depending on the Poisson's ratio of the elastic half-space [14]. Therefore, accounting for the tangential displacements demands a particular investigation.

The objective of the study is to specify how much impact the tangential displacement effects have on nanoindentation studies of material properties. To attain the goal we use the mathematical model of elastic contact represented in the previous paper [17] and expand the BASh relation for the tangential displacements. The model concerns an especially important case of shallow indentation (usually less than 100 nm) where the tip rounding is on the same order as the indentation depth. It considers the indentation of half-spaced samples by the rigid Berkovich indenter and accounts for the tangential displacements on the surface of the sample.

Short description of the model. We use the mathematical model of a unilateral contact between the Berkovich rigid indenter and an elastic half-space (sample). The indenter with the equation of the surface $x_3 = -f(x_1, x_2)$ is pressed by the force P to a boundary of the contacting sample (see Fig. 1, *a*). The sample is considered as a positive half-space $x_3 \geq 0$. The origin O of Cartesian coordinates, x_1, x_2, x_3 is put at the single point of the initial contact between the indenter and the sample. The contact region S is an orthogonal projection of the contact between the sample and the lateral surface of the indenter on the plane $x_3 = 0$ after deformation. The tip of the blunted indenter is simulated as a smooth surface (the homogeneous functions with the degree 2)

$$f(M) = \frac{r^2}{2R},$$

where R is the radius describing the shape of the blunted indenter tip. It accounts for the asymmetry of the Berkovich indenter, Fig. 1, *b*. $r = \sqrt{x_1^{\ 2} + x_2^{\ 2}}$.

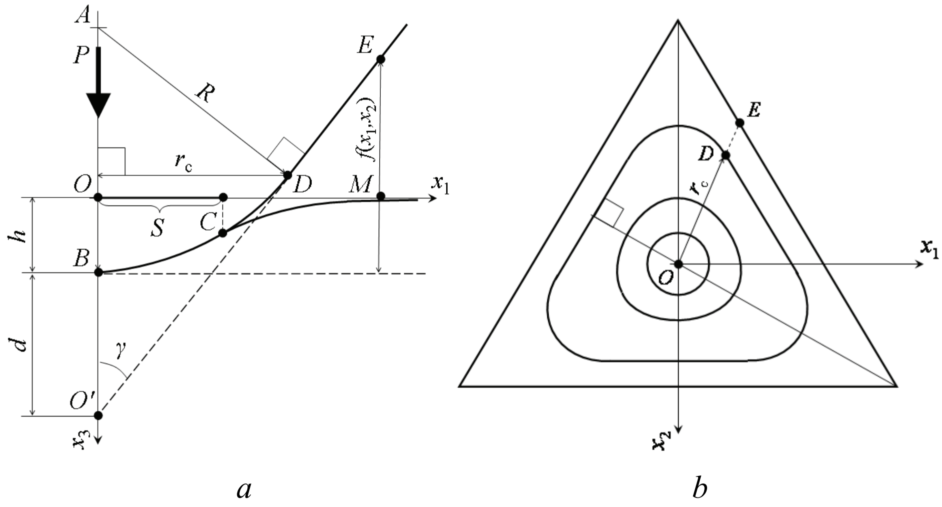

Fig. 1. Geometry of the simulated blunted indenter, *BCDE*, and of the ideal Berkovich indenter, *O'DE*. The segment *BD* is the arc of the circle with the centre *A* and radius *R*; *d* is the bluntness of the indenter tip. *OB* is the displacement of the indenter, which causes the contact *BC* with the sample (*a*). Cross-section of the simulated blunted indenter. The contour lines correspond to various positions of *D* (*b*)

Method of non-linear integral boundary equations (NIBEs) [18] was applied to formulate the contact problem. The numerical solution of NIBEs was carried out by means of the boundary element method. The final formula for the load-displacement diagram is

$$P(h) = \frac{\sqrt{2d}}{\lambda} \cdot P_0(h) \cdot h^{3/2} \ , \tag{1}$$

here function $P_0(h)$ is the dimensionless compression force, it was obtained numerically from the solution of NIBEs at different values of the mutual approach h; d is the bluntness of the indenter tip. Parameter λ is defined through the reduced Young's modulus E^*, $\lambda = \frac{1}{\pi E^*}$, $\frac{1}{E^*} = \frac{1-\upsilon_s^2}{E_s} + \frac{1-\upsilon_i^2}{E_i}$ (subscripts denote the parameters of the sample "s" and of the indenter "i"). For more details about the model and derivation of solution of NBIEs the reader is referred to [19].

Effect of tangential displacements on the nanoindentation study of the reduced Young's modulus.

Expression for the dimensionless compression force is given in the following form

$$P_0(h) \approx P_0 + b(\upsilon_s) \cdot \sqrt{\frac{h}{d}}, \tag{2}$$

where $P_0 = 1.277$ is a constant, $b(\upsilon_s)$ is a function depending on the Poisson's ratio of the sample material, $b(0.5) = 0$. The effect of tangential displacements is associated with the second term in (2). If the tangential displacements in the model are neglected, then the dimensionless compression force is constant $P_0(h) = P_0$, regardless of the value of Poisson's ratio υ_s. So, expressions for the load calculated with allowance for the tangential displacements $P_{TD}(h)$ and neglecting them $P_{no\,TD}(h)$ can be derived from (1) and (2)

$$\begin{aligned} P_{TD}(h) &\approx \frac{\sqrt{2d}}{\lambda} \cdot P_0 \cdot h^{3/2} + \frac{\sqrt{2}}{\lambda} \cdot b(\upsilon_s) \cdot h^2, \\ P_{no\,TD}(h) &\approx \frac{\sqrt{2d}}{\lambda} \cdot P_0 \cdot h^{3/2}, \end{aligned} \tag{3}$$

Following the technique of Oliver and Pharr we need an equation for the contact stiffness. The reduced Young's modulus is determined from the contact stiffness S at the beginning of unloading and the projected contact area A using BASh relation [8; 15; 16]

$$S = \frac{2\beta}{\sqrt{\pi}} E^* \sqrt{A},$$

where β is a constant that depends on the geometry of the indenter (1.034 for a Berkovich indenter and about 1 for the tip bluntness). As was mentioned in introduction, the BASh relation neglects the tangential displacements. We can derive from (3) a refined relation for the contact stiffness S_{TD} that accounts for the tangential displacements

$$S_{TD} = \frac{dP_{TD}(h)}{dh} \approx \sqrt{2\pi} E^* \cdot \left(\frac{3}{2} \cdot \sqrt{d} \cdot P_0 \cdot h^{1/2} + 2 \cdot b(\upsilon_s) \cdot h \right). \tag{4}$$

Tangential displacements influence the reduced modulus E^* by means of the contact stiffness only because the contact area is no longer explicitly presented in (4). The contact stiffness that neglects the tangential displacements is

$$S_{no\,TD} = \frac{dP_{no\,TD}(h)}{dh} \approx \frac{3}{2} \sqrt{2\pi} E^* \cdot \sqrt{d} \cdot P_0 \cdot h^{1/2}. \tag{5}$$

Let E^*_{TD} denotes the reduced modulus determined with allowance for the tangential displacements (4) and $E^*_{no\,TD}$ denotes the modulus determined neglecting them (5). Relation between E^*_{TD} and $E^*_{no\,TD}$ can be found from the comparison of S_{TD} with $S_{no\,TD}$. The contact stiffness is evaluated at the beginning of unloading $h = h_{\max}$ [8], see Fig. 2.

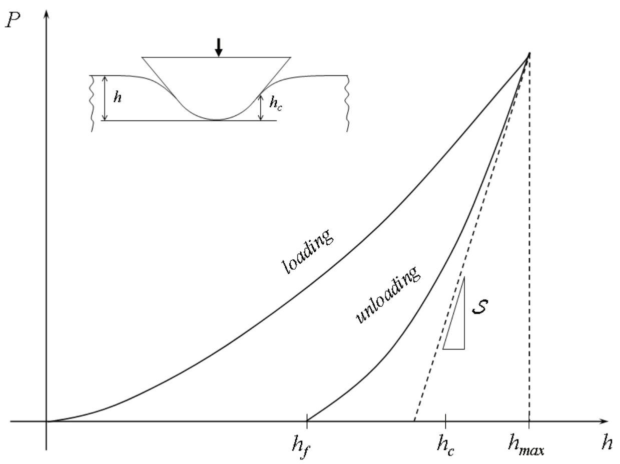

Fig. 2. A schematic load-displacement curve of a nanoindentation test. $h_{\max}$ – maximal displacement, h_f – final displacement, h_c – contact depth, S – contact stiffness

We should also account for the final displacement h_f after complete unloading [8]. Thus we set $h = h_{\max} - h_f$ to compare the contact stiffness in (4) and (5):

$$\frac{E^*_{TD}}{E^*_{no\,TD}} = \frac{\frac{3}{2}\cdot\sqrt{d}\cdot P_0\cdot(h_{\max}-h_f)^{1/2}}{\frac{3}{2}\cdot\sqrt{d}\cdot P_0\cdot(h_{\max}-h_f)^{1/2}+2\cdot b(\upsilon_s)\cdot(h_{\max}-h_f)} \approx 1-\frac{4}{3}\cdot\frac{b(\upsilon_s)}{P_0}\cdot\sqrt{\frac{h_{\max}-h_f}{d}} \approx 1-b(\upsilon_s)\cdot\sqrt{\frac{h_{\max}-h_f}{d}}$$

Here we used that $b(\upsilon_s) << P_0 = 1.277$, see table. The model was developed for a rigid indenter. Therefore the effect of tangential displacements on determination of the Young's modulus and of the reduced Young's modulus is the same:

$$\frac{E_{s,TD}}{E_{s,no\,TD}} = \frac{E^*_{TD}}{E^*_{no\,TD}} \approx 1-b(\upsilon_s)\cdot\sqrt{\frac{h_{\max}-h_f}{d}}\,. \tag{6}$$

Furthermore, we investigated the case of shallow indentation, $h_{\max}-h_f \approx d$. Therefore (6) reduces to:

$$\frac{E_{s,TD}}{E_{s,no\,TD}} = \frac{E^*_{TD}}{E^*_{no\,TD}} \approx 1-b(\upsilon_s)\,. \tag{7}$$

As follows from (6) and (7), the models neglecting tangential displacements overestimate the reduced and the Young's modules. For a wide range of materials the error in determination of the elastic modulus is about 4 % (see table 1). For materials with the Poisson's ratio less than 0.2 the error approaches to 6 %.

Table

The values of the parameters b [19] depending on the Poisson's ratio of the sample

υ_s	$10^2\cdot b$	υ_s	$10^2\cdot b$
0	6.17 ± 0.08	0.3	3.38 ± 0.05
0.1	5.56 ± 0.08	0.4	2.03 ± 0.05
0.2	4.63 ± 0.07	0.5	0

A difficulty of the Oliver-Pharr method is the estimation of the contact area [13; 16]. To avoid this, we propose to find the unknown parameters (d or $E^* = 1/\pi\lambda$) by fitting the function $P(h)$ in (1) to the elastic part of the indentation curves.

Conclusion. A simple expression is provided for the impact of the tangential displacements on nanoindentation studies of the reduced Young's modulus. Neglecting tangential displacements one overestimates the Young's modulus up to 6 % depending on the Poisson's ratio of the sample.

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ELECTROMAGNETIC EMISSION OF COMPOSITE MATERIALS AT HIGH-VELOCITY IMPACT LOADING

Research installation «aSTanin» for studying the processes of impact destruction of composite materials is elaborated. It includes a system for registration and analysis of electromagnetic (EME) and acoustic (AE) emission. The relationship between the accepted by the construction at the impact energy and the intensity of EME and AE in the investigated velocity range up to 1000 m/s is identified for specimens of textile-reinforced glass-fiber-composite on the basis of polypropylene.

Problem Statement

Modern constructions of building structures and transport vehicles in the field of ground automobile and railway transport and also in aviation and spaceship production, where reduction of the construction weight at retention of its functionality and high level of reliability has an especially great importance, widely use textile-reinforced hybrid-garn materials on the basis of thermoplastics. Advantages of their usage except of the aforementioned ones are possibilities of the constructive element form specifying in the phase of the material production before the moment of its final solidification. That also gives an opportunity to decrease the number of separate components at the design process and to substitute them for unified constructive elements of a complex form.

Disadvantage of the mentioned materials usage is their high sensitivity to fluctuation of the constructive elements production technological process parameters that especially increases the significance of detailed investigations of such composite materials behavior at various interaction conditions, which model the posterior conditions of the finished design functioning at its exploitation. An important aspect of materials behavior for their utilization in automobile and aviation industry is their reaction to a mechanical impact loading. It is explained with the typical nature of the caused with high velocity impacts damages in the mentioned fields. Cabs and bodies of motor cars accept damages invoked by collisions with other automobiles at car accidents and also with stones, which is thrown out from under the wheels of other vehicles. Damages in the result of collisions with birds are typical for aviation, as well as damages of aviation engine streamers and plane wings because of gripped with air-gas flows solid particles and stones, which even having low masses but high relative velocities result in significant damages and destructions. Thus a great interest arises in studying the character of the design damages at specified collision parameters such as mass and velocity of the impactor and also the energy characteristics of the initial energy of the interacting bodies redistribution between them and its transferring to the united load-carrying structure, which constitutive components are constructive elements of the composite material.

So studying the character of deformation and destruction of novel composite materials and composite elements at impact loading at various initial interaction parameters is of a great importance for elaboration of designs satisfying the safety and reliability demands.

Analysis of the Recent Researches and Publications

Mechanical oscillations including acoustic oscillations of materials, changing of distances between separate structure elements of complex materials, oscillations of the borders of their contact and of other possible inhomogeneities, where double electrical layers are formed, are accompanied with electromagnetic emission of the material (EME). As known, investigations of analogical processes at destruction of rocks show that the EME signal amplitude is proportional to the crack dimensions [1], and its frequency is inversely proportional to its size [2].

Various reasons and mechanisms of the EME origination are considered [3], such as piezomagnetic, inductive, deformative and inertial. They correspond to the basic elements of the solid body mechanics that are stress, deformation, velocity and acceleration. Conforming to that reasons the proposed by Guliemi and Levshenko linear equation of the electromagnetic signals generation is used [4-5]:

$$\frac{\partial B(x,t)}{\partial t}-\frac{c^2}{4\pi\sigma}\nabla^2 B(x,t)=\nabla\times C(x,t),$$

where $C=\sigma a+V\times B_0+\beta\theta E_0+\nabla\times M$, B - strength of the created magnetic-field, c - speed of lightin vacuum, σ - material conductivity, $a=\frac{\partial V}{\partial t}$ - general material acceleration, V - material velocity, B_0 - strength of the extraneous magnetic field, in scope of which the interaction takes place, E_0 - strength of the extraneous electric field, in scope of which the interaction takes place, $\theta=\nabla U$, U - field of dislocations, M - magnetic moment of the medium volume unit, such that $M_i=(\gamma_1 P_{II}\delta_{ij}+\gamma_2 P_{ij})B_0 j$ if considered in the Cartesian coordinate system, P_{ij} - pressure components in different directions, P_{II} - pressure in the direction, which is parallel to the applied axial load, $\beta=\frac{\partial \ln\sigma}{\partial\theta}$, γ_1, γ_2 - parameters of the mechanics and magnetic transformation, which are determined experimentally.

Thus investigations of EME and tight connected with its appearance double electrical layers is reasonable in the context of material adhesion. According to [6] the work of destruction of the adhesive bounding, which is acted against the action of electrostatic forces, is calculates as the following

$$A=2\pi\frac{\gamma^2}{\varepsilon}h,$$

where γ - surfacial density of the electrical charge, h - the split thickness, ε - the medium dielectric permeability.

It may be assumed that the tunnel effect, electric charge runoff because of surface condactivity and other similar effects, which may cause reduction of surfacial dencity of electrical charge at low interaction velocities, will not contribute to reduction of the work of adhesive tie breaks at higher velocities of disruption of connected material structural elements for example such as different composite phases on which verges double electrical layers take place. This assumption has an experimental confirmation [6]. Energy, which is accumulated as a result of moving electrical charges of the same sign apart, may be released owing to EME or a gas discharge through the gap between the separated surfaces. The more quickly is separation of the charges, the less time the mentioned surface charge reduction factors, which feature is to develop in time, have for making their influence, so the more intensive the discharge or the emission is. So it is possible not only to explain the proportional correspondence between the crack width h and the radiated electromagnetic energy, but also to suppose the EME intensity dependence from the interaction velocity. But for the adhesive strength calculation in correspondence to the modern electron adhesion theory and for determination of the relationship between the calculated values and the EME characterizing values, it is necessary to know a number of difficultly determined parameters, so the theory, as mentioned in [7], is comparatively seldom used practically.

There were also attemptions to find the mutual correspondence of the AE and EME parameters [8-10], which are based on the fact that the break of ties at crack creation leads to appearing of a fluctuation charge on the crack brinks, unsteady motion of which results in the EME. The movement of the already present and newly created dislocations, which take part into creation of double electrical layers together with surrounding charged point defects, takes place at material deforming long before the start of creation of the cracks. Namely these changing double electrical layers straight take part in mechanical-electrical transformations at the acoustic wave action [11]. The following relationship is used for characterization of the distribution of electrical fields at creation of cracks of normal tearing off and conveying the bond between the energy of acoustic signal and provoked with it at propagation through a material electromagnetic signal of the same frequency:

$$m_0 = \frac{\delta_0^2}{\sigma_{кр}\varepsilon},$$

where δ_0 - surface density of electrical charge, $\sigma_{кр}$ - critical stress of the crack development, which depends upon the modulus of elasticity, the crack development surface energy, initial crack dimensions and the value of the crack jump, Poisson coefficient, ε - the medium dielectric permeability.

The laws of the acoustic emission signal formation depending on the type of the composite material fibers destruction are investigated in the work [12]. Correspondence between the AE amplitude AE $U(t)$ in the time moment t and the loading velocity $V = const$ is determined there as follows:

$$U(t) = U_0 \frac{Vt}{t_{\max} - t_{\min}},$$

where $U_0 = N_0 \beta \int_{t-\delta/2}^{t+\delta/2} V(\tau) d\tau$ - constant value, N_0 - initial number of undamaged fibers, β - proportional coefficient, δ - duration of exitation, which is considerable less than the time of the specimen destruction process, $t_{\min} = \frac{\varepsilon_{\min}}{V}$, $t_{\max} = \frac{\varepsilon_{\max}}{V}$ - borders of the deformation time interval, $\varepsilon_{\min}$, $\varepsilon_{\max}$ - deformation interval borders.

The work [13] shows that the coefficient of the dislocation mechanical energy transformation into electromagnetic radiation is extremely low, but the EME intensity rapidly grows together with the frequency and amplitude increase of the dislocation segments oscillations. In addition to that this work indicates that the greater number of dislocation segments are activated simultaneously and in concord to each other, the higher is the EME amplitude.

Thus the problems of EME are considered traditionally in the context of seismographic displacements and rock burst prognosis and also in the context of water or water vapor crystallization in consideration of the important role of the double electrical layers formation in these processes (the Workman-Reynolds effect) [14], that is of a great significance in oceanology, glaciology, ecology and for researches of the kinetic of phase transformations, including crystallization, in insulators. But search for means of aviation safety increase and analysis of the recent investigations and publications in the sphere of EME shows availability of researches of the EME and AE relationship with the composite material deformation and destruction processes at high velocity impact loading, including studying of the effects, analogical to the Workman-Reynolds effect, in the processes of plastic deformation of the composite material matrix at the textile reinforcing fiber and matrix interface.

Elaboration of the Research Equipment

Redistribution of the energy between the structural elements, which function for the design safety, and the main load-carrying defended structure is of a great importance in the field of aviation safety problems as it is shown above. The parameter, which characterizes the effectiveness of this process and consequently the protective features of the energy-absorbing composite material, the structure protective elements are made of, is the value of the accepted by the protective elements energy. As the sensitive to the character of the deformation and destruction processes development parameter, the amplitude of the electromagnetic field oscillations at the processes of the EME of composite material at impact loading is considered.

Advantages of the described method is the technological possibility of the EME parameters nondestructive registration straight in the process of the impact interaction and with a high time resolution. The main aim of the developed method is connection of the temporal characteristics of the interaction process of the investigated material with the integral characteristics of the energy distribution, which directly indicative of the protective structure quality.

Maintenance of conditions of the high-velocity interaction of the material specimens and an impactor is achieved with usage of the elaborated and early described installation "Ganchen" as a part of research complex «aSTanin» (Acceleration System for Testing of Antidamage Innovations) [15]. Constituent parts of the complex are the system of the impactor acceleration, system of initial impactor velocity definition «ASPEED», ballistic pendulum as unified system for specimen fixing and impact interaction energy parameters registration, device for residual material deformations registration "ODD", computer system of information analysis, system of the experiment process control and also operator safety system [16]. Characteristic features of the used complex are a high adjustment precision, reliability and safety of work.

Impactor acceleration is attained according to the principle of thermodynamic gas expansion at the processes of chemical burning reaction with the energy extraction. The tests are accompanied with the experiment progress control, measuring equipment signal processing and obtained information storing. The developed system and research methodic allowed carrying out of a series of experiments for comparative analysis of specimens of textile-reinforced composite structures.

The described in fig. 1 principle experiment execution scheme realization provided an opportunity of real-time registration and automatic saving of the data about the EME and AE parameters for the following analysis.

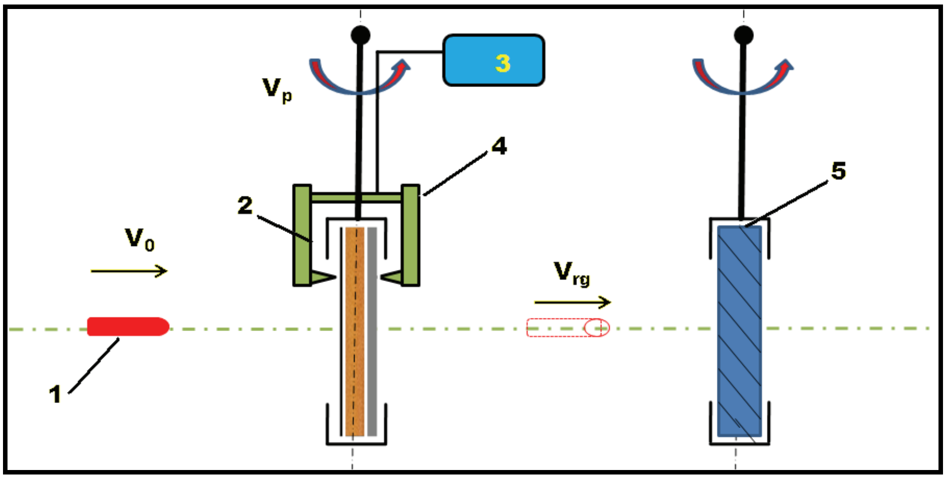


Fig.1. Principle experiment execution scheme:
1 – impactor; 2 – composite material as a barrier; 3 – EME and AE registration and analysis unit; 4 – sensor system of electromagnetic and acoustic fields; 5 – pendulum for registration of the impactor rest kinetic energy

Experiment Execution and Analysis of the Obtained Results

For investigations of textile-reinforced hybrid-garn composite materials on the basis of thermoplasts, a typical representative of the given class of materials was selected, that is manufactured on the basis of glass and coal fibers of the percent ratio of 20 % and 80 % and brought to the phase of finished constructive form at the temperature 200°C and pressure 20 MPa, Twintex T PP 60 745 AF 152.

Integral characteristics of the energy distribution were investigated as well as parameters of the deformation crater and the character of the material specimen destruction of the round form, diameter of 200 mm and thickness of 2 mm in the conditions of impact interaction at velocities of the range of 20…1000 m/s, peculiarities of the impact process were analysed.

Impactors were solid bodies of spherical form with diameter of 8,71 mm, weight of 2,7 g, made of the steel ШХ 15. In the course of the experiment process all impactors behaved as ideally nondeformable impactors, so that there were no residual damages, form or volume changes in every of the carried out experiments. Supported at experimental researches initial conditions are summarized in the table 1.

Table. 1.

Initial parameters and conditions at experiment researches

Experiment execution parameters	The parameter value	Dimension
Specimen material	Twintex T PP 60 745 AF 152	–
Form of material specimen	round	–
Diameter of material specimen	0,2	m
Type of material specimen fixing	rigid circular fixing	–
Workspace of material specimen	$15\cdot10^{-2}$	m
Material of the impactor	ШХ 15	–
Form of the impactor	spherical	–
Diameter of the impactor	$8{,}71\cdot10^{-3}$	m
Impactor weight	$2{,}7\cdot10^{-3}$	kg
Initial interaction velocity range	20…1000	m/s
Initial interaction energy range	$0{,}54\cdot10^{-3}$…1,351	kJ
Temperature at the tests execution	20±2	°C
Atmospheric pressure	10^{5}±20	Pa

Carried out experimental researches allowed determination of characteristic for the investigated composite material critical velocities, which correspond to change of the impact process character. Relationship of the impact crater parameters on the initial impactor velocity was found and thereafter from the initial impact initiating mechanical energy. Analysis of the impact process energy parameters allowed determination of energy distribution between the interacting bodies peculiarrities at the collision velocity increase.

Three characteristic ranges of the initial impactor velocity were found that correspond to a certain residual deformation damage type. The first range is characterized with an absence of noticeable matrix cleavage and composite fibers delamination (fig. 2, a).

a *b* *c* *d*

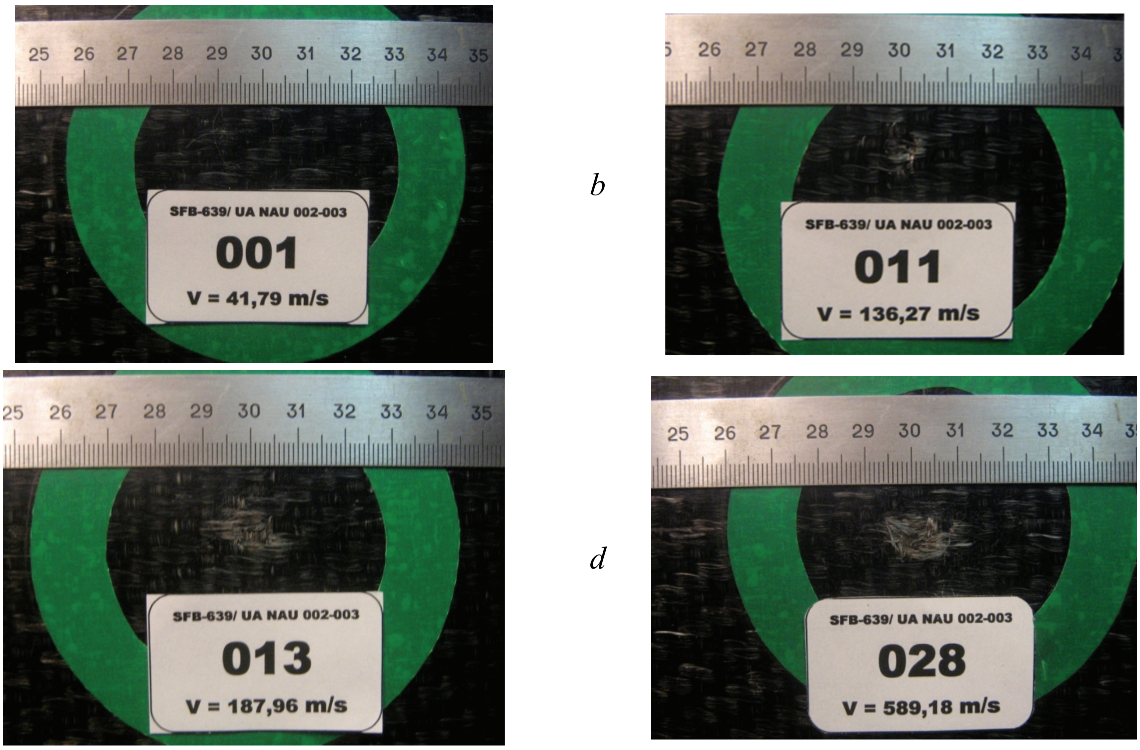
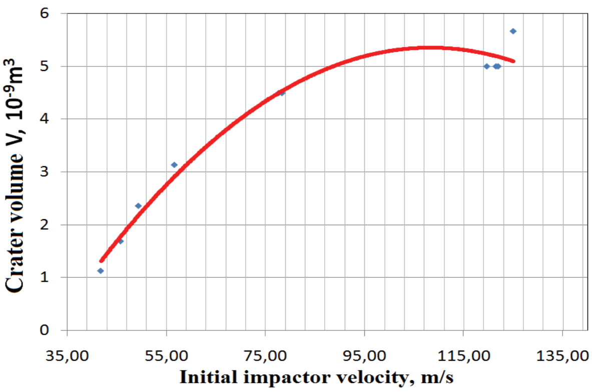


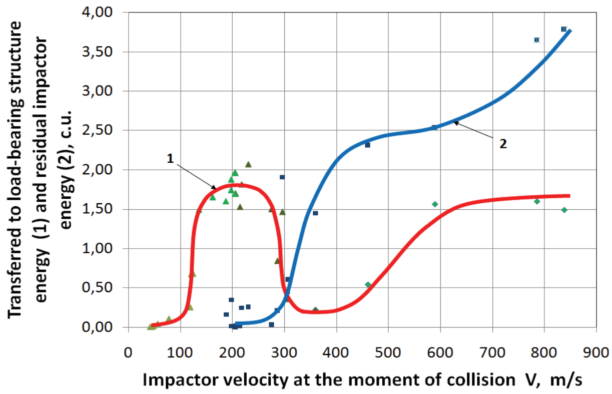
Fig. 2. Typical material specimen appearance in the first (a), second (b,c) and third (d) characteristic interaction velocity intervals

Comparatively slow increase of the residual deformation crater volume is observed (fig. 3, a). Delamination of fibers and matrix spalling makes a great contribution in the impact process at velocities higher than 130 m/s. Accordingly to that the accepted with the main bearing construction energy with the fixed specimen and the absorbed by the material energy increases sharply. Fig. 3, b illustrates dependence of the bearing construction energy on the initial impactor velocity for the investigated velocity interval. Impact energy redistribution between the interacting bodies at the collision velocity increase is clearly seen at this dependence comparison with the given on the fig. 3, b relationship for the residual impactor energy on its initial velocity. The scales for both dependences differ for enabling the curves better viewing. Typical material specimen outlook for the second characteristic interval of interaction velocities for initial velocities from 130 m/s to 190 m/s is given in the fig 2, b, c.

Dispersion of separate values is explained with the high level of instability of characteristics of the textile-reinforced composites including composites on the basis of glass fibers and polypropylene matrix because of nonideal distribution of the textile fiber framework in the matrix, unevenness of the adhesive binding between fibers and matrix quality, material thickness oscillations and mismatchbetween each other of the layers according to the criterion fiber-matrix along the specimen thickness. Therefore the considered material allows determination of only statistically averaged generalized criteria and demands taking into account deviations from the determined parameter distribution laws.



a



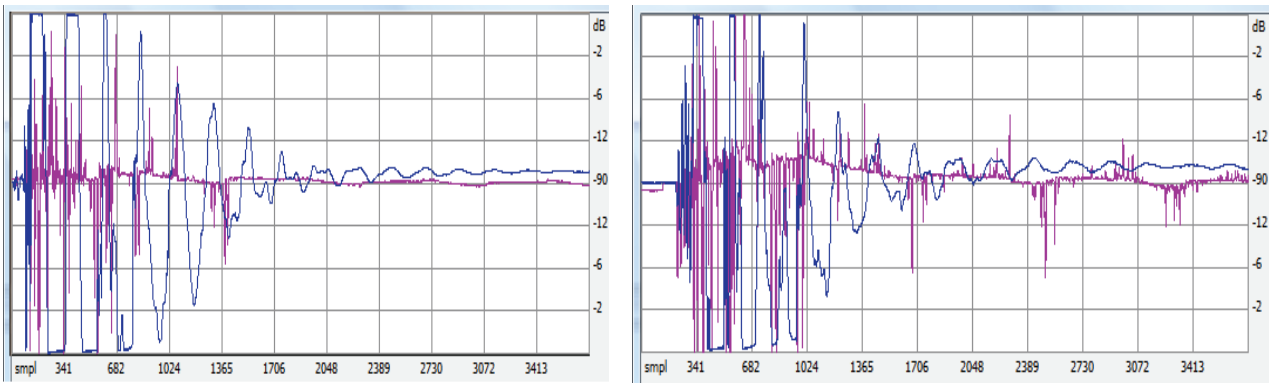
b

Fig. 3. Dependence of the investigated specimen impact crater volume magnitude after interaction in the first characteristic velocity interval (a) and comparative alteration of the transferred to the construction with the investigated specimen energy (1) and the rest kinetic energy (2) of the impacter after the interaction (b)

The interval from 190 m/s to 220 m/s involves critical for the investigated material velocities of transition from non-through specimen deformation to its through penetration. The main role in the result damage is played with rupture and napping of the load-bearing fibers and with the matrix material crumbling. The residual deformation crater in these experiments may not be determined. A typical damage for hugh interaction velocities is shown in fig. 2, e.

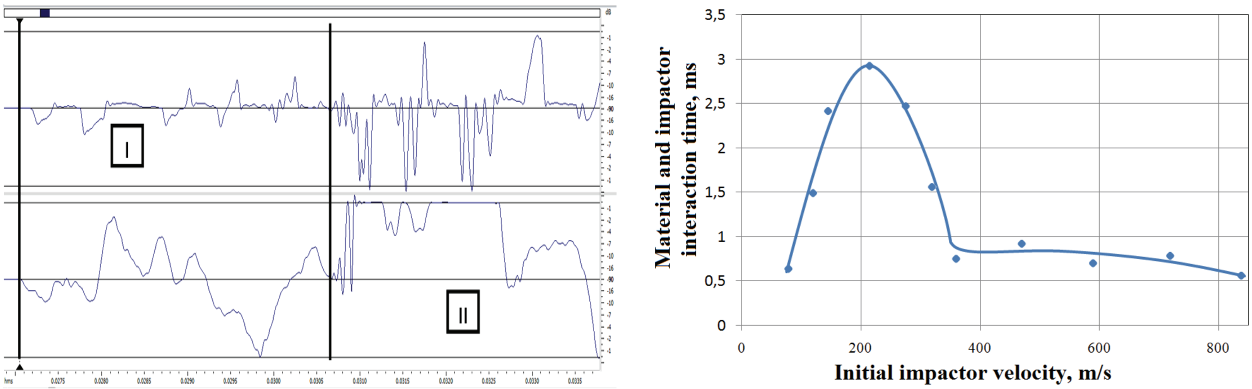
Fig. 4 shows dependences of the EME amplitudes on the observation time for impact interaction with collision velocity of 119,63 m/s (fig. 4, a) and 275,05 m/s (fig. 4, b). Peculiarity of the recorded thanks to usage of the developed research complex dependences is ability to analyze with help of them directly the process of the impactor interaction with the material. Fig. 5,a shows the time intervals of oscillation character change in time in the course of the impact interaction process: low frequency interval in the course of the straight material and impactor interaction and high frequency interval after the end of the straight material and impactor interaction. Calculated on the basis of the EME and AE parameter analysis time values of the straight impact interaction of the investigated material and the impactor are shown in fig. 5,b.

Built for EME and AE amplitude-frequency characteristics (fig. 6) illustrate presence of characteristic peaks of the oscillation amplitude at certain frequencies. For example for the velocity of 214,27 m/s the amplitude peak is observed at frequency $F(A_{max})$ = 215,33 Hz. The frequency of peaks for EME and for AE coincidence in this case for the mentioned velocity. But they differ as a rule for other velocities.



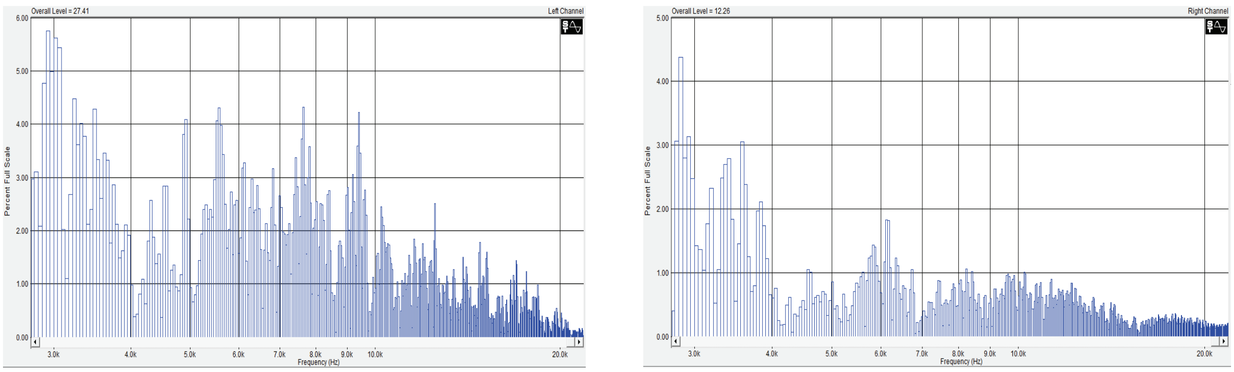
a *b*

Fig. 4. Typical dependances of the EME amplitude upon the observation time for impact interaction in the I (*a*) and III (b) characteristic velocity intervals



a *b*

Fig. 5. Characteristic intervals of the AE amplitude curve (upper graph) and EME amplitude (lower graph):
I – low frequency interval in the course of the straight material and impactor interaction
II – high frequency interval after the end of the straight material and impactor interaction (a)
and change of the straight material and impactor interaction time for different initial velocity values (b)



a *b*

Fig. 6. Amplitude-frequency characteristics of EME (*a*) and AE (b) for impact interaction at collision velocity of 214,27 m/s

Analysis of peaks of the maximum intensity for amplitude-frequency characteristics of EME and AE result in the given in fig. 7 dependences. The shown curves characterize mismatch of frequencies of the peaks of maximal intensity for the given characteristics that is deviations of parameters of the process, which is accompanied with EME and AE. As it may be seen from the graph, minimal deviations from the approximation curve are observed at interaction velocity of 190 m/s that corresponds to the start of the material penetration with the impactor stage and also correlates with the dependence for transmitted to the construction with the fixed specimen of the studied material energy at various initial impactor velocities.

Results of analysis of amplitude peaks at high frequencies are shown in fig.8. Approximated with exponential curves amplitude-frequency characteristics for EME show relationships of EME amplitudes at high and low frequencies at the same interaction velocities. Therefore it may be seen that EME amplitudes are distributed less uniformly relative to the values of corresponding frequencies in the interval of velocities of transition from non-through to through specimen penetration. On the contrary EME amplitudes are distributed more uniformly in the mentioned sense for lower and higher velocities relative to the critical ones.

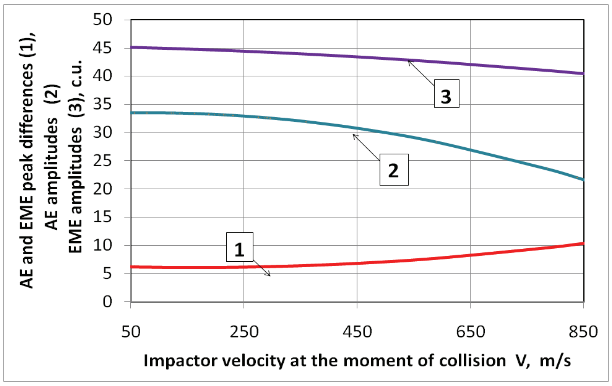


Fig. 7. Relationship of the difference of frequencies of peak EME and AE amplitudes upon the initial impactor velocity (1) and relationships of these corresponding to the peaks frequencies for AE (2) and EME (3)

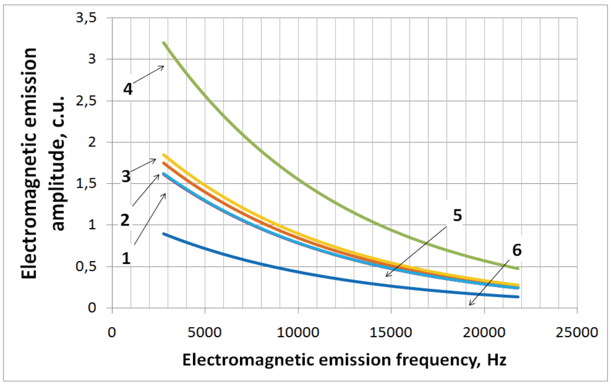


Fig. 8. Analysis of peaks of amplitude-frequency characteristics for high emission frequinces: 1 – V = 49,4 m/s; 2 – V = 119,63 m/s; 3 – V = 124,95 m/s; 4 – V = 198,18 m/s; 5 – V = 306,49 m/s; 6 – V = 984,74 m/s

Fig. 9 illustrates similarity of experimental curves, which characterize the accepted with the bearing structure energy dependence and EME peak amplitude dependence on the initial impactor velocity. Analysis of these values allows definition of two generalized characteristic ranges. One of them corresponds to the initial material strengthening up to the critical velocities of the start of its penetration with the impactor. The other interval illustrates the undulating increase of its carrying ability.

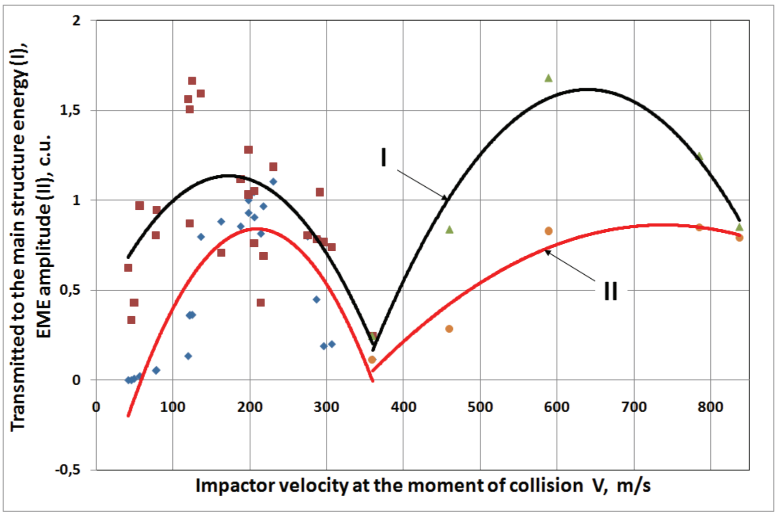


Fig. 9. Generalized relationship of the peak EME amplitude (I) and accepted by the construction energy (II) upon the initial impactor velocity in two characteristic ranges

Resume

Research installation «aSTanin» is elaborated for studying the processes of impact destruction of composite materials. One of the principle features of the complex is that it includes a system for registration and analysis of electromagnetic (EME) and acoustic (AE) emission.

Impact interaction of fiber composite test structures is investigated and experimental relationships of energy and deformation damage parameters upon the initial impactor velocity are found as a result of that. Research is carried out for test structure specimens on the basis of textile-reinforced hybrid-garn composite material Twintex T PP 60 745 AF 152.

The relationship between the accepted by the construction at the impact energy and the intensity of EME and AE in the investigated velocity range of 20…1000 m/s is identified for specimens of textile-reinforced glass-fiber-composite on the basis of polypropilen.

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CRITERION OF STRESS CONCENTRATION FOR EVALUATION OF THE LOWER LEVEL OF COMPOSITE MATERIAL STRENGTH LOSS AFTER A LOW-SPEED IMPACT

Earlier [1], calculation results of a carbon composite static expansion strength loss upper level after a low-speed impact of different energy by equivalent hole criterion were published. In the current work its lower level by criterion of concentration is evaluated. Results obtained by FEM are in a fine correspondence with experimental results.

Depending on the energy of a low-speed impact, the impact object may penetrate the material at various depths. Assuming that the impact object has a spherical surface, it allows supposing that the deformed surface of a sample consists of a direct contact zone of depth δ_0 and a conjunction zone of the contact surface displacement of depth w_0 (Fig. 1). Therefore, the task is to determine the actual, i.e. total penetration depth of the impact object $w_{\max} = w_0 + \delta_0$ and a stress state around the contact zone with the constant radius of the spherical surface R_m of impact object and different radiuses of the contact area R_c.

In the current investigation it is assumed that: $R_m = 3.2$ mm, a range of values is set as $0 < R_c < R_m$: $R_{ci} = R_{c(i-1)} + \Delta R_c$, where $\Delta R_c = \frac{R_m}{8}$.

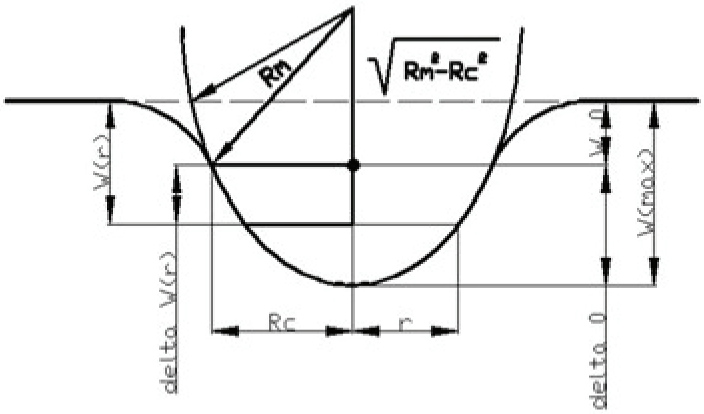


Fig.1. Deformed composite surface after a low-speed impact with an impact object with spherical surface.

Further is calculated: $\delta_0(R_c) = R_m - \sqrt{R_m^2 - R_c^2}$. Next step was to construct a piecewise-linear model of the deformed zone border. Every point on the deformed zone border has a defined radius of $0 \le r \le R_c$ and corresponding depth of $\Delta w = w(r) - w_0 = \sqrt{R_m^2 - r^2} - R_m + \delta_0$, counting from the intersection point of the undeformed zone surface with the impact axis. As a result, the impact zone was presented in a form of set of lineal intervals (Fig. 2). Each of these intervals is described by the equation: $\delta_{zi} = k_i r + b_i$, where: $k_i = \frac{\Delta w_{i+1} - \Delta w_i}{r_{i+1} - r_i}$, $b_i = \Delta w_i - k r_i$.

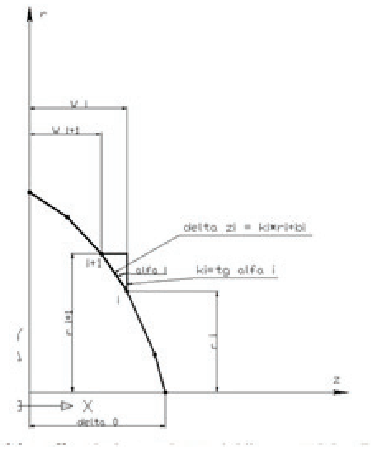


Fig.2. Finite element approximation of a deformed zone border.

For each of the calculated values R_c the contact zone is divided into 5 sections (Fig. 2). Finite element calculations were accomplished with an ELCUT program for an $t = 2$ mm thick plate of carbon composite КМКУ-2М.120.Э.01 with the following elastic constants:

$$E_\theta = E_r = 3.47 \cdot 10^{10}\ Pa; \quad E_z = 1.15 \cdot 10^{10}\ Pa$$

$$\nu_\theta = \nu_r = 0.33; \quad \nu_z = 0.11$$

according to the following algorithm:

- a contour (Fig. 3) and a grid of smallest КЭ with R_c radius is built;
- terminal conditions under compressive impact: surface e_1 displacement along the radius $\delta_r = 0$, and surface e_2 along the depth $\delta_z = 0$; distributed load $p = 0$ on e_3 and e_4 surfaces;

On each of the contact area intervals (e5–e9) displacements are assigned according to the linear law: $\delta_{zi} = b_i + 0 \cdot z + k_i \cdot r$. In a first approximation it is assumed that $w_0 = 0$. Consequential approximations are performed by matching the value of a free term b_i, which univalently determines the value of w_0. Calculation of stepwise approximations is performed until reaching $\sigma_z \to 0$ in the coordinate's point of $z = 0, R = R_c$ within the accuracy of ±1 MPa. Results of the proper solution are written along the lines which are parallel to the symmetry line with the step of $0.25 \cdot R_c$, from $r = 0$ to $r \approx R_c$. As a result we have a stress field around the contact zone and actual impact object penetration depth for each of the R_c values.

In [1] a method of determination of a cross-section lost area, using the above obtained results and experimental data, is presented [2].

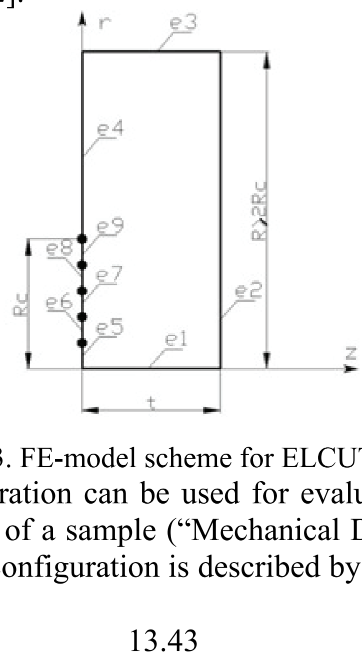
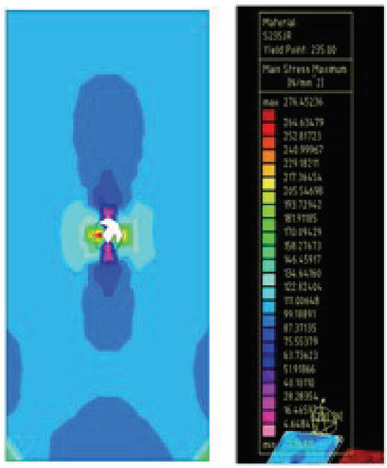


Fig.3. FE-model scheme for ELCUT.

The criterion of stress concentration can be used for evaluation of a lower limit of strength loss. According to the 3D FE-model of a sample ("Mechanical Desktop" software package) a dent is formed at the impact point which configuration is described by the Fig.1, and size is calculated in the [1] as S_{nomep}. As a terminal condition some value of the extension stress σ is set, in the current case it is $\sigma = 100$ MPa. It is assumed that the highest stress at the dent border (stress concentration) expands over the whole impaired cross-section (Fig. 4).

In this case we assume the strength loss coefficient to be: $\overline{P} = \frac{1}{k}$, where $k = \frac{\sigma_k}{\sigma}$, σ_k - stress concentration. Results are presented in the Table 1.



$R_c = 1.2\ mm$

Fig.4. Results of the КЭ-calculations of stress concentration at the deformed zone border.

Results. Table 1.

R_c, mm	R_c/t	$w_{\max}$, mm	$w_{\max}/t$	T, J	σ_k, MPa	$\overline{P}$
0.4	0.2	0,0135	0,00675	0,118	178	0,562
0.8	0.4	0,0742	0,0371	1,316	218	0,46
1.2	0.6	0,1825	0,09125	8,845	253	0,4
1.6	0.8	0,3286	0,1643	17,727	247	0,4
2.0	1.0	0,5568	0,2784	40,740	242	0,41

Experimental samples of the carbon composites were 12,5 mm wide and 2 mm thick at the working part. Impact damage was inflicted on a special impact testing machine. A load with a head diameter of $d_н = 6{,}4$ mm was freely dropped from the height of $h = 0{,}5$ m. Impact was inflicted to the surface of a sample, freely rested on a hard basement. Impact energy was determined according to the formula $T = mgh$. Its value was varied by the load mass: $m_1 = 2{,}16$ kg and $m_2 = 3{,}16$ kg.

After that samples were statically extended until destruction. Destruction stress σ_{p_imp} values of the impacted sample were recorded. After that a relative strength loss was calculated using the formula $\overline{P} = \frac{\sigma_{p\_imp}}{\sigma_p}$. Thus, 5 samples impacted with the energy of $T = 10{,}6$ J and 5 samples impacted with the energy of $T = 15{,}5$ J were tested. Experimental results are presented in the Table 2.

Results. Table 2.

T, J	$\overline{\boldsymbol{P}}$
0	0,991
0	0,993
0	1,016
0	0,942
0	0,961
0	1,097
10,6	0,682
10,6	0,847
10,6	0,779
10,6	0,528
10,6	0,628
15,5	0,706
15,5	0,631
15,5	0,682
15,5	0,528
15,5	0,713

Summary

As it can be seen from the graphs (Fig. 5), all experimental points are situated between the upper border of a strength loss, calculated by the criterion of equivalent hole, and the lower border of a strength loss, calculated by the criterion of stress concentration. It confirms that conducted experiments resulted in development of approach which can be used to reasonably determine the limits of a possible strength loss of a carbon composite after low-speed impact damage. This approach can be successfully used for creation of the continuous control system of the aircraft technical state.

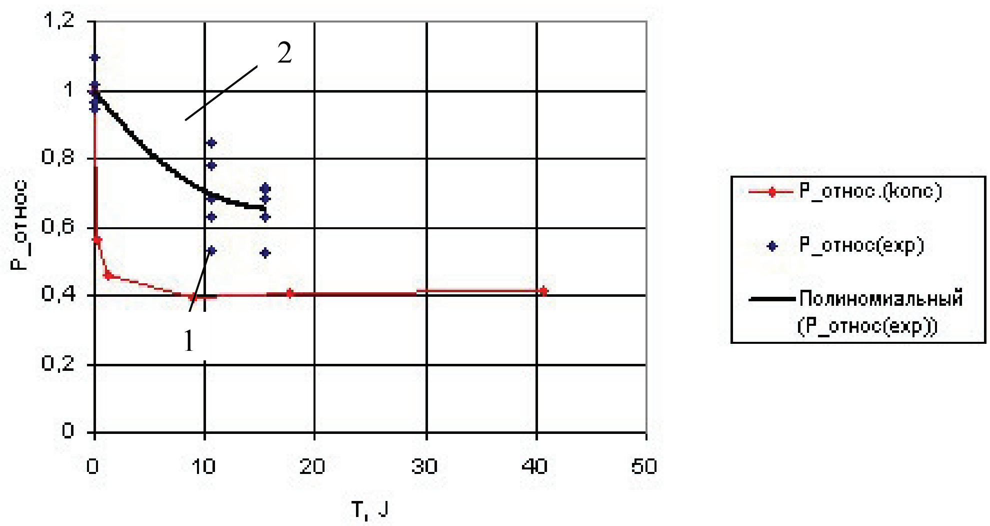


Fig.5. Material КМКУ-2М.120.Э.01 strength loss coefficient as a function of the impact energy:
1-By criterion of the stress concentrations
2-By the experiment results

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UDC 620:619.1

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ANALYSIS OF CRACK FORMATION PROCESS AT THE MULTIPLE DESTRUCTION OF ALUMINIUM ALLOY D-16AT

Pressing question of microcracks growth on a surface of constructional aviation alloy Д-16AT is investigated. Data about lengths of microcracks (MC) which appear during a loading before revealing of a macrocrack, growth rates of cracks and 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.

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. Standard corset specimens cut out from sheet aluminum alloy Д-16AT with the thickness of 1,3 mm with a plating layer. 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.

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.

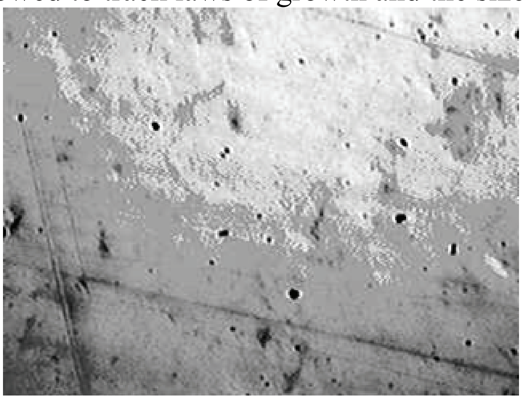
Identification of cracks, definition of their co-ordinates on the specimen surface sand measurement of it sizes was carried out visually by means of microscope ММР-4 ЛОМО and with application an eyepiece of a micrometer with which it is completed microhardnessmeter ПМТ-3.

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.

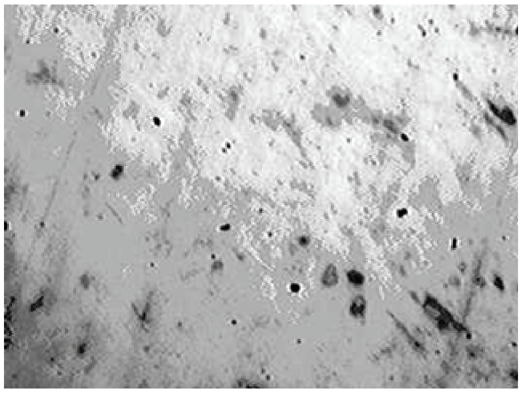
For each microcrack was defined it growth speed $\Delta h = \Delta l / \Delta N$, where Δl - a gain of length of a crack for ΔN loading cycles.

Experimental data and their discussion. 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.

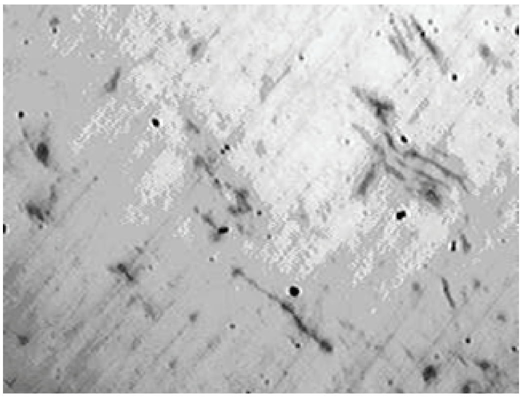
On fig. 1 a series of microphotos of origin illustrating sequence and growth MC on the polished surface of the specimen is presented. Use of an optical microscope and microphotos has allowed to track laws of growth and the size of MC.



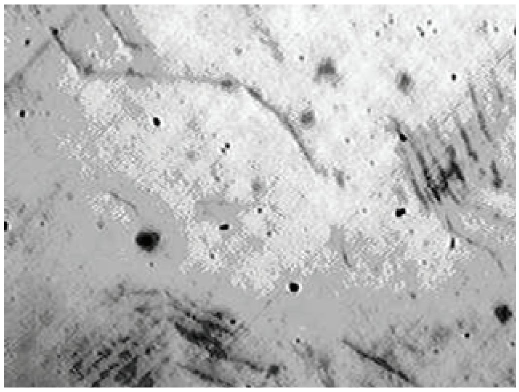
N = 80000 cycles



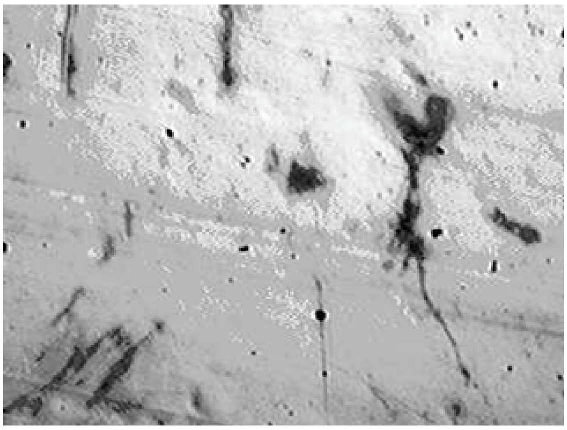
N = 90000 cycles



N = 100000 cycles



N = 110000 cycles



N = 115000 cycles

Fig. 1. Typical example of starting, growing and coalescence of fatigue MC. Microphotos of the polished surface of specimen Д16АТ alloy with tension σ = 250 MPa

These photos have been made by a digital camera by means of optical system of microhardnessmeter ПМТ-3 at optical zoom × 487. On the polished surface of the specimen which worked at a cyclic tension were observed numerous MC.

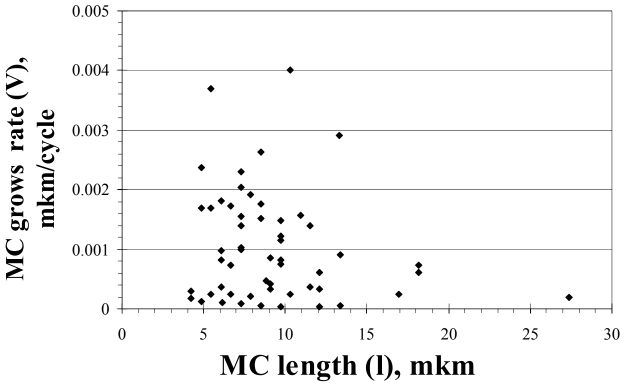


Fig.2. Dependence of the MC grows rate to their length

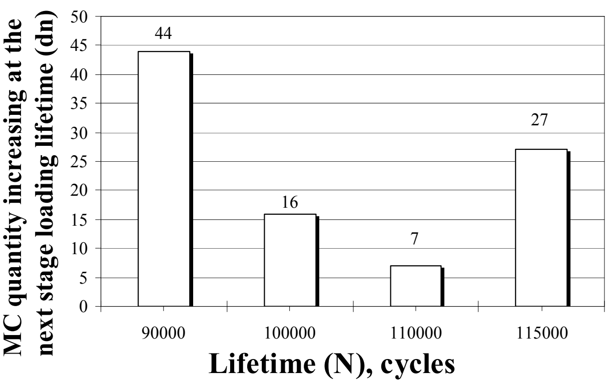


Fig.3. Dependence of the MC quantity increasing to the next stage loading lifetime

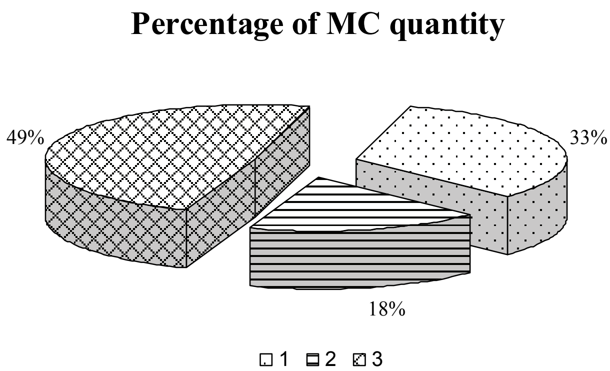


Fig.4. Percentage of MC quantity: 1 – *Δh=0*; 2 – which are disappeared; 3 – which are growing nonstop

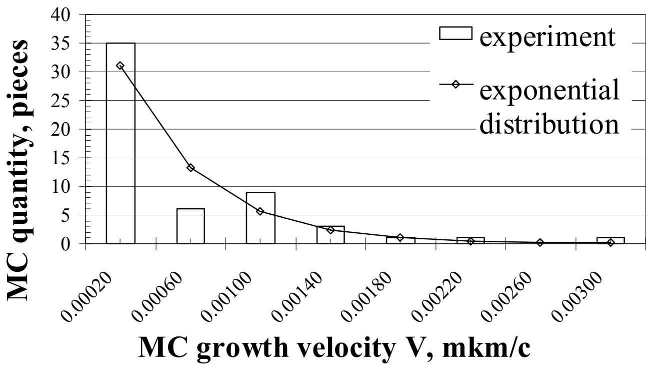


Fig.5. Dependence of the MC quantity to their growth velocity

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. 4). 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 (fig. 3). On the basis of the examined laws it is possible to draw a conclusion on casual character of MC growth rate (fig. 2).

From dependence on fig. 3 follows, that with an operating time, 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.

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 (fig. 3) 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. 4).

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.

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UDC 531.36; 534.1

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MODELING AND STABILITY ANALYSIS OF LANDING GEAR BY USING OF LMS SOFTWARE Virtual.Lab, Imagine.Lab AMESim AND Matlab\Simulink IN COUPLE

Main principles of modeling of physical processes by using LMS software are described. General emphasis put on coupling of several programs and showing possibility of separating physical modeling tasks and analytical tasks. Interaction of Virtual.Lab, Imagine.Lab ,Simulink and example with stability analysis of landing gear (shimmy analysis) are shown.

LMS Company has produced software package for creating multi-body analysis of dynamical systems. This package is very effective for performing analysis of dynamical systems behavior. It consists of two software complexes: 3D multi-body analysis - Virtual.Lab and 1D block-scheme modeling - Imagine.Lab AMESim. Using this complexes in couple with Matlab\Simulink is a good alternative for using software complex NASTRAN\Adams\Easy5. Possibility of using Virtual.Lab, Imagine.Lab and Simulink in couple is described in this article.

1. Modeling of simplified nose landing gear in Virtual.Lab. Simplified landing gear consists of three general parts: gear and two wheels. Gear consists of main lever fixed on fuselage, rotating clutch, rotating lever with trail for wheels. Main lever connected with rotating clutch by spring and rotating lever connected to rotating clutch by damper. It means that main lever is connected to rotating lever by cascade spring-damper. In this case self-oriented mode of steering system is modeled. Ground is the fixed element like main lever but runway has 1 DOF relatively to ground, so reversed motion of landing gear is studied (Fig.1).

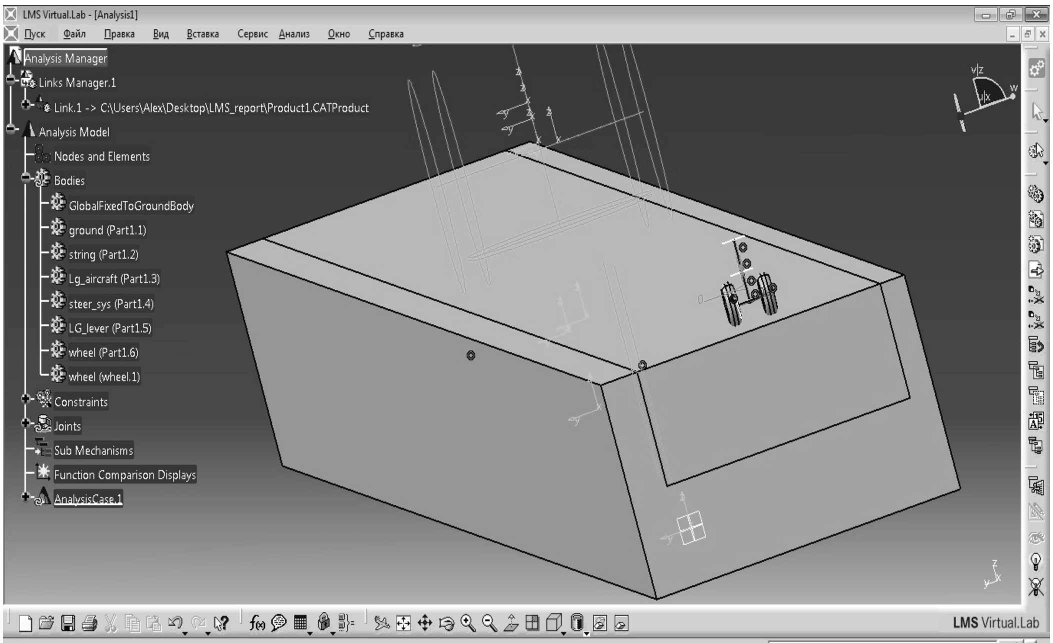

Fig.1. Landing gear with ground and runway modeled in Virtual.Lab.

After importing, creating and editing the bodies, constraints and joints must be created according to physical conditions (Fig.2). Main lever is fixed, rotating clutch has 1 rotating DOF relatively to main lever, rotating lever has 1 rotating DOF relatively to rotating clutch. Each wheel has 1 rotating DOF relatively to rotating axis on rotating lever. Wheels and runway are connected with boundary condition: TNO-TIRE MODEL. This conditions show behavior of rolling tire on the ground respectively to string theory by H.B. Pacejka [1,2]

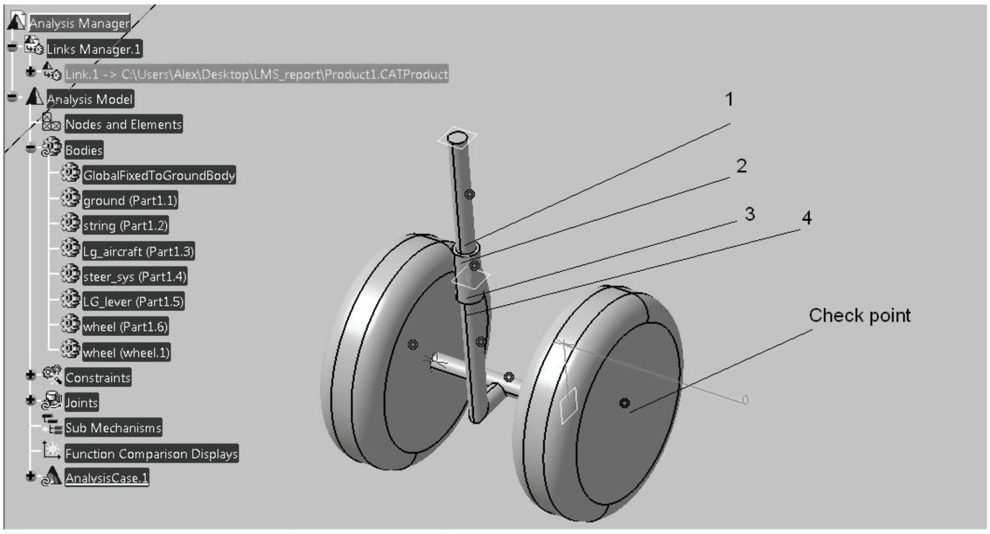

Fig.2. Dynamical system landing gear-runway connected with constraints and joints.

On Fig.2 points of input/output signal are shown. In point 1: angle deflection is input and reaction moment1 is output; in point 2: angle deflection is input and reaction moment1 reversed is output; in point 3: angle deflection is input and reaction moment2 is output; in point 4: angle deflection is input and reaction moment2 reversed is output. Check point: deflection pulse is input and deflection is output. Input/output points provide signal changing between Virtual.Lab and Imagine.Lab AMESim.

2. Co-simulation Virtual.Lab and Imagine.Lab AMESim. When co-simulation using the main solver of state equations is the Imagine.Lab AMESim solver. Virtual.Lab model with input/output points is compiled into block for using in Imagine.Lab AMESim.

3. Co-simulation interface Imagine.Lab AMESim to Simulink. The main advantage of Imagine.Lab AMESim is open interface that allows using AMESim with set of any programs in couple. For example there are interfaces AMESim to Simulink and Simulink to AMESim realized. In AMESim to Simulink mode the main solver is Simulink solver. In AMESim model signal changing block is created. Simulink block-scheme also contains signal changing block. It means that Imagine.Lab AMESim can be used like signal conductor between Virtual.Lab and Simulink (Fig.3).

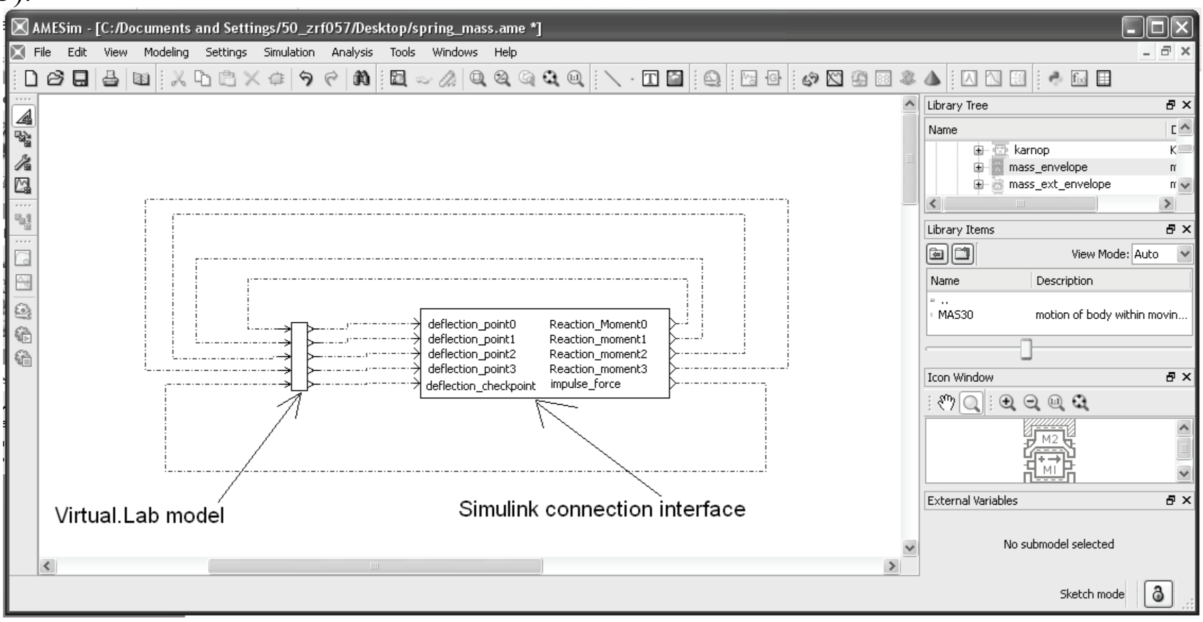

Fig.3. Using of Imagine.Lab AMESim like as conductor between Virtual.Lab and Simulink.

Virtual.Lab sends deflections of points 1,2,3,4 (Fig.2) to Simulink and Simulink returns reaction moments to Virtual.Lab in the described example.

4. Study of stability of landing gear motion in the parameter space by using Simulink.

Simulink block-scheme of the dynamical system landing gear - runway is shown on Fig.4.

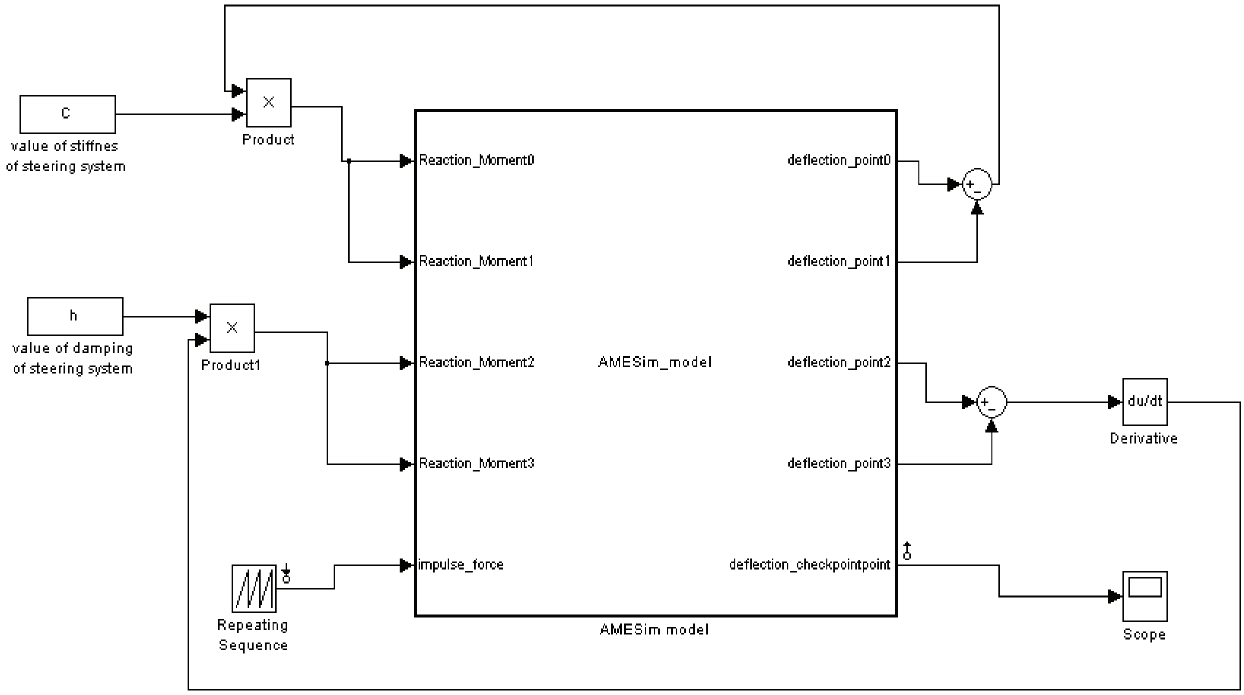

Fig.4. Simulink block-scheme of dynamical system landing gear - runway.

When Simulink obtains values of point1 and point2 deflections, reaction moment1 is calculated as multiply difference between deflection point1 and deflection point2 by stiffness of steering system. It means that main lever is connected to rotating clutch by linear spring. Also time derivative of difference between deflection point2 and deflection point3 multiplied by damping ratio that gives reaction moment2. It means that rotating clutch is connected to rotating lever by linear damper.

4.1. System linearization. To linearize the dynamical system linearization input\output points should be created (Fig.5).

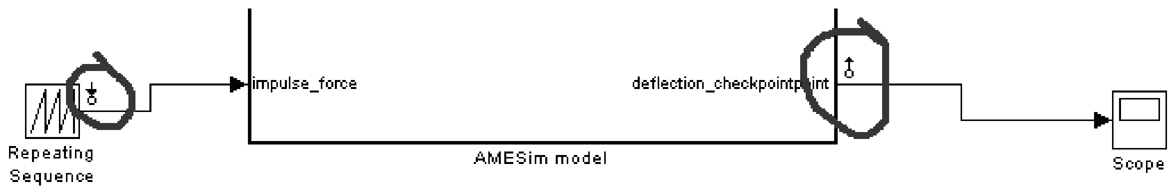

Fig.5. Linearization points input\output.

The impulse entrances on input point and response is obtained in output point. Simulink analyses transfer function between input and output and creates matrixes A,B,C,D for linearized LTI (Linear time-invariant system) dynamical system.

$$\begin{cases} \dot{X} = A \cdot X + B \cdot u \\ y = C \cdot X + \mathrm{D} \cdot u \end{cases} \qquad (1)$$

To determine stability margin in space of parameters C,h,V (stiffness of steering system, damping ratio, velocity) eigenvalues analysis [3] of matrix A is performed. The result is shown on Fig.6.

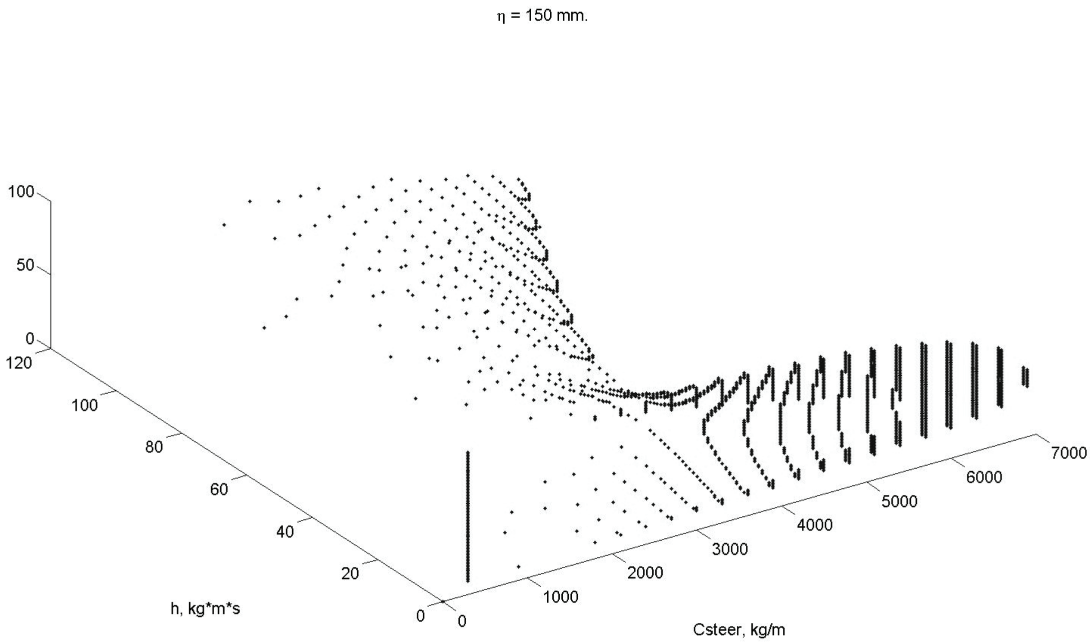

Fig.6. Stability margin in space of parameters stiffness of steering system, damping ratio, velocity.

Conclusions

- Software package LMS Virtual.Lab and Imagine.Lab AMESim is the modeling dynamical system behavior tool. It has rich set of features to determine any physical conditions, constrains and elements properties, so many kinds of physical situation can be modeled.
- Open interface with CAD system CATIA allows to use geometrical models created by engineers in all stages of project.
- Possibility of connecting with Matlab\Simulink is an important feature for developing and modeling complicated systems with automatic control.
- Virtual.Lab has no inside FEM solver, but open interface allows to use NASTRAN or any other solver to determine flexible parts.

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BACTERIOGENIC PRODUCTS USING FOR INCREASING PERFORMANCE CAPABILITIES OF THE DETONATION COATINGS

In given work the attempt has been done to investigate the natural microorganisms influence and, in particular, biomineralisation effect on the friction and wear processes. In the light of tribology the outlooks of microbial biotechnology as a method of improving performance capabilities of the materials for friction units and bacteriogenneous products using for increasing wear resistance, runningability and structural adaptability of frictional unit parts are considered.

Introduction. The phenomenon of tribosynthesys the formation of secondary structures on the friction surfaces is often considered now as one of the necessary conditions of the tribological interfaces normal functioning. Developing the new materials, ecological and energy-saving technologies propose new possibilities forbiological technologies in tribology.

Analysis of the literature sourses. In the work [1] we have already begun to consider bacteriogeneous products as perspective materials for increasing performance capabilities of the friction units.

The conclusions have been done that the matters (organic and nonorganic) which are precipitated by some microorganisms both intra- and extracellularly – in the biofilm composition may be used for friction units runningability and adaptability increasing.

Sulfur cycle microorganisms have been investigated well (partly, therefore, they have been choosen as model objects), in point of view of microbial corrosion investigators [2 – 4] are one of the factors of corrosion appearance. In particular, *Desulfovibrio Desulfuricans*, which mineralises sulfides in its biofilm is well known as one of the stimulants of microbial corrosion. In the living biofilm of this bacteria transformation of sulfides takes place. It is sulfidisation – the transition from iron to the matters which are enriched with sulfur: FeS (over some intermediate forms) is transformed into FeS_2 [5].

The purpose of this work is to confirm the suppositions, that a matter immobilised by microbial biofilm and includes phosphorus and sulfur, can make easier the process of surface structural adaptation, facilitate adhesion reducing, resist to seizure and take a part in frictional secondary structures forming [6, 7]. The tasks of investigation has included testing of the composition and structure of microbial biofilm matter, receiving the preparates, which are suitable for using in friction units; mechanical testing and obtained results analysis.

Materials and methods. In the experimen the next materials have been used: detonation coating on steel 45 – oxyde ceramics Al2O3-Cr2O3-TiO2 thickness 300 μm. The specimens of coating have been deposited on the outer cylindrical surface of the rings with outer diameter 50 mm. They are standard specimens for testing at the friction testing machine 2070 SMT-1. As a counterbody used quenched steel 45 rings of standard size 50mm. The tribotestings have been carried out with the help of 2070 SMT-1 friction testing machine by disc-disc scheme at the net sliding conditions in the range of sliding speed: 0.4, 0.8, 1, 1.5 m/c and loads 200, 300, 350, 400 and 1000 N.

The preparate of *D. Desulfuricans* biofilm has been used as addition (after heat treatment) to the lubricant. The lubricant was MC-20. X-ray microanalysis (EDS) has shown iron, phosphorus and sulfur presence in biofilm preparate.

Sulfur and its compound presence in the lubricants can yet, increase the corrosion ability. However, live microorganisms presense in an anaerobic medium containing some water quantity may lead to noncontrolled process of biocorrosion. That is why preparate of biofilm used in this work was sterilized by the way of autoclaving and drying at 100ºC.

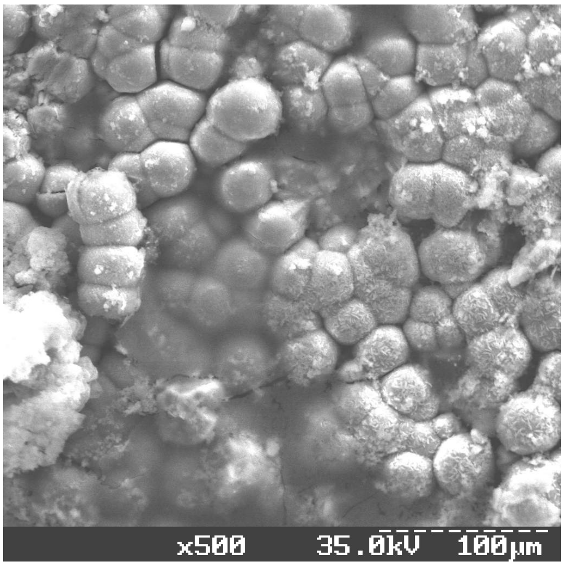

Fig 1 Biofilm *Desulfovibrio Desulfuricans* containing Fe, S, P, Ca on the metal surface

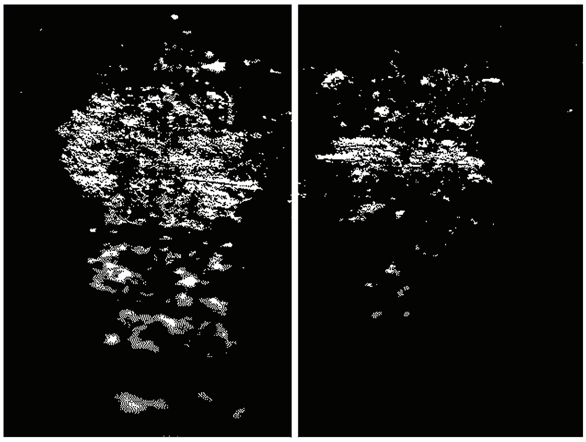

Fig 2 Wear traces on the ceramic surface, Fe X-ray dot-map. Left – lubricant “MS-20”, right – lubricant “MS-20” with biofilm preparate addition..

The biofilm (fig. 1) has been received in anaerobic conditions in the 400 ml flascs with Postgate media on substrate – low carbon steel plates (20 cm^2 per flasc). The surface of substrate, the inner walls of flascs with 30-day *D. Desulfuricans* cultures have been covered with biofilm, which has been collected disintegrated and than sterilized. Dried biofilm preparate in the form of fine dispersed powder mixed into MC-20 lubricant. Preparate was analysed in scanning electron microscope-microanalyser. Energy dispersive X-ray spectrometer showed 14.45 % of oxygen, 1.33 % phosphorus, 17.07 % sulfur, 6.85 % calcium and 60.3 % iron in this additive. Sufficient amount of calcium were caused by calcium lactate addition into Postgate media for bacteria and biofilm growing.

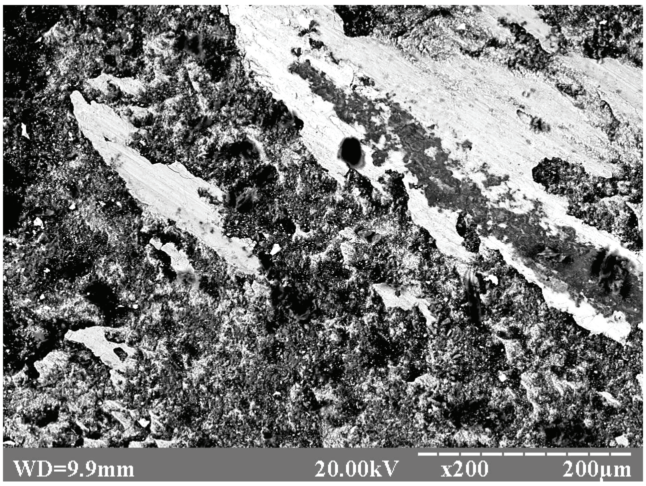

Fig. 3 Specimen surface after dry friction testing

The microscope MBS-10 used for specimens observing during the investigation. Scanning electron microscopes REMMA-102-02 and REM-106-I (SELMI) were used for microanalysis and photography of microbial preparates and the specimens after mechanical testing.

In one run of experiment testing carried out in pair steel-ceramics without lubricant. In the other cases tribotesting carried out using liquid lubricant MS-20 and MS-20 containing 5 % addition – sterilized preparate of *D. Desulfuricans* biofilm.

Results and discussion. During testings the coefficient of friction behavior were more or less stable in all cases. At that the coefficient of friction was appreciable reduced after biofilm preparate addition into the lubricant. In case of testing without lubricant (dry friction), the values of the coefficient of friction, specimen wear and temperature in the contact were considerably higher than in testing with lubricant. That is why more attention payed to the results of testing with lubricant. Microscopic investigations showed that in dry friction conditions a counterbody material was spreaded on the hard coating surface, forming almost continuous transfer layer in some cases. The fenomenon of seizure and spreading of steel observed after tribotesting with lubricants. The fragments of counterbody often filled the pores in ceramics surface. After biofilm preparate addition into lubricant, the wolume of counterbody materials transferred on the specimen essentially reduced and the coefficient of friction were reduced at that. EDS microanalysis showed 0.2 % phosphorus, 0.3 % sulfur and only 5.2 % iron in the surface composition after testing with biopreparate. While in the surface composition of the specimen tested in lubricant MS-20 without additions were discovered more than 23 % iron, no presence of phosphorus, 0.2 % sulfur and 0.2 % chlorine.

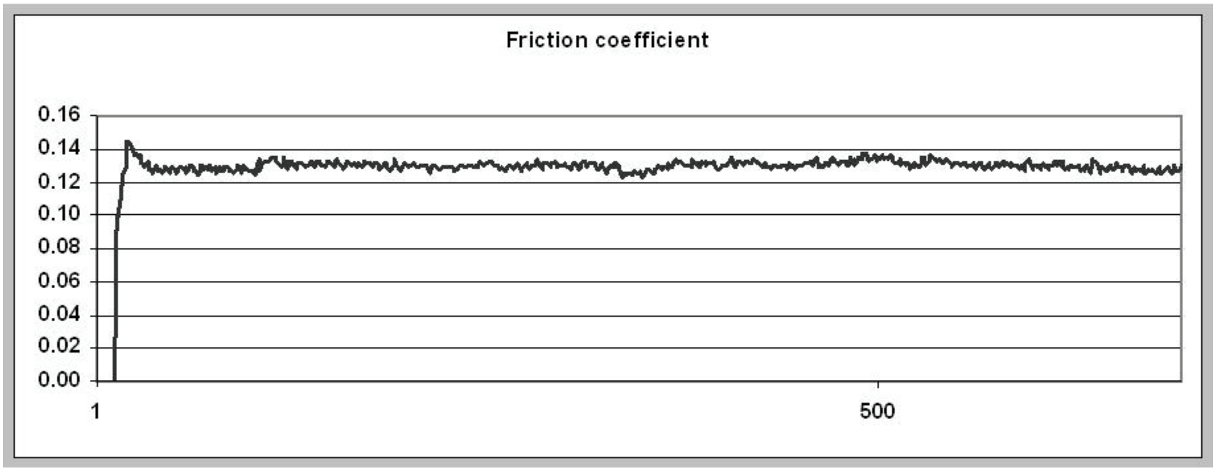

Fig 4 Friction coefficient curve. Load – 1000 N, speed – 0.8 m/c, way 500 m, lubricant – MS-20

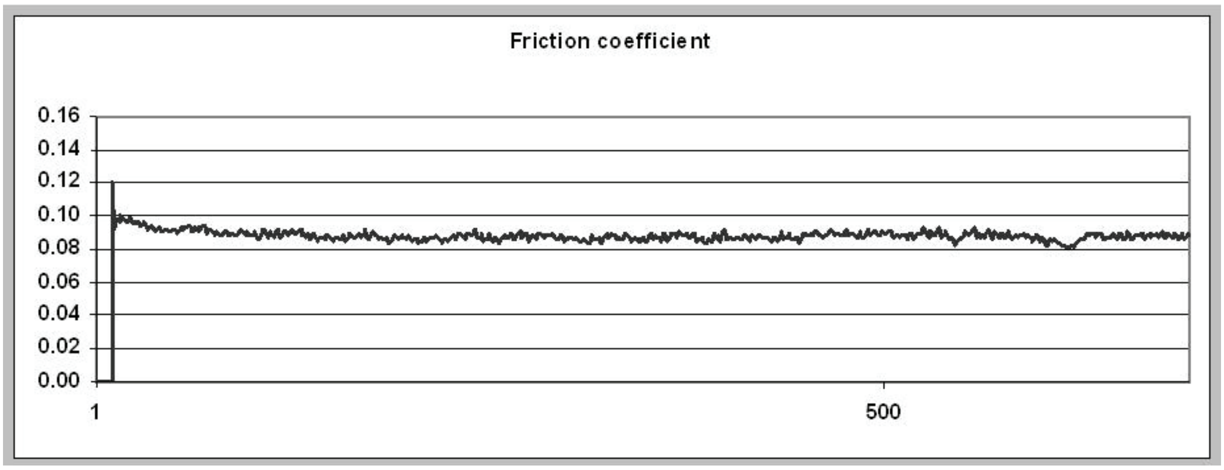

Fig 5 Friction coefficient curve. Load – 1000 N, speed – 0.8 m/c, way 500 m, lubricant – MS-20 with 5 % biofilm preparate addition.

Conclusions. Testings of antifrictional bacteriogeneous additions to lubricant showed some positive effect of these additions on the process of running ability and structural adaptability of the friction unit parts. The addition did not act destructively on the detonation oxyde coating. Counterbody material – steel was also weared less after using this addition.

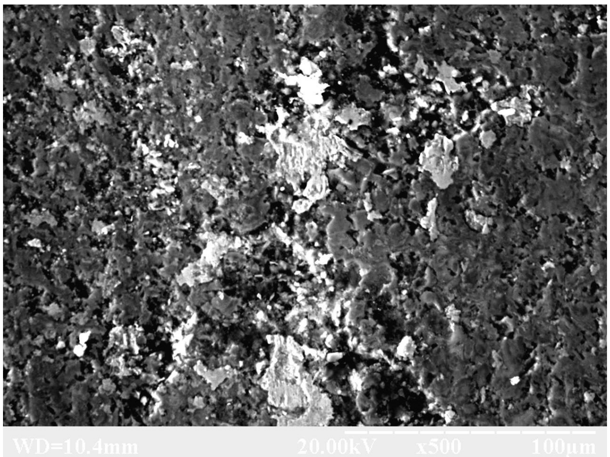

Fig. 6. Specimen surface after testing in MS-20 lubricant. Pores in ceramics filled with Steel (light) particles

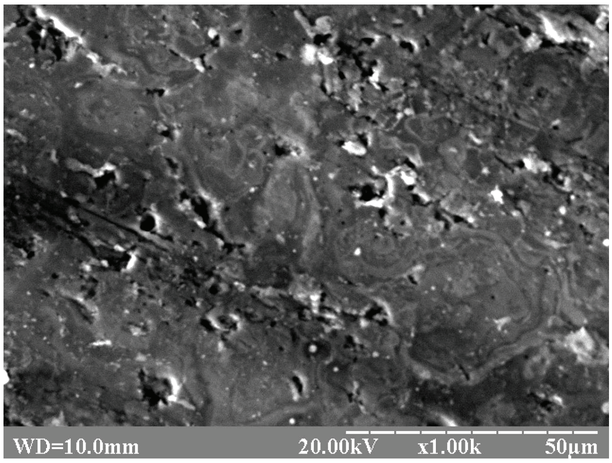

Fig. 7. Specimen surface after testing in MS-20 with biofilm preparate addition lubricant.

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UDC 629.7062.3:629.734/.735

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JUSTIFICATION OF INCLINATION OF THE THRUST VECTORS OF THE TWO-ENGINED UAV POWER PLANTS

The new pattern of mounting two engines is presented on the unmanned aircraft vehicle of the normal aerodynamic scheme. The reasons for harmful nosing up and diving moments and the method of their elimination is suggested.

Essentiality. The given research is related to the two-engined multiuse unmanned aircraft vehicles (UAV) which satisfy the demand for such vehicles in civil aviation during carrying out different types of aerial works: air photographing, patrolling, etc. The results can be applied in the development of unmanned transmitters of removable onboard equipment depending on the specific purpose.

Stating the problem. The known two-engined UAVs, intended for long distance surface surveillance (more than 2 hours of flight). Their advantage over the one-engined pattern is the risk decrease of non-fulfilling the flight task due to engine stop. They are built according to the few known component schemes.

According to the first scheme, the engines are placed on the wings across the UAV, on fuselage pylons or in the nose part of fuselages if in the two-fuselage pattern, as, for example, in the French UAV *DRAC* [1].

The disadvantage of the indicated scheme is the asymmetrical thrust at the loss of power by one engine or its total stop. This can negatively influence the lateral firmness of the UAV and result in an aviation accident [2].

According to the longitudinal scheme, the indicated disadvantage is eliminated. This scheme was applied in construction of *Hunter* UAV which was a joint production of Israel and the United States of America (Fig. 1).

Figure. 1. Side view of *Hunter* UAV

However, modern surveillance equipment needs low level of oscillation influence, front video cameras require a free front semi-sphere for realization of review, while for the optics the influence of product workings of the front power-plant (PP) is harmful. These are the substantial disadvantages of *Hunter* UAV.

The two-engined special purpose UAV constructed at the National Aviation University has recently become known [3]. It does not have the above-listed drawbacks. However, in accord with its scheme, the two-engined special purpose UAV has a high aerodynamic drag ratio which results of the additional aerodynamic drag created by the channel between the centerwing of wing, pylons and the gondola of fuselage. In addition, though the rectangular wing is technological in implementation, it reduces the aerodynamic characteristics of the UAV. This needs additional expense of the fuel during long distance flights. In case of engine failure of one PP, the compensatory capacity of the automatic control system of the UAV can be insufficient for the created diving or nosing up moments. Therefore, the UAV can start to continuously descend or climb or to periodically oscillate according to its transverse axis.

Problem solving. The basis for the technical solution of the problem is increasing the flight performance and technical characteristics of the two-engined special purpose UAV (Fig. 2) by improvement of its layout scheme. This will enable the decrease in aerodynamic drag, elimination of oscillation in the case of failure of one of PP and on therefore, shall increase the efficiency of UAV's application in aerial works.

Figure 2. ¾ view on the left side of the special purpose UAV developed by the NAU

The task of improving the above-mentioned UAV is solved in the following way. The wing is arrow-shaped and trapezoidal, set on one central pylon. The PP is inserted into aerodynamic rings and changes the thrust vector. The V-like tail unit is set without an additional tail fin in the new two- engined UAV (Fig.3).

Figure 3. General view of two-engined UAV with PP shifted angles of thrust vectors

The wing, tail beam, tail unit and fuselage gondola form the aircraft of the generally accepted scheme. Underbody of pylon is connected with a fuselage gondola in which the actual load, fuel supply, rear PP, automatic control system and other UAV systems are placed. The underbody of gondola is used for mounting optical and other lower hemi-sphere space surveillence equipment, for fastening the take-off and landing devices. Mounting of the PP is executed at the rear part of the gondola. The optical equipment of review of the front semi-sphere and radio electronic equipment of the UAV is placed at the front part of the gondola.

The arrow shape of wing will provide an increase of the UAV route steadiness and will allow not to set an additional fin which simultaneously will result in decreasing the resource-demanding construction and overall vertical size of the UAV. Trapezoid wing and mounting it on one central pylon will provide increase of aerodynamic quality of the UAV. As a result, there shall be a decline of fuel expense during the most beneficial cruise mode (the mode which corresponds to the maximum flight distance) [4].

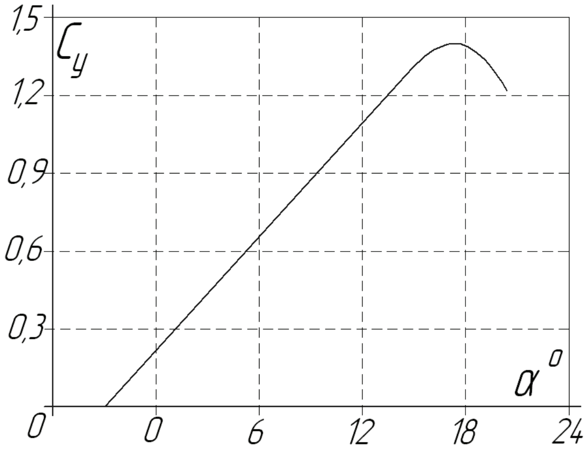
Application of the PP with the shifted thrust vector will allow quick elimination of the undesirable vibrations of the UAV in relation to the transverse axis (*oz*) in the case of failure of one PP. This will appear as a result of appearance of the compensating moments resulting from thrust in relation to the center of the UAV mass. In addition, it is known that PP with airscrews set into aerodynamic ring increase the output-input of airscrews ratio and decrease the expense of fuel during the cruise mode of flight [5].

During the onground maintenance of the UAV the possibility of injuring the personnel is eliminated by the opened airscrews during work of engines.

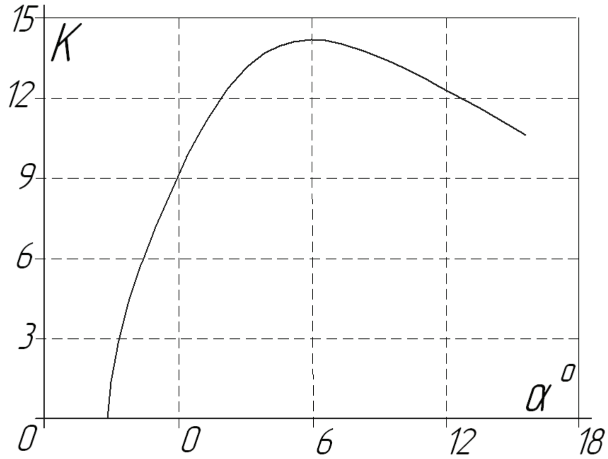
The two-engined UAV has the followings specifications:

1.	Starting mass of UAV, kg	-150
2.	Actual load, kg	-40
3.	Max. speed, km /h	- 250
4.	Cruising speed, km/h	- 180
5.	Power of engines, kW	- 2 x 11= 22
6.	Max. distance in the automatic mode, km	- 500
7.	Max. height of flight, m	- 3000
8.	Max. duration of flight, hours	- 6

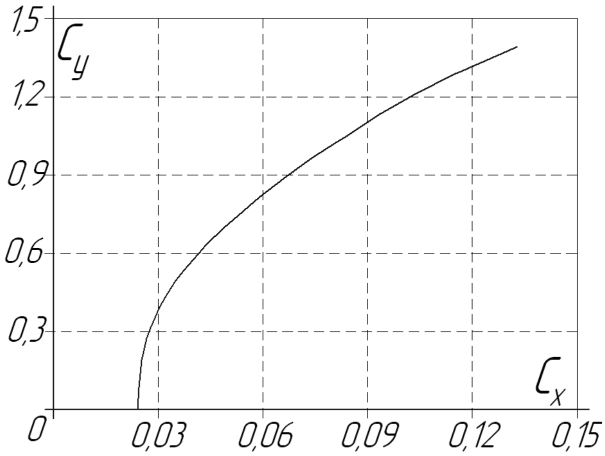
Dependencies of C_y (α), *K (α)* and the polar of the developed UAV are given in figures 4a, 4b and 4c.



a)



b)



c)

Figure 4. Dependence of C_y and K on α and polar of developed UAV

Structurally, the developed UAV's (Fig. 5) wing consists of two halfs 1, a centerwing 2, a tail beam 3, a V-like reverse tail unit 4, front 5 and rear 6 PPs, a central pylon 7, a fuselage gondola 8, a parachute compartment 9, and a landing gear (undercarriage) 10.

PPs 5 and 6 consist of multiblade airscrews 11, aerodynamic rings 12 and engines 13. Rings 12 simultaneously act as protective device from the injuring the personnel during onground maintenance of PP.

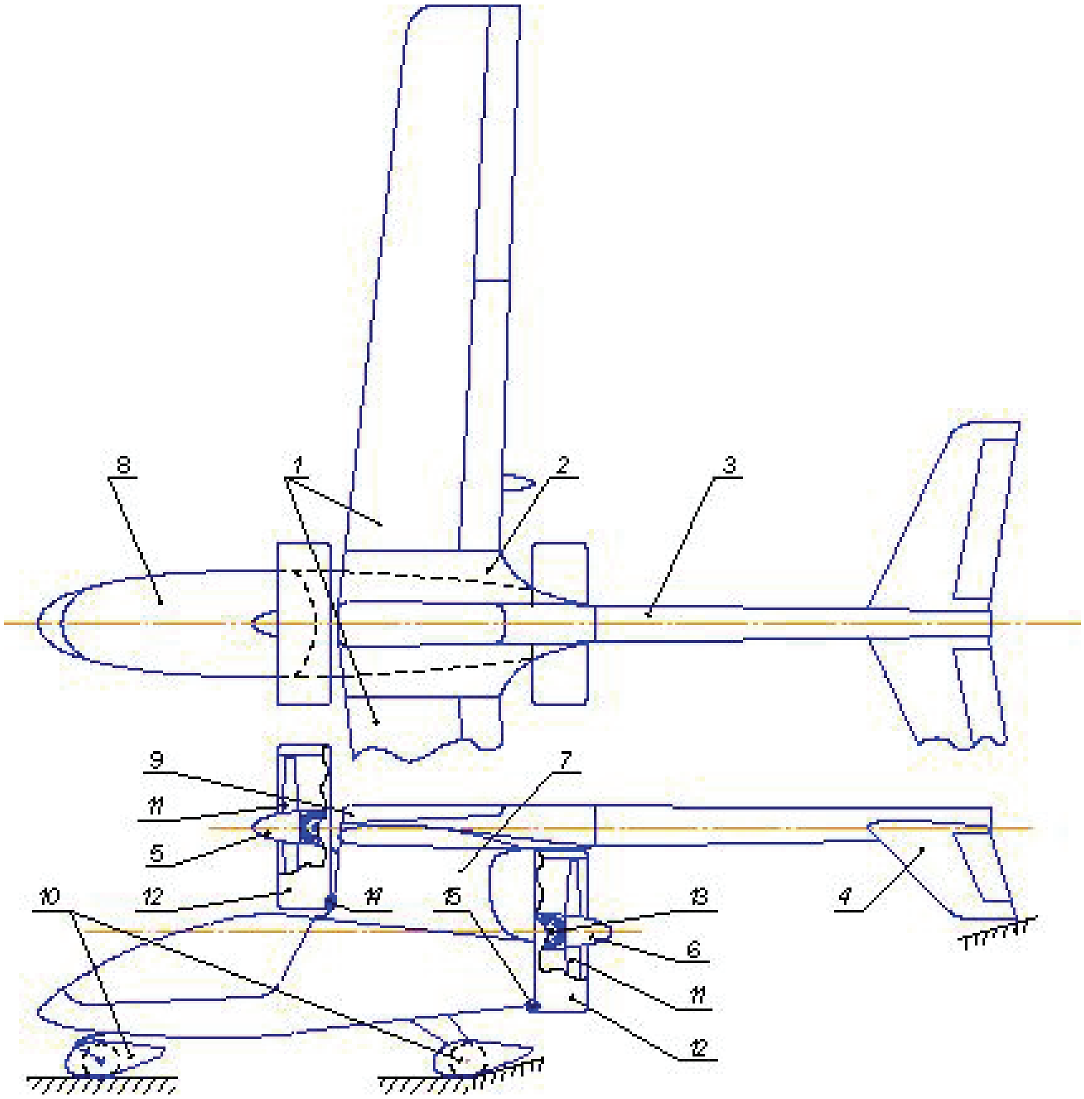


Figure 5. Projections of the two-engined UAV with the power purposes with shifted angles of thrust vectors

PP can turn on the vertical plane on angle φ in relation to hinges 14 and 15.

For the one-engined version of UAV with an overhead PP (Fig.6) a tailcone 16 is set into the place of rear PP.

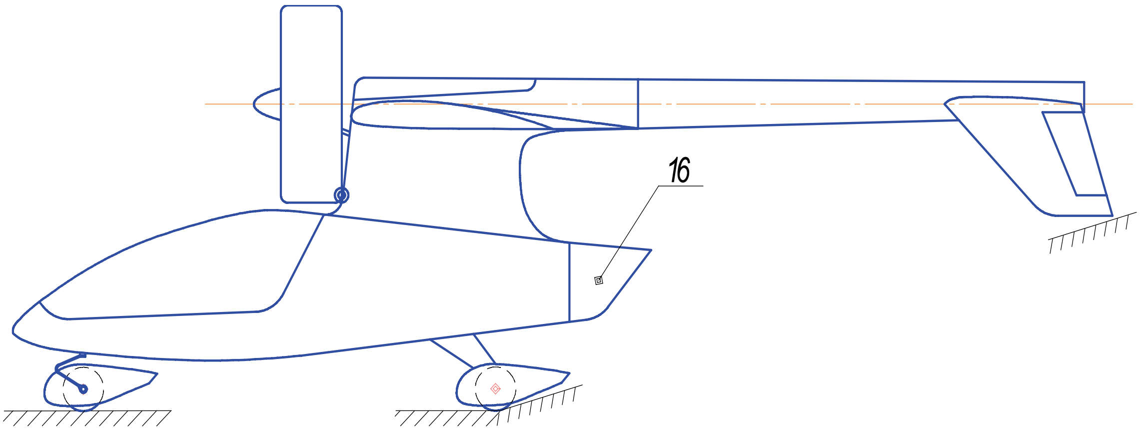


Figure 6. One-engined version of the UAV developed on the basis of two-engined UAV

According to Fig. 5, arrangement of the UAV requires turning of PP on some angles. On Fig. 7 a calculation scheme is presented as explanation of the indicated angles of PP thrust vectors.

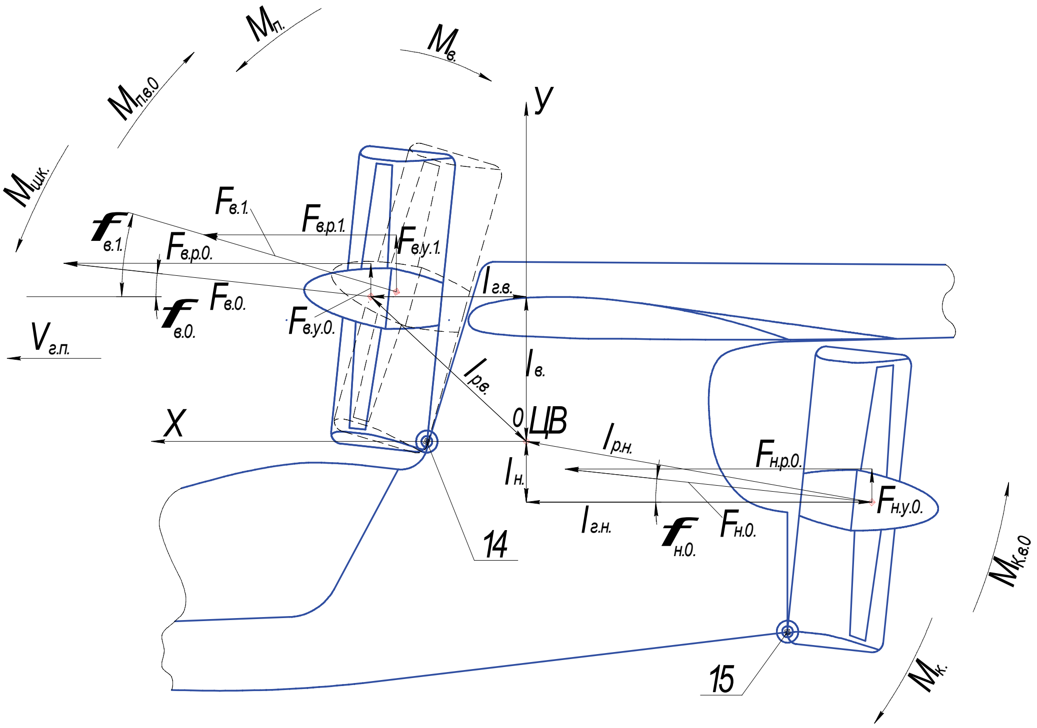


Figure 7. Scheme of harmful and recuperative moments from thrust of PP of the developed UAV origination

It is known that on the set mode of horizontal flight of UAV, sum of all moments in relation to the center of inclination *CI*, in particular which is examined in a projection on a vertical plane, must be equal to:

$$\sum Moz = 0 \tag{1}$$

In a sum moments the aerodynamic forces and tractive forces which appear in tail $M_{t.oz}$ and nose $M_{n.oz}$ parts of UAV projection on the indicated plane ($M_{t.oz}$ and $M_{n.oz}$ divided by *oy*). When for some reasons of correlation (1) grows into inequality, it will mean that UAV will be on transient behavior which is initiated according to the flight plan or other irregularly.

For the indicated scheme, moments from lower and upper PP $M_{d.}$ (a moment on diving) and $M_{n.}$ (a moment on noising up) enter to (1) of establishment of vectors of their tractive forces under upper $\varphi_{u.o}$ and lower $\varphi_{l.o}$ angles, that provides those values M_d and M_n when the UAV is in horizontal flight. Thus moments M_d and $M_{n.}$ are opposite in direction and equal in value, and the aerodynamic moments of UAV remain unchanged [6].

M_d and M_n moments are products of vectors of upper $F_{u.o}$ and lower $F_{l.o}$ forces. The shoulders of their resultant actions $l_{u.r}$ and $l_{l.r}$ which are resultant in triangles which consist of upper and lower action shoulders of horizontal constituents $l_{u.}$ and $l_{l.}$ and vertical constituents $l_{u.h}$ and $l_{l.h}$. The angles $\varphi_{u.o}$ and $\varphi_{l.o}$, are angles between the projection of vector of horizontal speed of the UAV,$V_{h.p}$ and the vectors of forces of $F_{u.o}$ and $F_{l.o}$.

It is necessary to notice that in this position forces $F_{u.o}$ and $F_{l.o}$. cause their vertical constituents into being, accordingly $F_{up.p.o}$ and $F_{lp.p.o}$. The constituents develop their counteractive moments of $M_{u.d.o}$ and $M_{u.n.o}$. Forces $F_{up.p.o}$ and $F_{lp.p.o}$. can be calculated from the correlations:

$$F_{u.p.p.o} = F_{u.o} \times tg\varphi_{u.o} \tag{2}$$

$$F_{l.p.p.o} = F_{l.o} \times tg\varphi_{l.o} \tag{3}$$

The value of forces (2) and (3) are their initial values which correspond to angles $\varphi_{u.o}$ and $\varphi_{l.o}$, on UAV.

Resultants of forces of $F_{u.o}$ and $F_{l.o}$ and $F_{up.p.o}$ and $F_{lp.p.o}$ forces, accordingly $F_{u.r.o}$ and $F_{l.r.o}$ are directed parallell to the vector of horizontal speed of UAV, $V_{h.p}$. The counteractive moments $M_{u.d.o}$ and $M_{u.n.o}$. are opposite in directions to M_d and M_n. and to one other. In the set horizontal flight $M_{u.d.o} = M_{u.n.o}$ (4). In the irregular flight mode which can result from the stop of one of PP, falling of power of one of engines of PP, damage of airscrew, etc. the indicated moments will become unequal, that:

$$M_d \neq M_n \tag{5}$$

$$M_{u.d.o} \neq M_{u.n.o} \tag{6}$$

Accordingly, condition (1) will be:

$$\sum Moz \neq 0 .$$

Depending on whicht moment will be greater in value M_d or $M_{n.}$, the UAV will pass to the mode of diving or the mode of nosing up. A difference in the values of moments will lead to harmful moment of M_h :

$$M_d - M_n = M_h \tag{7}$$

This will actually be the reason for vibrations (disbalancing) of the UAV in relation to *oz* axis. For the indicated scheme of UAV, disbalancing is eliminated by turning of PP on angles, different from $\varphi_{u.o}$ and $\varphi_{l.o}$. Here must be a moment of M_r, which will counteract M_h.

For an example, we will consider the origin of M_V for the case of lower PP stop. Accordingly, $M_d > M_n$ and $M_{u.d.o} > M_{u.n.o}$. and harmful moment of M_h. originates as a deduction $M_d - M_n = M_r$.

The recovery moment M_r appears on overhead PP, with the increase of angle to the value. Then the value of force of $\varphi_{u.o}$ will reduce to the value of $\varphi_{l.o}$, but concordantly (2), it the vertical constituent $F_{l.p.p.o.}$ will grow to the value:

$$F_{u.p.p.1} = F_{u.1} \times tg\varphi_{u.1}$$

The recovery moment *Mr,* which is initiated $F_{u.p.p.1}$ will equal:

$$M_r = F_{u.p.p.1} \times l_{u.r} \tag{8}$$

The small changes of length of shoulder of $l_{u.r.}$ can be neglected. According to the scheme (Fig. 7), M_r will be opposite in direction to On condition that value M_r=M_h in the correlation (1) will resume the equality:

$$\sum Moz = 0$$

The value of thrust of the overhead PP will reduce to the level:

$$F_{u.1} = F_{u.p.p.1} / tg\varphi_{u.1}$$

Direction of the resultant vector $F_{u.r.1}$ will coincide with the direction of horizontal speed of UAV, V_{hp}. The management of thrust vectors angles of the power plant of the developed UAV is mixed with a signal in the channel contour of the UAV.

Conclusions:

1. Application of PP with the shifted thrust vector will allow to quickly eliminate the undesirable vibrations of the UAV according to the transverse axis (oz) in the case of one PP failure.

2. For the indicated scheme, moments from lower and overhead to PP M_d (a moment is on diving) and Mn (a moment is on noising up) are balanced conditioned by establishing vectors of their tractive forces on angles $\varphi_{u.o}$ and $\varphi_{l.o}$. That provides those values M_d and Mn, when UAV is in the set horizontal flight; thus moments M_d and Mn are opposite in direction and even in value , and the aerodynamic moments of UAV remain unchanging.

3. Recovery moment of M_r, which is initiated by $F_{u.p.p.1}$ will even

$$M_r = F_{u.p.p.1} \times l_{u.r}$$

4. Changing the vectors of thrust of PP and accordingly changing the value of horizontal constituents of their thrust forces is the effective mean of eliminating harmful diving and nosing up moments for the UAV of the suggested scheme. It can serve as the additional constituent of managing forces at switching the turn signal of PP in the regarded UAV channel.

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THE WAYS FOR INDETERMINISM OVERCOMING IN THE ANALYSIS OF FLIGHT CREW ERRORS

The occidental and national approaches to determination of flight crew errors as well as the model of danger and error in flight and factorial model of flight with due regard for the nature of Sechenov reinforced reflexes (SRR) are under consideration in this paper; the application of the last model allows to lower the accident rate level.

Introduction. Human factor is of great importance for guaranteeing high reliability of aviation equipment and aircraft flight security. Statistical data indicate that more than 70 per cent of aviation incidents and occurrences, 50 per cent of different technical equipment refusals, and more than 60 per cent of accidents in the world take place because of human factor.

According to the results of conducted research, human activity is the reason for approximately 90 per cent of all the occurrences. These data indicate that human features form difficult problem which is to be solved by those who are responsible for aviation system designing, production, operation, and functioning control.

More detailed research indicates that all the incidents and occurrences are the consequences of man-operator's errors. If this error is not the error of a crew or a flying control officer, it means that it is the error of attending personnel or other specialists, who are connected with aviation technique during all its life cycle. Every link in the aviation occurrences chain is caused by human error. On the basis of these data it may be concluded that actually the effect of human factor is equal to 100 per cent instead of 70 per cent as stated in [1].

Problem definition. By now there are many models of errors have been developed in the International Civil Aviation Organization (ICAO). These models are the basic ones for consideration of human factor problems. They are the same for flight analysis under normal conditions and for flight analysis in special situations. For example, it is noted in Chapter 1 of the ICAO Circular 238-AN/143 "Human Factor. Collected Materials #6. Ergonomics" that control over the errors of man-operator is the component of ergonomics research. The similar information is contained in other ICAO circulars and instructions on human factor, however up to now there hasn't been put the emphasis on analysis of reasons for these errors.

According to the State All-Union Standard 26387-94 "Human-Machine System" the error means failure to carry out the prescribed operations or their incorrect carrying-out by operator.

In science the stage for ordering is of great importance for understanding the general nature and general principles of transition from system research to process research as the new scientific strategy in the field of human factors studying.

In our research we were guided by Sechenov transactions who, owing to his dialectic approach, correctly described the process of human movements in the course of operation. Unfortunately, such scientists as N.A. Bernstein, P.Y. Halperin and others didn't understand correctly Sechenov transactions in this field, and as a result of such misunderstanding his transactions were oversimplified in such a way that the main idea of these works was missed. It is a pity, but in the interpretation of Sechenov transactions by the overwhelming majority of modern scientists we do not find the correct approach to the question of pilot controlling movements while pilot actions are under the factor blunder (FB) conditions.

The value of Sechenov work is in consideration of controlling movements together with the control over delay of movements. I.e. as a dialectician he considers such philosophic categories as action and counteraction.

He wrote, “Together with the phenomenon when the human being learns to classify his movements by means of the frequent associated reflexes, he also gets (through the same reflexes) ability for these movements delay” (Fig. 1).

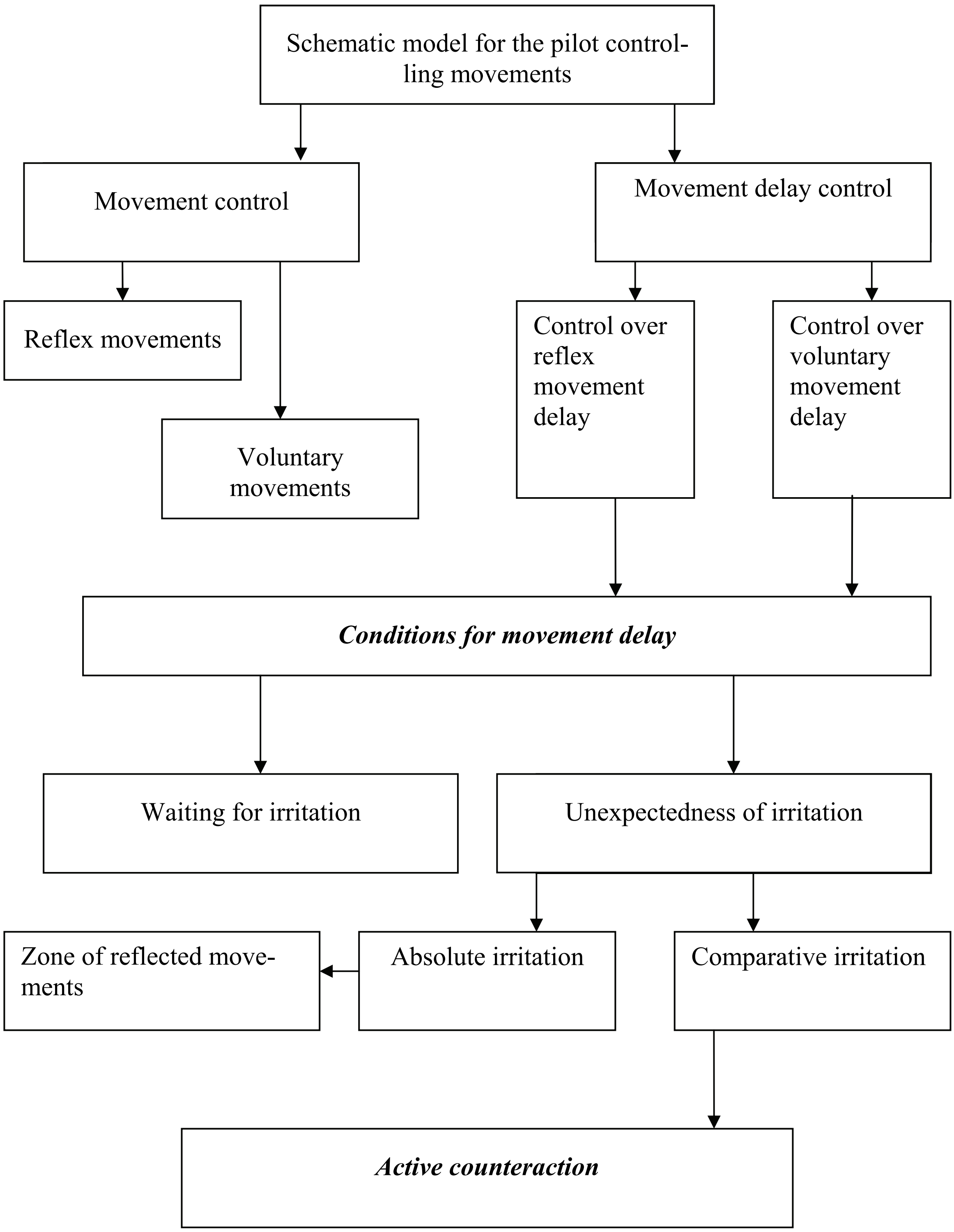

Fig. 1. Schematic model for the pilot controlling movements

Using Sechenov theory as the base and analyzing our statistical data we have reached the conclusion that pilot reflected movements are called the movements performed by pilot in the state when he does wrong actions and disproportionate movements after the beginning of the confusion which is connected with the extreme situations in flight when the pilot loses his head. Fatal air crashes happen as a result of pilot wrong actions and his disability to react against FB. These fatal air crashes happen and will happen until we begin to teach our pilots to react actively against FB.

The problem, in essence, is this: in addition to pilots training in correct actions it is necessary to give them knowledge of mechanisms for delay of reinforced reflected movements which lead to the inappropriate control actions towards aircraft operating control and pilot wrong actions. Thus it is necessary to provide task-oriented indication that informs of FBs, which attack a pilot, and his reinforced reflected movements, which he usually does not notice. That's why it is necessary to equip all modern flight trainer and airplanes with indicators of complex failures (i.e. FB) occurrence. It is necessary as well to provide the indication of inappropriate pilot movements, about which we can judge from the change of amplitudes of flight parameters [2].

Factor flight model with regard to the nature of sechenov reinforced reflexes (srr) (model developed by y. gryshchenko, v. gulenko, e. hohlov) [3]

Consider the matter and substance of our proposed approach and the latest action and counteraction model (ACM).

The basis for national approach is to consider both the actions and counteractions. And not the error of flight crew is the reason for aircraft occurrence, but the reason or reasons which produce these errors. I.e. the reason, as such, is removed from the sphere of causality, and we consider the reasons which produce this error. So, in effect we form two qualitatively different approaches to aircraft occurrence causality: occidental approach considering the error as the reason for aircraft occurrence, and national approach considering the reasons for errors as the reason for aircraft occurrence. Such a profound determinism in consideration of causality of aircraft occurrences is in complete conformity with the character of fundamental research in national engineering psychology, ergonomics, and operation theory.

In accordance with ACM factor flight model and with due regard for SSR nature, the flights are considered as extremely complex processes and their moments; during these moments risk may come from the expected events, uncertain events, unexpected events, and external errors. The factor blunders (FB) form the most complex uncertainty in flight. The factor blunders (FB) are the interaction between different factors. Previously it was impossible to find scientific works in the field of SSR delay training under FB influence, and our model allows to do this.

Compared to the occidental model, one more distinguishing feature of our model is the possibility of earlier incident (occurrence) prevention [4-6].

The complexity of this problem solving lies in the fact that using the factor analytics of errors causality we meet with the problem of a great number of interactive factors accounting (PGNIFA). Ukrainian scientists have found more than 1500 such factors. That's why the problem of annihilation (elimination) of flight crew errors is very complicated, even though the reasons of those errors are known (Fig. 2).

Conclusion.

Now we carry out research, directed at solving the problem of errors elimination down to "zero" level. As to the principles of its forming, action and counteraction model (ACM) allows to solve this problem and eliminate the possibility of any error. It is precisely the way by which the occidental specialists describe the achievement of "zero"-level accident rate of airline. The restrictions on the domain of error existence by normal (non-emergency) flights and introduction of conditioned reflexes for the flights under the conditions of suddenness and unexpectedness form the foundation and logical concept which provide such an important (for practical work) transition from availability of crashes to the sphere of total absence of crashes.

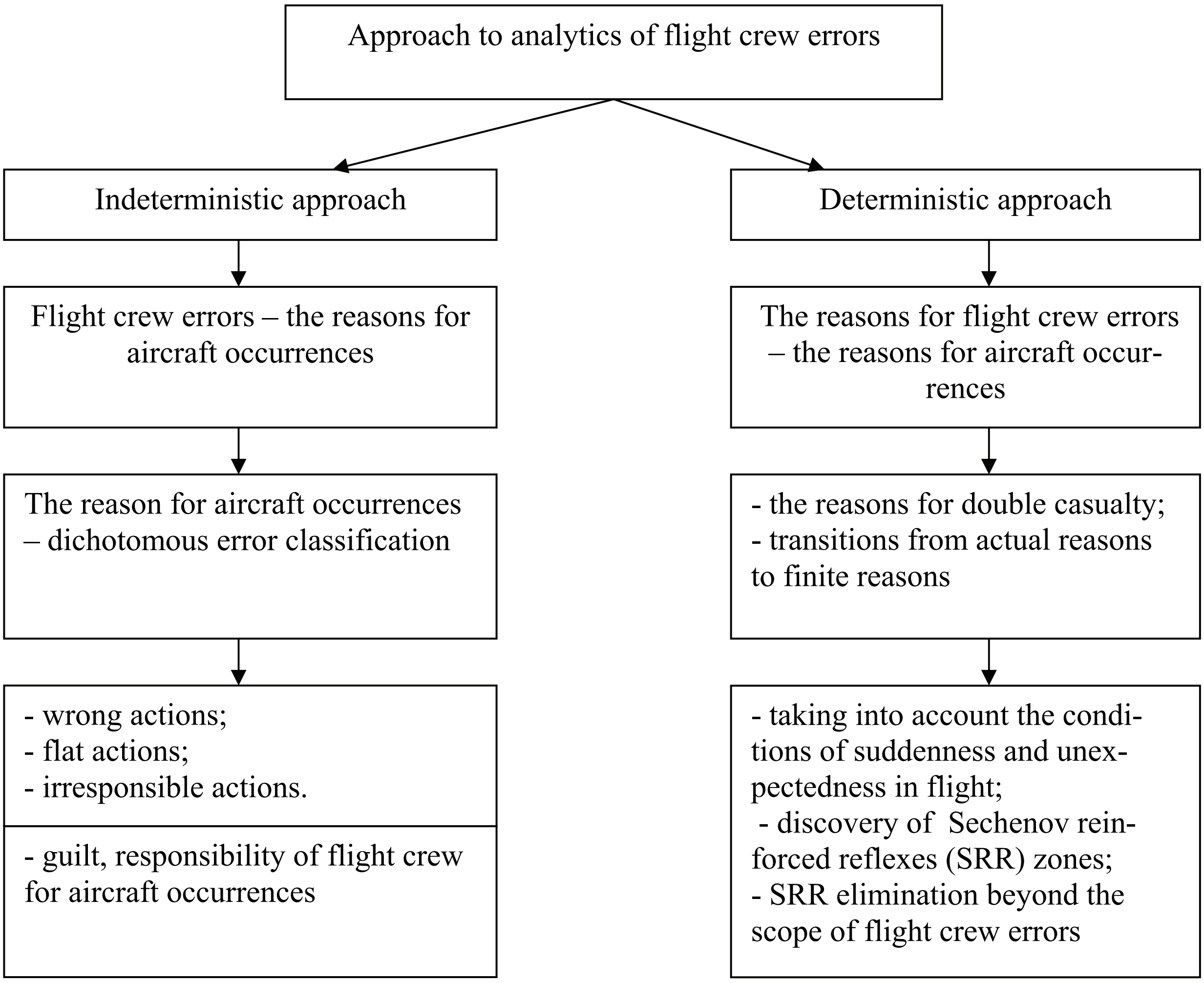

Fig.2. Two approaches to analytics of flight crew errors (actual and perspective)

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VITALS SYSTEMS OF PILOTLESS AIRCRAFTS

The ground of totality choice of vitals systems of pilotless aircrafts for their technical diagnostics is given.

Statement of problem. Pilotless aircrafts all more confidently declare about itself as about the new type of aviation transport which dynamically enters to the market of aviation services. Now development of pilotless aircrafts attained a level when creation of high-performance, multifunction pilotless aircrafts, pilotless aviation complexes which allow widely to use them in a civil sphere became possible. Pilotless aircrafts are able to execute the wide circle of aviation works for the different users of services, including works which by the piloted aircrafts, carrying out is impossible or not enough effectively. High operating and economic effectiveness is provided such qualities of pilotless aircrafts as multifunctionality, mobility, compactness, possibility of use out of the air fields or poor prepared grounds at comparatively low labour intensiveness of preparation to flight and maintenance. In addition, possibility of the use of pilotless aircrafts for fulfillment of dangerous tasks with high probability of loss of pilotless aircrafts, and also tasks, which it is impossible to carry out by the piloted aircrafts through physiology limitations due to presence of man on aircraft board, allow to extend the traditional list of aerial work. Due to this the pilotless aircrafts are complemented by possibilities of the piloted aviation, and at fulfillment of some types of aerial work the pilotless aircrafts can replace the piloted aircrafts, like robotization of some operations in an industrial production, and even to fulfill those types of works which is impossible to fulfill by the piloted aviation. It allows considerably to extend the market of aviation services, functional possibilities of aviation segment of a transport system on the whole, to promote efficiency, productivity and safety of application of aviation technique.

Introduction of pilotless aircrafts in practice of fulfillment of aerial work restrains, in particular, by absence of operator confidence that the pilotless aircrafts will be able without failures and with the proper level of flight safety to fulfill the direct tasks during the appointed life time. At the same time the manufactures of aeronautical engineering do not have the proper tool by which they will be able to determine the limits of the appointed life time for pilotless aircrafts as a whole, from a review as on life time of components and as on the feature of concrete production processes of aerial work. In addition, for the identification of reliability support periodicity of pilotless aircrafts and their vitals systems it is necessary a calculation and experimental data in relation to readiness of pilotless aircrafts to fulfillment of aerial work and determination of life time. Therefore it is very actual a problem of development of methods and facilities of technical diagnostics of pilotless aircrafts which will allow to make well-grounded decision about the use of pilotless aircrafts in necessary time. Very important is maximal reduction of refusals due to their timely prevention.

One of main factors of reduction of simples to operate of pilotless aircrafts and increase of efficiency of their use is diminishing of time of determination of working capacity of pilotless aircrafts and search of refusal place in their concrete construction. There is a sharp necessity not through hours, but in the mode of the real time to follow operation processes of pilotless aircrafts. This problem can be decided due to development and introduction in operation of facilities of complex technical diagnostics of pilotless aircrafts. Diagnosing allows making grounded decision about the use of pilotless aircrafts in necessary time and removes a possibility to fall out. Very important has maximal reduction of refusals due to their timely prevention. It is possible to attain only at individual and religiously research of every pilotless aircraft and generalization of experience of its operation. Accordingly a purpose will be achieved due to technical diagnostics on principles of monitoring of the general state of pilotless aircrafts.

The large list of works is devoted to technical diagnostics. Works of Mozgalevskiy A.A., Parhomenko P.P., Sogomonyan E.S., Birger I.A., Fomin Y.A., Glazunov L.P., Pavlov B.V., Klyuev

V.V. belong to this list. However, for today, in literary sources information is absent about works devoted the analysis of pilotless aircrafts from point of view of determination of intercommunication between the complex of diagnostic information and technical state of pilotless aircrafts.

Therefore the problem of development of the system of technical diagnostics of pilotless aircrafts, that is totality of facilities, pilotless aircrafts and performers necessary for conducting of diagnosing (control) after rules, set in technical documentation, is very important. In addition, the necessity of increase of operating faultlessness due to the identification of defects, forecasting of their development is actual task, as its decision will allow increasing efficiency of functioning of pilotless aircrafts as the whole.

The important component of decision of problem of creation of facilities of complex technical diagnostics of pilotless aircrafts which will allow conducting the estimation of working capacity of pilotless aircrafts without intervention from a man-operator is determination of totality of vitals systems of pilotless aircrafts of airplane type.

Totality of vitals systems of pilotless aircrafts. As well as the piloted aircraft, pilotless aircraft of airplane type consists of airframe uniting pilotless aircraft in a single whole. From positions of system theory the airframe has signs of the system, namely: totality of elements incorporated by system formative factor – ability to carry out flight. Accordingly airframe is the first vitals system of pilotless aircraft for which airworthiness acknowledgement is necessary to conduct a quality inspection of such components as:

– quality of airframe skin,
– quality of external skins,
– releasable airframe connections,
– airframe hinges,
– airframe internal components, and
– elements of other vitals systems of pilotless aircraft and service load.

For providing by electric feeding of all electrical customers at board of pilotless aircrafts it is necessary to check the side power supply system representing by:

– power supply of airborne electronics (side storage batteries connected by a negative tire and generators),
– servo-motors of control surfaces and power-plant control,
– loops of servo-motor connections with the power electro-boxing,
– connection loops of processor (autopilot) with the power electro-boxing,
– connection loops of radio receiver with the power electro-boxing,
– connection loops of side computer with the electro-net of pilotless aircraft and peripheral devices,
– connection loops of primary measuring sensors of the technical state of pilotless aircraft,
– connection loops of useful radio electronic equipment with the side electric system,
– other loops (electric cables) of pilotless aircraft,
– electric wiring,
–electro-switches and other elements of distributing of electric power between consumers.

The fuel system intending for storage, distribution and feed of fuel to the power-plants of pilotless aircraft is one of it important systems. In consists of:

– fuel tank with the filling throat,
– pipelines,
– fuel pumps,
– filters,
– fuel level sensors,
– fuel pressure sensors, and
– faucet of the emergency fuel discharge.

Separate vitals system of pilotless aircraft is power-plant consisting of:

– engines,
– their airscrews with cowlings,

– motors,
– mufflers,
– dropped,
– ignition electronic systems,
– electric cable loops, and
– servo-motor panel of distance stop of pilotless aircraft power-plant.

With the purpose of power-plant diagnosing the pilotless aircraft must be equipped by:
– shaft speed sensors, and
– cylinder head temperature sensors.

The engine ignition electronics and electric cable loops to the engines must be diagnosed in addition.

The pilotless aircraft survival system intended for providing of the safe descent of pilotless aircraft during at accident in air and parachute landing of pilotless aircraft at necessity consists of:
– rescue parachute of domical type with the system of its fastening to the wing load-bearing element,
– opening servo-motor of parachute hatches,
– mean on the forced power-plant stop,
– primary sensors,
– electric cable loops,
– side electric switches (together with end switches) and
– contact boxes (demountable connectors).

The important vitals system of pilotless aircraft providing its operation during all technological flight cycle is the service system of paying load of pilotless aircraft which consists of:
– video signal transmitter,
– cameras of daily and nightly vision,
– power supply batteries,
– charging units,
– electric wiring,
– switches,
–power supply controller,
– elements of the mechanical fastening of paying load to the fuselage pod, and
– transmitting antenna.

Essentials of pilotless aircraft are the surface systems of:
– power supply,
– radio control (intended for remote control of pilotless aircraft, organization of bilateral radio contact at information passing from pilotless aircraft and reprogramming of its flight profile during technological cycle),
– navigation (intended for programming of flight profile and support of the declared profile (or its changes) during technological time),
– information handling, and
– take-off of pilotless aircraft,

as preparation for flight, its conducting and successful landing of pilotless aircraft depends from them. As a rule at the pilotless aircraft operation an aerodromless takeoff modes, in particular catapult devices, are used. For support of the technical state control of surface complex of pilotless aircraft control and catapult device it is necessary to control:
– power supply of surface electronic (storage batteries and generators),
– power surface electric cables and connectors,
– connection loops of pilotless aircraft control desk,
– stores and devices of information handling with surface computers,
– primary measuring sensors of the catapult technical state,
– technical state of mobile apartment of surface control complex.

Conclusions

Totality of vitals systems of pilotless aircraft for their technical diagnostics includes:
- airframe,
- system of side power supply,
- system of radio control,
- system of navigation,
- fuel system,
- power-plant,
- survival system,
- service system of paying load,
- surface systems of:
  - power supply,
  - radio control,
  - navigation,
  - information handling, and
  - take-off.

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ACCELERATION SENSES AND COMFORT LEVEL MODELING FOR THE LIGHT AIRCRAFT FLIGHT IN THE CONDITIONS OF INTENSIVE TURBULENCE

The complex problem about parameters choice of light airplane equipped with the lift direct control system flying with low speed is considered with the purpose to improve passengers comfort and to mitigate negative influence on crew members during flight in conditions of turbulence or vertical wind gusts. As a model the system of differential equations of first order is used. It describes the longitudinal motion of an airplane in turbulent atmosphere with application of lift force direct control system and acceleration loads perception by human organism.

Modern standards, rules and guidelines pay much attention to the flight safety but almost nothing is said about comfort criterion. For up-to-date well-equipped airplanes having similar performances exactly the level of comfort can be the dominant feature. Moreover, discomfort caused by “bumpiness” and acceleration loads during flight in turbulence induces airsickness, traumas, influences the condition of pilots, their reaction and adequacy of decision-making that leads to the decrease of safety level.

For elimination or at least decrease of such negative influence active and passive control systems are created in particular systems of lift force direct control [1].

The motion of aircraft that is made equivalent with a rigid body can be described with the help of a system of six differential equations: three of them describe the condition of forces balance in projections to the coordinate axes, and three others describe the moments balance condition respectively three coordinate axes [2].

Assumption that the airplane is considered to be a rigid body mass and inertia performances of which are the functions of time must be taken into account as an approximation. In reality, in flight the control surfaces deflect and the aircraft configurations changes in time. Besides, due to the fact of inevitable deflection the configuration of airplane structure also changes [3].

For general evaluation of airplane dynamic performances it is possible to assume simplified layout of rigid body with constant configuration.

In this research only the longitudinal motion of an airplane is taken into consideration because it simplifies calculations and takes into account the most unpleasant and the most dangerous loads such as normal load directed „from head to legs” and „from legs to head”, caused by vertical acceleration of an airplane.

For the longitudinal motion of an airplane it is possible to use the system of only three differential equations that describe the components of resultant aerodynamic force along the longitudinal axis x and vertical axis y and the moment M_z respectively transverse axis z. Substituting correspondent well-known aerodynamic formulas of lift, drag, pitching moment and their coefficients it is possible to get the following system of differential equations for longitudinal motion of an airplane:

$$\frac{dV}{dt}=\frac{P}{m}\cdot\cos(\alpha+\varphi)-\frac{\left[C_{X_0}+\frac{1}{\pi\cdot\lambda}\cdot(C_{Y_0}+C_Y^{\alpha}\cdot\alpha)^2\right]\cdot\rho\cdot V^2\cdot S}{2\cdot m}-g\cdot\sin(\vartheta-\alpha)\,, \tag{1}$$

$$\frac{d\alpha}{dt}=\frac{P}{m\cdot V}\cdot\sin(\alpha+\varphi)+\frac{(C_{Y_0}+C_Y^{\alpha}\cdot\alpha)\cdot\rho\cdot V^2\cdot S}{2\cdot m\cdot V}-\frac{g\cdot\cos(\vartheta-\alpha)}{V}\,, \tag{2}$$

$$\frac{d\omega_z}{dt}=\frac{1}{J_z}\cdot\left[m_{z_0}+m_z^{C_Y}\cdot\left(C_{Y_0}+C_Y^{\alpha}\cdot\alpha\right)+m_z^{\omega_z}\cdot\omega_z+m_z^{\delta}\cdot k\cdot(\vartheta-\vartheta_0)+m_z^{\delta_{\text{int}}}\cdot\delta_{\text{int}}\right]\cdot\rho\cdot\frac{V^2}{2}\cdot S\cdot b_a\,, \tag{3}$$

$$\frac{d\vartheta}{dt} = \omega_z \tag{4}$$

The model of longitudinal motion of an airplane is added with two differential equations that describe a turbulent component of velocity and are based on the Dryden's model [4]:

$$\frac{d\eta}{dt} = \frac{1 - 2 \cdot \sqrt{3}}{\sqrt{\pi}} \cdot \sigma_w \cdot a^{-2} \cdot \xi(t) - \frac{2}{a} \cdot \eta - \frac{1}{a^2} \cdot V_y\,, \tag{5}$$

$$\frac{dV_y}{dt} = \frac{\sqrt{3}}{\sqrt{\pi}} \cdot \sigma_w \cdot a^{-1} \cdot \xi(t) + \eta\,, \tag{6}$$

where η – is an auxiliary variable, $\xi(t)$ – is a "white noise", and V_y – is the vertical component of wind velocity, that is included into the equation of an airplane motion.

One of the ways to reduce loads caused by vertical acceleration is to apply the system of wing lift force direct control system with the help of specially designed surfaces on a wing, which can be presented by spoilers and interceptors.

For modeling such a system the model of an airplane longitudinal motion in turbulent air is added with the following equation:

$$\frac{d\delta_{\text{int}}}{dt} = -\frac{k_{\text{int}}}{\tau} \cdot w - \frac{1}{\tau} \cdot \delta_{\text{int}}\,, \tag{7}$$

where δ_{int} – is the angle of spoiler (interceptor) deflection; k_{int} – is the coefficient that determines the efficiency of aerodynamic damper; w – vertical wind speed; τ – constant of time delay at the system operation. The more the time delay is, the higher load arises. The earlier system starts to operate, the smaller an additional lift caused by wind will arise, that is the turbulence influence will be lesser.

The rate of control surfaces deflection must be very high, that is why flaps in this case will be inefficient. The author considers it to be quite reasonable to install systems equivalent or similar to Doppler's laser speed measuring device [5] as the device that registers the turbulence in front of an airplane.

Applying the abovementioned model the coefficient of normal load for different flight conditions was calculated according to the following formula:

$$n_y = \left[C_{Y_0} + C_Y^{\alpha} \left(\alpha + \frac{V_y(t)}{V} \right) \right] \frac{\rho \cdot S}{2 \cdot m \cdot g} [V^2 + 2 \cdot \alpha \cdot V \cdot V_y(t)]\,, \tag{8}$$

Obtained results were used for graphs drawing. The increment of normal load coefficient is considered by absolute value ($\Delta n_y > 0$).

Airplanes with wings having better carrying ability will be more subject to the wind influence which creates additional lift or downforce. Heavier airplanes will react to the influence of turbulence not so actively as easier ones due to higher wing loading at all the other conditions being equal. It is evident that greater amplitude of wind gust will cause stronger oscillations of normal load coefficient.

Nowadays there are a lot of models of acceleration motion perception by human organism, in particular models that describe the dynamics of otolithes and endolymph in the channels of human vestibular apparatus [6]. This research work applies the model that is based on vertical acceleration of an aircraft:

$$\ddot{\Omega}_y = a_{0y} \cdot \ddot{S}_y - a_{1y} \cdot \dot{\Omega}_y - a_{2y} \cdot \Omega_y , \qquad (9)$$

where $\dot{\Omega}_y$ – is a function of perception of acceleration motion caused by an airplane vertical acceleration $\ddot{S}_y$; a_{0y}, a_{1y}, a_{2y} – coefficients that describe dynamics of accelerations perception. $a_{0y} = 1; a_{1y} = 1.64; a_{2y} = 0.2.$ The threshold level of acceleration motion perception along the vertical axis is $\Omega_y^{thresh} = 0.626^{+\Delta=+0.17}_{-\Delta=-0.17}$ [7].

After transforming of second order differential equations to the first order ones the following model of acceleration perception will be as follows:

$$\begin{aligned} &\dot{\Omega}_y = \frac{d\Omega}{dt} = \psi, \\ &\dot{\psi} = \frac{d\psi}{dt} = a_{0y}\left[\left(n_y - \cos\vartheta\cos\gamma\right)g + L_s\dot{\omega}_z\right] - a_{1y}\psi - a_{2y}\Omega, \end{aligned} \qquad (10)$$

It is also included into the model of airplane motion in turbulent air. The results are given on the diagrams 1, 2.

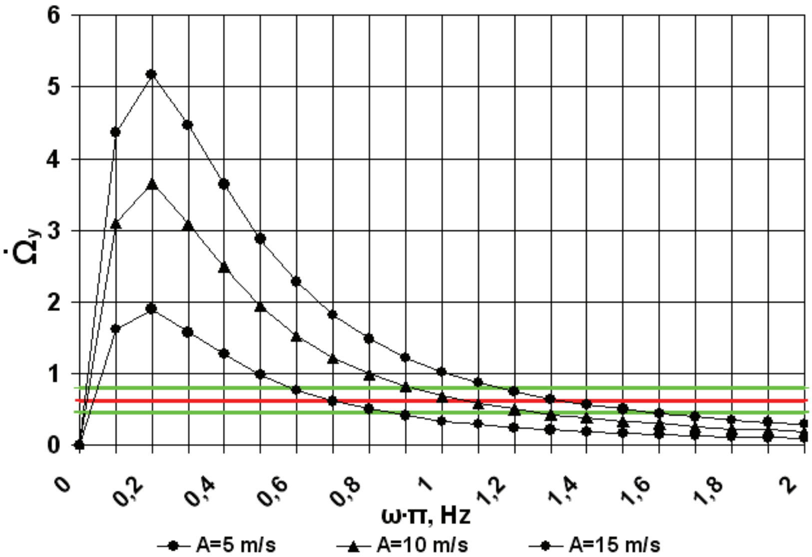

Diagram 1. Dependence of acceleration motion perception function on amplitude and frequency of the wind.

For estimation of comfort (or discomfort) level on the basis of accelerations perception by human organism the comfort criterion (K criterion)is introduced which can be presented in the following form:

$$K = \int_{\omega_1}^{\omega_2} \left|\Delta n_y(\omega)\right| \cdot \tilde{W}(\omega) \cdot d\omega , \qquad (11)$$

where $\tilde{W}(\omega)$ – is a weight function of vertical load; ω_1 та ω_2 – wind gust amplitudes, within the range of frequencies most influential for the human organism.

Taking in mind the main psychophysical law (Fechner law) the comfort criterion can be modified:

$$K_\Omega = \int_{\omega_1}^{\omega_2} \left|\Delta E\right| \cdot \tilde{W}(\omega) \cdot d\omega , \qquad (12)$$

where $\Delta E = k \cdot \ln\left(\frac{\Omega}{\Omega_{\lim}}\right)$ – is the increment of acceleration motion perception function.

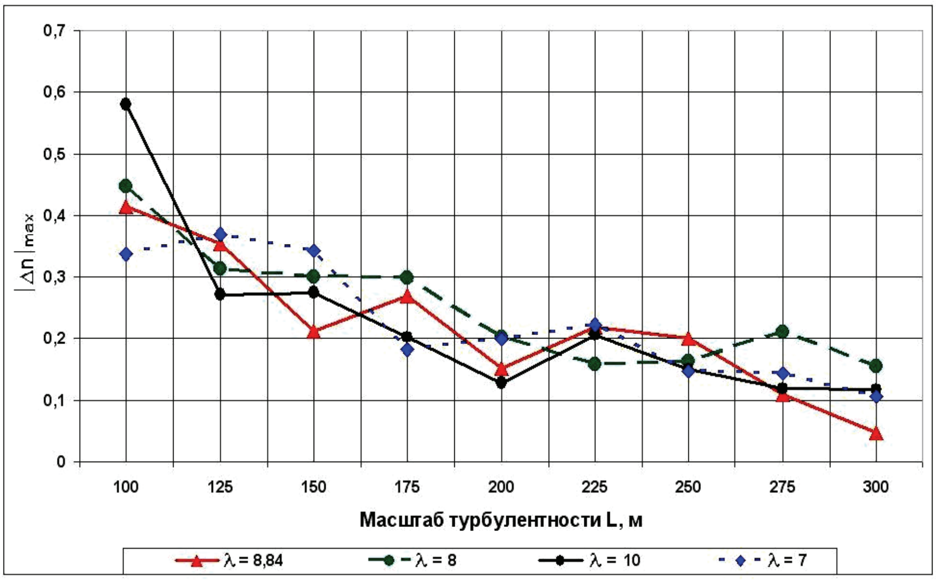

Diagram 2. Dependence of maximum absolute increment of normal load on turbulence scale and L and wing aspect ratio λ.

Conclusions

Loads because of acceleration that influence passengers and crew is one of the most critical factors, which determines the level of comfort. Acceptable level of loads depends on their spectrum of frequencies, direction and duration. Approximate range of the most discomfort frequencies of wing gusts is 0.4 – 3 Hz. For evaluation of passengers and crew comfort level it is necessary to use comfort criterion that gives the ability to make a parametric analysis and to determine the most optimum performances of an airplane taking in mind the level of comfort and fight safety.

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APPROACH TO FLIGHT SAFETY IN TERMS OF THE SUBJECTIVE ANALYSIS

It is made an attempt to combine the thesis of the newly developing theory of the subjective analysis with the traditional approach to flight safety problems settings. Considered two specific examples, critical for flight safety, of a stopped taking off and going-around with the aid of preferences functions.

It seems perspective to use some thesis of the subjective analysis in application to flight safety problem research, because it allows looking into the problem from a new point of view [1-3].

Making allowance for human factor in problems of flight safety is an obligatory component of the research, and in case of particular aviation incidents or accidents – component of investigations. Statistics says that the factor in the cause chain holds the “honored” first place. Specialists emphasize to “human factor” from 60 up to 80 % of special flight situations when it caused an aviation incident or accident.

Speaking of the perspective use of the subjective analysis, in the form that it is given in this paper, we mean the following: it is quite sure to say that every time when special situation arises there are a few alternative strategies of the crew behavior or all personnel, which supports carrying out the flight, that intend to parry negative circumstances. Exclusions, of course, are cases when nothing already depends on the crew. However in most cases, crews take measures to saving their aircrafts and successful completing the flights.

Let us denote the alternative strategies σ_k, and the all set of allowable strategies S_a. A preference $\pi(\sigma_k)$ is formed on the set S_a. The distribution of the preferences changes in the course of a flight situation development. The set of S_a is included to a formal description of the flight situation and it is also a dynamical object: the contents of the alternatives changes during the time. As a rule, there is a sharp deficiency of the time for decision making: a choice of “the best” alternative. We enclosed the words “the best” in quotation marks in order to emphasize the fact that the strategy which is “the best” from the point of view of the crew at the moment the special situation arises, actually may happen to be not the best.

Here are a few examples that show how alternative situations arise.

If, when accelerating before taking off, an engine failure happens, thus there are two possibilities: to continue the take off (the strategy σ_1) and to stop the take off (the strategy σ_2). Every time the choice of the strategy goes by the way of comparing the speed at the moment of the failure with the so called critical speed. The rule is: if the speed of $V(t_f) \geq V_{cr}$, the take off should be continued, if $V(t_f) < V_{cr}$, the take off is being stopped. A flight situation can be more difficult due to other circumstances although. Then it is a more difficult case and more complicated problem, and then this simple rule must not be used just exactly in that view. Strictly speaking, two alternatives exist at the condition $V(t_f) < V_{cr}$:

$$S_a|\ V(t_f) < V_{cr}\text{: } (\sigma_1, \sigma_2);\ S_a|\ V(t_f) \geq V_{cr}\text{: } (\sigma_1). \qquad (1)$$

Let us just imagine that an engine failure is complicated with a fire. Then there are disposable resources of time t^{disp}, connected to rate the fire develops. Required time t^{req}, in a case of a continued take off, coming back maneuver, landing, evacuation etc. – may happen to be more than t^{disp}. At the same time stopping the take off (on the condition of $V(t_f) \geq V_{cr}$) is connected to the danger of rolling out of the runway, and, as the result of this, an accident or the crash.

In such conditions, for some time there are two alternatives. Disposable time for making a decision is very short. At the set of S_a (1) a distribution of preferences arises, which quickly evolves under the influence of the exhaugeneous circumstances: $\pi(\sigma_1)$, $\pi(\sigma_2)$. The problem is to model the distribution of the preferences, trace its modification in time, and determine the conditions of the decision making.

An aircraft movement during acceleration for the take off is described by the simplified equations:

$$m\frac{dV}{dt} = P(V,t) - X(V) - N(V)f\,; \tag{2}$$

$$0 = Y(V) - G + N\,, \tag{3}$$

where V – velocity of the center of mass, m – the mass, P(V, t) – the summarized engines thrust, which depends on the velocity V and time t (the real dependence on the time t occurs in a case of a stopped take off – the thrust reverse, the real dependence X of t is explained by a possible change of the aerodynamic configuration when the take off is stopped, for example, letting the brake shields out), G – weight of the aircraft, X(V), Y(V) – the force of the forehead resistance and the lifting force, N – the summary normal reaction of the runway, f – coefficient of friction. The passed way is determined by the equation

$$\frac{dx}{dt} = V\,. \tag{4}$$

Transforming the mentioned before equations (2-4), we get the relationships:

$$\frac{dV}{dx} = \frac{1}{mV}P(V,t) - X(V) - (G - Y(V))f\,; \tag{5}$$

$$\frac{dt}{dx} = \frac{1}{V}\,. \tag{6}$$

If we choose the velocity V as the independent variable (paying attention to the fact that before braking starting it changes monotonously), we will get the relationships from equations (5, 6):

$$\frac{dx}{dV} = \frac{mV}{P(V,t) - X(V,t) - (G - Y(V))f}\,; \tag{7}$$

$$\frac{dt}{dV} = \frac{m}{P(V,t) - X(V,t) - (G - Y(V))f}\,. \tag{8}$$

The direct calculations of the way passed and the time spent allows by the method of comparison of these magnitudes with the disposable values of L^{disp} and t^{disp} to determine the residual space and time resources, which in their turn, exert an influence upon the distribution of preferences.

The second example of alternative situations existence is given by an approach and lending procedure in some more difficult conditions, when during descending the two alternatives arise: σ_1 – continuation of the approach and lending and σ_2 – going-around. The latter can be induced by some unpredictable or unforeseen obstacles on the runway, large impermissible deviations from the course-glissade line, meteorological conditions change, and other circumstances. The problem of the limited deviations during an aircraft approach and descending before lending has been considered in the science monograph [4].

The areas of the permissible side deviations: the side deviation from the course plane Z and course angle ψ are shown on the fig. 1.

Every point at the areas boundary is determined by solving an optimization problem of the maximum quick-action for a conditional extremum in conditions of different, including, not differentiating restrictions for phase and governing variables, accomplishments.

Maneuvering when going-around has been investigated in the work [4]. It has been solved the problem of certification requirements substantiation for an aircraft, that corresponds to the II[nd] International Civil Aviation Organization (ICAO) category. The statistical modeling of flight has been used.

On the fig. 1 the curves numbers symbolize: 1 – the distance to the edge of the runway is 1,000 m; 2 – the distance to the edge of the runway is 800 m; 3 – 600 m; and 4 – 500 m correspondingly.

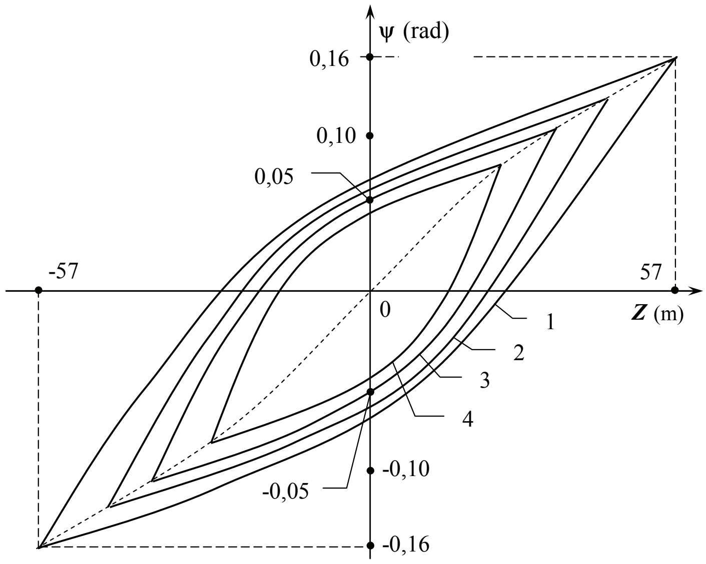

Fig. 1. The areas of the permissible side deviations

On the fig. 2 it is shown how the altitude of H_{gs} the go-around starting (the aircraft Il-86) depends upon the accepted magnitude of the mistake of the first kind α and the most strongly influential parameter of τ – the delayed reaction for making a decision "go-around".

The value of α is connected to the mean statistical magnitude of n – the number of the landings for which there is one go-around and a priory chosen probability of $P_{SPE} = (10^{-5}...10^{-7})$ – a small probability of the event arising, by the formula

$$\alpha = n\, P_{SPE}. \tag{9}$$

It is quite seen that the H_{gs} significantly depend upon the depicted parameters and, for example, at the $\alpha = 10^{-3}$ and $\tau = 3.16$ s (in accordance with the ICAO requirements) $H_{gs} \approx 30$ m.

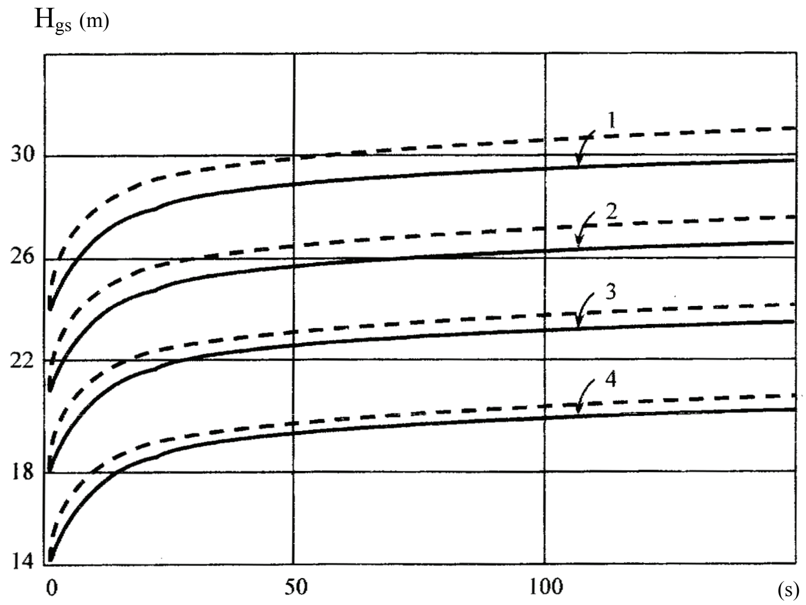

Fig. 2. The altitude of the go-around starting

Let us consider the maximally simplified model that allows showing the approach to the subjective factor paying attention to. We assume that an aircraft movement happens to be in the vertical plane, the side motion and wing are absent. In the trajectory reference system the motion of the aircraft center of mass is described by the equations

$$m\frac{dV}{dt} = P(V,t) - G\sin\theta - X(V,t); \tag{10}$$

$$mVv\frac{d\theta}{dt} = Y(V, y) - G\cos\theta, \tag{11}$$

the motion around the center of mass by the equation

$$I_z \frac{d\omega_z}{dt} = M_z(\alpha, \omega_z, V, t). \tag{12}$$

It is assumed that the pilot is able to estimate the comparative danger of the consequences of one or the other choice from the set of S_a. We define this estimate as the subjective probability $P(\sigma_k)$ of the event.

The canonical distribution of the preferences

$$\pi^{-}(\sigma_k) = \frac{P^{-\alpha}(\sigma_k) e^{-\beta\bar{\tau}(\sigma_k)}}{\sum_{q=1}^{2} P^{-\alpha}(\sigma_q) e^{-\beta\bar{\tau}(\sigma_q)}}. \tag{13}$$

The distribution (13) is the solution of the optimization problem with the functional

$$\Phi_{\pi^-} = -\sum_{k=1}^{N} \pi^{-}(\sigma_k) \ln \pi^{-}(\sigma_k) - \beta \sum_{k=1}^{N} \pi^{-}(\sigma_k) \bar{\tau}(\sigma_k) - \alpha \sum_{k=1}^{N} \pi^{-}(\sigma_k) \ln P(\sigma_k) + \gamma \sum_{k=1}^{N} \pi^{-}(\sigma_k). \tag{14}$$

The peculiarity of the functional is the structure of the efficiency function

$$E_{\pi^-} = -\sum_{k=1}^{N} (\alpha \ln P(\sigma_k) + Gb\bar{\tau}(\sigma_k)) \pi^{-}(\sigma_k), \tag{15}$$

to which the logarithm of the subjective probability is included.

Also subjective preferences play their role in personnel options [5]. Other aspects of subjective and economical factors influence on the flight safety were considered in [6, 7].

Conclusions

Problems of flight safety in the settings types of the equations (2-12) may be added with the condition of a set of the achievable for a subject alternatives S_a, for example, given by the inequalities (1). Distributions of subjective preferences allow evaluating in the real view critical psychic-physics factors of an active element of the complex technical system with the human included with the help of equations (13-15).

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METHOD OF EVALUATION OF ANALYTICAL AIRWORTHINESS OF PLANES AS OBJECT MANUAL

Stated the rationale for the method of analytical evaluation of the airworthiness of planes as the object of manual control with an arbitrary structure. The method is based on the application of a mathematical model developed by the author of perception pilot quality control object depending on its static and dynamic characteristics.

Creating a manned aircraft requires predicting their performance under the terms of agreement with the possibilities of the pilot. According to various studies the pilot seeks to provide the best quality of the tasks of piloting by making compensation to the contour of an airplane to address its shortcomings as an object of manual control [1,4,6]. The need for such compensation leads to an increase in psychophysical load pilot, reducing reserve time on tasks related piloting and reduce flight safety. [1,3,5,6].

Existing methods for assessing the airworthiness of planes as a management object (its stability and control) based on its representation in the form of a simplified model with fixed structure and does not allow to obtain accurate assessment of the quality of modern aircraft, especially with automatic devices to improve stability and control [3, 5,7].

In connection with the foregoing, forecasting evaluation airworthiness aircraft depending on its characteristics as an object of manual control to date is an actual scientific problem.

The paper aims to study the method of analytical evaluation of airworthiness of the aircraft on the parameters of its mathematical model as an object of manual control with an arbitrary structure on the basis of modeling and the process of piloting an airplane pilot, and using the known laws of interaction with the human touch of the space elements of the physical space [1,2,5].

The process of piloting simulated in the form of a follower sistmy "pilot - airplane", shown in Figure 1.

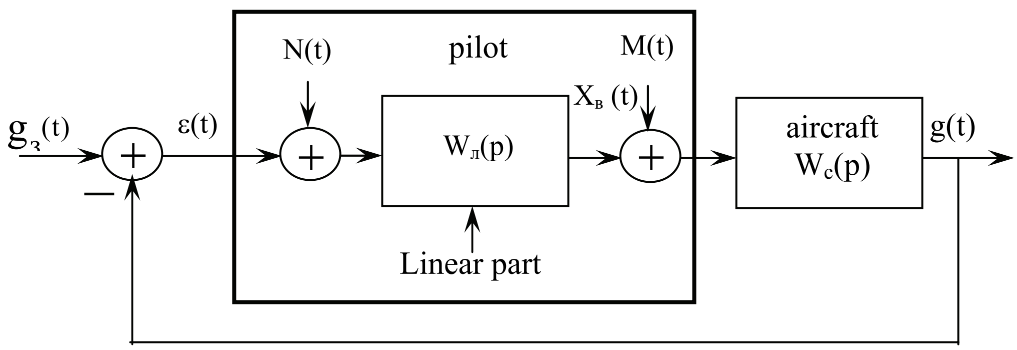

Figure 1

The useful signal at the input of the system is formed by transforming the white noise w (t) through a filter of the form

$$\ddot{g}_з(t) + 2\xi_*\omega_*\dot{g}_з(t) + \omega_*^2 g_з(t) = \omega_*^2 w(t),$$

where ξ_* and ω_* provide the possibility of forming characteristic of the various management tasks signals.

The dynamic properties of the pilot in control loop modeled as a quasi model including a linear component and the Remnant, taking into account the noise observation N (t) and engine noise M (t) in the form of normal stationary random processes are not correlated with each other and a useful signal (Figure 1). Simulation of the noise N (t) and M (t) in the system by using their spectral characteristics of

Sn (ω) and Sm (ω), respectively, proportional to the variance of error tracking σ^2_ε and dispersion control the actions of pilot σ^2_x taking into account the threshold of sensitivity [3, 4, 5].

Obtained in experiments value error variance tracking σ^2_ε have a high correlation with peer review pilot, reflecting his perception of the quality of the aircraft as the control object. It is therefore assumed that the compensation introduced by the pilot in the control loop, is aimed at providing in the system of minimum tracking error variance σ^2_ε in the form of functional [3,4,6]

$$\sigma_\varepsilon^2(i\omega) = \int_0^\infty S_\varepsilon(\omega)d\omega, \quad (1)$$

where Sε (ω) - the spectral characteristics of tracking error signal ε (t).

According to the laws of psychophysics (Weber's law regarding the signals that change over time), the pilot can not perceive itself integral (1), and the change of the signal spectrum Sε (ω).

Spectrum signal Sε (ω) is formed governing the actions of the pilot, who describes his mathematical model in the contour control of the aircraft. To simulate the compensation introduced by the pilot in the control circuit and its relationship to the quality of pilotage, consider the linear component of the pilot model in the absence of compensating action, and after their introduction.

In the absence of compensation in a control loop of the linear component of the model corresponds to the uncompensated pilot model of the form [3,4,5]

$$W_л^н(i\omega) = K_Л^Н \exp(-i\omega\tau_Л), \quad (\tau_Л = 0{,}3 \ \ c).$$

In this case, the uncompensated open-loop system "pilot - airplane" corresponds to the frequency response

$$W_p^H(i\omega) = W_Л^H(i\omega) \cdot W_c(i\omega). \quad (2)$$

After the introduction of pilot compensation control circuit, the frequency response of open-loop system is transformed into the compensated

$$W_p^K(i\omega) = \Delta W_K(i\omega) \cdot W_p^H(i\omega), \quad (3)$$

where ΔWк (iω) - compensation, which makes a pilot in the open-loop system.

With that in mind, Sε (ω) can be represented as the following expression

$$S_\varepsilon(\omega) = |W_\varepsilon^K(i\omega)|^2 \left[S_{BX}(\omega) + S_{Ш}(\omega)\right];$$

where $S_{Ш}(\omega) = |W_p^K(i\omega)|^2 \ S_n(\omega) + |W_c(i\omega)|^2 \ S_m(\omega);$

$W_\varepsilon^K(i\omega) = (1 + W_p^K(i\omega))^{-1},$

$S_{BX}(\omega)$ - the spectral characteristics of the signal $g_z(t)$.

The range tracking error Sε (ω) has two pronounced local maximum at the characteristic frequencies. First maximum corresponds to the frequency ω_{BX} characterizing the width of the spectrum input signal, the second - the frequency of resonance ω^K_p closed system "pilot - airplane. In the neighborhood of these frequencies are the main focus power spectrum Sε (ω), which gives rise to compensation values at specified frequencies ((ΔWк (i ω_{BX}) and ΔWк (iω^K_p)) as stimuli (incentives), the largest of which is formed by the perception of the quality of airplane pilot.

To determine the type of model, the transformative value of the stimulus in the value perception of the quality of the aircraft as a pilot facility manual control, represent the frequency compensation through the compensation of amplitude and phase in the form

$$\Delta W_K(i\omega) = |\Delta W_K(i\omega)| \exp(i\Delta\Psi_K(\omega)). \quad (4)$$

If compensation is not available at ωвх ($\Delta W_к(i\,\omega_{BX}) = 0$), on the basis of Fechner's logarithmic law to the stimulus $\Delta W_к(i\,\omega^{К}_{p})$, the value perception of the pilot has the form

$$I_К = K\lg \Delta W(i\omega^К_p)\,. \tag{5}$$

In view of (5) relations (2) and (4), we obtain the perception of the pilot in the form of

$$I_К = K\lg\frac{|W^К_p(i\omega^К_p)|\exp(i\Psi^К_p(\omega^К_p))}{|W^Н_p(i\omega^К_p)|\exp(i\Psi^Н_p(\omega^К_p))}. \tag{6}$$

Turning to the logarithmic amplitude and not performing complex transformations, we obtain the value perception of the quality of the aircraft pilot, which is characterized as $\overline{Z} = \{Z_i\}$ manual control parameter space, in the form of the following functional

$$I_К = I_o\left\{\Delta L^2_К\left[|W_c(i\omega^К_p,\overline{Z})|\right] + \rho^2\Delta\Psi^2_К\left[\Psi_c(\omega^К_p,\overline{Z})\right]\right\}^{\frac{1}{2}}. \tag{7}$$

where: $\Delta L_К(\omega^К_p) = 20\lg\dfrac{|W^К_p(i\omega^К_p)|}{|W^Н_p(i\omega^К_p)|}$;

$\Delta\Psi_К(\omega^К_p) = \Psi^К_p(\omega^К_p) - \Psi^Н_p(\omega^К_p)$;

$\rho = \dfrac{20\lg e}{57{,}3}\left[\dfrac{дБ}{град}\right]$;

$I_0 = \dfrac{K}{20}\left[\dfrac{1}{дБ}\right]$ - the zoom factor of the expert scale.

In the case $\Delta W_к(i\,\omega_{BX}) \neq 0$, expression (5) appears additive quantity $\Delta I_к$ reflecting compensation at low frequencies ($\omega \approx \omega_{BX}$). Since at these frequencies the phase compensation is insignificant and has virtually no effect on the characteristics of a closed system, the change $S\varepsilon(\omega)$ at these frequencies can be achieved only in the amplitude compensation by changing the pilot of his gain on the uncompensated value.

Condition $K_л = K_{л_{опт}}$ corresponds $\Delta W_к(i\,\omega_{BX}) = 0$ and sold at the optimum gain for the pilot the aircraft $K_c = K_{c_{опт}}$. As an open system $K_p = K_{л_{опт}}K_c$, then for close to ωвх frequencies, rightly

$$\Delta W_К(i\omega_{BX}) \cong \frac{K_c}{K_{сопт}}.,\ \Delta I_К = \Delta I_К\left(\frac{K_c}{K_{сопт}}\right). \tag{8}$$

Based on the results of experiments and transformations Psychophysics (Fechner law and Stevens) A specific form of dependence (8) has the form

$$\Delta I_К = \begin{cases} \alpha_ф\left|\lg\dfrac{Kc}{K_{сопт}}\right| - \alpha_0,\ \Delta I_К > 0{,}2 \\ \alpha_c\left[\dfrac{K_c}{K_{сопт}} - 1\right]^2,\ \Delta I_К \in [0;0{,}2]. \end{cases} \tag{9}$$

where $\alpha_ф, \alpha_c, \alpha_0$ - coefficients depending on the task of piloting (phase of flight).

Thus, the degree of perception of the quality of the aircraft as a pilot facility manual control, depending on its characteristics determined by the functional

$$I_к = I_о\left\{\Delta L_к^2\left[|W_c(i\omega_p^к,\overline{Z})|\right]+\rho^2\Delta\Psi_к^2\left[\Psi c(\omega_p^к,\overline{Z})\right]\right\}^{\frac{1}{2}}+\Delta I_к\left(\frac{K_c}{K_{сопт}(i\omega_{вх},\overline{Z})}\right). \qquad (10)$$

Evaluation of the reliability of the results of calculation by the functional (10) was carried out using the model of "cutoff" [1,3,4,5] to model the amplitude and phase frequency response of the compensated open-loop system. As a result, found that for airplanes with different characteristics in different tasks and the control channels of the experimental data on the settlement is within 10% range of the scale of peer review pilot. Such scattering does not exceed the scattering estimates exhibited different pilots under the same conditions.

The studies also found that the plane was well perceived by the pilot as an object uprvleniya if the values of the parameters provide the minimum of functional (10), which allows to use this functionality in optimization problems, the characteristics of stability and controllability of the aircraft.

Findings

1. A method of analytical evaluation of the airworthiness of planes as the object of manual control of any structure.

2. This method is based on the application of the developed model of expert evaluation of thepilot stability and controllability of the aircraft depending on their static and dynamic characteristics.

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MATHEMATICAL MODELING OF MANIPULATED TURBULENT SHEAR FLOWS

The mathematical method of turbulent boundary layer and wall jet prediction, which is based on unified algebraically-differential turbulence model is proposed. The important property of the developed model is its ability to account the effects of turbulence manipulating, namely: surface roughness or microrelief, dilute polymer solution injection, large eddy breakup devices as single tools and in any combinations. The components of the elaborated model are adopted to corresponding local zones of turbulent flow.

Flow control is a powerful way to reduce drag and prevent separation. Modern drag reduction methods can be characterized by sufficiently wide range of existing tools having small enough interval of field conditions, under which the positive effect of their application can be reached. That is why it is very important to use different combinations of these methods that will positively influence each other and improve the result of separate use each of them. The **goal** of this paper is to represent and verify the elaborated mathematical model and corresponding calculation method of turbulent boundary layers and wall jets, developing under the separate or combined influence of several basic kinds of drag reduction methods, such as: Large Eddies BreakUp devices (LEBU), ribbed streamlined surfaces and near-wall injection of dilute solutions of polymeric additives. The developed method is based on the Reynolds equations together with the following turbulence model [1-3]:

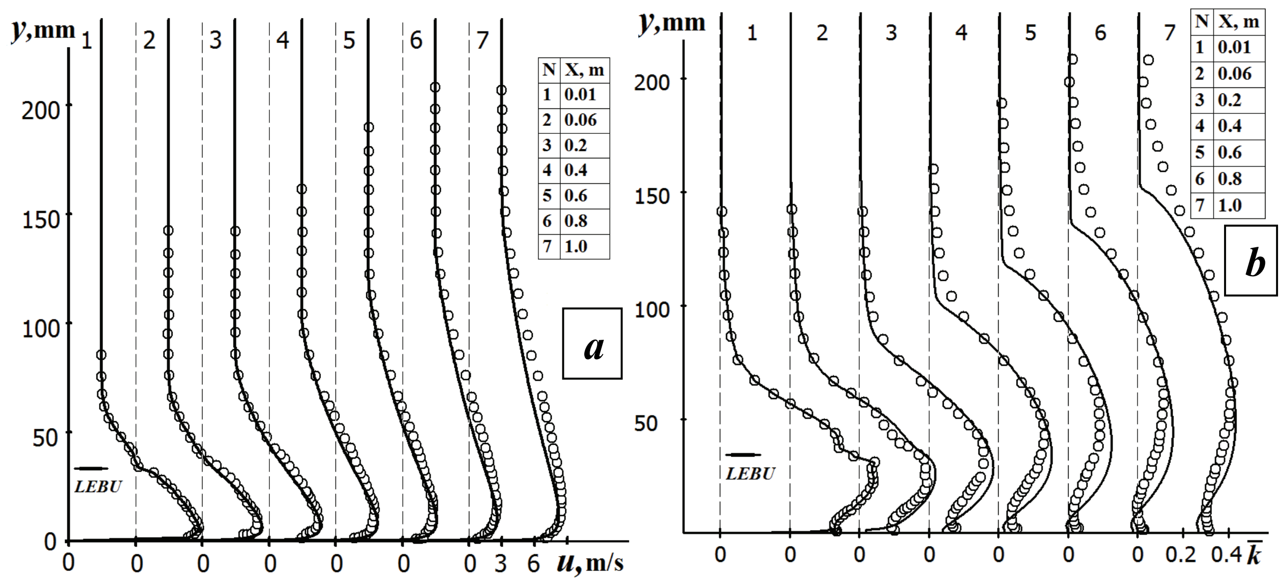
$$\nu_t = \nu_{twake} \tanh\frac{\nu_{twall}}{\nu_{twake}}, \quad \nu_{twake} = C_\mu \frac{k^2}{\varepsilon}, \tag{1}$$

$$\nu_{twall} = \chi y \upsilon_* \sqrt{\bar\tau} D_m, \quad D_m = \tanh\frac{\sinh^2[\chi_1 y_1^+ \sqrt{\bar\tau}]\tanh[\sinh^2(\chi_2 y_1^+ \sqrt{\bar\tau})]}{\chi y_1^+ \sqrt{\bar\tau}},$$

where $y^+ = y\upsilon_*/\nu$, $\upsilon_* = \sqrt{\tau_w/\rho}$, $\bar\tau = \tau/\tau_w$, $\chi, \chi_1, \chi_2, C_\mu$ – model coefficients. The model (1) has a hybrid structure. Its internal part ν_{twall} is an algebraic representation of a turbulent viscosity and the outer part ν_{twake} is a traditional Jones-Launder $k-\varepsilon$ model. The algebraic approach is well-adjusted for description of small-scale turbulence structure in the vicinity of a wall. Besides, it was expanded for the cases of accounting the effects of surface relief and polymer injection in the near-wall region due to introducing the shifting functions Δy^+_{rel} and Δy^+_{pol}, so $y_1^+ = y^+ + \Delta y^+_{rel} + \Delta y^+_{pol}$. These functions reflect a well known effect of a shift the logarithmic part of a wall law scaled velocity profile in a semilogarithmic representation $u^+ = f(y^+)$ on some value Δu^+ up or down depending on presence of polymer additive solutions or surface relief influence respectively. There are many sources of experimental data, establishing the dependencies between Δu^+ and parameters of surface relief or polymer additives. The advantage of the proposed approach is possibility to connect Δu^+ with Δy^+ analytically. In particular, for a surface with riblets and in case of near-wall polymeric injection the following dependence can be applied $\Delta y^+ = \chi_1^{-1}\tanh(\chi_1 \Delta u^+)$. Due to the additive property of shifting functions Δy^+_{rel}, Δy^+_{pol}, and a structure of a model form of a turbulent viscosity for the inner region, it allows to account effectively in calculations the data, obtained experimentally for any special type of a surface relief or polymeric solution injection both separately and in any combinations. On the other side, in outer region the two-equation differential $k-\varepsilon$ turbulence model is used. It describes well the different aspects of evolution of large-scale turbulent vortical structures. In particular, this model can be applied for prediction of LEBU presence effect. That is why the $k-\varepsilon$ model is more adopted for turbulence description in the outer region vs. algebraic model. Nevertheless, it is not physically valid near the wall, but this disadvantage is effectively eliminated by the structure of the proposed approach, namely, the algebraic model works near the wall as a damping function for a differential component of model (1). Several practically actual applications of the developed model for the combined schemes of turbulent flow control are presented below. Figure 1 demonstrates the predictions of average velocity (***a***), kinetic energy (***b***), turbulent shear stresses (***c***) and wall shear stresses (***d***) distributions (lines) in wall jet flow, forming along flat plate behind LEBU (experiment: S.Mochizuki, S.Yamada, H.Osaka (2006) - circles). Figures 2,***a.b*** illustrate the calculated profiles of average (***a***), fluctuating (***b***) velocities (lines) in a boundary layer, developing over a revolutionary body ($d=10$ mm) behind LEBU in comparison with the V.I.Kornilov's experimental data (2005) - circles. Figure 2,***c*** demonstrates the theoretical distribution of a local skin friction coefficient $C_f = 2\tau_w/(\rho u_\infty^2)$ along longitudinal coordinate x (lines) for the conditions of mentioned above experimental data (circles). Figure 3,***a*** shows the deformations of average velocity logarithmic profiles (lines) as a result of different shapes of surface relief influence (experiment: S.Okamoto, T.Uchida, T.Yoneyama, K.Takiguchi, S.Kimura (2000) - points. Figures 3,***b,c,d*** represent by lines the predicted average (***b***), fluctuating (***c***) velocities and turbulent shear stress distributions (***d***) in a submerged wall jet, spreading along the ribbed surface (experimental data: S.Yamashita, H.Hayashimoto, Y.Inoue, Y.Iwakami (1994) - circles. Figure 1,***e*** demonstrates (by lines) the computed dependence $C_f(x)$ for the conditions of experimental data considered above (circles).

Conclusions and directions of further researches. The proposed model demonstrates the ability to account correctly both single and combined influences, directed on a turbulent boundary layers and wall jets, which are oriented on different scales of vortical structures of turbulent motion. The structural model elements are effective locally in the regions, where they have the greatest level of physical correctness and ability to describe an action of the mentioned above flow control methods.

The further perspectives of this model development will be connected with accounting additional flow control factors and searching some other more adoptive and more universal possibilities of linking the internal and outer representations of the worked out turbulence model.



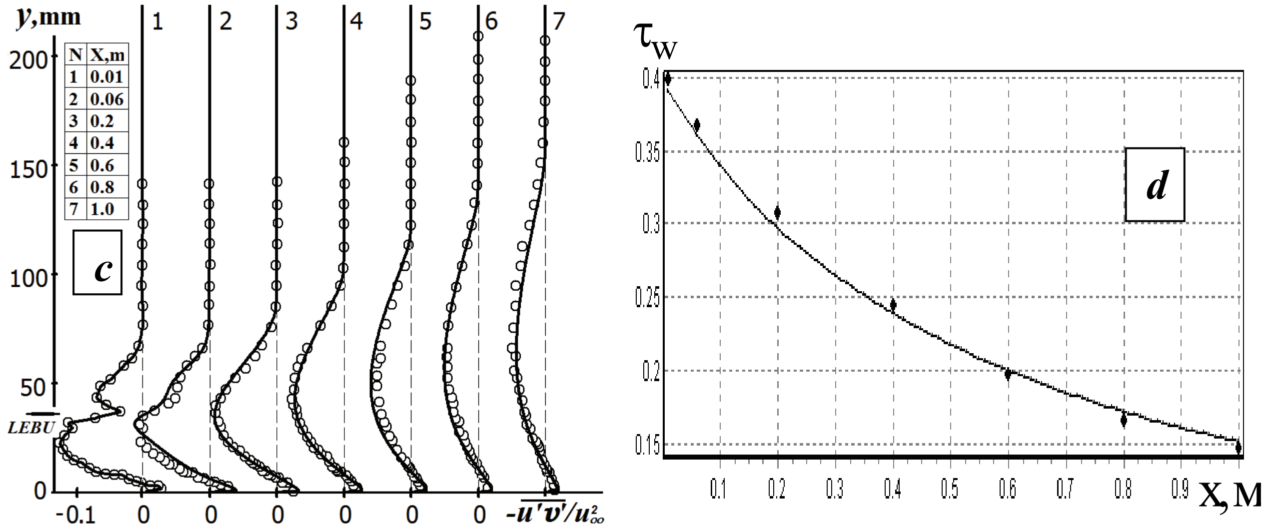


Fig.1. Mathematical modeling of a turbulent wall jet on a flat plate with the presence of LEBU

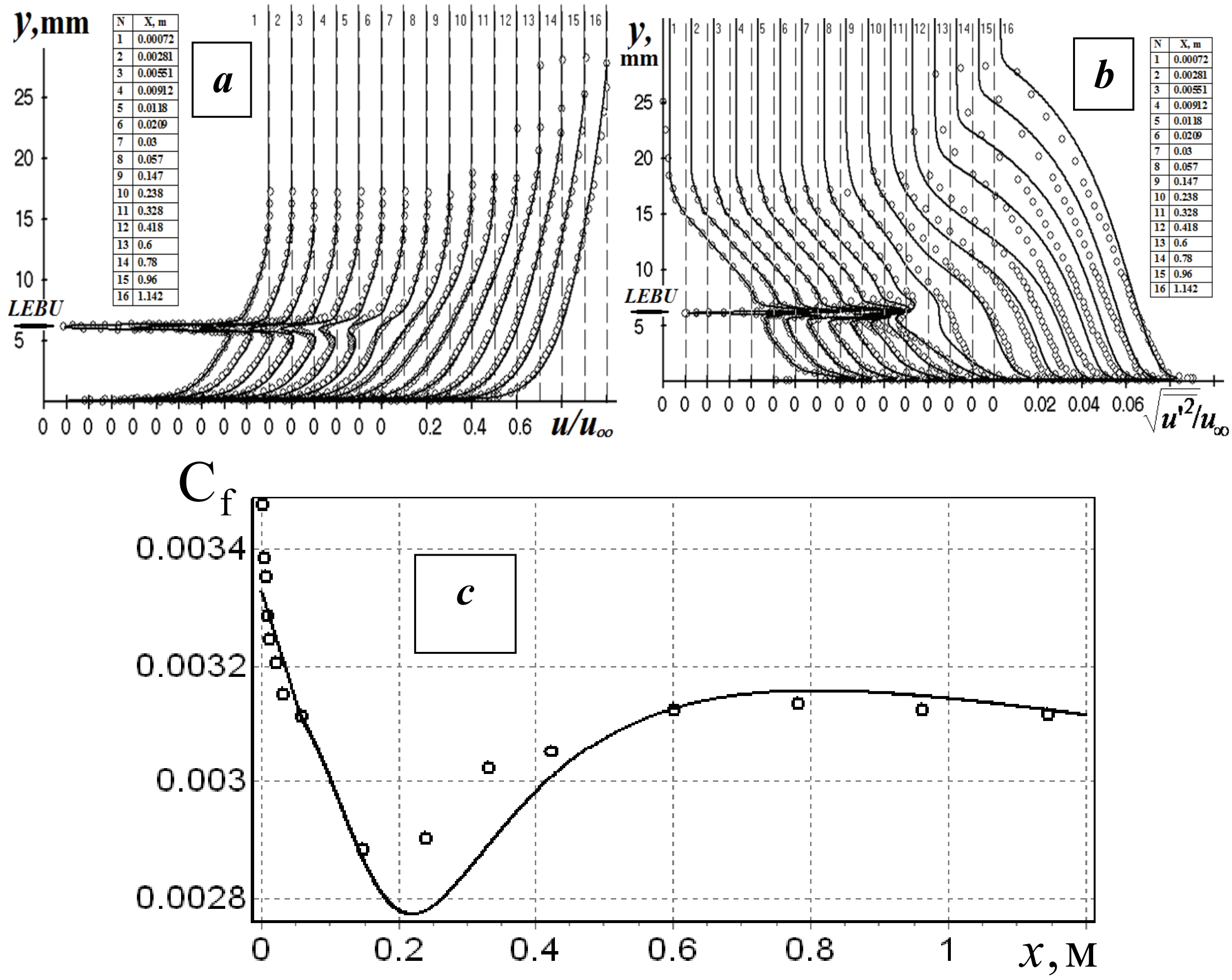


Fig.2. Mathematical modeling of a turbulent boundary layer on a body of revolution with the presence of LEBU

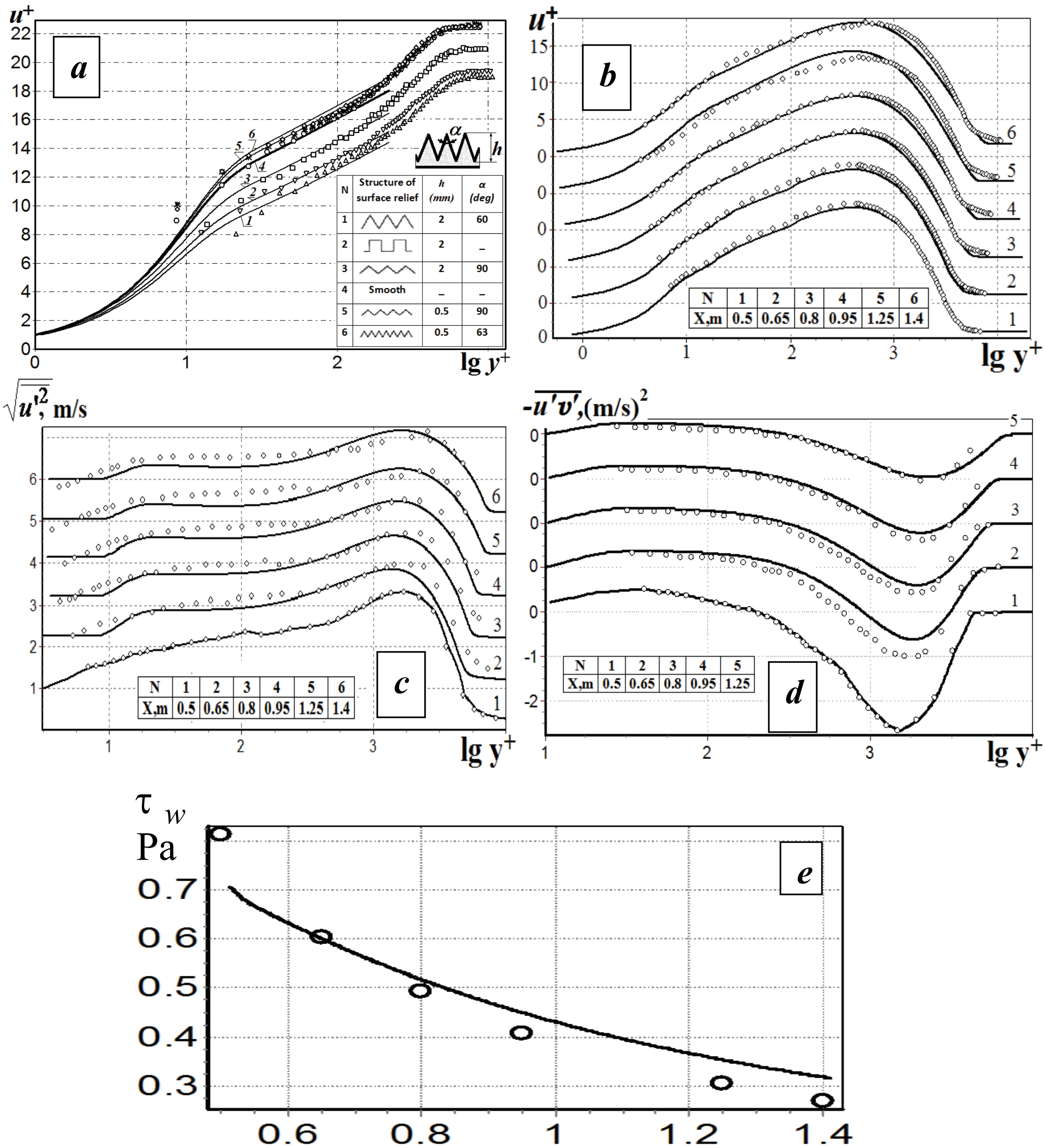


Fig.3. Mathematical modeling of a turbulent wall jet on a flat plate with riblets ($h = 0.6$ mm, $\alpha = 63^o$)

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UNSTEADY AERODYNAMIC DERIVATIVE OF WING WITH VORTEX GENERATORS

The work contains results of wind tunnel unsteady investigation of wing with vortex generators.

Problem statement.

At flights of airplanes in a disturbed atmosphere aerodynamic characteristics essentially change at the expense of features of non-stationary flow. Knowledge of aerodynamic characteristics allow to model more authentically an airplane flight dynamics, to create perfect automatic control systems and objectively to investigate air events. According to firm Boeing most often air events occur in a turbulent air. Flight in such atmosphere leads to physiological influence on crew, creation of aerodynamic overloads which influence on fatigue strengths, changes of an aerodynamic drag, lifting forces, and also to change of the aerodynamic moments which characterise firmness and controllability.

The problem of control of turbulence and airflow separation always remains perspective as with theoretical, and practical the points of view. Its solution provides knowledge of physical laws of flow and prospect of reduction of resistance and the requirements connected with it to propulsion, noise reduction or changes of noise characteristics to object which moves, control of characteristics of turbulent accompanying tracks behind bodies in problems of flight operation of air transport, industrial aerodynamics and ecology.

Importance of a problem stimulates creation of significant number of strategy of control by turbulence and control facilities vortical structures.

The analysis of researches and publications.

Research of non-stationary modes of motion of an airplane is an actual problem of flight operation and safety of flight. нестационарности on aerodynamic characteristics of flight vehicles (A\C) many activities both domestic, and foreign authors [1-4] are devoted influence research.

In activity [5] influence of generators of vortexes in the form of flow on a leading edge on integrated aerodynamic characteristics of a wing on small and supercritical angles of attack is investigated. It is established that the given generators of vortexes effectively delay flow separation and considerably increase supercritical values C_y. At the same time in activity [6] the conclusion becomes, that contouring of a nose of a structure considerably influences wing dynamic characteristics.

The activity purpose − detection of influence of generators of vortexes in the form of flow on a leading edge on non-stationary components of aerodynamic coefficients.

Experimental installation.

Experiment was conducted in aerodynamic complex TAD-2 NAY. Wind tunnel TAD-2 NAY - straight-flow type with octagonal in section a working section in the sizes 4 2,×5 × 5,5 m. The working section has slot-hole walls with degree of permeability of 18 %. The maximum speed of an airflow in a working section - to 42 km/s, the maximum driving power - 660 kw.

TAD-2 Intended for аерофізичних researches and equipped 6-componental тензовагами, built in in working section forgery, rotary circle with a turn range ±360°,, installation of compelled oscillations ОП-2, aerosol systems for modelling of an icing and showers and other equipment. More detailed data resulted on web page of aerodynamic complex НАУ (http://nauka.nau.edu.ua/wt).

On installation of compelled oscillations OP-2 has been established venting wing section (fig. 1), that executed harmonious oscillations round an axis of 0.25 chords kept away on distance from a wing leading edge. For the purpose of increase in effective lengthening of a wing section, near the right end face of a compartment on distance of 5 mm. The established vertical immovable screen, the size of the screen provides lengthening $\lambda_{эф}$=3,62. A wing venting in 56 points on one section. Pressure transducers MPXV5004G are disposed in the central section of a wing. Data acquisition was provided interface plate of multichannel input PCI-1747U of firm Advantech. The rule of a structure of a wing during oscillations was supervised encoder Rotery Encoder E40S8-100-3-2 firms Autonics which has been established on an axis of a handwheel of a drive.

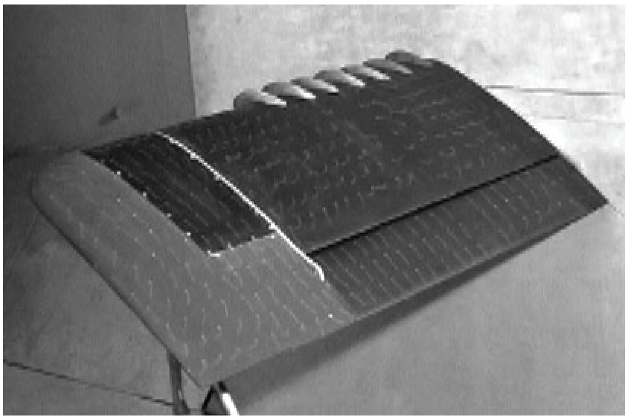

Fig. 1. The General view of model of a wing with the established generators of vortexes.

The model of a wing section scope l = 1.166 m and a chord b = 0.51 m has structure P-301 with relative thickness (c=14 %). Wing area makes S = 0.5656 $м^2$, the sweep corner is equaled to zero.

Generators of vortexes (GV) are executed in the form of a leading-edge wing extension. Educational surfaces of generators of vortexes have the same structure, as on the wing.

Experiment was conducted in a range of Reynold's numbers $Re=5*10^5 \div 1*10^6$, Strouhal numbers Sh=0.1÷0.7. Harmonious oscillations occurred to amplitude 2.50 in a vicinity of angles of attack 9.90 for linear area of relation $C_{ya}=f(\alpha)$, and 22.60 for critical modes.

Technique of processing of results.

Distribution of mean values of factors of air pressure on a surface of model which has been received in trumpet experiment, allows to determine aerodynamic coefficient, namely, the Cy - a lift coefficient, Cxp - a pressure drag coefficient (does not consider friction force of air in a model surface) and Mz - factor of the longitudinal moment. Indicated aerodynamic coefficients are determined by numerical integration of a curve of change of factors of pressure on a surface of model which previously was aproximated whith a cubic spline. Thus aerodynamic characteristics of a structure were determined according to expressions:

$$Cx = ((P_u\, dy_u + P_l\, (-dy_l)), \qquad (1)$$
$$Cy = ((P_l - P_u)\, dx,$$
$$Mz = ((P_l - P_u)\, x\, dx,$$

where dx - a projection of an elementary platform dL on an axis x,
dy - a projection of an elementary platform dL on an axis in,
x - co-ordinate of an elementary platform dL on an axis x,
P_l - pressure factor on a lower surface,
P_u - pressure factor on the upper surface.

Thus, value Pi between drainage apertures and structure co-ordinates between certain points are interpolated by a cubic spline, and numerical integration implements along axis X with step 0.001 from a chord. At definition of moment Mz, ydy we neglect influence, as this value is small in comparison with xdx.

Instant values of an angle of attack which answer instant values of factors to pressure and an oscillation phase are determined by expression

$\alpha = \alpha^0 - A^*\sin(\varphi)$, (2)

where α^0 - an initial angle of attack concerning which occur oscillation;

And - oscillation frequency behind an angle of attack;

$\varphi = \omega\tau + \varphi^0$ - a phase of oscillations;

ω - frequency of oscillations.

During oscillatory motion of a structure its aerodynamic characteristics essentially differ from characteristics at stationary flow. For quantitative definition of changes of factors of the Cy, Cx and Mz caused of unsteady it is used the following technique.

We take away from Cx_{dynamics}, the Cy_{dynamics} received during the dynamic experiment, previously calculated static values for corresponding angles of attack, we find non-stationary components ΔCy, ΔCx, ΔMz

ΔCy = the Cy_{dynamics} – the $Cy_{\text{a statics}}$, (3)

$\Delta Cx = Cx_{\text{dynamics}} - Cx_{\text{a statics}}$,

$\Delta Mz = Mz_{\text{dynamics}} - Mz_{\text{a statics}}$.

In relation $\Delta Cy = f(\alpha^*)$ in points $\alpha^* = 0$, according to model of a harmony [2]:

$Cy = Cy0 + Cy^{\alpha}\alpha + Cy^{\alpha^*}\alpha^* + Cy^{\alpha^{**}}\alpha^{**}$. (4)

The non-stationary component $\Delta$of the Cy is influenced only by the $Cy^{\alpha^{**}}\alpha^{**}$. So we find the $Cy^{\alpha^{**}}$:

$Cy^{\alpha^{**}} = \Delta$the $Cy_{\alpha^*=0}/\alpha^{**}_{\alpha^*=0}$, (5)

where $\Delta$the $Cy_{\alpha^*=0}$ – a total non-stationary component $\Delta$of the Cy during the moment when $\alpha^* = 0$,

$\alpha^{**}_{\alpha^*=0} - \alpha^{**}$ in the moment when $\alpha^* = 0$.

In appropriate way derivatives $Cx^{\alpha^{**}}$ $Mz^{\alpha^{**}}$ are determined

$Cx^{\alpha^{**}} = \Delta Cx_{\alpha^*=0} / \alpha^{**}_{\alpha^*=0}$, (6)

$Mz^{\alpha^{**}} = \Delta Mz_{\alpha^*=0}/\alpha^{**}_{\alpha^*=0}$.

Technique of definition of derivatives Cy^{α^*} Cx^{α^*} Mz^{α^*} similar to the above-stated. In relation $\Delta$of the Cy = f (α^*) in points $\alpha^{**} = 0$, according to model (4) on a non-stationary component $\Delta$of the Cy the $Cy^{\alpha^*}\alpha^*$ influences only $Cy^{\alpha^*}\alpha^*$. So we find Cy^{α^*}

$Cy^{\alpha^*} = \Delta Cy_{\alpha^{**}=0}/\alpha^*_{\alpha^{**}=0}$, (7)

where $\Delta\ Cy_{\alpha^{**}=0}$ – a total non-stationary component Δ Cy during the moment when $\alpha^{**} = 0$,

$\alpha^*_{\alpha^*=0} - \alpha^*$ during the moment when $\alpha^* = 0$.

In appropriate way derivatives $Cx^{\alpha^{**}}$ $Mz^{\alpha^{**}}$ are determined

$Cx^{\alpha^*} = \Delta Cx_{\alpha^{**}=0}/\alpha^*_{\alpha^{**}=0}$, (8)

$Mz^{\alpha^*} = \Delta Mz_{\alpha^{**}=0}/\alpha^*_{\alpha^{**}=0}$.

The analysis of the received results.

In Fig. 3-8 influence from installation of generators of vortexes on relation non-stationary aerodynamic derivative of Strouhal numbers (St) and Reynolds numbers (Re) is shown.

a) b)

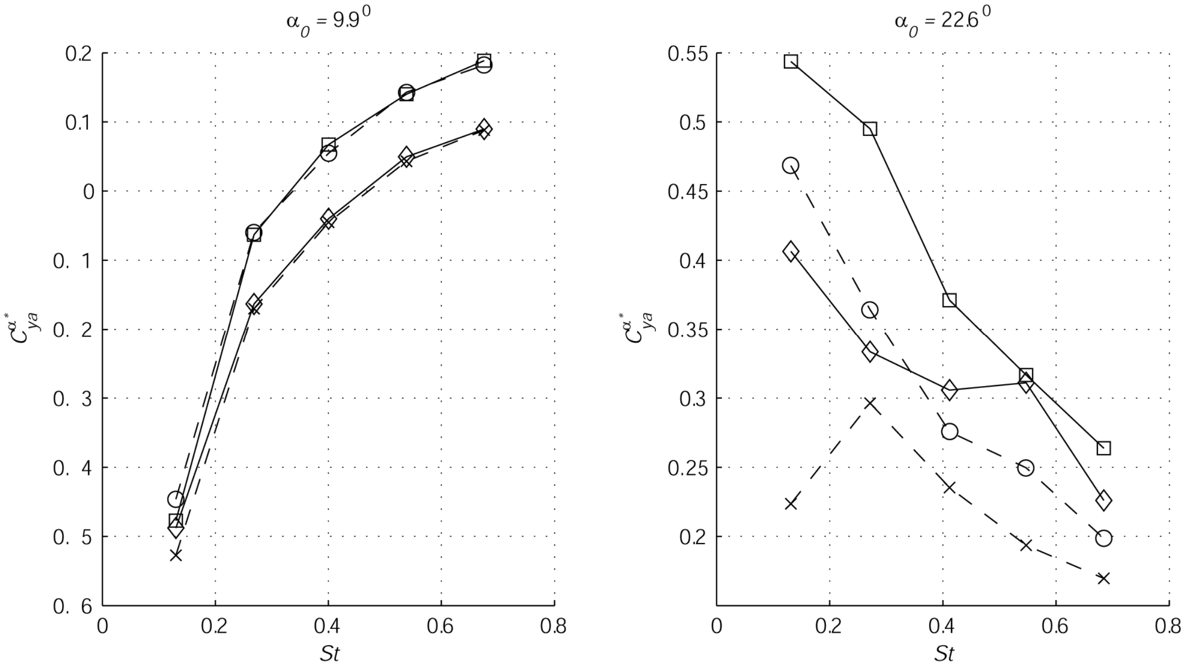

Fig. 2 – influence of GV on non-stationary derivatives $C_{ya}^{\alpha*}$ for angles of attack α=9.9^0 (a) and α=22.6^0 (b):
– –x– – clear wing Re=7·10^5, – –◊– – clear wing Re=10·10^5, –□– GV Re=7·10^5, –o– GV Re=10·10^5.

a) b)

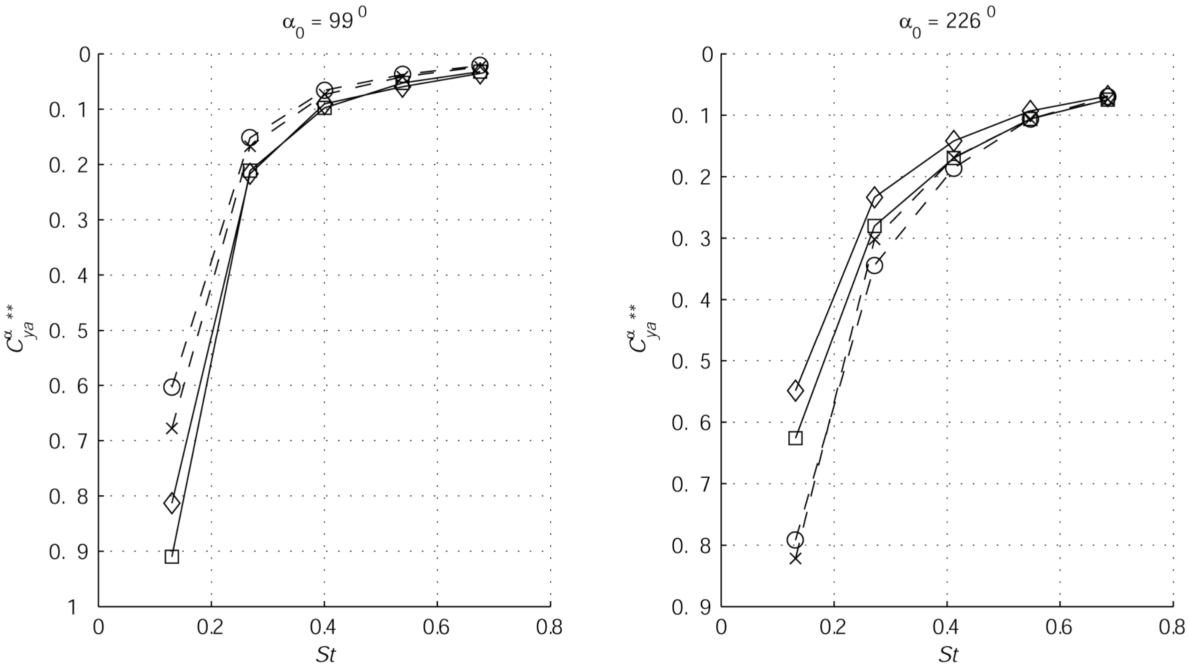

Fig. 3 – influence of GV derivatives $C_{ya}^{\alpha**}$ for angles of attack α=9.9^0 (a) and α=22.6^0 (b):
– –x– – clear wing Re=7·10^5, – –◊– – clear wing Re=10·10^5, –□– GV Re=7·10^5, –o– GV Re=10·10^5.

a) b)

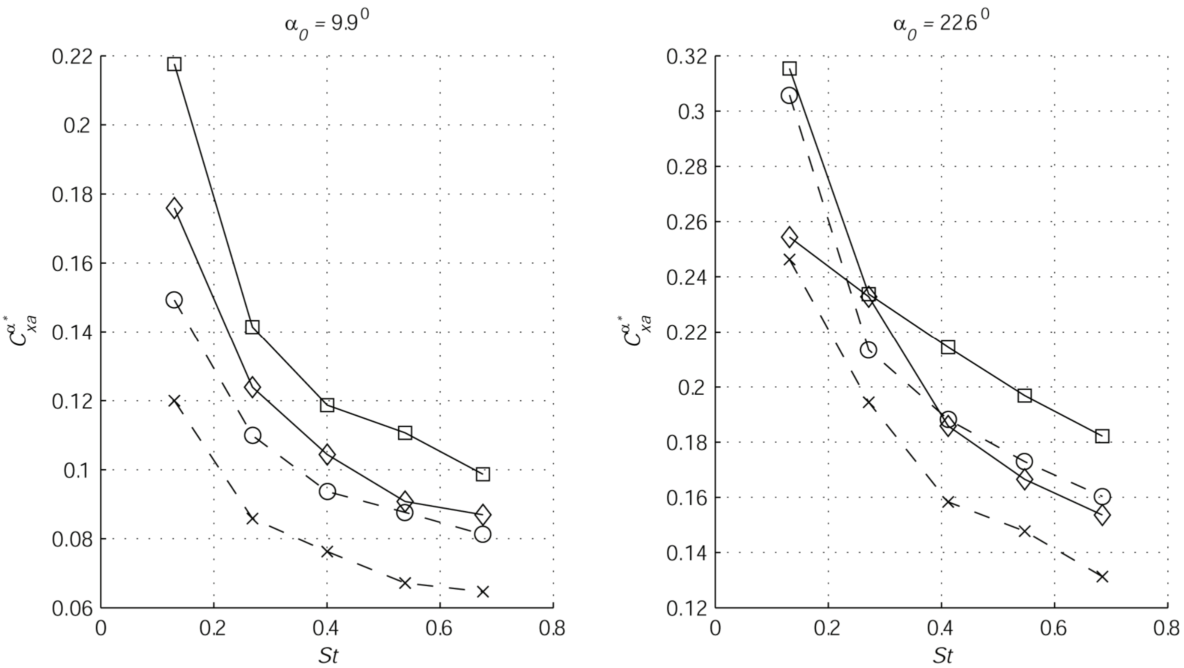

Fig. 4 – influence of GV on non-stationary derivatives $C_{xa}{}^{\alpha^*}$ for angles of attack α=9.9^0 (a) and α=22.6^0 (b): – –x– – clear wing Re=7·10^5, – –◊– – clear wing Re=10·10^5, –□– GV Re=7·10^5, –o– GV Re=10·10^5.

a) b)

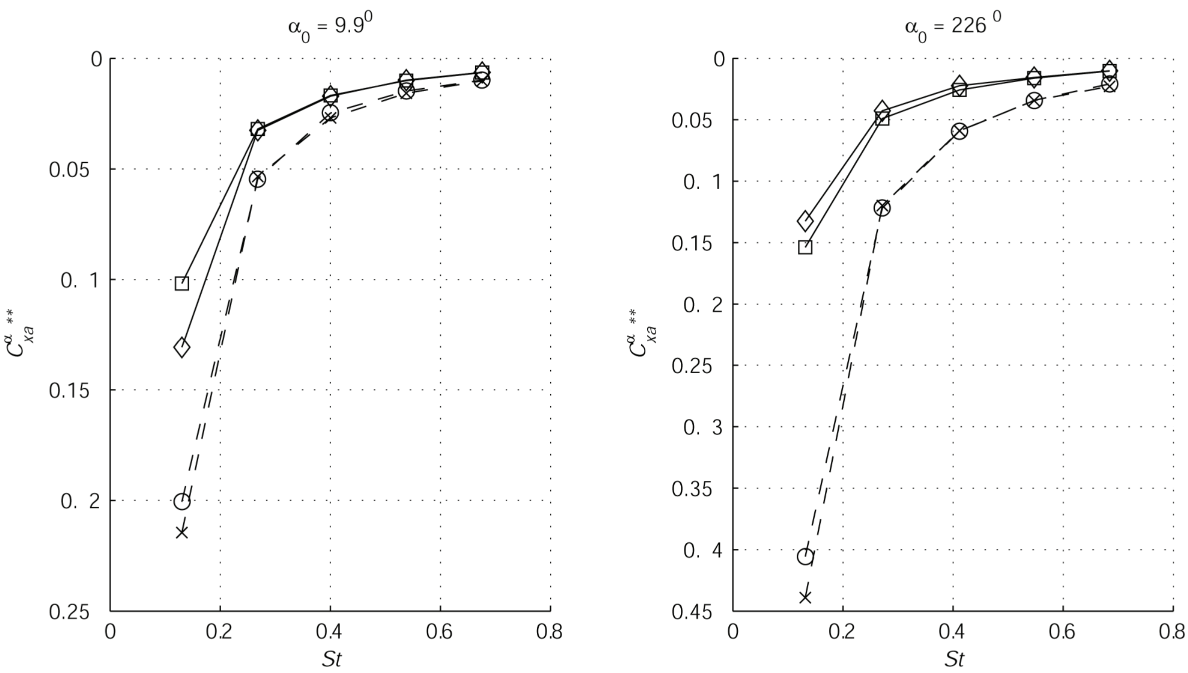

Fig. 5 – influence of GV on non-stationary derivatives $C_{xa}{}^{\alpha^{**}}$ for angles of attack α=9.9^0 (a) and α=22.6^0 (b): – –x– – clear wing Re=7·10^5, – –◊– – clear wing Re=10·10^5, –□– GV Re=7·10^5, –o– GV Re=10·10^5.

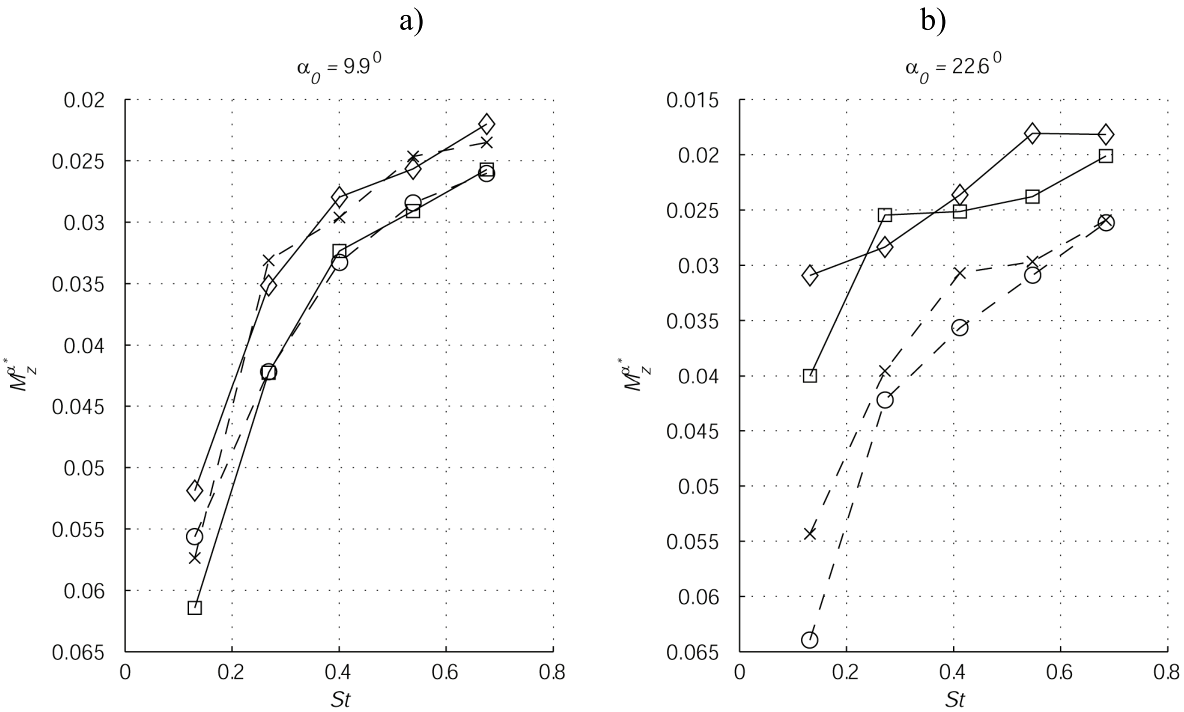

Fig. 6 – influence of GV on non-stationary derivatives $M_z^{\alpha*}$ for angles of attack α=9.9^0 (a) and α=22.6^0 (b):
– –x– – clear wing Re=7·10^5, – –◊– – clear wing Re=10·10^5, –□– GV Re=7·10^5, –o– GV Re=10·10^5.

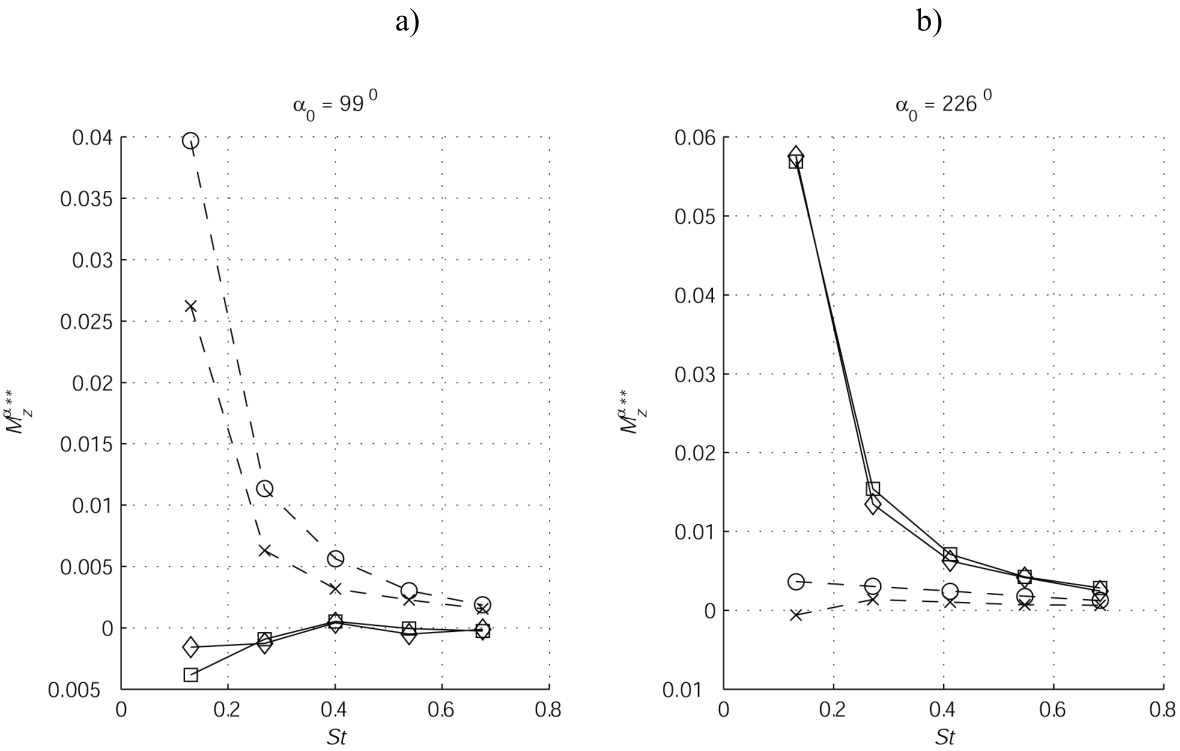

Fig. 7 – influence of GV on non-stationary derivatives $M_z^{\alpha**}$ for angles of attack α=9.9^0 (a) and α=22.6^0 (b):
– –x– – clear wing Re=7·10^5, – –◊– – clear wing Re=10·10^5, –□– GV Re=7·10^5, –o– GV Re=10·10^5.

In a vicinity of small angles of attack installation of generators of vortexes does not influence almost derivative $C_{ya}^{\alpha*}$ but non-stationary component $C_{xa}^{\alpha*}$ increases almost on 30 %. Research in a vicinity of critical angles of attack have shown significant influence from installation of generators of vortexes on derivative $C_{ya}^{\alpha*}$, that it was increased at 40 % compared with a corpulent wing, which testifies about большем deployment of a dynamic loop of relation C_{ya}=f(α) (a Fig. 8). Generators of vortexes have considerably affected the second derivatives of lift coefficients $C_{ya}^{\alpha**}$ and to drag coefficient $C_{xa}{}^{\alpha**}$ that are responsible for a corner of an inclination of a dynamic loop. This influence decreases with Strouhal number increase. On the big angles of attack the first derivative of pitching moment $M_z^{\alpha*}$ for all range of Strouhal numbers has considerably changed$^{\alpha}$. Also on 25 %, the second derivative of pitching moment $M_z{}^{\alpha**}$ for small Strouhal numbers has changed,$^{\alpha}$ but with increase in frequency of oscillations influence of generators of vortexes on $M_z{}^{\alpha**}$ sharply decreases.

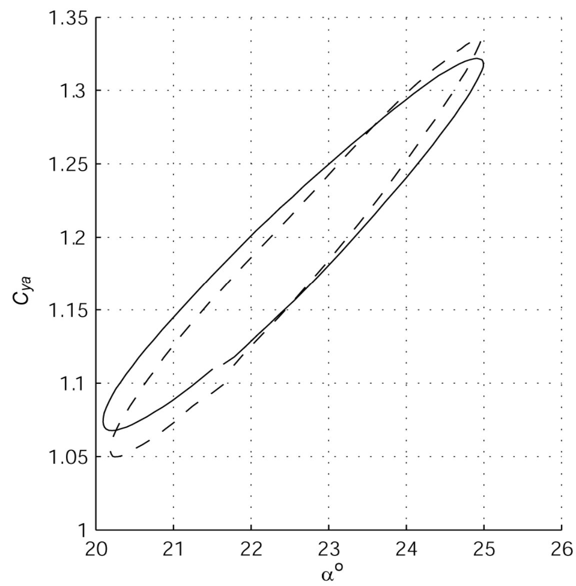

Fig. 8 - Comparison of dynamic loops to factor Cya that appear in oscillatory motion: -- a corpulent wing; - wing with GV.

Conclusions.

Dynamic tests of a wing with the established generators of vortexes have shown significant influence GV on non-stationary aerodynamic derivatives for all range of Strouhal numbers and Reynolds that was investigated. If in a vicinity of small angles of attack essentially changes the first derivative to drag coefficient $C_{xa}{}^{\alpha*}$ on critical angles of attack GV considerably change the first derivatives of all investigated aerodynamic coefficients breathes$^{\alpha}$: $C_{ya}{}^{\alpha*}$, $C_{xa}{}^{\alpha*}$, $M_z^{\alpha*}$. It indicates on большее deployment of dynamic loops on relations of corresponding aerodynamic coefficients to an angle of attackα. Influence of installation GV on the second derivatives of aerodynamic coefficients decreases with increase in frequency of oscillations. Results testify about grater unsteady effects at oscillation of a wing with the established generators of vortexes in comparison with oscillations of a clear wing.

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FLOWVISION-HPC: SOLVING COMPLEX AERODYNAMICS PROBLEMS OF AICRAFT DESIGNING

Applying FlowVision-HPC CFD code for different complex problems of aircraft designing is presented in this paper. Hydroplane gliding, helicopter emergency landing on the water surface, airfoil aerodynamic shape optimization, simulating aircraft airfoil and fuselage aerodynamic interaction are solved by unique CFD approach in frame of FlowVision-HPC code and are discussed in this paper.

FlowVision-HPC is general purpose Computational Fluid Dynamics (CFD) software for modeling 3D laminar and turbulent steady and unsteady gas and liquid flows in computational domain with complex curvilinear shapes. Finite Volume approach is the basis for the software numerical contents. High-accuracy numerical schemes, efficient numerical methods, and robust physical models guarantee reliable results. FlowVision is an easy to use CFD code with intuitively straightforward interface. The post-processor provides a user with up-to-date visualization methods and data processing tools. FlowVision-HPC operates on parallel computers with shared, distributed, and combined memory as well as on sequential computers and personal computers.

FlowVision-HPC is based on mesh with local dynamic adaptation. Initially mesh is Cartesian. Curvilinear boundary is Boolean subtracted from initially rectangular cells, thus, cells intersected by boundaries is transformed to arbitrary shaped polyhedrons [1]. This method was called by authors [1] as Sub-Grid Geometry Resolution (SGGR) Method, because of there is no any shape simplification of the curvilinear boundaries inside the cells. This is opposite to the well-known “cut-cell” method where curvilinear boundary is replaced in cell by plane. Fluid flow governing equations is solved by second order high accuracy numerical scheme [2] in spite of calculation mesh geometry complexity produced by SGGR. Navier-Stokes equations is solved by implicit split method [1]. Sparse algebraic system of equation is solved by Krylov type methods.

FlowVision-HPC is used for modeling different problems of aviation industry to make conclusion about effectiveness of its application for aircraft designing. It was used for simulating common and local aero-hydrodynamic of Be-200 [3] hydroplane. Different separate tasks were examined, among them:

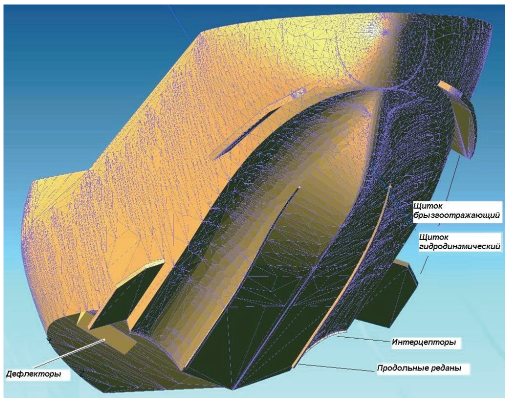


Figure 1. Hull of Be-200 aircraft

- Hydrodynamics of fuselage and distribution lift force over the hull,
- Influence of shield shape and position on wave waterlines near nose of the hull,
- Influence of shape and position of longitudinal steps on waves near hull and on hydrodynamic properties of hydroplane,
- Influence of interceptor and deflector positions on hydrodynamic torque and trim at take-off and landing operations.

Part of aircraft Be-200 fuselage with shields and steps are shown in Figure 1. Comparison simulation and experiment is shown in Figure 2. As one can see simulation and experiment has good convergence. At speeds less then 11 m/s, including motion with maximum hydrodynamic drag (“camber resistance”), results of simulation and experiment in TSAGI channel coincides with accuracy less then 5%.

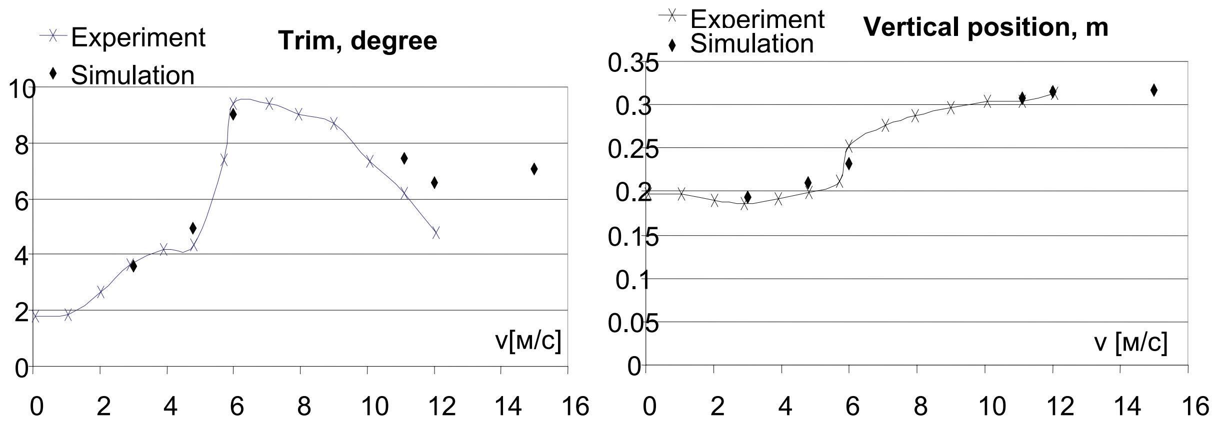


Figure 2. Comparison with experiment of trim and hull position of Be-200 aircraft model as function of speed

Helicopters accomplishing long flights above large water areas must obligatory have possibility for save emergency landing on the water surface (Figure 3). The ballonets are such device supplies this lending. The ballonets are inflated by crew in case of splashdown. Ballonet damps the landing forces and are used to secure the helicopter buoyancy.

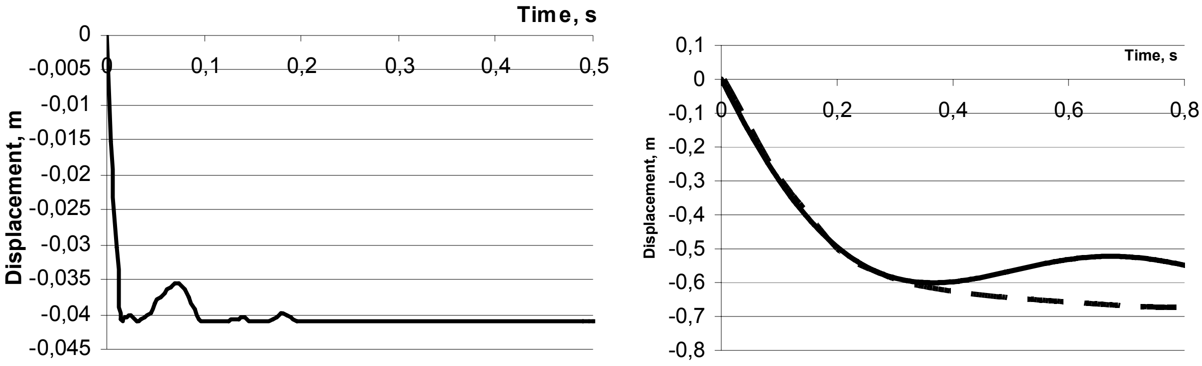
Figure 3. Helicopter with inflated ballonet

During the splashdown the ballonets are deformed and absorb the energy reducing the forces and making the emergency landing safe for the crew and helicopter. Accurate and adequate solving of this problem requires simultaneous simulation of water motion, ballonet deformation and impact of the helicopter hull with water; thus it requires modeling strong Fluid-Structure Interaction (FSI). This problem is solved by coupling two different codes: Abaqus FEA code and FlowVision-HPC CFD code. Helicopter hull, suspension of ballonets and ballonets themselves are defined in Abaqus as flexible bodies represented by FE mesh. The FE mesh is imported to FlowVision as one of the boundaries of the computational domain. The FE representation can freely move and deform in the computational domain [4].

One of the important characteristic of the landing or splashdown is speed of center mass and its acceleration. Using these values force acting on crew during impact is defined. Vertical displacement of center mass is shown in Figure 4 for both cases – impact with land (Figure 4,a) and splashdown (Figure 4,b).

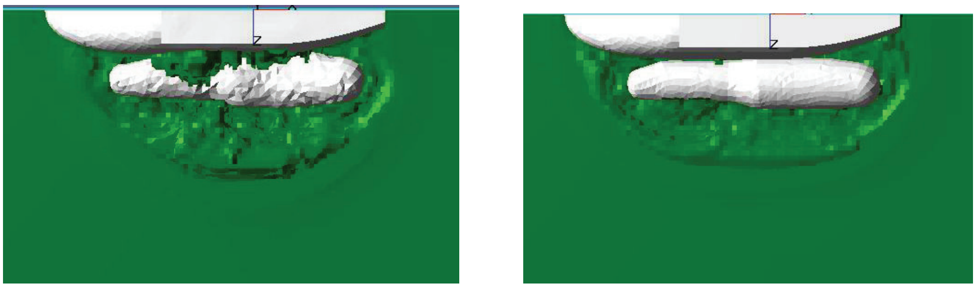
The influence of the ballonet stiffness on the behavior of the helicopter during splashdown is investigated. Center mass displacement is shown in Figures 4, b by solid and dashed lines. Simulation of helicopter with rigid ballonets is provided without coupling with Abaqus, only FlowVision is used for this simulation. One can see that ballonet deformation lead to deeper submersion of the helicopter in water. Acceleration as expected is larger in case of rigid ballonets.

Helicopter generates waves during impact with the water surface. These waves are shown in Figure 5. Wave generation results in oscillating vertical speed of helicopter with decreasing amplitude after impact. One can see that helicopter with soft ballonets generates waves more intensively. It results in better absorption of kinematical energy and lower accelerations during splashdown.



a) b)

Figure 4. Vertical displacement of helicopter center mass.
a) Landing. b) Splashdown; solid line – rigid ballonets; dashed line – deformed ballonets



a) b)

Figure 5. Comparison of water distribution over the helicopter for a) soft and b) rigid ballonets, time is 0.825 s after splashdown.

Optimizing position of different parts of aircraft mechanized wing for maximum lift and minimum drag is another challenging problem. This problem is solved by FlowVision-HPC code together with multicriterion and multiparameter optimization software IOSO [5]. Shape of the wing with part of the fuselage and experimental data is got from NASA resource [6].

Figure 6. Mechanized wing in aerodynamic tunnel (from [6]).

Airflow near the mechanized wing model is considered under the following conditions in aerodynamic tunnel: Attack angle is = 13^o, Reynolds number = 4.3x10^6, Mach number = 0.2.

Computational domain and mesh refinement near nose of the wing is shown in Figure 7. To compare results with experiments simulation is provided for different mesh adaptation near the wing. Result of comparison between experimental data and simulation of drag coefficient Cx and lift coefficient Cy is in Table 1. One can see good coincidence between experiment and simulation, so this mesh can be used for optimizing position of wing flaps to have maximum lift and maximum aerodynamic quality Cy/Cx.

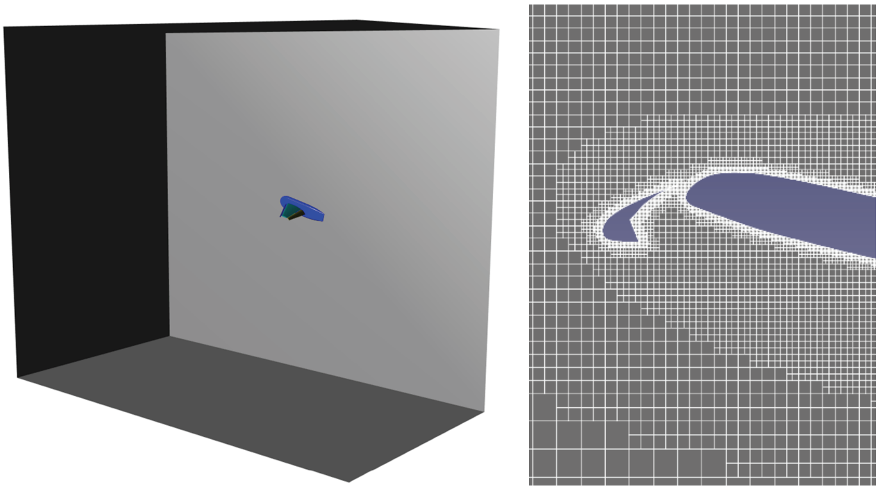


Figure 7. Computational domain and mesh refinement near the wing

	Cx	Cy
Experiment	**0.33**	**2.05**
Simulation, mesh ~2x10^6 cells	0.3384 (+2.6%)	1.949 (-4.9%)
Simulation, mesh ~3.7x10^6 cells	0.3358 (+1.8%)	1.998 (-2.6%)

Table 1. *Coefficients of drag Cd and lift Cp (relative accuracy)*

Results of such optimization are shown in Figure 8 in form of Pareto-set. To have this result IOSO software runs 120 simulations of airflow around the wing with different flaps positions. Pareto-set has 18 solutions. One can see, that increasing lift (solution (a) in Figure 8) results in decreasing aerodynamic quality, and, in contrary, increasing quality results in decreasing lift (solution (c)).

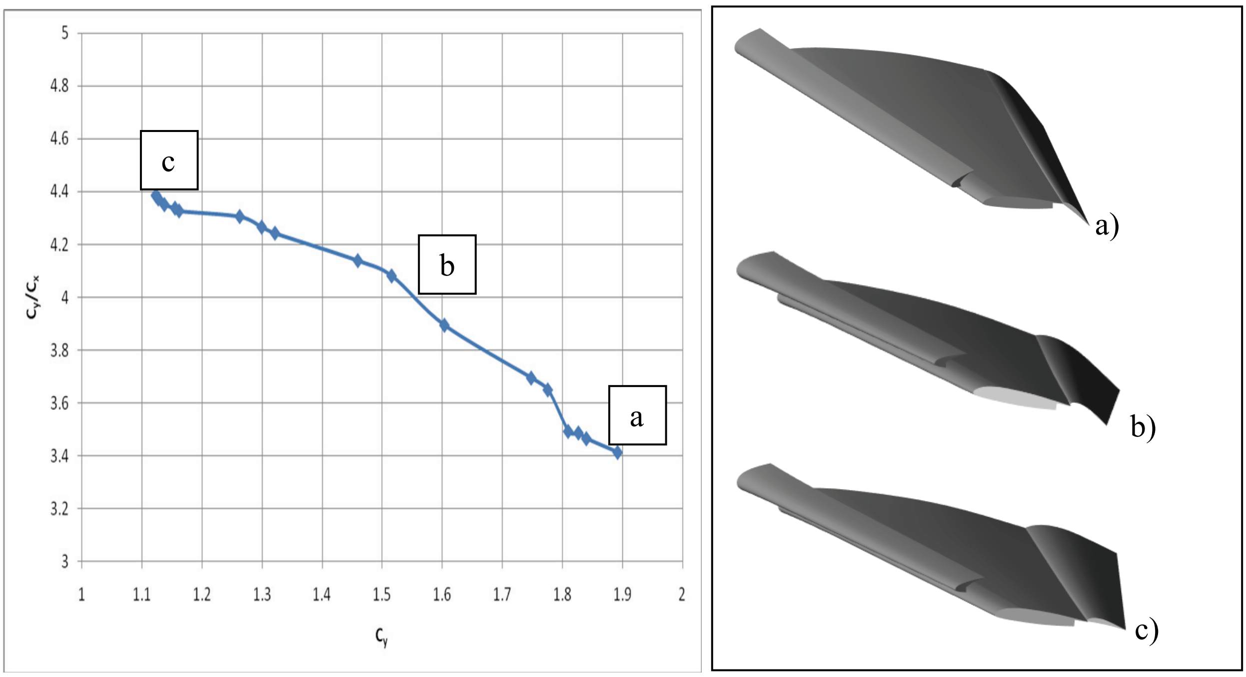


Figure 8. Pareto set of mechanized airfoil optimization and flaps position for maximum lift (a), maximum aerodynamic quality (c) and compromise solution (b)

Conclusion

FlowVision-HPC CFD code is based on advanced numerical methods for solving fluid and gas governing equations in computational domain with complex curvilinear shape and moving flexible boundaries allows to solve such complex problems like hydroplane gliding, helicopter emergency landing on the water surface, airfoil aerodynamic shape optimization, simulating aircraft airfoil and fuselage aerodynamic interaction. Comparison with experiment for each case study shows high reliability and accuracy of these methods.

Using FlowVision-HPC for aircraft designing process provides engineers with more accurate and detailed information of the processes during hydroplane gliding or helicopter splashdown. Some of this information cannot be got from experiments or full-scale aircraft testing.

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INFORMATION – ANALYTICAL SYSTEMS FOR EARLY DISTINGUISHING IN-FLIGHT NONSTANDARD SITUATIONS

It happened so, that aboard metering systems in fact produce excessive volume of information, which effective use may deliver principally new unique possibilities for early distinguishing and forecasting both nonstandard and dangerous in flight situations. Both systemic – analytical & systemic – creative approaches is the ideological base of information – analytical system conceptions and functioning algorithms creation, implementation and maintenance.

The classification of information obtaining processes may look like follows: the event itself establishment; calculation; metering; check in; diagnostics; image recognition. This classification is rather relative.

The event establishment in static systems looks like the most simple one. However, in dynamical systems, during the transient processes intervals, the problem of a dangerous or ultimately undesired event establishment becomes much more complicated, especially in multidimensional systems.

The problem in question is greatly complicated in metering systems with uncertainties.

To be certain let us consider the problem of wind shift event establishment and the event parameters identification to produce necessary control, minimizing air crash probability during glide path motion.

If we use the only angle-of-attack instrument readings we will not exactly guess: if the wind shift is the “child” of fair or contrary wind, of ascending or descending air flow.

So the reading of one device, named angle-of-attack instrument, would be necessarily added some other information to increase the wind shift event establishment and parameters identification precision.

And here some the aircraft spatial motion parameter, precisely metered, would come to our mind. To be more exact we mean; longitudinal and vertical accelerations and speeds, including ground speed and air speed, readed relatively air by variometer etc.

To our mind, the devices signals, processed properly, may successfully solve the problem of wind shift mentioned above.

The next problem of ultimate both importance and complexity is take off weight exact determining just before the departure. This problem is closely correlated with fuel genuine quality measuring, under any weather conditions: temperature, humidity etc.

If any airports was equipped with weighing device of necessary simple and reliable design, providing the weighing high precision. Alas! The necessity of creation new family of aboard metering systems, able to precisely forecast nonstandard situations becomes practically evident. Also it’s evident, that such kind of system would be provided the ability to properly analyze the complex (or the set) of aboard devices readings and to produce necessary controls for flight automatic control system.

It looks reasonable to name such systems “Information-analytical systems”.

The aircraft in flight current mass determining problem seems to be solved by information-analytical system exclusively. The system to be created for this sake would necessarily take into consideration the reading of piloting & navigating subsystem devices, fuel consumption measuring subsystem reading, the airframe proper aerodynamical characteristics and parameters, as well as their cross correlation peculiarities.

The next problem is precise measuring the aircraft both ground and in flight longitudinal centering current value. To our mind this problem may be solved by: only aboard metering devices reading and proper software use during flight; by use one additional weighing ground places device and proper extremely simple software at the ground. Here we also would use information-analytical system to ultimately simplify the centering current value metering technology.

The last, but not the least, problem is the task of each engine thrust current value determining at any moment of it's maintenance, including: start thrust, in flight thrust, the thrust of newly produced engine etc. To our mind the problem solution success would be predetermined by systemic-analytical and systemic-creative decisions able making information-analytical system. The main peculiarity of such system is considering each engine as a part of the system, including: air, air frame, landing, gear, runway, fuel consumption control system, piloting & navigating system. Such an approach seems to look the most productive way.

To be more certain it's reasonable to consider processes, taking place in the system: airframe; landing gear; runway; air, during different intervals of an airplane maintenance.

Let us suppose, that the aircraft motion along the runway may be described by equation (1)

$$m\frac{d^2x(t)}{dt^2} = F_{te}(t) - F_{ad}(t) - F_{fr}(t), \qquad (1)$$

where m- the aircraft mass,

x- aircraft displacement,

$F_{te}(t)$ - total thrust of engines,

$F_{ad}(t)$ - aerodynamical drag,

$F_{fr}(t)$ - friction force between landing gear wheels and runway;

Let $F_{ad} = K_1 V_x^2, K_1$ is known, (2)

$F_{fr} = K_2 V_x, K_2$ is known, (3)

x is measured in nonintermitten way, F_{te} & m are unknown and must be determined by proper information –metering technology and algorithm.

Totally we are to simultaneously determine instantaneous values of two parameters: m ,. F_{te}

For this sake it looks realizable to compose two independent metering equations (4), (5)

$$m\frac{d^2x(t_1)}{dt^2} = F_{te} - A(t_1), \qquad (4)$$

$$m\frac{d^2x(t_2)}{dt^2} = F_{te} - A(t_2), \qquad (5)$$

Let m and F_{te} are unknown, but constant. The system (4), (5) may be transformed to system (6), (7)

$$F_{te} - a_1 m = A(t_1) = A_1, \qquad (6)$$

$$F_{te} - a_2 m = A(t_2) = A_2, \qquad (7)$$

which solution may be done by Kramer method:

$$\Delta = \begin{matrix} 1 & -a_1 \\ 1 & -a_2 \end{matrix} = a_1 - a_2; \qquad \Delta m = \begin{matrix} 1 & -A_1 \\ 1 & -A_2 \end{matrix} = A_2 - A_1;$$

$$m = \frac{\Delta m}{\Delta} = \frac{A_2 - A_1}{a_1 - a_2}; \qquad F_{te} = \frac{\Delta F_{te}}{\Delta} = \frac{a_1 A_2 - a_2 A_1}{a_1 - a_2};$$

Surely, first of all we would convince ourselves, that equations (6) and (7) are algebraically independent.

Now let m, F_{te} are constant and unknown. The value of aerodynamical drag $K_1 V_x^2(t)$ may be measured, as well as coefficient K_1 is known.

This option of problem may be presented by system of metering equations (8), (9), (10)

$$\frac{md^2x(t_1)}{dt^2} = F_{te} - K_2 V_x(t_1) - K_1 V_x^2(t_1), \tag{8}$$

$$\frac{md^2x(t_2)}{dt^2} = F_{te} - K_2 V_x(t_2) - K_1 V_x^2(t_2), \tag{9}$$

$$\frac{md^2x(t_3)}{dt^2} = F_{te} - K_2 V_x(t_3) - K_1 V_x^2(t_3), \tag{10}$$

which may be transformed to system of three algebraic equations (11), (12), (13)

$$F_{te} - b_1 K_2 - a_1 m = B_1 \tag{11}$$

$$F_{te} - b_2 K_2 - a_2 m = B_2 \tag{12}$$

$$F_{te} - b_2 K_2 - a_2 m = B_2 \tag{13}$$

which solution looks like follows:

$$\Delta = \begin{matrix} 1 & -b_1 & -a_1 \\ 1 & -b_2 & -a_2 \\ 1 & -b_3 & -a_3 \end{matrix}; \qquad \Delta F_{te} = \begin{matrix} B_1 & -b_1 & -a_1 \\ B_2 & -b_2 & -a_2 \\ B_3 & -b_3 & -a_3 \end{matrix};$$

$$\Delta K_2 = \begin{matrix} 1 & B_1 & -a_1 \\ 1 & B_2 & -a_2 \\ 1 & B_3 & -a_3 \end{matrix}; \qquad \Delta F_m = \begin{matrix} 1 & -b_1 & B_1 \\ 1 & -b_2 & B_2 \\ 1 & -b_3 & B_3 \end{matrix};$$

$$m = \frac{\Delta m}{\Delta}$$

$$F_{te} = \frac{\Delta F_{te}}{\Delta};$$

During climbing and horizontal flight the slogan $K_2 V_x(t_1)$ may be excluded from equations (8), (9), (10), and this system will look like follows

$$m\frac{d^2x[(t]_1)}{dt^2} = F_{te} - K_1 V_x^2(t_1), \tag{14}$$

$$m\frac{d^2 x[(t]_2)}{dt^2} = F_{te} - K_1 V_x^2 (t_2), \tag{15}$$

which may be transformed to the system of two algebraic equations (16), (17)

$$F_{te} - c_1 m = D_1, \tag{16}$$
$$F_{te} - c_2 m = D_2, \tag{17}$$

which solution, in turn, looks like follows

$$\Delta = \begin{matrix} 1 & -C_1 \\ 1 & -C_2 \end{matrix}; \quad \Delta F_{te} = \begin{matrix} D_1 & -C_1 \\ D_2 & -C_2 \end{matrix};$$

$$m = \frac{\Delta m}{\Delta}$$
$$\Delta m = \begin{matrix} 1 & D_1 \\ 1 & D_2 \end{matrix}; \quad F_{te} = \frac{\Delta F_{te}}{\Delta};$$

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AN AIRCRAFT AIR SPEED METERING SYSTEM DYNAMICAL ERROR DECREASE

Air speed metering system is an important piloting & navigating arrangement, which both static and dynamical errors may be followed by ultimately undesired sequences, including air crashes.

Static errors nature has been researched thoroughly. Dynamical errors nature is conditioned by numatic inertia of air mass inside pipelines, feeding the system in question with aerial input signals: velocity head & static pressure. The static pressure transfer pipeline time constant, which may be represented like an aperiodic dynamical link, greatly differs the velocity head pipeline transfer time constant. This very difference is physical hardly eliminatable reason of the system dynamical errors.

The task to be solved analytically, not by numerical methods, is formulated like follows.

An aircraft Air Speed Metering System (ASMS), which simplified block-diagram is depicted at Fig.1 is simultaneously feeded by two aerial signals: Ps signal of instantaneous atmosphere static pressure, Pd – velocity head pressure.

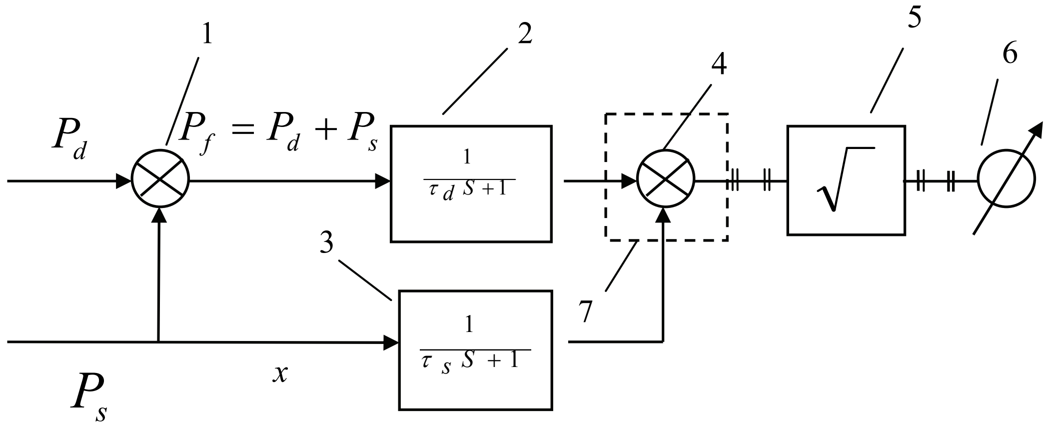

Fig. 1. An aircraft air speed metering system block-diagram.

1- head velocity gauge;
2- head velocity pipeline;
3- static pressure pipeline;
4- membrane box;
5- functional transformer;
6- indicator;
7- hermetical cause;

It's known apriori, that $\tau_s >> \tau_d$

Moreover, it's impossible to exactly measure both τ_s and τ_d. In other words, current values of these time constants would be considered unknown.

It's absolutely evident, that any change of atmospheric pressure would reach the membrane box much quicker, than the volume of hermetical cause.

That is the physical reason of the ASMS dynamical errors, conditioned by static atmospheric pressure during climbing or descending, for instance.

To be certain, let the static pressure is of jump kind $+\Delta P_S$.

The ASMS output signal may be represented by equation (1)

$$U(t) = \frac{\rho V^2}{2} + \Delta P_s(1 - e^{\frac{t}{\tau_d}}) - \Delta P_s(1 - e^{\frac{t}{\tau_s}}), \quad (1)$$

where ρ - air density;
V- air speed;

Let ΔP_S to be also unknown.

To bring ASMS dynamical error to zero it's necessary to produce the control Y(t), which would satisfy the equation (2)

$$Y(t) = \Delta P_s(1 - e^{\frac{t}{\tau_d}}) - \Delta P_s(1 - e^{\frac{t}{\tau_s}}) = 0, \quad (2)$$

It means, that Y(t) would be equal to

$$Y(t) = \Delta P_s(1 - e^{\frac{t}{\tau_s}}) - \Delta P_s(1 - e^{\frac{t}{\tau_d}}) = 0, \quad (3)$$

or $Y(t) = \Delta P_s(e^{\frac{t}{\tau_d}} - e^{\frac{t}{\tau_s}}),$ (4)

To create necessary control according to (4) it's necessary to find out instant values of ΔP_S, τ_d and τ_s, preferably by analytical, not numerical, algorithms. In fact the τ_d and τ_s current values completely characterize the corresponding pipelines technical state, e.g. in such a way the diagnostics task may be solved.

Further we compose the system of four metering equations (5), (6), (7), (8), supposing that time calculation beginning moment coincides with the beginning of time axis.

Also we introduce the following notices:

$$p = e^{\frac{t}{\tau_d}}, q = e^{\frac{t}{\tau_s}}, t_2 = 2t_1, t_3 = 3t_1$$

$$U(t_1) = \Delta P_s(p - q) + U_0, \quad (5)$$

$$U(t_2) = \Delta P_s(p^2 - q^2) = (p - q)(p + q) + U_0, \quad (6)$$

$$U(t_3) = \Delta P_s(p^3 - q^3) = (p - q)(p^2 + pq + q^2) + U_0, \quad (7)$$

$$U(t_4) = \Delta P_s(p^4 - q^4) = (p - q)(p + q)(p^2 + q^2) + U_0, \quad (8)$$

Let us consider that initial condition $U(0) = \frac{\rho V^2}{2}$ by some instrumental way may be excluded from consideration.

By successive dividing equation (6) by equation (5), equation (7) by equation (6), and equation (8) by equation (7) we can obtain

$$\frac{U(t_2)}{U(t_1)} = C_{21} = p + q, \quad (9)$$

$$\frac{U(t_3)}{U(t_2)} = C_{32} = \frac{p^2 + pq + q^2}{p+q}, \tag{10}$$

$$\frac{U(t_4)}{U(t_3)} = C_{43} = \frac{(p+q)(p^2+q^2)}{p^2 + pq + q^2}, \tag{11}$$

It is worth notion that thanks to the observation

$$\begin{aligned} C_{32}C_{43} &= p^2 + q^2 \\ aC_{21} &= p+q, \end{aligned} \tag{12}$$

And

$$\frac{U(t_2)}{U(t_1)} = C_{21} = p+q, \tag{9}$$

the system (12), (9) may be solved relatively p and q

$$p = C_{21} - q, \tag{13}$$

The square equation (13) solution brings the parameter q value. After that the linear equation (9) brings the parameter p current value. It means that time constants τ_s and τ_d may be considered found out. Then anyone may obtain the static pressure jump ΔP_S value from equation (5).

Here it's necessary to specially underline, that the problem has been solved by taking sufficient quantity quants of output ASMS signal under circumstance of three uncertainties!

So the task of the control creation, minimizing current value of ASMS dynamical error may be considered solved.

If the ASMS output signal observation beginning doesn't coincide with the time axis zero, the same task solution attempt delivers the following kind of output signal

$$U(t) = \Delta P_s (1 - e^{\frac{t_n}{\tau_d}}) - \Delta P_s (1 - e^{\frac{t_n}{\tau_s}}) = 0, \tag{14}$$

Where n=i, i+1, i+2, i+3, i+4, i+5.

The dynamical situation of discreet accounts obtaining is presented at the Fig.2

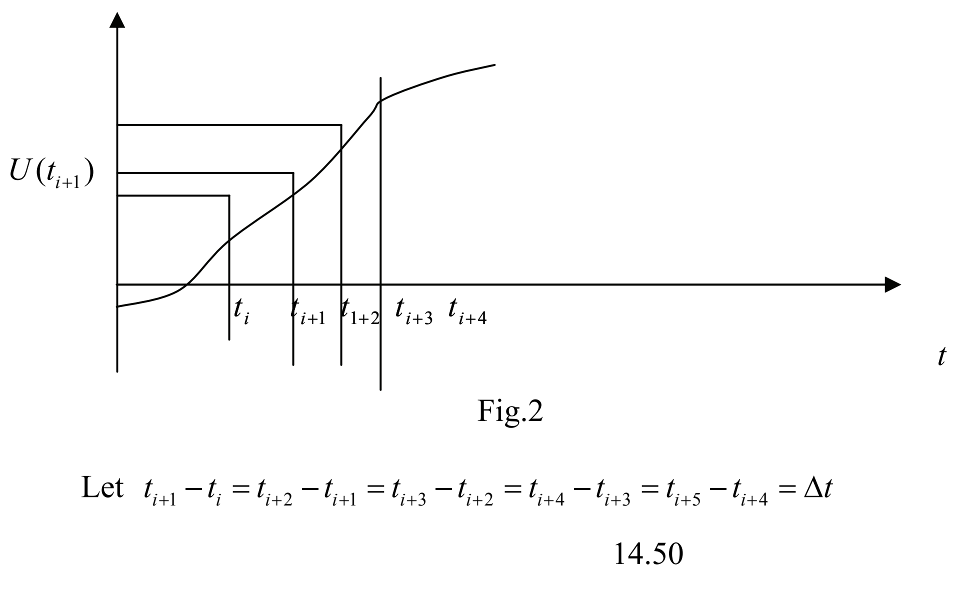

Fig.2

Let $t_{i+1} - t_i = t_{i+2} - t_{i+1} = t_{i+3} - t_{i+2} = t_{i+4} - t_{i+3} = t_{i+5} - t_{i+4} = \Delta t$

Taking into account the assumptions made, one may obtain the system of metering equations

$$U(t_1) = \Delta P_s(e^{\frac{t_i}{\tau_s}} - e^{\frac{t_i}{\tau_d}}) \tag{15}$$

$$U(t_{i+1}) = \Delta P_s(e^{\frac{t_i+\Delta t}{\tau_s}} - e^{\frac{t_i+\Delta t}{\tau_d}}), \tag{16}$$

$$U(t_{i+2}) = \Delta P_s(e^{\frac{t_i+2\Delta t}{\tau_s}} - e^{\frac{t_i+2\Delta t}{\tau_d}}), \tag{17}$$

$$U(t_{i+3}) = \Delta P_s(e^{\frac{t_i+3\Delta t}{\tau_s}} - e^{\frac{t_i+3\Delta t}{\tau_d}}), \tag{18}$$

$$U(t_{i+4}) = \Delta P_s(e^{\frac{t_i+4\Delta t}{\tau_s}} - e^{\frac{t_i+4\Delta t}{\tau_d}}), \tag{19}$$

$$U(t_{i+5}) = \Delta P_s(e^{\frac{t_i+5\Delta t}{\tau_s}} - e^{\frac{t_i+5\Delta t}{\tau_d}}), \tag{20}$$

Thorough the system presented is nonlinear, it's possible to solve it analytically.
It's reasonable to use the following notices

$$p = e^{\frac{t_i}{\tau_s}}, q = e^{\frac{t_i}{\tau_d}}, r = e^{\frac{\Delta t}{\tau_s}}, s = e^{\frac{\Delta t}{\tau_d}}$$

and to transform the system $(15) \div (20)$ into system $(21) \div (25)$.

$$U(t_{i+1}) - U(t_i) = C_{10} = \Delta P_s p(r-1) - \Delta P_s q(s-1), \tag{21}$$

$$U(t_{i+2}) - U(t_{i+1}) = C_{21} = \Delta P_s pr(r-1) - \Delta P_s qs(s-1), \tag{22}$$

$$U(t_{i+3}) - U(t_{i+2}) = C_{32} = \Delta P_s pr^2(r-1) - \Delta P_s qs^2(s-1), \tag{23}$$

$$U(t_{i+4}) - U(t_{i+3}) = C_{43} = \Delta P_s pr^3(r-1) - \Delta P_s qs^3(s-1), \tag{24}$$

$$U(t_{i+5}) - U(t_{i+4}) = C_{54} = \Delta P_s pr^4(r-1) - \Delta P_s qs^4(s-1), \tag{25}$$

So the problem formulated may be solved analytically by nonnumeric algorithms.

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AIR TRANSPORT IN POLAND IN THE AGE OF WORLD ECONOMIC CRISIS

The last decade is a period of big changes in the air transport in the world. Recently many factors have influenced this market positively and negatively, leading to its rapid growth or spectacular crash. Factors that should be mentioned are:

–growing oil prices,

–changes in a structure of the air sector, related to the intensification of competition between air hauliers, especially as a result of emergence of low-cost carriers,

–growing costs of functioning connected with the change of requirements concerning safety of flights, as a result of the terrorist attack in New York on 11 September 2001,

–environmental factors,

–the world economic crisis.

This presentation concentrates on effects of the world economic crisis and its major influence on air transport in Poland.

The cause of the biggest, since the time of the crisis of 1929-1933, recession on world markets was a collapse of mortgage credits with the increased risk market in the United States. This moment influenced the condition of all businesses and began the economic crisis of the 21st century. The effects of the crisis in Poland are lower than in other countries. Let us, for example, compare dynamic of Gross Domestic Product real growth rate in Poland, European Union, United States and Japan. As we may see on a graph below, dynamic of the economic activity, defined as the value of all goods and services produced less the value of any goods or services used in their creation, was higher in Poland than in considered countries.

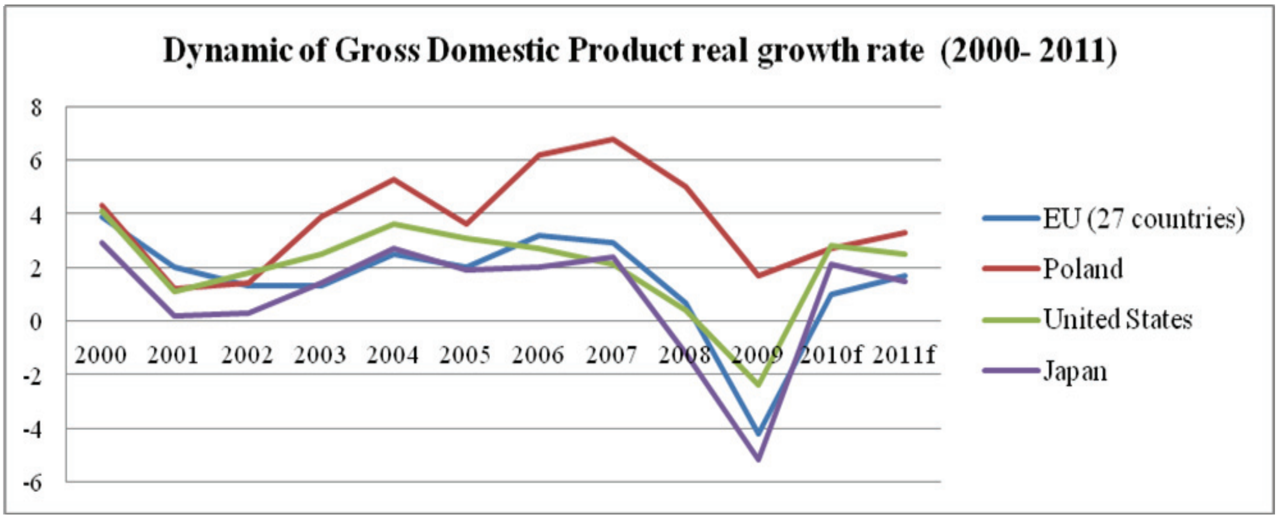

Fig. 1. Source: Eurostat

Transportation sector is known to play crucial role in economic development. It is closely connected with surroundings, in which it functions, and its growth results from planned needs of the economic system. Analysis of the influence of the air transport on the development of the world economy shows that this sector income, in spite of some fluctuations, has a growing tendency, and in comparison to profits of other economic sectors, it is very high. In 2008 income of air transport sector gained 564 billion USD; however planned income for 2010 is 522 billion USD. Passenger transport has the most essential influence on get income, in the year 2008 they constituted close to the 78% of total income of the sector, the year 2010 is scheduled to be about 76%. Such state of affairs results from a rising style of life and a need of fast and reliable transport. In this case, the time is treated as basic economic value.

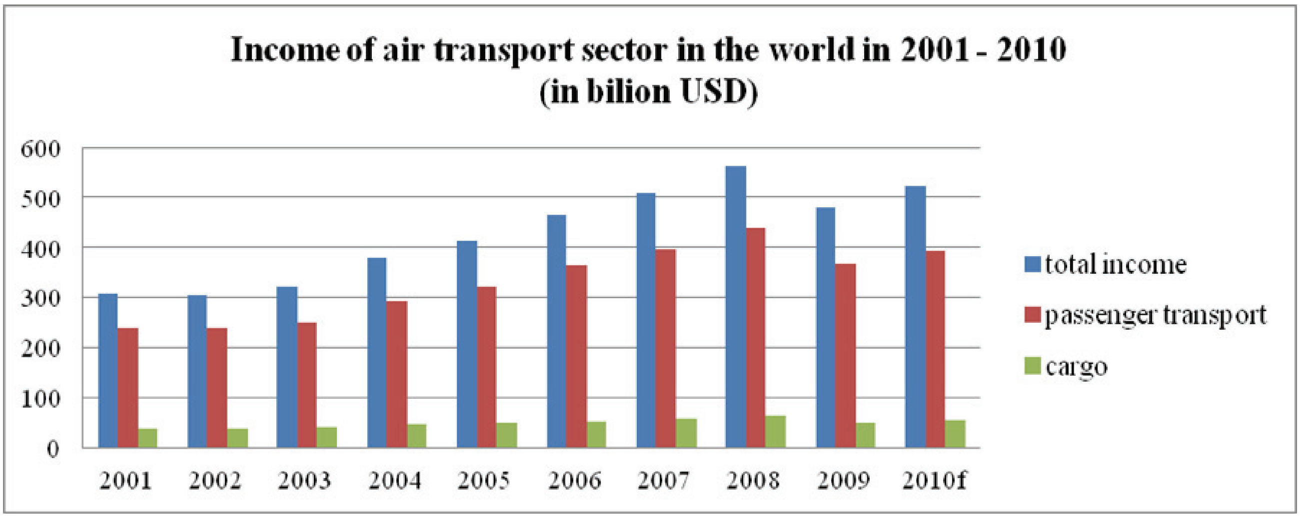

Fig. 2. Source: IATA

In Poland income of air transport sector is also impressive. In spite of economic hesitations in this area, increasing trend of income is visible, although the crisis affected adversely the profitability of the sale and the wealth managers of airports and hauliers.

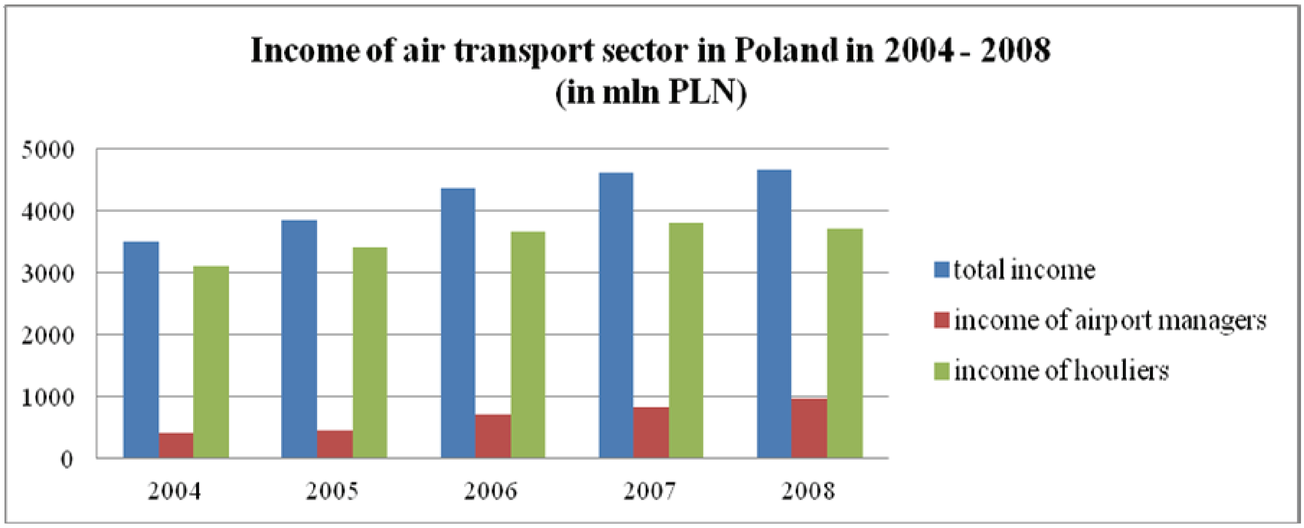

Fig. 3. Source: ULC

Such economic situation of Polish air transport is created by many factors. In spite of certain symptoms of the crisis the assessment of the state of the considered sector is positive. With reference to it, one should combine this phenomenon with the fact, that Polish air transport is not as developed as, for example, air transport markets in Spain, Greece or Italy, where the largest decrease in the number of passengers was recorded in the last years.

Polish market of passenger air transport has developed dynamically in the last years. The main reason of this situation is a liberalization of the market, connected with membership of Poland in the European Union, entering foreign hauliers to home air transportation market, opening by them new air connections, emergence of low-cost carriers, development of the airport infrastructure financed from the European Union funds, domestic and local budgets. According to IATA – Poland is in the lead in terms of the dynamism of the growth in passenger transports.

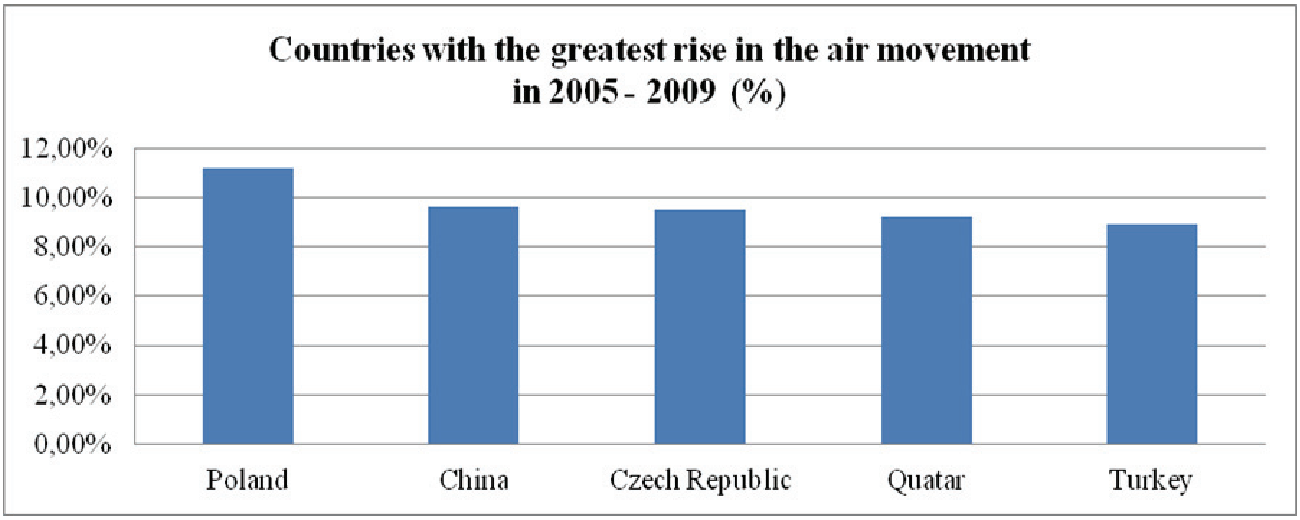

Fig. 4. Source: M. Pilarczyk, „Polskie regionalne porty lotnicze w obsłudze ruchu pasażerskiego", str. 42, [w:] Logistyka i Transport, zeszyty naukowe 2(3)/2006, Międzynarodowa Wyższa Szkoła Logistyki i Transportu we Wrocławiu, Wrocław 2006, http://www.test.msl.com.pl/pliki/zeszyty/nr3.pdf

The dynamism of the growth in the number of passengers in 2004-2008 is assessed on the level of the 234%. In 2004 Polish airports waited on scarcely 8.834.912 passengers, in comparison the number in 2008 was 20.657.754. Only year 2009 diverges lightly from the earlier growth trend, an 8.25% fall appeared. The number of passengers decreased to 18.945.857 and was lower than in 2007.

Fig. 5. Source: ULC

Optimistic ULC forecasts from 2008, which concerned numbers of passengers waiting on at the air transport in the years 2003-2030, were not entirely true. The end of 2008 and 2009 entirely changed the direction of movement in the air transport.

From analysis of ULC presented in April 2010, correcting earlier forecasts, it is obvious that in 2030 the number of 80 million passengers waiting on annually is not possible, as assumed before. Actually, it is assessed that, at quite fast growth of the number of passengers since 2010, transporting over 63 million passengers in 2030 is possible.

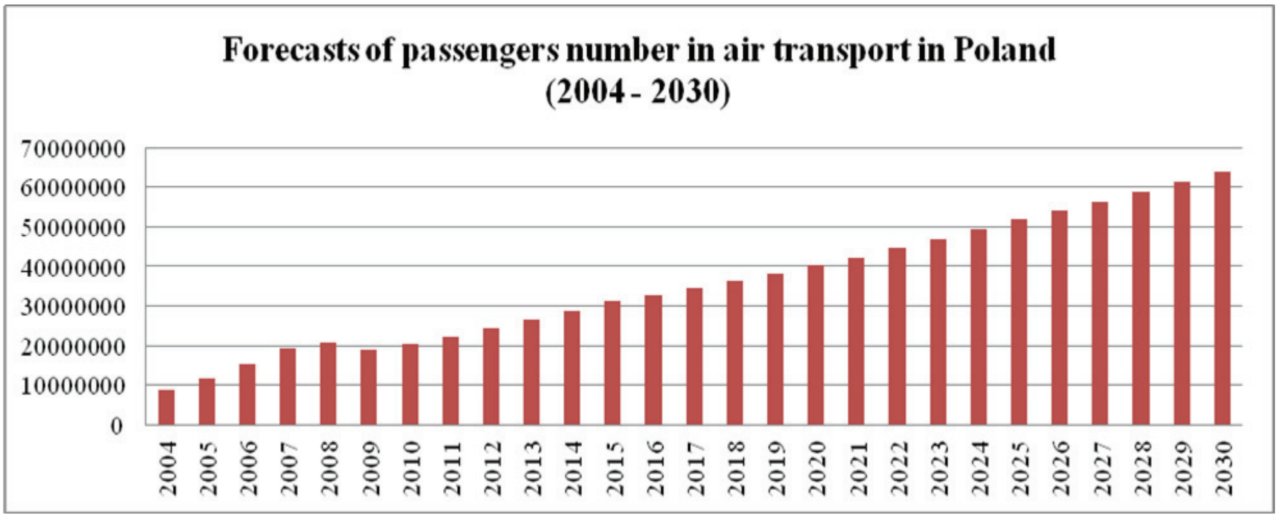

Fig. 6. Source: ULC

In the course of a few years a gradual decentralization of the air traffic has been observed in Poland. From 2007 participation of a Warsaw airport in passenger transport was reduced in favor of different regional airports. Although the Okecie Airport has strong position on the map of Polish airports, statistics of Eurostat show that two Polish regional airports noted the greatest growth of passengers number: Poznan and Katowice. This is a result of increasing operations performed by low cost carries during the years.

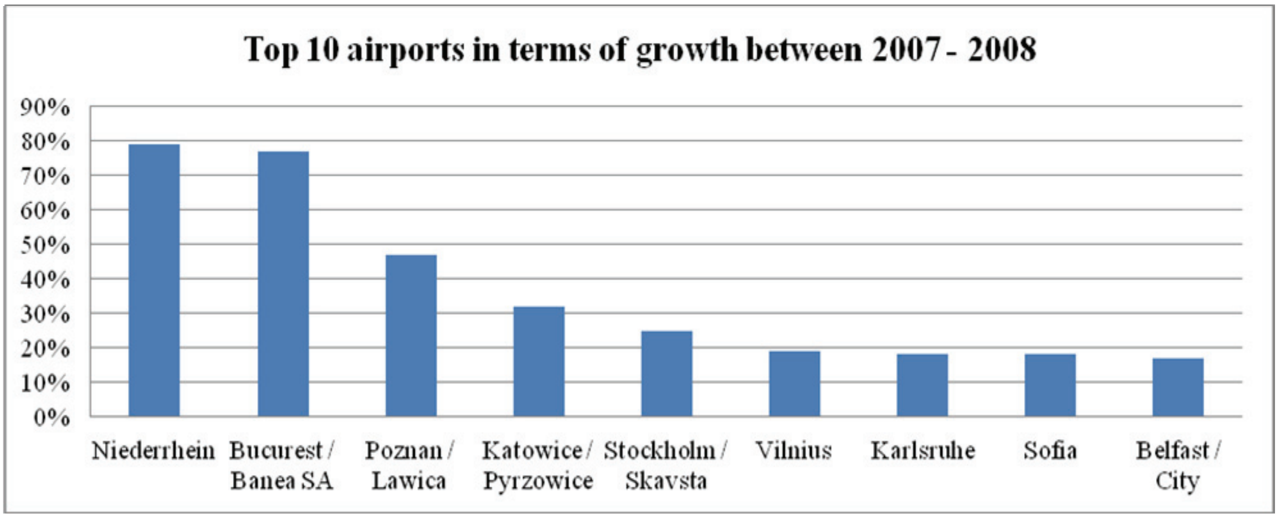

Fig. 7. Source: Eurostat

The rise in the number of low-cost carries, that are active in the Poland, generated a new demand for air transport. Thanks to them, an accessibility to air services increased. Attractive offers on more competitive conditions and open labour markets in countries of the Union European additionally encourage to use these services. Tourist transport and a number of journeys connected with seeking for work has increased.

In spite of the participation of low-cost carriers, the air transport has a growing tendency, still the main position among hauliers in Poland has LOT – Polish Airlines. At the moment the economic situation of this Polish haulier is not beneficial. The main reason of such situation is a high cost of its functioning. In order to remove the erroneousness, the repair programs, based on the change of the company managing system, are being prepared. For example, they provide implementation of the outsourcing.

Presented remarks and forecasts show that it is possible to expect further development of the Polish air transport. The world financial crisis is a form of the test of the sector effectiveness and it enables to eliminate these participants of the market and the principles of activity, which are uneconomical.

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COMPUTATIONAL FLUID DYNAMICS METHODS USED IN UNMANNED AERIAL VEHICLE DESIGN

The work includes review of basic methods of computational fluid dynamics using numerical methods to solve aerodynamic and structural problems occurring in the design of unmanned aerial vehicles.

Introduction

The paper provides an overview of the numerical methods used by the authors by performing some aerodynamic calculations and developing a truly new UAV concept. Computational work and design of the project have recently begun. The authors hope that the discussion of their work will help them to avoid some mistakes that are often very difficult, if not impossible to avoid so that the outcome of their project could rise into the air and land safely. The aim of this paper is also to attract interested people and institutions that would be willing to cooperate on this project. The project has a Polish patent with the application No P.389964 dated on 12/21/2009. The aircraft is a combination of airplane and airship. A well thought solution to the hull stringers enables changing its volume. This allows the ship can fly quickly to the destination and then hang up like a balloon, or move like a blimp. The following summary presents a rough idea of this solution. Although the structure may seem too complicated, it is still just a hybrid of the airplane and airship. Due to the fact that the aerodynamics of the first and the second solution is well known, there is no concern that this ship will not fly, however further work on the construction of the new technological solutions is desired.

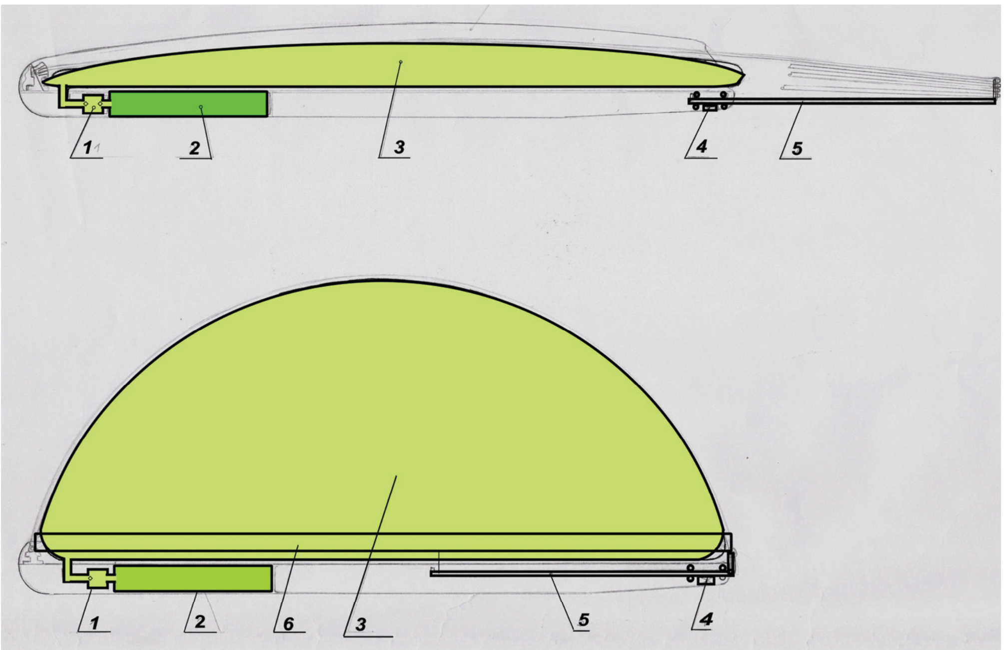


Fig. 1. Unmanned aerial vehicle with the fuselage of variable volume

Principle: Engine (4) through the gear causes movement of the bracket (5) which is fastened to one of the two ends of the movable frame. This causes the approach of both ends, and bulging stringers of the fuselage. At the same time lighter than air gas through the open valve is recessed into the shell (3) causing it to discharge. After filling the plane becomes a airship or balloon. To make a fuselage, use the motor with gearbox (4) Move the bracket (5) so as to prolong the fuselage stringers, while the gas is removed from the shell to the atmosphere through the valve (1) or pump using motorized pumps (1) the tank (2) The authors believe that it is possible to achieve endurance from 5 to 14 days (due to the porous coating). The most frequently used numerical methods in the calculation aerodynamic of aircraft are Panel Methods, Finite Element Method (FEM) and Finite Volume Method (FVM).

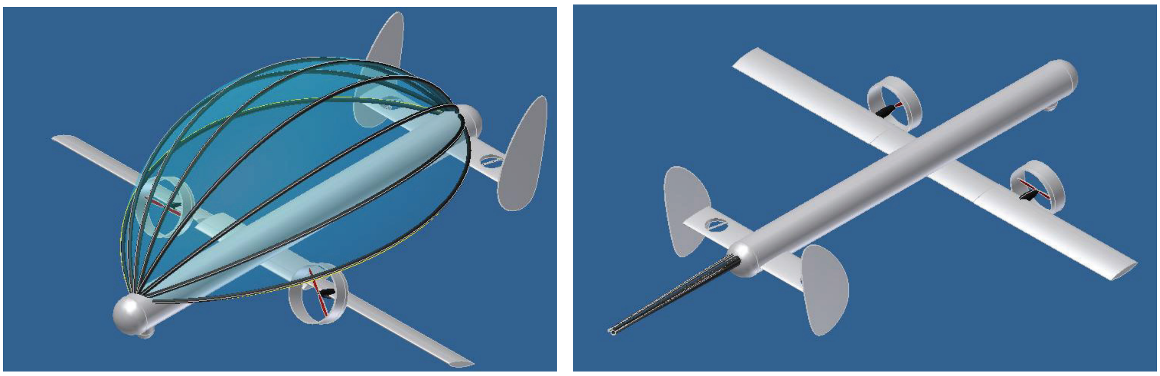


Fig.2. Unmanned aerial vehicle in flight configuration airship and airplne, made in Autodesk Inventor

Panel Methods

In many cases low cost of the calculation methods offset their lower accuracy. This applies particularly to the aircraft modeling. In general, we can often produce a new wing profile faster and cheaper than calculating it using a dense grid of the finite element method or finite volume method. The accuracy of the potential methods is often increased by using them together with the analytical solution of the boundary layer. Such solution is used in most programs, both free open source XFOIL, XFLR5 and commercial MSES, PANUKL ones. There are many methods of the panel types differing in respect to the boundary elements used and to the type of applied boundary conditions (Neumann or Dirichlet). To solve problems in which we expect the occurrence of zero circulation is sufficient to use the same sources, distributions, and for the cases where there is a lift force, distributions of the vortices or dipoles should be used, sometimes together with the distributions of sources. Methods that rely on the distribution of the discrete vortices, stable or linear distributions of variables are also known as methods of surface distribution of vorticity, the SVM-Surface Vorticity Methods. In the panel methods the surface of the flowed body is divided into boundary elements called panels. Determination of the flow forces acting on a body placed in the flow is reduced into finding the values of functions describing the distribution of these peculiarities (e.g., spendings and reductions, circulation or vortex dipole moments). The characteristic of the impenetrable wall of the contour profile is used here. The result is a system of linear equations that allows the calculation of hydrodynamic parameters needed. Then, the tangential velocity and the Bernoulli equation, pressure distributions are determined. The distribution of the parameters of the potential flow is calculated with a relatively high accuracy. It allows calculating the parameters of the boundary layer and thus makes it possible to calculate the resistance of profiled and the nature of boundary layer separation point and the plane of the profile. The most important assumptions made while constructing the physical model of the flow are: fluid non-viscosity and non-vortex (except for a trace of vortex). Viscosity effect is simulated by a Kutta condition-Zhukovski, which can be interpreted as a zero circulation at the trailing edge per unit length. The mathematical model consists of the following equations; Euler's equation, continuity equation, and state equation. The calculation method depends strongly on the modeling of the aircraft's solid. In principle, two approaches are commonly used for this purpose. The object is being modeled either by using thin surfaces or as a three-dimensional block. The three-dimensional surface of the plane's solid is usually divided into rectangular flat panels. It is assumed that the vortex track is flat and runs parallel to the undisturbed velocity and to the chord (blade)[1,2,4].

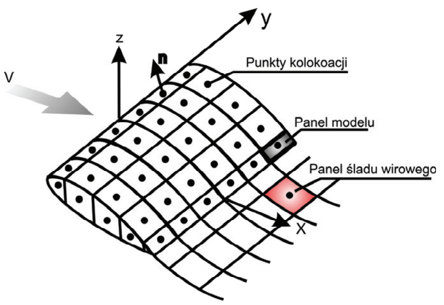


Fig. 3. Approximation of the surface of the aircraft solid using system panels. Authors' own research based on [4].

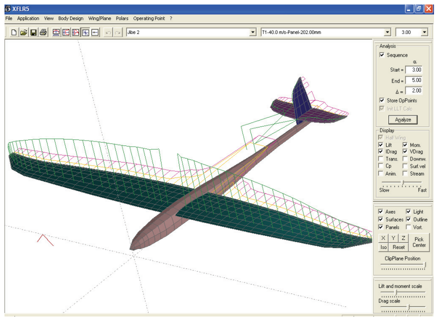


Fig. 4. Distribution of the lift, drag- XFoil counted by using XFLR5. Authors' own research.

Finite Volume Method

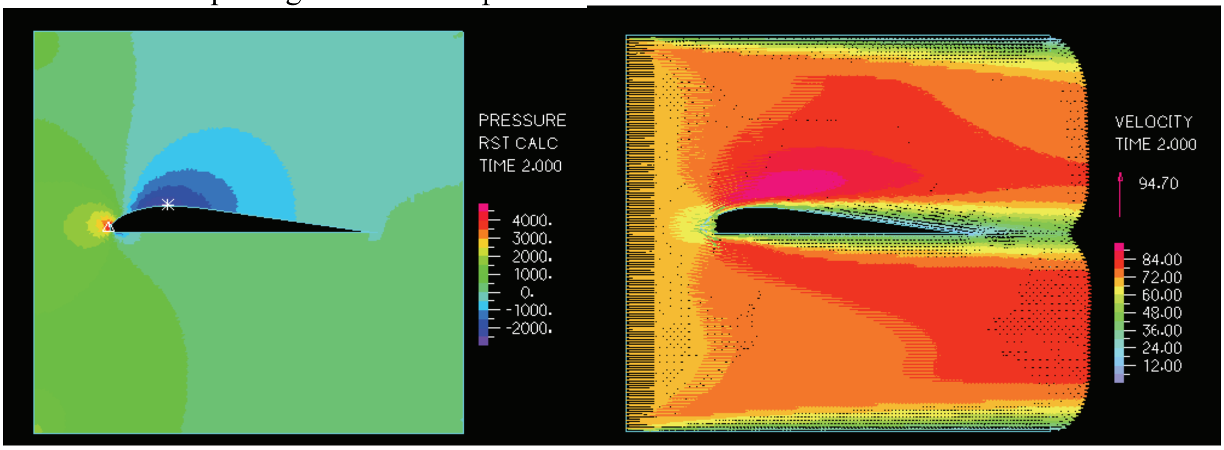
Navier-Stokes equations are much more capable of modeling the phenomena occurring in the fluids. This method was developed to solve problems where the principle of the continuity of the variable fields in the area under consideration does not need to be satisfied. It is based on the analysis of the variable fields' behavior within the grid cells and not in the grid nodes. Fluid movement in the domain describes the Navier – Stokes equation (1) whose parts refer to the unsteady fluid motion, convection, fluid motion under the force of buoyancy, diffusion, disturbances' deterioration (this part is responsible for modeling of the viscous items and for the generation - taking into account external forces acting on the fluid (e.g., rapid pressure changes on the propeller)[3].

$$\underbrace{\frac{\partial}{\partial t}\int_V \rho\phi\, dV}_{\textbf{Unsteady}} + \underbrace{\oint_A \rho\phi\,\mathbf{V}\cdot d\mathbf{A}}_{\textbf{Convection}} = \underbrace{\oint_A \Gamma\nabla\phi\cdot d\mathbf{A}}_{\textbf{Diffusion}} + \underbrace{\int_V S_\phi\, dV}_{\textbf{Generation}} \qquad (1)$$

Major components of the package are Gambit pre-processor, grid generator, Tgrid generator, and editor of the unstructured grid, which is also one of the components used in the regeneration of the grid. The main program running all the calculations is the CPU Fluent, post processor is used for presenting the results of the calculations visually. In the finite volume method grids on which calculations are performed have a big influence on the accuracy. The grid can have a certain topological structure (structural network), which accelerates the calculation. It may also lack such a structure (unstructured mesh) and then it is very easily to make a grid around the object with a complicated shape. They can create volumes of 4, 5, and 6 -dimensions, it is also possible to calculate the elements with more dimensions (polyhedral)[6]. Often a network of mixed (hybrid) grid is created, where the boundary layer are modelled with several structural layers of the grid, while all other area is non-structural. Particular attention and interest should be paid to the fact that ANSYS FLUENT has already solved the problem of modeling the changing tilt of the rotorcraft's wings while changing flight modes. In addition, the package has the ability to simulate multiphase flows, track cloud particles with a given distribution of density, and modelling the interaction with liquid particles suspended in it. The possibility of simulating the stationary rotor by the means of the time-averaged surface pressure jump (FAN model).

Finite Element Method

The most commonly used programs/ packages for the MES analysis that are cuurently available on the market are: ABAQUS, ADINA, ANSYS, FIDAP, MSC / NASTRAN, MSC.Marc, MSC / PATRAN, MSC / Fatigue, OPERA-2D [7]. The finite element method FEM, just like the finite volume is a numerical method used for approximation of the Navier – Stokes partial differential equations. ADINA CFD package is built similarly to the ANSYS FLUENT. In the FEM calculation area is divided into many sub-areas (the so-called mesh). Analysed continuous centre is represented by the "averaging" the physical state of the body parts.[7] The functions, which are solutions to the partial differential equations, are approximated locally in each finite element using special test continuous functions that are clearly determined by their values at certain points called nodes (nodes lie inside the element or on its boundary). Exemplary calculations of the pressure and velocity distribution done in the package ADINA are presented below.



Both the FLUENT software and ADINA, ANSYS, ABAQUS packages enable the analysis of very wide range of flow phenomena and thermodynamic data. These packages are becoming more versatile; they have various models of the boundary layer, turbulence, chemical reactions, combustion, and many other useful features used in the flow analysis of flows in a commercial use.

Conclusion

Numerical differentiation of the potential is in general cumbersome and can be a source of many errors, especially in the case of large, irregular grids, such as the bends of the leading edge – for these reasons the authors do not use the panel method. ANSYS FLUENT package seems to be the most acknowledged tool for aircraft design. Cases similar to those needed in our project have already been calculated and therefore the basic aerodynamic model will be done in this program. Due to the fact that the interactions between the air and the flowed body must be taken into account the authors perform some calculations using the package ADINA. They are aware that the use of computer simulation methods requires considerable experience and skills both in the preparation of the model as well as in the critical analysis of the results obtained.

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SIMULATION MODELING OF ACCUMULATED ERROR OF DISCRETE DRIVE KINEMATIC CHAIN

The methods of determining of simulation modeling of accumulated errors of discrete drive kinematic chain of industrial robot manipulator are considered.

The calculation methods of discrete drive with step motor (SM), for estimation of accuracy of operative unit link displacement of manipulator kinetic chain by means of screw gear are suggested in the article.

The total error of discrete drive includes electric error of discrete displacement of an operating unit in view of mechanical error of accumulated error of gear and screw gear step (F.1). Depending on the number of controlled impulses turning the rotor of SM to a certain angle, simultaneously the turning of each gear, kinematic chain drive to a corresponding angle takes place, which influences the final advance of manipulator operating link.

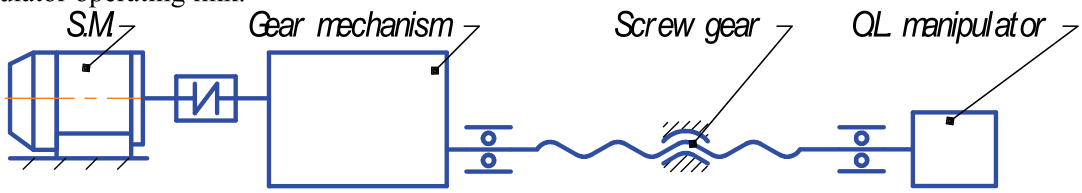

Fig. 1 – Mechanism of manipulator link kinematic chain drive

The step-type behaviour of step motor δ is determined according to formula:

$$\delta = \alpha_Д \cdot K_M \qquad (1)$$

where $K_M \le \Delta / \alpha_Д$ - magnification of driver mechanism transmission within the accuracy with parameter Δ acceptable accumulated error of manipulator operative ling displacement, which is determined by simulation modeling, mkm.

The value of unit step $\alpha_Д$ is determined according to formula:

$$\alpha_Д = \pi / p \cdot m_1 , \qquad (2)$$

where $\alpha_Д$ - is a units step, $\alpha_Д = 0{,}04361$; p - the number of terminal pairs; m_1 - the number of commutation clock time of SM control.

In its turn, for discrete drive the unit step is connected with electric step in ratio:

$$\alpha_Э = z_r \cdot \alpha_Д = 360^\circ / m_1 . \qquad (3)$$

Then the number of terminal pairs, for instance ШД-5Д1М, for $\alpha_Д = 1{,}5^\circ$ is determined under ratio conditions, for the number of rotor serrations $z_r = p = 360^\circ / \alpha_Д m_1 = 360^\circ / 2m \cdot \alpha_Д = 20$ and clock time number $m_1 = 2m$, where $m = 6$ number of phases.

At the expense of electromagnetic delayed action of currents relative to stresses, which with inductive resistance of windings equals 90 el. degrees, the limiting dynamic error is between -90 el.degr. $\le \Delta\theta \le 270$ el.degr. Analysing the process it is more convenient to operate with relative value of angular error of rotor position $\Delta\theta / \alpha_Д$ in step fraction.

Taking into account (inf. 3) ultimate values of static, at the expense of the angle of mismatch of reversal and synchronizing moments and dynamic relative angular errors, it may be taken the form of the number of commutation clock time:

$$\Delta\theta_C / \alpha_Э \le 0{,}25 \cdot m_1 ; \qquad \Delta\theta_Д / \alpha_Э \le 0{,}75 \cdot m_1 , \qquad (4)$$

whence $\Delta\theta_C \le 3 \cdot \alpha_Э$, $\Delta\theta_Д \le 9 \cdot \alpha_Э$, at $\alpha_Э = 30^\circ$ under according to inf. 1

To determine the transmission ratio K_M is calculated accumulated error of drive mechanical unit step in view of screw gear by means of the method of simulation modeling Monte-Carlo.

To calculate accumulated error of manipulator operating link the drive scheme is conventionally divided (F.1) into the gear group and screw gear with the aim of determining the influence of each of them on the total error of mechanical section of drive kinematic chain.

There is the equation of kinematic balance of manipulator displacement ling:

$$1 eng.turns \cdot U_{1n} \cdot p_{вп} = S,$$

where $U_{1n} = u_1 \cdot u_2 \cdot ... \cdot u_n$ - transmission relationship of gear kinematic chain, which according to the construction can have different number of engagement pairs; $p_{вп}$ - screw gear step.

While developing the investigation methods of kinematic accuracy norm on the example of gear wheels of the 6th degree of accuracy between the limits of absolute value $m = 1...3{,}5$, mm is taken according to ГОСТ 1643-81.

Accumulated error worm gear step is characterized by cyclical deflection $\Delta t_{в1}$ of helical line of bolt during its displacement relative to a nut. Tolerance $\delta t_в$ for cyclical error of helical line of worm gear of screw gear with step 12 mm is taken as for worms, in accordance with ГОСТ 3675-56 with equals 13 mkm.

Assuming a certain distribution of transmitting references of screw gears, the revolutions of each gears are determined as one revolution of worm gear. For expanding of the results of drive gear quantity effect, 7 engagement pairs were taken as the value of total kinematic error.

The total accumulated error of manipulator outlet link displacement is determined according to the formula:

$$\Delta p_{\Sigma} = A_i \sin(k_i \varphi_j + \psi_i) + \delta T_{\Sigma j}, \qquad (5)$$

where A_i - kinematic error norm of *i* gear in accordance with worm gear turning angle, mkm; φ_j - worm gear turning angle; k_i - the number of revolutions of *i* ling on turning the worm gear to the given angle; ψ_i - random quantity of phase shift error *i* link; $\delta T_{\Sigma j}$ - acceptable deflection of screw line of worm gear to the angle of its turning φ_j.

The investigation of total accumulated error of manipulator end link displacement is carried out in view of kinematic error of each gear of kinematic chain while turning worm gear at each $\varphi_j = 9^\circ$ by means of simulation modeling. Phase shifts ψ_i are between $[0^\circ...360^\circ]$, where the quantity of load condition is considered between $[0^\circ...270^\circ]$ and is determined as $(360^\circ)\cdot C$, where C - random figures of even law of distribution in the interval $0...1$ were generated with the help of the program "generator of pseudocasual numbers".

For instance, total accumulated error of displacement in view of all drive kinematic chain links in turning of control gear to 9° makes up:

$$\begin{aligned}
\Delta p_{\Sigma 9^\circ} &= (0{,}625\sin(0{,}6\cdot 9^\circ + 360\cdot 0{,}9355) + 0{,}325) + (0{,}625\sin(0{,}6\cdot 9^\circ + 360\cdot 0{,}3973) + 0{,}325) + \\
&+ (0{,}625\sin(0{,}6\cdot 9^\circ + 360\cdot 0{,}2395) + 0{,}325) + (0{,}625\sin(0{,}4\cdot 9^\circ + 360\cdot 0{,}2133) + 0{,}325) + \\
&+ (0{,}625\sin(0{,}4\cdot 9^\circ + 360\cdot 0{,}9035) + 0{,}325) + (0{,}625\sin(0{,}25\cdot 9^\circ + 360\cdot 0{,}4693) + 0{,}325) + \\
&+ (0{,}625\sin(0{,}25\cdot 9^\circ + 360\cdot 0{,}3275) + 0{,}325) + (0{,}625\sin(0{,}25\cdot 9^\circ + 360\cdot 0{,}7653) + 0{,}325) + \\
&+ (0{,}625\sin(0{,}25\cdot 9^\circ + 360\cdot 0{,}9115) + 0{,}325) + (0{,}625\sin(0{,}2\cdot 9^\circ + 360\cdot 0{,}7013) + 0{,}325) + \\
&+ (0{,}625\sin(0{,}2\cdot 9^\circ + 360\cdot 0{,}555) + 0{,}325) + (0{,}625\sin(0{,}08\cdot 9^\circ + 360\cdot 0{,}8773) + 0{,}325) + \\
&+ (0{,}625\sin(0{,}08\cdot 9^\circ + 360\cdot 0{,}1595) + 0{,}325) + (0{,}625\sin(0{,}025\cdot 9^\circ + 360\cdot 0{,}8933) + 0{,}325) = \\
&= 7{,}349705\ mkm
\end{aligned}$$

The results of dependence of total accumulated error of manipulator outlet link displacement of mechanical drive unit while turning of worm gear in the limits of load condition (270°), which makes up thirty samples $m = 30$, are shown in Fig. 2.

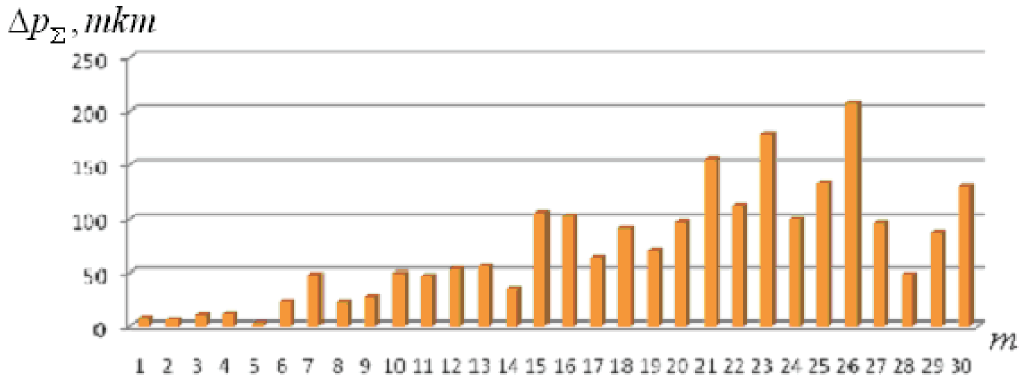

Fig. 2 – Total accumulated error of manipulator outlet link displacement
for one revolution of worm gear

With the aim of receiving confidence information the calculation of total accumulated error $\Delta p_{\Sigma 500} = \Delta p_1 + \Delta p_2 + ... + \Delta p_{500}$ is performed by means of mathematical statistics methods for samples of 500 outlet link manipulator displacement.

The spectrogram of oscillation distribution of total accumulated error of manipulator outlet link displacement from mechanical drive unit effect is shown in Fig. 3

Calculated value of total accumulated error of mechanical drive unit for 500 displacement ran $\Delta p_{\Sigma 500} = \Delta p_1 + \Delta p_2 + ... + \Delta p_{500} = 90921{,}035$ mkm, thence the expectation of accumulated error of manipulator outlet link is: $M\left|\Delta p_{\Sigma \max}\right| = \dfrac{\sum_1^{500} \left(\Delta p_\Sigma\right)_i}{500} = 181{,}842$, mkm.

The variance quantity is: $D\left|\Delta p_{\Sigma \max}\right| = \dfrac{\sum_1^{500} \left(\Delta p_{\Sigma \max}\right)_i^2}{500} - \left(M\left|\Delta p_{\Sigma \max}\right|_i\right)^2 = 165 \cdot 10^6$, mkm.

The root-mean-square deviation is: $\delta\left|\Delta p_{\Sigma \max}\right| = \sqrt{D\left|\Delta p_{\Sigma \max}\right|} \approx 4062$, mkm.

Relative frequency $p_\nu^* = m_\nu^* / 500$, where p_ν^* - hit probability of error value into ν group; m_ν^* - the number of hits in ν group; closeness of probability $f_\nu^* = p_\nu^* / \Delta a$, Δa - discharge length in mkm.

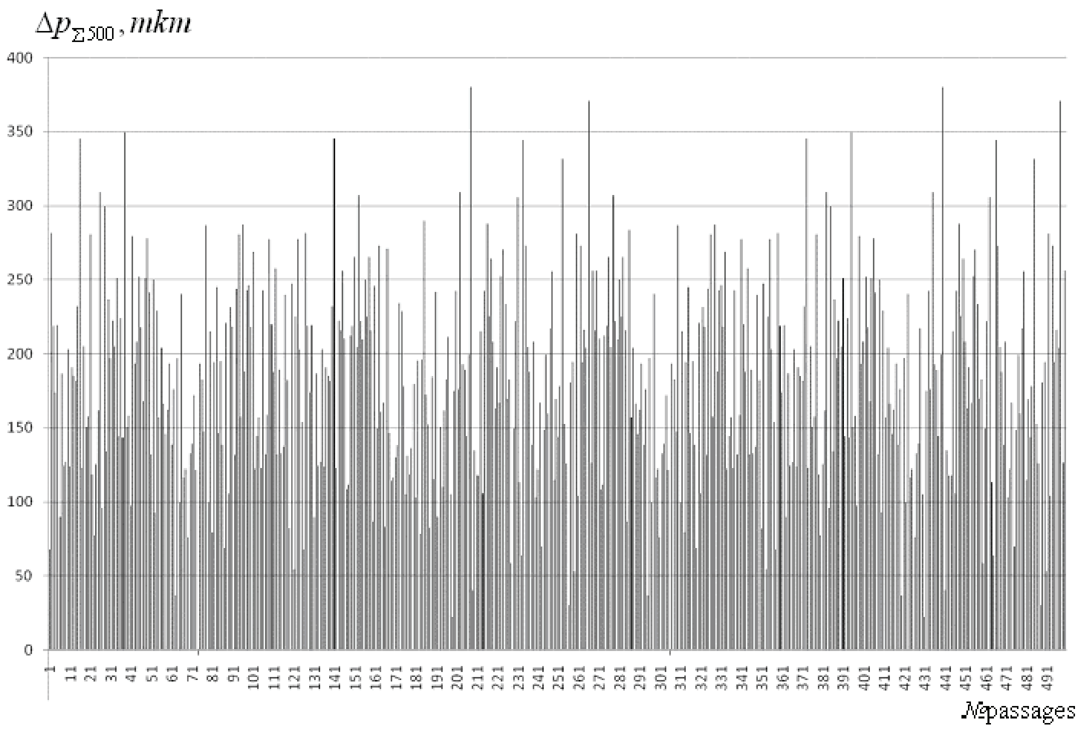

Fig. 3 – Spectrum of oscillation of total acumulated error

Splitting all domain of values $\Delta p_{\Sigma\max}$ into 16 bits long $\Delta a = (a_\nu, a_{\nu-1})$, calculated value probability density of normal distribution according to Gauss formula is:

$$f(\Delta p_{\Sigma\max}) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{(\Delta p_{\Sigma\max} - M)^2}{2\sigma^2}} = \frac{1}{4062\sqrt{2\cdot 3{,}14}} e^{\frac{(90921{,}035 - 181{,}842)^2}{2\cdot 4062^2}} = 98{,}2 \cdot e^{-250} \cdot 10^{-6}$$

In accordance with the taken data the histogram of probability density of normal distribution is shown in Fig. 4.

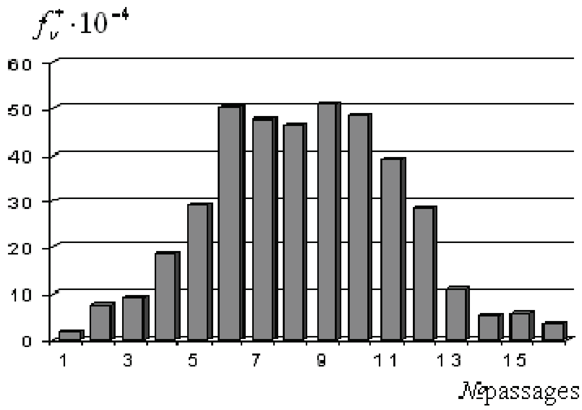

Fig. 4 – Value distribution of accumulated error in accordance with probability density.

The determination of the influence of the error of each separate link on accumulated error of mechanical part is calculated with the formula:

$$E_i = \frac{M|\Delta p_{\Sigma\max}| - M|\Delta p_{\Sigma\max}|_i}{M|\Delta p_{\Sigma\max}|} \cdot 100\% .$$

So, the influence of error of the first screw gear is $E_1 = \frac{181{,}8 - 168{,}9}{181{,}8} \cdot 100\% = 7{,}095\%$.

According to the distribution table the eleventh pinion exerts the greatest effect on the total accumulated error of manipulator outlet link displacement.

Influence of i gear	E_1	E_2	E_3	E_4	E_5	E_6	E_7
%	7,09	6,99	7,20	7.14	7,20	7,26	7,04
Influence of i gear	E_8	E_9	E_{10}	E_{11}	E_{12}	E_{13}	E_{14}
%	7,04	7,02	6,99	7,59	7,17	7,07	7,43

Thus, the total accumulated error of discrete drive consists of error of electric step $\alpha_Э$ SM, which is characterized by step value $\alpha_Д$, (inf. 3) and manipulator outlet link displacement from drive mechanical error which the total accumulated error of displacement. The value of drive mechanism transmission ratio according to accuracy makes up $K_M = \delta / \alpha_Д \le 181{,}8 / 1{,}5^\circ = 121{,}2$ mkm/degr. In this case the step – type behaviour of step motor is $\delta = 0{,}04361 \cdot 121{,}2 = 5{,}3$ mkm.

Conclusion

The developed calculation methods of total accumulated error of kinematic accuracy of kinematic chain with the use of different constructive designs of industrial robot manipulator drive makes it possible to estimate its precise characteristics while designing and servicing a robot in the process of maintenance.

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INTELLECTUAL ROBOT-TECHNICAL DEVICE FOR DETECTION OF MATTERS

In the article it is offered the structure of intellectual robotics measuring device for detection of matters and objects, work of which is based on oscillation stop of measuring oscillator at the coincidence of frequency of oscillator and own resonance frequency of matter which is identified, and structure of measuring channel of this intellectual robotics measuring device.

The modern stage of development of industrial production pulls out the promoted requirements to exploitation of difficult technological objects and technological processes, to exactness of measuring of parameters, which characterize a technological process.

There are such conditions, when a man can not execute the function of operator of measuring device at measuring of parameters of technological process or in other situations. These can be cases, when some values, for example, promoted radio-active background, presence of explosives, harmful chemical or biological substances able to carry a threat life or health of man. In such cases uniquely possible is the use of robot-technical devices.

Presently in different industries of industry measurings robots find application which possess good mobile properties; by the high level of automation of measurings, due to application of intellectual programmatic procedures both in the process of management a robot and in the process of treatment of results of measuring. Application of artificial neuron networks, elements of fuzzy logic in the programmatic structure of mobile measuring robots allows to promote their intellectuality, controllability, and also exactness of measuring.

Similar robot-technical devices must possess property of adaptiveness of conrol, which foresees both the own autonomous conduct of robot, directed on realization of the loaded algorithms, and on possibility of external remote control from a man-operator. It can be necessary in the case of origin of non-standard situations in the process of implementation of the tasks a measuring robot.

Detection of matters and objects is one of perspective line of developing in measuring technique. In a number of cases man on one or another reasons is unable to execute the functions of user of device directly in place, therefore the functions of finding out matters can be laid on multifunction intellectual robot-technical devices (IRTD). Similar IRTU is able to execute a number of operations:

- detection of matters;
- authentication of type of matter;
- calculation of volume of matter;
- simplest manipulations are in the place of detection of matter.

The structure of electronic part of IRTD must include next blocks: intellectual (microprocessor) block; block of wireless duplex communication with an operator; secondary control block of motions mechanical elements of robot-technical device and its manipulators; measuring block. Intercommunication among the blocks of electronic part of IRTD is shown on a fig. 1.

A basic block, responsible for detection of a matter, is no doubt, measuring block, as further actions of all device depend from its exactness.

As a matter which is detected it can be hidden from a direct contact with the primary transformer of device, preferable there is the use of non-invasive detection of a matters.

In particular, one of perspective ways of developing of device which based on non-invasive detection of a matters is application of method of oscillation stop of LC-oscillator, winding of inductance of which, winded on a ferrit coil by the type of the open circuit is the sensible element of device.

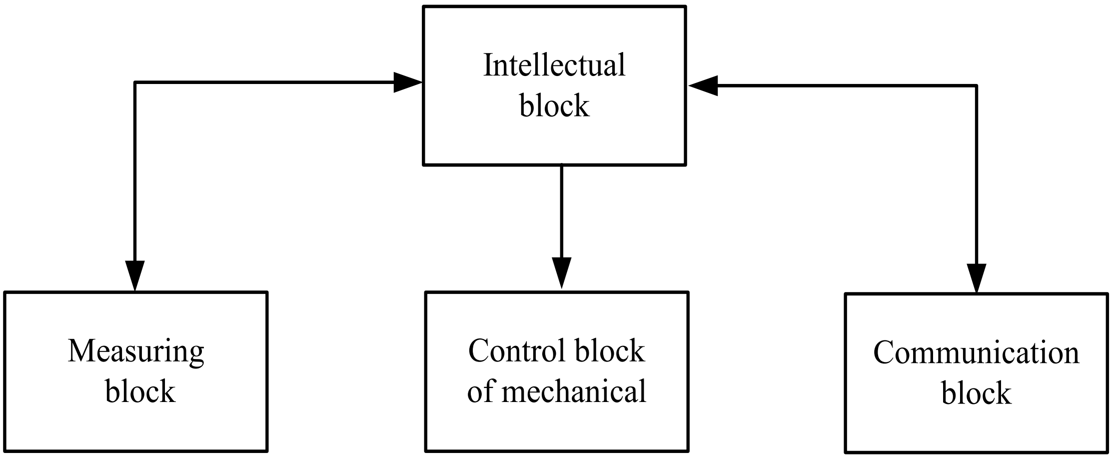

Fig. 1. Structure flowchart of electronic part of IRTD

Oscillation stop takes place at the coincidence of frequencies of oscillation of measuring generator and own resonance frequency of matter have been detected due to the sharp falling of good quality of winding on a resonance frequency [1]. On condition of realization of the mode of scanning of frequencies of measuring generator organization of selecting control of matters is possible in a wide enough range.

At the use of the indicated method of detection of matters, sensible elements (SE) are placed on extremities of manipulators of IRTD. Sensible elements by wires are connected with the circuit of generator, which is placed into the case age of IRTD. The structure flowchart of measuring channel will look like, presented on a fig. 2.

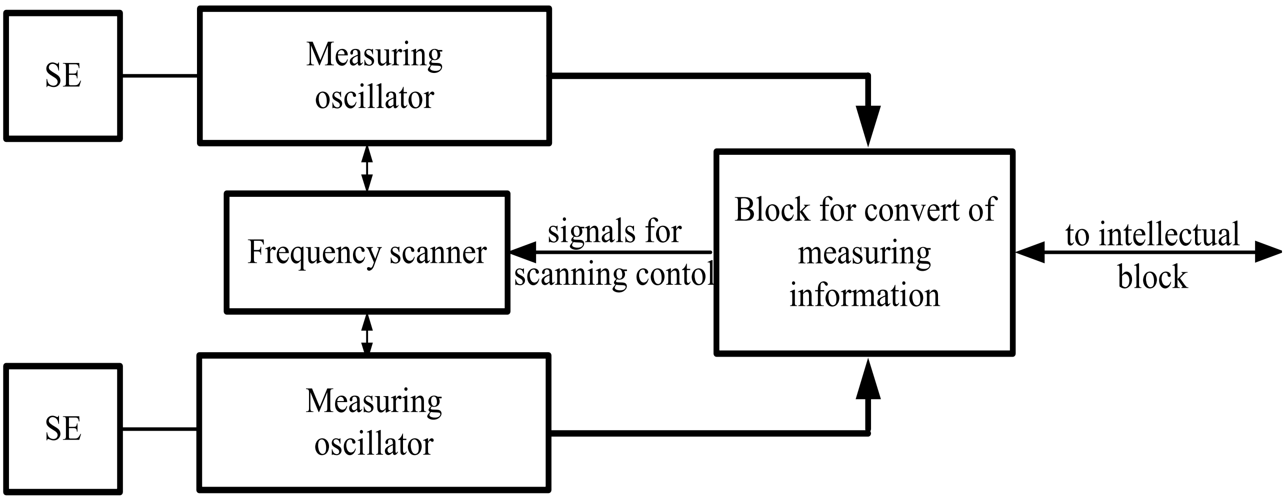

Fig. 2. Structure flowchart of measuring channel

The chart of measuring information gaining is shown below (fig. 3).

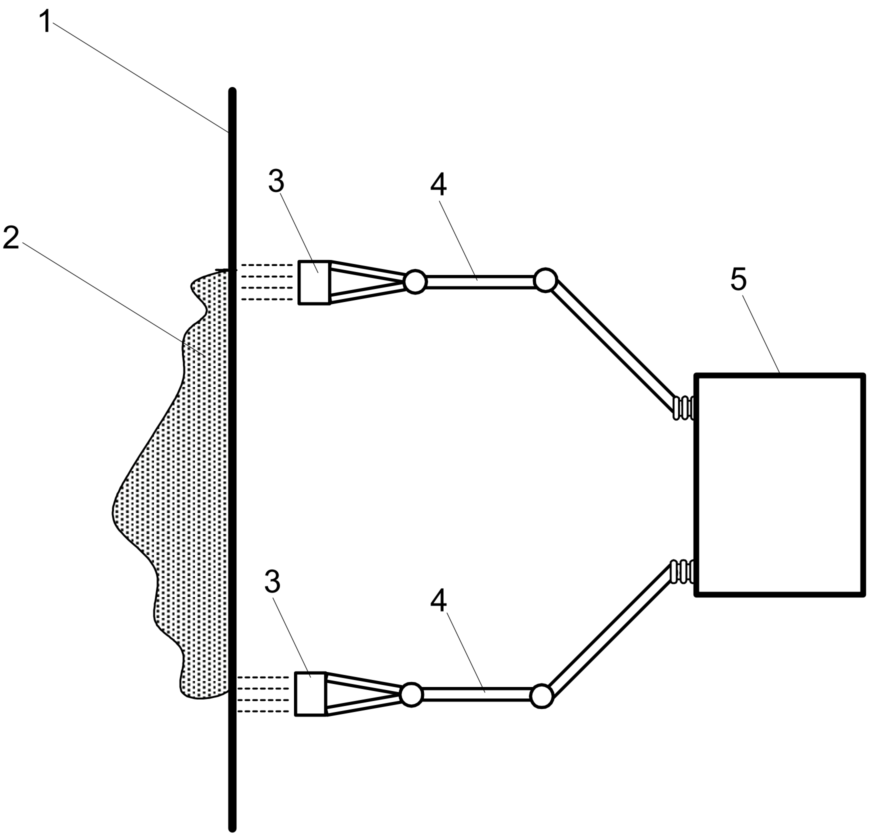

Fig. 3. Chart of measuring information gaining

1 – external barrier;
2 – matter which detected;
3 – SE (winding of metering oscillator);
4 – manipulators of robot-technical devise;
5 – case of IRTD.

After authentication of matter on the basis of analysis of measuring information in an intellectual block, by moving of manipulators with SE the margins of his localization are determined and his volume is calculated.

Conclusions

It is developed structure flowchart of electronic part of intellectual robot-technical device for detection of a matters and structure flowchart of its measuring channel, which functioning on the basis of non-invasive method of selective control.

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UDC 681.2 (043.2)

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APPLICATION OF THE GUIDED ROBOT-TECHNICAL DEVICES IS IN PLANT CULTIVATION

In the article is offered f structure and algorithm of work of intellectual robot-technical device, intended for the automatic bringing of fertilizers, which foresees control of his moving by the systems of GPS- navigation, and also presence of a few measurings channels.

Proceeding reduction of part of products of domestic agricultural production relative to the imported products, looked after in the last decade, it is caused many reasons. One of the more sufficient causes of this reduction is a human factor. Outflow of labour force from countryside, caused low payment of hard work, low terms of living condition, of no prestige of agricultural professions. Unfortunately, this process, is irreversible.

Therefore actual is the wide applying in agricultural industry, in particular in a plant cultivation, an intellectual robot-technical devices (IRTD) and complexes for implementation of conservative, repetitive actions.

Such IRTD, must execute the set of functions, directed on realization of standard operations of plant cultivation - plowing, sowing, cultivating, fertilizer application in a ground, reaping and other. Surely, IRTD will not be able to execute work of agronomist, specialists of plant protections and other professionals, which making a final decisions, organization and strategy of current agricultural work. Ukraine possesses mainly flat relief of the territory, therefore introduction of robot-technical devices in agriculture appears are perspective.

Obviously, that realization of the indicated operations will demand the earnestly researches and experimental-design works a big number of scientists and developers in creation, test and introduction of similar IRTD.

For the last 30 years in the developed countries, including in Ukraine, is developed automatic control unit of agricultural machines and mechanisms. The systems of the automatic driving (SAD) were developed in a complex with the systems of automatic direction of motion, the automatic checking (SAC) of agricultural mechanisms systems, systems of automatic control executive mechanisms (SAE), were developed a some schematic circuits of control and measuring units [1]. Possibility of radionavigation control application of motion of robotics aggregates of tractors was examined also with the use of tellurometer method, foreseeing setting of three transceivers for determination of localization of tractor aggregate on the area of a field. Showed experimental researches of the offered chart good exactness of similar method. The mean root square error of rejection of aggregate motion from the setting trajectory made 0,13 m.

We are considering, what functions must possess IRTD, which is used for bringing in ground of a granular fertilizers. Foremost, it is a function of automatic control a tractor aggregate to which join spreader device - it a function foresees driving of IRTD to the place of fertilizer application, moving on the set territory (of field) and return to the permanent location (station).

A next function is a receipt of setting from a wireless channel about the required mode of fertilizer application - most intensive, intensive, softintensive and etc. After the receipt of setting, IRTD includes the subblock of management of shutters of spreader device for opening them on the required size. A feed-back from the measuring devices of control of the required level of shutters opening of spreader device and possibility of self correction in the case of the inexact opening of shutters is foreseen in this mode. On a figure 1 the flowchart of co-operation of blocks of IRTD is presented in indicated mode.

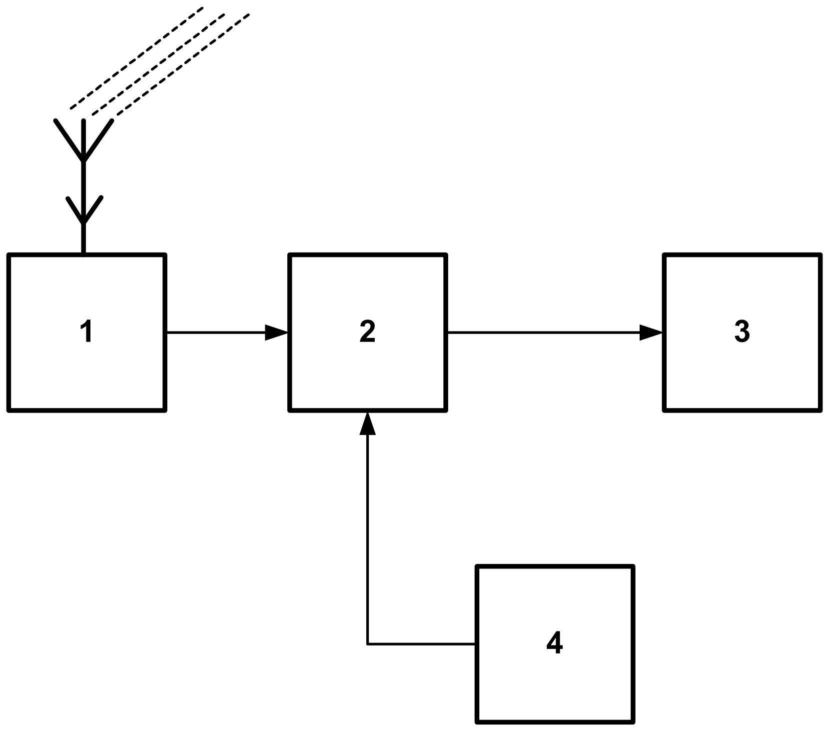

Fig. 1. A flow diagram of co-operation of blocks of IRTD is in the mode of regulation of opening level of shutters

1 - receiver of IRTD;
2 - IB IRTD;
3 - block of management of shutters;
4 - measuring block of control of opening level.

Third function - which comes after setting of the necessary mode of fertilizer application, it is a function fertilizer application immediately. On this stage IRTD includes the engine of spreader device in the required speed and executes a management a tractor aggregate, which, moving on the set trajectory in the set margins of area of the sown field, provides the even bringing of fertilizers. Control of moving of tractor aggregate can be realized by facilities of the satellite systems of determining the location of GPS or GLONASS.

We'll consider more in detail the mode of functioning of IRTD which control of intensity of fertilizer application is executed on. This stage is most responsible, as there will be a small harvest of the reared agriculture at the insufficient level of the borne fertilizers, and at the excessive bringing of fertilizers reared agriculture products will not pass ecological examination.

After the receipt of setting with information about the concrete mode of fertilizer application, the intellectual block (IB) of IRTD is given out the single control action to manipulator which opens the shutters of spreader device on the one level. Further IB IRTD interrogate a non-contact measuring device about the value of opening of shutters. If this value less required, IB IRTD repeats an opening command on one level. Similar actions repeat oneself until information is got with setting will not coincide with by information of non-contact measuring device. In the case of coincidence of these information IB IRTD gives out to manipulator the command of engaging of the hard fixing of shutters, in order to prevent their spontaneous sinking as a result of vibration and shaking of tractor. As a measuring device it is possible to use one of schemes, offered in [2].

A presence of the indicated measuring mean is obligatory in a structure IRTD. Also, at will of customer of robot-technical device, it can be equipped additional measuring channels. It can be, for example, measuring device of type of granular fertilizer, which are loaded in the bunker of spreader device. The presence of similar supervisory block will allow to prevent the possible thefts of fertilizers. Except for this block in the structure of supervisory controls two sensors of control of level can be entered loads, signaling about the limit of filling of bunker and about his devastation, are a sensor of «top level» and sensor of «lower level».

At fertilizer application for the full cover of the field area, the trajectory of motion of tractor aggregate on the field reminds a «snake». Thus «head of snake» to be in one corner of the field, and its «tail» is in opposite. Task of control by GPS-system of navigation to be taken to realization of a few functions. Foremost, it is a function of determination of initial point on the field («head» or «tail of snake») on which to hatch tractor aggregate, and also initial vector of direction of motion - this information must enter together with setting. Also together with setting information enter data about length and width of the field rectangle.

After beginning of motion of tractor aggregate at the engaging spreader device, IB IRTD in the real-time mode executes control of motion of tractor aggregate , the set algorithm of motion a «snake» will be realized here. In case if a fertilizer is finished in the bunker of spreader device, the sensor of «lower level» signals in IRTD about it. IB IRTD passes the commands of stop of tractor aggregate, shutdowns of spreader device, unblocking and closing of shutters. After this IB IRTD memorizes the co-ordinates of point of stop and vector of course of tractor aggregate and gives out the command of leaving from the field for addition to the volume of fertilizer and further continuation of work. Work is considered complete, if the opposite corner of the field is attained is will the point of stop the co-ordinates of which are also memorized. Thus IB IRTD also gives out commands on the shutdown of spreader device and closing of shutters, in order that the remaining volume of fertilizer did not scatter on a road. After this IB IRTD driving a tractor aggregate into place of his steady station.

Conclusions

An organizational structure and exemplary algorithm of work of intellectual robot-technical device, intended for the automatic bringing of fertilizers, which foresees control of his moving by the systems of GPS - navigation, and also presence of a few measuring channels is offered.

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THE COMPUTERIZED CONTROL OF MEASURING ROBOTIC SYSTEM

In this paper the computerized robust fuzzy control for measuring robotic system to track a smooth desired trajectory has presented.

Over the last decade, the analytical study of nonlinear control using universal function approximators has received much attention [1]. Mostly neural network or a fuzzy logic system (FLS) is used to approximate the nonlinearity of the system to be controlled and a controller is synthesized based on this approximation (indirect control) or a control low is directly designed using neural networks or FLSs based on stability theories [2], [3]. In the class of approximators which are linear in the weights, FLS is much closer in spirit to human thinking and natural language. It provides an effective means of capturing the approximate, inexact nature of the real world.

In practical this methodology appear very useful when the processes are too complex for analysis using conventional techniques or when the available sources of information are interpreted qualitatively, inexactly or with large amount of uncertainty.

In addition to the classical feedback control theory, adaptive control and robust control are effective techniques to treat system uncertainties [4]. Adaptive control by tuning on-line its parameters can deal with large uncertainties, but generally suffers from the disadvantage of being able to achieve asymptotical convergence of the tracking error, also the on-line computation load is usual heavy.

In robust control designs on the other hand, a fixed control law based on a prior information on the uncertainties is designed to compensate their effects and exponential convergence of the tracking error to a (small) ball centered at the origin is obtained.

However, if the uncertainties are larger than the, assumed bounds, no stability or performance are guaranteed. By combining both techniques, large uncertainties can be dealt with exponential convergence of the tracking error to a (small) ball centered at the origin is achievable and on-line computation load is kept to be minimum, since only uncertainty bounds are updated online.

This paper considers the problem of controlling a measuring robotic system described by Euler-Lagrange equations to follow a desired trajectory in the presence of uncertainties. A fuzzy logic system is used to approximate the unknown dynamics of the system [5, 6]. Based on the a priori information, the premise part of the FLS as well as a nominal weight matrix is designed first and is fixed.

A compensation signal to the weight matrix error is designed based on Lyapunov analysis [4, 7]. To further reduce the tracking error due to the function reconstruction error, a second compensation signal is also synthesized. By running two estimators online for weight matrix error bound and function reconstruction error bound the implementation of the proposed controller needs no a prior information on these bounds. Exponential tracking to a desired trajectory up to a uniformly ultimately bounded error is achieved with the proposed control. The effectiveness of this control is demonstrated through simulation and experiment results. The results also show that by incorporating a priori information about the system, the fuzzy logic control can result good tracking behavior using a few fuzzy IF-THEN rules.

Consider a fuzzy logic system [8] with the product-inference rule, singleton fuzzifier, center average defuzzifier and Gaussian membership function given by n_r rules

$$R^r : \text{If } x_1 \text{ is } A_1^r(x_1) \text{ and ... and } x_{n_i} \text{ is } A_{n_i}^r(x_{n_i}), \text{ then } y_1 \text{ is } b_1^r \text{ and } y_{n_o} \text{ is } b_{n_o}^r,$$

where R^r is the r-th rule, $1 \le r \le n_r$, $x = (x_1, x_2, ..., x_{n_i})^T \in X \subset R^{n_i}$ and are the input (n_i inputs) and the output (n_o outputs) of the fuzzy logic systems, respectively; b_j^r is the fuzzy singleton for the j-th output in the r-th rule.

The configuration of fuzzy logic systems are represented on fig. 1.

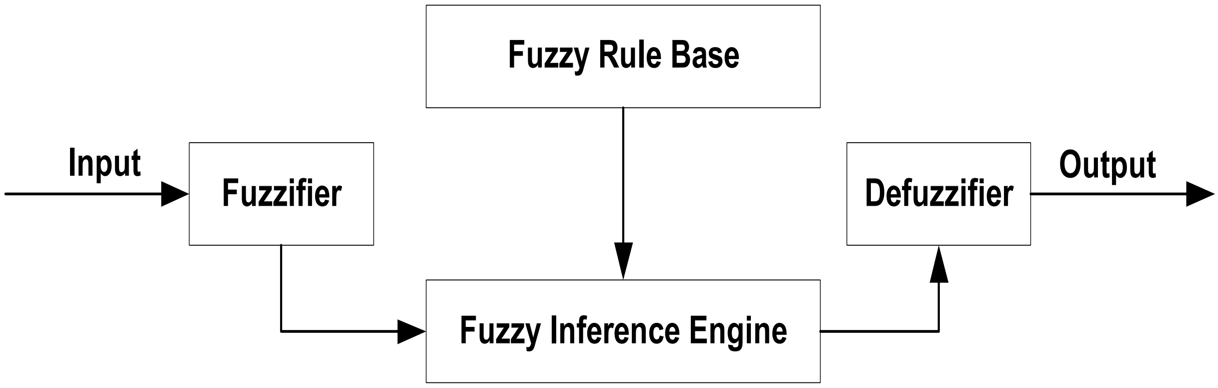

Fig. 1. Configuration of fuzzy logic system

$A_1^r(x_1),...,A_n^r(x_{n_i})$ are fuzzy sets with Gaussian membership functions

$$A_j^r(x_j) = \exp\left\{-\left(\frac{x_j - c_j^r}{\sigma_j^r}\right)^2\right\}$$

with c_j^r, σ_j^r design parameters. The k-th output of the FLS is given by

$$y_k = \sum_{r=1}^{n_r} w^r(x) b_k^r, \quad k = 1,...,n_o,$$

$$w^r(x) = \frac{A_1^r(x_1)\cdot A_2^r(x_2)\cdot ...\cdot A_{n_i}^r(x_{n_i})}{\sum_{j=1}^{n_o} A_1^j(x_1)\cdot A_2^j(x_2)\cdot ...\cdot A_{n_i}^j(x_{n_i})}, \qquad r = 1,...,n_r.$$

If the membership function are fixed, the normalized firing strength (activation degree) of the r-th rule w^r is a function of only x. Therefore, the output of an FLS allows a linear parameterization in its consequent parameters b_j^r

$$y(x) = \begin{bmatrix} y_1(x) \\ y_2(x) \\ \cdots \\ y_{n_o}(x) \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} \dots b_{1n_r} \\ b_{21} & b_{22} \dots b_{2n_r} \\ \dots & \dots \dots \dots \\ b_{n_o1} & b_{n_o2} \dots b_{n_on_r} \end{bmatrix} \times \begin{bmatrix} w_1(x) \\ w_2(x) \\ \cdots \\ w_{n_r}(x) \end{bmatrix} = B \times W(x). \tag{1}$$

In the rest of the paper $B \in R^{n_o \times n_r}$ will be referred to as the weight matrix and $W : X \to R^{n_r}$ the fuzzy basis functions. It is well known that the FLS (1) is a universal approximator in the sense that given any real continuous function $f(x)$ in a compact set $X \subset R^{n_i}$ and any $\rho > 0$ there exists an FLS such that

$$\sup_{x \in X} \| y(x) - f(x) \| < \rho,$$

where $\|\cdot\|$ denotes Euclidean norm or its induced matrix norm. In light of this result the function $f(x)$ can be expressed as

$$f(x) = B_* \times W(x) + \tilde{f}(x), \quad \forall x \in X \subset R^{n_i}$$

where $\widetilde{f}(x)$ is called function reconstruction error satisfying

$$\sup_{x\in X} \| \widetilde{f}(x) \| < \rho$$

and B_* is the optimal weigh matrix

$$B_* = \arg \min_{B\in R^{n_o \times n_r}} \left\{ \sup_{x\in X} \| B \times W(x) - f(x) \| \right\}$$

In the practice the optimal weight matrix may be not unique and unknown. Several methods based the gradient of an error function are available to estimate it [4]. When some part of an FLS (number of rules n_r, membership functions $A_j^r(x_j)$ or consequent parameters b_j^r) is fixed, the function reconstruction error bound ρ is unknown.

For the subsequent analysis using Lyapunov stability theory, we develop the error equations from the given plant dynamics

$$M(q)\ddot{q} + C(q,\dot{q}) + G(q) + F(\dot{q}) = u\,, \tag{2}$$

where $q,\ \dot{q},\ \ddot{q} \in R^n$ are the joint position, velocity, and acceleration, respectively. $M(q)$ is the $n\times n$ inertia matrix, $C(q,\dot{q})$ represents the Coriolis and centripetal forces, $G(q)$ is the gravity vector and $F(q)$ is the friction matrix. The friction F depends predominantly on velocity, but generally also on position, time and external forces. It constitutes one of the major source of the uncertainty in the measuring system.

Let $\dot{q}_r$ be the reference velocity and s the filtered tracking error defined as

$$\dot{q}_r = \dot{q}_d - \Lambda\widetilde{q}\,,\ s = \dot{\widetilde{q}} + \Lambda\widetilde{q} = \dot{q} - \dot{q}_r \tag{3}$$

with $\Lambda \in R^{n\times n}$ being a positive-definite matrix. It is clear from (3)

$$\dot{\widetilde{q}}(t) = -\Lambda\widetilde{q}(t) + s(t)$$

that if $s(t)$ is bounded and goes to a (small) ball centered at the origin, so do $\widetilde{q},\ \dot{\widetilde{q}}$. So the control law will be designed such that the filtered tracking error $s(t)$ is uniformly ultimately bounded. The dynamics of s are obtained from (2)

$$M(q)\dot{s} + C(q,\dot{q})s = u - f(x)\,,$$

where $x^T = \left[q^T\ \dot{q}^T\ \dot{q}_r^T\ \ddot{q}_r^T\right] \in R^{4n}$,

$$f(x) = M(q)\ddot{q}_r + C(q,\dot{q})\dot{q}_r + G(q) + F\,.$$

In the previous equation we assume that the frictions are a function of positions and velocities. From the result $f(x)$ can be approximated by an FLS in a compact set $X \subset R^{4n}$ (n denotes the degree of freedom the measuring robotic system)

$$f(x) = B_* \times W(x) + \widetilde{f}(x)\,, \quad \forall x \in X \subset R^{4n}$$

and the function reconstruction error is bounded by a unknown bund ρ_f

$$\| \widetilde{f}(x) \| \overset{\Delta}{=} \sup_{x\in X} \sqrt{\widetilde{f}^T(x)\widetilde{f}(x)} < \rho_f\,.$$

Consider the control low. Let $B_0 \in R^{n\times n_r}$ a nominal weight matrix and ρ_B a bound to the weight matrix error $\widetilde{B} = B_0 - B_*$, i.e.,

$$\| \widetilde{B} \| \le \rho_B\,.$$

We assume first that both bounds on the weight matrix error $\widetilde{B}$ and the function reconstruction error $\widetilde{f}(x)$ are known. The proposed control for the measuring system (2) is given in the following:

$$u = -K s + (B_0 + B_1) \times W(x) + u_f\,,$$

where $K \in R^{n \times n}$ is a positive definite matrix gain and $B_1(t) \in R^{n \times n_r}$ (n_r is the number of IF-THEN rules in an FLS) and $u_f(t) \in R^n$ are designed to compensate for the weight matrix error and the function reconstruction error, respectively

$$B_1 = -\rho_B^2 \frac{s W^T(x)}{\rho_B \| s \| \cdot \| W(x) \| + \vartheta_B} \tag{4}$$

$$u_f = -\rho_f^2 \frac{s}{\rho_f \| s \| + \vartheta_f} \tag{5}$$

with $\vartheta_B, \vartheta_f > 0$ design parameters.

The implementation of robustifying term (4), (5) requires information on the approximation error bound and bound on the unknown optimal weights of the universal approximator. By introducing an estimator of the uncertainty bounds, the control in this work needs no a prior information on these bounds. Also since there are only two parameters estimated online independent of the degree-offreedom of the system, the computational burden is mach less than that in an adaptive control, witch updates online the weight matrix typically of high dimension.

Conclusion

In this paper the computerized robust fuzzy control for measuring robotic system to track a smooth desired trajectory has presented. By combining advantages of FLS, adaptive controls and robust controls, the proposed control may incorporate easily priory information about the system, and achieves exponential convergence of the tracking error to a ball centered at the origin, whose radius can be made arbitrary small.

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UDC 531.7

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THE INFORMATION MODEL OF OBSTACLE AVOIDANCE BY THE MOBILE ROBOT

In the given work for the task solution of an obstacle determination on the way of movement of the robot according to the video information it is offered to use the combination of convolution neural network and classic multilinked neural network. The use of neuronetwork method in the information model of obstacle avoidance of the robot will allow it to function independently in uncertain and guarantee adaptability of behavior.

Introduction

At this point of development of robotics the most claimed is creation of robots, which are able to function independently in the environment. The environments with which the robot has to cooperate in such problems are characterized by low degree of organization. For the robot which is able to function independently in uncertain or mutable situation, it is necessary to sensing, providing the feedback of the environment and adaptability of behaviour. The sensory data delivered by the sensory system to adaptive control structure is used for completion of aprioristic data about the environment with the aim of formation of the correct output control actions, directed to the achievement and maintenance of some optimal behavior system. As the result it comes to possible the organization of adequate functioning of the robot in the dynamic environment [1, 2]. In such conditions functional capabilities and effectiveness of the robots to a great extent will depend on exploitable principles of sensory operations and management techniques.

The analysis of publications

The planning of transferences of mobile robots is the highest hierarchic step in the structure of control system, getting the task at the input and distributing motion paths at the output, under processing of them the robot succeeds. The robot movement in a priori non-formalizable environment means necessity of the decision of hard formalizable tasks, such as the formation of ways of obstacle avoidance by incomplete or noisy sensory data. Under the task solution of the movement control of the mobile robot along the reference trajectory there are two basic methods: program and trajectory (contour). The program management of the robot movement is based on classic construction principles of the follow-up systems [1]. The method supposes inclusion a special setting device (interpolator) in the control system, the device generates parameterized a desirable trajectory by the time. Exact qualifying standards to the interpolators, the necessity of reprogramming of reference movement with change of the robot movement nature determine the main lacks of the method and limit opportunities of application of the follow-up controls use. The method of the trajectory management [2, 3] supposes the use of current meanings digressions from predetermined trajectory and excludes the necessity of attracting the generators of the reference model. A desirable movement trajectory is presented by intervals of smooth curve, specified in the implicit form. The task of the path control lies in the robot stabilization concerning reference trajectory and maintenance of required traverse speed along it, i.e. the task adds up to the partial stabilization of multi-channel nonlinear system. In a number of practical cases there are tasks in which minimal a priori information about substantial characteristics for performance of task and parameters of the environment, the obvious task of the movement trajectory of the mobile robot can be absent, for example, desirable trajectory can be defined by flowsheet or defined points. Under such conditions the use of conventional methods becomes problematic; it appears the necessity of working out new and more perfect algorithm of movement management with the use of the adaptation principles and self-instruction.

Analysis of publications has shown that one of the possible methods to the task solution is t use of fuzzy systems [4, 5] and artificial neural networks [6-8]. The main advantages of neural networks are opportunity of simultaneous processing, stability to the mistakes and capability for summarizing of the stored knowledge. From the managing system, constructed on basis of classic mathematical sciences, the neural network differs that it is capable of different tasks training and adaptation without modification and it can be applied under construction of control system for the objects with hard formalizable characteristics, demanding the adaptation directly in the process of management.

Target setting

To devise the information model of “smooth” obstacle avoidance by the mobile robot, which allows to provide for eventuality of early obstacle detections and trajectory construction of their roundabout way.

Task solution

Taking into account the necessity of model construction of the “smooth” obstacle avoidance by the mobile robot it is expediently to form the motion paths not in the form of straight line but in the quadratic form, which are generally can represent circles, ellipse, parabolas, hyperbolas and points. In generalized kind for the task decision of synthesis of neuronetwork model of obstacle avoidance by the mobile robot it is necessary to take into account the following conditions and requirements:

1. Date-line for the control system are video images from the vision system;
2. The movement is carried out in three-dimensional configurational area. The type of configurational area – Cartesian system of coordinates;
3. Functioning in a real mode of time;
4. Capability of trajectory formation of static and dynamic obstacles avoidance;
5. Capability for the training and adaptation, stability to noise into data input and changes of the environment.
6. Output data is a motion path of the mobile robot as coefficients of quadratic form, target position of the robot, a map.

For the task solution of obstacle determination on the way of robot movement according to the video information in given work it is offered to use a combination of convolution neural network (CNN) and classic multilinked neural networks [9]. The convolution neural network is particular form of NN, which is suitable to the intellectual processing of visual and audio data in the best way. CNN unite three architectural ideas in themselves for the achievement of the invariance to the shift and distortion of the original image: local fields of perception, separable weights and spatial undersampling [10]. CNN consist of alternate layers of furl and undersampling. The image acting on an input is exposed to furl with some convolution kernel in accordance with expression:

$$C\{n\}(i,j)=F\left[\sum_{k=1}^{ks}\sum_{l=1}^{ls}K\{n\}(k,l)\cdot S(i-k,j-l)+B(n)\right],$$

where C – the result of convolution (the map of characteristics), n – the number of layer, i, j – indexes, determining the location in the map of characteristics, F – the function of satiation, usually assigned as a sigmoid or tangential function, k, l – indexes, determining the location of an element of the convolution kernel matrix, ks, ls – dimensions of convolution kernel, K – convolution kernel, S – input image, B – matrix of displacement.

The convolution kernel is set of separable weighting coefficients. The result of the given operation is also some image, which is called as a map of characteristics. Depend on selected convolution kernel the map of characteristics will pick out those or other characteristics of input image. For more complete allocation of characteristics of input image it is used some different convolution kernels that it turns out some maps of characteristics at the output of the convolution layer.

After the convolution layer it follows a layer of averaging-out and undersampling, which reduces the dimension of a map of characteristics, thereby reduces the sensitiveness outputs to shifts and turnings. Such alternation of convolution and undersampling layers results in gradual increase a number of maps of characteristics at a decrease of their dimension from a layer to a layer.

The outputs of convolution neural network together with the data about the current trajectory at the output are given to classic multilinked neural network for the formation of coefficients of the quadratic form.

For the correct work of a neuronetwork model it is necessary to choose a number of layers and neurons correctly in the layers of convolution and classic fully connected neural networks.

The choice of quantity of layers for the convolution network is determined by the dimension of input data and the complication of required characteristics of the image. In such way when as at undersampling the image diminishes twice down and across, the number of layers is proportional to the dimension of an input image. For the selection of quantity of neurons of the classic full connected neural network it is offered to use the algorithm OBD (Optimal Brain Damage), which iteratively removes neurons, which are weakly equipped in the computational process.

For the training of the neural network it is required to form as much as possible representational learning sample. For that it is necessary to determine the type of input and output data and also view all possible classes of situations, in which can be found robot.

Input data for the neural network are two types of information: an image from the vision system, which is traffic matrix and coefficients of quadratic form, describing the desirable motion path. The output data are coefficients of quadratic form, describing the adjusted motion path

The stochastic learning gives the best fit for the training of convolution networks with the help of a gradient-descent method. Such type of training has some advantages in comparison with batch learning. First of all the stochastic learning is faster inasmuch as it does not demand of Hessian calculation for all training patterns. In the second place the stochastic learning is less exposed to hit in the local minimums and therefore it often gives better results than batch learning. In the third place the stochastic learning can be used for tracking the changes in the process of learning needlessly of necessity waiting of the end of learning.

Suppose learning sample from m elements. Let also adjustable parameters of the network including weights, displacements represents vectors $W = \left[w_1 \ldots w_n\right]$ The total amount of weights and displacements are respectively equal *n*. The number of output of network is equal *k*. The outputs will be denoted as $q_{1 \ldots k}$. Let $D = \left[d_1 \ldots d_k\right]$ - is required value of sampling. In such way the error vector $e = \left[e_1 \ldots e_k\right]$, where $e_i = d_i - q_i$ For the mean-square criterion function, adjusted as:

$$E = \frac{1}{m}\sum_{i=1}^{m}\frac{1}{2}\sum_{j=1}^{k}\left(d_j^i - q_j^i\right)^2$$

upper index denotes the number of the learning sample. Also we will enter the vector for the comfort:

$$e = \left[e_1^1 \ldots e_k^1, e_k^2 \ldots e_k^m\right]^T.$$

Taking into account entered table of symbols, Jackobian will be equal:

$$J = \begin{bmatrix} \frac{\partial e_1^1}{\partial w_1} \cdots \frac{\partial e_k^1}{\partial w_1}, \frac{\partial e_1^2}{\partial w_1} \cdots \frac{\partial e_k^m}{\partial w_1} \\ \vdots \quad \ddots \qquad\qquad \vdots \\ \frac{\partial e_1^1}{\partial w_n} \cdots \qquad\qquad \frac{\partial e_k^m}{\partial w_n} \end{bmatrix},$$

then gradient can be calculated as:

$$g = J \cdot e = \begin{bmatrix} \frac{\partial e_1^1}{\partial w_1} e_1^1 + \frac{\partial e_2^1}{\partial w_1} e_2^1 + & \cdots & + \frac{\partial e_k^{m1}}{\partial w_1} e_k^m \\ \vdots & \ddots & \vdots \\ \frac{\partial e_1^1}{\partial w_n} e_1^1 + \frac{\partial e_2^1}{\partial w_n} e_2^1 + & \cdots & + \frac{\partial e_k^m}{\partial w_n} e_k^m \end{bmatrix}$$

whence follows, that gradient is a column bit vector, each element of it defines the total influence of each weight on value of criterion function.

Conclusion

In spite of progress of mathematical modeling, an opportunity of construction of control systems are limited thereupon. The use of combination convolution neural network and classic multilinked neural network in the model of “smooth” obstacle avoidance by the mobile robot will allow it to functionate independently in uncertain or variable environment and provide with feedback from the environment and adaptability of behavior.

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AUTOMATION OF THE INFORMATIVE FLOWS IN THE COMPUTER SYSTEMS MANAGEMENT

Expediency of algorithms development of the informative flows automation is reasonable in computer control system in order to optimize the activity of production and planning of enterprises. The features of ASM functioning for the data flows distribution automation in the process of making decision are considered. Complex application of IT and mathematical modeling of flows distribution of these administrative CS is offered.

Modern managers and specialists constantly need to have vast and reliable information in order to manage an organization and implement work efficiently. It can be achieved through the means and methods of informative flows automation [1].

That is why the correct choice and development of software for the informative flows automation within the informative systems is a major task of optimization of productive activity of organizations and establishments in the modern terms of swift development and input of the newest information telecommunication systems in all spheres of the society.

Herewith, the basic data when managing the quantity and the quality of the information which circulates in the structure of the informative management systems is creating the informative data, their modification and keeping (if it is necessary), and also realization of information exchange.

As the informative data, as a basic element of the computer system informative flows, often are often delivered to the user, administrator and manager in the conditions of vagueness (that is conditioned by transience of the situation and necessity of making an adequate decision in a non-standard situation), in the automated systems of management (ASM) one of the tasks is a transmitting the information minimum to the management staff, that is necessary for determination of the production state and making necessary (most acceptable under certain circumstances) decision [2].

In this case there is a necessity to keep mandatory requirement to the database given in the system, which must be optimally organized on the basis of using the unified system of the technical and economic information classification and coding and also unified systems of documentation.

Besides, the informative providing (IP) ASM must give all the functional subsystems the necessary information of corresponding volume on conditions of terms definiteness and in the appropriate form. It will provide keeping corresponding requirements of arranging informative data flows and optimization of the computer system functioning efficiency in general.

In relation to the description of the process of establishment or organization management structure with the purpose of the production planning activity optimization when creating IP first of all the process of collecting the source information about external environment and object of management (incoming information database creating), preparation and collection in accordance with the applied managerial model (intermediate information database creating), and also development of the administrative measures algorithm (managerial on-line information database creating) should be provided.

Herewith it is necessary to take into account the fact that while gathering the information the initial informative data are those which can be a source for other documents in the future [3].

In relation to the description of the ASM functioning, it should be noted that on the lowest levels of the system the detailed information about management object operates. And further, on receiving the informative data from the lowest levels of managing to higher ones, the information is corrected by excluding the unnecessary details from the blocks (the process of integration or compression of the information).

In particular all the above-mentioned show that the active information which moves from the top levels to the bottom ones multiplies itself on the middle levels that generate the additional information.

The degree of the integration (multiplication) β is accounted by the coefficient $\beta = \frac{J_{exit}}{J_{enter}}$ where J is the volume of the information.

Thus, for the supplemental information $\beta \leq 1$, and for the active information - $\beta \geq 1$.

The important question of the managerial computer system development of the informative flows automation is organizing the process of collecting the initial information about external environment and management object. Efficiency of the first stage of the computer system functioning application in relation to forming the block of basic data determines the quality of receiving the intermediate (secondary) information, which is received as a result of the initial information processing by sorting, classification, selection, calculation and so on).

Therefore the study of existing informative data flows improves the quality of the designed system considerably. In this case the main aim is to reveal the possibility of the automation of gathering, transmission and reports or their parts processing (informative data structuring) in the structure of the managerial computer informative system [4].

The effective modern instrument of the informative data structuring in the managerial computer systems is a mathematical modeling. The creation of the model IP must be based on the results of the detailed investigation of the management object, exposure of the conformities to natural law of functioning the informative flow and determination of the solvable tasks. Besides there must be a certain connection of logical and physical levels of the ASM organization for the average calculation of the information management system data flows.

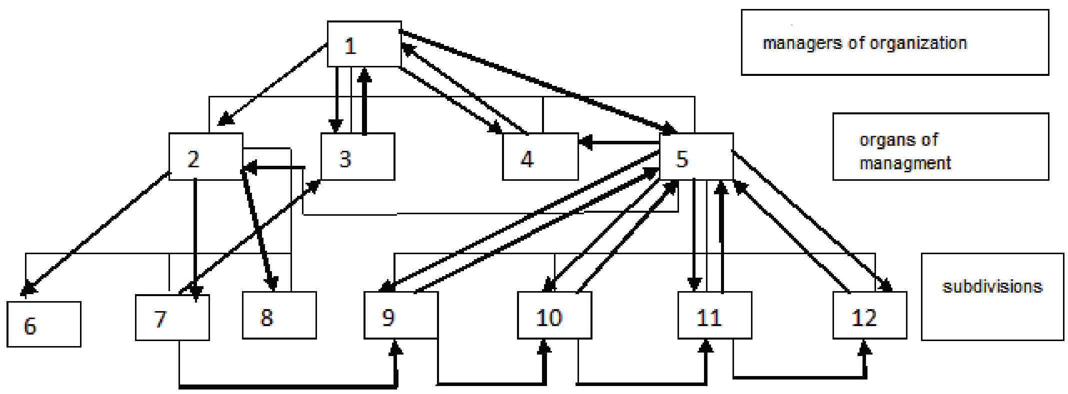

Fig. 1. Functional diagram of the information management system data flows.

On the basis of the received previous results the analysis of the documents structure is performed and their compatible forms, suitable for processing in computer, are developed.

On the basis of the analysis results the algorithm of the informative flows automation is developed, with realization of the informative flows systems analysis (determination of the problems level, environment of distribution, type of the information, and also interrelation of the data flows). The mentioned algorithm must take into account the process of forming the goals (political, economic, ethic, technical), and also determination of the managerial process variables (economic, organizational, legal, informative).

Besides, the flows of information can be formed as a linguistic information transfer, as an information transfer of ordinary documents with hand delivery, using hardware of hand input, or with automatic introduction of reports.

It is also important to consider the information flow as a unit of two notions - the chart and the elements of the flow. At the same time two basic factors - direction and fluency are determined in the stream of information (SI). The streamline is set by the place of its entrance (designation or code) of subdivision, and the fluency (value) λ is determined by the volume of information $\Delta\nu$ (bit, amount of documents, lines, signs, etc.), which is transmitted in time unit Δt (duration of transmission, reception or processing) unit.

$$\lambda=\Delta\nu/\Delta t.$$

The next question of development of the informative data flows automation algorithm in the structure of the managerial computer system is accounting the dependence of the information flows on the informative system functioning regime. In relation to ASM of the separate enterprise a permanent informative constituent and informative constituents of the flow, which have a period of twenty-four hours change, ten-day period, month and etc. in SI are distinguished.

For example, for subdivision with two-shift work at duration of 8 hours change and at 25 working days in a month closeness of information for a monthly interval, unit of information per person:

$$\lambda = \lambda_{const} + \frac{\nu}{8} + \frac{\nu}{8\times 2} + \frac{\nu}{8\times 2\times 10} + \frac{\nu}{8\times 2\times 25},$$

where is λ_{const} a closeness of the permanent flow.

Reflecting the informative flows of the informative system it is purposeful to fold the informatively-logical charts of separate functions and parts of the algorithm of functioning of the computer system co-operation. The results are tabulated; it represents the setting of operations, incoming and initial information. In this case it is efficient to use the methods of formalization with further computer processing.

For example, using the method of graphs (fig. 2), the element of the flow is compared with the tops of the graph, and every pair of the tops is connected by an arc which goes from x_i x_j, where an element x_i is the entrance for the element x_j. The extended graph adds the operators-manage and determinations of ASM administrative functions direction.

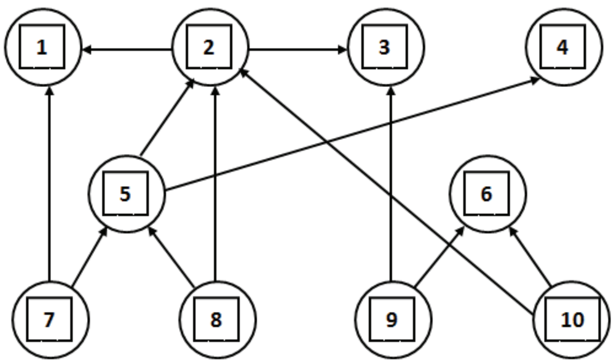

Fig. 2. Informative graph of the automated flows [5].

Herewith, the system of the classification and code of the information provides formalization of the information, suitable for further computer processing.

The important constituent of efficiency of the system of data flows functioning automation in ASM of an enterprise is an algorithm of information processing by means of software and hardware facilities. For processing different structural blocks, such as scalar data and arrays, which can be classified on the classification signs of semantic maintenance, technology of the use, carriers of data and technical descriptions are used [6].

In particular processing of array is the process of its transformation. Thus typical operations with arrays are sorting, confluence, partition, search or change of transmitters.

It should be noted that modern facilities of documents electronic circulation enable to create the integral systems with the simultaneous processing of the structural and unstructured data (such as separate lists, orders, instructions, video and audio information etc.) Further automation of the e-mail management process provides adjusting the data flows of the users' addresses that regulates the complete cycle of documents circulation of an organization.

The important question of ASM informative data flows automation of enterprises is application of corresponding interface of knowledge representation forms into user's automated working place of the managerial computer system. Answering the referred question heuristic models are mostly used. In particular most consulting models in knowledge database keep the rules being used at the moment and the information about a problem area.

Semantic networks in basis of knowledge representation use formalization as a graph with the noted tops and arcs. The tops of the graph is some essence (objects, events, processes, phenomena), and the arcs are relations between them.

More difficult method of knowledge representation is a method of frames, which is used in mighty consulting models. Frames are specific objects that correspond to the concepts of evident area, and have an internal structure as slots (data, rules and other frames).

Conclusion

Summarizing all the above-mentioned, it should be noted that the purpose of the various information flows automation of the computer control system is improving the existing circulation of organization's documents, forms of documents, reduction of their number and copies, optimization of documents routes and algorithm of their forming.

That is why one of the basic tasks of ASM informative data automation is development and introduction of facilities and methods of computing appliances for providing efficient and rational electronic circulation of documents. This is of great importance for the managerial information and telecommunication systems of the special setting, which function in the conditions of vagueness and transience of terms. Answering the noted question is possible via complex application of modern network information technologies in combination with the methods of mathematical modeling of the informative data flows distribution algorithms of the managerial computer systems.

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VIBRATION MONITORING IN THE ROBOTISET ENGINEERING SYSTEMS

The inertia and an elastic is the reasons of origination of vibrations and mechanical resonances which disturb normal functioning of the robot, especially on low frequencies when resonance amplitudes cannot be neglected. As a result there are uncontrollable aberrations from a mechanical trajectory of the manipulator and transient response even for fast systems is augmented.

Modern industrial robots are the devices operated programs consisting of the mechanical manipulator and the reprogrammed control system which are applied to migration of installations to space in various flow processes.

The manipulator of the industrial robot, depending on mission, consists of the several mechanical links merged in one kinematic system. As a rule, manipulators have from 2 to 6 degree of freedom. Manipulator links, ensure translational and robot angular motions in space. The kinematic construction defines area of working space and weight-lifting capacity of the manipulator. Depending on type of performed operation, on the manipulator it is erected either the fascinating device, or the instrument.

Manipulator driving are made by means of hydraulic, pneumatic, electric and combination actuators. Control of the manipulator is made by means of a number of sensors of the links installed on drives. Sensors, finally define manipulator location in space and give a signal on execution of this or that driving in these or those axes.

As robots operate in various conditions, the probability of excitation of vibrations during driving of their loose ports is very great. Depending on points of the application, directivity, magnitude and phase responses of separate disturbing forces their total affecting will be various. This phenomenon try to eliminate in the various ways at different levels.

The time of execution by the robot of a cycle of migrations of a detail in many respects defines productivity of all robotised complex. Therefore the demand to speed of the robot there are enough high. The time of execution by the production operation robot is caused by laws of change of superposed forces and time lag of links of the mechanism. The law of change of operating forces depends on type of the used drive and from a control system aspect. In drives of robots cyclic, position or contour control systems are applied.

At a cyclic control system relative migrations of links are restricted to mobile stops and terminal switches.

On fig.1 the kinematic scheme of three mobile robots of the manipulator (1, 2, 3 - mobile links, 0 - a motionless link) is figured. Here the cyclogram of customisation of a sequencer (full lines) and a cyclogram operations (dotted lines) is resulted. The common work cycle time T_c consists of a stopping time in the set rules (on a cyclogram the stopping is displayed by straight lines parallel a horizontal axis *t*) and a time of relative migrations of links from one set rule in another t_{nx} and it is inverse t_{ox} (slant straight lines on glow irises). The stopping time is usually set by process conditions. The time of execution by the robot of movements is defined by dynamic characteristics of drives and the manipulator - impellents and forces of resistance, masses and moments of inertia of links.

Let's observe operation of the pneumodrive of migration of the arm of the manipulator (fig.2). On a signal from a sequencer in the right cavity of the cylinder compressed air which works on the piston with force $F_{d3} = p \cdot S_n$, where *p* - an air pressure, S_n - the active square of the piston moves. Under the influence of this force the piston and the arm 3 are displaced to the left with fixed acceleration and with increasing speed V_{32} (fig. 2.a). Limitation of a course of the piston can be carried out or an abutment stop without the damper, or a stop with the damper.

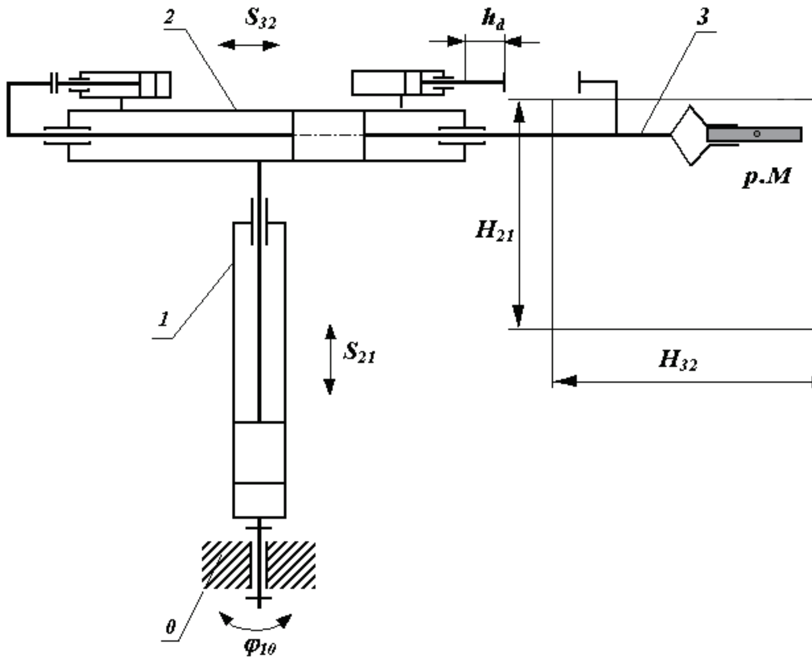

Fig.1. Kinematic scheme of three mobile robots of the manipulator

At a stopping on a stop without the damper, speed of a link 3 should instantly will be diminished from some finite value to null. At such change of speed acceleration a_{32} tends to infinity. Such stopping of a link is called as rigid blow. It is accompanied by the big dynamic loads on links of a mechanism. As the real manipulator represents the elastic-inertia system these loadings will call a recoil of a link 3 from a stop, and also oscillations of all mechanism. The gripper will make oscillations concerning the set end position. Die-away time of this process $\Delta \boldsymbol{t}$ (fig. 2a) considerably reduces speed of the industrial robot.

To diminish these oscillations or in general to expel them it is possible, having ensured an unaccented stopping $V_{32n}=0,\ \ a_{32n}=0$, where V_{32n}, a_{32n} - relative speed and relative acceleration of links at the moment of a stopping.

However it is realizable only in the adjustable drive at contour control. Besides at unaccented остановe in the end of a course relative speed is close to null, therefore the gripper travelling time in a demanded rule considerably increases. The conciliatory proposal is остановwith soft blow at which relative speed in the end of course $V_{32n}=0$, and acceleration is restricted by some legitimate value $a_{32n} \le [a]$. In mechanisms with cyclic control the regime of driving with soft blow is ensured with installation of stops with the dampers extinguishing kinetic energy of the arm of the robot.

Damper account is carried on from condition $A_{\Sigma n}=0$ which is ensured with equality for a motion cycle of operation of impellent $A_{F\,d3}$ and operations of force of resistance of damper $A_{F\,c}$ (fig. 2):

$$A_{F\,d3}=-A_{F\,c} \ \text{or} \ A_{F\,d3}\cdot(H_{32}-h_d)=-F_c\cdot h_d .$$

In this expression two magnitudes F_c and h_d, are unknown and by one of them are set, second - count.

But thus agency on a net moment of mass of a detail with which robot is not considered spends manipulations. Therefore it is offered to use the active damper operated on mass of a detail and link acceleration, that, in turn will allow to minimise a time Δt .

For this purpose we will solve an inverse inverse problem of dynamics which consists in that on the set generalised co-ordinates, speeds and accelerations to define working in jointings of the manipulator of force and the moments. For the purpose of deriving of more effective from the computing point of view of algorithms it is possible to use Newton's – Euler equations.

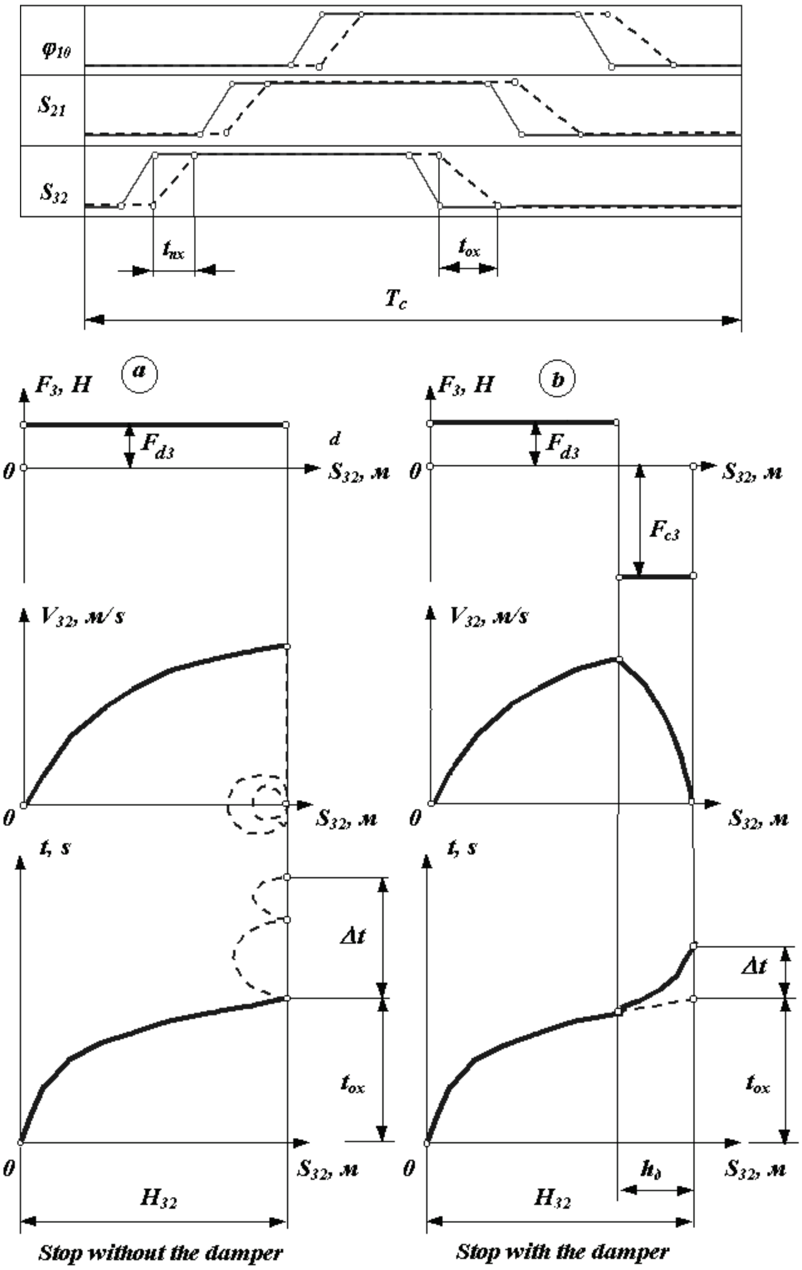

Fig.2. Cyclograms of a sequencer and the industrial robot.

Result of a leading-out of equations of motion of the manipulator Newton's method - Euler is the system of the direct and inverse recurrent equations in succession applied to links of the manipulator.

Newton-Euler's method consists of two steps:

1. We discover all the kinematic of variables a dynamic equation necessary for deriving. To these variables refer to linear both angular velocities and accelerations of the centres of masses of each link, and also speed and acceleration of generalised co-ordinates. The algorithm begins scaling of the first link and proceeds to last link taking into account the previous results.

2. Recursive scaling of the equation of Newton-Euler with use of the kinematic variables gained on the first step. Scaling procedure begins with last link and moves to the first.

$$f_{n-1,n} = f_{n+1,n} - m_n g + m_n a_{cn}\,.$$

$f_{n-1,n}$ - force from which *n*- th link affects a link *n-1;*

$f_{n+1,n}$ - force working on a robot power unit in a tangenting point (it is defined along a mechanical trajectory and it is measured by means of sensing transducers);

m_n - mass *n*- th link;

a_{cn} - linear acceleration of the centre of masses *n* -th link;

Diminishing *n* in a reduced equation it is possible to count forces of interacting between other links.

For the common case recursive procedure of scaling of forces and the moments in the form of the equation of balances looks like the following:

$$\begin{cases} f_{n-1,i} = f_{i+1,i} - m_i g + m_i a_{ci} \\ N_{i-1,i} = N_{i-1,i} + I_i \omega_i + \omega_i \times (I_i \omega_i) - r_i c_i \cdot f_{i,i-1} + r_{i-1} c_i \cdot f_{i-1,i} \end{cases},$$

where: $r_i = b_{i-1} \cdot f_{i-1,i}$ - translational motion ;

$r_i = b_{i-1}^T \cdot N_{i-1,i}$ - rotation motion ;

b_{i-1} - the unit vector directed along an axis z_{i-1}.

Transient response is defined by following expression:

$$\Delta t = \frac{\ln V_0 - \ln \Delta_\text{p} - \ln \sqrt{\left|\left(\beta / C\right)^2 - 4m/C\right|} / 2\frac{m}{C}}{\beta / 2m},$$

where: V_0 - speed of the tool of the manipulator at the moment of an exit on a finite point;

Δ_p – positioning permissible error;

C - rigidity;

β - damping coefficient;

m – detail mass.

Conclusion

Apparently from the gained expressions by a time of transients calling manipulator vibrations at the set mass of a detail *m* it is possible to operate by means of the adaptive damper, changing its rigidity and damping coefficient.

Thus, application of the adaptive damper allows to minimise a time of oscillating process in a manipulator stopping time, reduces amplitude of vibrational oscillations, raises exactitude of manipulators defined by lapses of positioning of a characteristic point of a gripper (point M) and lapses of angular orientation of a gripper.

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THE ELABORATION OF THE PROGRAM OF CALCULATION OF RATE OF MOVEMENT OF CLEANSING DEVICE

This work is devoted to the decision of problem of upgrading of cleaning of internal cavity of main gas pipeline by means of cleansing devices. Realization of the high-quality cleaning is executed with the purpose of increase of hydraulic efficiency and carrying capacity of gas pipeline to the project values. The methods offered by an author consist in providing of optimal rate of movement of cleansing device on all length of area of gas pipeline. It will provide more effective cleaning, without additional expenses.

Cleaning of internal cavity of gas pipeline is executed for the increase of its hydraulic efficiency and carrying capacity to the project values. Now a few methods of cleaning of pipeline are known. To them belong mechanical, vibromechanical, ultrasonic, chemical and others. On main gas pipelines most widespread is a method of the mechanical cleaning by means of scrapers, delimiters, pistons etc.

The rate of movement of cleansing device on length of gas pipeline grows from the beginning of area and to the end with every kilometer and depends on the change of basic parameters of the mode of operations of gas pipeline: sizes of pressure of gas, temperature, and expense. Sometimes speed of cleansing device at the end of area of gas pipeline can attain a size in 1.5 times more than the size at the beginning of area of gas pipeline. In result, the cleansing device moving with speed more than his optimal set speed, diminishes the efficiency of work and does not provide the complete cleaning of gas pipeline the same.

Thus, it is necessary to support the set rate of movement permanent on all length of area. For this purpose with every change of basic parameters of work of gas pipeline, it is necessary to compensate their value according to the set rate of movement of cleansing device. It will make the change of loading compressor stations (CS) during motion between them of cleansing device.

So we change the mode of operations of area of gas pipeline, and regulate the set rate of movement of cleansing device on all length of area by changing loading compressor station through corresponding time.

The program of calculation in the environment of Visual Basic was made for determination of size of change of loading CS, and rate of movement of cleansing device, and also determination of time of change of loading. The short graphic algorithm of this program is shown on a picture 1.

Essence of calculation consists in the following.

1. It determines the carrying capacity of gas pipeline – q (million.m³/24 hours), between two compressor stations:

$$q = 3.26 \cdot 10^{-7} \cdot d^{2.5} \sqrt{\frac{P_n^{\,2} - P_\kappa^{\,2}}{\lambda \cdot Z_{cp} \cdot \Delta \cdot T_{cp} \cdot L}}, \qquad (1)$$

Where, P_κ, P_n – finite and initial pressures of gas are in a gas pipeline, kgf/cm²;

λ – coefficient of hydraulic resistance;

T_{cp} – mean value of temperature of gas, º K;

Δ – relative gas density;

L – length of the pipeline, km.

And middle rate of movement of cleansing device - V (m/s) on length of area through each 10 kilometers:

$$V = 0.0052\frac{T_{cp} \cdot z_{cp} \cdot q}{d^2 \cdot P_{cp}}, \tag{2}$$

Pcp – mean value of pressures of gas, kgf/cm²;
d – internal diameter of gas pipeline, mm ;
Z_{cp} – coefficient of gas compressibility.

2. Determines loading of the compressor stations, on which a start and reception of cleansing device is conducted:

$$\frac{\varepsilon^{\frac{k-1}{k}} - 1}{\frac{n}{n_н}\sqrt{\frac{z_{зв} \cdot R_{зв} \cdot T_{зв}}{z_{вс} \cdot R \cdot T_{вс}}}} = \left(a + b\left(\frac{Q_{вс}}{\frac{n}{n_н}}\right) + c\left(\frac{Q_{вс}}{\frac{n}{n_н}}\right)^2\right)^{\frac{k-1}{k}} - 1\ , \tag{3}$$

$\frac{n}{n_н}$ – loading of the compressor stations, %; ε – degree of increase of pressure on compressor stations;

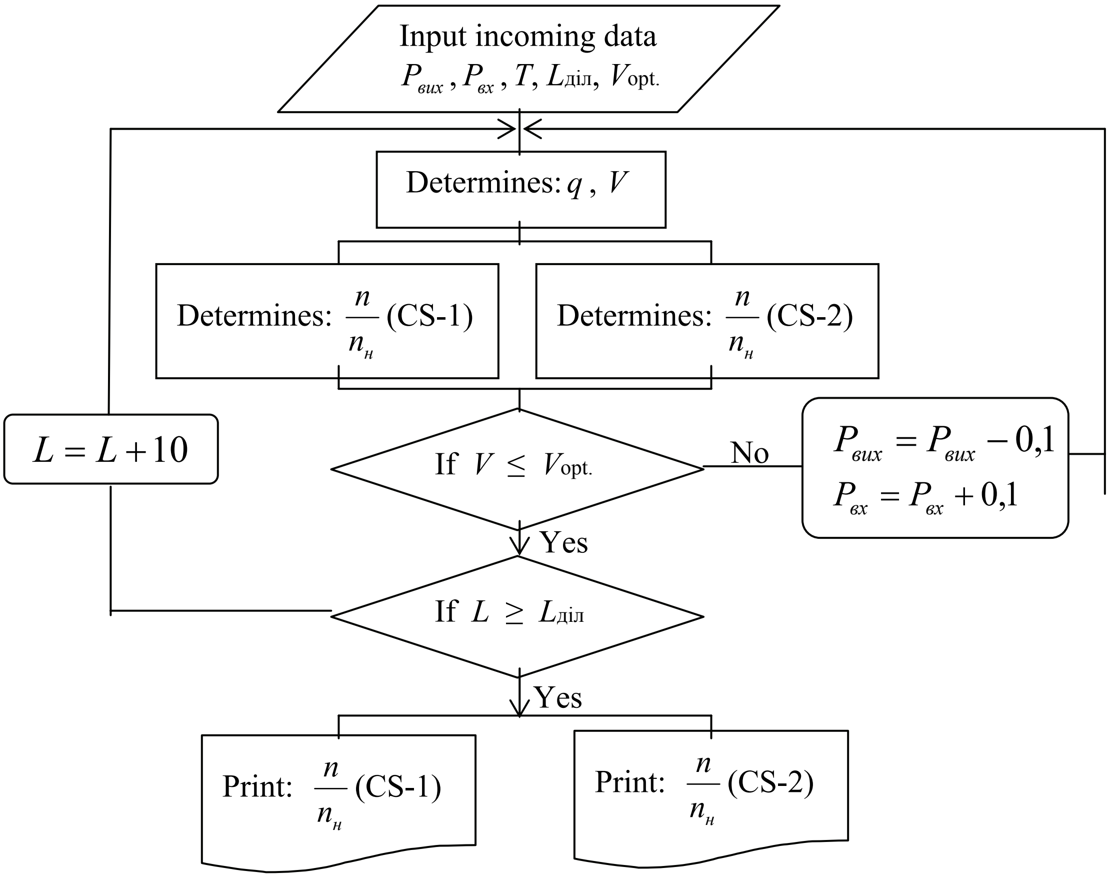
$$\varepsilon = \frac{P_{вих}}{P_{вх}}, \tag{4}$$

$P_{вих}, P_{вх}$ – entrance and initial pressures of gas are in a compressor stations, kgf/cm²; $Q_{вс}$ – carrying capacity of compressor stations, million.m³/24 hours; $z_{зв}, R_{зв}, T_{зв}$ – erected parameters of gas; *zвс, R, Tвс* – parameters of gas on the entrance of compressor stations; *a,b,c* – coefficients of mathematical model of descriptions of compressors of compressor stations;

3. Farther the sizes of the found middle rate of movement of cleansing device made on every area with the set speed are compared by means of logical operators of the program. If middle speed will exceed the value of the set speed on a 1 m/s, the program diminishes the value of actual speed by means of change of sizes of pressures of gas at the beginning and at the end of area of gas pipeline (at the beginning of area - pressure falls down, in the end - rises on 0, 1 kgf/cm²).

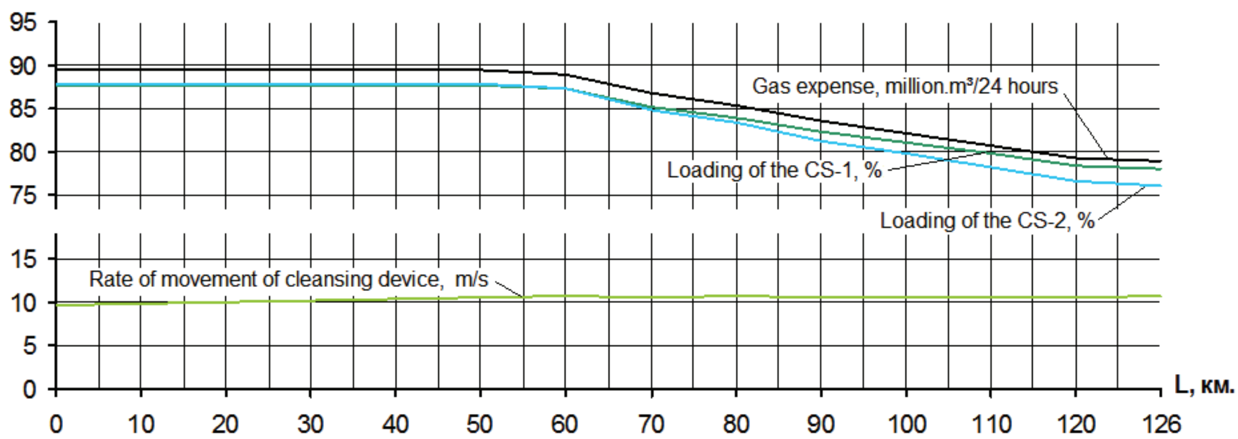
4. The values of incoming data of calculation change accordingly, the calculation of values of carrying capacity, loading of CS is conducted on new, and sizes of middle rates of movement of cleansing device on length of area through each 10 kilometers, so an analogical calculation is conducted, only with the incoming data which are set by the program. If the rate of movement of cleansing device on an area did not diminish on 1 m/s from the set speed, then the program changes the value of pressures of gas on 0,1 kgf/cm², and a calculation recurs again. It will be carried out until the above-mentioned condition is executed. And farther a calculation is conducted for a next area like previous.

5. The time of change of loading CS is determined in dependence on the rate of movement of cleansing device, and area of gas pipeline passed by it. Wave of pressure, which appears at the change of entrance and initial pressure of gas in a gas pipeline moves instantly, and arrives at any area for a few minutes.



Picture 1. - Short graphic algorithm of program.

From data of experimental calculation (Picture 2, Table 1), between the fiftieth and the sixtieth kilometer of gas pipeline the rate of movement of cleansing device becomes more on a 1 m/s from the set speed. Farther the values of initial and finite pressure of gas begin to deviate on an area, and all modes of operations of gas pipeline change, that causes to the change of loading on CS. Then after the sixtieth kilometer there is a permanent change of all parameters of the mode of gas pipeline which supports the stable rate of movement of cleansing device, so its traffic regulation is executed by the change of loading compressor stations.



Picture 2. - Dependences of parameters of the mode of operations of gas pipeline.

Table 1 - Results of programmatic calculation of change of loading of CS are in relation to the rate of movement of cleansing device

Length, km	Expense, million.m³/ 24 hours	Rate, m/s	Loading CS-1, %	Loading CS-2, %	Temperature ºC	Pressure (initial) kgf/cm²	Pressure (finite) kgf/cm²
0	89,4	9.659	87.68	87.92	40	72.4	51.8
10	89,4	9.803	87.68	87.92	38.25	72.4	51.8
20	89,4	9.957	87.68	87.92	36.60	72.4	51.8
30	89,4	10.123	87.68	87.92	35.02	72.4	51.8
40	89,4	10.302	87.68	87.92	33.53	72.4	51.8
50	89,4	10.495	87.68	87.92	32.11	72.4	51.8
60	88,968	10.654	87.28	87.40	30.72	72.3	51.9
70	86,760	10.604	85.22	84.86	29.21	71.8	52.3
80	85,416	10.646	83.98	83.34	27.82	71.5	52.6
90	83,592	10.611	82.29	81.28	26.41	71.1	53.0
100	82,200	10.623	81.02	79.76	25.15	70.8	53.3
110	80,784	10.621	79.74	78.22	23.80	70.5	53.6
120	79,344	10.602	78.43	76.68	22.55	70.2	53.9
126	78,864	10.652	78.00	76.16	21.88	70.1	54.0

Conclusion

Analyzing a programmatic calculation it is possible to say, that it is really possible to regulate the rate of movement of cleansing device by changing the loadings of the compressor stations on all length of area of gas pipeline. It is not advantageous on one side, as a mode of operations of gas pipeline breaks, but on the other side, this method is advantageous enough, as it will provide optimal motion of cleansing device, and thus high-quality cleaning of gas pipeline.

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APPLICATION OF INDUCTIVE MODELS FOR INFORMATION TRANSFORMATIONS IN A ROBOT IS THE TECHNICAL SYSTEMS OF ENVIRONMENT MONITORING

Abstract. *Using inductive models as ITA in a robot is the technical systems of multilevel environment monitoring is suggested. GMDH is suggested to coordinate interactions of separate elements in the structures of such systems. To evaluate the influence of the factors characteristics of which are included to the structures of an inductive model fixing of output rates of these characteristics to the diapason of their changes in the input data massif is used.*

The most typical problem in constructing a robot is the technical monitoring systems is that of transforming the information about concentrations of harmful substances in waters, air, soil, food products and characteristics of anthropogenic emissions

$$X=\{x_1, x_2, \dots x_n\}, \tag{1}$$

into the information about the quantity of various diseases among people under such conditions:

$$Y=\{y_1, y_2, \dots, y_m\}. \tag{2}$$

Functional dependence

$$Y=f(X) \tag{3}$$

is called the information transformation algorithm (ITA) and is an element of the hierarchical structure that ensures the processing of the monitored information.

The process of obtaining the dependence (3) is known as the synthesis of information transformation algorithms. The program module that ensures the synthesis process is called a synthesizer.

As the functional dependence (3) is a multi-parameter model of a complex structure using GMDH for its synthesis is suggested. Work of the synthesizer is based on GMDH algorithms. Inductive models are used as ITA in case their quality values are not worse than the predetermined boundary values. Criteria of regularities, unbiaising and other data used in a typical GMDH algorithm are qualitative index of the model. The type of the qualitative index is determined on the stage of projecting the structure of the information transformation subsystem.

Thus quality characteristics of a separate inductive model determine the credibility of information received at the monitoring output and which serves as the basis for the control of the anthropogenic load on the environment. That is why it's necessary to determine technologies of model synthesis that can be used for projecting automated systems of the multilevel socio-ecological monitoring.

Synthesizers of such models should meet several requirements. Using inductive models as ITA ensures solving main problems of the projecting hierarchical multilevel information transformation systems, namely forming the hierarchical structure of the information transformation subsystem and coordinating interactions of its elements.

To ensure the coordination of the interactions of the separate elements of the hierarchical structure of the information transformation subsystem a new method of forming such systems is suggested, namely that of bottom-up synthesis of the information transformation algorithms. Each of the inductive ITA of a higher level is synthesized on the basis of many Y signals that come to its input from the outputs of numerous ITA of lower levels according to "all-to-one" principle. In this case the coordination of inter-level interactions of local ITA is ensured through inductive synthesis of algorithms of a higher level. Fig.1 shows the hierarchical structure of the information transformation subsystem obtained through the bottom-up synthesis of local ITA.

To ensure this process it’s necessary to solve the problem of difference in self-descriptiveness of data massif that comes to the input of the algorithms of different levels. That’s why the model synthesizer should have necessary adaptability in order to ensure constructing models that can be used as ITA at all levels of the information transformation without any resetting of the synthesizer. It can be achieved through higher diversity of the GMDH algorithms.

The inductive model used as ITA contains the information about influence of each factor on the monitored object. The synthesizer should also ensure accessibility to this information. Influence evaluation of various factors with different characteristics is one more problem that can be solved by using weighting coefficients which are calculated according to the equation

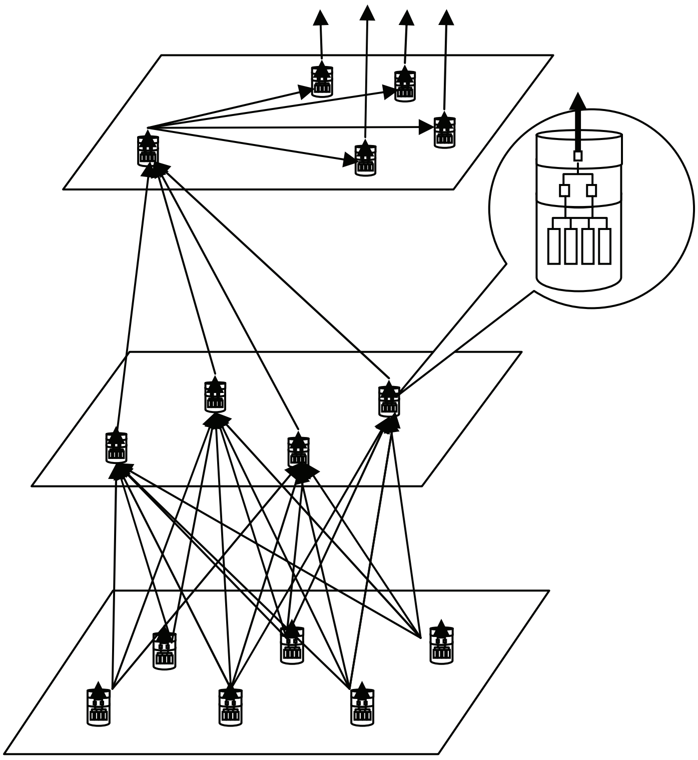

Fig. 1. – Structure of subsystem of transformation of information on inductive models

$$C_i = \frac{F'_i}{\sum_{i=1}^{n} F'_i} \tag{4}$$

where C – is the weighting coefficient of the i-parameter;

F – is a partial derivative of the model according to the i-parameter

N – is a quantity of variable model parameters.

F is calculated according to equation (5):

$$F'_i = \frac{\Delta y_i}{\Delta x_i}, \tag{5}$$

where Δx_i – is the change value of the i-parameter;

Δy_i – is the change of the function value obtained when the parameter is changed in Δx_i.

The problem of differences in characteristics scale is solved by fixing of proper output rates of change values of the parameter to the diapason of this value changes in input data massif.

Using inductive models as the ITA allows forming the hierarchical structure of the information transformation subsystem (ITS) to coordinate the interactions of its separate elements. A method of the ascendant synthesis of ITA was developed to coordinate the interactions of the ITS elements [2]. Each of the multiple inductive ITAs of a higher level is synthesized on the basis of the multiple Y signals that come to its input from an output of the multiple ITAs of a lower level according to “all-to-one” principle. In this case the coordination of the local ITAs occurs in the process of the inductive synthesis of the higher level algorithms.

To ensure this process it was necessary to solve the problem of different informativity of the data massifs that come to the algorithm inputs of different levels. To improve the diversity of the GMDH algorithms the technology of the multi-layer model synthesis was developed. The said multi-layer models combine in their structures the one-layer models of one and the same object received according to the final algorithms [3]. Criteria of one-layer model selection and methods of their joining in multi-layer structures have been developed.

Control of the information transformation quality is ensured through the substitution of one or several models the output data quality of which has deteriorated. The control subsystem consists of two echelons.

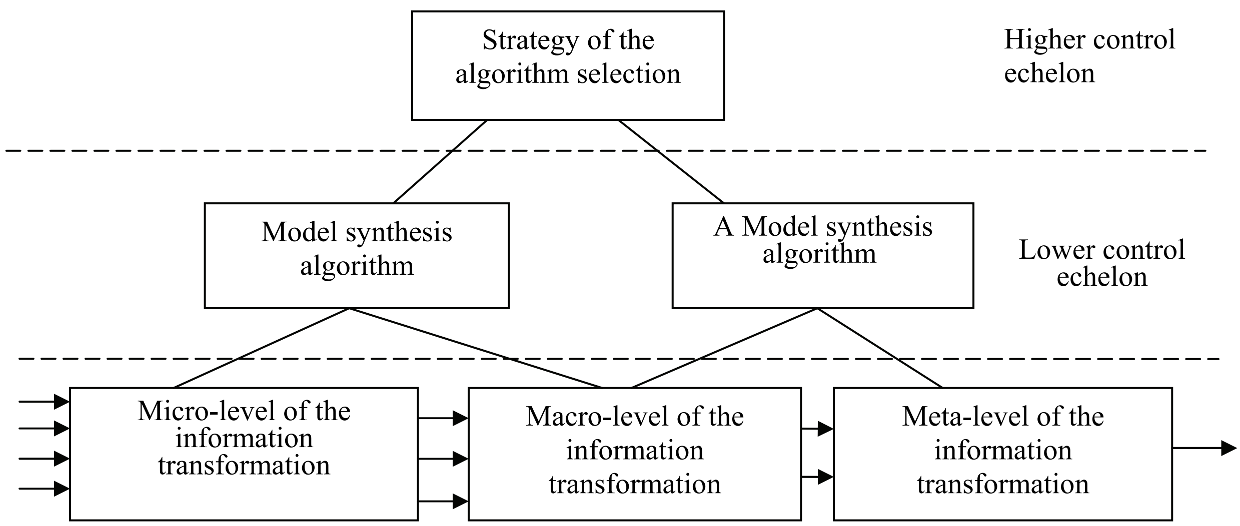

Fig.2. Hierarchical control system of the information transformation

Model synthesis of the monitored objects of the corresponding level is ensured at the lower control echelon. The model synthesis algorithm is selected at the higher control echelon. A new algorithm is constructed if necessary.

It was found that the ability of the information transformation subsystem to dynamically rebuild its structure is widely used during the working process. The necessity of such rebuilding arises on an average 2-5 times during the process of taking decisions. A change in the vector of outer tasks causes the substitution of the task to find the dependences for the tasks to prognose the consequences of the governing influence application. Addition of new data to the database leads to the necessity to analyze the influence of the dynamic processes on the neighboring regions that have not been taken into consideration before. In all these cases it’s necessary to rebuild more than 50 elements of the multi-level structure of the ITS.

As the rebuilding of the structure demands ensuring the ascendant synthesis of the inductive models, changes in the characteristics of the input data massifs lead to worsening the adequacy of some of these models. That’s why the model synthesizer must possess necessary adaptivity, namely, to ensure making models that can be used as ITAs at all information transformation levels without resetting the synthesizer when the characteristics of the input data massif are changed. In such cases the heightened diversity of separate GMDH algorithms is not sufficient even in case of making multi-layer ITA structures. A new method of the adaptive synthesis of the information transformation algorithm was developed. The main feature of this method is using the procedure of input data classification aimed at selecting the best algorithm of the model synthesis. Several algorithms of different types are used in the model synthesis process according to the characteristics of the input data. Quality of the transformed information is improved, while time for rebuilding ITS structure is reduced from 65 to 2.5 minutes.

Quality evaluation of the efficiency of the suggested multi-layer models and methods shows that their operation and accuracy are 2.3 times better than the existing ones. Theoretical results of the investigation were proved by developing the information technologies of the multi-level SEI and their introducing as automated systems for the processing the regional socioecologic information, by developing methods and technical devices for measured information processing while determining the compositions of the environmental objects. The suggested models and methods can be applied in medicine, economics and other spheres in order to improve control of the monitoring information systems.

Conclusions

Using inductive models as ITAs in complex systems of multi-level environment monitoring is suggested. GMDH is suggested to coordinate interactions of separate elements in the structures of such systems. To evaluate the influence of the factors characteristics of which are included to the structures of an inductive model fixing of output rates of these characteristics to the diapason of their changes in the input data massif is used. The suggested approach to the problem allows forming the multi-level structures of the information transformation subsystem, coordinating the elements of these structures and creating hierarchical subsystem of the information transformation quality control.

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ENHANCEMENT OF DYNAMIC PRECISION OF COORDINATE DRIVES OF ROBOTIC MEASURING COMPLEXES

This article presents a new structure of follow-up control system regulator that allows to obtain enhanced dynamic measurement characteristics of coordinate drives of robotic complexes. An opportunity to improve performance through the realization of a drive with a variable structure is examined. The paper lays out findings of a comparative analysis testing the performance of the base and the proposed structures exposed to various input actions.

Introduction. The coordinate drives of the linear motion are widely used in the modern production equipment, intended both for manufacturing of various complex-shaped components and for the control of their characteristics on the finishing stage of production. In these processes, the control of geometrical parameters of the manufactured products has proved to be of high importance. In order to implement this control, automatic coordinate measuring machines are widely used. Most of them are based on the principle of the reconstruction of complex spatial motions of the sensing element around the surfaces of the measured object with a periodic reading of the coordinates [1, 2].

Problem definition. Guided coordinate drives are systems designed for automatic regulation and as such are exposed to high precision and operating speed requirements. There are power and mechanical factors which impose limitations on the providing an improved dynamic precision of drives, and perfection in these areas is difficult and expensive. However, there are certain unutilized improvement capacities in the application of untraditional methods of construction of sensor-based systems at algorithmic level, in particular, of follow-up control system regulators at algorithmic level [3, 4].

Problem solution. In this article, a new structure of regulator of the coordinate drive is proposed, which allows to substantially improve the dynamic characteristics of a follow-up system (Fig. 1). The structure of the regulator is amended by elements computing speed u_v of the error signal u_d and its acceleration u_a. The computer of modulation coefficient k_m forms a control signal depending on the correlation of signals u_v and $(u_v - u_a)$. The k_m reaches the maximum value in the absence of the acceleration of error signal and diminishes to zero in accordance with the functional dependence of $f(u_v, u_a)$. The modulated adjustment signal u_c is input into an integral regulator together with the error signal u_d.

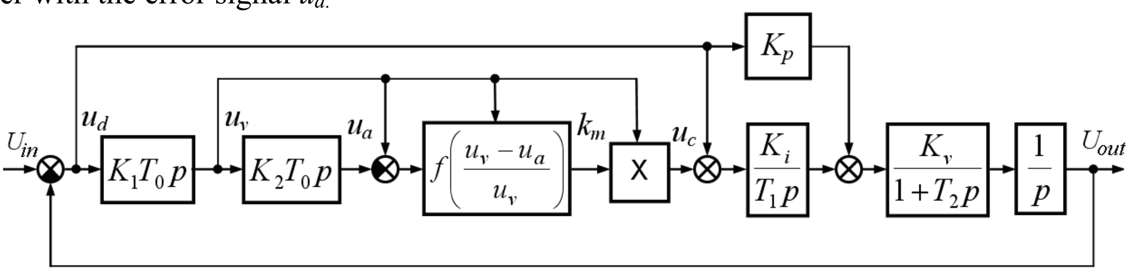

Fig. 1. Flow chart of the follow-up system with a functional regulator

In order to compare dynamic characteristics of the follow-up systems with the conventional and the proposed structure, areas of optimum parameter values for each of the structures are identified. The transmission function of the base follow-up system with the PI-regulator in a open position has the following form:

$$K(p) = \left(K_p + \frac{K_i}{T_1 p}\right) \cdot \frac{K_v}{1 + \sqrt{2}T_2 p + (T_2 p)^2} \cdot \frac{1}{p}$$

where p – operator of differentiation; K_p, K_i – coefficients of proportional and integral constituents of the regulator; K_v – conversion coefficient of high-speed contour; T_1, T_2 – time constants.

For the modeling purposes it is assumed that $K_1 = K_2 = K_p = K_i = 1$, $\omega_2 = 1/T_2 = 800$ rad/s (upper combined frequency). The parameters ω_0 (that cutoff frequency, numerically equal to K_v) and $\omega_1 = 1/T_1$ (lower combined frequency) were modified from 50 rad/s to 800 rad/s. The results of the phased impact are presented in diagrams 2, 3. For a base structure, an over-regulation (Fig. 2, a) has an evident minimum at $\omega_0 = 250$ rad/s practically for any ω_1 in the range. On the other hand, the duration of the transitional process (Fig. 2,) at $\omega_0 = 250$ rad/s reaches a minimum at $\omega_1 = 125$ rad/s.

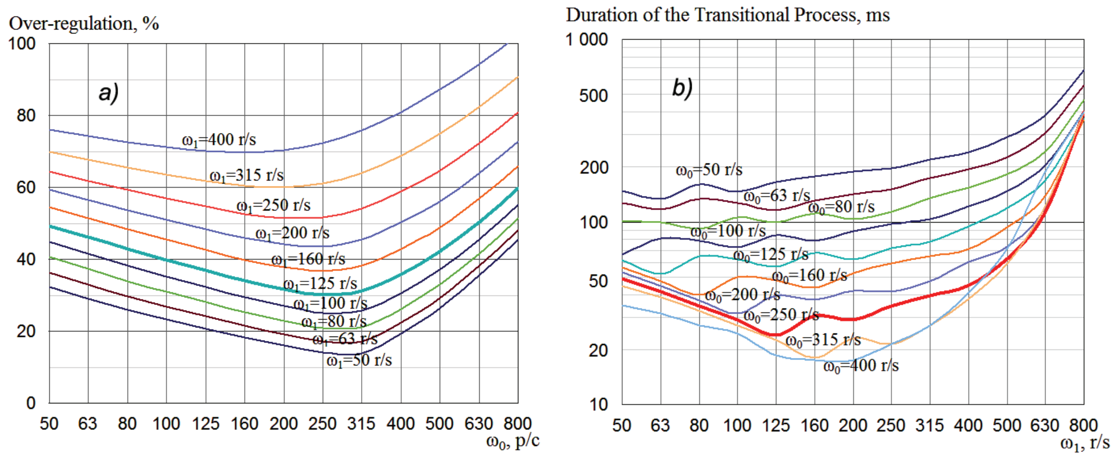

Fig. 2. Dependence of transitional process characteristics on ω_0 and ω_1 for a base structure

In the proposed structure (Fig. 3, *a*), an area of ω_0 values below 200 rad/s is distinguished, in which there is no over-regulation and which does not depend on ω_1. The second factor – the duration of the transitional process (Fig. 3, *b*) is inversely dependent on frequency of ω_0, therefore the maximum value ω_0 is chosen. For $\omega_0 = 200$ rad/s the optimum value of frequency of ω_1 equals 400 rad/s.

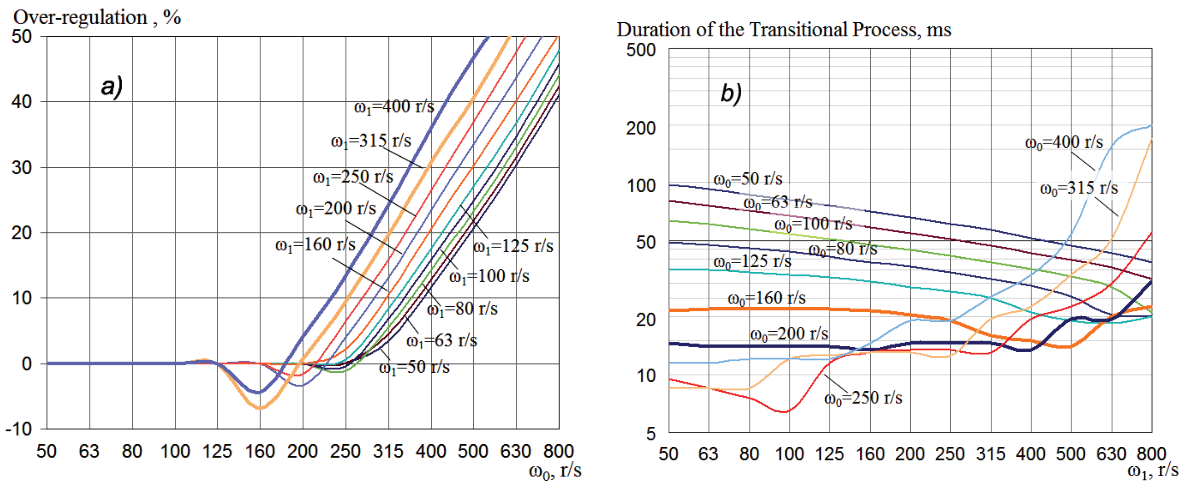

Fig. 3. Dependence of transitional process characteristics on ω_0 and ω_1 for the proposed structure

The final results of the experiments are laid out in Table 1. Figure 4 presents amplitude-frequency characteristics of the examined structures in the tuned state.

The characteristic chart of the base structure crosses the 0 dB axis at an angle of 20 dB/dec, and the cutoff frequency ω_0 is twice higher than ω_1. The proximity of frequency ω_2, which characterizes limitation of transmission band of the high-speed contour, does not allow to improve the dynamic properties of the system in its base configuration. The characteristics of the improved structure are presented for two extreme cases: the lower curve corresponds to a blocking of the differential link, and the upper curve corresponds to its operating mode. In the proposed structure LPFC crosses the 0 dB axis at an angle of 40 dB/dec up to unconventionally high values of ω_{1m}. The coefficient of the introduction of the k_m adjustment is modulated by correlation of factors describing the current state of the system, namely, signals of deviation and its first and second derivative.

Table 1

Final parameter values of the examined structures in the tuned state

Parameter	Base structure	Proposed structure	
		$k_m = 0$	$k_m = 1$
Lower combined frequencies ω_1 and ω_{1m}, rad/s	125	400	200
System cutoff frequencies ω_0 and ω_{0m}, rad/s	250	310	500
Upper combined frequency ω_2, rad/s	800	800	800
Ratio of frequencies $\omega_0/\ \omega_1$ (ω_2 / ω_0)	2 (3,2)	0,62 (3,2)	2,5 (1,6)
Correlation of amplification coefficients $\|K(\omega)\|$ in proposed and base structures at frequencies:			
below 125 rad/s	-	3,1	3,1
200 rad/s	-	2	2
250 rad/s	-	1,6	2
315 rad/s	-	1,25	2
higher 400 rad/s	-	1	2
Order of inclination LPFC at $\|K(\omega)\|$ =1, dB/dec	20	40	20

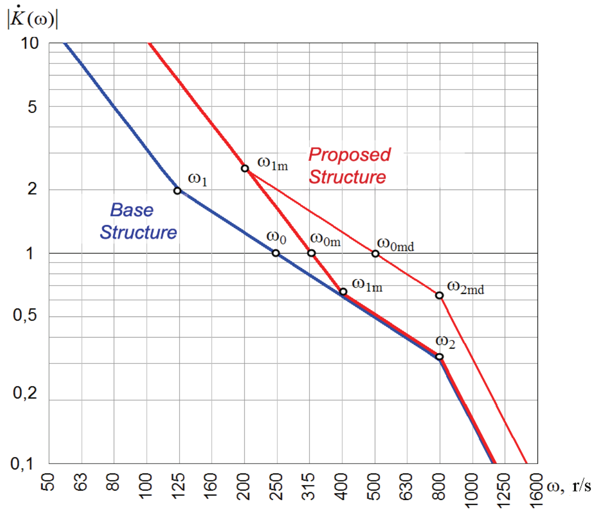

Fig. 4. LPFC of the examined structures

The comparative charts in Fig. 5, 6 and Fig. 7 demonstrate views of transitional processes and follow-up dynamics for a surface with a circular-type relief accordingly at different levels of limitation of the module of signal $|u_d|$ of the deflection sensor.

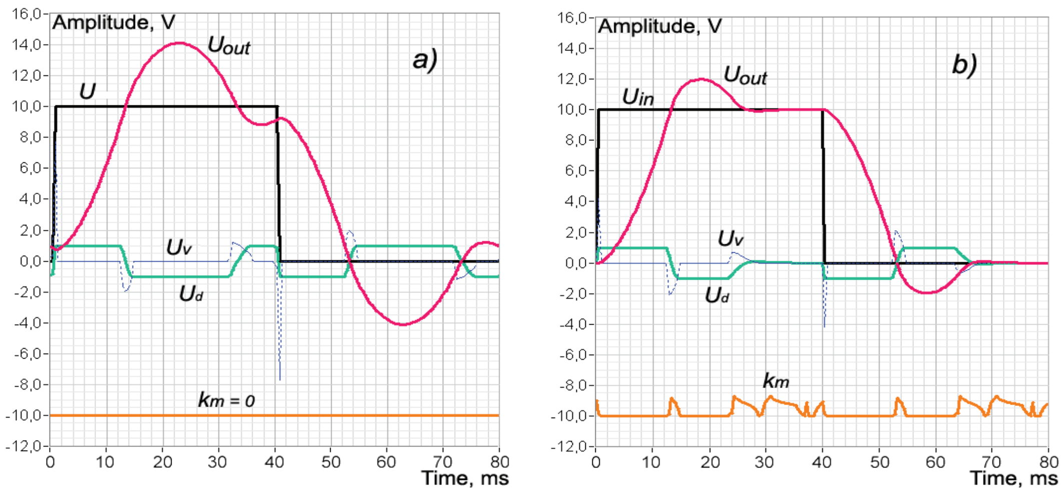

Fig. 5. Transitional processes of base (a) and proposed (b) structures at $|u_d| \leq 1\,\text{B}$

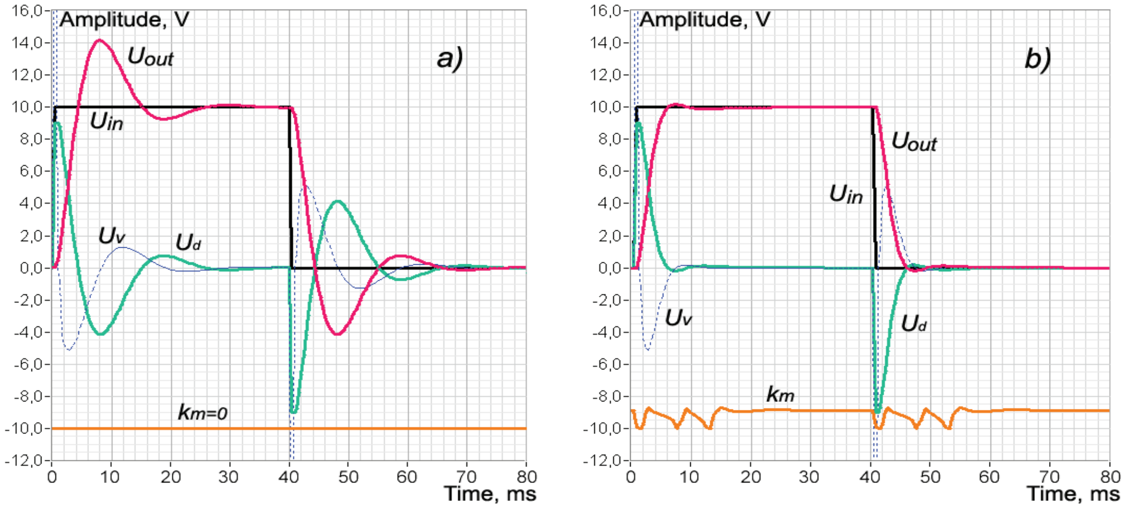

Fig. 6. Transitional processes of base (a) and proposed (b) structures at $|u_d| \leq 9$ B

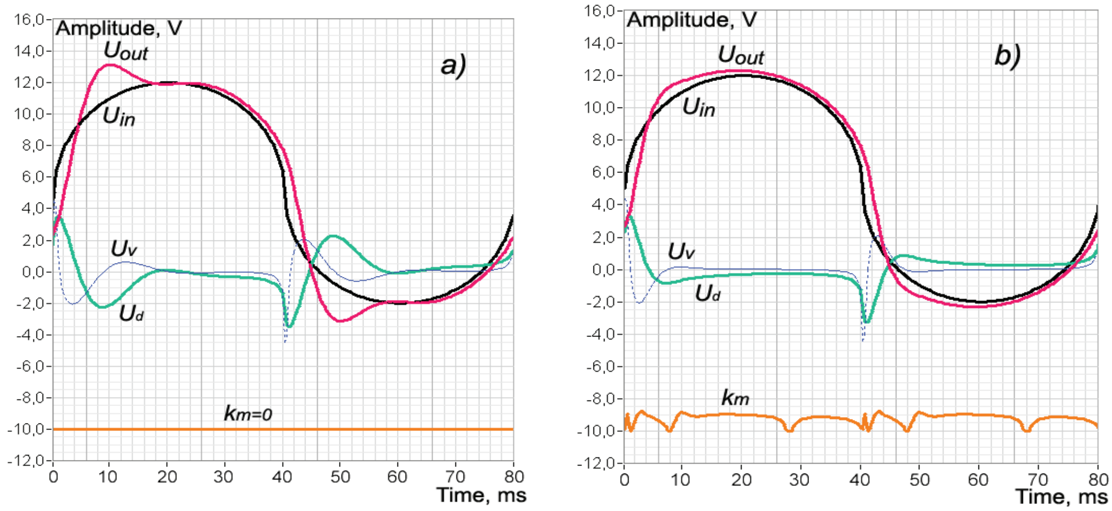

Fig. 7. Performance of base (a) and proposed (b) structures at $|u_d| \leq 1$ B

The results suggest that the introduction of the modulated differential amendment enhances qualities of the system. The adaptive quality of the frequency characteristics allows to attain a combination of robustness to impact of interferences with a high processing speed.

Conclusions

Compared to the base system, the proposed system has a twice broader transmission band. Also, the amplification in the open condition is two times higher at the upper working frequencies, and three times higher in the low-frequency range. Such improvements in the frequency characteristics of the system enable 1.6-2.5 times decrease in errors during the reconstruction of complex trajectory motions. The proposed system demonstrates dynamic characteristics superior to those of a conventional system even under the conditions of significant attenuation of the deflection sensor signal.

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POSITIONING OF AEROSPACE VEHICLES IN MULTIDIMENSIONAL METRIC OF GALOIS

На основі аналізу методів позиціонування в просторі обґрунтовано необхідність переходу від паралельної до вертикальної інфотехнології формування повідомлень. Запропоновано застосовувати методи рекурсивного кодування Ґалуа. Визначено властивості запропонованих методів кодування, розроблено математичні моделі та методи кодування в багатовимірній метриці Галуа. Здійснено оцінку ефективності застосування вертикальної інфотехнології.

A control of space vehicles in space envisions their rigid positioning in co-ordinate system with absolute fixation to a conditional pole of co-ordinate system/1 - 3/. Our environment exists in three-dimensional space with the fourth vector of development as time, therefore it is possible to present an arrangement of any object to any moment of time, at least, three values of co-ordinates. Distinguish the next basic systems of coordinates :

on a plane - rectilineal, from them - two-dimensional rectangular Cartesian;
curvilinear, from them - polar;
in space - rectilineal, from them - three-dimensional Cartesian;
curvilinear, from them - spherical,
and polar-cylindrical.

The two-dimensional rectangular Cartesian system of coordinates is used limitedly for positioning of aerospace devices as a result of restriction of possibility of its application in two dimension. Systems of co-ordinates on a plane - polar and in space - polarly-cylindrical purchased wide application in the systems of radiolocation for positioning of aviation vehicles with the insignificant flying height. Three-dimensional rectangular Cartesian system of co-ordinates in space is oriented to definition of co-ordinates mainly aviation vehicles in relation to the planet surface. However, at realization of transcontinental flights on large distances, when an error, predefined by the spherical form of Earth, grows considerably, a necessity is passing to the spherical system of co-ordinates, in which the absolute positioning of object is carried out in relation to geographical longitude and geographical latitude of planet. The flying height of airmobile vehicle is defined generally by altitude over a conditional sea level. For flying vehicles of type as a wing-rocket, motion of which is carried out above a terrene on subzero heights, positioning in three-dimensional space comes forward as especially actual.

The modern digital systems use a bit-position, unitary and number-impulse codes /4 - 6/ at primary transformation of data in a digital code, which are characterized by considerable bit redundancy and low noise stability. On the basis of binary codes of the Rademaher system the most modern digital systems are function, and Gray codes, which allow to avoid interbit ambiguousness of read-out, are one of the cores at positioning.

At the analysis of existing and development of perspective coding methods offered approach to positioning of aerospace vehicles, which is based on principle of indissolubility of flying trajectory of object and consists in that every body which carries out moving in space is unable to carry out the change of the location in space for the infinitesimal time interval. Therefore, choosing the step of discretisation, we are always able to carry out converting of position of mobile object into a code with the set exactness of code presentation.

Development of new methods of positioning of aerospace vehicles was based on passing to the code systems in the Galois base. Use of the recursive code systems Galois has allowed to realize for the first time a vertical information technology with a bit oriented compression of Hartley of data flows.

Code sequences of Galois form the special class of block polynomials cyclic codes /7, 8/. At data coding message are identified with polynomials, and procedure of code consists in multiplying to the fixed polynomial. A standard polynomial of degrees n basis of p above the commutative ring of $GR(p^n)$ are expression

$$a_{n-1}p^{n-1} + ... + a_1 p^1 + a_0 p^0 = \sum_{i=0}^{n-1} a_i\, p^i\,,\quad a_i \in R,$$

here coefficients of a_i univalently define a vector $a = (a_{n-1}\,, ...\,, a_i\,, ...\,, a_1\,, a_0)$.

For a block (n, s) - codes in each block are defined $r = s - n$ control characters. In the array of the field of $GF(2^n)$ a complete encoding matrix has a dimension $N \times N$ ($N=2^n$), in which encoding vectors are dimension polynomials n, ordered in matrix $N \times n$, and other $N - n$ digits are surplus, used for noise protection, and their amount r defines the degree of defence and amount of the potentially corrected errors.

Methodology of multidimensional coding is based on recursive organization of code elements in a generation matrix which is directly mapped from the base of Galois /7/. The mathematical model is described by vectorial expression

$$N_j = (g_{j-n-1}\,, \ldots\,, g_{j-1}\,, g_j),$$

here $g_{j+1} = \sum_{j=j}^{j-n+1} a\, g_j \mod p,$ g_j - are the least positive residuals of recursive sequence of ring $GR(p^n)$ on the modulo of prime number p, p - calculus base (further $p = 2$), a - a logical vector of the code key of ring $GR(p^n)$, n – word length of a code of presentation $(n \log_p N)$, N - an amount of quanta of data forming.

Complete field of Galois code elements of dimension $N \times N$, ordered with a memberwise recursive change in obedience to the symmetric diagonal of matrix, is closed in the abstract code cylinder in high N and length of a circles of basis N. On both butt ends a cylinder is latchable in the abstract figure of higher order of organization of the code system - torus. Each of numbers on lines, which is determined as a current report, the vector-line of dimension answers $1 \times N$ of code elements. Obvious considerable redundancy in dimension of N-digit vectors, predefined by the recursion packing. According to Shannon continuous number of the i-reports from N in the matrix of dimension $N \times N$ is univalently defined by the vector of dimension n.

The field of code elements of Galois narrows to the dimension of $N \times n$, id est the height of abstract code cylinder diminishes from N to n at the same length of circle of basis of N. A torus is torn by the exception of sector in high $N - n$. The got matrix is a mapping of the parallel recursion code system Galois, where each the i-report from N appears the parallel n-digit fragment of code elements, located on the generatrix of abstract code cylinder.

The modification of an order of parallel vectors in vertical allows to make univalent identification of i-numbers of report from N arbitrary the matrix-column of code elements of dimension of $N \times 1$ from the complete matrix of Galois of dimension $N \times N$, that is defined by an initial vector of binding of zero cut an abstract code cylinder as a ring long N.

A bit oriented information transfer foresees authentication of position the code sequences of Galois for n the last counted bits on each of co-ordinate axes. Unlike bit oriented of unitary coding which foresees an account all without the skip of the counted reports from zero to current bits, that in maximum case presents N, the Galois coding allows to reduce time of authentication of absolute value to the value which answers time of read-out of n of the last signs of Galois. The coefficient of diminishing of time of authentication presents $k=N/n$ and, depending on word length of informative words, can arrive at a few orders.

The code sequences of Galois, which belong to the class of block (n, s) - codes, allow to carry out determination and automatic updating of the counted errors for redundancy $r=s-n$ check characters without considerable complication of the algorithmic and technical providing /4, 7/.

Thus, a transition to vertical information technology by the Galois coding allows to reduce considerably redundancy of information which is processed by a tracking system, realize permanent not surveillance on a code scale, but only in necessary moment during the following of n code signs, to carry out an error protection and decrease time of authentication.

Statement of methods of multidimensional coding of positions of aerospace vehicles we will continue coding methods in two-dimensional space (on a plane) in obedience to the laws of which positioning of low flying objects is carried out as wing-rockets with independent control of height of flight.

The first method with two bit binding of knots or squares of a co-ordinate network consists in that code binding of i-th knots for vertical lines is carried out in obedience to one vector of feed-backs to the first bit of g_i of code pair of g_iq_i, and binding for vertical lines is carried out in obedience to other vector of feed-backs to the second bit of q_i pair of g_iq_i. The code of vertical component is formed from the signs of the first bits of g, and the code of horizontal component is formed by the signs of the second bits of code pair of q. If the method of marking of code signs it is possible, then every code pair of g_iq_i can be replaced by one sign in the quadded notation scale.

The considered method of positioning is surplus as a result of two bits Galois code binding each of knots or squares of co-ordinate network. The increase of coding efficiency is arrived at by diminishing of bit of Galois signs from two to one as a result of polar-cylindrical and polar-spiral order change of code elements. The method of the polar-cylindrical positioning in two-dimensional space is based on an appropriation to every knot or square of co-ordinate network of only bit of code Galois sign in obedience to the synthesized matrix of code elements of dimension of $N \times N$, as a result get possibility of determination of absolute value of position of mobile object on a plane with exactness $\delta = 1/N$.

In the Galois code co-ordinate network co-ordinate each of knots is defined n-digit codes which at different terms can be formed on different from contiguous n digits accordingly for the horizontals n_h and vertical lines n_v. On fig. 1 an example of reading of position codes towards increase of sequence numbers is made, and on fig. 2 - towards their decrease.

$$\begin{array}{cccc}
g_i & g_{i+1} & \cdots & g_{i+n-1} \\
g_{i+1} & & n_h & \\
\cdots & n_v & & \\
g_{i+n-1} & & &
\end{array}$$

Figure 1 - Forming a position codes towards increase of sequence numbers

$$\begin{array}{cccc}
 & & & g_{i-n+1} \\
 & & n_v & \cdots \\
 & n_h & & g_{i-1} \\
g_{i-n+1} & \cdots & g_{i-1} & g_i
\end{array}$$

Figure 2 - Forming a position codes towards decrease of sequence numbers

An polar-cylindrical form is oriented to positioning of vehicles in the square field of co-ordinate network ($N \times N$), as a result of recursive change, the dimension of horizontal and vertical axes is identical.

The polar-spiral form of organization of code sequences of Galois is analogical polar-cylindrical with a that difference, that code rings have brief on unit length of $N=2^n$-1, as a result get unique property of through recursion interdependence of all code elements along a spiral, rings, generatrices and complete period of spiral, reserved in a torus. In the polar-cylindrical coding form of co-ordinate network the elements of contiguous rings do not have direct logical dependence inter se. At an polar-spiral coding all code elements of Galois sequence are logically interdependent inter se, each of next rings is logical continuation of previous ring with a phase mutual change on one digit, that allows to carry out spiral organization of rings inter se. Logical shorting of beginning of the first ring with an end forms the last figure of higher order of spatial organization - torus from multi phase $T=n(N-1)$. Expansion of dimension each of rings from n to $N-1$ allows to extend the code field and synthesize other abstract figure - torus with extended multi phase $T=(N-1)(N-1)$. The properties of recursive interdependence of code elements allow to promote the level of error protection.

The dimension of digit of co-ordinate network of the code field presents $(N-1)\times(N-1)$ bits on each of axes.

Comparing of the offered bit oriented methods of positioning to the typical methods of parallel coding, when every knot of co-ordinate network is encoded by binary codes of co-ordinates for vertical lines and horizontals, allows to estimate its efficiency as correlation of complete volumes of information which potentially can be formed at parallel I_p and vertical I_w coding

$$k_{еф} = I_p / I_w$$

For the code field with the dimension of co-ordinate network $V \times H$.

$n_v = E^{\wedge}[\log_2 V]$, $n_h = E^{\wedge}[\log_2 H]$ - it is a binary codes word length of co-ordinates for vertical lines and horizontals, where V, H is an amount of digits of positions accordingly for vertical lines and horizontals

$$I_p = V\,H\,(n_v + n_h);$$
$$I_w^2 = V\,H\,(1 + 1) = 2\,V\,H;$$
$$I_w^1 = V\,H(1) = V\,H.$$

I_w^2 - is a volume of information which is formed by the method of two Galois bits attachment;
I_w^1 - is a volume of information which is formed by the methods of one Galois bits attachment.

$$k_{еф}^2 = I_p / I_w^2 = V\,H\,(n_v + n_h) / \; 2\,V\,H = (n_v + n_h) / \; 2;$$
$$k_{еф}^1 = I_p / I_w^1 = V\,H\,(n_v + n_h) / \; V\,H = n_v + n_h \,.$$

Conclusion

As appears from the analytical dependences, at achievement of high exactness of positioning which requires considerable expansion of bit of informative words, efficiency of application of the offered methods of code of Galois acquires enough large values.

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THE APPLICATION OF GAS CHROMATOGRAPHY IN EXAMINATION OF MATERIALS, SUBSTANCES AND PRODUCTS

As for the sphere of materials, substances and products examination, an important task is to determine the qualities and quantities of the substances and liquids composition represented in the research. For this reason to detect the mixture components the hybrid methods have been used since recently, which are based on the preliminary splitting and further detection of the components.
***Key words:** gas chromatography; high-performance liquid chromatography; aldehydes; esters; alcohols; performance index; drug aids; reproducibility; molar mass; solubility; indestructible control.*

Introduction

The subjects of the technical examination of materials, substances and products are carbohydrates (combustive-lubricating materials and petrochemical products); aldehydes; esters; alcohols used in the analysis of food substances; aromatic amines, sulphoamides, drugs used in the analysis of drug and psychotropic aids. It is possible to research these compounds using the method of gas chromatography as it is the most available and relatively less labor-consuming hybrid method. [1]

At present the methods of nozzle and capillary gas chromatography are the most popular ones.

The most important parameter in the gas chromatography is the time during which the substance being split is held inside the splitting system. It is determined by the sorption processes and by its spreading in the column. This parameter depends on many factors. These are the composition of the stationary phase, the gasholder composition, the length and the type of the column, its temperature, the retained volume, etc. [2]

The advantage of the nozzle column in gas chromatography is the low cost. As the sensitivity of this method is lower than that of the capillary column, the amount of the substance being detected should be larger in the sample. Due to this fact some less sensitive (cheaper) detectors can be used and the use of special samples injection facilities can be eliminated.

Despite the low cost of nozzle columns, the method of capillary columns use has been used since recently. The advantages of this method are the higher effectiveness, the reduction of stationary phase, which raises the selectivity of splitting and allows to decrease the temperature of the analysis in comparison with the nozzle column (this increases its lifetime); besides, the sensitivity of the analysis is increased; the small sizes of the column help to reduce the dimensions of the equipment, improve the conditions of thermostating (presentation of temperature conditions), which improves the repeatability of this method. However, the raise of the analysis sensitivity leads to the necessity in use of special facilities, samples and more sensitive detectors. [3]

It is vital that the principle of chromatographic component splitting is based on the changing when the sample materials turn from liquid into gaseous state, and also on the process of spreading by splitting components between the stationary and moving (gasholder) phases.

At low pressures the solubility of gases in a liquid is proportional to the pressure of gas over a liquid (Henry equation):

$$X_{\Gamma} = K_{\Gamma} \cdot p, \qquad (1)$$

where X_{Γ} is gas concentration in the fat solution; K_{Γ} is the Henry constant value; p is the partial gas pressure.

Until now the two coefficients of gas solubility have been used for quantity calculations in gas solubility of liquids.

The solubility coefficient (or just the solubility) of Ostwald (S) is defined as gas capacity (measured at a given temperature and at equilibrium pressure) dissolved at a unity of a liquid capacity.

The coefficient of Bunsen absorption (α) is defined as gas capacity measured in normal conditions, it is dissolved by the liquid capacity unit at a given temperature, when the gas pressure over it equals to 105 Pascal.

$$\frac{S}{\alpha} = \frac{T}{273}, \tag{2}$$

The solubility of solids is defined by the Schroder equation

$$\frac{d \ln X}{dT} = \frac{\Delta H}{RT^2}, \tag{3}$$

where ΔH is the solubility enthalpy of a solid in a liquid, which almost equals to the melting enthalpy of a solid for ideal solutions.

In the integral formula (used for the temperature interval, where ΔH = const)

$$\ln \frac{x_{T_2}}{x_{T_1}} = -\frac{\Delta H}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right), \tag{4}$$

For a given temperature the relation of the third component concentrations in two equilibrium phases is a constant value, it doesn’t depend upon absolute quantities of all the substances which take part in the distribution:

$$c_1/c_2 = K, \tag{5}$$

where c_1 is the equilibrium concentration of a substance which performs distribution in the first phase;
c_2 is the equilibrium concentration of a substance which performs distribution in the second phase;
K is a constant value (or the coefficient) of distribution.

In some systems the substance which is distributed as a result of its molecules dissociation, has unequal average particles size in different solvents. Meanwhile the last correlation is inapplicable, and the distribution law equation is the following:

$$c_1^{\nu}/c_2 = K, \tag{6}$$

where ν = M''/M' (M' is the average molar mass of a substance being distributed in the first phase; M'' is the average molar mass of a substance being allocated in the second phase).

While distributing the third substance among the two liquids, which are not mixed up, it may happen that the dissociation rate of a substance being distributed differs in various solvents. Let’s mark the dissociation rate of a substance which is distributed. In the first solvent it will be α_1, in the second one - α_2. Then the law of dissolution will be the following:

$$c_1(1 - \alpha_1)/[c_2(1 - \alpha_2)] = K. \tag{7}$$

In the distribution law equation the concentrations should be replaced by activities for concentrated solutions:

$$a_1/a_2 = K, \tag{8}$$

where a_1 and a a_2 are the activities of a substance, which is distributed in the fist and second phases.

If the distribution coefficient and the dependence of the activity on the substance concentration which is distributed in one of the solvents are known, then it is possible to set the same dependence for the compound solution. [4]

Practical use

Using the method of gas chromatography in the analysis of liqueur-vodka products the quality and quantity identification of aldehydes, esters, fusel oils, methyl alcohol are performed. This allows to determine whether or not these liquids correspond to state standard specification, and also to determine the general characteristics of kinds and groups of the certain liquids. Due to the research of liquids containing alcohol it becomes possible to find out the way they were fabricated. This could have been either diluting cognac by some water-alcohol mixture, or the cognac was made without cognac alcohols. Thus, the chromatogram of the liquids studied is compared with the samples given by the producers.

The main quality parameters of the cognac which can be fabricated, are organoleptic and physical-chemical factors, stability factors (warranty period of storage, bottling lifetime and physical-chemical stability), organomic factors (labeling, a bottle shape), and economical factors (a bottle fullness, its contents, price, cognac classification according to the quality level).

In general, there is a range of methods which prepare samples for the chromatographic analysis during the process of cognac examination. These methods concern the extraction by organic solvents, chemical discoloring of liquids, distillation, concentration by the molecular grids. However, all the methods mentioned above cause the loss or new formation of aromatic substances at some rate, so they do not perform the real chromatographic results. That is why we use the method of 1 micro liter injection of a liquid directly into the column.

The use of capillary column and the method of direct injection allows us to distinguish precisely volatile components and get the true quality and quantity grade of contents of aromatic substances in the liquid being studied.

In most cases to fabricate cognacs not cognac alcohols are used, though the use of cognac alcohols was detected several times. In such cases the comparative research of chromatographic peaks of producing fabrications and certified cognac alcohols should be held.

While examining cognacs a more complicated chromatographic situation can arise helping to distinguish the fabrication from the standard drink. Thus, the amount of ethers, phenolic aldehydes which are the result of aging and make the taste of high-quality drinks, is absent or small in the chromatograms. The range of ethers and their quantity estimation helps to evaluate the quality of a cognac. Further comparative research of cognacs of different qualities using the method of gas-liquid chromatography has proved that the amount of aromatic components in the contents of cognacs grows with their age.

In some cases one can see the peaks at the cognac chromatograms, which are not identified yet. They let us speak about quality and value of the alcoholic drinks more accurately when these peaks expand.

Thus, the use of the modern gas-liquid chromatography methods allows us to distinguish the fabricated cognacs from the standard ones as for the contents of aromatic components rather quickly and easily. In most cases a specialist having ethanol samples can estimate their quality, age and taste range.

While examining homemade alcoholic drinks (moonshines) it becomes possible to define their general kind as for the components contents, because proof may differ, as it is connected with the technology of production.

The analysis of drug, psychotropic aids and medicines

For the last time there have been more examinations to detect the amount of components in the contents in the complex mixtures in order to identify them and define the source of their origin. The method of gas chromatography allows to define the quality and quantity characteristics if substances which contain derivatives of amphetamine, also heroin, cocaine, medicines, etc. The application of this method also allows to determine the general source of the opium origin (poppy straw concentrate, acetyl adobe), poppy straw, sploff, sploff gum (hashish) as for the quality and quantity rate of substances in them, and to define the unknown substances according to the index of retention of the well-known substances.

Since recently it is necessary proceed the accreditation for the functioning of the laboratory. One of the most important demands for receiving this accreditation is to obtain the reliable results. To estimate the reliability of the results it is vital to get the information about the repeatability of the received results.

This problem can be solved by setting of a relative retention time. In this case the sample and the compared substance are chromatographed in the same conditions. The relative retention time is the ratio of the pure retention time of the sample to a certain compared substance. Besides, the relative retention time can be accurately measured only in the case of equal conditions and retention times have no big differences. The permanent terms can be kept only when using the same equipment. [5]

Conclusion

The most prevailing method of comparison and repeatability of data in and among laboratories as for retention is the use of retention indexes developed by Kovach for the distribution chromatography and based on the use of н-alkanets as compared substances.

If the retention indexes are defined correctly, using the checked methods, they can serve as reference data in any labs.

The inter-laboratory standard deflection of R1 measured ranges from 15 to 20 R1 units, when the screening (studying of the unknown substance) "searching panel" ranges from +/- 50 to 60 R1 units, and R1 of unknown substance is compared with R1 of given substances.

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MATHEMATICAL MODEL OF CONDENSATION ON THE SURFACE

The processes of vapor condensation on the surface of the ribs of triangular cross section and presents a model of the processes

In recent years, of particular interest to engineers and scientists working in different areas of technology, cause different forms of application of so-called microfinned surfaces for heat exchangers for different applications, including in aviation and space technologies. It turns out that is very promising for these forms of process intensification and improvement of weight and size characteristics of the devices their application to the condensation surface. At the same time still remain outstanding in full terms and conditions of the impact on this process of various physical forces [1].

It is in this context, as well as the approach to the problem of interaction of physical forces in the condensation, which in recent years developed by the authors carried out this work.

Consider the process of condensation on the ribbed surface, shown in Figure 1. Over the ribbed surface is saturated steam, from the bottom surface of the wall heat dissipation. Condensed liquid flows down along the axis x from the top edge to the base. Next, the liquid moves in a groove along the bottom edge (along the axis z). Consider the case where the influence of gravity negligible. The cause of the fluid is the force of pressure. The minimum pressure in the liquid film will be in the cross section exhaust (with $z = z_f$), the maximum - on top of ribs. Along the fluid

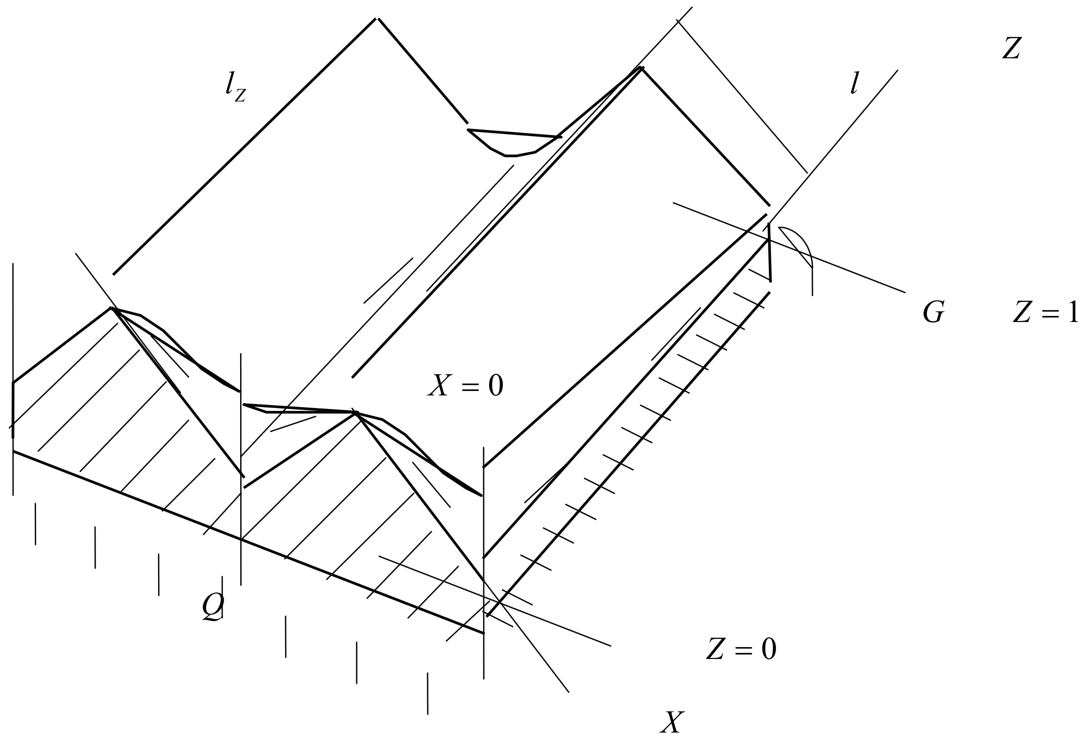

Fig. 1. The scheme of condensation on the finned surface with condensate removal from the intercostal grooves

pressure in the film decreases because of frictional forces. We assume that on the side of the ribs fluid velocity along the axis z, negligible in comparison with the velocity along the axis x.

When moving stream of liquid in triangular groove along the bottom edge of the main role played by velocity component along the axis z.

The problem of condensation on the surface of the ribs corresponds to one of the problems discussed earlier in connection with the analytical studies of condensation in the condensation with suction outside surface heat transfer [2 and 3].

To get a complete model of the process necessary to address this problem jointly with the problem of fluid flow with variable flow in a triangular groove along the bottom edge (along the axis Z) to the section of exhaust.

We tentatively believe that before the cut (in Fig. 1) the fluid flow is one-dimensional along the axis X, while $X > X_f$ over one-dimensionally along the axis Z to the source of suction. Along the axis Z of the liquid flow rate is variable and, in any section Z is determined by the equation

$$G = \rho_l w \delta_f \delta_f \; ctg(\beta / 2) \tag{1}$$

changing the flow rate is in accordance with the equation

$$dG = 2\rho_l u_f \delta_f \; dz \tag{2}$$

of the last two equations should be

$$\frac{d(w\delta_f^2)}{dz} = 2u_f \delta_f \; tg(\beta / 2) \tag{3}$$

or in dimensionless form

$$\frac{d\,\mathrm{Re}_Z}{dZ} = \frac{\mathrm{Re}_f \; tg(\beta / 2)}{\Delta_f L^2} - \frac{2\,\mathrm{Re}_Z}{\Delta_f}\frac{d\Delta_f}{dZ} \tag{4}$$

Here β - the angle at the base of the groove; w - the average speed in the living section of the flow of fluid along the axis z; the index f refers to the parameters of liquid film prix $X = X_f$; $\mathrm{Re}_Z = \dfrac{\rho_l w l}{\mu_l}$; $Z = z / l_Z$; $L = l / l_Z$.

Pressure losses during the motion of fluid in the groove along the bottom edge (along the axis Z) in the simplest case for laminar flow are determined by the equation:

$$\frac{dp}{dz} = \frac{C}{\mathrm{Re}_Z}\frac{\rho_l w^2}{2d_e} \tag{5}$$

where C – constant; d_e - the equivalent diameter.

Taking $d_e = \dfrac{4\varpi}{\Pi} = \dfrac{4\delta_f^2 ctg\;\beta / 2}{2\delta_f (1 + ctg\;\beta / 2)} = \dfrac{2\delta_f}{1 + tg\;\beta / 2}$ and passing to dimensionless variables from the last equation we get:

$$\frac{dP_f}{dZ} = \frac{C}{8} \frac{(1 + tg\,\beta / 2)^2 \,\mathrm{Re}_Z}{\Delta_f^2} \qquad (6)$$

A mathematical model of the process of condensation in the case of isothermal condensation surface contains the equation of the previous papers [2,3] with appropriate boundary conditions and equations (3,4,5 and 6) with their boundary conditions (7):

$$\text{при } Z = 0 \ \ \mathrm{Re}_Z = 0; \text{при } Z = 1 \ \ P_f = P_{f1} \quad \Delta = \Delta_{f1} \qquad (7)$$

Adoption of rules of the boundary conditions in (7), as discussed in previous variants of a model problem for an element of the condensation surface with suction fluid, are not the only possible other types of boundary conditions.

Algorithm provides a numerical solution of ordinary differential equations (4), (6) with boundary conditions (7), at each step of which is the numerical solution of ordinary differential equations. In both cases, the problem reduces to the Cauchy problem, and the missing terms on the left borders were determined by the given boundary conditions at the right edge by solving the corresponding nonlinear equations.

Examples of the results of calculations for the conditions specified in Figure 4, are shown in Figure 2 and Figure 5. The distributions of film thickness along the generate of the fin (Fig. 2) correspond to the previously performed calculations with the only difference being that all these distributions are not obtained for the different modes of suction fluid, but for different sections of the same regime. The difference is caused by different values in each section due to hydraulic losses in the flow of fluid from the groove at the base of the ribs.

As follows from Figure 3, hydraulic losses along the groove (on axis Z) vary substantially linearly. This nonlinearity is caused, on the one hand, the increasing flow of liquid along axis Z the creek, on the other hand - the decreasing cross-sectional area (Fig. 2) due to the forces of surface tension.

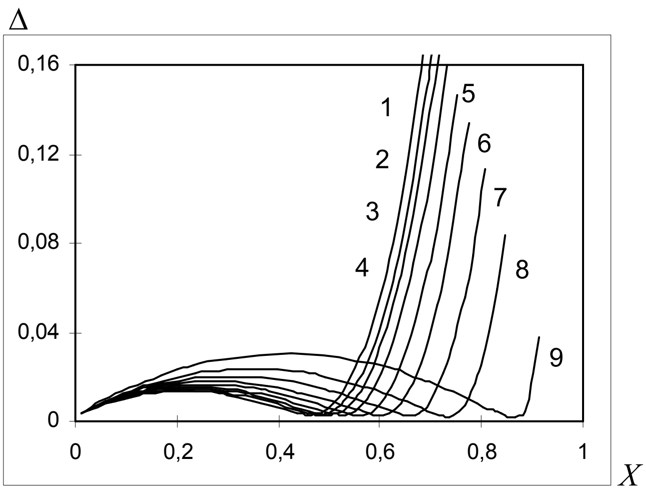

Fig.2. The distributions of the condensate film thickness along the surface of condensation for the various sections Z: 1 - 0,1; 2 - 0,3; 3 - 0,4; 4 - 0,5; 5 - 0,6; 6 - 0,7; 7 - 0 , 8; 8 - 0,9; 9 - 1

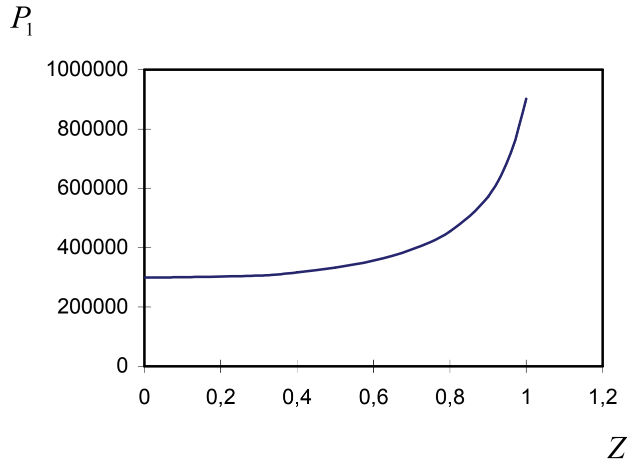

Fig.3. Change the dimensionless pressure along the drain ditch in $B = 0$, $K = 0{,}001$, $A = 2 \cdot 10^{-5}$, $P_{Z=1} = 9 \cdot 10^4$, $\beta = \pi / 2$.

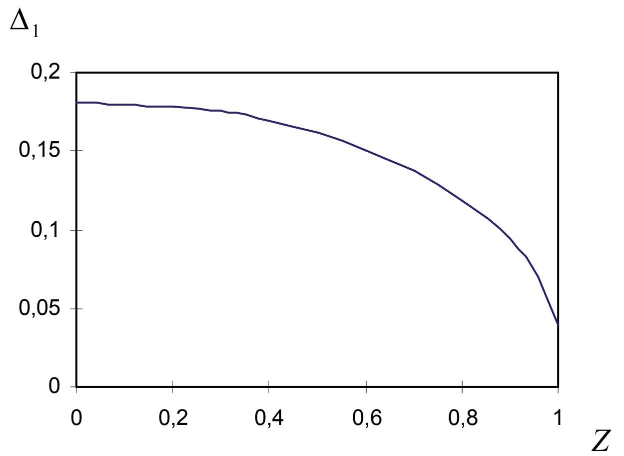

Fig.4. Change of a thickness of a film of a condensate in the bases of an edge along a flute of tap of a liquid for the specified conditions.

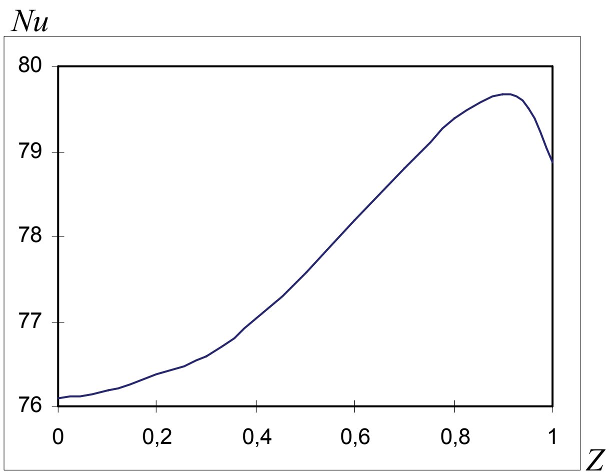

Fig.5. Average change on forming edges of Nusselt number in a direction of tap of a liquid for the specified conditions

Conclusion

Because of differences in the distributions Δ of cross sections varies along the axis Z and the average Nusselt number on the generator (Fig. 5). This curve is typical for the condensation with suction liquid film maximum. Obtained by calculating the difference of the curvature of the film on the cross sections along the axis Z (Fig. 2) corresponds to the difference of pressure in the liquid film. This should lead to the movement of fluid along the axis Z entire surface, not only at the base of the ribs. As expected, within a liquid film on the surface of condensation, strictly speaking, not one-dimensional, as assumed in the model. How significant contribution of this not one-dimensional, and the circumstances in which it appears, should establish a special additional payments.

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THE ANALYSIS OF METHODS OF REDUCTION OF DIMENSION OF THE DATA FOR THE SYSTEMS OF ADAPTIVE TRAINING

It is adduced the analytic review of the methods, which allowing to reduce dimension of the data at the classification of the patterns of knowledge of trainees. Descriptions of terms "the trajectory of training" and "the pattern of knowledge of the trainee" are adduced. It is marked that not all of the methods of preliminary classification of a pattern of knowledge of trainee allow to provide the adaptability of the training system. It is offered for the task solution of preliminary classification of patterns of knowledge of trainees on the assumption of providing with adaptive work system to use instruments of neural network. Especially, to use neural networks with the training in Hebb`s method.

Introduction

For today the information technologies are narrowly enough used in the system of adaptive training. In general the use of information technologies is limited to systems of adaptive textual control, where they allow to execute testing and to take stock of indices of progress in the convenient form. On one of grade levels of adaptive systems there is a problem of preliminary classification of patterns of knowledge of trainees for adaptive system of training.

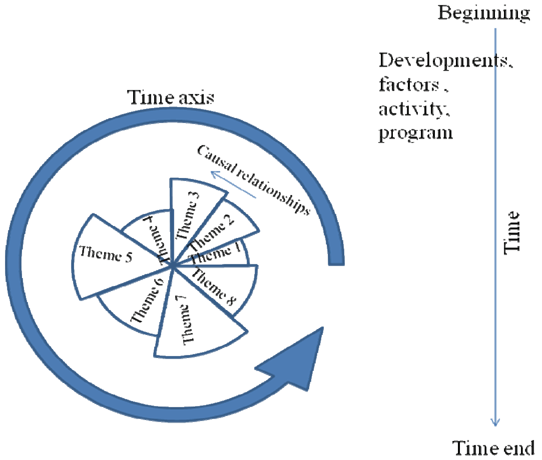
In the article it is presented the analysis of methods of reduction of dimension of the data, subjected to the classification, adduced the main advantages of neural network use with the training in Hebb`s method, for preliminary classification of patterns of knowledge of trainee for adaptive system of training.

The main definitions and target setting

A trajectory of training is set of actions, which allows to achieve an essential level of knowledge and skills for time allocated on training.

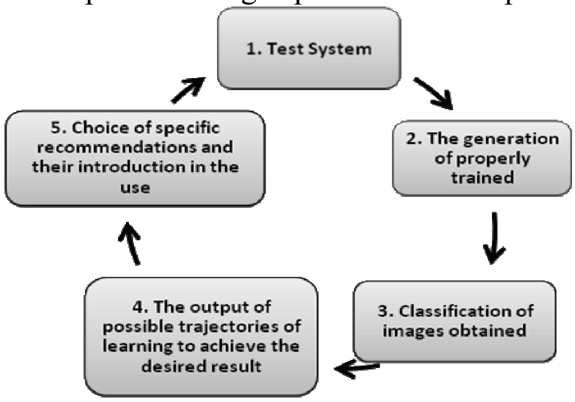
An pattern of knowledge of trainee is set of characteristics, the meanings of which are different for each individual who is studied taking into account a causal effect between meanings of these characteristics on different grades of levels. Given characteristics are formed on macro, - meso and – micro levels of training (educational course, discipline, studies).

Having organized an pattern of each trainee, the teacher can draw a conclusion about the most effective system of teaching and issue of educational material on each stage of training. The stages of training can be presented in the form of multidimensional "spiral" diagram of an pattern of trainee (picture 1).



Picture 1. Cut of pattern of knowledge of a trainee

The term of "spiral" for the given diagram is connected with that progress by the disciplines and other characteristics of an pattern of trainee are submitted to determinate causal effect. The possible training cycle in the system of adaptive training is presented in the picture 2.



Picture 2 The cycle of training in the adaptive system

Let is consider in more details the stage №2 on the diagram of the training cycle. At this point it is made preliminary classification of the results of analysis of more significant characteristics of trainee which has in mind that from the great number of measured characteristics of specific trainee it is necessary to pick out the meanings which will most strongly influence on following classification of objects and at the same time having executed reduction of dimension of the data.

The reduction of dimension of the data is reduction of a number of characteristics, describing a condition of an object in such way that the loss of significant characteristics at further use of information adds up to minimum.

The realization of given operation allows to diminish the quantity of calculations at the following classification and also minimizes quantity of transmitted information and adds up influence of "noises" to legitimate values.

2. The analysis of methods of preliminary classification of patterns knowledge of trainee.

For today the main method for reduction of dimension of the data is factor analysis. [1, 2]. Factor analysis (FA) is a method, which is widely used in psychology, political science, sociology, economy etc. The main idea of the method consists in establishments of secret factors influenced on transformation, with the help of matrix correlation analysis of the basic data. Whereupon it is obviously possible to throw off the data where changes of which influence on changes of the object quality in minimal way.

The main tasks of FA are to establish dependences between variables and cancellation a number of variables.

2.1. The main methods of factor analysis

Let is consider the main methods of factor analysis with the aim of determination of their adaptability for the task solution:

Correlation analysis is a processing technique statistics method contained in study of correlation coefficient between one pair or great number of pairs of characteristics for establishment between them statistic correlations. An evident defect of the given method is the fact which can be used only for determination of line dependences of concerned data, also the fact of correlation dependence in itself do not suggest which of variables precedes or is a reason of changes, or in general variables casually concerned with each other, for example, in view of action of the third factor. Reasoning for the aforesaid the given method basically is out-of-date for the numeral cancellation of variables.

Maximum likelihood method is a method of estimation of unknown parameter by means of maximization of a likelihood function. It is based on supposition that the information about statistical sampling contains the likelihood function. The estimation of maximum likelihood is a popular statistical method which is used for creation a statistic model on basis of data and realization of estimate of model parameter. The given method is not used for preliminary classification of an pattern of a trainee because it fulfills a task: it finds an average meaning of data about a totality based on the information of the random sample with the help of the likelihood function. Also for the given moment it is difficult to select a likelihood function for the statistical sampling of the data of trainees. The Principal component analysis (PCA) is an approach to the problem of reduction of dimension of data, which are lied in that the most important data are estimated (their changes are maximal), after calculation of proper numbers and eigenvectors of the covariance matrix of basic data. It includes a large quantity of methods, realized for different cases of data presentation and through the different ways of their processing. PCA is a method of FA which uses a procedure of orthogonal factors rotation. The given method can be used at a generation of the pattern of a trainee because the main idea of the method coincides with the idea of allotment of an pattern as a totality of main characteristics of the object taking into account possible nonlinear dependences in the values of variables. Moreover there are easy enough PCA in realization.

2.2. The characteristics of the basic analytical approaches for the principal component analysis

An approximation of data by linear variety is a task of the best approximation of finite aggregate of points by straight lines and fatnesses. It is applied for the kind task solution of optimization.

The search of orthogonal projection with the most dispersion. The main aim of the method is to find such orthogonal transformation in the new system of coordinates for which it is realized the next condition: sample variance of data along values k coordinate is maximal on the assumption of orthogonality of the first k-1 coordinates;

The aforesaid methods are unusable for the task solution in view of necessity of availability of small quantity of sample elements on the initial stage of system work, their difficult realization and absence of adaptability in these methods to quantity changes and structure of input data.

2.3. The characteristics of the neuronetwork technologies applied for the task solution of preliminary classification of patterns.

Recently in increasing frequency for the task solution of classification in the conditions of availability of vagueness it is used instruments of neural networks [5, 6, 7, 8]. We will consider kinds of neural networks (NN) which are more applied for the task solution.

Self-organizing map of Kohonen is emulative neural network with the training without a teacher fulfilling a task of the visualization and clusterization. It is a method of many-dimensional space projection into the space with lower dimension. It is initially known the dimension of the input data, all it along it is bullied the initial variant of the map. In the process of the training the vectors of weight junctions verge towards input data. For each observation it is chosen more similar junction to weight vector and the meaning of its weight vector verges towards to the observation.

Neural network with “narrow entrance” is a neural network which is used for the task solution of pressure. The network topology and algorithm of its training are like that data of high dimensionality are required to be transferred from an input of neural network on its output through the channel which has a comparatively small size. In the process of such neural network functioning the algorithm of back error propagation minimizes the mistake. The weights of connections from the input layers of neurons and up to the middle layer will work on the compression of a signal and the other – on its decompression. The networks which realize the method of “narrow entrance” are more suitable for effective pressure of data for the following transmission because at the heart of architecture of the given network it is underlied multi-layers perceptron, learned on a method back error propagation. Moreover the network can work incorrectly in case of random dependence formation in the basic data. The possibility of reduction of dimension of the data is ill-defined side effect.

Neural network of Hopfield has property of signal regeneration on its damage pattern. Also it allows to realize the task of auto-associative memory which has been formed in the process of training, so the task solution of providing the adaptability is difficult.

The neural networks with the methods of training by Hebb – neural networks with principle of training put forward by Hebb, the neurophysiologist – "strengthening of more frequently associated connections and weakening of less cooperated". In the nature of the network it is laid a realization of a PCA method in its classic variant: determination proper value of the correlation matrix. Generalized algorithm of Hebb`s training can be presented by the following sequence of operations:

11 At the moment of time n=1 we initialize synaptic weights Wji of the network by accidental small values. We set η some small value to the parameter of speed of training.

2. For n = 1, j = 1, 2…., 1 and i = 1, 2…, m t will calculate.

$$y_j(n) = \sum_{i=1}^{m} w_{ji}(n) x_i(n),$$

$$\Delta w_{ji}(n) = \eta \left[y_j(n) x_i(n) - y_j(n) \sum_{k=1}^{j} w_{ki}(n) y_k(n) \right]$$

Where x_i (n) – i component of input vector x (n) of dimension m x 1; l – required number of the principal components.

3 Increase the meaning n per unit, pass on to the step 2 and continue as long as synaptic weights Wji achieve a conservative value. For more n the synaptic weights Wji of neurons j meets to i-component of eigenvectors compared with j proper value of correlation matrix of input vector x(n).

The data which was received at the output of network coded with the help of 1-first eigenvectors we can renew with the help of multiplication with transposed matrix of eigenvectors.

In the general form the given network realizes orthogonal projections of multidimensional data into the space with smaller dimension along of them the dispersion of the data will be maximal, it allows to provide data compression for the following their estimation or reconstruction with smaller error.

Conclusion

The networks with the training by Hebb are taught all the time of the life, it makes them more adaptive to the changes in the data and they are simple enough in the realization in comparison with the models which were listed above and it is their advantage too.

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SECONDARY STANDARD OF ELECTRICAL POWER FOR INDUSTRIAL BAND

Purpose of the secondary standard of electrical power for industrial band - metrology assurance of the power generating companies, manufacturers of power standards, regional departments of the Dergspogyvstandard of Ukraine, verification and calibration laboratories.

Introduction

Measurement of electrical power is used in different brunches of industry and science. Measurement technique widely used for optimization of technological processes in all brunches of Ukrainian industry, electric energy production etc

Metrological assurance of this measuring technique regulates in Ukraine in accordance with the requirements of DSTU 4116-2002 «Metrology. State calibration scheme for electrical power and power factor measurements in the frequency range from 40 to 20000 Hz». Due to the need to prevent wear of the State standard of electrical power and power factor and for the possibility of more rational organization work of the laboratory was changed program of the development of national standard base of Ukraine for 2006-2010. It was chanced in 2007. This work was divided for two parts. The main purpose is creation of two secondary standards:

- Secondary standard of electrical power for industrial range of frequencies;
- Secondary standard of electrical power for extended range of frequencies;

Executor of this work is the State Enterprise "Ukrainian State Scientific-Production Center of Standardization, Metrology, Certification and Consumer Protection (SE Ukrmetrteststandard).

Purpose of the secondary standard of electrical power for industrial band - metrology assurance of the power generating companies, manufacturers of power standards, regional departments of the Dergspogyvstandard of Ukraine, verification and calibration laboratories.

Secondary standard of electrical power for industrial band (hereinafter - the secondary standard) is intended for the storage unit of electrical power from 0,001 watts to 72,000 watts by voltage from 1 V to 600 V, current from 0,001 A to 120 A and frequency from 40 Hz to 70 Hz and transfer unit size to measuring equipment that used in the national economy.

Secondary standard receives electrical power unit from the State standard of electrical power and power factor, which heads the state calibration scheme DSTU 4116-2002 and is kept in the State enterprise "Ukrainian State Scientific-Production Center of Standardization, Metrology, Certification and Consumer Protection (SE Ukrmetrteststandard).

Metrological characteristics of the secondary standards corresponded with DSTU 4116-2002.

Secondary standard transfers electrical power unit to working standards of electrical power (WSEP) of 1st and 2nd levels, by direct measurement method or by using comparator.

Electrical power standards of 1st and 2nd levels intend for calibration of the measuring techniques by using method of direct comparisons, or by indirect measurements. Total volume of electricity meters, which operate in Ukraine is more than 18 million.

In Ukraine operates more than 200 working standards of electrical power of 1st and 2nd levels which pass the annual calibration in SE Ukrmetrteststandard using secondary standard. In (Fig. 1) shown working standards volume as diagram. 1st level standards - accuracy: 0.05. 2nd level standards - accuracy: 0.1, 0.2.

Fig.1. Number of working standards that was calibrated during year with using secondary standard

Description of the secondary standard and its structure

Secondary standard of electrical power intended for testing and research of working standards in the frequency range from 40 to 70 Hz.

The secondary standard has next characteristics: Measured power from 1 to 72000 W at a current from 0.001 A to 120 A, voltage from 1 V to 600 V, frequency range 40 Hz to 70 Hz. On Fig. 2 shown the photo of the secondary standard.

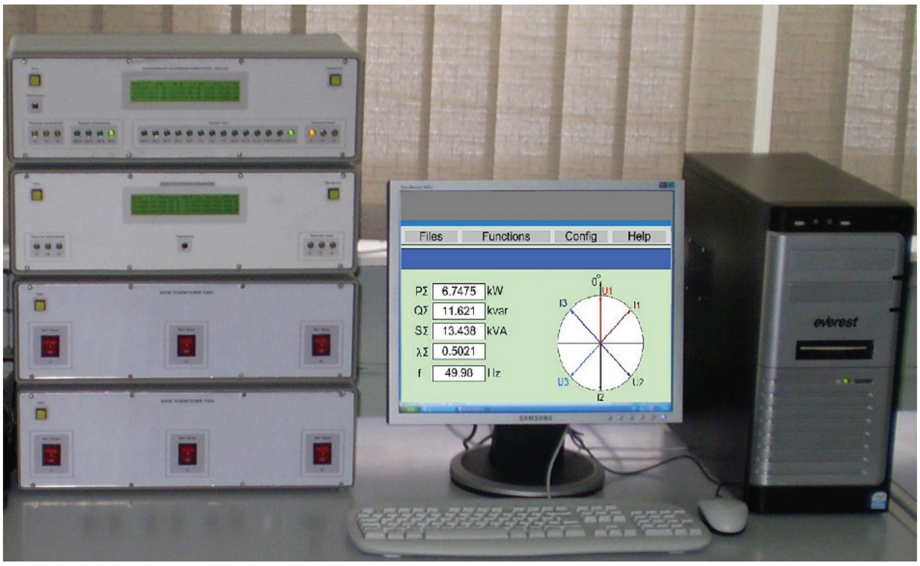

Fig. 2. Secondary standard of electrical power for industrial range of frequencies

After analysis during development and researches was developed structure scheme of the secondary standard. Because of high current and voltage signals was decided to create secondary standard as set of blocks. On Fig. 3 shown structure scheme of the three phase block and marked next:

1-3 – scale convertors of voltage;

4,11 – multiplexors;

5,12 – analog-digital convertors;

6 – display;

7-9 – scale convertors of current;

10 – microprocessor;

13 – amplifier for voltage channel;
14 – amplifier for current channel;
15 – phase shifter.

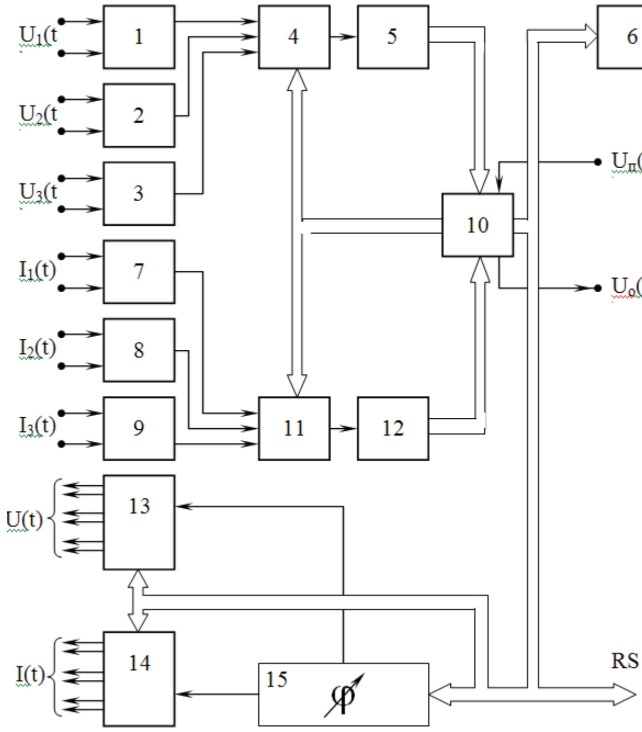

Fig. 3 Structure scheme of the three phase block

Secondary standard is set of measuring devices which contains:
- High accuracy measuring block;
- High accuracy generator;
- Voltage amplifiers block;
- Current amplifiers block;
- High accuracy voltage convertors;
- High accuracy current convertors;
- Computer.

High accuracy measuring block

High accuracy measuring block intended for measurement voltage signals from 1V to 600 V, current signals from 0.001 A to 120 A (frequency range from 40 Hz to 70 Hz). Connection schemes: 4 wires active energy, 3 wires active energy.

During work on High accuracy measuring block displayed next information:
- voltage range;
- current range;
- integration time;
- RMS value of phase voltage;
- RMS value of linear voltage;
- RMS value of current;
- active energy of each phase and summary active energy;
- reactive energy of each phase and summary reactive energy;
- apparent energy;
- power factor.

High accuracy generator

To investigate the instability level of voltage signals from the reference time used multimeter HP 3458A.

Since the instability error of the level of generated voltage signals for all types depends on the signals level, the generator has been researched at four different voltage: 1 V, 0.1 V, 0.01 V and 0.001 V. Results are shown in Tabl. 1-2.

Table 1. Instability of generated signals level (1 min).

Nominal voltage, V	**Instability of the level, %**					
	Channel 1 (U1)	**Channel 2 (U3)**	**Channel 3 (U3)**	**Channel 4 (I1)**	**Channel 5 (I2)**	**Channel 6 (I3)**
1	0,001	0,001	0,002	0,002	0,001	0,001
0,1	0,004	0,003	0,005	0,004	0,004	0,005
0,01	0,007	0,009	0,007	0,008	0,009	0,007
0,001	0,023	0,020	0,025	0,024	0,026	0,022

Table 2. Instability of generated signals level (1 min).

Nominal voltage, V	**Instability of the phase, %**					
	Channel 1 (U1)	**Channel 2 (U3)**	**Channel 3 (U3)**	**Channel 4 (I1)**	**Channel 5 (I2)**	**Channel 6 (I3)**
1	reference	$0{,}001^0$	$0{,}001^0$	$0{,}001^0$	$0{,}002^0$	$0{,}002^0$
0,1	reference	$0{,}002^0$	$0{,}003^0$	$0{,}002^0$	$0{,}004^0$	$0{,}003^0$
0,01	reference	$0{,}006^0$	$0{,}005^0$	$0{,}006^0$	$0{,}007^0$	$0{,}008^0$
0,001	reference	$0{,}010^0$	$0{,}009^0$	$0{,}009^0$	$0{,}011^0$	$0{,}012^0$

Analysis of the results of this research phase, to the following conclusions:

- Instability of generated voltage signals level (1 min.) with nominal voltage 1 V is in a range from 0.001% to 0.002%;
- Instability of generated voltage signals level (1 min.) with nominal voltage from 0.1 V to 0.001 V is in a range from 0.003% to 0.026%;
- Instability of generated voltage signals phase (1 min.) with nominal voltage 1 V is in a range from 0.001% to 0.002%;
- Instability of generated voltage signals phase (1 min.) with nominal voltage from 0.1 V to 0.001 V is in a range from 0.002% to 0.012%;

Block of the high accuracy generator is designed to generate 6 synchronized voltage signals. Special software drives by generator working modes.

Features:

- Number of channels: 6;
- Nominal output voltage: 1 V ;
- The possibility of independent control of each 6-signals;
- The ability to install RMS voltage range from 0 to 610 V;
- The ability to install RMS output current ranging from 0 to 120 A ;
- Possibility to change the frequency range from 40 to 70 Hz;
- Software for the PC.

Software for control generator modes shown in Fig. 4.

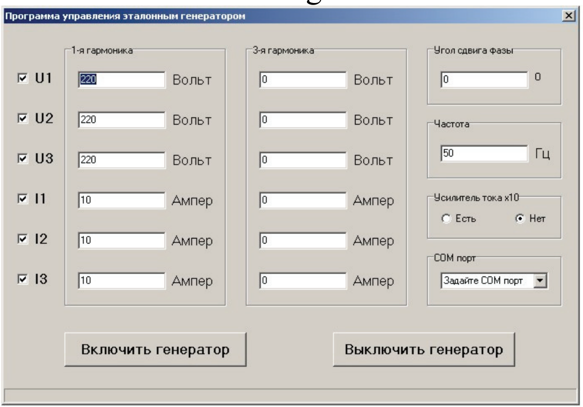

Fig. 4. Software for control generator modes

Switching modes of the high accuracy generator provides via RS-232. The frequency is set once for all 6 signals in the range from 40 to 70 Hz. Discrete set of frequency equal to 0,001 Hz.

Angle of phase shifting between voltage signal and current signal can be set from 0 to 360 deg. with 0,010 discreteness.

Voltage and current amplifiers blocks

The structure of secondary standards includes three-phase voltage amplifier, which operates in the frequency range 40 Hz to 70 Hz. Voltage amplifiers block consists of amplifiers and voltage transformers. Some characteristics of voltage amplifiers block were examined, namely: nonlinear distortion factor (hereinafter - NDF) of voltage signals channel and voltage level instability for 10 min for voltage signals.

Also was developed central device of the secondary standard at industrial frequency - control block for voltage amplifiers and transformers. This block controls with software the operation of three-phase voltage amplifier on the industrial frequency in different modes: receiving commands from the operator with a keyboard unit, indication of alphanumeric information on display, perform mathematical processing of data arrays, which aims at forming digital data streams.

Formed flows with help of the DAC channels are converted into analog voltage with required voltage amplitude and frequency. Since the DAC output signals have high parasitic components, structural scheme includes block of filtration and level adjustment. Block was accurately researched.

Analysis of the investigations results makes the following conclusions:

- NDF of the output voltage signal for first channel is in the range from 0.060% to 0.080%;
- NDF of the output voltage second for first channel is in the range from 0.057% to 0.072%;
- NDF of the output voltage signal for third channel is in the range from 0.062% to 0.082%;
- Instability of the generated voltage signal (10 min) for first channel at voltages from 60 V to 380 V is in the range from 0.001% to 0.003%;
- Instability of the generated voltage signal (10 min) for second channel at voltages from 60 V to 380 V is in the range from 0.001% to 0.003%;
- Instability of the generated voltage signal (10 min) for third channel at voltages from 60 V to 380 V is in the range from 0.002% to 0.003%.

The structure of secondary standards of electrical power includes a three-phase current amplifier, which operates in the frequency range 40 Hz to 70 Hz and currents ranging from 0.01 A to 10 A. Current amplifiers block consists block consists of amplifiers and current transformers. It operates similar to voltage amplifiers block and is intended to generate current signals. To protect the three-phase currents block and devices that are connected, to the structural scheme introduced protection against overload current channels.

Power amplifier unit designed to convert voltage from a nominal value of 1 A to 10 A. The maximum current that can be formed on current amplifiers block is 12 A.

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MOBILE AUTOMATIC ANALYZER OF PHYSICOCHEMICAL PARAMETERS

The researched automatic analyzer of oil products quality characteristics, based on the hydrodynamic method is considered.

The implementation of effective multifunctional measuring systems for oil products physicochemical parameters operative control in aviation requires the use of modern software-technical instrumentality based on progressive information technologies and new generation design techniques. Establishment of new automated information measuring systems is one of priority directions of modern computer technologies development. Known measuring methods and devices of oil products quality characteristics can't fully satisfy the requirements of modernity. That is why, it is actually to develop the automated multifunctional measurement systems that can provide high accuracy and timeliness of data collection on the current values of oil quality during the transportation and warehousing in airports.

The main aim of this research is to create multi parametric mobile measurement system that should resolve the following tasks:

- measurement of physicochemical parameters of oil products (kinematic viscosity, density, dynamic viscosity);
- measurement and accounting of additional quality parameters. Provide the calculation of gasoline octane number, cetane number for diesel fuels, viscosity index of lubricating oils using data main quality characteristics of the explored environment;
- implementation of convenient, informative visual representation of received information in real time mode;
- the time sequence of the explored oil parameters changes accumulation;
- provide the possibility of system settings flexible change when moving from one environment to another;
- the unification of used equipment for analyzer components quick replacement and to provide it's work in a variety of fixed and mobile conditions;
- the integration possibility of the developed system into automated process control systems of higher level, and provide the transfer of measurement data without distance limitations.

At the developed system for measuring density and viscosity of oil products the hydrodynamic method is used and synthesized based on it throttle bridge converter (TBC) [2]. The hydraulic bridge circuit is formed with two laminar and two turbulent throttle elements. The principle of measurement is the continuous pumping of explored oil product through the TBC and astatic automatic balancing of bridge circuit by changing the product volumetric flow. By the value of volumetric flow and total pressure drop on the TBC identified at the moment of balance, the kinematic viscosity and density of petroleum products is calculated.

Based on the measured density and viscosity values other oil products quality indices such as diesel fuel cetane number can be calculated.

Structure diagram of the analyzer for measurement of oil products quality is shown on Fig. 1.

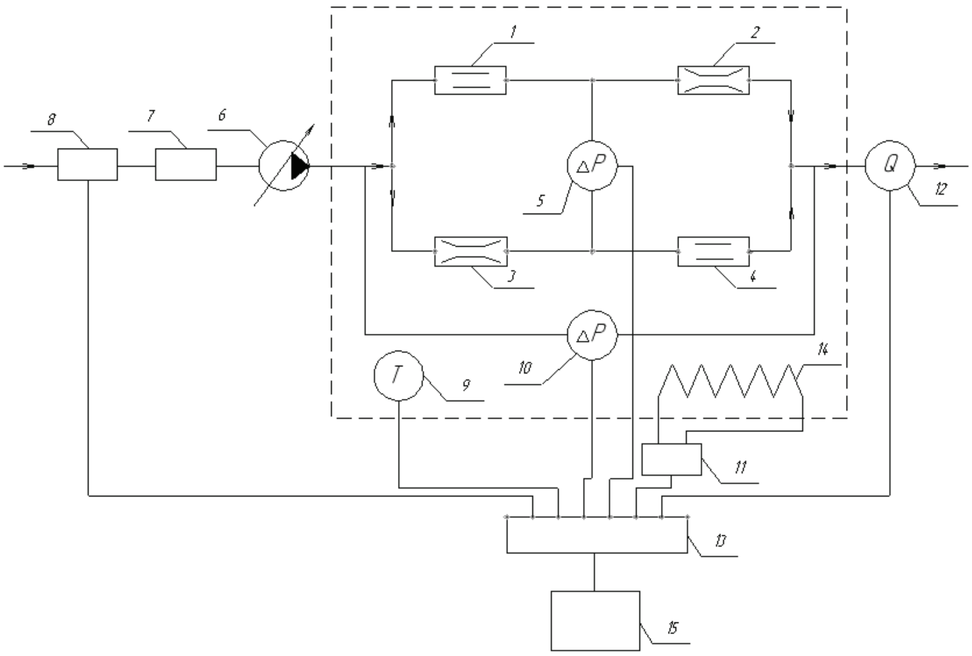

Fig. 1. Structure scheme of multifunctional oil product quality characteristics analyzer
1, 4 – laminar throttle; 2, 3 – turbulent throttle; 5 – zero indicator; 6 – pump; 7 – induction motor; 8 – frequency converter; 9 - temperature sensor; 10 – differential manometer; 11 - solid relay; 12 – flow meter, 13 - Programmable Logic Controller (PLC) 14 - heating element; 15 - automatic-workplace (AWP).

Laminar and turbulent throttles 1-4 form a hydraulic bridge that is the primary transducer of the analyzer. The output signal about balance from differential manometer 5, which is a zero indicator, goes to the analog input of programmable logic controller 13. Depending on the signal received from the zero indicator PLC forms tasks for frequency converter 8, on it's output frequency depends the rotor speed of induction motor 7 which is connected with gear pump 6, which pumps the explored liquid. Depending on the output signal value obtained from the temperature sensor 9 controller gives a signal to the solid relay 11, which controls the turning on the heating element 14 to stabilize the temperature of the explored oil product.

Based on the flow value determined at the balanced state of throttle bridge circuit using flow meter 12, the PLC calculates values of kinematic viscosity of the explored liquids by folloving expression

$$\nu = kQ \quad , \tag{1}$$

where ν- kinematic viscosity of the investigated product; k - coefficient that depends on the geometric dimensions of throttles in the measurement bridge, Q - volumetric flow of the product.

Based on the total value of differential pressure on the bridge, measured with differential manometer 10, and the value of flow on the bridge, by the controller with already known dependence [2] the density of liquid is calculated by formula

$$\rho = k_p \frac{\Delta P_\Sigma}{Q^2} \quad , \tag{2}$$

where ρ - density of the explored environment k_p - constant of proportionality, determined on construction and geometric dimensions of throttles ΔP_Σ- the total pressure drop in the primary converter.

Depending on the value of density and kinematic viscosity PLC also determines the dynamic viscosity by the equation

$$\mu = \nu\rho \quad , \tag{3}$$

where μ - dynamic viscosity

For diesel fuel analyzer is an opportunity to determine the cetane number (CN), whose dependence on density and kinematic viscosity of fuel is determined by the following formula [3]:

$$CN = (\nu + 17{,}87)\frac{1{,}5879}{\rho} \quad (4)$$

where ν - kinematic viscosity of diesel fuel in [mm2/s]; ρ - the density of diesel fuel in [g/cm3].

Discovered and measured data the programmable logic controller transmits on automatic-workplace 15, which displays and stores information about the kinematic viscosity, density, dynamic viscosity, temperature of the explored liquid and values for diesel CN.

Automated workplace realized on the basis of modern SCADA (Supervisory Control And Data Acquisition) system Trace Mode 6.

Supervisory control and data acquisition system gives an opportunity for a more convenient processing and presentation of data received from the controller. All collected information is archived according to the time of its arrival into the SCADA system. The composition of real-time supervisor is the following screens: the main mimic panel of oil products quality multi-analyzer, trends for representation of kinematic viscosity and temperature, researched oil product parameters setting screen, trends of general pressure drop and dynamic viscosity, pressure changes in the indicator diagonal and control.

As programmable logic controller (PLC) VIPA 114-6BJ02 System 100V is used, that is a universal multifunctional software and hardware means. Sharing data in real time between the SCADA-system and controller VIPA System 100V is based on software technology embedded object linking for industrial process automation (OLE for Process Control).

Vipa OPC-server based on DA (Data Access) technology, a universal fixed programming interface that provides data collection process, commands transfer and procedures executions on the basis of communication channels. Software for analyzer is designed in instrument environment WinPLC7, which also serves for the configuring and programs repair. The used PLC programming can be realized by using one of three language of IEC (6) 1131-3 standard: STL, FBD, LAD. The communication of controller with PC and downloads of programs into the PLC is realized on MP2I interface with help of the appropriate adapter.

The programmed controller (PLC) implements the following functions: gathering data from existing sensors in the system, their primary treatment, compensation of differential pressure in bridge circuit indicator diagonal, system of temperature stabilization.

Fluid flow control circuit operates as follows. In the established mode at a pressure difference at the indicator diagonal is zero and pump runs with a constant performance. In case of changing of the dynamic viscosity or density of the analyzed product the pressure drop occurs at the bridge circuit converter indicator diagonal. This change comes through the differential manometer on the input of PID-regulator, depending on the sign and magnitude of input signal by preset law it produces the control signal that goes to the input of frequency converter. As a result, a frequency converter changes the frequency of the asynchronous motor power voltage, which leads to changes in engine frequency speed and accordingly the pumping intensity so that pressure drop at indicator diagonal again became zero. By the value of flow in the balance point of bridge converter circuit analyzing system determines the kinematic viscosity by (1), and by the flow value and total pressure difference on the bridge circuit at first determines fluid density by (2) and then the dynamic viscosity based on equation (3).

Periodic switching on the heating element provides the product temperature stabilization at a given value. Coolant temperature in the thermostat is measured using termistor. After linearization and transformation into uniform electric signal, the resistance value goes to the analogue input of the microcontroller. The resulting temperature value is compared with a given one. Depending on the value of unbalance signal, the PI-regulator changes the impulse width. Depending on impulse width, the controller provides the control pulse into the input of solid relay, and accordingly the time of heater is being switching on.

According to the gear pump is used as a flow generator with rigid pressure characteristic, the value of flow in the system is measured by counting the pulses over time of coming to the input of the PLC with an angular rotation sensor (encoder). With a special clutch the encoder connects to the engine's rotor. The engine, in turn, through the gear connected to the gear pump. The pump's flow depends linearly on the turning rate and does not depend on the parameters of the explored liquid, including viscosity, density and temperature. The received values of the pulses number is transmitted by the controller into the SCADA-system where it is recalculated into the values of oil products quality characteristics.

During the experimental researches of the model of automatic analyzer with using two oil products that had differs by values of kinematic viscosity the next schedules of parameters change have been received:

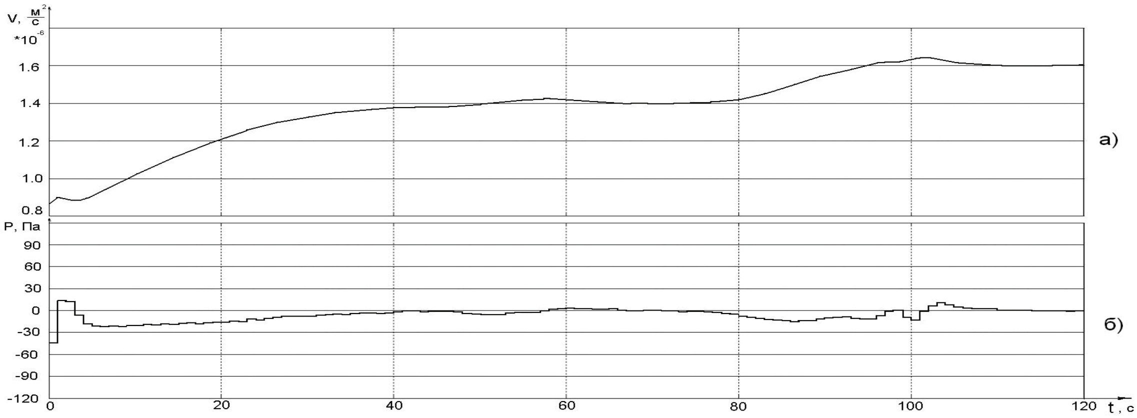

Fig. 2. The transition characteristic of a viscosity a);
pressure change at the indicator diagonal of the TBC b)

From the figure above one can see how the difference of hydraulic pressure in the bridge diagonal is changing during the experiment (Fig. 2. b). During the analyzer's work the unbalance of the bridge being compensated. The system requires some time for this process. Designed analyzer has the ability to change it's software settings to achieve optimal value of duration and quality of the transition process parameters. From Fig.2 a) one can see the dynamic properties of the model when the analyzed environment viscosity changes by steps.

For complete balance of the TBC immediately after the start of measurement analyzer spent time in 70 seconds and in the process of sudden change in viscosity this value is 25-30s.

Conclusions. Based on theoretical and experimental researches the mobile automatic analyzer of physicochemical parameters of oil products has been developed. The model of experimental sample of automatic analyzer has been explored and its main operational and metrological properties have been determined.

The designed analyzer can be used as a mobile laboratory unit for the oil products quality characteristics exploring. There are also applications created by the analyzer and a set of software and hardware for automation of manufacturing equipment, airport logistics structures. There are also provided the usage of the developed analyzer and the complex of software and technical means for the manufacturing equipment control and airport logistics structures automation.

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THE QUESTION OF RATIONAL CONSTRUCTIONS OF DEVICES AND MACHINES FOR USE ON THE LUNAR SURFACE

In this article some approaches to the development of a method of rational constructions forming of devices and machines to work in the physical conditions of the Moon are planned

The questions of human lunar exploration and organization of space technology is now becoming increasingly clear contours. Construction of lunar objects of scientific and applied nature is not so distant future, perhaps the first decades of the XXI century. According to this, there are many problems associated with the development of the lunar soil and rocks. That causes the problem of creation unusual for terrestrial practice lunar construction equipment.

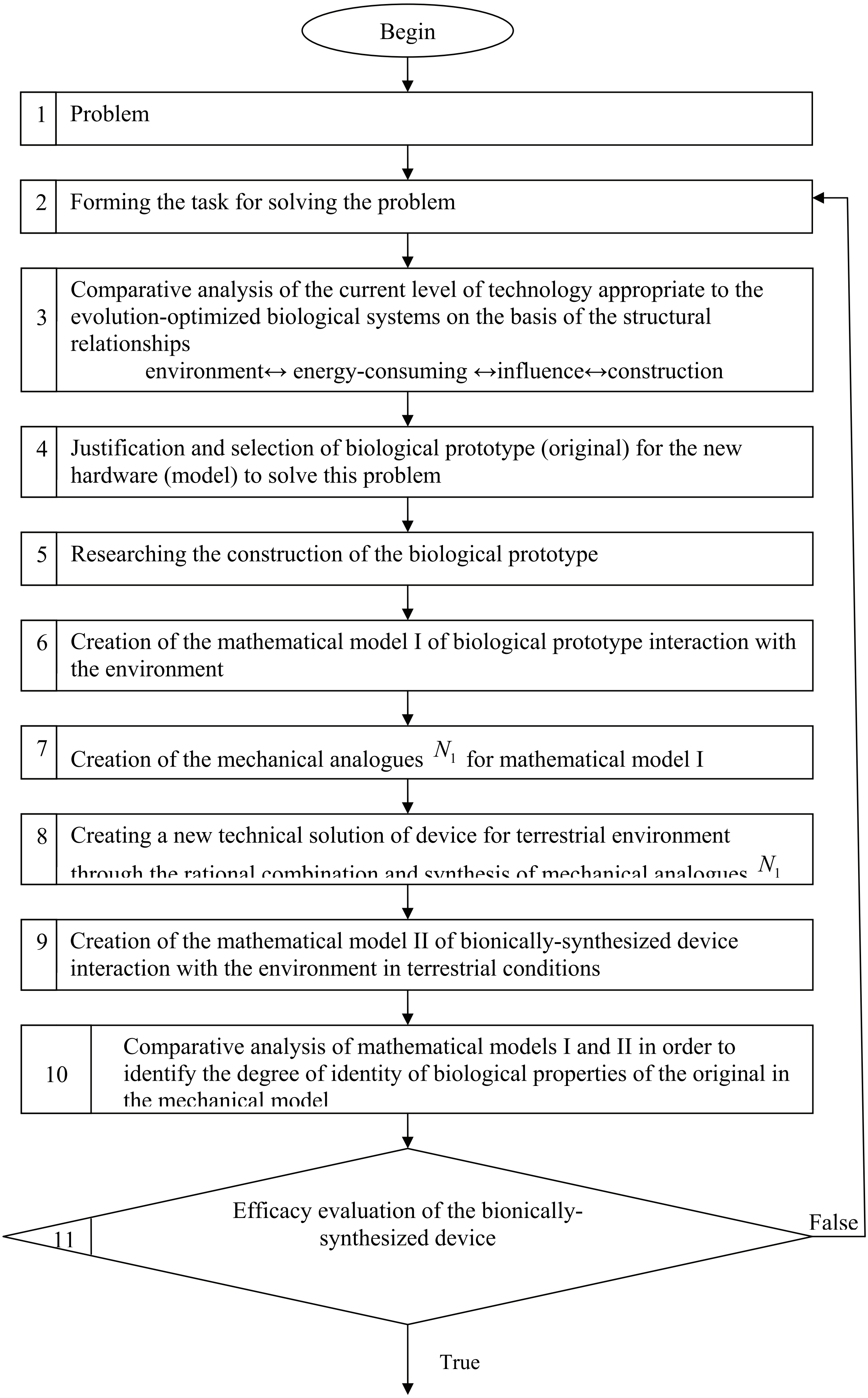
What should be the vehicle for the excavation of lunar soil, what would be the optimal parameters and the geometry of the working bodies, what energy sources will be used? Answers to these questions remain unclosed. Nowadays it is clear that these machines will be presented to the most stringent requirements: minimum of material consumption, energy intensity and a maximum of eco-security.

In this aspect the bionic approach for the method finding of creation an optimal constructions of lunar building vehicles looks very promising. This method is based on the analysis of evolutionary optimization formation of structures of biological soil-developing systems (organisms) and the optimal constructing of machinery for excavation works with the mandatory adjustments of the parameters that characterize lunar soil and affecting it's physical environmental conditions.

At present there is some experience of development of lunar soil and movement on the lunar surface, both human and machine in unusual for human physical conditions: ultrahigh vacuum (gas pressure at the surface is $1.33 \cdot 10^{-8}$-$1,33 \cdot 10^{-14}$ Pa), large night and day temperature difference 98.15 K and 398.15 K, the acceleration of gravity (1.623 m/s^2) almost 6 times less than on the Earth; meteoritic bombardment; hard cosmic radiation; electrostatic migration of silt particles, receiving a positive charge as a result of electronically issue arising under the influence of various kinds of radiation, etc.

These features of interaction are the main factors, which influence on the physical and mechanical properties of lunar soil and the specificity of its deformation by different counterfaces and working organs.

Looking at the dynamics of development and progress, we can make a conclusion that in addition to the existing lunar soil science, new branch of science - a lunar engineering and, in particular, the lunar construction machinery is appearing. The research of method development for creating optimal constructions of lunar building vehicles and their working groups leads us to the block-diagram (Fig. 1) - the algorithm for creating devices and machines for using them in extraterrestrial (for example lunar) conditions.


Begin
1
Problem
2
Forming the task for solving the problem
3
Comparative analysis of the current level of technology appropriate to the evolution-optimized biological systems on the basis of the structural relationships
environment↔ energy-consuming ↔influence↔construction
4
Justification and selection of biological prototype (original) for the new hardware (model) to solve this problem
5
Researching the construction of the biological prototype
6
Creation of the mathematical model I of biological prototype interaction with the environment
7
Creation of the mechanical analogues N_1 for mathematical model I
8
Creating a new technical solution of device for terrestrial environment through the rational combination and synthesis of mechanical analogues N_1
9
Creation of the mathematical model II of bionically-synthesized device interaction with the environment in terrestrial conditions
10
Comparative analysis of mathematical models I and II in order to identify the degree of identity of biological properties of the original in the mechanical model
11
Efficacy evaluation of the bionically-synthesized device
False
True

15.65

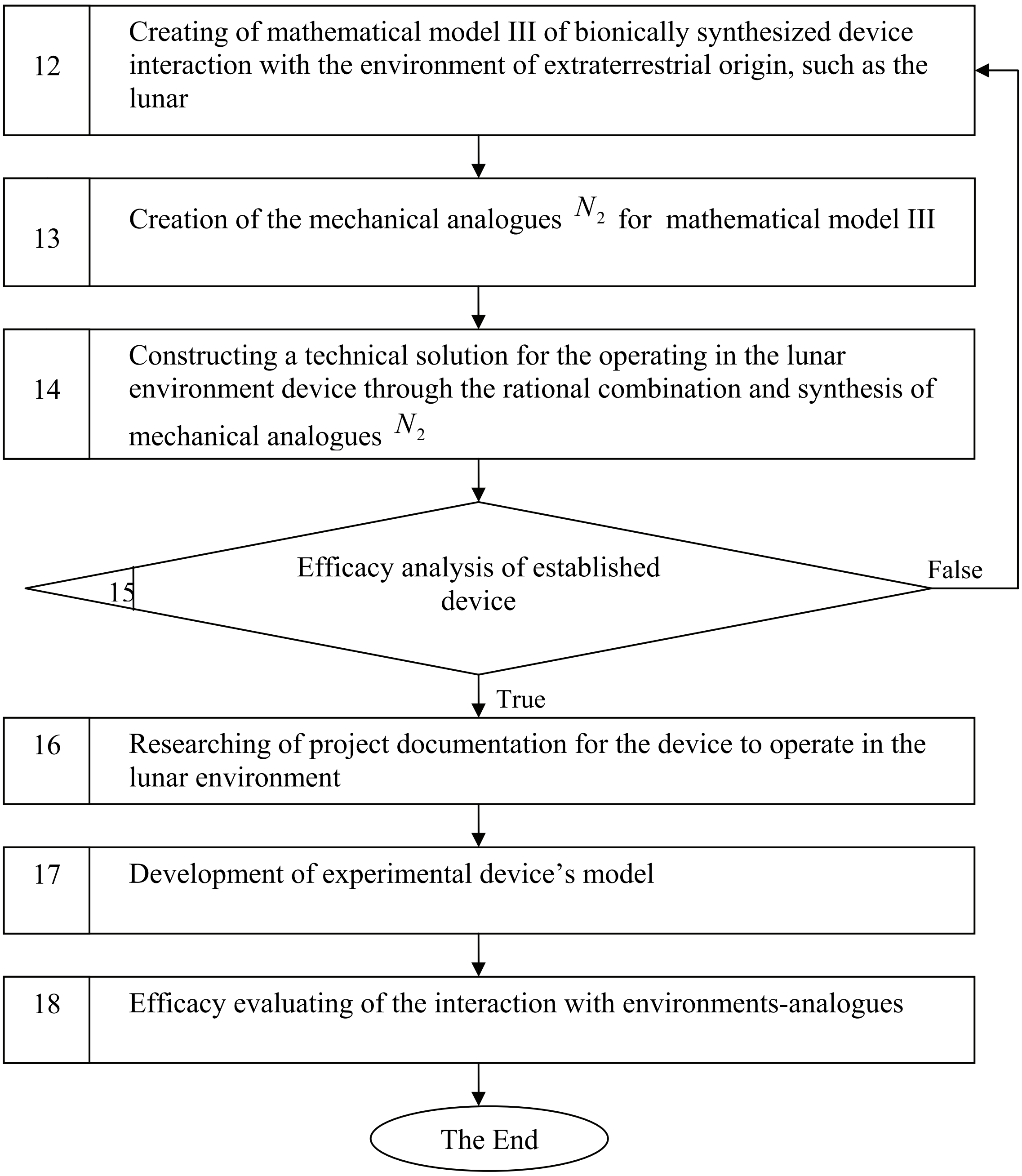


Fig. 1. Rational construction algorithm of devices and machines for use on the lunar surface

Block-model of structural relations in p.3 has the form (Fig. 2).

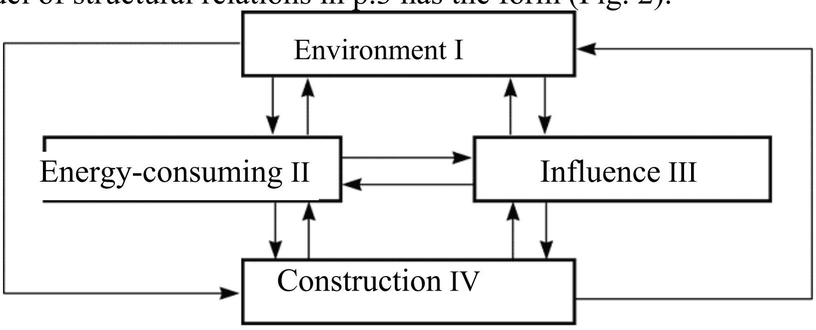


Fig.2. Block-model of structure: environment↔ energy-consuming ↔influence↔construction

From Fig. 2 we can conclude that different in nature settings, $x_1,\dots,x_n$ and $y_1,\dots,\ y_m$ (1-4) of the model and analytical expressions that describe their relations (5-6) take the form

$$\left(\overbrace{x_1,\dots,x_i}^{(I)},\overbrace{x_{i+1},\dots,x_k}^{(I,II)},\overbrace{x_{k+1},\dots,x_\ell}^{(I,III)}\right)\to I \quad (1)$$

$$\left(\overbrace{x_{i+1},\dots,x_k}^{(I,II)},\overbrace{x_{\ell+1},\dots,x_p}^{(II,III)},\overbrace{x_{p+1},\dots,x_q}^{(II)}\right)\to II \quad (2)$$

$$\left(\overbrace{x_{k+1},\dots,x_\ell}^{(I,III)},\overbrace{x_{\ell+1},\dots,x_p}^{(II,III)},\overbrace{x_r,\dots,x_n}^{(III)}\right)\to III \quad (3)$$

$$(y_1,\dots,y_m)\to IV \quad (4)$$

$$\begin{cases} f_1(x_1,\dots,x_n,y_1,\dots,y_m)=0,\\ \dots\dots\dots\dots\dots\dots\dots\dots\\ f_j(x_1,\dots,x_n,y_1,\dots,y_m)=0,\\ \dots\dots\dots\dots\dots\dots\dots\dots\\ f_{n+m}(x_1,\dots,x_n,y_1,\dots,y_m)=0, \end{cases} \quad (5)$$

where: $1\le i<k<\ell<p<q<r<n$, $m\le n$,

$1\le j\le n+m$;

$$y_1=\varphi_1(x_1,\dots,x_n),\dots,y_m=\varphi_m(x_1,\dots,x_n). \quad (6)$$

These functions of different nature settings in the first stage may provide only an implicit form, because they have a very complex branching multilevel nature. The disclosure of such uncertainty, of course, is very difficult process.

Thus, from the analysis of presented, we can conclude that the work in this direction will require large-scale, capital-intensive research. However, in the case of a positive outcome, a method of forming of the optimal construction of lunar building vehicles can be developed on this basis for different purposes. If you change the parameters of the lunar environment on the parameters characterizing the properties, such as Venus or Mars, we'll get the rational construction of building machinery for these planets, which is very promising.

Of course, at this stage we can only speak about the birth of such foundations, as the lunar construction engineering and space technology in general. However, the intensive development of productive forces and major achievements in space science and technology over the past decade, are the guarantor of the inevitability of the organization of production in space and on the moon in particular, which opens a qualitatively new attractive prospects and opportunities.

Conclusion

The approaches of the method development of rational constructions of devices and machines creation are given for use on the lunar surface on bionic basis.

UDC 519.65

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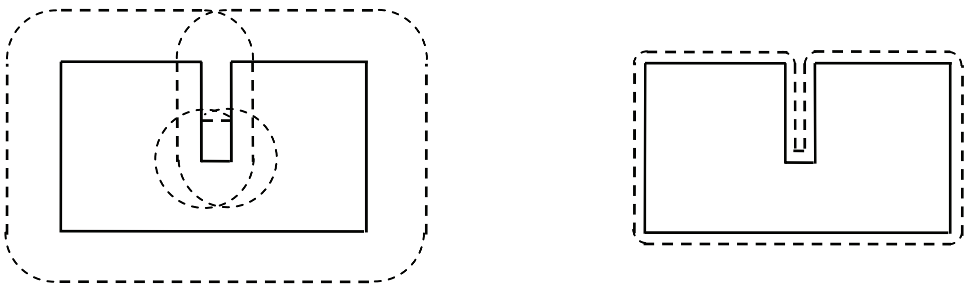
TRAJECTORY OF MOTION OF MILLING CUTTER AT SHAPE FORMATION OF CONTOUR, FORMED BY INVOLUTE SPLINE

In this article is written algorithm of building the trajectory of motion the center milling cutter to the contour, which is described by involute spline. It was proved that the trajectory of motion milling cutter can be describe analytically.

The task of building the trajectory of shapeformation on equipping with CNC deals with finding equidistant contour to the contour of detail. However, in depending on arranging out of details equidistant contour can keep the loop of self-intersecting pic.1.a. The result of motion of center of milling cutter by equidistant contour will be a trace contour, which keep inside the contour of detail. If trajectory of shape formation has loops of self-intersections then the trace contour will intersect the interior of detail, so come from event that is named in shapeformation like “slice of detail”.

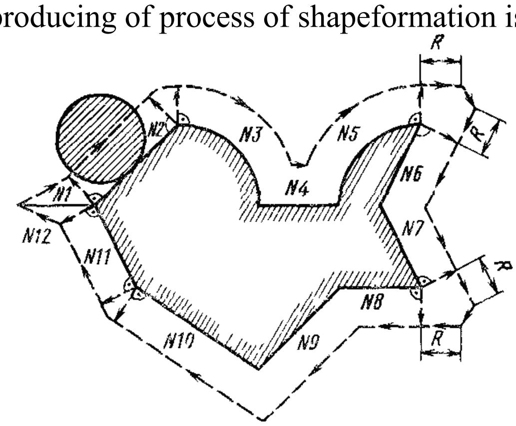


a) b)

Pic.1. Equidistant to the contour. a) equidistant with loop of self-intersecting;

b) equidistant without loop of self-intersecting;

In works [1, 2] is written algorithm of building the trajectory motion of milling cutter with algorithm linear and circular interpolation: with propose accuracy the curve is broken up segments; in start and finish points of each segment of the curve build the normal with length equally *h*; finish points of normals is connected by segments of straight line or arc of circle. However given equidistant contour of detail not allow to use as trajectory of motion of milling cutter, because the loops of self-intersect were not deleted. The task of deleted the loops of self-intersect is proved by method of flatting with different strategy of way around the knots points pic.2. Disadvantage of this method is with increasing of accurance increase the quality of knots of interpolation, so the volume of program is increased and the producing of process of shapeformation is lowed.



Pic.2. Contour of detail with trajectory of shapeformation.

Analytically building of equidistant contour without loops of self-intersect is allowed to remove these disadvantages. The prove the task of analytically building trajectory of shapeformation can get, but not it all class of functions. For instance, the equidistant to the polynomial curve isn't polynomial curve [3].

The trajectory of shapeformation will be build analytically if contour of detail is written by the class of functions, which is closed by operation of building of equidistant. Involute spline geometry, which is written in works [3, 4] is given that property, what allow to build analytically of equidistant contour to the contour of detail, which is written by involute spline.

In work [4] was given the equation of the involute curve, which is single diagnosed by the table, which consist from six parameters (table 1)

Table 1

Length of arc	Start point and angle			Radius the curvature of arc	
				Start	Finish
L	x_0	y_0	φ_0	∞	∞

The goal of this article is analytically building the trajectory of shapeformation to the contour of detail, which is given by involute spline.

Let contour of detail is written by involute spline. Equidistant contour to contour of detail will be build with algorithm, which is written in work[5]. However, for the building the trajectory of shapeformation is necessary to delete the loops of self-intersection of equidistant contour.

The loop of self-intersect arise in intersect of arcs equidistant contour. For deleting the loops of self-intersection is necessary to find number of intersected arcs of equidistant contour with using of computer graphics (algorithm 1).

Algorithm 1

1. i = 1, k = 0;
2. if i > n (n – quantity the arcs of contour) then return k and exit from program;
3. j=1;
4. find the step of curves with numbers i and j to output their on the screen ds_1, ds_2;
5. $df = ds_1$;
6. If $df \le L_1$ light on the screen pixel with coordinate $x = x(df), y = y(df)$;
7. $df = df + ds_1$, go to the step 5;
8. if j > n (n – quantity the arcs of contour) then i++ and go to the step 2;
9. $df = ds_2$
10. If $df \le L_1$ light on the screen pixel with coordinate $x = x(df), y = y(df)$;
11. If pixel with coordinate has a color like color of curve with number i, then output i and j.
12. $df = df + ds_2$, go to step 10.

It is necessary to deleting the loop of self intersection find coordinate point of intersection, define the parameters of intersected curves (table 2, table 3), delete the curve which numbers between *i* and *j*.

Table 2

Parameters of equidistant curve with number i

Type of arc	Length of arc	Start point and angle			Radius the curvature of arc	
					Start	Finish
Line	L_{tpr}	x_0	y_0	φ_0	∞	∞
Arc of circule	$R \arccos\left(1-\frac{L_{tpr}}{2R^2}\right)$	x_0	y_0	φ_0	R	R
Arc of involute	$\frac{L_0\left((R_k+h)^2-(R_{tpr}+h)^2\right)}{R_{tpr}^2-R_n^2}$	x_0	y_0	φ_0	R_n	R_{tpr}

Table 3

Parameters of equidistant curve with number j

Type of arc	Length of arc	Start point and angle			Radius the curvature of arc	
					Start	Finish
Line	L- L_{tpr}	x_{tpr}	y_{tpr}	φ_{tpr}	∞	∞
Arc of circule	$L-R\arccos\left(1-\frac{L_{tpr}}{2R^2}\right)$	x_{tpr}	y_{tpr}	φ_{tpr}	R	R
Arc of involute	$\frac{L_0\left((R_{tpr}+h)^2-(R_k+h)^2\right)}{R_n^2-R_{tpr}^2}$	x_{tpr}	y_{tpr}	φ_{tpr}	R_{tpr}	R_k

Where, R_{tpr} – radius and $L_{tpr}=\sqrt{(x_0-x_{tpr})^2+(y_0-y_{tpr})^2}$ – length of the arc with number *i* of involute in a point of intersection equidistant arcs. φ_{tpr} – angle of tangents, x_{tpr}, y_{tpr} – coordinates the point of intersection equidistant arcs.

So equidistant contour has the base interpretation like a contour of detail, then in point of intersection should be execute the condition of sewing.

The condition of sewing in knots of contour

Let examine the contour like a spline curve on the web of knots $\Delta = \{l1, l2,\ldots,ln\}$. Spline curve is belong to space C^2[l1, ln] – uninterrupted two-differential functions. The conditions of the uninterruptions is written like:

$$\begin{cases} x_i^+ - x_{i+1}^- = 0, \\ y_i^+ - y_{i+1}^- = 0. \end{cases} \tag{1}$$

Where, x_i^+, y_i^+ – the coordinates of finish point arc with number *i*; x_{i+1}^-, y_{i+1}^- – the coordinates of start point arc with number *i+1*;

The condition of sewing by first differential could be written like a condition the sewing of tangents from left and right. However, the knot of contour could be unsmooth, but angularity i.e. meaning of first derivative in knot of contour sharply change. In that chance conditions of is written like:

$$\left|\varphi_i^+ - \varphi_{i+1}^- - \alpha_i\right| = 0 \tag{2}$$

Where, αi –exterior of angle in knot with number *i*.

The condition of sewing by first differential could written like condition of sewing by curvature. The signs of finish radius of arc with number *i* and the start radius of curvature arc with number *i+1* are opposite, i.e. the conditions (3) is broken:

$$\left| R_n^{i+1} - R_k^i - \rho_i \right| = 0 \tag{3}$$

Where ρi – exterior of leap meaning of radius of curvature arc with number *i*.

In the chance, where the condition of sewing is broken, between the arc with numbers *i* and *i+1* is fitted in arc of involute with parameters (table 4):

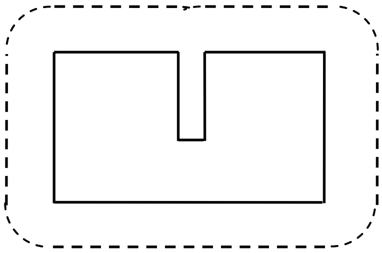
Table 4

Parameters the arc of involute

Type of arc	Length of arc	Start point and angle			Radius the curvature of arc	
					Start	Finish
Segment of line	L=ε	x_{ik}	y_{ik}	φ_{ik}	∞	∞

Where xik, yik – coordinates of finish point and φ_{ik} – angle of arc with number *i*;

As a result given equidistant curve with out loop of self-intersection could be use as a trajectory of shapeformation pic.3.



Pic.3. Trajectory of shapeformation.

Conclusion

Analytically building of equidistant contour is possibly written the trajectory of shapeformation and contour of detail in the one class of functions. As a result the program of shapeformation of detail on equipping with CNC is simply, what essential increase the producing the process of shapeformation.

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METHODS OF THE RESOURCES DISTRIBUTION BETWEEN THE MODERNIZATION PROJECTS IN AVIATION TECHNICS

In work the decision of a problem of search of the best distribution of resources between projects is considered with the help clonal immune algorithm. The method of task decision of management considered in article projects of aviation technique modernization offered on the basis of immune algorithms allows shows achievement of necessary authenticity of planning results of conducting of its modernization and validity of practical recommendations of the conditions of vagueness of financing.

In modern conditions the market constantly makes new more rigid demands to the aviation technics (AT) that requires its continuous improvement. From the account of constant ageing of aviation park and economic crisis modernization of existing aviation park and continuation of its service life is one of the ways satisfaction these requirements.

AT modernization is understood as restoration obsolete (in the functional relation) its samples by replacement of a design, element base, materials or manufacturing techniques for the purpose of improvement characteristics and increase of efficiency use.

Modernization of aviation park resolves, unlike purchase of new samples of AT, to finish the out-of-date technics for level which meets modern requirements, at expenses 10 times the smaller. Therefore AT modernization is a priority direction of the majority countries of the world, even such as the USA, Russia, Great Britain, France, etc. Widely known in the world are such military planes as bombers B-52, B-1, Tu - 95, fighter F-16, MiG-29, etc. that as a result of reusable modernization are on arms more than 30 years and meet modern requirements. Many civil passenger planes also constantly pass modernisation for satisfaction to ICAO requirements.

Necessity carrying out the modernisation of AT samples requires the decision of its problems which are connected with a substantiation of their modernisation, definition of optimum variants of modernisation and formation of optimum (rational) plans its carrying out.

The decision of these problems requires complex methodical maintenance on which quality validity of decisions are accepted, and possible considerable expenses, coordination with its lacks depends. Working out of such maintenance should include concepts, methods, techniques, algorithms, criteria. There are difficult problems, which devoted number of researches both received considerable scientific and practical results. So, for example, the solved problems with a substantiation of aircraft modernisation and aviation complexes (AC) on their basis; definition of optimum variants of modernisation on the basis of a synthesis problem, etc.

However, a problem of management projects for modernisation and formation of optimum (rational) plans carrying out have a number of unresolved questions. Such problem is one of the important at AT modernisation and depends on efficiency of carrying out and use of resources. The result of the decision this problem is optimum (rational) distribution of resources between robots and executors at planning and projects management of modernisation, which will be timely and in full expected result to meet requirements of criterion "efficiency-cost".

The problem of resources distribution at modernisation 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 modernisation, 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.

The purpose of this article is working out a method and model the decision of a management projects problem for AT modernisation on the basis of new methodical device - immune algorithms [1-4]. Application of this method will allow to lower errors at AT modernisation planning and validity of practical recommendations in the conditions of uncertainty of maintenance with resources.

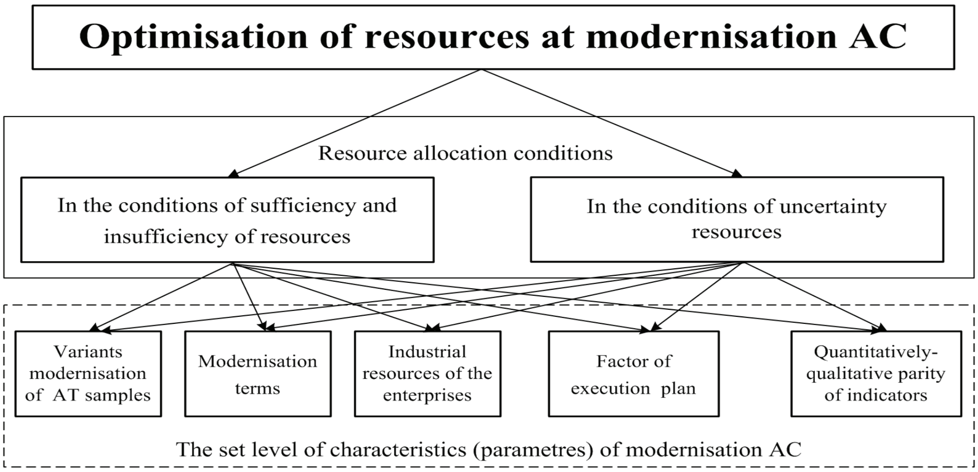

Fig. 1. The scheme of resources distribution for the project of AT modernisation

For the decision a task , it is offered to consider modernisation 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 modernisation;
- Type AC that modernisations are subject;
- Capacities of the enterprises on which modernisation will be spent;
- Possible variants of modernisation behind AC types;
- Volumes of different resources types for modernisation, including financial;
- Terms of receipt resources, etc.

The factors with uncertainty are volumes and terms of delivery resources (for example, financial).

The are a wide nomenclature of resources and works for maintenance of modernisation process. It is defined by financing volumes, types and variants of AC modernisation. 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 modernisation.

The plan of AC park modernisation 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 modernisation;

$\{D\} \neq \varnothing$ –Set of characteristics of capacities of the enterprise;

$\{E\} \neq \varnothing$ – Set of characteristics the modernisation plan;

$\{u\}$ – The distribution law of financial resources $u(t)$,

$\{\xi\}$ – Characteristics of modernisation 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 modernisation which would provide the maximum gain of potential possibilities of all AC park and would satisfy with restriction (2):

$$\begin{cases} \sum_{i=1}^{n} s_i \le S_{giv} \\ T_{gen} \le T_{giv} \end{cases} \qquad (2)$$
,

where S_{giv} - volume of financial resources which is allocated for all modernisation program; T_{gen}, T_{giv} - terms carrying out of modernisation (the general and provided by the modernisation program accordingly).

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 [3].

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 [3,4].

For decision such problem has been selected the algorithm of clonal selection, which concerns to immune algorithms.

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 [1,3]. The three-dimensional matrix is one of the most convenient representations problem. Matrix axes are: AC types, on which modernisation is carried out; variants of each AC type modernisation; works on performance of modernisation process.

For realisation an algorithm of clonal selection and decision of modernisation 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 [1-3].

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 [4].

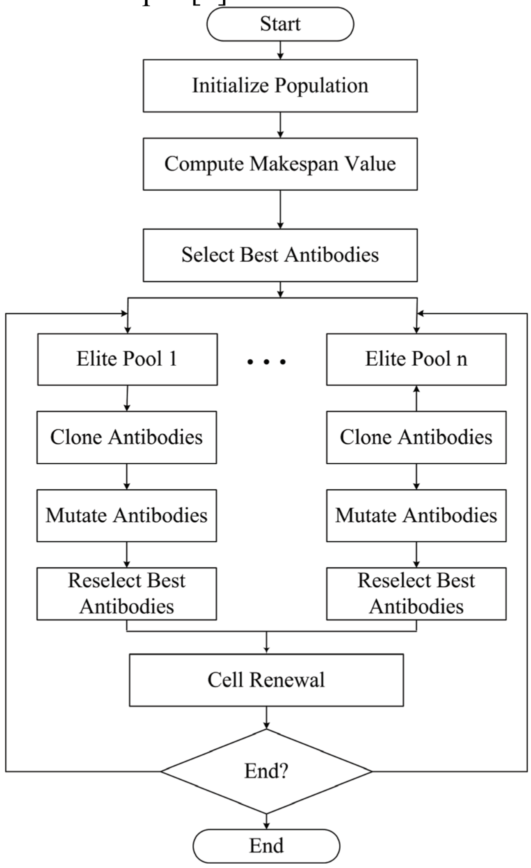

Fig. 2. The work of clonal selection algorithm

Conclusion

Thus, on the basis of formalisation of the research problem and its solution, are developed:

- The conceptual approach to the solution of problems of modernisation of an AT;
- Structurally functional model of the problem solution of AT modernisation projects control;
- A complex method of the problem solution of of AT modernisation projects control on the basis of algorithms of artificial immune networks and байесовских trust networks.

The methods the decision of a problem allow to receive well-founded modernisation plans in the conditions of uncertainty and to discharge errors at planning.

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THE POSSIBLE METHODS TO REDUCE THE TIME REQUIRED FOR PILOT TO PREVENT EVOLUTION OF ABNORM AL CONDITION IN FLIGHT

The possibility to reduce the time required for pilot to prevent evolution of abnormal situation in flight by using information system that inform the flight crew in the form of tips is considered.

Introduction. Analysis of the causes of accidents and the abnormal situations in flight for the period of operation of the aircraft fleet from 2003 to 2008 [2, 4] hat the main factors affecting the dynamics of change in the level of safety are the factors related untimely and improper actions of the crew during counteracting of abnormal situations in flight.

Problem statement. The analysis of the accidents, due to crew error [3], showed that the transition from the special situation of catastrophic characterized by an extremely small time development and the crew does not always have the time required to counteract or stabilize the situation. One of the solutions of the problem can be to research the possibility to reduce the time required for crew to counteract evolution or to prevent abnormal situation transition in a catastrophic. Research in this direction involves the analysis of response for originated situation in all components of the system "flight-crew-environment" that affect the time it takes the crew to prevent the development of operating systems in flight. The proposed publication is dedicated to solve these problems.

Solution of the problem. To estimate the time and its characteristics it is investigated the longitudinal movement of the aircraft in the wheel control mode. As a standard abnormal system the situation that arose when traversing a zone of storm activity and turbulence by Tu-154 (flight 612, 22.08.2006, crashed near Donetsk) has been chosen. The block diagram of "aircraft - crew - environment" system in abnormal situation in flight is designed (Fig. 1) [5].

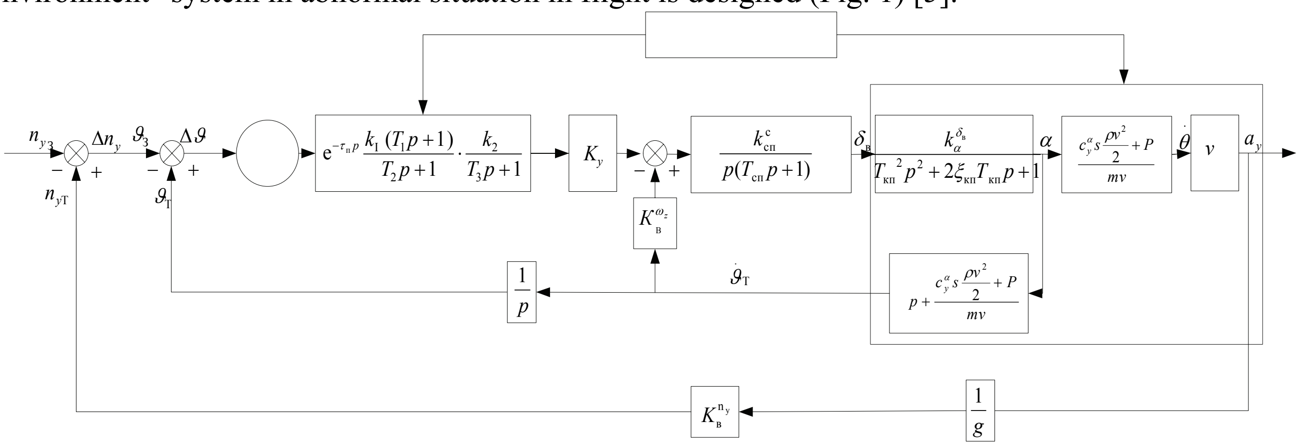

Fig.1. Block diagram of "aircraft - crew - environment" system in abnormal situation in flight (longitudinal channel): FDI=flight director indicator

To study the effects of abnormal situation on "flight-crew-environment" system take a number of assumptions: the flight is carried out with constant initial velocity V_0., pitch angle ϑ_0 and angle of attack α_0, as a disturbing factor in the impact of selected vertical gust W_V.

Under the action of wind disturbing the vertical wind, which was presented in the form of steps, randomly change the angle of attack α_W, that would ultimately lead to the increment of load n_y. Increasing the angle of attack and overload to their critical values leads to a loss of stability and the subsequent stalling of the aircraft. Obviously, these parameters will determine the nature of the situation, and its rate of development characterized by an angular acceleration of the pitch $\dot{\omega}_z \approx \ddot{\vartheta}$ [1].

In view of the above mentioned assumptions and developed on the basis of the structural scheme (fig. 1) a mathematical model for a system of "aircraft - crew - environment" as a set of model aircraft, crew protection, which interact in the development of abnormal situation in flight is shown in fig. 2 [5].

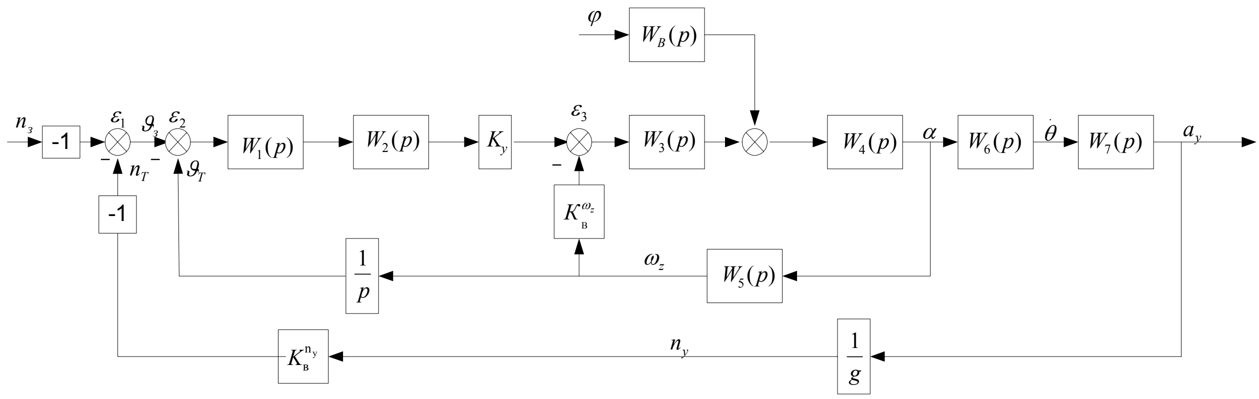

Fig.2. Structural mathematical model of "aircraft - crew - environment " in terms of abnormal situation in flight

From the inner loop (fig. 2) pitch angle control, define the image of the changing angle of attack under the influence of perturbing the vertical wind W_V.:

$$\alpha(p)=\frac{\mathrm{W}_4(p)(\varphi(p)\mathrm{W}_\mathrm{B}(p)+K_y\mathrm{W}_1(p)\mathrm{W}_2(p)(p)\vartheta_з(p))}{p+\mathrm{W}_3(p)\mathrm{W}_4(p)\mathrm{W}_5(p)(K_y\mathrm{W}_1(p)\mathrm{W}_2(p)+K_\omega)}p \tag{1}$$

Based on this equation and taking into account the fact that $\omega_z(p)=\alpha(p)W_5(p)$ (fig. 2) we obtain an expression for the angular velocity of pitch:

$$\omega_z(p)=\frac{\mathrm{W}_5(p)(\mathrm{W}_4(p)(\varphi(p)\mathrm{W}_\mathrm{B}(p)+K_y\mathrm{W}_1(p)\mathrm{W}_2(p)(p)\vartheta_з(p))}{p+\mathrm{W}_3(p)\mathrm{W}_4(p)\mathrm{W}_5(p)(K_y\mathrm{W}_1(p)\mathrm{W}_2(p)+K_\omega)}p \tag{2}$$

Of the external circuit (fig. 2) define the image to change under the influence of effect the normal vertical wind overload:

$$\begin{aligned} n_y(p) &= \alpha(p)W_6(p)W_7(p)\frac{K_B^{n_y}a(p)}{g} = \\ &= \alpha(p)W_6(p)W_7(p)K_B^{n_y}\Delta n_y(p) \end{aligned} \tag{3}$$

The mathematical model (1-3) allow us to study the dynamics of the behavior of "aircraft - crew - environment " in a typical of abnormal situation in flight.

For modeling the impact on the system nature of the model operating in flight SamSim 1.1.3 software tools it is used. The reaction of the vertical effect maneuver was evaluated first without the intervention of the crew, and then in view of its interference with different dynamic properties and at different times.

In modeling the impact on the system of effect of external factors used software tools SamSim 1.1.3. The symptoms of a vertical wind gust was estimated at first without intervention pilotand subsequently in the light of the pilot intervention with different dynamic properties and at different times (fig. 3).

Analysis of simulation results shows that the reaction system at the forcing of vertical wind gusts depends strongly on the moment of the pilot interventions in the management plane t_i. From the analysis of graphs in fig.3 implies that there are some extremely late moment when the pilot in control of the plane in which the angle of attack in the process of counteracting the effects of operating the flight arrives, but does not exceed its maximum allowable value (fig. 3 a). From time to time display of operating up to the maximum lateness of the date of intervention in the pilot control t_i of the aircraft and will be available time needed to counteract arisen abnormal situation in flight.

This period corresponds to the maximum permissible period of development of the situation. Obviously, the smaller the value t_p, the fewer opportunities for the pilot to prevent passage of the situation in an emergency.

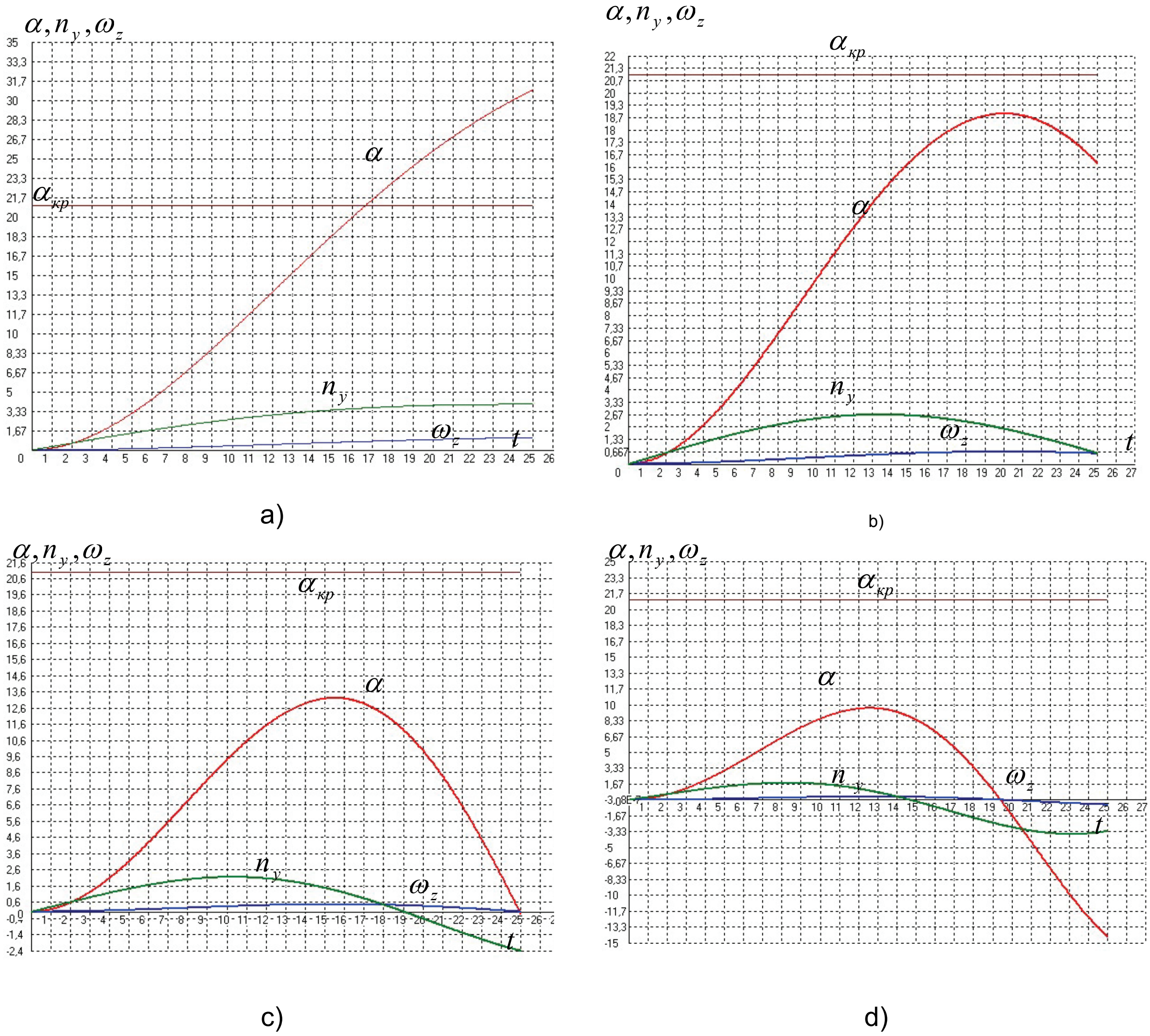

Fig. 3. Temporal characteristics of changes in the angle of attack, pitch rate and acceleration: a) without pilot intervention, b) in view of the pilot interventions at the time t_1; c) in view of the pilot interventions at the time t_2; d) in view of the pilot interventions at the time t_3

To assess the possibility of reducing the time required the pilot to prevent the particular situation in flight, we will analyze the influence of individual characteristics of the pilot at the time it takes for him to pilot the intervention in the management plane.

To this end, represent every step of the pilot actions in the form of transfer functions [6]:

$$W(p) = e^{-\tau_{п} p} \frac{k_1 \, (T_1 p + 1)}{T_2 p + 1} \cdot \frac{k_2}{T_3 p + 1}, \qquad (4)$$

where $\tau_п$ - delay time of the reaction of the nervous system, the pilot; n-number of flight parameters defined by the pilot by means of information display, T_1 - time constant of pre-emption, which is produced by the operator on the basis of previous experience; T_2 - time constant, delay the pilot, T_3 - time constant, characterizing the dynamics of the neuromuscular system; k_1 - gain of the pilot; k_2 - gain of the neuromuscular level, p - the operator of differentiation.

The first link of the pilot, which is receiving and reading the summation of display information on the dynamic properties, is amplifying with time delay $e^{-\tau_п p}$.The analysis shows that the delay time $\tau_п$ depends on the number of flight parameters defined by the pilot by means of information display, as well as training and physiological state of the pilot.

The second link is a specific computing element in self learning. This element has the properties of the amplifier, the inertia and forcing links. The inertia is caused by need to find a solution by generalizing the pilot information. The pilot aims to compensate for its inertia forcing the creation of pre-emptive signals. The analysis shows that quite professionally trained pilot forcing the time constants T_1 link and an inertial (aperiodic link) T_2 similar in magnitude.

Motional effects on the pilot's controls in the implementation of the control signals produced by the central nervous system are approximated by the inertial unit of the first order.For a professional pilot with a high level of fitness in the absence of disturbing effects (for standard mode) in a position to fully compensate for the effect of its inertia, ensuring equality $T_1= T_2$. In this case, the transfer function of pilots (4) takes the simpler form:

$$W(p) = k_п \frac{e^{-\tau_п p}}{T_3 p + 1} \quad , \qquad (5)$$

where the coefficient $k_п=k_1k_2$.

Conclusions.

Thus, the analysis of the linear model pilot has shown that, in general, he acts as a lowpass filter with a certain delay. Within the limited bandwidth of the input signal an output signal proportional to the pilot's input, but has some lag time.This delay will determine the time required for a pilot intervention in control of the aircraft to ward off the OS in flight. Since this time will depend on the quantity and information value of parameters entering the pilot, one of the areas to reduce the time required the pilot to parry or stabilization of the type operating system may be the use of information system issues recommendations crew in the form of hints prescriptive.

These tips, in essence, will be the recommendations for action, prompting the crew, some of the possible alternatives, he should use in this, specifically the current flight situation.

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INTELLECTUAL DECISION SUPPORT SYSTEM IN STOCKS RESOURCES MANAGEMENT OF AIRPORT

The study is to reduce total costs arising from the operation of multi-systems through the creation and use of intelligent decision support systems in inventory management of material resources of airport. In work the structural model of system was worked out that incorporates intelligent technology based on artificial neural networks and fuzzy logic.

Demand among consumers of aviation services is casual and ambulatory nature because it is not known in advance when and where the airport will need this or that detail (for airfield equipment, or even to a particular type of aircraft), to eliminate breakage and enforcement of functions.

Effective inventory control of material resources (MR) in the wild provides accounting Logistics (person who makes decisions - PMD) a large aggregate of various factors, often undefined nature. Operational solutions to these challenges is not always possible, primarily due to limitations of physiological capacity and logistics necessary decision in real-time developments. The output of this situation is a decision support system (DSS), a qualitatively new level of automation processes in various spheres of human activity. It allows for intellectual support to the logistics in making its decisions to solve problem situations that are characterized by great complexity, uncertainty and structuring.

Today, decision-making in the management of logistics resources stocks, mainly based on their experience and intuition. Therefore, there was a need to provide intellectual support decision making logistics. One of the types of information systems that provide intelligent decision support is DSS, because their creation is the goal.

The objective is to develop information technology intellectual decision support for inventory control by methods based on artificial neural networks and fuzzy logic.

Survey is the inventories is most expensive elements of logistics systems, not only because they are "frozen" means, but also require significant expenditures for their maintenance and replenishment.

The subject of research is providing information and intelligent DSS.

Decision Support System is an interactive system that gives users easy access to models and data to support decision making in the management of stocks MR. DSS implemented in such important features as interactivity, integrating, capacity, accessibility, flexibility, reliability, robastist, manageability.

Interactivity DSS means that the system responds to various types of which one is going to affect the computing process. Integrating DSS is a system compatibility components for data management and communications with users in the process of decision support. Power means the ability of DSS to answer basic questions. Accessibility DSS is this ability to issue responses to user search queries in the correct form and required time. Flexibility characterizes DSS system can adapt to changing needs and situations. Reliability means the ability of DSS to perform the desired function over a specified period. Robastist DSS is a system's ability to recover in case of error situations both external and internal origin. Controllability DSS means that the user can control the system.

All types of DSS are characterized by a clear structure that contains three main components: the user interface subsystem, database management subsystem (DMS) and database management subsystem models (DMSM). The three subsystems form the basis of classical DSS structure through which the past differ from other types of information systems.

The database can be defined as a set of elements organized according to specific rules, which provide general principles describing, storing and manipulating data independent of applications. How end users (applications) to the database is using a database management system DMS.

A database management system models (DMSM) DSS provides easy access to models and helps them to use. Obviously, the base model is an important aspect of this system. Important role in the management system model is given to communication with the user interface DMSM. In particular, we are working to create a GUI with built-in tools based on natural language in enabling the user to enter commands and questions are understandable language. It is very important that the system had the ability to automatically choose the most suitable problem solving module based on the incoming request parameters and type of mathematical model. Classical DSS structure shown in Fig. 1.

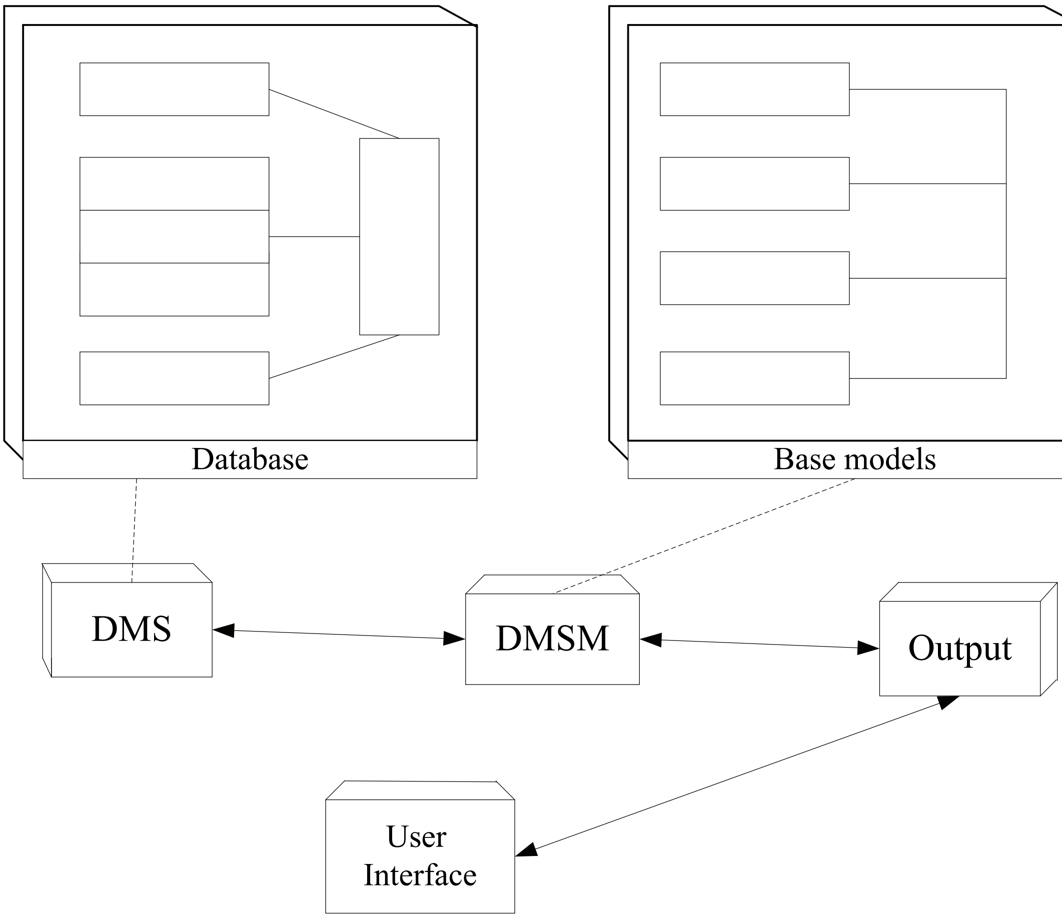

Figure 1. Classical structure of DSS to manage inventory MR

As recently rapidly growing global network Internet, corporate network (Intranet) and among organizations (Enternet) network, we added two new DSS subsystem - system management messages (communications) - SMM and intelligent technology.

As intelligent technologies, they are acceptable tools for DSS. In this system we plan to introduce technologies that are based on fuzzy logic and neural networks. Fuzzy logic we use to build a system of rules which is based on our database. A function of neural networks is that they learn to create models directly from data using repeated their study to identify relationships and build a model. They build models by trial and error. The network generates value by comparison with actual values. If the approximate estimation of source parameter is invalid, then the model is adjusted. This iterative process involves three steps: prediction, comparison and adjustment (or correction). Neural Networks applied in a simple DSS for classifying data and predictions. This input combined and weighed on the basis of which the generated output value. Modern Neural Networks are a number of properties characteristic of the biological neural networks, including the human brain. Their main feature is the ability to learn. To solve any problem on a traditional computer must know the rules (mathematical formula), which from the input data can be original, ie to find a solution for the problem. And by Neural Networks can find a solution without knowing the rules, with only a few examples.

Using Neural Networks approach to solving problems is closer to human than traditional computing.

The proposed structure of our DSS to manage inventory is shown in Fig.2.

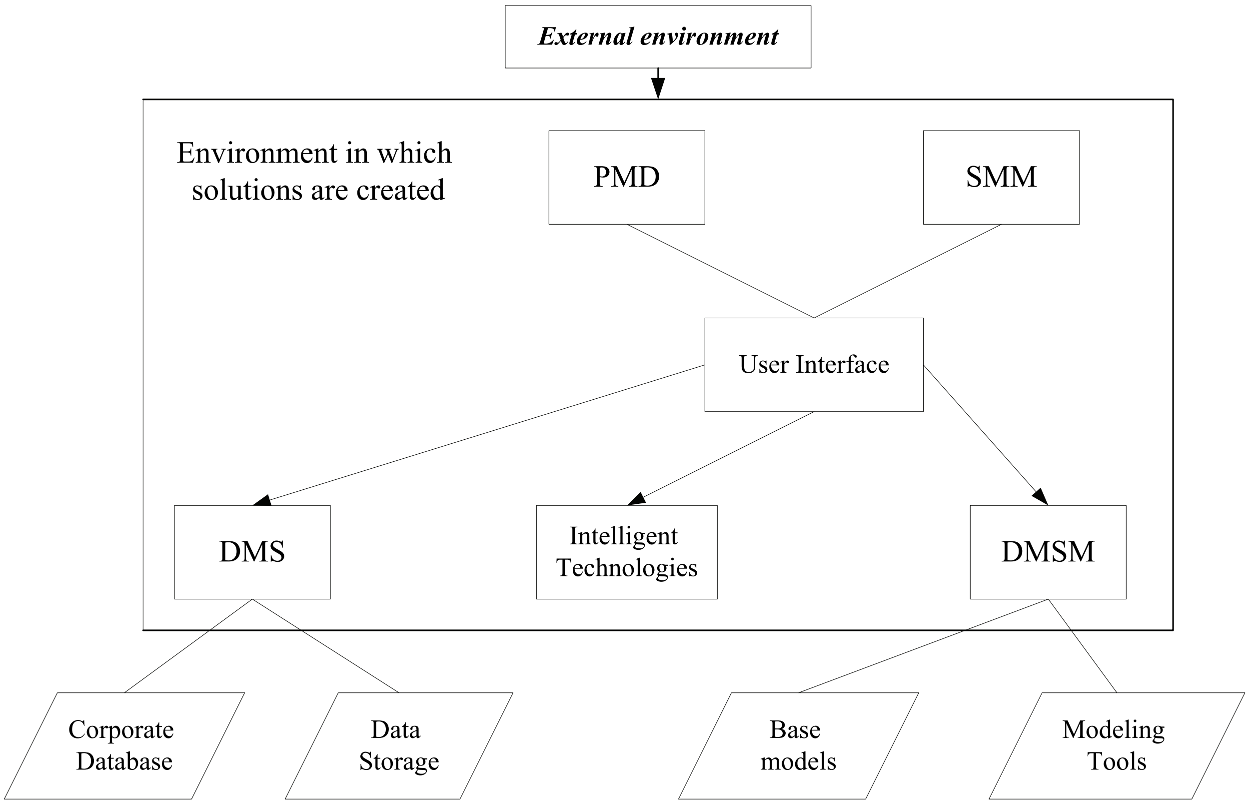

Figure 2. The structure of modern inventory management in DSS MR

Based on the proposed DSS, we create intelligent DSS.

Intelligent decision support system (IDSS) is a computer information system, used for various activities when making decisions in situations where it is impossible or undesirable to have an automated system that holds the entire process of decision. These systems use a database, analytical tools and large base of mathematical models in solving problems characterized by complexity, uncertainty and structuring.

ISPPR perform the following functions:

- Helping the operator to assess the situation, make a selection criteria and assess their relative importance;
- Generate possible solutions;
- Assess decisions and choose among them better;
- Provide a constant flow of information on the process of decision making and help coordinate group decision;
- Simulate the decisions;
- Carry out dynamic computer analysis of the possible consequences of decisions;
- Spend collecting data on the implementation of decisions and assess results;

- Based on the analysis of decisions and evaluating their effectiveness is addeducation IDSS.

IDSS requirements at the strategic level:

- Ensure the timely, efficient analysis and processing of much information;

- Implement knowledge modeling and decision making processes based on knowledge and human experience;

- Consider the dynamics of change and instability, both internal conditions of production systems and the environment;

- Possess the ability to study on the basis of experience and adaptation to environmental change.

Knowledge Base IDSS proposed to submit a proposed algorithm (a system of rules): if (situation), the (necessary action) that can provide optimal control of MR, update database with new situations and to use this knowledge logistics in this area. Using machines logical conclusion with the rules is the most common development environment for knowledge-oriented DSS. Rules are easy to understand explanations and, when knowledge stored as rules. From a developer modification and maintenance of databases made simple, easy to integrate knowledge and likely the rules.

Conclusions

Despite intensive development IDSS used in these techniques and the ability of hardware and software that are growing from year to year, are still in this area remains unclear and many unresolved issues: the specification of solvable problems to them adequate knowledge of modeling and processes. The rapid development of computer technology, extraordinary opportunities and catholicity of its application have generated in recent years the desire to face new practical problems based on more complicated models, streamlined the need for obtaining and processing complex and inaccurate information. Often, due to the in IDSS main source of information are people, information is very difficult or even impossible to formalize.

The quality of the system of inventory control MR is affected by external factors that have stochastic nature, which essentially seesaw depend on the particular conditions of consumer and economic environment, as well as the level of all kinds of expenses arising in the process of providing consumers with MR.

It can be concluded that effective inventory control MR in modern conditions is impossible without a broad introduction to the process of intellectual information technologies, decision support systems.

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SYSTEM AND PARAMETRICAL QUALITY FUNCTIONING OPTIMIZATION OF AVIONICS LOGICO-DYNAMIC SYSTEMS UNDER TRANSITIVE CHARACTERISTICS

Questions of parametrical optimisation of functional systems of avionics of a logico-dynamic class under transitive characteristics by adjustment and adjustment of representative parameters on life cycle stages are considered.

The problem prologue.

Parametrical reservation of avionics systems is one of the effective in operation ways of fault tolerance increase of avionics at the minimum operational expenses. *The method of direct quality estimations* logico-dynamic systems (LDS) functioning is effective at the determined estimations and restoration of demanded level of parametrical reservation, especially in the presence of the operational statistics on refusals and malfunctions. The method and questions of parametrical optimisation are full enough shined in works [1,2]. The combination of the "rigid" determined and likelihood estimation methods of quality indicators of functioning LDS of avionics to "soft" estimations allows to find the rational system approaches based on expert estimations and quantitative scales of technical condition LDS (serviceable, efficient, rejected) or (normal functioning, partially normal, abnormal, emergency – for electrosupply systems).

Modern third generation systems of avionics of air courts (AC), constructed on new element base IMA, are failure-safe systems with the built in monitoring systems (BMS), display of the information and the alarm system to a uniform methodological basis and necessary maintenance. Therefore expansion of their technical possibilities raises their competitiveness, diagnosability and all together – efficiency on all stages existence <designing> → <certification> → <batch production> → <operation>, i.e. on all life cycle (LC). New synergetic avionics possibilities have essentially expanded maintenance of properties of functional systems (FS) fault tolerance, it diagnosability, forecasting, a specific definition and processes optimisation of properties FS at stages LC perfection.

Research problem statement.

In problems of synthesis of fault tolerance FS (ACS, EPC, SCLD etc.) maintenance and practical realisation in the conditions of aviation enterprises <EDB> → <certification> → <serial factory> → <operation> the problem of quality estimations of avionics functioning systems is actual as working capacity of blocks, subsystems and modules does not guarantee working capacity of all system. At stages LS of an estimation problem of quality new possibilities differ essentially, increased, but in the development their set is subordinated criterion function – to creation of information technology of restoration of a technical condition of design level (especially at gradual refusals).

For conditions of aviation enterprises special interest represents a method based on functional definition of quality as the sum of integral, the set positive square-law form of phase co-ordinates and values of other square-law form of these co-ordinates in the end of an interval at the fixed initial values. Synthesis algorithm ACS on the basis of minimisation of it functional at introduction of additional restrictions is in detail considered by A.A.Krasovkij with reference to ACS flight AC.

The analysis of indirect methods (root, frequency) and *integrated estimations* shows their qualitative character of estimations, but not defining days off of parameters (accuracy, speed) and possibilities of rational restoration in operation, i.e. management techniques technical condition FS. Methods do not allow unequivocal definition of the form of transient that creates the big uncertainty when as optimum transient can be considered as much as possible approached to an entrance signal, however for AFCS reproduction of indignation of type "jump" is inadmissible. Besides rupture of negative feedback at functioning FC is excluded.

The method of direct estimations [1,2] allows to estimate most precisely and visually quality AFCS, SCLD, EPC and others closed ACS, on construction of transient or use of the real response in experiment, using private indicators of quality (PIQ). *System optimisation* is formed at level of requirements – criteria to quality, resources, dynamics of processes at stages LC. As restrictions resources act: technical and methodical (on operations; on a set functional; operators and structures of algorithms; to functioning conditions; logicians of avionics work and conditions of a algorithms structures coordination and logic of problems).

Formal statement of system optimisation problem:

$$I(k)=\begin{cases} I_{k\beta}(z(k)),\ k\in W_\beta; \\ \sum\limits_{\alpha\in E^{(A)}} T_{\alpha\beta}(k),\ k=m+1,...m+k; \\ L_\beta(T_{\alpha\beta}/h_{\alpha\beta}(\sum\limits_{p\in E^{(p)}}\xi(\alpha),\ k=p. \end{cases}$$

In function a predicate the system optimisation problem looks like:

$$æ(k)=\begin{cases} 1, if\,(\mathrm{I(k)}><\mathrm{X}(k)\vee(I(k)-ext2)\vee(I(k)\in\theta(k)), \\ 0,\ \text{otherwise}. \end{cases} \qquad æ=\bigwedge_{k=1}^{p} æ(k)$$

The general condition of system optimisation offered by V.M.Glushkov and developed in works by V.S.Mihalevich, V.L.Volkovich, A.A.Timchenko [3], looks like $æ \overset{\Delta}{\Rightarrow} 1$

The criterion is *the generalised system requirement* to target indicators and resources created IACS aviation enterprises when efficiency of functioning LDS of avionics are estimated by expression: $æ^* = [æ_1^* \cap æ_2^* \cap æ_3^*]$, where sizes $æ_1^* \cap æ_2^* \cap æ_3^*$ characterise normal levels of special flight situations (CFC, DS, AS) on separate or to an aggregate effect (avionics refusals, influence of environment, crew action etc.).

Formation of set PIQ.

We consider, that for modelling problems set of transients or experimental real processes on a time piece $[t_1, t_n]$ is set: $x_i=x(t_i)$, where $i\in\overline{1,n}$.

Set PIQ of transients considers all their possible configurations, when chances:

• on time interval $[t_1, t_n]$ the establishment $x_{уст}$, i.e. $(x_i-x_{i-1})\le\Delta$, *where* Δ - standard size of the admission is possible;

• on all sites on the press value stands out $|x_i-x_{i-1}|>\Delta$.

The expanded list PIQ used in the theory and practice of conformity estimation FS to standard requirements, includes following indicators:

1. Time of the first coordination $\tau=t_i,\ i=\min\{i: x_i\ge x_{зад}\}$.
2. Time of achievement of the first maximum $t_{\max}=t_j,\ j=\min\{j: x_{j+1}\le x\}$.
3. Amplitude of the first emission $H=x(t_{\max})$.
4. Transient time $t=\begin{cases} t_П-t_1, if\ \ for\ \forall|x_i-x_{i+1}|>\Delta, \\ t_i-t_1, if\ \ for\ \exists|x_i-x_{i+1}|\le\Delta. \end{cases}$
5. The established value of parameter $x_{уст}=\begin{cases} x(t_П), if\ \ for\ \forall|x_i-x_{i+1}|>\Delta, \\ x(t_i), if\ \ for\ \exists|x_i-x_{i+1}|\le\Delta. \end{cases}$
6. Frequency of fluctuations $\omega=1/T$, where T – the period of fluctuations defined as a difference of the moments of time when the transient curve reaches maxima in first and second time.
7. Reregulation $\varepsilon=\{[x_{\max}-x(\infty)]/x(\infty)\}\cdot100\%\ or\ \varepsilon=[(H-x_{уст})/x_{уст}]\cdot100\%$.

8. Mean-square value of parameter $\sigma = \sqrt{\frac{1}{m}\sum_{i=1}^{n}(x_{зад} - x_i)^2}$.

9. Attenuation $\xi = [\ln(H - x_{зад})/(H_i - x_{зад})]/(t_{\max}^{/} - t_{\max})$, where H_i – amplitude of second emission, $H_i = x(t_{\max})$.

10. Statistical error ACS $\Theta = x_{уст} - x_{зад}$.

Set PIQ in enough full measure characterises a problem of formation of the generalised indicator of quality (GIQ) ACS in problems of technical conditions identification in the conditions of aviation enterprises.

Formation GIQ ACS **of avionics.**

Quantity PIQ is usually limited depending on problem conditions, it is considered to judge enough on four indicators accuracy ACS (AFCS, EPC, SCLD etc.) at set to "a tube of admissions» *æ / Θ₀=0,05 and ε / Θ₀=0,05:* $\sigma^{opt} = \sigma^{\min} = 0$; $\mu^{opt} = \mu^{\min}$ $t_{рег}^{opt} = (t_{рег}^{\max} + t_{рег}^{\min})/2$; $\overline{\omega_c^{opt}} = \overline{\omega_c^{\min}} = 0$.

PIQ it is necessary to understand so: $\mu^{opt} = 0$ - equality to zero of the second minimum; $\overline{\omega_c^{opt}} = 0$ - performance of conditions at which $t_{соб} \to \infty$. Other boundary values PIQ depend on a design and appointment AC, a mode of flight, a control path, and value PIQ can have the interpretations ergonomic, strength, aerodynamic character.

Construction of criterion K_i is offered [1,2] in the form of a straight line in co-ordinates $K_i = f(\Pi_i)$: the beginning – in a point $(\Pi_i^{opt}, 1)$ and the end $(\Pi_i^{гр}, 0)$, that corresponds to technical condition ACS (the serviceable TS, the efficient TS (from the beginning up to the end) and refusal).

Analytical expression for K_i looks like $K_i = 1 - (\left|\Pi_i^{opt} - \Pi_i\right|)/(\Pi_i^{гр} - \Pi_i^{opt})$

Indicators PIQ in the dimensionless form after normalisation look like:

$K_1 = 1 - Y_1\mu$; $K_2 = 1 - Y_2\sigma$; $K_3 = 1 - Y_3\overline{\omega_c}$; $K_4 = 1 - Y_4\left|t_{рег} - Y_5\right|$,

where - constant rationing PIQ.

The estimation of quality ACS is carried out on GIQ: $GIQ = [K_1, K_2, K_3, K_4]$, i.e. as conjunction (logic product). For non-failure operation AFCS:

$$GIQ = [0;1];\ \mathrm{X} = [K_1 > \Theta] \wedge [K_2 > \Theta] \wedge [K_3 > \Theta] \wedge [K_4 > \Theta] \Rightarrow 1.$$

For failure conditions AFCS: $GIQ = -1; \overline{\mathrm{X}} = [K_1 < \Theta] \wedge [K_2 < \Theta] \wedge [K_3 < \Theta] \wedge [K_4 < \Theta]$.

Haviside's functions estimating efficient conditions for a case when K_i has not optimum values, are defined by logic conditions:

$$\begin{cases} X_1 = [K_1 > \varepsilon_1] \wedge [K_2 > \varepsilon_2] \wedge [K_3 > \varepsilon_3] \wedge [K_4 > \varepsilon_4]; \\ X_2 = (K_1, K_2, K_3, K_4) = 1; \end{cases}$$

$$\begin{cases} X_1 = [K_1 \ge \varepsilon_1] \wedge [K_2 \ge \varepsilon_2] \wedge [K_3 \ge \varepsilon_3] \wedge [K_4 \ge \varepsilon_4]; \\ X_2 = [K_1 \ge 0] \wedge [K_2 \ge 0] \wedge [K_3 \ge 0] \wedge [K_4 \ge 0]; \end{cases} \qquad \begin{cases} X_1 = (K_1, K_2, K_3, K_4) = 1; \\ X_2 = (K_1, K_2, K_3, K_4) = 1. \end{cases}$$

Communication between efficient and failure conditions is defined by expression:

$K^{отк} = RK^1 \cap K^2$, where R – reliability AFCS at the maximum effect; $K^{отк}$ – area отказных conditions; K^1, K^2 – areas of safe work ACSin space of parametres K_1, K_2, K_3, K_4 at

$$(\mu, \sigma, \overline{\omega}, t) \in K^1 \ or \begin{cases} (K_1, K_2, K_3, K_4) \in K^1 \quad (1) \\ (K_1, K_2, K_3, K_4) \in K^2. \quad (2) \end{cases}$$

In a general view Haviside's function of condition ACS is identified by expressions (1,2):

$$X(K^1) = 1;\quad X_{K^1}(\vec{K}) = 1 \ \ (3) \Rightarrow \ \ X_{K^2}(\vec{K}) = 0 \Rightarrow \vec{K} \in K^{отк} \ \ (4).$$

In case of partial loss of working capacity ACS $K_i \in \begin{cases} [0, 1] \\ [\varepsilon_i, 1] \end{cases}$, (5) and the criterion of safe work looks like: $K^{бр} = \{(K_1, K_2, K_3, K_4)/K_i \in [\varepsilon_i, 1], i = 1,...4\}$ (6)

Criterion of partial loss of working capacity:

$$K^{P.I.Q.} = \{(K_1, K_2, K_3, K_4)/K_i \in [\varepsilon_i, 1], i = 1,...4\} \quad (7)$$

In a general view the criterion of partial loss of working capacity is expressed

$$\widetilde{K}^{PIQ} = \left\{(K_1, K_2, K_3, K_4)/K_i \in [\varepsilon_i \in [\overline{\varepsilon}_i, 1] \in \widetilde{I}\right\} \quad (8) \quad \widetilde{I} = \{1, 2, 3\}.$$

For ACS the most informative criteria are criteria K_1 and K_4, and ignoring of others leads to incompleteness of display DU.

Use of mathematical models for formation DU assumes that requirements to its borders are more rigid, than requirements to BMS. It is natural, as level of parametrical reservation should be supported soundly. For system adjustment « AFCS - AC - environment» is the most important to define the parametres which changes are not provided. From p-dimensional space "are cut out" n-dimensional, where n=p-m. If the m-dimensional space is not crossed anywhere with defined BMS$_{расг}$, it is possible to make the conclusion, that the system is in a disabled condition and restoration of working capacity in the conditions of aviation enterprises is impossible.

If in DU to allocate a subarea characterised by maximum value EDB hit of a point of adjustment (the centre of adjustment CA) in this subarea characterises an adjustment subarea that means from the point of view of EDB – optimum adjustment though from practically realised party it is possible to speak about «an adjustment kernel». Operation conditions vary, CA "leaves", i.e. the TS degrades, and the adjustment optimality loses sense as to realise such leaving of representative parametre practically difficultly. On fig. various configurations DU of some ACS (AFCS, ACS, SCLD) are shown.

Conclusions and recommendations

1. Parametrical reservation is the most effective way of restoration of TS SAU by adjustment and adjustment of representative parameter.
2. Application of a method of direct estimations of quality of functioning ACS on the transients, based on use of quantitative private indicators of quality, allows to be released from lacks (uncertainty of decisions for integrated estimations and only their qualitative character; root methods allow to define stability borders, but do not range them).
3. Трудноувязуемость indirect and integrated estimations with requirements to dynamics «AFCS - AC - environment», defined by the standard documentation on operation.
4. Unacceptability for ACS an optimum understood at integrated estimation as transient as much as possible coming nearer to spasmodic that contradicts operational and ergonomic requirements (on discomfort for passengers).
5. Universality of a method of direct estimations of quality «AFCS - AC» character in definition DU, SS, CA when correction is found at program level with the noncriticality account to possibilities of the COMPUTER and the account of that identified DU, SS and CA is much less, than areas ВСК, that in turn raises level of parametrical reservation.

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SCIENTIFIC BASES AND METHODS OF SUPPORT FAIL-SAFE OF THE INTEGRATED COMPLEX «CREW - THE AIRCRAFT - THE ENVIRONMENT»

Introduction. *Support the fail-safe of the integrated complex «crew – the aircraft - the environment» is the complex task solved at stages of creation and usage to destination of aircrafts. It is built at creation of the aircraft, the land equipment, stuff for an air traffic control (ATC), and also in concepts of selection and preparation of flight and land crews.*

Task setting. As the integrated complex «crew – the aircraft – the environment» fulfils critical functions in relation to flights safety (FS) to it, according to [1], the demand of necessity of high functional integrity is done. Why must fulfill the following conditions: any individual refusal should not lead to a functional fault and, thus, create potential danger; the control should provide complete enough coverage of outlines of the equipment to guarantee that any fault which can lead to danger, will be detected; the sequence of appearance of numerous refusals should be analytically researched to instal that potential possibility not detections of a dangerous situation is extremely small; the probability of occurrence of complete functional refusal should be extremely improbable.

Task solution. Functional integrity of [1] systems is understood as the possibilities of performance put in its structure flight-technical and eksploitation-technical characteristics (FTC and ETC), equipments realised by components and the software by introduction in structure functional, informational, parametrical and other sorts of backup. Thus, she specifies in property of system to save the functional suitability at the sudden and step-by-step refusals, realised first of all structural backup of system, support of necessary levels of backup and ability to change the structure to (reconfigure) at refusals. In general, the functional integrity, as the property of the system can be expressed as a function of a number of its individual parameters:

$$\Phi = \Phi(C, S, Q, R) \; , \tag{1}$$

where: C - an indicator of the complexity of the system; S - the structure (configuration) of the system; Q - Quality (accuracy, speed, oscillation, etc.); R - reliability index.

Indicators of functional integrity (1) are mutually correlated, linked ambiguous and could be reduced to that of reliability: a fail-safe, fault tolerance, functional efficiency, reliability, durability, maintainability, survivability, and others.

At the present stage of development and state of the global aviation science and technology can not create a totally trouble-free functionality of the system of AC, therefore, the design uses a global probabilistic criterion - the probability of successful outcome of the flight, a regime for "ongoing work" at unit failures, ie due to different types of redundancy, when provided a fail safe.Bookings can be categorized into types: parametric, structural, modal (loading), informational, functional, ergatic etc. Under the parametric redundancy refers to the determination of system operation, setup subdomains, Centers for setting system parameters, with the property representative. The introduction of parametric backup allows to restore the technical properties on the life cycle (life cycle) without modifications by setting and adjusting.

In a structural reserve function of the failed channel performs a backup. There are over 100 types of structural redundancy, increase the reliability of the relatively minimal functional structure.Under the regime (loading) means the potential of redundant systems to increase uptime by reducing the load (the regime). It is established that a number of electromechanical devices, electronic devices, electrolytic capacitors, etc. can in order to raise uptime while reducing the operating mode at 20 ... 30% of the nominal value. Information redundancy is the effective way to improve the reliability of failures, intermittent failures by repeating the instructions, tips (for the system "crew - Sun"), the introduction of additional structural reserves. Functional redundancy systems assumes the task of "reserve" channel, designed to perform other functions when the primary system fails. Human-machine redundancy can be considered as the degree of automation of the process, when the crew performs the functions of active monitoring (fully automated) and management (if incomplete). You can talk about other kinds of redundancy (time, etc.).

If the number of avionics systems parametric, structural, informational and modal reservation is subject to the design, certification, development and operation (the lower level of the objective), the functional information represents a higher hierarchical level, and ergatic backup - top. Thus, the ranking of levels of redundancy to justify the feasibility of complex characteristics of reliability, as the characteristics of the collective type.

Fail-safe is an integrated feature of the quality and level of interaction ergatic complex ”crew-aircraft-environment” which quantitatively assesses the quality of functioning of the complex, taking into account the efficiency of interaction of the crew on a particular section of the flight path of aircraft in a real environment.

Fail-safe - a composite index of reliability of functional systems (FS), which characterizes the regime of "ongoing work" on some level of quality with one or more failures of equipment and / or software [2].

Probabilistic criterion of system performance aircraft, avionics and complex "crew - aircraft – environment” - the probability of successful outcome of the mission represents a conjunction of: avionics fault tolerance (the probability of fault-tolerant work in special conditions (SC); survivability avionics (the probability to missing aircraft and avionics in conditions of extreme operation in the SC, fail-safe - the likelihood that ergatic complex "crew - aircraft – environment” parries failures when they occur, the actions of the environment, the errors of the crew at an acceptable level (without changing the flight plan), the probability of fault-tolerant service of FS [3]:

$$P_{БИП}(t) = \sum_{i=1}^{n} P_{ав}(t) \cdot \sum_{j=1}^{m} P_{ОВВ}(t) \cdot \sum_{l=1}^{c} P_{эф}(t) \cdot \sum_{k=1}^{f} P_{СОБП}(t), \quad (2)$$

where: $P_{ав}(t)$ - resiliency avionics, $P_{ОВВ}(t)$ - survivability of aircraft and avionics, $P_{эф}(t)$ - fail-safe set of "crew - aircraft – environment”, $P_{СОБП}(t)$ - failover services for FS.

Fail-safe - a comprehensive probability (statistics), the reliability characteristics of "crew-aircraft–environment», as the final link in BP is determined by a conjunction (logical product): fault-tolerance file systems, file system and survivability of aircraft, safety of flight crew actions in situations of contact with the repudiation outcockpit situation, Manager, head of operations and runway.

A probabilistic criterion for successful outcome of the flight (2) is global in nature and can be adjusted to additional portions of the flight requirements. It could be expressed in a temporary function, which determines its time-binding of all phases of flight and takeoff, flight and landing:

$$P_{бип}(t) = P_{бип}(t_{взл.}, t_{пол.}, t_{пос.});\; P_{бип}(t) = P_{бип}(K_{p_{взл}} t_{взл.}, K_{p_{пол}} t_{пол.}, K_{p_{пос}} t_{пос.}),$$

where: $K_{p_{взл}}$, $K_{p_{пол}}$, $K_{p_{пос}}$ - risk factors of the crew on stage, respectively, takeoff, en route and landing. Risk coefficient of the crew changes the values of the stages of flight in a wide range. Parameters of the environment have a significant value on the error probability of the crew: Flight visibility, pressure and air temperature, wind velocity components, the excess of the terrain, the radio equipment for FS. An obvious need for a systematic approach is creating a multi-level system PD.

Design Ensuring fail-safe on the principles of operation of a closed system life cycle: < projecting > →<certification>→< certification of serial production > →<usage> with providing back connection operator with EDB and the industry, and the system security is layered.

Consider the technical levels of security, the possibility of FS and aircraft in general, inherent in the designs, structures, circuit designs, methodologies ground and flight tests, for conditions a through design and implementation of CALS-technologies (Continuos Acquisition and cycle Support - a continuous informational support life cycle product). The scheme of a systematic approach CALS technologies to create modern aircraft of civil and military purposes is given in [4].

The systematic approach to creating modern aircraft provides reliable interaction dialectical pairs (chains): <efficiency>→ < quality> →< system >→< process>→< reason>→< result > → < CALS-technology> →< quality> . A comprehensive quality assurance system as the target program includes a logical sequence of stages of life cycle:<projecting> → < certification>→ < mass production>→<usage>according for quality assurance: <At the stage of R & D> → < ahead of aircraft Certification> → <In mass production>Provide Performance Quality >.

The introduction of technology through design CALS significantly accelerates the implementation of the project to create a modern aircraft and reduces the overall cost of the project. At the first level of reliability structures realized of aircraft, based on the requirements of the regulatory framework. It produces a sufficient degree of resiliency aircraft, with the expansion of its other technical features.

The second level is provided to serve as an aircraft systems at unit failures due to redundancy and fail-safe levels at the expense of crew actions in the "crew - aircraft – environment" or the automatic control system, if a high probability of error of the crew. The third level is provided by the implementation of actions to safeguard the conditions of survival of the crew and passengers, when prevention of aircraft in emergency impossible. At the fourth level of "designer" and "operator" jointly develop tools and methods for training of flight and engineering crews to reduce risks in the management of FS and flight control systems, as well as deviations of equipment and crews in the operation.

At the fifth level of "operator" analyzes and summarizes the deviations in the elements of safety systems, together with the "Designer" assess the degree of risk of flight situations and develop measures to eliminate recurrence of dangerous deviations and assess effectiveness. Analysis and generalization of aircraft operations allow you to work out measures to ensure the availability and fail-safe in view of possibilities operator to manage complex technology that lowers the risk of errors in flight and ground personnel.

The modern concept of successive transformations of states of the world of "industrial" to "technologically advanced, and their leaders - the" information development ", characterized by their focus to the creation on the basis of integrated automated control systems (IACS), the new features go to the programmed operation of aircraft.

Creation of the institutional, technical and technological basis for the implementation of IACS LTC and ETC aircraft with avionics include the following areas: programming life cycle of avionics based on the target programs are designed, serial and operating companies and certification bodies; forming system requirements and criteria tree "system performance; creation of program-methodical complex of technical means (PMC and CTM); creation of information technologies for the airline based monitoring, diagnosis and prediction of technical state of avionics in the process of evolution, revealing the inner content of the implementation of LTC and ETC.

Conclusions. Close interaction of the computing environment, a new avionics with traditional devices (actuators, sensors, indicators, etc.) and modern innovations in navigation, separation, warning of a collision, satellite communications can make substantial progress in improving FS of aircraft and performance (fault tolerance, fail-safe , flexible interface).

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POWER EFFICIENT ALGORITHMS OF ASYNCHRONOUS-STARTING ELECTRIC DRIVES WITH CURRENTS LIMITING

The article is devoted to the control of asynchronous electric drive's start, which is powered by a frequency-controlled current source with a constant slip without measurement of slip. Also the energy performance of electric drive in the process of startup is analyzed.

Introduction The process of induction motor's (IM) with squirrel-cage rotor startup is characterized by a large value of current consumption, which is 6-8 times higher than the nominal. This requires ensuring adequate power supply as well as starting regulator and protective equipment, which leads to an increase in capital expenditures. Therefore, the application of heavy-duty or in the case of independent power supply or at a comparable motor and a source the direct start IM is impossible.

Statement of a problem One possible way to limit the level of current consumed by IM, there is powered its stator circuits from the current source (CS) [1].

When the stator winding of IM with squirrel-cage rotor is powered by a CS of constant frequency, the properties and characteristics of the motor are very different from those inherent in the traditional scheme of power from a voltage source of constant frequency. If the induction motor powered by a voltage source, the value of stator current depends on the load on the motor shaft, and the value of the magnetizing current with changes in the load remains practically unchanged. If the motor is powered by a current source, that provides constant current in stator circuit of the IM, then the substantial variation in rotor's current, that is defined by the change of load torque on the shaft and the sliding of the rotor, leading to a change in a wide range of current of the magnetizing circuit. Hence the analysis of modes of induction motor, which is powered by a current source of constant frequency, it is necessary to consider the change of resistance of the magnetizing circuit due to changes in the degree of saturation of IM magnetic circuit. Changing the magnetic flux of the motor, which is powered by current source, when the load changes significantly effect the laws of change of rotor current and electromagnetic torque with the variation of the slip [2, 3].

Feeding the induction motor from the current source leads to a significant decrease starting torque of the motor. To ensure the effective startup of the electric drive with a moment load on the shaft, provided current limiting of induction motor's stator at a given level in the process of startup, it should be powered by the controlled-frequency current source. By setting the desired value of induction motor's stator current as well as the required rate of increase of the frequency of power supply during start-up, we can realize the most favorable start of the induction motor [2].

The algorithm of starting of the electric drive with a current limiting Analysis of static characteristics of the induction motor, which is powered by a current source with variable frequency, can be made using the T-equivalent circuit [4].

When the parameters of equivalent circuit lead to a nominal frequency current source $f_{1н}$, the parameter r'_2/fs can be written as r'_2/s_e, where s_e - slip on the natural characteristics of induction motor. If an arbitrary value of frequency f_2 of power supply the slip of the rotor in the motor mode of induction motor changes in the range $0 < s \le 1.0$, when you lead it to the value s_e, it will vary in the range $0 < s \le f_i$. The value of s_e is proportional to the absolute rate of induction motor's rotor sliding on the magnetic field at an arbitrary frequency.

Expressions for determining the magnetizing current and rotor current, reduced to the stator for an arbitrary frequency f_i can be written as:

$$\dot{I}_0 = \dot{I}_1 \frac{jx'_2 f_i + r'_2/s}{j(x_0 + x'_2) f_i + r'_2/s} = \dot{I}_1 \frac{jx'_2 + r'_2/s_e}{j(x_0 + x'_2) + r'_2/s_e}, \tag{1}$$

$$\dot{I}_2' = \dot{I}_1 \frac{j x_0 f_i}{j(x_0 + x_2') f_i + r_2'/s} = \dot{I}_1 \frac{j x_0}{j(x_0 + x_2') + r_2'/s_e}\,. \tag{2}$$

Since the electromagnetic torque of induction motor with a value of rotor current at an arbitrary frequency power is given by

$$M_{em} = \frac{m_1 I_2' r_2'}{\omega_{0\,i} s},$$

where $\omega_{0\,i} = \frac{2\pi f_{1н}}{p} f_i = \omega_0 f_i$, then

$$M_{em} = \frac{m_1 I_1^2 r_2'}{\omega_0 s_e} \cdot \frac{x_0^2}{(x_0 + x_2')^2 + (r_2'/s_e)^2}\,. \tag{3}$$

To calculate the currents and torque of the induction motor according to (1) - (3) as a value of s_e at intermediate frequency current source, we will take the values $f_i s$. The critical slip and a maximum torque of induction motors, as well as the value of starting torque at an arbitrary frequency of the current source can be calculated using the relations:

$$s_{kr_i} = \pm \frac{r_2'}{f_i (x_0 + x_2')}, \tag{4}$$

$$M_{\max} = \frac{m_1 I_1^2}{2\omega_0} \cdot \frac{x_0^2}{x_0 + x_2'}, \tag{5}$$

$$M_{n_i} = \frac{m_1 I_1^2 r_2'}{2\omega_0} \cdot \frac{f_i x_0^2}{f_i^2 (x_0 + x_2')^2 + r_2'^2}, \tag{6}$$

As follows from relations (4) - (6) the critical slip increases with decreasing frequency and magnitude of maximum torque of the induction motor feeding from the current source does not depend on the level of frequency. The value of starting torque reaches a maximum value $M_{ni} = M_{max}$ at a frequency $f_i = r_2'/(x_0 + x_2')$, that corresponds to the torque magnitude on the natural mechanical characteristics of the motor ($f = 50$ Hz) with $s_e = s_{e\,kr}$.

Fig. 1 shows the mechanical characteristics of IM 4A160S2У3, which supplied from the current source with the stator current I1 = 2In and frequency of 50, 25, 10 and 2 Hz. A distinctive feature of these characteristics is the same hardness in the range of slides $0 < s \le s_{kr\ i}$ and the constant value of maximum torque at $s_{kr\,i}$ regardless of the frequency of the current source.

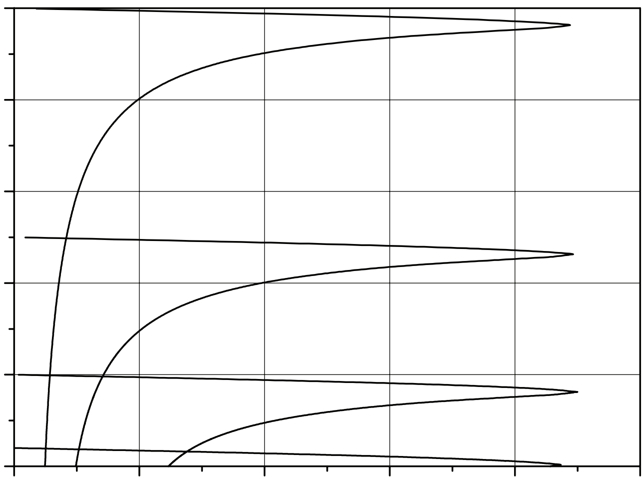

Fig. 1

The calculations showed that with the changing of current source frequency to a given multiplicity of stator current the value of phase voltage when sliding $s_i = s_{kr}$ i vary almost in proportion to the frequency of the current source. The monotonic increase in phase voltage on the stator winding of the induction motor during acceleration in the range of slides the $s_n < s_i \leq s_{kr}$ for different values of frequency and magnitude of current power source allows the use of the value of phase voltage as a control factor for change in the frequency of the current source at frequency during motor start.

Principles of the organization controlling the frequency of the current source at frequency induction motor start can be explained using Fig. 1. If the initial moment of starting the induction motor to set the frequency of 2 Hz with a double-fold of stator current, it will develop torque, equal to the maximum (2.4 M_n). At this time the voltage on the phase of stator windings will be equal to 0,142 relative units (r.e.). The motor will accelerate because of (under) the influence of the electromagnetic torque and the voltage on the stator winding will increase. If after increasing the voltage we begin increasing the frequency of the current source of a certain law, as a function of voltage on the induction motor stator winding, in the acceleration process we can ensure the permanence se, and hence the electromagnetic torque. If we provide s_e constant values at $s_{e\,kr}$, then a speed-up of the motor will happen to the value of electromagnetic torque, which is close to the maximum. As we know, in the zone of low frequencies significantly increased the proportion of active resistance to the full equivalent resistance of the motor. Therefore, when the motor feeds from the voltage source it requires an increase in ratio U/f at low frequencies. When the induction motor feeds from the current source there is an automatic correction level phase voltage with decreasing frequency. Due to this phenomenon the law of the variation of voltage with decreasing frequency is close to linear.

Choosing a suitable law of the variation of frequency as a function of phase voltage motor' stator in a frequency range from 2 to 10 Hz (where most affected nonlinearity control loop frequency) we can ensure the harmonization of the rate of change of frequency and voltage during the motor speed-up. When we negotiated the rate of increase of frequency with the level of voltage variation on the stator motor which is powered by a controlled-frequency current source, during its starting we can provide a speed-up of the motor with the desired constant electromagnetic torque in the range $M_c < M \leq M_{max}$.

Thus, the usage as a control loop frequency of the current source phase voltage on the induction motor' stator winding as the control action allows us to carry out motor start with a given value of electromagnetic torque, or the size of sliding s_e. The direct measurement of these variables to control the frequency of the power source is extremely difficult.

To evaluate the dynamic properties and energy performance of the considered electric drive in the starting mode we were calculated values at start-up asynchronous electric drive with 4A160S2У3 type of motor. At the same time we have been reviewed by the next character of the drive load: $M_r = M_n(n / n_n)^2$ and $M_r = M_n$ at a value of total moment of inertia $J_{\Sigma} = 4J_m$ and the stator current limiting on the level $I = 2I_n$. Control the tempo of change of frequency from the current source carried on a linear $f = –4+49{,}3U_1$ as a function of phase voltage at the stator winding of the motor.

Table 1 shows the calculated values of starting parameters of the asynchronous electric drive with the frequency start under these conditions.

Table 1

Comparison of parameters of frequency starting at different characters of load

m_r, r.e.	t_s, sec	W_s, kJ	ΔP_{mid}, kW	$P_{mid\,din}$, kW	S_{1mid}, kV·A	η, r.e.	$\cos\varphi_m$, r.e.
$(n / n_n)^2$	0,688	35,75	5,193	12,42	24,28	0,703	0,725
1,0	1,085	56,43	5,201	7,79	22,17	0,602	0,586

In the table shows: m_r - the relative magnitude of the moment of resistance; t_s, sec - the acceleration time of electric drive from standstill up to a frequency value of 50 Hz; W_s, kJ - the energy losses in the motor during start-up; ΔP_{mid}, kW - average power loss evolved into the motor during start-up; $P_{mid\ din}$, kW - the average dynamic power; S_{1mid}, kV·A - the average total power, which consumes electric drive from the power network during starting; η - efficiency of the process of starting; $\cos\varphi_m$ - the average power factor during starting.

As follows from the data given in Table 1, during the frequency start with the current limiting of motor stator at $I = 2I_n$ and selected the variation of frequency in the asynchronous electric drive process of speed-up, we obtain the lowest values of start time, the energy loss at starting and, consequently, the maximum values of efficiency of the process of start. Values of efficiency of the process start equal 0.703 for $M_r = M_n(n\ /n_n)^2$ and 0.602 for $M_r = M_n=const.$ High average power factor, which is equal to 0.725 under the condition $M_r = M_n(n\ /n_n)^2$ and 0.586 under the condition $M_r = M_n=const$, cause relatively small magnitude of the total power consumed from the power supply ($S_{1mid} = (\Delta P_{mid} + P_{mid\ din})/\cos\varphi$).

The average electromagnetic torque of the electric drive in the process of start-up with the 2-fold value of electric current in the stator is close to the critical moment of the motor. Consequently, we can say that if we choose the law of changing the frequency of the current source in the process of start-up of the asynchronous electric drive then the absolute value of sliding $s_e = s_f \cdot f/f_н$ remains constant and close to the value $s_{e\ kr}$.

Figure 2 shows the calculated waveform start induction motor with $J_\Sigma = 4J_m$ at constant (nominal) moment of resistance on the shaft.

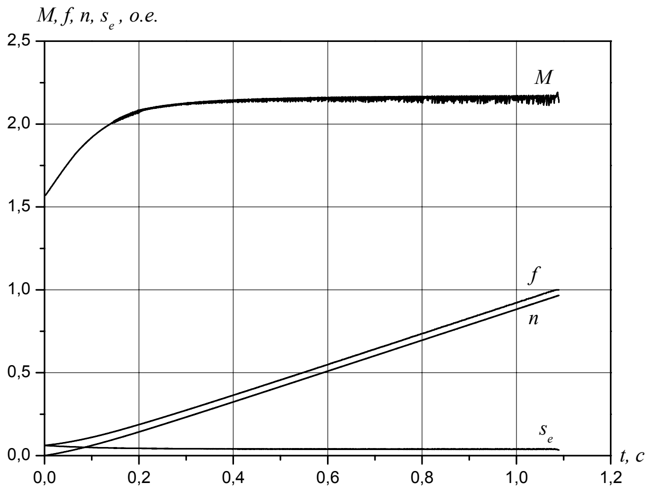

Fig.2

Conclusions Thus, the formation of the control signal frequency of the current source in terms of phase voltage induction motors in the process of dispersing it allows you:

- to provide a drive in the process of start the properties of the source of the moment;
- indirectly, to manage the process of frequency starting from the controlled - frequency current source of the condition of constant absolute velocity of sliding of the rotor without any sensors.

In this case this method of start provides a high energy and dynamic performance of electric drive.

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METHOD OF TIMING DISTRIBUTION IN RADIO NETWORKS

The author propose a method for synchronizing base stations of wireless access technologies by using signals from GPS satellites and shows its advantages compared with traditional methods of distribution of the synchronizing signal, in condition of places with a high density of base stations of different wireless technologies.

Technologies of mobile backhaul networks evolve from circuit switching to packet switching in order to meet the increasing demands on bandwidth (both in the core and access networks). A prerequisite for the emergence of mobile operator PTN (packet transport network) is providing carrier-class synchronization to the remote base station network.

Synchronization is very important for mobile wireless networks because wireless access, which is used in these networks, working with a dense distribution of bands reception/transmission (in GSM-900 standard protective band – band between channels – to channel band ratio is 0.008). That is an accurate signal source is needed to prevent interchannel interference.

Bad synchronization (worst than that specified in Table 2) will also have negative consequences for handover between base stations. Handover - the process of transferring of the voice call between base stations, in case of changing the parameters of the radio channel. If the frequencies of transmission/reception in neighboring cells do not strictly correspond to each other, it may be a distortion of the speech information, the appearance of delays in the signal, up to drop the connection.

Existing methods of synchronization are economically inefficient in the case of the small physical location, which contain a large number of base stations of different technologies (estimated we can speak about 10 BS in a circle of radius 100 m). That's why is actual task of development of such a method (with minimal cost), which would give acceptable results in the distribution of clock over short distances.

The above information give enough reasons to understand, that sync always should been implemented in radio access network. Radio networks can be divided into two categories:

- Frequency Division Duplexing (FDD): Radio Access Networks in this category use two sets of frequencies for transmit/receive. These networks require frequency synchronization in order to accurately send and receive traffic. Traditional GSM and WCDMA (UMTS) FDD networks fall in this category and need only frequency synchronization.
- Time Division Duplexing (TDD): Radio Access Networks in this category use a single frequency for transmit/receive and a demarcation based on timeslots is identified for both transmission and reception. These networks require also precise time synchronization in order to accurately send and receive traffic. For example, CDMA2000, mobile WiMAX and CDMA2000 systems all demand microsecond-level time synchronization between base stations.

Concerning the frequency synchronization the requirements are very strict. For example 3G UMTS systems required a tolerance of as little as 50 parts per billion in long term frequency accuracy. The official specification from 3GPP, TS25.104 Release 8 [1] mentions: The modulated carrier frequency of the BS shall be accurate to within the accuracy range given in Table 1 observed over a period of one timeslot.

When time synchronization is required, it also has strict requirements.

For example the radio interface requirement for WCDMA (UMTS) TDD base stations is a frequency accuracy of ±50ppb; for the TDD mode there is the additional requirement for the phase alignment of neighbouring base stations to be within 2.5ms.

Table 1.

Frequency error minimum requirement

BS class	*Accuracy*
Wide Area BS	*±0.05 ppm*
Medium Range BS	*±0.1 ppm*
Local Area BS	*±0.1 ppm*
Home BS	*±0.25 ppm*

In the case of CDMA2000 the time synchronization requirement is that for all base stations, the pilot time alignment error should be less than 3ms and shall be less than 10ms.

The table below provides a reference for today's wireless technologies and their synchronization requirements.

Table 2.

Requirements on the accuracy of frequency and phase in the various wireless technologies.

Wireless Technology	Frequency Accuracy	Time Requirement
GSM [4]	±0.05ppm	N/A
WCDMA (UMTS) FDD [5]	±0.05ppm	N/A
WCDMA (UMTS) TDD [6]	±0.05ppm	2.5μs
CDMA2000 [7]	±0.05ppm	3μs
Mobile WiMAX [17][1]	±2ppm	1μs
LTE [18]	±0.05ppm	From 1μs to 50μs[2]

Conventionally GSM, WCDMA (UMTS) FDD base stations (CDMA2000 uses GPS receivers because of the need for time synchronization) that are connected via TDM networks can be synchronized via TDM timing (PDH or SDH). Following a master-slave architecture, the timing (frequency synchronization) is distributed over the TDM links from an accurate primary reference clock to slave clocks. Timing hierarchy for TDM network presented at figure 1.

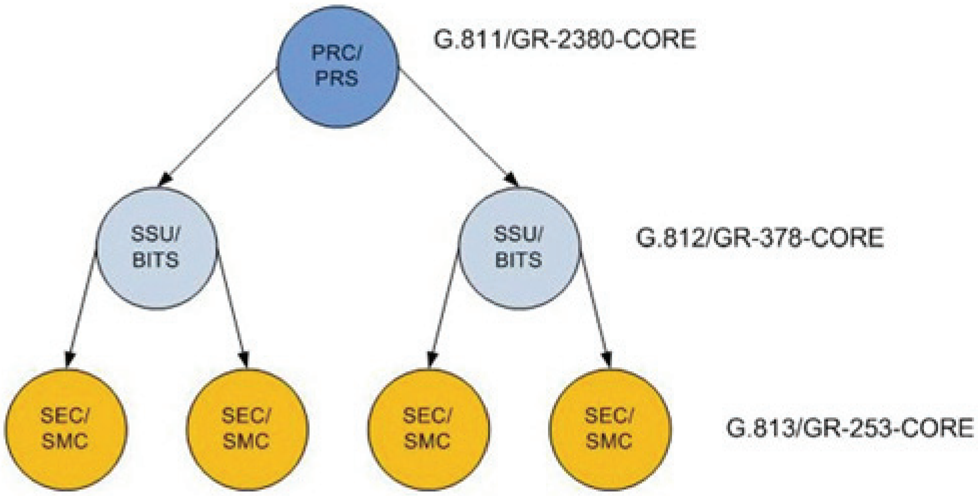

Figure 1. SDH/SONET network synchronization technology

With the replacement of TDM links with Packet Switched Networks (PSNs) such as Ethernet, IP or MPLS, this simple method of providing a frequency reference is lost, and frequency information must be made available in some other way.

As previous sections of this paper show, synchronization is a crucial factor in mobile backhaul, and probably the most challenging capability to be supported over packet-switched networks. In a TDM network, clock is transported natively over the network, but with a packet-based transport network that is asynchronous in nature, it is a necessity to develop mechanisms to transport the clock in a very accurate and reliable manner with minimum bandwidth consumption. These mechanisms need to overcome packet-based network issues, such as varying delay, jitter and packet loss.

In January 2009 Metro Ethernet Forum published the MEF 22 (Mobile Backhaul Implementation Agreement – phase 1) [2] which provides guidelines for implementing mobile backhaul network that is based on Carrier Ethernet. The synchronization requirements specified in MEF 22 are derived from the ITU-T Recommendation G.8261 [3], which studies timing and synchronization over packet based networks and also examines the requirements for different mobile technologies. Main idea of clock distribution presented at figure 2.

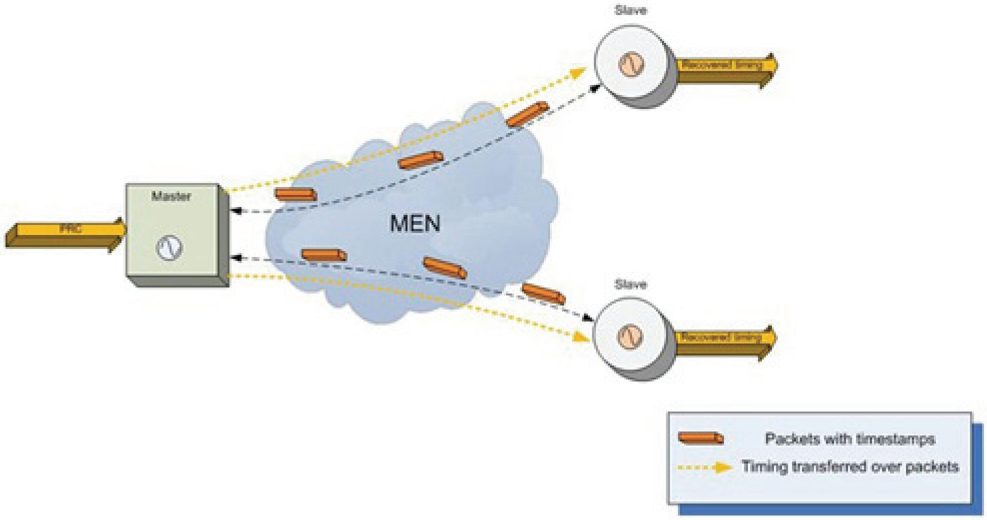

Figure 2. Timing distribution in packet network

Consider the ten radio BS in one, relatively small location (diameter ≈ 200 m). It is proposed to organize there a little timing network, independent from the rest part of the distribution system clock network. To implement such a scheme it is necessary to organize the transmission clock signal from the local oscillator, as which can act a typical GPS receiver signal:

- Frequency accuracy while tracking GPS < 10^{-12} (24-hour avg);
- Frequency accuracy in holdover < 10^{-10} per day;
- 1 PPS accuracy while tracking GPS < 50 nanoseconds RMS to UTC;
- 1 PPS drift in holdover (after 72 hours locked to GPS) <±10 microseconds in 24 hours.

From this technical specification we can make such a conclusion: the level of frequency accuracy both in the direct satellite tracking mode, and in holdover mode fully satisfies the above requirements; the phase distortion is normal when tracking satellites, and a bit beyond the necessary limits for 72 hours holdover mode (in mobile communication system for three days is more than enough time for the necessary work for troubleshooting, so that value can be neglected).

A typical generated 1PPS signal has properties:

- Waveform: 400 microseconds, ± 1microseconds pulse, positive edge synchronized to UTC;
- Level: TTL into 50 ohms;
- Accuracy to UTC: < 50 nanoseconds RMS ;
- Connector: BNC.

Frequency synchronization is performed at a frequency of 10 MHz (or 5 MHz) through the signal of sinusoidal form.

Once the signal is received at the output of the GPS-generator, it is necessary to apportion it between the synchronized devices. This can be achieved in two ways: using radio transmitter at GPS receiver, and radio receivers at the end devices or send sync via coax cable.

The first method involves the installation of a GPS receiver, low-power transmitter that would broadcast omni-directional sync to a distance of the system (≈200 m in diameter). This signal is captured to receivers installed on the terminal equipment (terminal equipment in our case – radio network base stations The advantage of this method is the ability to deliver clock to inaccessible places, which is difficult or impossible when using cable lines. From the obvious drawbacks – the need for signal processing chain coax cable -> radiolink -> coax cable with decreasing of timing accuracy at each of this transformations; dependence on the external conditions. These deficiencies can lead to degradation of the signal parameters to an unacceptable value.

Another possible way is to transfer the finished synchronization signal over cable lines, without the use of radio links. This solution is most attractively because the signal is immediately withdrawn from the specialized interface of GPS receiver, than sent to the cable system and learned at end devices, without any additional changes. Lack of this method - a small system flexibility due to the limited length of cable.

Compared with traditional methods of synchronizing transmission of information, briefly discussed above, the proposed method has several advantages:

- does not depend on technology used in the core network;
- sync signal goes a small distance from the GPS receiver units to the consumer, that is practically eliminated the influence of the last mile;
- can be implemented on existing equipment.

Conclusion

1. To solve the technical challenges of transmit of necessary synchronization information to mobile base stations required to have a GPS receiver in cluster of these BS, to provides an accurate signal to stations.

2. Proposed method allowes modernization, which means that application depending on the specific operating conditions (for example - to send signal over an optical fiber, using the method as a backup for existing).

3. As a result, require more careful study:

- Details of signal conversion at the junction of media (coax <> air, coax <> fiber);
- The impact of the distortions arising from the transfer in different environments, the signal quality;
- alternative methods of synchronizing base stations of mobile communication.

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THE METHOD OF COMPARATIVE ANALYSIS OF SOFT HANDOVER TECHNOLOGY IN CDMA NETWORK

In this paper, we investigate the effect of soft handoff region size, use mathematical model to analyze the performance of CDMA soft handoff system and compare these result with those of hard handoff.

CDMA (Code Division Multiple Access) technology is an important technology for third generation mobile communication system. One of its advantages is greater capacity compared with other access technologies. The capacity of CDMA cellular system is limited by interference level. The capacity of CDMA system is called soft capacity, because its capacity is flexible and depend on the required communication quality. The higher the required quality, the lower the capacity. Another advantage offered by CDMA system is its soft handoff ability, because there is no frequency switch while the user move to the adjacent cell. Consequently, MS can communicate with the nearest base station (BS) with strongest signal. In boundary region, the terminal is monitored by two or more BS', so the user terminal will select the best signal received. Therefore, the inter-cell movement does not break conversation. This is so called "make before break". In CDMA system with soft handoff, MS in a soft-handoff region (SR) uses multiple radio channel and receives signal from multiple base station simultaneously. The SR can be considered as a factor to analyze handoff in CDMA system. In this paper, we investigate the effect of soft handoff region size, use mathematical model to analyze the performance of CDMA soft handoff system and compare these result with those of hard handoff.

Handoff In CDMA System

In cellular mobile communication system, user mobility causes variation in link quality and interference level, that sometimes user has to move among serving base stations. This movement is called handoff. There are two types of handoff, i.e. hard handoff and soft handoff. In hard handoff, the ongoing connection will break before the new connection is made. Hard handoff is usually called "break before make", where a new channel is set up after the release of the old channel. A certain amount of margin may be introduced to eliminate the ping-pong effect. CDMA cellular system uses identical frequency in each cell; hence it is possible to make connection with new cell before leaving the old one. This technique is called soft handoff, where MS in proximity of cell boundary can communicate with two or more base stations. *Soft handoff* provides *macro diversity*, in which more than one BS is involved in communication process. This is illustrated in figure 1.

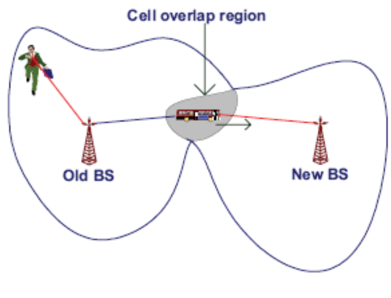

Figure 1. Overlap region

Pilot in soft handoff system is classified into 4 sets, i.e. *active set* (AS), *candidate set* (CS), *neighbor set* (NS) and *remaining set* (RS). Those pilots will be added or deleted from the set after comparison with thresholds below:

TADD: a pilot in neighbor or remaining set moves to candidate set if Ec/Io is greater than TADD

TDROP : a pilot in active set or candidate set moves to neighbor set, if Ec/Io falls below TDROP in the period of T_TDROP

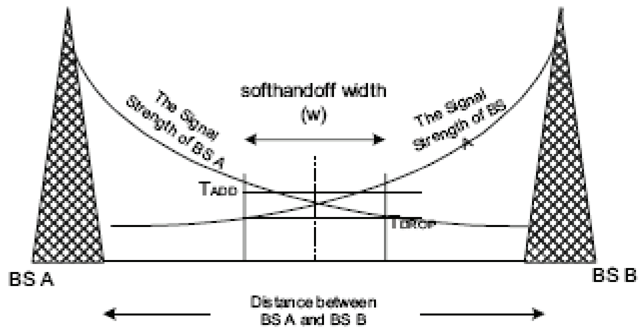

Figure 2 : soft handoff pilot

The reason in using these two different thresholds is to avoid ping-pong effect of a pilot that is continuously added and omitted from soft handoff. When MS is in soft handoff, two or more pilot signals are in the active set, MS use traffic channel simultaneously with these cells.

Soft Handoff Model

In order to analyze system performance of CDMA soft handoff, several assumptions are made in this research:

Cell structure is formed as hexagonal region as shown in figure 3. For simplicity of handoff analysis, a cell is geometrically divided into 3 regions [4], i.e.:

1. *inner cell region*
2. *soft handoff region*
3. *outer cell region*

These regions are surrounded by *inner boundary* and outer *boundary*. Region surrounded by a cell boundary is called *ordinary cell*.

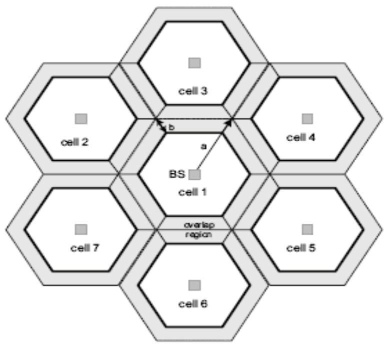

Figure 3 : Hexagonal cell structure

In cell structure model for this research, there is a given *overlap region*. In this cell structure, *soft handoff region (SR)* is a part of 6 *overlap regions*. Region outside of SR in ordinary cell is called non-SR (NSR).

Traffic Model

There are several assumptions in analyzing soft handoff, as stated below:

- Each MS is uniformly distributed
- *New call arrival* follows *poisson* process with rate λn
- *Call holding time Tc* is distributed exponentially with average $1/\mu c$

Handoff Call Attempt Rate

To calculate the handoff call attempt rate soft handoff, we first consider number of handoff call attempt rate during a call holding time (Tc) K, where K can be expressed as:

$$\overline{K} = \frac{(1-P_B)x(P_{NS}P_I + Ps)}{\left(1-(1-P_{fh})y\right)^2} \qquad (1)$$

then soft handoff call rate can be expressed as:

$$\lambda_h = \lambda_n \overline{K} \qquad (2)$$

where :

PB = blocking probability; P*fh* = handoff failure probability; PNS = new call arrival probability in non-SR region; PS= new call arrival probability in SR region; PI=probability of new call leaving inner cell; x = probability of new call request handoff ; y = probability of handoff call request HO

Because there is no margin in hard handoff, during handoff connection with new BS will be established and at the same time, old BS will be released. Case with b=0 represents hard handoff model. Handoff call rate (λh) for *hard handoff* is expressed as:

$$\lambda_h = \lambda_n \frac{\mu_{cell}(1-P_B)}{\mu_c + \mu_{cell}P_{fh}} \qquad (3)$$

where :

λh = new call arrival rate; 1/μsel = cell residual time; 1/μc = mean holding time

Analysis Of Simulation Result

Analysis and simulation results are explained below:

Factor of increasing capacity.

Considering other cell's interference, CDMA capacity inversely related with (1+f). In this research, factor of increasing capacity is defined as the ration of (1+fhard) to (1+fsoft) or [4]

$$F = \frac{(1+f_{hard})}{\left(1+f_{soft}\right)} \qquad (14)$$

considering 2 tiers from center cell, a=1, path loss exponent=4 dan □=8 dB, various value of f is acquired as shown in table 1.

Table 1: simulation result of the factor of increasing capacity

b	0 (hard handoff case)	0.1	0.2	0.3	0.4	0.5
f	2.38	1.38	0.94	0.77	0.68	0.61
F	1	0.42	1.74	1.89	2.01	2.18

Figure 5 depicts the increasing of CDMA capacity as the raising of b for various value of Eb/No. With the above simulation parameters, CDMA capacity at Eb/No=7 dB is: for single cell is 57, for b=0 (hard handoff case) is 17, for b=0.1 is 24, for b=0.2 is 29, and for b=0.3 is 32.

The influence of b variation to the mean channel holding time

The influence of b value variation to the mean channel holding time is shown in figure 6, assumed a=1, 1/μc=100 seconds and 1/μsel=100 seconds. Curve in figure 7 shows that the greater b value, the longer mean channel holding time. If compared with hard handoff, the increasing is 48% for b=0.1, 9% for b=0.2, and 13% for b=0.3.

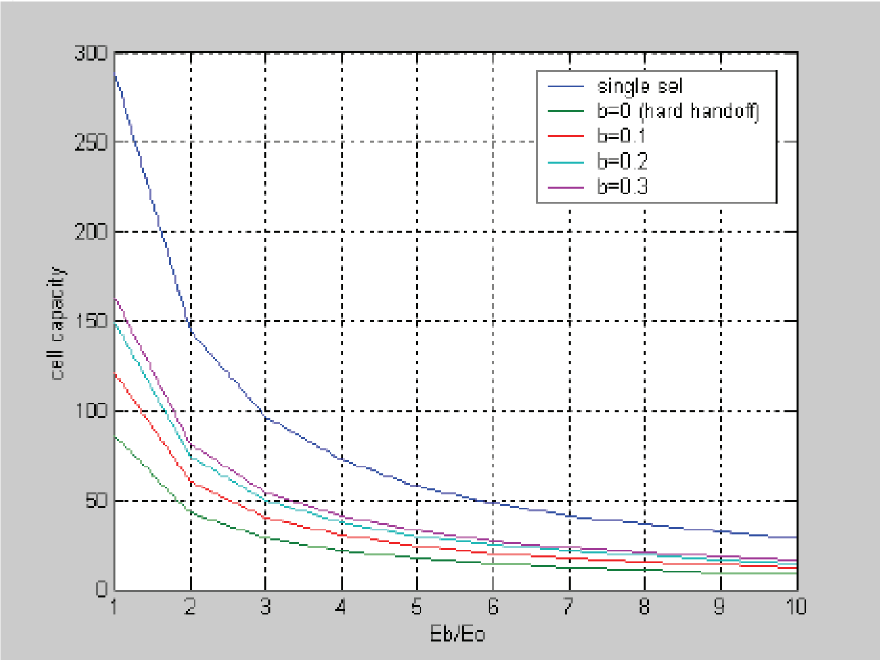

Figure 5 : Cell capacity

The influence of b variation to the mean channel holding time

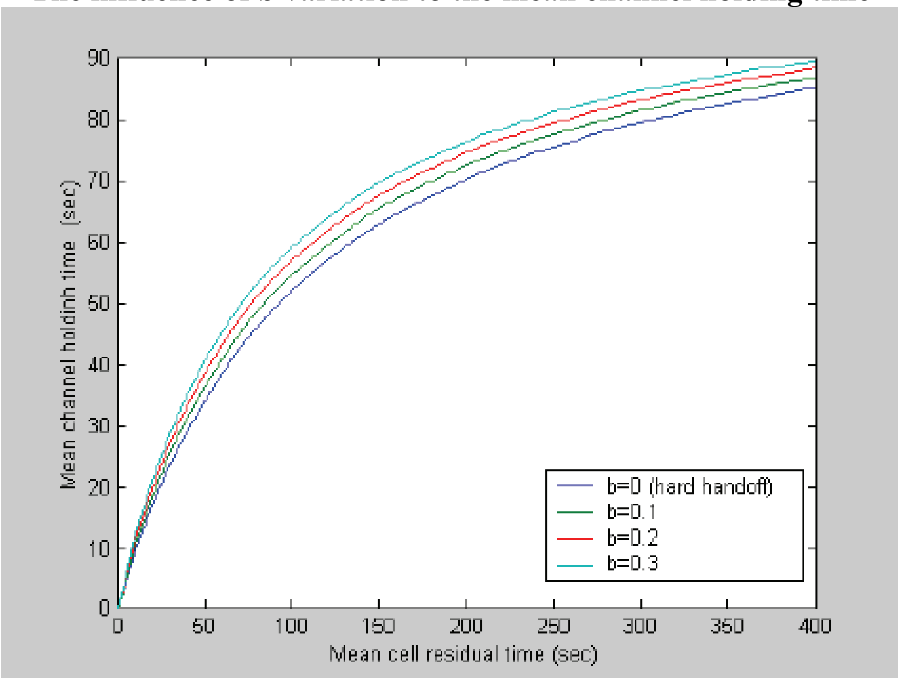

Figure 6 : mean channel holding time

The influence of b value variation to the mean channel holding time is shown in figure 7, assumed a=1, 1/μc=100 seconds and 1/μsel=100 seconds. Curve in figure 7 shows that the greater b value, the longer mean channel holding time. If compared with hard handoff, the increasing is 48% for b=0.1, 9% for b=0.2, and 13% for b=0.3.

The influence of b (soft handoff region) variation to the blocking probability

Blocking probability for various b (soft handoff region) value is shown in figure 7. It can be observed that the greater b, the lower blocking probability for the same traffic load. For blocking probability of 2%, traffic load/cell for single cell is 40 Erl, for b=0 (hard handoff case) is 25.5 Erl, for b=0.1 is 27 Erl, for b=0.2 is 31 Erl, and for b=0.3 is 32 Erl. If traffic per user is assumed 50 Erl, then number of subscribers that can be served in the cell are: for Single cell is 800 subscribers,for b=0 (hard handoff case) is 510 subscribers, for b=0.1is =540 subscribers, for b=0.2 is 620 subscribers, for b=0.3 is 640 subscribers

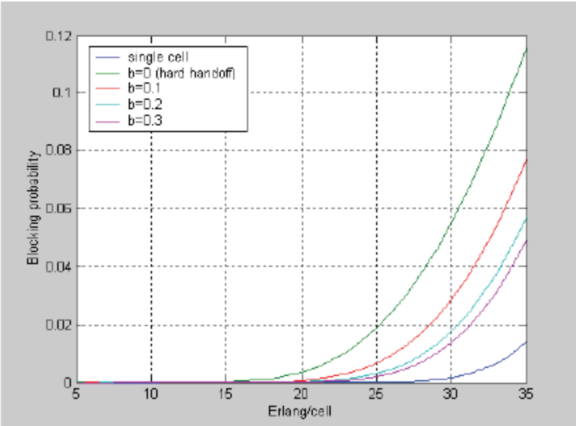

Figure 7 : Blocking probability

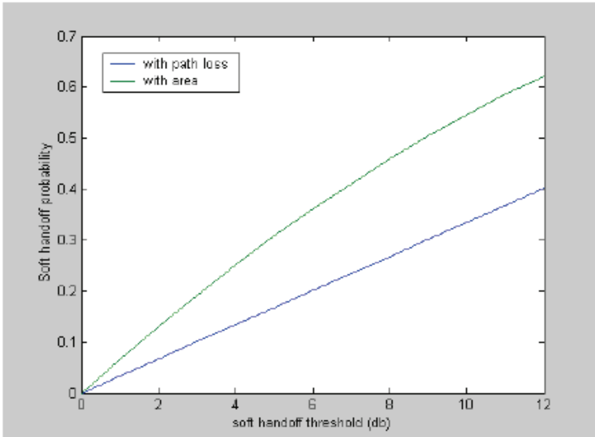

Figure 8 : Soft handoff probability

Handoff failure probability for handoff scheme without priority/reservation equals to blocking probability, because there is no particular treatment for handoff traffic.

The effect of soft handoff threshold to soft handoff probability is depicted in figure 8. For both models, the greater the given threshold, the higher the soft handoff probability. For handoff probability between 0.1 to 0.3, the threshold is mathematically expected 2 dB to 4 dB. While path loss model requires soft handoff threshold 2 dB to 8 dB. (using Okumura Hata model).

Conclussions

According to the simulation result, several conclusions can be taken: Soft handoff in CDMA improve performace, blocking probability decrease when soft handoff region larger. In this paper we have shown that soft handoff also increase reverse link capacity by a factor of better than 2 (for overlap region (b) = 0.4) if we compare with hard handoff case (b=0). According to figure 7, the reverse link capacity can support over 510 subscribers for b=0 (hard handoff case), 620 subscribers for b=0.2 and 640 subscribers for b=0.3 .

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THE ALGORITHMS OF CHANNELS' DESTINATION IN MESH-NETWORKS 802.11S

Abstract: *In this work the algorithms of channels' destination for multichanel mode of mesh-network are reviewed and analyzed. The algorithms should be applied for standardization technology of mesh-network 802.11s. Among analyzed algorithms there are: centralized (C-Hyacinth) and decentralized algorithms of channels' destination (D-Hyacinth), CoMTaC algorithm. The aim is to find out the expediency of them.*

Topicality

Standard wireless LAN networks IEEE 802.11 allows to use jointly several non-overlapping frequency channels to increase the total bandwidth provided by the terminal device. But the simultaneous use of multiple channels are rarely used in networks based on 802.11 and working on the principle of Ad Hoc. 802.11s specification involves the joint use of multiple channels. It is therefore necessary to determine the algorithm of channels' destination in multichannel mode of mesh-network.

The problem of channels' destination

The task of the of channels' destination in a multichannel wireless mesh-networks is to assign a channel to each interface with proportional bandwidth of virtual connection to the alleged loading on the connection. The simplest solution of this problem is to assign the same set of channel interfaces to each node. The maximum bandwidth with this method is too limited. It is also inappropriate to purpose each interface of different channels, working with the least used channels, as in the case of cellular networks. This decision does not even guarantee the delivery of base network connectivity. The node must share a common channel with each of its neighbors in its zone of interference, if the node needs to establish a connection with him. On the other hand, the node can not have a large number of common channels to any single node.

The main constraints that must be taken into account fr the algorithm of channels' destination are:

- number of channels that can be assigned to a wireless mesh-network nodes, limited by the number of interfaces that this node is equipped;
- two nodes between which creates a virtual connection, through which the expected transfer of traffic, must interact with a common channel;
- the sum of the expected load on the virtual connections interfering with each other and are assigned the same channel can not exceed the value of bandwidth;
- the total number of available radio channels is fixed.

Centralized algorithm of channels' destination (C - Hyacinth)

One of the most known algorithms of channels' destination in the IEEE 802.11s networks is an algorithm of Hyacinth. He determines the scheme of channels' destination, not dependency upon the used algorithm of routing. This algorithm was created for networks with a prevailing vertical traffic. The algorithm describes both centralized and up-diffused mechanisms.

The algorithm of channels' destination, taking into account loading on connection, looks like the following. It is assumed that every node has connection with all stations, being in its area of steady reception. It is needed to notice that the algorithm of routing depends on throughput of every connection, which, in turn, depend on the method of channels' destination, and the method of channels' destination depends on the expected loading on connection, which depends on routing. Thus, circular dependence turns out. For its solution it was decided to begin with the estimation of the expected loading without the account of capacity (fig. 2), and then iterationly repeat the process of channels' destination and routing to the moment, when the capacities of each of connections will be maximally near to the supposed loading. In the beginning on the entrance of algorithm of channels' destination the estimation of loading acts on connections. An output is a capacity of connections. The algorithm of routing uses them for the calculation of paths which are used for the calculation of the expected loading.

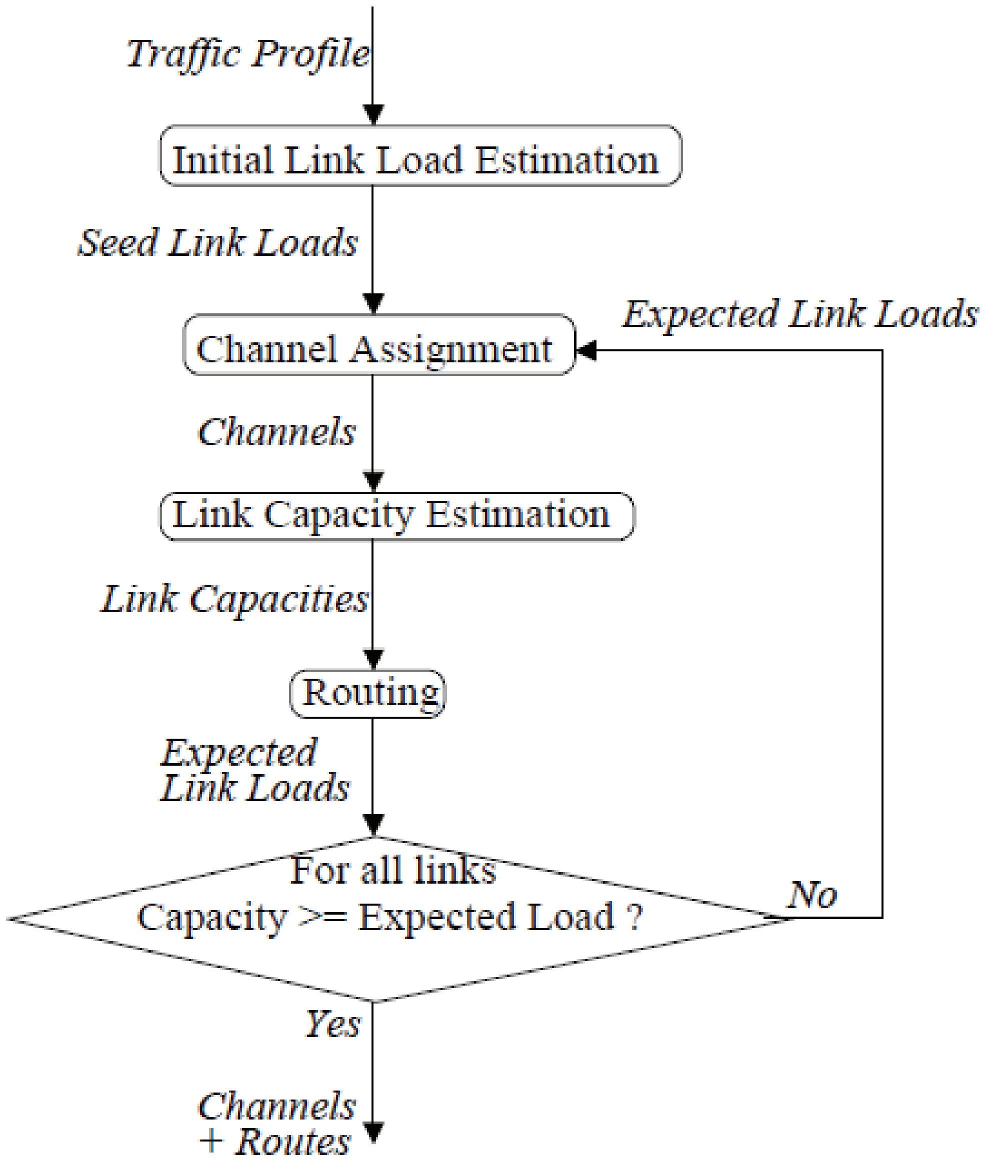

Fig.1. Scheme of the initial assessment load

If at the end of iteration appeared, that the expected loading more capacity, then a process recurs and closed, if a further improvement does not take place.

Assume a node X has already discovered a path to the wired network. It periodically, every Ta time units, broadcasts this reachability information to its one-hop neighbors using an ADVERTISE packet. Initially, only the gateway nodes can send out such advertisements because of direct connectivity to the wired network. Over time, intermediate WMN nodes that have a multi-hop path to one of the gateway nodes can also make such advertisements. The ADVERTISE packet that X sends out contains the .cost. of reaching the wired network through X. Upon receiving an advertisement, X's neighbor, say node Y, can decide to join X if Y does not have a path to the wired network, or the cost to reach the wired network through X is less than Y's current choice. To join node X, Y sends a JOIN message to X. On receiving the JOIN message, X adds Y to its children list, and sends an ACCEPT messageto Y with information about channel(s) and IP address to use for forwarding traf_c from Y to X. In terms of the routing tree, X is now the *parent* of Y, and Y is one of the *children* of X. Finally, Y sends a LEAVE message to its previous parent node, say V. From this point on, Y also broadcasts ADVERTISE packets to its own one-hop neighbors to further extend the reachability tree. Fig 2 shows the message exchange sequence.

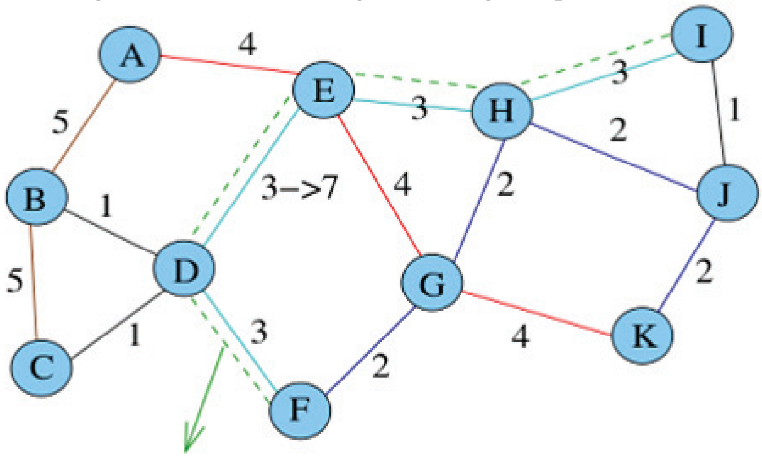

Fig. 2. This example shows how a change in channel assignment could lead to a series of channel re-assignments across the network.

As the "price" can be used several metrics. The simplest of them - is the distance in steps up to the gateway. The second metric - this is the remainder of the capacity of the gateway after connecting nodes to it. The third metric - is the minimum remaining bandwidth among all connections on the chosen path.

The basic problem of the up-diffused channels' destination is that if it is made decision to change the channel on one of connections, then this change can affect nearby connections (by virtue of the limited number of interfaces). One of such cases is in fig.2. Here change of channel on connection of D - F draws successive changing channels on connections of D - E, E - H, H - I. For prevention of such situation all node's interfaces divided into two non-overlapping great numbers: UP-NICs for socializing with a parent and DOWN-NICs for socializing with descendants. Every node is accountable for the purpose of channels for all interfaces from DOWN-NICs.

Each of the stations keeps information about "alternative parents" for maintenance the way to the gateway in the cases when some from the stations falls out. If a site does not have "alternative parents", he sends the package of FAILURE in order that already its descendant found alternative paths.

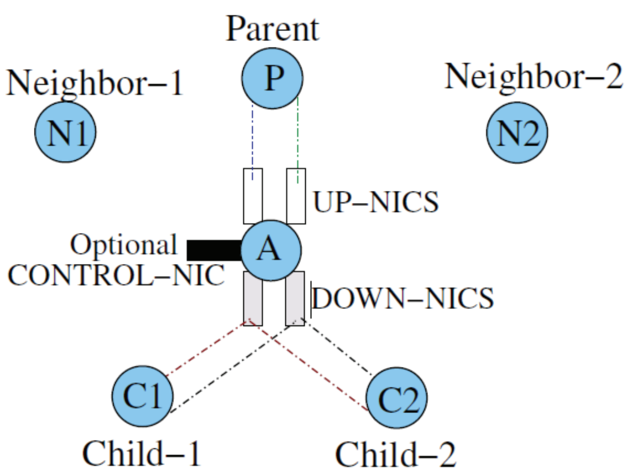

Fig.3. Division of interfaces to UP - NICs and DOWN – NICs

Algorithm of CoMTaC

Algorithm of CoMTaC, a few paths allow to use at once for communication of data from one station to other. A network appears as a graph G(V, E), where V is a great number of nodes (mesh-stations), and E is a great number of possible connections between these nodes. Logically on each of node the so-called is distinguished default-interface (interface by default). In future, all interfaces, different from interfaces by default, we will call non - default -nterfaces. On the first stage all network is broken up on clusters, after there is channels' destinations.

For breaking up on clusters the following procedure is used. On the entrance of algorithm there goes graph G (thus each of nodes knows distance to the gateway), and also great number of all gateways. Initially each of gateways is appointed by the leader of the cluster, and all node, connected to this leader, become part of cluster automatically. To save the connectedness of network, into every cluster of default-interface of all node, making a cluster, one of channels (default-channel) is appointed. Advantage of such division is minimization of number of nodes that are needed to be broadcasted with packages from a few interfaces.

Further an algorithm tries to build plural paths between node with involving of non-default-interfaces. For this purpose from a primordial graph a subgraph is distinguished such, that for any two tops those paths are leave only between them, the "cost" of which does not excel more than at of one times of minimum "price" between these node.

Since neighbours are chosen for each of nodes, it must every connection be appointed by interfaces on both stations. Because amount of interfaces is limited, at switching of some interface on other channel it can be required to change channels on the chainlet of the stations, thus this chainlet can be large enough.

At start the channels are appointed for default-interfaces of each of clusters. One of interfaces, being not default-interface, of each nodes' such way is configured, that he periodically (every TE of time units) listens an environment set time on each of channels. The packages accepted this way serve for determination of chanel's loading.

The offered chart of channels' destination allows to promote a network performance in 2 times as compared to the chart of D-Hyacinth. It is explained foremost by the use of multy paths, and also diminishing of overhead costs by diminishing of number of stations, which must be broadcasted on all the radiointerfaces.

Conclusion

The work at 802.11s standart demands the solution of chanel's destination for multichanel mode. In this work three algorithms of channels' destination at the multichannel mode of mesh – network are analyzed. But all these algorithms - D-Hyacinth, C-Hyacinth, CoMTaC does not take into account individual descriptions of different networks. Therefore for the increase of indexes of carrying capacity multichannel mesh -сети it is necessary to combine the considered algorithms depending on direction, distribution and type of traffic into a network.

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THE OPTIMAL CONTROL OF UAV NETWORK TOPOLOGY

Abstract: *proposed a method for optimal control of UAV network topology based on adaptive algorithms of UAVs network placement and movement in space to enhance the connectivity of wireless ad hoc networks.*

Introduction

Recently acquired wide application of new telecommunication system based on air-based platforms, which can perform the role of unmanned aerial vehicles (UAVs) [1]. Traditionally, the emphasis was on relatively large platforms such as *Global Hawk* and *Predator*, but recently the attention to small “miniature UAVs” (MUAVs) is increasing, which is cheaper, easy to use, easy to transport and does not require runway bands or special launcher [2]. Such MUAVs equipped with communication devices may further explore the hard reachable areas (natural disasters, technological disasters, etc.) and increase operational efficiency occasional terrestrial wireless (ad-hoc) networks (WaN), which promptly deployed for information exchange the units of Ministry of Emergency Situations, soldiers, etc.

An example of such network architecture based on UAVs shown in Figure 1.

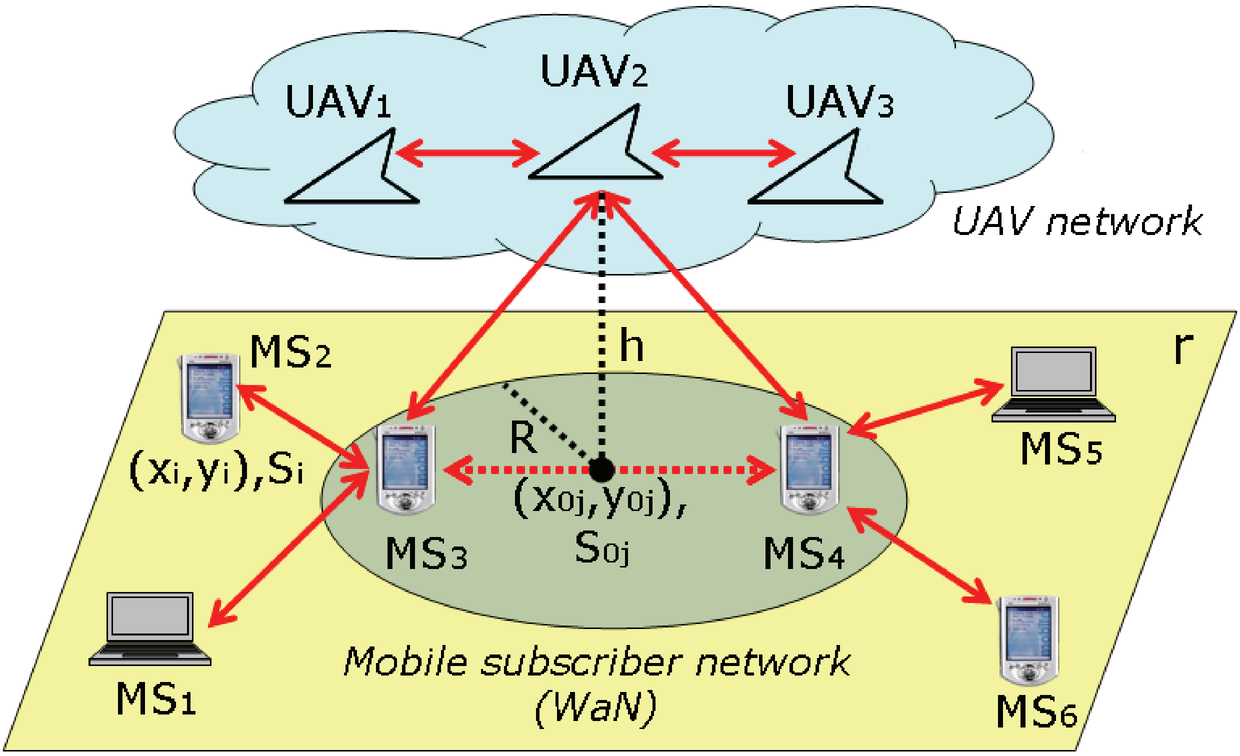

Fig.1 An example of hierarchical WaN based on UAVs

The first (ground) level of such a network is a network of mobile subscribers (MS), which directly interact with each other, forming a WaN. The second (air) level is the network UAVs operating as relay nodes and provide better network connectivity of problem areas (eg, between nodes 3 and 4, as shown in Figure 1).

The functioning of such complex hierarchical networks is not possible without effective control system [3], which is part of network management subsystem UAVs. One of the main functions of the subsystem - is managing the UAV network topology, that is finding the required number of UAVs, their place of location and movement in space.

UAV network control encountered a number of difficulties associated with large-scale multi-level network, multi-criteria multi-extremum of solvable problem and imperfection of existing optimization methods. This raises the need for decomposition approach: general topology control problem is divided into several subtasks with specific performance criteria priorities (minimum of used hardware resources (UAVs), maximum of connectivity (structural safety), or network performance, etc.).

The *purpose* of this paper is to optimize the network topology of UAVs by the criterion of improving WaN connectivity. When network connectivity is meant the ability of any pair of nodes to exchange information using intermediate nodes as repeaters [3]. Solving of this problem began a series of native and foreign scientists in the works [2-5]. However, the methods of network topology UAVs are unable to effectively solve problems of large dimension, so the problem needs further research and find new solutions.

Problem statement

Let set: a set of ground nodes V_i, $i = \overline{1,N}$, where N - number of ground nodes (MS) scattered in some area r, m^2; set UAVs B_j, $j = \overline{1,K}$, where K - number of UAVs; R = const - the radius of coverage of each UAV (if they are on relatively the same height h of the earth surface), m; $(x_i, y_i), S_i$, $i = \overline{1,N}$ - coordinates of placement and speed of ground nodes on the earth's surface (obtained through GPS). We suppose that all MS are on relatively equal ground surface height (h = 0m). Then problem statement can be formulated as follows.

Formulation 1 (placement of UAVs set): to find such location coordinates of UAVs set in the space $(x_{0j}, y_{0j}, z_{0j}), S_{0j}$, $j = \overline{1,K}$, in which the objective function of connectivity U, which defined in the work [6], will be minimal. Mathematical problem statement will be as follows:

$$\min_{(x_{0j}, y_{0j}, z_{0j}),\ j=\overline{1,K}} U. \tag{1}$$

Formulation 2 (movement of UAVs set): to find such value and direction of movement speed of UAVs set, in which increase of objective function of connectivity ΔU will be maximal. Mathematical problem statement will be as follows:

$$\max_{S_{0j},\ j=\overline{1,K}} \lim_{\Delta t \to 0} \frac{\Delta U}{\Delta t},\ v_{min} \le \left\| S_{0j} \right\| \le v_{max}, \tag{2}$$

where $\Delta U = U(x_{0j}(t + \Delta t), y_{0j}(t + \Delta t)) - U(x_{0j}(t), y_{0j}(t))$;

t, $t + \Delta t$ - current and next time;

v_{min}, v_{max} - minimal and maximal speed of UAVs movement.

Method of optimal UAV network topology control

Method of optimal UAV network topology control for improving of WaN connectivity consists of adaptive algorithms for optimal placement and movement of UAVs network in space.

Algorithm for optimal placement of UAVs set (in the case of differentiated function of connectivity [6]) based on gradient method of finding optimum. Gradient of connectivity function is defined as follows:

$$\nabla U = \frac{\partial U(x_0, y_0, z_0)}{\partial x_0}\vec{e_x} + \frac{\partial U(x_0, y_0, z_0)}{\partial y_0}\vec{e_y} + \frac{\partial U(x_0, y_0, z_0)}{\partial z_0}\vec{e_z}, \tag{3}$$

where $\vec{e_x}$, $\vec{e_y}$, $\vec{e_z}$ - unit vectors.

To reduce the complexity of the gradient method will use a linear search algorithm, which will choose the stop criterion $\left\|\nabla U\right\|^2 \le \varepsilon$, where ε - some small number. In this case, assume that the optimum found.

Then the overall placement algorithm will have the following form (see Table 1).

Table 1

Algorithm for optimal placement of UAVs set

Initializing	The initial search for optimal allocation of points set of UAVs using lattice or centroidal initialization, j = 0, t = 0.
Iteration	1. j = j+1. Determination of gradient ∇U_j^t from (3). 2. t = t+1. Linear search gradient direction in order to optimize connectivity U, ie $x_0^t + y_0^t + z_0^t = x_0^{t-1} + y_0^{t-1} + z_0^{t-1} - \varsigma \nabla U_j^t$. Stop criterion $\lVert \nabla U \rVert^2 \le \varepsilon$. 3. If $j < K$ та $[A_{пр}] \ne 0$ transition to Step 1, otherwise END.

Algorithm for optimal movement of UAVs set in space is based on operational observation of optimal placement points, determined from optimal placement algorithm. In the case of inactive (fixed) MS, UAVs move in a circle of minimum radius, determined according to vehicle engineering control devices. In the case of low activity of MS, UAVs begin to move on cycloid, and at the growing mobility of MS – straight with speed, which is proportional to the increase of objective function gradient according to (2). When gradient of connectivity reaches some maximum value, UAVs move towards optimum straight with maximum speed. In case of failure of observation led to an optimal placement algorithm. Thus algorithm for optimal movement of UAVs set in space can be presented in tabular form (Table 2).

Table 2

Algorithm for optimal movement of UAVs set in space

Observations	Determination $(x_i, y_i), S_i, i = \overline{1, N}$.
Movement	1) *Circle*: if $\left.\mu \frac{\Delta U}{dt}\right\vert = 0$, $S_0 = v_{min}$, where μ – coefficient of proportionality. 2) *cycloid*: if $\left.\mu \frac{\Delta U}{dt}\right\vert < v_{min}$, $S_0 = v_{min}$. 3) *line*: if $v_{min} < \left\vert \mu \frac{\Delta U}{dt} \right\vert < v_{max}$, $S_0 = \left\vert \mu \frac{\Delta U}{dt} \right\vert$; if $\left.\mu \frac{\Delta U}{dt}\right\vert > v_{max}$, $S_0 = v_{max}$.
Failure of observation	Go to the algorithm for optimal placement of UAVs set (Table 1).

The effectiveness of the proposed algorithms shows the following graphics of WaN connectivity depending on number of UAVs for different sizes of ground area of MS location r (Figure 2).

Analyzing these graphics can be concluded that the use of one UAV gives the most gain of WaN connectivity (110%); using the second and all the next UAVs – increase of WaN connectivity is significantly decreases. So there is a hardware resource optimization problem (determining the optimal number of UAVs) for the required network connectivity that can be solved in the future.

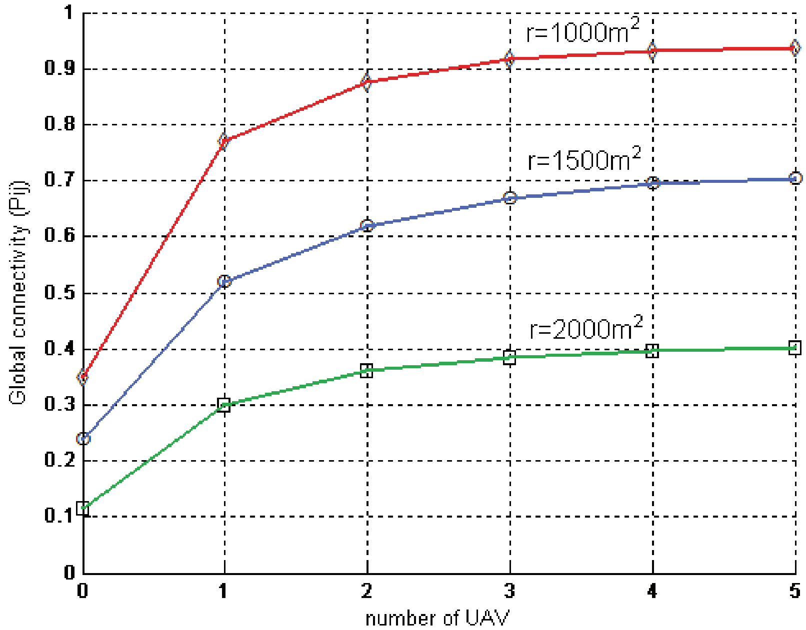

Figure 2. Graphics of WaN connectivity depending on the number of UAVs (at N = 10)

Conclusion

The method of optimal UAV network topology control for improving of WaN connectivity was developed, which consisting of adaptive algorithms for optimal placement and movement of UAVs set. Application of heuristic techniques of initial approximation can substantially reduce the complexity of the gradient search of an optimal allocation of UAVs.

Simulation results confirm the effectiveness of proposed algorithms. Apply at least one UAV gives 110% gain of global connectivity.

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REVIEW THE USE OF SENSOR NETWORKS, PRINCIPLES AND WAYS OF INCREASING THEIR EFFECTIVNESS

***Abstract**: The development of wireless technology has allowed the creation of wireless sensor networks. The article provided systematic data on these networks, characteristics of construction and selection of priorities to increase their efficiency based on application of "principle of justice."*

Urgency of the theme

One of the main components of telecommunications systems is a wireless sensor network (WSN), which represent a specific structure that provides the task of monitoring, collection, storage and processing. Direct use of existing technologies for building WSN is problematic because of specific conditions of operation of WSN in critical situations (fire, accident, deadlocking, protected, etc.).

Under effective of sensor systems is understood to ensure the characteristics of speed and mobility, and ensure high reliability of such systems in extreme conditions, taking into account the special value of the information contained in alarm, the minimum delay time for delivery of these signals, taking into account the sensitivity and distribution of information units on overload. Of particular importance in the WSN gets "the principle of justice" regarding priority messages during the transmission of useful information to the data center.

All these issues were still not sufficiently investigated and require systematized.

General Information

Modern sensory system – is distributed information system that configures it selves, which consists of a center for collecting, processing and storage. It is based on the small intelligent sensor devices that provide controlled removal of information from objects. Thus, the sensor network is a specialized information system that includes: procedures for supervision, monitoring, detection of information signals transmit information center, group processing information, making decisions and drawing conclusions, storage and archiving of data.

We can select the following classification of sensor networks:

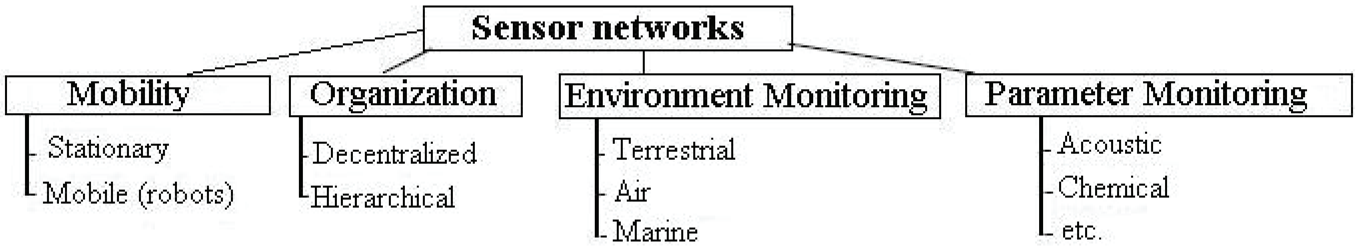

Fig. 1 Classification of sensor networks

One of the topical applications of stationary sensor networks – is the monitoring of residential, commercial and office facilities. This so-called problem of creating "Smart House". In such system installed sensors for various services "Smart House": light control, climate, home electronics.

An example of mobile sensor networks can be a network used in the biological field, for example, to systematically measure the parameters of human health indicators (pressure, temperature, etc.).

Most existing at this time of sensory systems: systems that provide fire-monitoring control facilities and the integrity, security systems usually use the transfer of information signals via dedicated or independent channels allocated. The general structure of such systems (burglar or fire alarms) presented in Fig. 2. In such structure at one end of the system installed sensor, which operates the system 1/0, on the other end – control signal showing the presence of a signal 0 or 1.

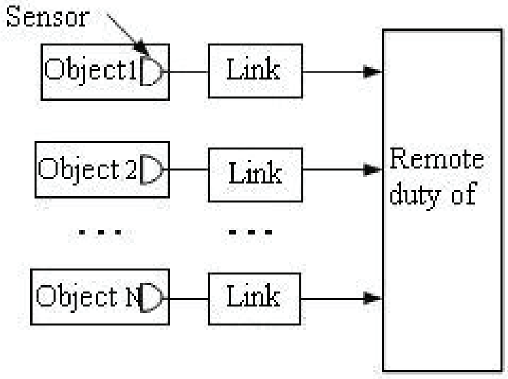

Fig. 2 Structure of the security and fire alarm

The advantage of this structure is very high efficiency, since information about changing settings allows reacting quickly on changes that appear. The disadvantages of this structure include:

– Poor reliability of links and a large number of false alarms associated with the change of line parameters, collapse, reduced capacity and lack of power;

– Low deployment speed and capacity-building and others.

Principles of sensor networks

Sensor networks are built using two types of physical devices: full-function device (Full Function Device, FFD) and a device with limited functionality (Reduced Function Device, RFD). Device FFD can take us as multiple FDD, and several RFD, while the device RFD unimplemented function to link to other RFD. For devices FFD is characterized by the presence of large computational resources and large amount of memory because it is implemented as an evaluation channel to another device, the choice of route network transfers, etc.

Fully functional network devices operate in three modes (depending on the initial configuration): coordinator, router and end node, and devices RFD – only in the end node mode.

Hierarchical WSN architecture is characterized by centralized information processing and programmable sources, which increase the reliability of information transmission, selectivity in the topology and network scalability. On Fig. 3 is an example of four-level WSN hierarchy.

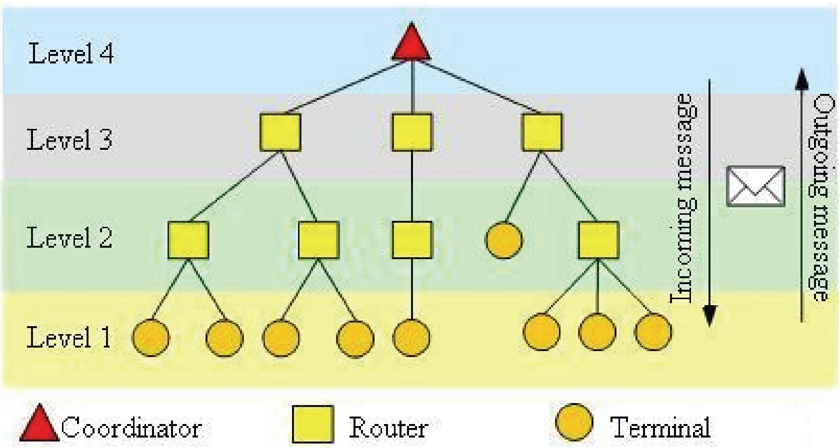

Fig. 3 Hierarchical structure of four-level sensor network

Currently, more than 1000 scientific publications from around the world about the hierarchical construction of sensor networks, because this structure allows to build networks based on PAN, LAN, MAN (Fig. 4), as well as fixed networks "Smart House", to improve indicators, which remove sensors from the different applications (Figure 5).

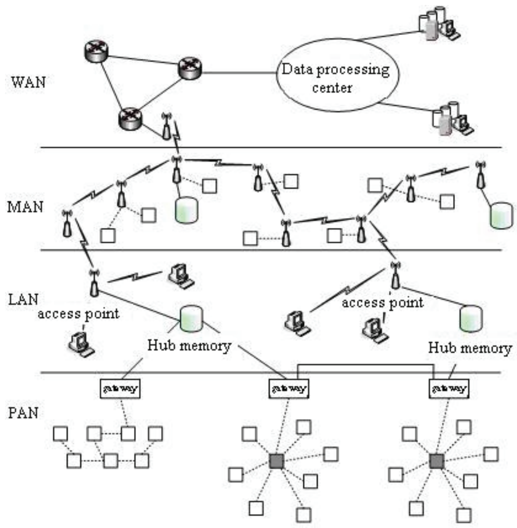

Fig. 4 The hierarchical structure of sensor network based on PAN, LAN, MAN

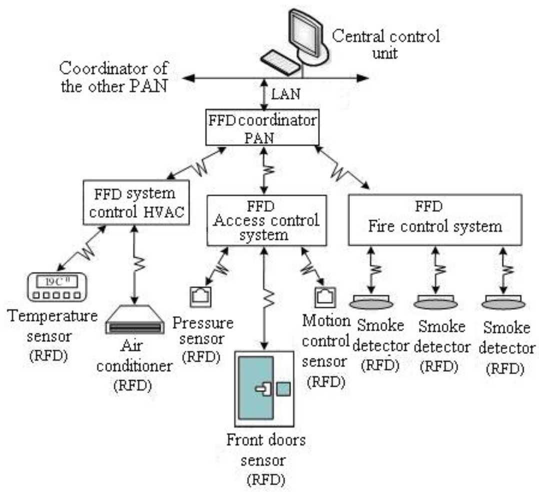

Fig. 5 The hierarchical structure of "Smart House"

So we can conclude that the most promising and relevant sensor networks structure is hierarchical structure.

Ways to improve the efficiency of sensor networks

1) Energy saving mode of operation

Most sensors are mobile devices with built-in power sources. Therefore, one of the factors is the duration of operation of node is the power. Passive scanning channel leads to considerable energy losses. Solving the problem is a node's periodic activity (Fig. 6). That is, the node can operate in three modes: operating – full-functioning node, passive – temporary channel scanning for the presence of carrier and data synchronization for all nodes and off, in which the node is not functioning.

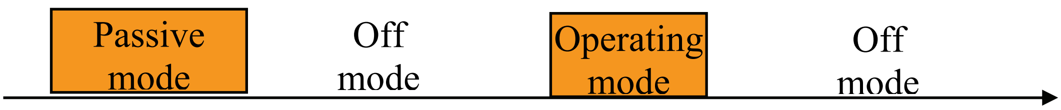

Fig. 6 Cycle operation node

2) Adaptation of existing wireless technologies for building sensor networks

Network WPAN can operate over multiple standards. Family of standards IEEE 802.15 for organizing wireless networks, the hallmark of which is a small range of network devices – personal networks. Family of IEEE 802.15 consists of several standards: 802.15, 802.15.1, 802.15.3, 802.15.4. Each of these standards can be used for sensor networks.

Using the standard 802.15.4 in WSN provides the largest coverage area, voice and data, and in addition, devices operating in power saving mode, which is important for the operation of WSN in critical conditions. Besides ZigBee sensor technology used in devices with a wide variety of functions and data processing that function as a gateway between different wireless networks, which also extends the functionality of sensor networks. If the security system, based on ZigBee, detected attackers, the network connection is IEEE 802.11, to notify the control center, which, in turn, decide on the transfer of SMS-messages to mobile phone service protection.

3) Develop methods to ensure justice for WSN efficiency

A Justice Service in WSN is a critical parameter. Justice in the classical variant meaning "balanced" data streams from service priorities.

Consider the well-known, common forms of justice, a view which differ criterion of justice.

<u>Max-min optimization criterion.</u> In this criterion is a fair allocation of rates, which further increases the speed of a one source, can be realized only by reducing some are already less than the speed of other source. Max-min form of justice is a generalization for the network tie one resource

when all the sensory information of one network is of equal value. In this case, the permissible speed position $\lambda = (\lambda_1,...,\lambda_I)$ such that for any other permissible accommodation $\nu = (\nu_1,...,\nu_I)$ executed: if $\nu_i > \lambda_i$, then there exists i' such that $\lambda_{i'} \le \lambda_i$ and $\nu_{i'} < \lambda_{i'}$. Application of this criterion is the most rational in the absence of transmission of emergency information, the operation of WSN as a transit or the telecommunication network in the passive mode.

Proportional justice criterion. In this form the criterion of justice, the situation contributes to streams using a smaller number of network channels. Terms of such justice is reduced to the following form:

$$\sum_{i=1}^{U} \frac{\nu_i - \lambda_i}{\lambda_i} \le 0 \ ,$$

and meet the target and logarithmic functions sources $\Phi_i(\lambda_i) = \log(\lambda_i)$.

The criterion used efficiently if all the sensor networks carry information at the same level value. We recommend applying this criterion when WSN dealing normally periodic surveys and gather information from sensors on objects of monitoring.

Criterion of justice in the form of minimum potential delay. This criterion corresponds to the target function is inversely proportional to speed: $\Phi_i(x_i) = -1/\lambda_i$.

Parametric class of target functions is given

$$\Phi_i(x_i) = \begin{cases} (1-k_i)^{-1} \lambda_i^{1-\alpha}, & k_i \ne 1 \\ log(\lambda_i), & k_i = 1 \end{cases}.$$

For the coefficient *k* must be performed the condition $k \ge 0$. This criterion includes the target functions corresponding max-min (when $k \to \infty$) proportional (when $k = \infty$) and minimum potential delay (when $k = 2$) forms of justice. The case $k = 0$ corresponds to the distribution of velocities at which the combined capacity is the largest. The most rational use of this criterion in a critical situation – fire, accident, infiltration of the protected premises, etc., when emergency information will be the highest priority for transmission, but for other traffic also produced a certain bandwidth.

Conclusion:

In the article features were provided particularly design principles of wireless sensor networks. On the basis of several publications concluded that the most promising and relevant structure is hierarchical, which allows properly distribute transmitted traffic.

We described the methods of improving efficiency of sensor networks using energy-saving mode, adapting existing technologies to build wireless sensor networks. We also consider "the principle of justice" based on four criteria, which allows the most important message to give the greatest priority in critical situations.

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SYNTHESIS OF THE OPTIMUM OBSERVER OF THE STATE FOR THE UAV ADAPTIVE CONTROL SYSTEM

It is in-process observed a procedure of synthesis of the optimum observer of a state with application of the shaping filter of Dryden modelling stochastic effects of a turbulent air for an automatic control system of flight vehicles which execute functions of high-altitude aeroplatforms of telecommunication systems (TS). Thus synthesis happens to consider thus both stochastic effects of a turbulent air and noise of measurements.

Introduction

Now one of most universal remedies of a problem solving of synthesis of management systems of flight is the method of analytical constructing. The main distinctive singularity of algorithm observed here is use of the shaping filter of Dryden for simulation analysis of effects of stochastic effects of turbulence on a flight vehicle.

Formulation

Let's observe a problem to synthesis of the optimum observer of a state of continuous installation (in our case UAV). In the majority of practical problems of control (in particular in flight control problems) on installation of control noise w_1 which disturb system condition X act and it is possible to metre only some linear combination of state Y that contains noise of measurement w_2 - a white noise of sensors with a matrix of covariance RN. Such stochastic installation for synthesis of the optimum observer of a state can be presented a set of equations in a state space.

$$\begin{aligned} \dot{X} &= AX + BU + w_1 \\ Y &= CX + DU + w_2 \end{aligned} \qquad (1)$$

$$[A \in R^{n\times n}, B \in R^{n\times m}, C \in R^{l\times n}, D \in R^{l\times m}]$$

It is necessary to note, that the exposition (1) actuates as well the power unit model, i.e. the exposition (1) presents a series connection of a power unit with installation. Act on installation of control of white noises is a condition of use of procedure of synthesis of the optimum observer of a state, and turbulence of an aerosphere is a colour noise. Therefore necessity of actuation for its structure of the shaping filter (Dryden's filter) is a singularity of the exposition of installation in spacious states, its entry is indignant with a white noise, and on an exit we have colour noise which characterises turbulence of an aerosphere. Thus, entries of the expanded installation in spacious states will be indignant with a white noise, n that satisfies the conditions expositions of installation for synthesis of the optimum observer of a state, and directly colour noise will act on our installation. The stochastic vector of turbulent wind speed w_1 (vector of exterior disturbances) is presented Dryden's by the standard model [1-3], that determines a matrix of spectral densities of this vector. Let the shaping filter is represented in spacious states four of matrixes $[A_f \in R^{p\times p}, B_f \in R^{p\times s}, C_f \in R^{r\times p}, D_f \in R^{r\times s}]$. Development of a procedure of synthesis of the optimum observer of a state which includes a procedure of synthesis of the shaping filter, a design procedure of the expanded installation control is an activity problem.

Procedure of synthesis of the optimum observer of a camp

Let's actuate Dryden's shaping filter in the exposition in state space UAV (1). The Series connection of the filter of Dryden and model UAV (1) leads to the expanded model in a state space that has vector $X_{ex} = [X, X_f]^T$ and fours of matrixes of a state space

$$[A_{ex} \in R^{(p+n)\times(p+n)}, B_{ex} \in R^{(p+n)\times(s+m)}, C_{ex} \in R^{l\times(p+n)}, D_{ex} \in R^{l\times(s+m)}],$$

Where $B_{ex} = [B, Bg]$, Bg - a matrix of transfer of stochastic disturbances from the shaping filter to installation of control (UAV)

The entry of matrix Bg is jointed to an exit of the shaping filter which disturbs matching variables in spacious states UAV. As the outcome is had the expanded system in a state space

$$\begin{aligned} \dot{X}_{ex} &= A_{ex}X_{ex} + B_{ex}U + n_1 \\ Y &= C_{ex}X_{ex} + D_{ex}U + w_2 \end{aligned} \tag{2}$$

Where w_2, n white noises. That disturb a system condition and measurements.

Let's give the exposition of stochastic disturbances (a turbulent wind) which act on UAV. According to [1] turbulent wind can be presented as equilibrium process which depends on a velocity and can be divided into three components: the longitudinal u_g, side v_g, and vertical w_g. The shaping filter is presented by such transmitting functions:

- The longitudinal component of a turbulent wind:

$$H_u(s) = \sigma_u \sqrt{\frac{2L_u}{\pi V}} \cdot \frac{1}{1+\frac{L_u}{V}s}; \qquad H_p(s) = \sigma_w \sqrt{\frac{0.8}{V}} \cdot \frac{\left(\frac{\pi}{4b}\right)^{\frac{1}{6}}}{L^{\frac{1}{3}}_w\left(1+\left(\frac{4b}{\pi V}\right)s\right)} \tag{3}$$

- A side component of a turbulent wind:

$$H_v(s) = \sigma_v \sqrt{\frac{L_v}{\pi V}} \cdot \frac{1+\sqrt{3}\frac{L_v}{V}s}{\left[1+\frac{L_v}{V}s\right]^2}; \qquad H_r(s) = \frac{\frac{s}{V}}{1+\frac{3b}{\pi V}s} \cdot H_v(s) \tag{4}$$

- A vertical component of a turbulent wind:

$$H_w(s) = \sigma_w \sqrt{\frac{L_w}{\pi V}} \cdot \frac{1+\sqrt{3}\frac{L_w}{V}s}{\left[1+\frac{L_w}{V}s\right]^2}; \qquad H_q(s) = \frac{\frac{s}{V}}{1+\frac{3b}{\pi V}s} \cdot H_w(s) \tag{5}$$

Where b - wing span of an airplane; L_u, L_v, L_w - matching scales of turbulence; $\sigma_u, \sigma_v, \sigma_w$ - standard deviations of matching components of a velocity.

The scale and intensity of turbulence is altitude functions. Gate out two bands: low altitudes and mean high altitudes.

The scheme shaping is presented the filter on fig. 1.

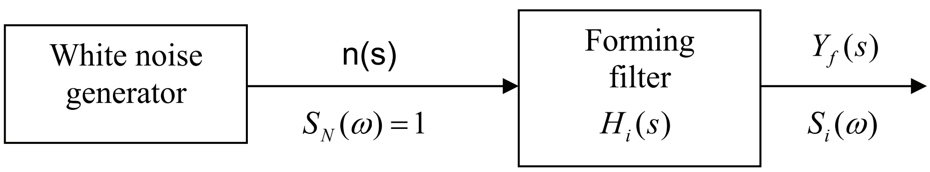

Fig. 1. The Flowchart of the shaping filter

On fig. 1 entry shaping to the filter is indignant with an uncorrelated white noise n(s) with spectral density $S_N(\omega)$ on an exit casual process $Y_f(s)$ with spectral density $S_i(\omega)$ is gained.

After calculation of four of matrixes of the shaping filter: $[A_f \in R^{p\times p}, B_f \in R^{p\times s}, C_f \in R^{r\times p}, D_f \in R^{r\times s}]$, and creation of the expanded model of installation of control (UAV) $[A_{ex} \in R^{(p+n)\times(p+n)}, B_{ex} \in R^{(p+n)\times(s+m)}, C_{ex} \in R^{l\times(p+n)}, D_{ex} \in R^{l\times(s+m)}]$, Synthesis of the optimum observer of a state happens on known algorithm.

Synthesis and simulation analysis of the optimum observer of a state

Let's record the equation in spacious states of the determined installation of control (UAV) without power units for the longitudinal channel

$$\begin{aligned} \dot{X} &= ApX + BpU \\ Y &= CpX + DpU \end{aligned} \tag{6}$$

$X = [u, w, q, \Theta, h, \Omega]^T$ - A vector of variables of a state, where u - a velocity concerning an axis x, w - a velocity concerning a Z-axis, q - angular rate of a pitch, Θ - pitch angle, h - an altitude, Ω - quantity of turnovers of the shaft of the propeller in a minute; $U = [\delta_e, \delta_T]^T$ - a command vector, where δ_e - an aberration of ailerons, δ_T - an aberration to thrust sector; $Y = [V, \alpha, q, \Theta, h]^T$ - a vector of measurements, where V - velocity UAV, α - an angle of attack, q - angular rate of a pitch, Θ - pitch angle, h - an altitude.

For synthesis of the optimum observer of states it is necessary to set four of matrixes in spacious states of the determined installation of control without power units, and four of matrixes of power units. Besides it is necessary to have performances of noise of sensors and stochastic disturbances which act on installation, namely performances of turbulence of an aerosphere.

Power unit UAV is presented by four of matrixes:

$$\begin{bmatrix} \mathrm{Aa} & \mathrm{Ba} \\ \mathrm{Ca} & \mathrm{Da} \end{bmatrix} = \begin{bmatrix} -1/\mathrm{Ta} & 1/\mathrm{Ta} \\ 1 & 0 \end{bmatrix},$$

Where Ta=0.5 - power unit time constant

For a longitudinal motion it is possible to present an input vector of the shaping filter thus: $n = [n_x, n_z]^T$, and the day off - $Y_f = [u_g, w_g, q_g]$, where u_g - turbulent incremental velocity concerning an axis x, w_g - turbulent incremental velocity z, q_g - a turbulent increment of angular rate of a pitch. Using the formula in spacious states for a longitudinal motion it is possible to present (3) model of a turbulent wind in a kind:

$$\begin{aligned} \dot{X}_f &= A_f X_f + B_f n \\ Y_f &= C_f X_f + D_f n \end{aligned} \tag{7}$$

Where

$$A_f = \begin{bmatrix} -0.032 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & -0.013 & -0.23 & 0 \\ 0 & 0.033 & 0.497 & -6.238 \end{bmatrix};\ B_f = \begin{bmatrix} 0.327 & 0 \\ 0 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix};\ C_f = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.033 & 0.497 & 0 \\ 0 & 0.002849 & 0.39 & -1.692 \end{bmatrix};$$

$D_f = zeros(3x2)$

Let's record a matrix of covariance of noise of measurements w_2 and matrix Bg:

$$RN = \begin{bmatrix} 0.2 & 0 & 0 & 0 & 0, \\ 0 & 0.2 & 0 & 0 & 0, \\ 0 & 0 & 0.01 & 0 & 0, \\ 0 & 0 & 0 & 0.25 & 0, \\ 0 & 0 & 0 & 0 & 25 \end{bmatrix}; \quad Bg = \begin{bmatrix} 0.2197 & -0.6002 & 1.4882 \\ 0.5820 & 4.1204 & -22.4024 \\ -0.4823 & 4.5284 & 4.7512 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

The scheme of the expanded installation of control with the optimum observer of states is displayed on fig. 2.

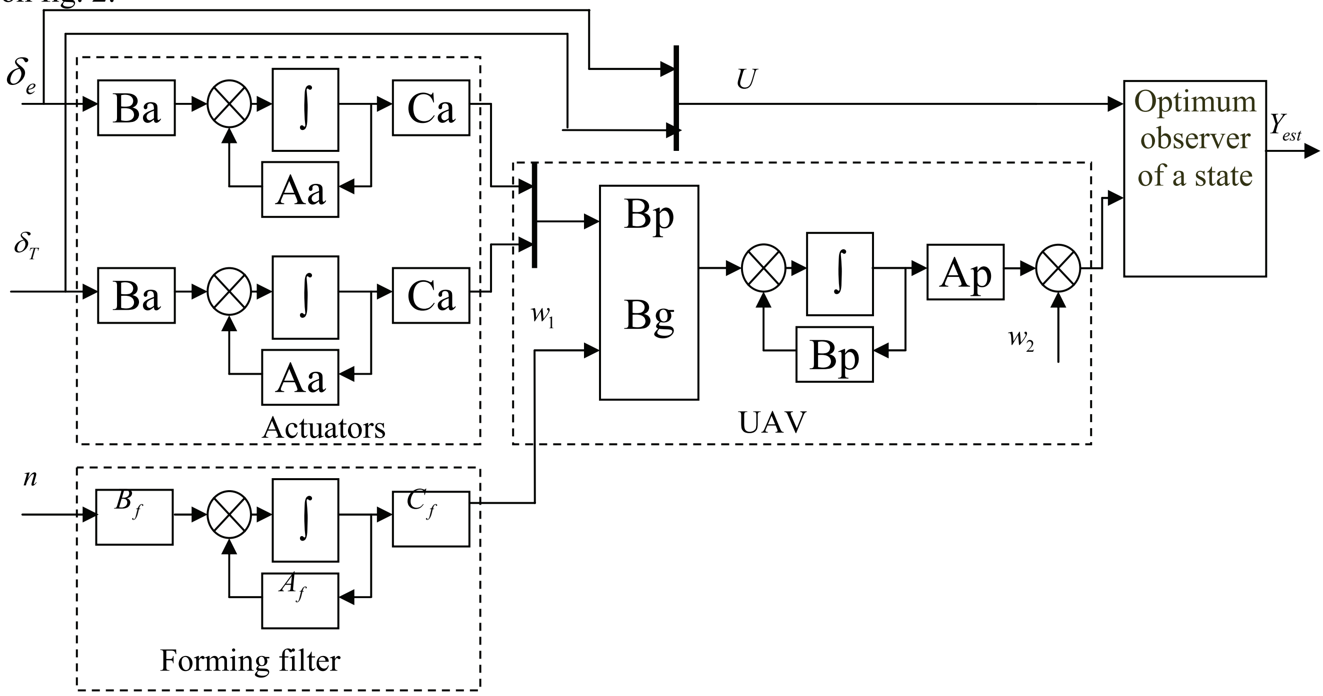

Fig. 2 Scheme of the expanded installation of control with the optimum observer of a state

Conclusions

The purpose of the conducted probing is development of a procedure of synthesis of the optimum observer of a state with application of the shaping filter of Dryden for simulation analysis of stochastic effects of the turbulent air considered at a system synthesis of automatic steering by a pilotless flight vehicle of the easy class-room. According to the presented procedure for the given robot plane the structure of the shaping filter and structure of the expanded installation of control is determined. Synthesis of management systems by flight grounded on a method of analytical constructing in a combination to procedure of calculation of parameters of the optimum observer of a state to application of the shaping filter of Dryden. The calculated parameters betray to all closed-loop system of control as a whole properties of an optimality and autoadaptivity in the conditions of preliminary indefiniteness concerning possible disturbances of channels TKS called by unforeseen modifications of meteorological conditions.

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WAYS TO IMPROVE THE POSITIONING ACCURACY OF MOBILE SUBSCRIBERS IN CELLULAR NETWORKS

The authors propose a way to improve the accuracy and reliability of the coordinate of mobile subscribers based on the sharing of satellite-based positioning (SBP) and the positioning technology in mobile communication networks (PTMCN). Proposed for the current cycle, calculate the coordinates of a mobile subscriber to control the level of interference arising from the use of SBP and PTMCN, and choose the technology that currently provides more accuracy.

1. Topicality

All the technologies associated with positioning in cellular networks known as Mobile Location Service (MLS).

However, we emphasize that the periodic updating of the location of causes interference to radio equipment, such as speakers or headphones can hear the characteristic pulse pickup, slowly decaying with the decrease of the power radiated by the device, which automatically adjusts to the minimum level. The same mobile phone induced noise will cause the appearance of a computer monitor or television beautiful horizontal stripes, and optical mouse will make tear cursor around the screen. Among other things, this leads to accelerated discharge of batteries. This should be distinguished services to identify the exact position (coordinates x, y, location-based service) and services tied to the user's geographic location (district, province, location-dependent service) (Figure 1). In the first case, service navigation, obtain relevant information related to the coordinates in the second, knowledge of the exact coordinates are not required, the system uses the term "area" (location). To provide services related to the knowledge of the area in which the user is not required virtually no investment from both the operator and user. Used existing equipment, including mobile phones. An example of such services can be broadcast messages, they vary depending on the location of the subscriber. This is a simple service, which is organized on a territorial basis, similarly organized search for the nearest gas stations, hospitals, cinemas and other needed places: on the phone just a request comes in, while on the operator side, there is information from a base station, he did. For database objects to search for the next, and then in one form or another, they are transferred to the phone user. Interestingly, the quality of service in this case depends only on how carefully was compiled database objects to which stations they were assigned. Often located near the object can be practically inaccessible because of lack of roads to it, but the one that lies a little further, by contrast, is more convenient.

The main problem of GPS and A-GPS - a significant dependence of the signal quality of the weather conditions, as the basis of their principle of operation is communication with satellites in orbits nizkostatsionarnyh. In bad weather conditions the accuracy of these technologies is becoming worse. Consequently, customers will not receive the claimed quality of service. At the same time to use technology in their work only cellular network weather has virtually no effect on the quality of services provided, but are inferior in accuracy. The article is devoted to finding ways to co-management of GPS technology and positioning technology in cellular networks.

2. The main contents of the article

Let us turn to the technologies that are used for positioning in cellular networks. To date, they can be divided into three large groups on how to calculate coordinates.
GPS (Global Positioning System) - the application of standard GPS-receivers, embedded in the phones or technology A-GPS (in the latter case, to calculate the coordinates additionally used information from the network); Cell Identifications (CI) - method of calculating the coordinates on the basis of grid cells and its modifications Service Area Identity, LocWAP, enhanced Cell-ID, Timing Advance (TA), round Trip Time (RTT), RX levels;Enhanced Observed Time Difference (E-

OTD GSM), Advanced Forward Link Triangulation (AF-LT CDMA), Idle Period Downlink (IP-DL WCDMA) - methods based on the calculation of signal delay. The calculation shows that the technology of GPS and A-GPS gives greater accuracy in the absence of weather disturbances (Fig. 1)

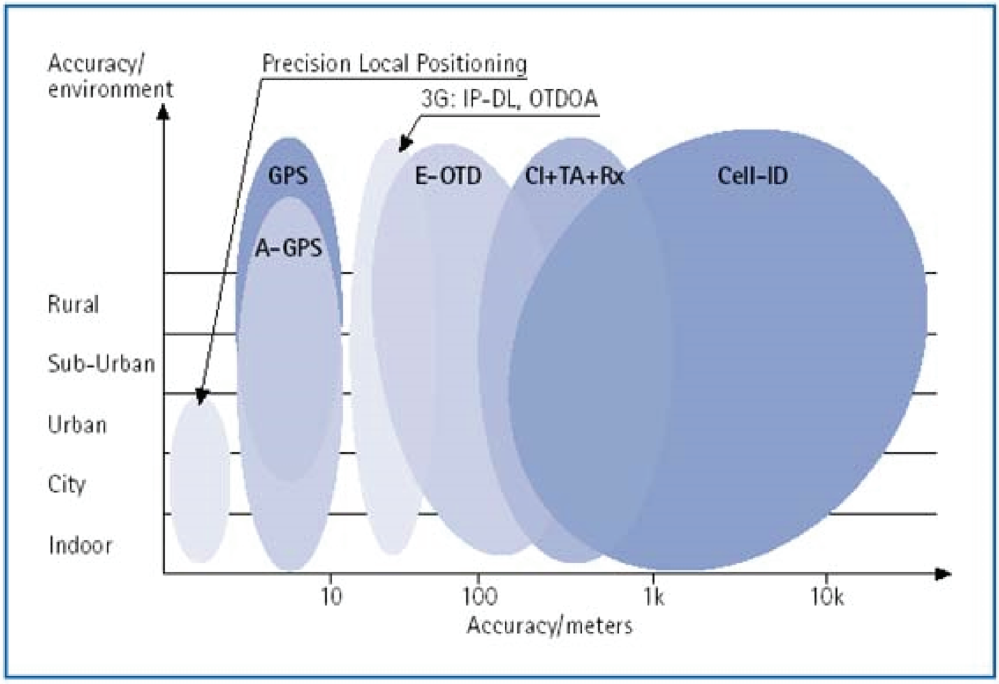

Figure 1. Relotive coverage and accuracy of most important positioning method

Consider the basic technologies of positioning alone. Technology CI implies that the user can be identified by the active sauté, in which it is located. You do not want to finalize the phone, and changes in the software the operator is minimal. But the accuracy of positioning can be from 150 meters in the city and 35 kilometers for his feature. More precise positioning technology called CI + TA, where TA - Time Advanced, time for the signal from the phone to the base station (this time measured by any device, in particular, the parameter TA is available from the engineering menu). Technology CI + TA uses two procedures:

- Definition of the base station, which operates phone, we note that while the distance and direction to the phone are unknown;
- Calculate the removal of the phone using a time delay while we obtain a circle, which can be located terminal. Given that the base stations have antennas arranged by sector, you can see in any sector is the apparatus. As a result, we obtain the approximate coordinates of the phone. The problem is that the sector is 30 to 45 degrees, and the spread of values is quite large (an average accuracy of about 200-300 meters).

Technology UpLink Time Of Arrival (UL-TOA) - requires calculations, which measure the travel time of no signal from one base station, and just three. The main condition of synchronization is time for all stations (applies more to the GSM, CDMA in time synchronized by default). So, having received a request from the phone, all three base stations transmit the time of its receipt at the center of the calculation of the coordinates. Then it suffices to solve the system of equations:

$R1=v*t$

$R2=v(t+t1)$

$R3=v(t+t2)$

where Rx - the distance from the base station to the terminal; t - time for the signal to the "first" BS; t1 and t2 - time difference of receipt of the signal at the first BS and the other BS; v - velocity of propagation of radio waves. And the current coordinates of the user will be received. Three unknowns (Rx is expressed through x, y): t, x, y. To improve accuracy, you can use the four BS, etc. (Fig.2)

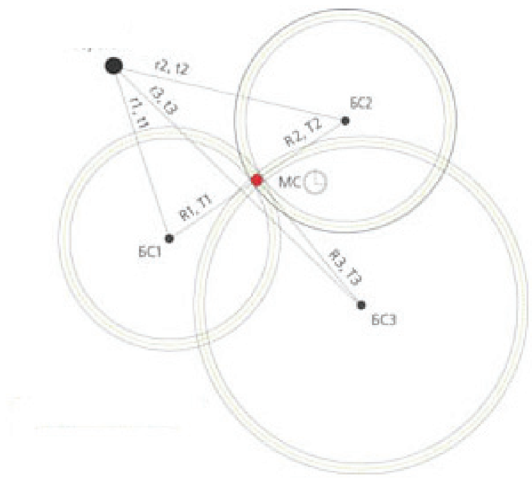

Figure 2. Graphical technology model UL + ToA

Technology UL + ToA does not require changes in mobile phones, but requires additional investment in network infrastructure. Potential accuracy from 100 to 300 meters.

Technology E-OTD-C is measured by the time of receiving a signal from the base station to the mobile terminal, as well as the reference point (base station). The calculation uses five variables:

Mobile Observed Time - the time during which the signal comes from the base station to the terminal. The time is calculated according to the clock mobile terminal;

Location Observed Time - the time during which the signal comes from the base station to the control point measurements. The time is calculated according to the clock measurement point (base station);

Offset (difference) time between the internal clock phone and clock control point.;

DMB (Distance from MS to BTS) - the geometric distance from the mobile phone to the base station;

DLB (Distance from LMU to BTS) - the geometric distance from the reference point of measurement to the base station;

These values are linked by the following expression:

$DMB - DLB = v\,(MOT - LOT + \varepsilon)$ (x)

where V - velocity signal (the speed of radio waves). For each base station is its equation of the form (x). This is due to the fact that the system has three unknown quantities: the position of mobile terminal (x, y), as well as the unknown displacement. Thus, we have exactly three base stations needed for the calculation. The approximate position of the terminal is determined by the intersection of three circles in the center of each base station is located. The radius of circles is defined as the time delay signal. (Figure 3)

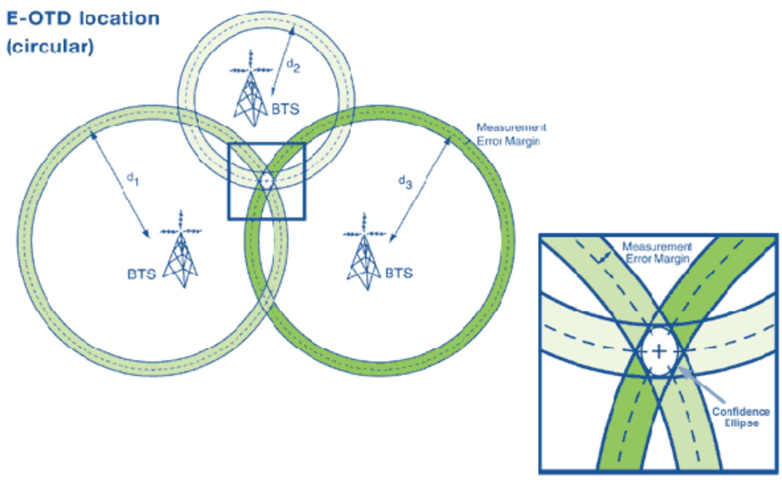

Figure 3. Graphic technology model E-OTD

The cost of the new technology is relatively low, the cost is required only for the network portion of the infrastructure, replacement of mobile terminals is not required, although it is possible. Accuracy varies from 40 to 150 meters.

GPS and A-GPS. The simplest and most logical solution was to embed a common GPS-receivers in the same ordinary cell phones. In this case, no need to spend large sums on the development of network devices and protocols, and the user can immediately be set with the greatest accuracy positioning. The first problem faced by the producers - is a high price devices as well as its large size and short time working in the mode of determining the coordinates. The devices are cumbersome, time to work about 1-2 days, and at a constant monitoring of coordinates - just a few hours. But while the coordinates are very accurate. The algorithm for determining the coordinates of GPS and A-GPS is the following: the signal is also supplied to the mobile phone, but then he was transferred to the base station, which calculates the coordinates of the phone, then sending them back. The accuracy of calculations can be from 5 to 50 meters, while the standard GPS provides from 0.1 to 30. Note that in CDMA base stations are equipped with their own GPS-antennas and, accordingly, receivers. Therefore, repeaters can be used the signal from the satellites. Thus, the work of service is achieved even where there is no direct visibility of satellites or signal rather weak (rooms included). Time calculating current position is from 20 to 40 seconds, on average, it's still 20 seconds.

Technically, the definition of the coordinate system A-GPS in a CDMA network is implemented as follows. In the presence of a signal from the satellites are the coordinates of the three satellites, the calculation is made network equipment. If the signal from the satellites do not, then the calculation is based on the testimony of no less than 20 base stations.

Findings

How to improve the accuracy of positioning the mobile subscriber in the mobile communication networks can be realized by using alternately two technologies: E-OTD and A-GPS. At the same time in sunny cloudless weather will work only technology A-GPS, and with the deteriorating weather and reduce the positioning accuracy below the threshold of E-OTD technology will be switching customers to E-OTD. In this case, we will decrease the accuracy to 15-20m, but the accuracy will be higher than for A-GPS with poor communications with the satellite or even its disappearance. At the same time as mentioned above A-GPS goes for the calculation of the testimony of no less than 20 base stations of Technology E-OTD.

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COMPARATIVE ANALYSIS OF INFORMATION SECURITY SYSTEMS IN WI-FI NETWORKS

The article explored the basic principles of the three protection technologies ifnormatsiyi Wi-Fi networks: WEP, WPA, WPA2. With one of the methods of vector optimization comparative analysis of these technologies and found optimal for several criteria - WPA.

Standard 802.11 devices communicate with each other, using transmit data signals transmitted in the radio spectrum. The data transmitted by radio receiver, which believes that the receiver also works in the selected computer modeling. The disadvantage of this mechanism is that any other station that uses the range, too, can take the data.

If you do not use any security mechanism, any standard 802.11 station can process the data sent over wireless LAN receiver unless it is in the same computer modeling. To provide even minimal security level, system should has the following components:

-Funds for a decision on who or what can use wireless LAN. This requirement is met by the authentication mechanism that provides access control to the LAN.

-Protective equipment information transmitted through the wireless environment. This requirement is met through the use of encryption algorithms. Information security in wireless networks is ensured both by authentication and by encrypting. None of these mechanisms alone can not protect your wireless network, because they combine separate algorithms, the most famous are WEP and WPA.

Wired Equivalent Privacy (WEP) – an algorithm for network security Wi-Fi. Used to protect privacy and data transferred authorized wireless network by listening. There are two types of WEP: WEP-40 and WEP-104, differing only in length key. Currently this technology is obsolete, as its evil can be done in just a few minutes. However, it continues to be used widely.

Normal user is interested in the fact wich information protection technology used in its laptop, PDA or smartphone and how the company providing this service, it can protect against information attacks. Today is a very widespread use of Wi-Fi networks are not only at home but also in corporate offices, cafes, restaurants, exhibitions, etc. And very often in such networks using an outdated technology of information security, based on the protocol WEP (Wired Equivalent Privacy). The standard encryption can be easily hacked, even with proper configuration, a weak resistance algorithm. Despite the fact that new devices support more secure WPA encryption protocol and WPA2, many older access points do not support it and need replacement.

WPA and WPA2 (Wi-Fi Protected Access) - is an updated certification program wireless devices. Technology WPA replaced Protection Technology Wireless WEP. Pluses WPA data security is enhanced and strengthened access control to wireless networks. An important feature is compatibility between the set of wireless devices as hardware, software and on.

The structure of WPA security technology can be vividly expressed by the following formula, which defined the Wi-Fi Alliance:

WPA=802.1X+EAP+TKIP+MIC.

Apparently, WPA is the sum of several technologies. The formula also shows that the WPA standard provides protection specialists use of known protocols 802.1X, EAP and TKIP. Mechanism for user authentication protocol hruntuyetsya EAP (Extensible Authentication Protocol). In technology features WPA privacy and data integrity based on the protocol TKIP, which unlike the WEP protocol uses a more efficient mechanism for key management, but the same RC4 algorithm for encryption. According to the Protocol TKIP, network devices are on 48-bit initialization vector (as opposed to 24-bit initialization vector protocol WEP) and implementing regulations change sequence of bits, which eliminates the re-use of keys and "replay-attacks. In the

TKIP protocol is provided for generating a new key every packet transmitted and improved integrity control messages using cryptographic checksum MIC (Message Integrity Code), which does not allow a hacker to modify the content of packets transmitted (forgery-attack). To access point Blom were compatible with standard WPA, enough to upgrade their software. To translate the same network infrastructure to a standard 802.11i, which defines the technology is newer WPA2 protection needed new equipment that supports the encryption algorithm AES. The following table (Table 1) clearly presents a comparison of information technology security WEP, WPA and WPA2, their basic properties, encryption and authentication methods that are used.

Comparison of technologies of information security in Wi-Fi networks *Table 1.*

Technology	Encryption Algorithm	Key generation protocol	Key length, bit	Authenti-cation	Checksum algorithm
WEP-40	RC4	KSA	40	Open System Shared Key	CRC32
WEP-104	RC4	KSA	104	Open System Shared Key	CRC32
WPA	AES	TKIP	128	EAP	MIC
WPA2	AES + CCMP	TKIP	128	EAP	MIC

From the table it is evident that technology WEP-40 and WEP-104 differ only in key length. Both technologies use the same encryption algorithm RC4 (Rivest Cipher 4 English or English. Ron's Code, also known as ARCFOUR or ARC4 (English Alleged RC4) - stream cipher, which is widely used in various systems of information security in computer networks (eg in protocols SSL and TLS, the security algorithm for wireless WEP, to encrypt passwords in Windows NT). The main advantages of cipher - high-speed and variable key size. RC4 very vulnerable, if not used incidental or related keys, a key stream used twice. Also, in both technology and WEP-1940 WEP-104 uses a checksum algorithm is CRC32 (Cyclic redundancy code, cyclic redundant code) - digital method of identification of sequence data that is computed over the values of the cyclic code.

The next two tehnolohoiyi WPA and WPA2 encryption algorithm only differ. WPA2 is also used in Advanced Encryption Standard (AES), also known as Rijndael - symmetric block encryption algorithm. AES algorithm is the next generation of encryption, approved by the National Institute of Standards and Technology (NIST). IEEE has developed a mode of AES, specifically designed for use in wireless LAN. This mode is called mode account clutches block cipher (Cipher Block Chaining Counter Mode, CBC-CTR) with the control authentication messages couplings block cipher (Cipher Block Chaining Message Authenticity Check, CBC-MAC), all together it means acronym AES-CCM.

The main difference from WPA WPA2 is to implement it and CCMP encryption AES, thereby WPA2 is more secure than its predecessor. In 2009, employees of the University of Hiroshima and Kobe University have developed and successfully implemented in practice a new method of attack that allows you to break any WPA connection without limitations, and at best, breaking time of 1 minute. It should be noted that the connection was not WPA2 prone to these attacks is by using it more secure key encryption standard AES. Conduct a comparative analysis of information security systems in Wi-Fi networks using one of the methods of vector optimization method of sequential concessions. Under this method, first set of preference criteria, while at first the most important concerns.

For this method you first need to assess each criterion. Thus, the criterion of "encryption" technology for WPA2 10-point scale Rate 10 because it is through improved encryption algorithm AES + CCMP, until now it was not broken. To put WPA technology assessment in July, because this protocol can be broken under certain circumstances. Rate RC4 algorithm 2 because it is obsolete and it must scrap a little time.

Accordingly we give each evaluation criterion of the effectiveness of information security. Also, expand the table, adding it has several important criteria such as accessibility and cost. Under the criterion of efficiency we mean the cost parameter hardware that can support this technology, information security and availability of the criteria-the use of this technology in various devices standard 802.11. As a result, we obtain the following table:

Expert evaluation of technologies of information security by criteria *Table 2.*

Technology	Encryption Algorithm	Key generation protocol	Key length, bit	Authenti-cation	Checksum algorithm	Economy	Accessi-bility
WEP-40	2	5	3	2	6	9	10
WEP-104	2	5	8	2	6	9	10
WPA	7	9	10	10	8	6	10
WPA2	10	9	10	10	8	3	4

Further, according to the method is the optimum solution for the first criterion and set it on concession Δf1. Once this problem is solved by the second criterion of additional restrictions f1 ≥ f1max ─ Δf1, where f1max-maximum of the first criterion. After finding the optimal solution on the criterion of f2 is assigned to an assignment and it solved the problem on the third criterion with two additional restrictions on the first two criteria. Same goes for solving advanced problems until found for all criteria in a concession to other criteria. Meanwhile, the concession for
each criterion Δf = 3 (usually gets 30% of maximum). Get:

$f_1 \geq 10-3$; $f_1 \geq 7$

$f_2 \geq 9-3$; $f_2 \geq 6$

$f_3 \geq 10-3$; $f_3 \geq 7$

$f_4 \geq 10-3$; $f_4 \geq 7$

$f_5 \geq 8-2$; $f_5 \geq 6$

$f_6 \geq 9-3$; $f_1 \geq 6$

$f_7 \geq 10-3$; $f_7 \geq 7$

Conclusions

1. Optimal by criterion vector technology of information security in Wi-Fi networks is WPA.
2. But the most secure is WPA2. For use in wireless client devices to update their software.
3. Technology WEP should be considered one that is already outdated.

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DETERMINATION POSSIBILITIES TO USE THE ALTERNATIVE ENERGY IN AIRPORTS

Article is devoted consideration of possibilities of use secondary energy sources for the airports. By authors of article it is spent analyze concerning existing variants of recycling of heat of ventilating emissions, sewage and the fulfilled gases of the heat substation for the State enterprise «International airport «Borispol»».

The enterprises of aviation industry appear the powerful users of fuel energy resources (FER). Therefore at the terms of constantly growings prices on the basic types of FER and considerable external economic dependence on the suppliers of power mediums, energy-savings, and efficiency acquire the special actuality for the general increase of economic efficiency of industry on the whole. One of measures energysaving is introduction of existent untraditional energy sources on enterprises. [1, 2]

Objects of research are the systems of ventilation, water-supply and overflow-pipe and system of heatsupply of the State company «International airport «Borispil'»».

Main tasks to research undertaken include:

- analysis of existent sources of the second power mediums;
- estimation of potential to use the second power mediums on the example of airport «Boryspil»;

Airport - multipurpose transport company that is part of the aviation ground transportation system, which provides take-off and landing transport ships and ground handling, reception and departure of passengers, baggage, mail and cargo, as well as the conditions necessary for the operation of airlines, civil aviation regulatory , customs and other activities, promotes business activity, aimed at improving the level of passenger service and ensure economic stability airport. To perform their functions using airport airfield, terminal, airport land, ground facilities, equipment and involves staff. [3]

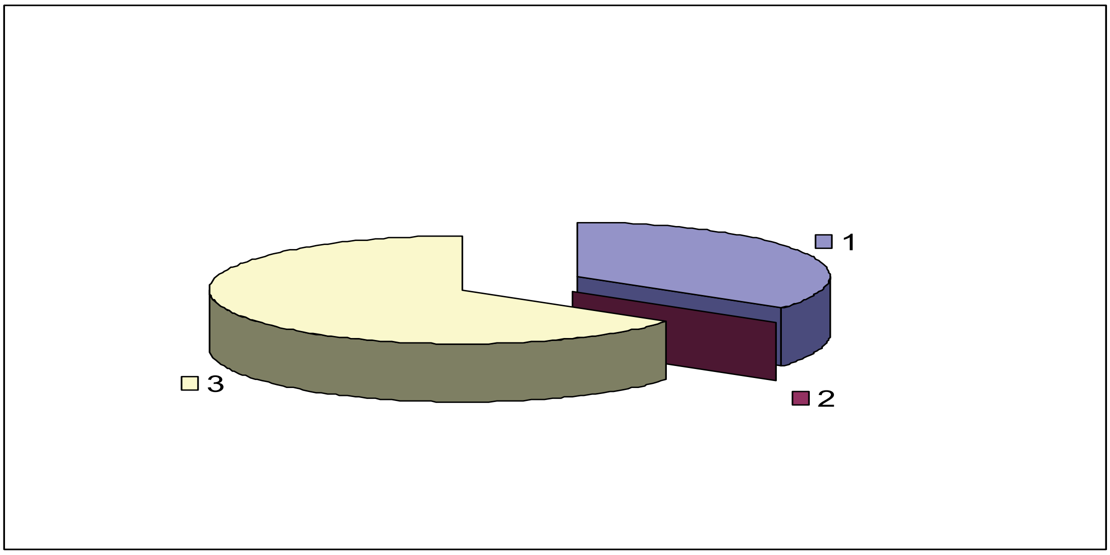

Figure1 – Energy balans of airport "Borispil'"

Note:
1 – heat energy (34,98 %)
2 – power energy (65 %)
3 – gas (0,02 %)

For implementation of the functions airports are used by the air field, air terminal, surface buildings, equipments, and attracts an auxiliary personnel. Their exploitation, as a rule, needs considerable expenses of thermal and electric energy, by confirmation of power balance of consumption of FER presented in Fig. 1. For example, the consumption of power energy is the most part 65 % and equivalency 20700 MW*h.

For example, in recognition of energy efficiency savings made in its buildings and facilities, Athens International Airport has been presented with the GreenBuilding Award The airport has been implementing energy saving measures since 2003 and joined the EC's GreenBuilding programme in 2006.

The objective of the programme is to raise awareness and stimulate energy efficiency investment in non-residential buildings.

Through reductions in power consumption of air-conditioning, ventilation and lighting, in 2006 the airport saved 3,750 MWh compared to 2005 (-9.0%) and 2,921 MWh (-4.7%) compared to 2006. In terms of emissions, the reductions saved 3,560 tonnes of CO_2 in 2006 and 2,775 tonnes in 2007. This is despite a 9.7% increase in the number of passengers handled in 2007 compared to the previous year.

Total electricity consumption during 2006 decreased by 1.3% in comparison to 2005, mainly due to efforts such as fine-tuning the central lighting and air-conditioning controls. The average electricity consumption per passenger has decreased consistently since 2003 due to the application of energy-saving measures. Secondary energy potential represent a type of energy (thermal, chemical, mechanical, electrical) contained in the waste of intermediate or finished products. Secondary energy resources - energy potential products, waste by-products and intermediates produced in manufacturing units (installations, process) and is available in the unit, but may be partially or wholly used for other power supply units (processes).

Alternative resources are divided pas secondary material and energy. In the secondary material resources understand the production and consumption waste (including household) used in the sector with the current state of science and technology.

Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). [4, 5]

While most renewable energy projects and production is large-scale, renewable technologies are also suited to small off-grid applications, sometimes in rural and remote areas, where energy is often crucial in human development. Climate change concerns, coupled with high oil prices, peak oil, and increasing government support, are driving increasing renewable energy legislation, incentives and commercialization. They can be used for heating greenhouses and so on.

There are such possible secondary sources of energy in airport :

- air emissions;
- wastewater;
- heat systems.

System ventilation with heat recovery ventilation exhaust air requires energy costs for heating the air less than other systems. At the same time reducing their constituent power, heating, new construction at reduced investment costs. Additionally, by using heat recovery systems, reduced fuel costs, as used in domestic heat (thermal implied allocation of rights, electrical appliances, lighting, hot water vapor kitchens and bathrooms, etc.). Temperature, ventilation systems emitted is 20 ... .25 º C.

Systems purge ventilation heat utilizers will almost halve the cost of fuel for heating and ventilation, using 50-70% of exhaust heat for heating intake air [6, 7].

Cold ewage water enters the building from winter temperatures 5-8 ° C. Then it warmed up in pipelines, heated, mixed with hot water and leaving building with a temperature of 10-18 ° C. sewage taken from a very large amount of heat. This heat, which is in the sewage, not using modern to recycle sewage heat and bring their temperature to the temperature of water that goes. Transformation temperature sinks 10-18 ° C is 5-6 kW of electrical energy can be spent to get 5-6 kW of useful heat energy utilized [7, 8].

On balance of airport «Boryspil» is 3 boiler rooms which work on a gas fuel [9]:

- heated-production (providing of necessities of heating and hot water-supply of users of territory of air-port) – provided with a gas-supplying from two different sources, in case of the emergency disconnecting of gas-supplying the foreseen work of one of caldrons of the system of heating on an oil-fuel (solar oil); set for 2 caldrons for the systems of heating and hot water-supply (worker and reserve);
- a boiler room of base composition of providing of necessities of heating and hot water-supply of users is on territory of base composition– basic fuel is gas, not provided with reserve; 2 caldrons are set for the systems of heating and hot water-supply (worker and reserve);
- boiler room of hotel «Air-port» is a basic fuel – gas, not provided with reserve; 2 caldrons are set for the systems of heating and hot water-supply (worker and reserve).

Increase fuel efficiency in boilers by recycling heat from exhaust gases is one of the major trends in energy.

Gases from the boiler have a pretty high temperature, which often exceeds the minimally required for safe operation of gas-smoke path. The value of units of physical heat more than the lower rate of fuel consumption and higher exhaust temperature of flue gases. Maximizing heat of exhaust gases is possible only to a lower temperature of the heat exchanger below the dew point, ie 45 - 60 º C heat of vaporization and utilization contained in gases. Thus, on the one hand, there is the maximum utilization of heat previously spent gases in the atmosphere and on the other hand, ensured normal operation of gas-smoke path. [8, 9].

Utilization heat from flue gases can be used to heating water to temperatures of 50-110 º C, which can be used: for heating water in the boiler, heating ventilation air in buildings, heating water for heating systems and more.

For possible three cases of utilization of warmth, will define their estimation of potential to use of waste energies according to the next

$$P=Q_{вс}*\eta= V\cdot C_n\cdot(t_{в1} – t_{в2}) *\eta,$$

where P –potencial of thermal energy, kW

Q - amount of warmth, kW

V,.- volume of the considered system м^3/h

$C_n\cdot$ - heat capacity of air, Dg/кg·grad (according to [12])

t_1, t_2 – – temperatures accordingly on an entrance and output, ^{0}C

η - the energy output:input ratio of the systems

The results of calculations are erected in a table.. 1

Table 1

Estimation of potential to use the second power resources for the systems of ventilation, heat- and water-supply of State company «International airport «Boryspil'»»

	$t_{в1}$, ^{0}C	$t_{в2}$, ^{0}C	V,. м^3/h	C, Dg/кg·grad	Q, кW	η, %	P, kW
System of ventilation	20	10	760000	1010	2560	50	1280
System of watersupply	15	5	85,5	4200	1000	50	500
System of heatsupply	180	90	6900	1050	800	75	170
Summary							1950

Taking into account, that on heating of airport it is needed almost 15 Gkal/h of power, that equivalently Q_{sum}=17,4 Mw. If Q_{sum} equivalent 100%, then using heat recovery of exhaust gases can absorb 1 % of the total power required for heating the airport, waste water - 3% and systems of air emissions - 7.4% .

Pry using complex heat recovery from the three sources mentioned above can be obtained about 10% of the total power Qsum needed to heat the entire airport.

Conclusions:

1. Price advance on fuel resources, increase of requirements to the problems of ecology, the problems of social character, related to the tariffs on power mediums, stipulate introduction of alternative technologies of production in the systems of energy supply of large industrial objects, including in air-ports .

2. There are gaseous, liquid matters - wastes of technological processes, the temperature of which is more high of ambient temperature belong to the second power resources. In airport we can get energy from possible second energy sources such as vent extrass; flow water; exhaust gases of the heat substation.

3. At the use of complex utilization of heat from the systems of ventilation, water- and heatsupply can be got about 10 % from total power of Qsum, necessary for heating of all airport

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DIAGNOSING OF CONTROLLED DYNAMIC SYSTEMS USING THE QUORUM-METHOD

The report discussed the possibility of applying the quorum-method in the diagnosis of dynamic control objects, mathematical models of whose are represented as the system of ordinary nonlinear differential equations. Offered method allows detecting refusals up to the channel, both in static and in transitional modes.

At technical operation of dynamic control objects with large dimension, mathematical models of whose are represented as the system of ordinary nonlinear differential equations, task of isolation disrepairs, which arise in these system, up to the channel, is of interest. This task, commonly referred the task of alarm-diagnosing, was considered in the [1] for the case of linear systems. If input vector dimension is strictly less than output vector dimension, then this task, consider as a special case of structural identification, can be solved using the apparatus of pseudoinverse operators in the complete absence of information above input signal [2], [3]. At the same time as pivotal parameters, characterizing a technical condition of control object, were selected parameters of system linear differential equations, which obtained by linearization of the original nonlinear model at points that correspond to static mode. This, in turn, leads to the fact that the linearized system of equations in the deviations is a system of ordinary differential equations with constant coefficients.

In general, the linearized system of equations in deviations to the original nonlinear model of control object, is unstationary, and has the form:

$$\frac{d\tilde{x}(t)}{dt} = \mathbf{A}(t)\,\tilde{x}(t) + \mathbf{B}(t)\,\tilde{u}(t), \tag{1}$$

where $\tilde{x}(t)$, $\tilde{u}(t)$ - vectors of dimension *n* and *m*, respectively, $m \le n$, $\mathbf{A}(t)$, $\mathbf{B}(t)$ - time-varying matrix, size $n \times n$ and $n \times m$, respectively.

The report examines one possible solution of the faults localization in the original nonlinear controlled dynamical system in the case, when system, that obtained by linearization, is not stationary, i.e. has the form (1). The task is solved both in static and dynamic modes based on the quorum-method.

Denote $\tilde{x}(t)$ - the reaction of the linearized system at the input disturbance $\tilde{u}(t)$, $t \ge t_0$. Then, for $t > t_0$

$$\tilde{x}(t) = \mathbf{\Phi}(t)\tilde{x}(t_0) + \mathbf{\Phi}(t)\int_{t_0}^{t} \mathbf{\Phi}^{-1}(\tau)\mathbf{B}(\tau)\tilde{u}(\tau)\,d\tau,$$

where $\mathbf{\Phi}(t)$ - fundamental matrix solution of the homogeneous system $\frac{dx(t)}{dt} = \mathbf{A}(t)\,x(t)$, that satisfy $\mathbf{\Phi}(t_0) = E$, E - identity matrix of size $n \times n$.

As $\tilde{u}(t)=0$ at $t \le t_0$, then $\tilde{x}(t_0) = 0$. Given this, denote

$$\mathbf{H}(t,t_0) = \mathbf{\Phi}(t)\int_{t_0}^{t} \mathbf{\Phi}^{-1}(\tau)\mathbf{B}(\tau)\,d\tau. \tag{2}$$

It is obvious that for each $t \ge t_0$ $\mathbf{H}(t,t_0)$ - it is the matrix, size $n \times m$, and $\mathbf{H}(t_0,t_0)=0$.

Let the static mode of the original nonlinear dynamical system correspond output signal $x_{st}(t)$ and input signal $u_{st}(t)$. At time t_0 act on $u_{st}(t)$ using small perturbation $\tilde{u}(t)$.

Denote $x(t)$ - reaction of diagnosed object on the perturbed control $u_{st}(t)+\tilde{u}(t)$ at $t>t_0$. Then the difference $\Delta x(t)=x(t)-x_{st}(t)$, will coincide with $\tilde{x}(t)$ at $t>t_0$, and will be zero at $t=t_0$, up to terms of higher order.

Under the refusal of *i*-channel in system means inequality $\Delta x_i(t)\neq\tilde{x}_i(t)$ at a certain time interval $t>t_0$. Inequality, as well as equality is understood to within infinitesimals of higher order. At heuristic assumption about the impossibility of the simultaneous failure of two or more channels of the system, necessary to establish a failure in the system, if any, and also specify a channel containing the failure.

At time $t=t_0$ will indignant *j*-coordinate of the vector control $u_{st}(t)$ onto a small jump λ_j, $j=\overline{1,m}$, without disrupting the normal functioning of the object diagnostics, i.e. let

$$\tilde{u}^j(t)=\lambda_j\left(0,...,1(t),...,0\right)^T.$$

Considering (2), will obtained the response of the linearized system (1) to a perturbation $\tilde{u}^j(t)$ in the form of:

$$\tilde{x}^j(t)=\lambda_j\left(h_{1j}(t,t_0),h_{2j}(t,t_0),...,h_{nj}(t,t_0)\right)^T,\ j=\overline{1,m},\ t>t_0,$$

and, consequently, with accuracy up to infinitesimals of higher order

$$\Delta x^j(t)=\lambda_j\left(h_{1j}(t,t_0),h_{2j}(t,t_0),...,h_{nj}(t,t_0)\right)^T,\ \text{at } t>t_0. \tag{3}$$

Equation (3), is a condition of collinear between vector $\Delta x^j(t)$ and vector, which coincides with the j-th column of matrix $\mathbf{H}(t,t_0)$, so we can write the following system of equations

$$\frac{h_{1j}(t,t_0)-\Delta x_1^j(t)}{h_{1j}(t,t_0)}=\frac{h_{2j}(t,t_0)-\Delta x_2^j(t)}{h_{2j}(t,t_0)}=...=\frac{h_{nj}(t,t_0)-\Delta x_n^j(t)}{h_{nj}(t,t_0)}\ \text{at } t>t_0.$$

Denote

$$\Delta_i^j(t,t_0)=\frac{h_{ij}(t,t_0)-\Delta x_i^j(t)}{h_{ij}(t,t_0)},\ i=\overline{1,n}. \tag{4}$$

Following the idea of the quorum-method [4], $\overline{\Delta^j}$ represents the average value Δ_i^j. For averaging the values Δ^j can be used schemes of quorum-element, which are presented in Fig. 1.

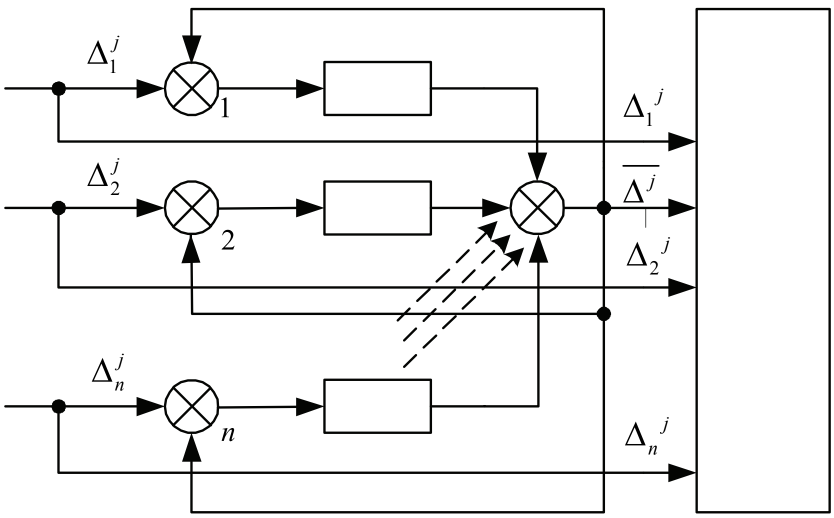

Fig.1. Scheme of quorum-element

Input values of each adders 1, 2, ..., n are values Δ_i^j, $i=\overline{1,n}$, that obtained by (4), and the result of averaging $\overline{\Delta^j}$, that obtained at the output of the adder S. Output values of each adders 1, 2, ..., n

are values of the difference $\varepsilon_i^j = \Delta_i^j - \overline{\Delta^j}$. This difference is amplified by amplifier (Gain). The considered scheme provides on output averaged value Δ^j .

As follows from the scheme (fig.1) at equal values of gain K

$$\overline{\Delta^j} = K\sum_{i=1}^{n} \varepsilon_i^j .$$

Since, $\varepsilon_i^j = \Delta_i^j - \overline{\Delta^j}$, then

$$\overline{\Delta^j} = K\sum_{i=1}^{n} (\Delta_i^j - \overline{\Delta^j}) = K\sum_{i=1}^{n} \Delta_i^j - Kn\overline{\Delta^j} \text{ , or } \overline{\Delta^j} + Kn\overline{\Delta^j} = K\sum_{i=1}^{n} \Delta_i^j .$$

From hear

$$\overline{\Delta^j} = \frac{K}{1+Kn}\sum_{i=1}^{n} \Delta_i^j .$$

With large gain ($K >> 1$)

$$\overline{\Delta^j} = \frac{1}{n}\sum_{i=1}^{n} \Delta_i^j .$$

Each Δ_i^j compared with $\overline{\Delta^j}$ in special scheme of comparison.

If object in operative condition all values $\varepsilon_i^j = \Delta_i^j - \overline{\Delta^j}$ are within the limits of admittances. Failure at some coordinates of object state vector $x(t)$ causes the excess of allowable values of the difference $\Delta_i^j - \overline{\Delta^j}$ and the result of comparison is used to indicate the presence of failure on the coordinate (channel). The block-scheme that implements the algorithm for finding faulty channel, is shown on Fig. 2.

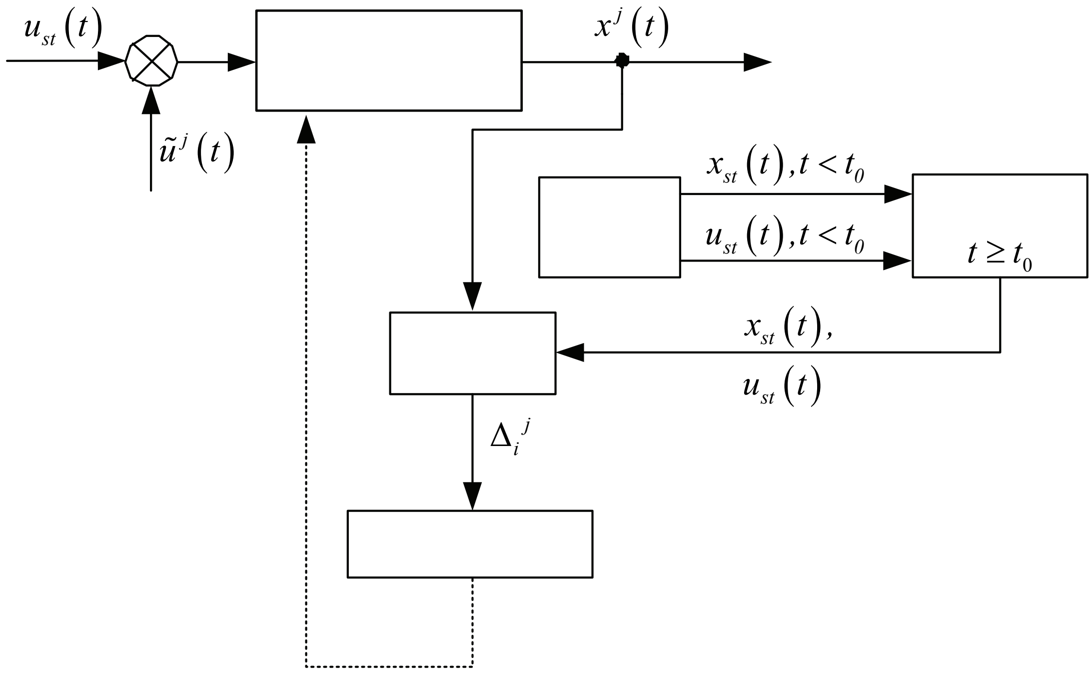

Fig. 2. Block-scheme of diagnosis, using quorum-element

In accordance with the scheme, perturbing test signal $\tilde{u}^j(t)$ at a time $t = t_0$ is fed to the adder, after which the total action of control $u_{st}(t) + \tilde{u}^j(t)$ is applied to the object.

The appointment of extrapolator it is extrapolation of values $x_{st}(t)$, $u_{st}(t)$ to the interval $(t_0, t_0 + T_j)$, T_j - duration of the test perturbation $\tilde{u}^j(t)$, using values $x_{st}(t)$, $u_{st}(t)$, at $t < t_0$, that obtained from the database.

At values $x_{st}(t)$ and $u_{st}(t)$ calculator determines the elements of the matrix $\mathbf{H}(t)$ on the interval $(t_0, t_0 + T_j)$, values of vector $\Delta x^j(t)$ coordinates on the same interval and coordinates of vector $\Delta^j = (\Delta_1^j, \Delta_2^j, \dots, \Delta_n^j)$, that must be compare.

Conclusions.

1) The report shows that the quorum-method can solve the problem of fault isolation in dynamic systems in a more general case, compared with the method based on the pseudoinverse operators. This is an obvious consequence of using test perturbation action of control.

2) In cases, where linearized system of equations in deviations is stationary, to determine channel containing the refusal, can be used as a method based on pseudoinverse operators, and the quorum-method. The use of the quorum-method allows localizing not only line in the matrix of transfer functions $\mathbf{W}(p)$, which must be subjected to correction, but the element (multiple elements) in this line.

3) After detection of the element in the matrix of transfer functions $\mathbf{W}(p)$, that does not correspond to the current technical condition of diagnosis object, new values the parameters of this transfer function can be determine by one of the known methods of identification, such as the method of learning model [5].

4) To obtain an estimate of trend for each coordinate vector of determin parameters, characterized the trend prevailing at the time of the last correction parameters of the transfer functions matrix $\mathbf{W}(p)$, as well as to account for constantly updated information, based on the system of continuous monitoring and using a quorum-element can be constructed an adaptive prediction model (coarse and accurate) that can respond quickly to changing the technical state of the object control [3], [6].

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MODERN DIRECTIONS OF QUANTUM CRYPTOGRAPHY

Systematization and classification of modern directions of quantum cryptography from the viewpoint of used quantum technologies are carried out. The qualitative analysis of advantages and disadvantages of various quantum protocols is made. The status of a problem of practical quantum cryptography using in telecommunication networks is considered.

Today there is virtually no area where Information Technology (IT) is not used in any way. Computers are serving for banking systems support, controlling work of nuclear reactors, controlling aircrafts, satellites and spacecrafts. Therefore, high level of automation depends on the security level of IT.

One of the most effective facility of ensuring confidentiality and data integrity during transmission is cryptographic systems. The purpose of such systems is to provide key distribution, authentication, legitimate users authorization and encryption. Key distribution is one of the most important problems of cryptography. This problem can be solved by means of [1]: Classical Information-Theoretic Schemes (requires channel with noise, efficiency is very low – 1-5%), Classical Public-key Cryptography Schemes (Diffie-Hellman scheme, digital envelope scheme; it has computationally security), Classical Computationally Secure Symmetric-key Cryptographic Schemes (requires the pre-installed key on both sides and can be used only as scheme of increase in key size but not as key distribution scheme), Quantum Key Distribution (provides information-theoretic security; it can also be used as a scheme of increase in key length), Trusted Couriers Key Distribution (it has high price and dependency from human factor).

In recent years, considerable interest belongs to Quantum Cryptography (QC). Quantum Key Distribution (QKD) [1, 2] plays a dominant role in QC. The overwhelming majority of theoretic and practical researches in QC are related with development of QKD protocols. Number of different Quantum Technologies of Information Security (QTIS) increases but there is no information about classification of these technologies in scientific literature (there are only a few works concerning classification of QKD protocols, for example [2, 3]). It makes difficult to estimate level of latest achievements and does not allow using QTIS with full efficiency. *The purpose of this article* is systematization and classification of up-to-date quantum technologies of data security.

Fig. 1 represents general scheme of quantum methods of information security (IS) for their purposes and for using QTIS.

QKD includes the following protocols: protocols using single (non-entangled) qubits (two-level quantum systems) and qudits (d-level quantum systems, d>2); protocols using phase coding; protocols using entangled states [1, 2].

The main task of QKD protocols is encryption key generation and distribution between two users connecting via quantum and classical channels [1, 2]. In 1984 Ch. Bennet from IBM and G. Brassard from Montreal University introduced first QKD protocol, which should has became alternative solution for the problem of key distribution. This protocol is called BB84 and it refers to QKD protocols using single qubits. States of these qubits are the polarization states of single photons. In the QKD protocols error searching and correcting is performed using classical public channel, which should not be confidential but only authenticated. For the detection of eavesdropper actions an error control procedure is used and for providing of information-theoretic security a privacy amplification procedure is used [1–3].

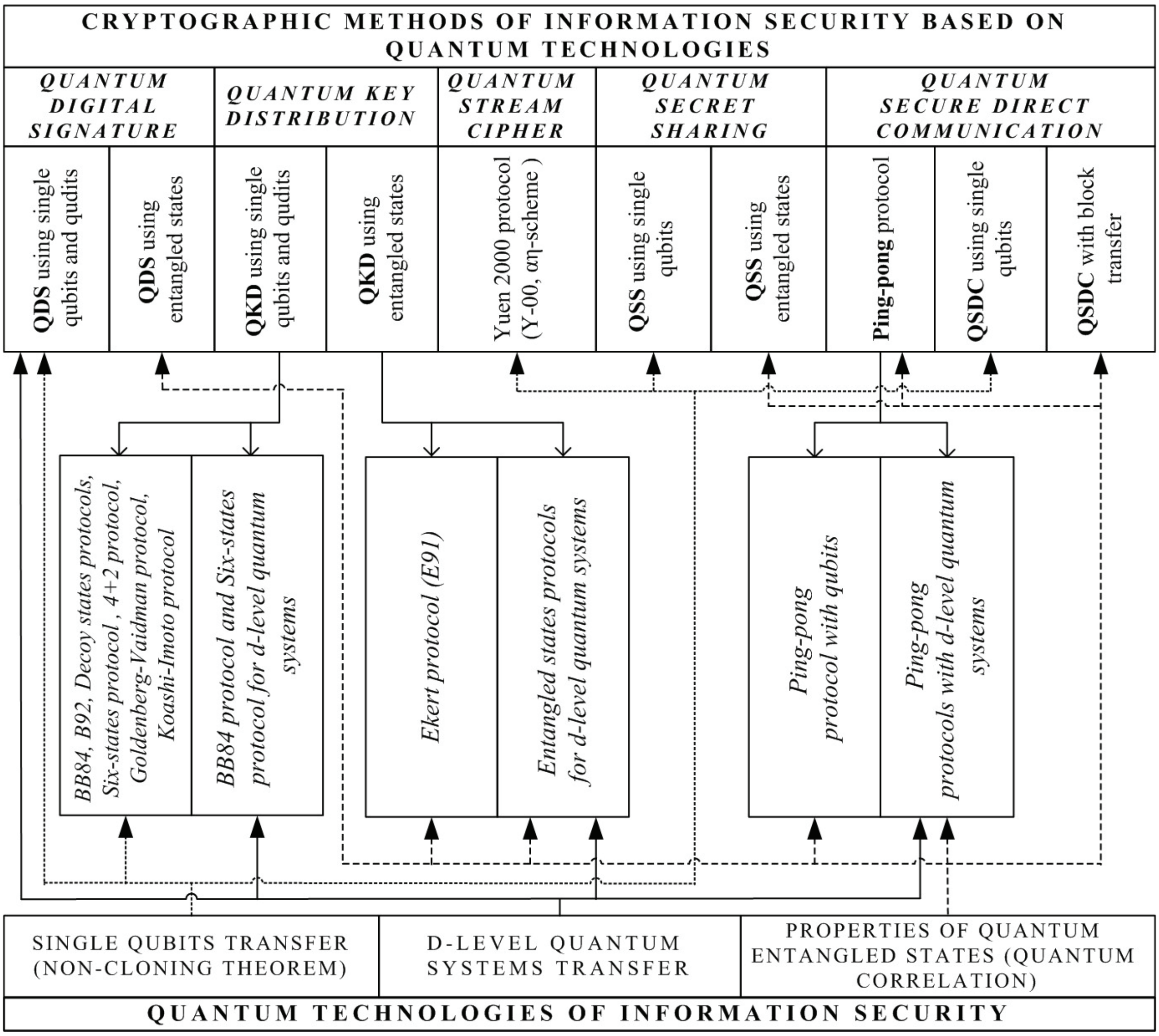

Fig. 1. Classification of quantum methods of IS

QKD protocols possess following advantages: 1) These protocols allow always detect eavesdropping because Eve's connection brings much more error level (compared with nature error level) to quantum channel. Quantum mechanics' laws allow not only detect eavesdropping but also set dependence between error level and intercepted information. This allows applying privacy amplification procedure, which decreases the quantity of information about the key that can be intercepted by Eve. Thus, QKD protocols have unconditional (information-theoretic) security; 2) Information-theoretic security of QKD allows using absolute secret key for the further encryption using well-known classical symmetrical algorithms. Thus, entire information security level increases. In addition, it is possible to synthesize QKD protocols with Vernam cipher (one-time pad), which in complex with unconditionally secured authenticated schemes gives totally secured system for information transferring.

The disadvantages of quantum key distribution protocols are: 1) System based only on QKD protocols cannot serve as a complete solution for key distribution in open networks (additional tools for authentication are needed); 2) Limitation of quantum channel length which is caused that there is no possibility of amplification without quantum properties losing; 3) Need of usage weak coherent pulses instead single photon pulses. This decreases efficiency of protocol in practice. But this technology limitation might be defeated in nearest future; 4) Data transfer rate decreases rapidly with increasing of channel length. For channel length is 100 km data transfer rate equals few bps; 5) Photon registration problem, which leads to key rate decreasing in practice; 6) Photon depolarization in quantum channel. It leads to errors during data transfer. Now typical error level equals few percents what is much greater than error level in classical communication systems; 7) Difficulty of practical realization of QKD protocols for *d*-level quantum systems; 8) High price of commercial QKD systems.

Quantum Secure Direct Communication (QSDC) protocols [4–6]. Main feature of QSDC protocols is that there are no cryptographic transformations, thus there is no key distribution problem in QSDC. In these protocols a secret message is directly coded by qubits' (qudits') quantum states, which are sent via quantum channel. QSDC protocols can be subdivided into several types: ping-pong protocol (and its enhanced variants), protocols using block transfer of entangled qubits, protocols using single qubits and protocols using entangled qudits. There are QSDC protocols for two parties and for multi-parties, e.g. broadcasting, or when one user is sending message to other under the control of trusted third party.

Advantages of QSDC protocols are: a lack in secret key distribution; the possibility of data transfer between more than two parties; the possibility of attack detection providing a high level of IS (up to information-theoretic security) for the protocols using blocks transfer. Main disadvantages are: difficulty in practical realization of protocols using entangled states (and especially protocols using entangled states for *d*-level quantum systems); slow transfer rate; need for large capacity quantum memory for all parties (for protocols using block transfer of qubits); asymptotic security of the ping-pong protocol. However, asymptotic security of the ping-pong protocol (which is one of the simplest QSDC protocol from the technical viewpoint) can be amplified by using methods of classical cryptography. Besides, QSDC protocols similarly to QKD protocols is vulnerable to man-in-the-middle attack, although such attack can be neutralized by using authentication of all messages, which are sending via the classical channel.

Quantum secret sharing (QSS). Most of the QSS protocols use properties of entangled states. The first QSS protocol has been proposed by Hillery, Buzek and Berthiaume in 1998 [7]. The sender shares his message between two (three) parties and only cooperation allows them to read this message. Semi-quantum secret sharing protocol has been proposed in [8]. Similar protocol for multiparty secret sharing has been presented in [9]. QSS protocols are protected against external attackers and unfair actions of protocol's parties. Both quantum and semi-quantum schemes allow detecting eavesdropping and do not require encryption unlike the classical secret sharing schemes. The most significant imperfection of QSS protocols is a necessity for large quantum memory that is outside the capabilities of modern technologies today.

Quantum digital signature (QDS) can be implemented on the basis of such protocols as QDS protocols using single qubits and QDS protocols using entangled states. QDS is based on use of quantum one-way function. This function has better security compared with classical one-way function and it has information-theoretic security. QDS protocols' main advantages are information-theoretic security and simplified key distribution system. The main disadvantage is the possibility to generate limited number of public key copies and the leak of some quantities of information about incoming data of quantum one-way function (unlike the ideal classical one-way function).

The world's first commercial quantum cryptography solution was QPN Security Gateway (QPN-8505) [10] proposed by MagiQ Technologies (USA). This system is cost-effective IS solution for government and financial organizations. It proposed VPN protection using QKD (up to 100 256-bits keys per second, up to 140 km) and integrated encryption. QPN-8505 system uses BB84, 3DES and AES protocols. Swiss company Id Quantique offers the system called Cerberis [11]. It is a server with automatic creation and secret keys exchange over a fiber channel (FC-1G, FC-2G and FC-4G). This system can transmit cryptographic keys up to 50 km and carries out 12 parallel cryptographic calculations. The last substantially improves system's performance. Cerberis system uses AES (256-bits) for encryption and BB84 or SARG04 protocols for quantum key distribution. Recently Toshiba Research Europe Ltd (Great Britain) presented another QKD system named Quantum Key Server [12]. This system has a very simple architecture and provides the generation up to 100 256-bits keys per second with their one-way transferring from sender to receiver. Quantum Key Server includes an integrated automatic control module that provides continuous monitoring of the system's optical characteristics and their regulation. Another British company QinetiQ realized the world's first network using quantum cryptography – Quantum Net (Qnet). The maximum length of communication lines in this network is 120 km. Moreover, it is a very important fact that Qnet is the first QKD system using more than 2 servers. This system has 6 servers integrated to Internet.

Conclusions. Today the most developed direction of quantum cryptography is QKD. In research institutes, laboratories and centers quantum cryptographic systems for secret key distribution are developed. Most of the technologies used in these systems are patented in different countries (mainly in USA). Such QKD systems can be combined with any classical cryptographic scheme that provides information-theoretic security and whole cryptographic scheme will have information-theoretic security also. Generally, QKD protocols can provide higher IS level than appropriate classical schemes.

Currently other directions of quantum cryptography in practice are not extended beyond the laboratory experiments. However, there are many theoretical cryptographic schemes that provide high IS level up to the information-theoretic security.

Thus, in recent years quantum cryptography rapidly develops and gradually takes the place among other IS means. Its advantage is high security level and some properties which classical IS means do not have. One of these properties is ability always to detect eavesdropping. Therefore, quantum cryptography represents the important step to improvement security of communication systems against cyber-terrorist attacks. Nevertheless, many theoretical and practical problems must be solved for practical using of quantum cryptography methods in existing communication systems.

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RISK MANAGEMENT ENHANCES SAFETY PROGRAMME DECISION-MAKING

Regulator's adoption of a model for managing its safety programme evolved out of the recognition that aviation safety is to be considered as a state of system which can be analyzed and controlled on the risk assessment

Adoption of a risk assessment model is an effective way to deliver and manage a civil aviation programme, because it applies equally to safety as to other broader management issues.

The risk assessment model and matrix introduced recently by the ICAO decision will help the organization make better decisions in an environment that is forever beleaguered by competing demands for limited resources.

While regulatory authorities may find the risk assessment model approach worthy of closer examination, aviation companies may do it as well, because risk management is an integral part of a safety management system (SMS). The tactics and strategies used to mitigate risk may be different, but the processes used to arrive at such tactics and strategies are the same.

Although the focus of this article is on aviation safety, the risk model has broad applicability: it can apply to security or environmental topics, and can also apply to other models of transport or management issues.

The adoption of the risk assessment model that is described below evolved out of recognition that safety is an absolute condition, but rather one where risks are managed to acceptable levels.

Safety defined

Although World Aviation Community has long emphasized the paramount importance of safety, the word "safety" is not yet defined in aviation legislation or departmental policy documents in many countries. The dictionary is equally unhelpful in this regard. The Concise Oxford Dictionary defines safety as: "freedom from danger or risk; being sure or likely to ring no danger; being safe" (1). The dictionary describes an absolute condition while few, if any, situations are completely free from danger or risk. Like all human enterprises, aviation is fraught with risk.

The absence of an operational definition of safety has been problematic for civil aviation. It is susceptible to wide, subjective interpretation, which can lead to conflicting priorities and the consequent allocation of resources to lesser issues; it hinders consistency in the delivery of regulatory programmes and quantitative performance measurement.

Simply put, in the absence of a formal, operational definition of safety, the dictionary's version cannot apply in an aviation context, or any other low-probability, high-consequence industry for that matter. Perhaps it was in a similar light that William W. Lowrance defined safety as "a judgement of the acceptability of risk, and risk, in turn, as a measure of the probability and severity of harm to human health." He summarizes by stating that "a thing is safe if its risks are judged to be acceptable" (2).

For the reasons stated above a working definition of safety is provided as "the condition where risks are managed to acceptable levels."

Having defined safety in terms of risk, the ICAO refined its mission statement, which aligns with the larger departmental mission as follows: to develop and administer policies and regulations for the safest civil aviation, using a system approach to managing risks.

That safety is the condition where risks are managed to acceptable levels is not new. It has been implied in the aviation industry for many years. However, the wider, explicit use of this definition is a relatively recent phenomenon. Defining safety in context and expressing the mission in terms of risk helps clarify the regulator's role and limitations. This new mission statement provides clarity of purpose: not only does it spell out the ICAO goal, but it also states how and for whom the organization is delivering its programme.

All parties involved in delivering on the mission must be able to see the whole, understand how things should work, and, more importantly, how they contribute to value creation. The risk model or pattern was developed to articulate and illustrate how this works.

Some may argue that, as a government entity, any CAA does not need a risk assessment model; it is not a business, as it is not involved in value creation. But the public values safety. Both the public and consumers of aviation services in particular look to the CAA to act as their safety advocate, ready to intervene in the sector as necessary to ensure appropriate measures are taken to manage aviation risks.

A risk assessment model incorporates all critical activities needed to deliver the safe operation. To deliver on its new mission and focus its interventions where they can have the most impact despite increasingly limited resources, the CAA has to adopt a risk assessment model that governs all activities and processes in the delivery and management of its oversight programme.

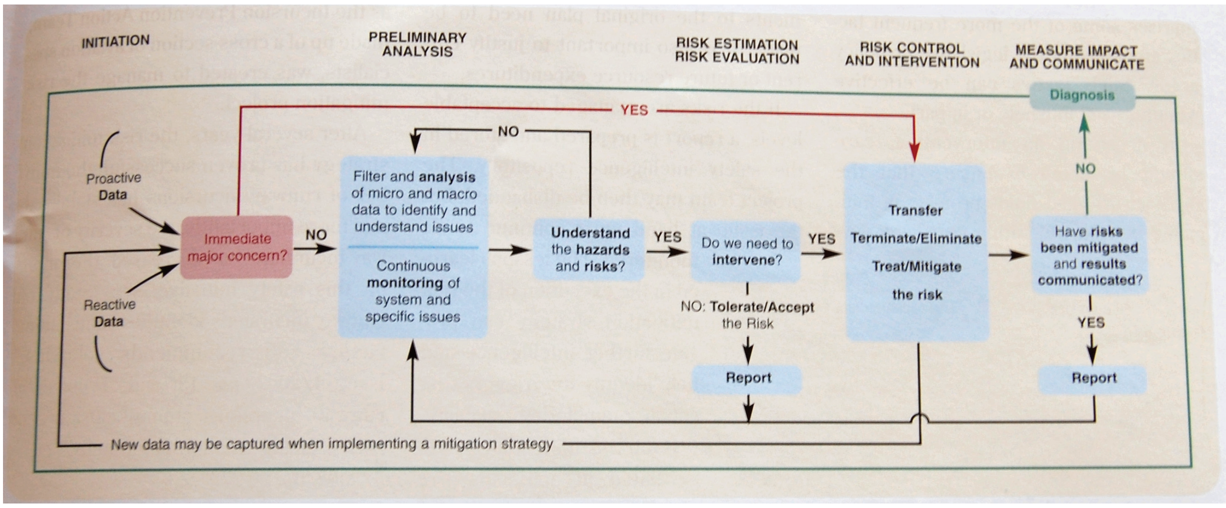

Figure 1. Risk assessment model used as a means of managing safety through risk management

As shown in *Figure 1*, this risk assessment model incorporates five phases: initiation, preliminary analysis, risk estimation and risk evaluation, risk control and evaluation, and impact measurement and communication.

Initiation and preliminary analysis. Except for those circumstances requiring the immediate tactical intervention on the part of the regulator to stop a situation that poses an immediate threat to aviation safety or respond to an accident or significant incident, the application of this model requires, first and foremost, the acquisition of safety intelligence, so called safety thinking, before making any decisions.

Safety intelligence is simply the data that are analysed to produce information necessary to understand the risk. When visualized as a pyramid, safety intelligence incorporates data at the bottom layer of the pyramid, from which information, knowledge and wisdom are derived in hierarchical fashion. Through an analytical process these data are transformed into information; the synthesis of this information leads to knowledge, and over time this body of knowledge becomes the accepted wisdom.

Data collection includes both reactive data obtained from occurrences, plus proactive data that may originate from hazard reports. These data are analysed to derive meaningful information from which decisions about risk can be made.

Ideally, risk analysis should address all dimensions that could lead to an individual, organizational or systemic accident. These accident dimensions can be broadly categorized as active failures and latent conditions. Regulators must take the broadest view and assume that latent conditions affecting individual behaviour, workplace conditions and organizational factors transcend the boundaries of a particular aviation company and encompass the legislative, socio-economic and political dimensions.

Safety culture must also be considered in the analysis since professional, organizational, industry and national cultures may influence the decisions, behaviour and actions of the players involved. A concept of accident causation includes organization, workplace, people, and defenses. The organizational processes are to improve workplace conditions and identify latent conditions.

The Safety Management System (SMS) approach (3) is being implemented to encourage the proactive management of conditions that could lead to accidents. These dimensions can be applied to normal working situations, hazards, incidents and accidents. By analyzing data from each dimension, the output is safety intelligence regarding the actual or emerging hazard expressed in terms of risk, specifically its probability, severity and the degree of exposure.

Risk estimation and risk evaluation. Once the hazard – both the likelihood of its manifestation and its severity – is understood, the question is then asked: "Are the risks associated with the hazard tolerable or acceptable?" If the answer is affirmative, the risks are considered acceptable and no intervention is required. However, the organization enhances monitoring and contributes to continuous learning by producing a report and storing this in a safety intelligence repository for future use. If the answer is negative, the risks are deemed not acceptable, and the follow-on question becomes: "How do we intervene to bring the hazardous conditions into the range of acceptability?" In exploring possible solutions, the dimension of cost-benefit is examined in the context of risk mitigation. The purpose is to establish whether the benefits of any proposed risk mitigation strategy offset the costs of its implementation.

Risk control and intervention. Generally, there are three strategies for managing risk: eliminate the hazardous condition, mitigate the risks, or transfer the risk by, for example, requiring carriage or liability insurance. In terms of mitigation, regulators can design and execute intervention strategies that address one or more components of the risk equation, in particular the probability, severity or amount of exposure associated with the risk.

Typically, aviation authorities can avail themselves of legislative or policy means to develop a strategy that can be used to varying degrees to mitigate the risks.

In designing an intervention, care should be taken to ensure that the approach adopted holds promise of mitigating the risks to within acceptable levels, meaning that the outputs, intermediate and ultimate outcomes must be observable and measureable. In addition, the strategy must be commensurate to the level of risk in terms of its cost-benefit.

Legislative	Policy
Rule-making The making, amending or repealing of: • Laws • Regulations • Standards The issuance/withdrawal of orders, exemptions, decrees or other items	**Promotion and Education** • Conferences, symposia, colloquiums • Newsletters, journals, papers • Briefings • Multi-media safety products

Regulatory Oversight	Strategic Investments/Divestiture
• Educating for compliance • Monitoring • Inspection • Audits • Enforcement	• Privatize • Commercialize • Nationalize • Subsidize
Authorizations (certification) The issuance, or withholding the issuance, or certificates, licences, permits, or other authorizing documents	**Strategic Leverage** • Public/Private Partnerships • Industry empowerment

Figure 2. Regular risk mitigation strategies fall under legislative or policy areas

The implementation of the risk mitigation strategy should be managed as a project with a team and a project plan that includes project accountability, timelines, resources and performance measures.

Aviation companies have a great many of strategies as their disposal to mitigate risk as well. These include engineered systems; organizational, procedural, and behavioural fixes, such as training and education; and\or personal protection from hazards. Safety would, however, encourage aviation companies to not rely solely on one strategy, but rather, as espoused by James Reason (4), a combination of strategies that achieve defences in depth.

Measure impact and communicate. After a time, the results of the risk mitigation strategy should be ascertained. This is done to determine whether the planned interventions are achieving the desired results and whether any adjustments to the original plan need to be made. It is also important to justify current or future resource expenditures.

If the risks are managed to acceptable levels, a report is prepared and stored in the safety intelligence repository, but the issue at hand must continue to be monitored. The lessons learned in the execution of the risk mitigation strategy can provide further intelligence and help identify the triggers that enhance monitoring capability.

If the risk mitigation strategy failed in achieving the desired results, this leads to a diagnostic exercise to discover where in the application of the risk assessment model the failure occurred. The answer may lie in the design or execution of the mitigation strategy, the decision-making process (i.e. the misapplication or inappropriateness of risk criteria), or the analysis or data-capturing phases.

Regardless of the outcome, an assessment of what worked, how well it worked, and what did not work, should be carried out – if for no other reason than to learn from each experience and improve the processes of the risk assessment model itself.

Challenges and benefits. The operational definition of safety and the risk assessment model it calls for do raise several broad questions. What are the risks inherent in aviation? Who is at risk? And, if the risks are to be managed to acceptable levels, what level of risk is acceptable to those at risk?

Answering questions such as these is not easy, but CA regulators are to be prepared to meet this challenge. Out of necessity, each CAA will perform the required calculations to arrive at a benchmark level of risk or risk profile from which it can establish goals, design and execute appropriate mitigation strategies, and measure and report on the results.

The rigorous application of the risk assessment model will enable CAA to target its interventions where they can have the most impact for the safety of consumers of aviation services.

It will enable better and more empirical performance measurement, allowing air travelers to connect these actions with visible outcomes.

The safety of the global air transport system should be considerably enhanced in coming years. The ICAO High-level Safety Conference in March 2010 produced some important recommendations which will enhance the collective ability to increase the level of aviation safety around the world. The recommendations are based on meeting the three key targets of ICAO's Global Aviation Safety Plan (GASP).

The first target calls for a reduction in the number of fatal accidents and related fatalities worldwide, irrespective of the volume of air traffic.

The second objective is a significant reduction in global accident rates. The concern here is that, while accident rates are low, they remain disturbingly unchanged. Future rate reductions are essential as the air transport system continues to grow.

The third safety-related target addresses the disparity in accident rates among ICAO's Regions and the fact that no one Region is supposed to have an accident rate exceeding twice the global average. This goal has not yet been reached as the true variances between Regional rates, and one in particular, still remain unacceptably high.

The fourth expectation was agreement on the development of a global organizational framework to protect the providers of sensitive safety data used for future information sharing initiatives. Without this protective framework, essential information will remain unavailable to ICAO and other organizations involved in the increasingly proactive analysis and resolution of global safety issues.

Finally, the fifth recommendation was for the creation of a new Annex dedicated to Safety. A dedicated Safety Management Annex would not only reaffirm that safety is ICAO's primary focus, it would provide the clarity required to assist in the further implementation of Standards related to State Safety Programmes and Safety Management Systems. A new Annex would also facilitate a coordinated approach for the promulgation of the practices necessary will assure the highest levels of safety throughout the international aviation system.

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THE RESEARCH OF RADIOBUGS SEARCHING

The article opens up main point of the improved method of searching for bugs. Described a device for measuring of distance by a sound which determines distance to the source of intercept of linguistic signal and show a distance to the bug.

Swift development of the modern systems of information loss puts under a threat plenty of state and private enterprises and considerably increases authenticity and possibility of unauthorized access to important information. There is a great number of methods of confidentiality violation from any organization and removal of important information by the technical information loss channels. The high level of risks also touches a state aviation and is one of major factors, that influences on its readiness to implementation of tasks on setting and such which can make the threat of providing of national safety.

One of the most widespread technical methods which are used for the unauthorized receipt of information are different electronic devices of information interception or so-called radiobugs (RB), which use a radio channel as environment of dangerous signals transmission. A basic place of their application is internal apartments of objects and establishments of both the state setting and business corporations. An exposure and exception of these devices is a separate and very difficult task in the system of measures for security information [1].

The most effective method of counteraction to the radiotechnical channel of loss, and also radiomonitoring listening devices is using program-controlling complexes or other monitoring devices.

Great part of technical channels of loss information can be organized for the intercept of linguistic information which is a difficult acoustic signal that determined in the range of frequencies from 300 Hertzs to 3,5 kHertzs [2]. For the intercept of acoustic signals on the air channel of loss information acoustic radiobugs can be used. These devices upgrade every time, becoming less and more unnoticeable, and methods of their search are more difficult [3].

During a patent search discovered that also existed plenty of the patented methods of distance determination, exposure of extraneous facilities of "undesirable" signals radiation, methods and systems of purpose surveillance, optical radiolocation built on and built on automatic exposure of signals.

Determination of radiobugs location can be executed by sight, and also using special devices: video cameras and dictaphones detectors, field indicators, radiofrequency measuring instrument and inceptorsi, scanner transceivers and spectrum analyzers, program-control complexes, nonlinear radars, x-ray complexes, ordinary testers, and also the special equipment for verification of telephone lines, etc [4].

The RB searching can be executed in a few stages. The first is verification of the investigated apartment for the existing radiowaves using radiomonitoring, that will define presence of RB in it. The second stage is a selection for the most effective methods of present listening devices localization. On this stage the various methods of RB localization can be used, but lets consider possibility for their search using acoustic location [5].

The use of acoustic location is widely known for determination of objects and distance to them in medicine, hydrolocation and others like that, but to the authors unknown literature where acoustic location was used for the RB search [6].

As an acoustic signal operates directly on the microphone of RB, then the search of listening devices can be determined on time of delay of acoustic signal, id est to time proportionally represented in distance.

Essence of method of acoustic location consists in that distance to the object is fixed on time-of-flight of signal to the object. If the known speed and time of distribution of acoustic signal, then it is possible to define distance to the object. For the search of RB the same principle is used, using test acoustic impulsive signal.

The structural scheme of radiobug searching installation presented on figure 1.

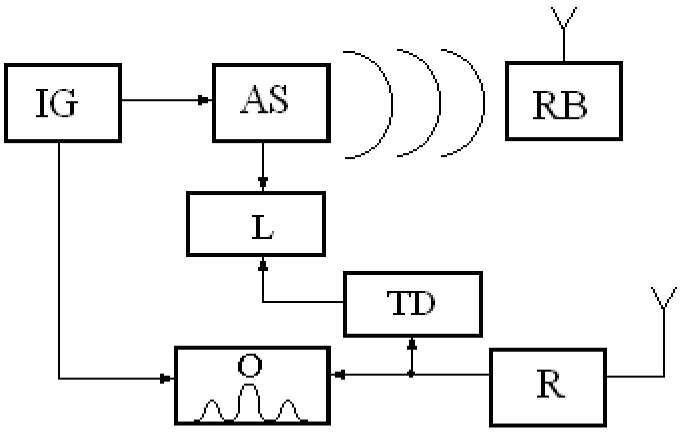

Fig. 1. The structural scheme of radiobug searching installation

Impulse generator (IG) generates an impulse signal which is given on the acoustic system (AS). In the moment of beginning of impulse from IG on the entrance of "x" oscillograph (O) the signal of synchronization is given. An AS radiates the impulse of sound in all directions.

In a case if RB is present in the apartment, an acoustic signal will act to it with a certain delay. Farther an acoustic signal with the help of RB will grow into an informative electromagnetic signal and will ray in ether. Receiver (R), which is set to the frequency of RB radiation will take electromagnetic information signal. Electromagnetic signal through detector of receiver will turn into a pulse signal and supplied to input "y" of O.

In this case on the screen of O there will be an impulse with a delay from the beginning of involute. Delay on the screen of O will consist of delay at widespread acoustic signal from AS to RB and distribution of radio signal from RB to the R. As time of distribution of electromagnetic waves on ether is small, both basic time of delay will be the same as time of distribution of acoustic signal. If time of delay to increase on speed of acoustic wave we will get the distance from the acoustic system to RB.

If we move AS in other point of apartment we can experimentally define distance to RB. Conducting the experimental measuring of distance to RB from different points, we can find the location of RB. The scheme of RB location presented on figure 2.

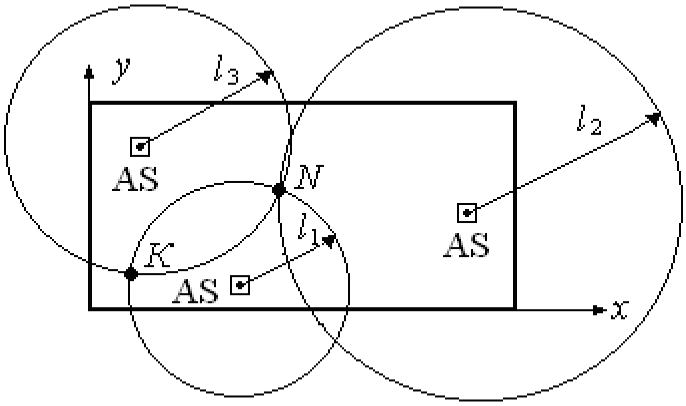

Fig. 2. The scheme t of radiobug location

Getting the value of time-delay of acoustic signal from the different points of apartment, the co-ordinates of which will set in accordance with the co-ordinates of apartment, it is possible to define the radiuses of circles, which appear as a result of action of sources of acoustic signals in a certain point. For this purpose will apply the ordinary formula for determination of delay duration of acoustic signal distribution using known size - speed of sound which is evened V_{sound} = 340 m/sec:

$$\tau = \frac{\ell}{V_{sound}} \quad (1)$$

where ℓ – distance from AS to RB.

Where the radius of distribution of acoustic wave will be determined from, as

$$\ell = \tau \cdot V_{sound} \quad (2)$$

Lets lay down the plan of apartment in a scale and designate the places of location of the acoustic systems (Fig. 2). Choose any three points in an apartment, to eliminate the vagueness of RB location in the K point. Using formula (2) will expect distances from AS to RB, which will equal the radiuses of circles with a center in the point of location AS.

$$\begin{aligned} \ell_1 &= \tau_1 \cdot V_{sound} \\ \ell_2 &= \tau_2 \cdot V_{sound} \\ \ell_3 &= \tau_3 \cdot V_{sound} \end{aligned} \quad (3)$$

The RB location will be determined the by the point of N of crossing of the got circles. In the center of AS is a laser (L), as shown on figure 2. Electrical or radio wave signal admitted by R comes to the threshold device (TD). If the signal overshoots the laser is turning on. TD activated only after the coincidence impulse in all three acoustic radiators.

There is an enormous amount of RB disguise methods of under the things of everyday consumption and structural implementation, which complicates their search considerably, but an in any case listening device contains a pickoff, which will react on the action of test acoustic signals.

For the increase of exactness of RB localization it must set a voice dynamics in different planes and determine its location by the volume (three-dimensional) chart of apartment.

The error of measuring of distance to RB will be determined by the form of test impulse (by the steepness of front) and principle of construction (functioning) of comparison block. To improve the accuracy of measurement used pulses with a complex type of modulation (for example, with linear frequency modulation), and special devices on their treatment, providing pressing after their treatment. The error of measuring using modern devices for realization of acoustic location method folds a 10…20 sm.

If it is impossible to find listening devices directly in the investigated apartment, to continue this method of acoustic location it is possible without no vibrations (on condition that walls and partitions between walls are not equipped by the special deafening and those which do not skip radiowaves). In fact, in case of RB location in other apartment, the intersection of concentric circles will be represented out of the investigated apartment. Exact place of RB location will not be represented, but direction in which the source of radiowaves is defining is possible.

In every concrete case methodology of determination of RB location changes (that is basic in experimental researches), but technology and principles of the research method unchanging for each of them and in any case gives a desirable result and put aim.

Conclusions. Introduction of this method of RB search in practice will assist independent (unassisted the special big devices) determination of extraneous radiowaves presence and determination of their sources location for secure of private and confidential information that circulate in an apartment.

This method is expedient for defense of linguistic information and conceptually new among already existing, that first of all underlines actuality of his application in the decision of important problems of modern sphere of informative safety.

The described methodology of RB localization belongs to principles of searching technique work, which is used in the systems of information security and can be used for measuring of distance to the RB and to specify his place of location.

Experience of the use of existent devices of searching technique testifies that only this method owns necessary function of determination of concrete point of place RB, what is considerably facilitates procedure of such unnecessary bugs' localization.

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FORMATION OF THE OBJECTIVE FUNCTION IN THE TASKS OF INFORMATION SECURITY MANAGEMENT

The model of search for the optimal defense resource allocation is presented and objective function that minimizes the information loss is chosen. The choice of parameters and dependencies that form the objective function is justified. Estimates of optimal resource allocation are represented. It is conducted sensitivity analysis of mathematical models to components of the objective function.

The main task of information security management is to optimize its indices. Looking for the solution of this problem and building a mathematical model, arise main difficulties when choosing the type of optimality criteria and the objective function, and defining the parameters and dependencies that are part of objective function. The first step in the formation of objective function is the choice of objective indicator. It can be the quantity of extracted information, information security costs, the total loss, which combine losses from leaks and the cost of its defense, cost effectiveness, and the combination of these and other indicators [1-3]. Select objective function as [3]:

$$I(x,y)=\sum_{k=1}^{l} I_k(x,y)=\sum_{k=1}^{l} g_k p_k q_k(x) f_k(x,y), \qquad (1)$$

where x i y - resources of attack and defense, respectively ($\sum_{k=1}^{l} x_k = X$, $\sum_{k=1}^{l} y_k = Y$);

$k=\overline{1,l}$ - object number;

g_k - amount of information on an object;

p_k - probability of attack on k - object;

$q_k(x)$ - probability of attack resource allocation x on k - object;

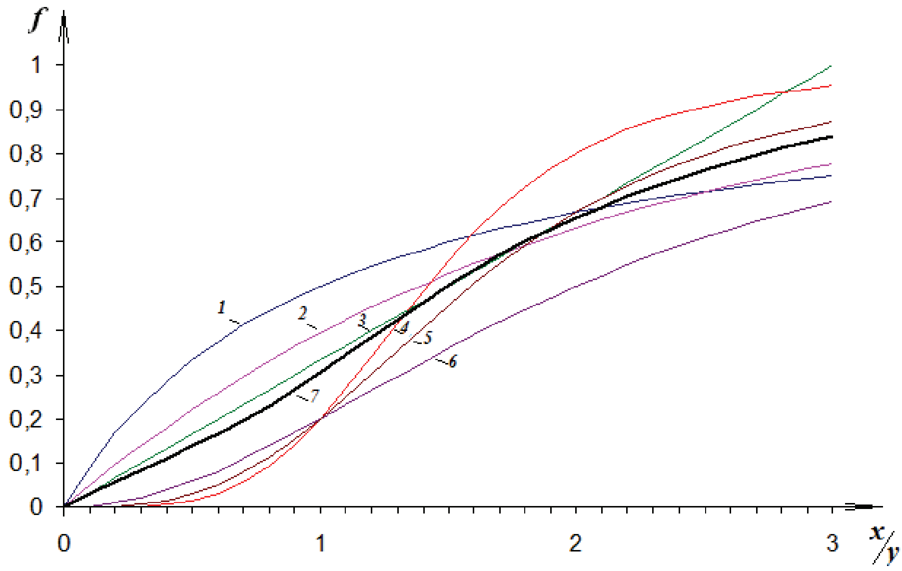
$f_k(x,y)$ - part of extracted information dependence on the ratio x i y.

Variables that are part of the objective function (1), determined on the basis of statistics or through peer review. Our interest in the objective function components due to the fact that we operate under uncertainty. In this case, the crucial question of sensitivity of optimal objective function value $I^0(x,y)=I(x,y^0)$ to change values that fall within its right side.

Begin the research of sensitivity analysis function $I(x,y)$ to dependence $f(x,y)$. For this purpose, consider some dependence $f_t(x,y)$ (t -dependence's number) and follow the changes the optimal resource allocation and relevant information loss when using each dependence $f_t(x,y)$.

Establishing a kind of dependence $f(x,y)$ should note the following considerations: when $x/y \to 0$ $f(x,y)\to 0$, when $x/y \to \infty$ $f(x,y)\to 1$. Consider a few functions that meet this criteria (Figure 1). Also, build averaged function (curve 7), thus seize the Bernoulli-Laplace approach, considering all the options dependencies $f_t(x,y)$ are equiprobable in the lack of statistical information.

Using the Belman's method [4], find the optimal resource allocation $\{y_k^0\}$ for defense and relevant part of extracted information I^0 for system with three objects in the case when an attack is launched on all three objects with coefficients $g_1=0{,}5$, $g_2=0{,}3$, $g_3=0{,}2$.



1 - $f = \dfrac{x/y}{x/y + 1}$;

2 - $f = 1 - e^{-0,5 \cdot \frac{x}{y}}$;

3 - $f = \begin{cases} \frac{1}{3} \cdot \frac{x}{y} & при \ \frac{x}{y} \le 3 \\ 1 & при \ \frac{x}{y} > 3 \end{cases}$;

4 - $f = \dfrac{\left(x/y\right)^4}{\left(x/y\right)^4 + 4}$;

5 - $f = \dfrac{\left(x/y\right)^3}{\left(x/y\right)^3 + 4}$;

6 - $f = \dfrac{\left(x/y\right)^2}{\left(x/y\right)^2 + 4}$;

7 - $\overline{f} = \dfrac{\sum_{i=1}^{6} f_i(x,y)}{6}$

Fig. 1 Dependencies of part extracted information on input resources

In Tab. 1 are given optimal allocations $\{y_k^0\}$ for various functions $f(x,y)$ and different values $Z = \dfrac{X}{Y}$. These allocations correspond to saddle points, i.e. providing compliance equality $\min_j \max_i I(x,y) = \max_i \min_j I(x,y)$, where i and j - options of resource allocation (strategies) attack and defense, respectively.

Table 1

Optimal defense strategies for different objective functions

Number of function $f(x,y)$	Optimal strategies	Z=0,5	Z=1	Z=1,5	Z=2	Z=2,5	Z=3
1	$y_1^0 : y_2^0 : y_3^0$	0,5:0,3:0,2					
	I^0	0,329	0,5	0,599	0,667	0,714	0,75
2	$y_1^0 : y_2^0 : y_3^0$	0,5:0,3:0,2					
	I^0	0,22	0,393	0,527	0,632	0,713	0,777
3	$y_1^0 : y_2^0 : y_3^0$	0,98:0,01:0,01					
	I^0	0,218	0,303	0,383	0,473	0,558	0,643
4	$y_1^0 : y_2^0 : y_3^0$	0,42:0,34:0,24	0,5:0,3:0,2	0,62:0,25:0,13	0,48:0,35:0,17	0,48:0,35:0,17	0,5:0,28:0,22
	I^0	0,167	0,4	0,566	0,795	0,905	0,952
5	$y_1^0 : y_2^0 : y_3^0$	0,43:0,33:0,24	0,5:0,3:0,2	0,59:0,26:0,15	0,52:0,33:0,15	0,51:0,31:0,18	0,49:0,33:0,18
	I^0	0,141	0,333	0,474	0,665	0,794	0,87
6	$y_1^0 : y_2^0 : y_3^0$	0,5:0,3:0,2					
	I^0	0,114	0,25	0,374	0,5	0,609	0,692
7	$y_1^0 : y_2^0 : y_3^0$	0,5:0,33:0,17	0,53:0,3:0,17	0,53:0,32:0,15	0,5:0,3:0,2	0,8:0,1:0,1	0,8:0,1:0,1
	I^0	0,178	0,345	0,504	0,655	0,739	0,796

As seen from the table, using linear function f_3 the best option for defense in case of any values Z is to focus its resources on the most critical first object. If the functions f_1, f_2, f_6 give the same result, namely: is the optimal allocation $\{y_k^0\} = (0{,}5;0{,}3;0{,}2)$, then use the f_4 and f_5 observe some deviations from these options depending on the value Z. For example, when Z=0,5 best option is the defense resource allocation in the ratio $\{y_k^0\} = (0{,}42;0{,}34;0{,}24)$ (function f_4) and $\{y_k^0\} = (0{,}43;0{,}33;0{,}24)$ (function f_5), when Z=1,5 optimal allocation when using f_4 - $\{y_k^0\} = (0{,}62;0{,}25;0{,}13)$ and for function f_5 - $\{y_k^0\} = (0{,}59;0{,}26;0{,}15)$.

Analyze the results taking into account the type of dependence $f_t(x, y)$ (fig. 1). When using functions f_1, f_2, f_6 information loss increases monotonically throughout the interval Z from 0 to 3 and reach values 0,7-0,75. Smooth running of curves apparently is the reason that the optimal defense resource allocation remains the same under any values Z.

Functions f_4 i f_5 have a slightly different nature. When $Z \le 0{,}5$ $f \gtrsim 0$, and the interval from $Z = 0{,}5$ to $Z = 2{,}5$ loss of information dramatically increase to the value $f = \overline{0{,}8;0{,}9}$, then gradually approaching 1. That is why on these three segments optimal defense resource allocation is differing.

Considering the power functions f_4, f_5, f_6, note that the optimal defense resource allocation does not depend on Z in power $n = 2$, and for the case n>2 it varies, reaching a maximum concentration of resources on first object when $Z = 1{,}5$ - the largest slope area of dependence $f_t(x, y)$.

Now try another method of averaging. We will not average function $f(x, y)$, where we find the result, but outcomes, i.e. $\{y_k^0\}$ i I_t^0, and conduct averaging on each function $f_t(x, y)$ and on value Z at that.

To conduct averaging Z, choose some normalized ratios C_Z ($\sum C_Z = 1$), considering that the probability of an attack resource allocation $Z = 2$ is highest. Averaged allocation calculates as follows:

$$(y_k^0)_Z = C_{0,5} \cdot y_k + C_1 \cdot y_k + C_{1,5} \cdot y_k + C_2 \cdot y_k + C_{2,5} \cdot y_k + C_3 \cdot y_k,$$

$$(y_1^0)_Z = 0{,}05 \cdot 0{,}5 + 0{,}15 \cdot 0{,}53 + 0{,}2 \cdot 0{,}53 + 0{,}25 \cdot 0{,}5 + 0{,}2 \cdot 0{,}8 + 0{,}15 \cdot 0{,}8 \approx 0{,}62.$$

The results are given in Tab. 2.

Table 2

Optimal resource allocations and relevant information loss by different averaging options

Z	Value of f averaging		Value of $\{y_k^0\}$ averaging	
	$\{y_k^0\}$	I^0	$\{y_k^0\}$	I^0
0,5	0,5:0,33:0,17	0,178	0,55:0,27:0,18	0,210
1	0,53:0,3:0,17	0,345	0,58:0,25:0,17	0,370
1,5	0,53:0,32:0,15	0,504	0,61:0,24:0,15	0,513
2	0,5:0,3:0,2	0,655	0,58:0,27:0,15	0,658
2,5	0,8:0,1:0,1	0,739	0,58:0,26:0,16	0,764
3	0,8:0,1:0,1	0,796	0,58:0,25:0,17	0,825
Value of Z averaging	0,62:0,23:0,15	0,531	0,58:0,26:0,16	0,614

The results in table conclude that averaging value $\{y_k^0\}$, obtain optimal allocation virtually identical for all values Z - $\{y_k^0\} = (0{,}58 : 0{,}25 : 0{,}17)$ (with modifications maximum 0,03), whereas the optimal allocation is found using the averaged function $\overline{f}(x,y)$, in sharp contrast to values $Z=2{,}5$ and $Z=3$ towards concentration of a significant part of resources ($y_1=0{,}8$) on the first object, where the largest amount of information. However, in this case of averaging the expected information losses less than in the case of averaging $\{y_k^0\}$.

Averaging Z also allows comparing the two approaches. These allocations contain only minor differences, so any of the methods can be used when searching for the optimal resource allocation.

To summarize, we note that using the averaged function $\overline{f}(x,y)$ found the optimal resource allocation is little different from the average optimal allocation, but this method requires fewer calculation procedures. Therefore, to study the impact of other components of the objective function for optimal results be using the averaged function $\overline{f}(x,y)$.

Turn now to the other variables in (1). Considering the values g, p, q, f independent variables, based on Taylor's theorem we have:

$$\nabla I^0(g,p,q,f)=\nabla_g I^0\partial g+\nabla_p I^0\partial p+\nabla_q I^0\partial q+\nabla_f I^0\partial f$$

and determine sensitivity coefficients of function $I^0(x,y)$ to these variables:

$$\alpha_g=\frac{\partial I^0}{\partial g}=\nabla_g I^0;\ \alpha_p=\frac{\partial I^0}{\partial p}=\nabla_p I^0;\ \alpha_q=\frac{\partial I^0}{\partial q}=\nabla_q I^0;\ \alpha_f=\frac{\partial I^0}{\partial f}=\nabla_f I^0.$$

For example, consider the value g. Coefficient α_g shows how to change the quantity of extracted information with optimal defense resource allocation, if the actual value g different from the adopted. If $\Delta g=0{,}1$, we have: when $Z=1$ $\Delta I^0=0{,}057$, when $Z=2$ $\Delta I^0=0{,}065$, when $Z=3$ $\Delta I^0=0{,}080$.

Apparently, the sensitivity of the optimal solution increases with $Z=\frac{X}{Y}$. Similar findings we get for other variables. Because the rate of change of partial derivative linear function with respect to independent variables c_s expressed the value of this function at $c_s=1$ (in our case - the product of all other variables), it is clear that the sensitivity α_{c_s} will be the greater, the more value $I^0(g,p,q,f)|_{c_s=1}$ at the stationary point.

Conclusions

Using the Belman's method and target function (1) is found optimum defense resource allocation under uncertainty. Considering the difficulties of establishing the type of dependence of part extracted information on input resources, different methods of averaging is analyzed – the dependencies themselves $f(x,y)$ and averaging the results $\{y_k^0\}$. As result of research substantiated the expediency of using the averaged function $\overline{f}(x,y)$.

On the basis of analysis sensitivity coefficients of objective function to input data is made conclusion that considered model can be used to find optimal solutions because deviations from the expected loss is permissible under uncertainty.

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THEORETICAL BASIS OF ANALYTICAL METHODS IN CRYPTANALYSIS IN MARKOV BLOCK CIPHERS

The differential (subtractive) and linear methods for cryptanalysis of block ciphers are considered.

When block ciphers are designed the great importance is paid to their resistance according to analytic and technical crypto attacks. The most powerful analytic methods in cryptanalysis of block ciphers are differential (subtractive) ones (DCA) [1, 2] and linear (LCA) [3]. The method for generation of hardware errors and method for measurement of the power radiation [1, 5] refer to the technical attacks on the block ciphers.

At present moment DCA and LCA methods are recognized as the basic criteria for crypto stability of algorithms. The content of DCA is the analysis for the degree of the influence from extension of changes in the open text on the changes in the cipher text. The characteristics of such type are closely connected to automatic correlation properties of Boolean functions, which form the round transformations of block ciphers, and exactly those automatic correlation properties are defined by:

- criteria for extension in changes $PC(n,1)$ for every Boolean function that creates the cryptographic primitive;
- mutual distribution of avalanche vectors of all modifications in a round of ciphering.

LCA is based on linear approximation of nonlinear round modifications. The linearization of such type is closely connected with the correlation of Boolean functions that create these modifications and with the set of refinery functions. The quality of linearization is determined by the properties of linearization and nonlinearization of Boolean functions $(L(f), N(f))$ that create the cryptographic primitive and the entire round modification in whole $(L(F), N(F))$. Exactly functions $f_i(X)$ have the name of Boolean functions that create the modifications $Y = F(X)$.

The expression, provided below, is called the nonlinearization of Boolean functions $f(x)$, which is set by the reflection of linear vector space $GF(2)^n$ on the field $GF(2)$ (or set) of two elements $\{0,1\}$, that is $(GF(2)^n \to GF(2))$:

$$N(f) = \min_{\forall f_{aff}} DH(f, f_{aff}), \tag{1}$$

where $DH(f,g)$ – Hamming distance between two Boolean functions $f(x)$ and $g(x)$; it represents a number of values, by which these functions differ one from another that corresponds to the condition $DH(f,g) = WH(S(f) \oplus S(g))$, in which $S(f) \oplus S(g)$ – binary operation for bitwise addition of data sequence in Boolean functions $f(x)$ and $g(x)$, these sequences consist of elements $\{0,1\}$ and are expressed by: $S(f) = \{f(\beta_0), f(\beta_1), \ldots, f(\beta_{2^n-1})\}$, where β_j possesses all various values from $GF(2)^n$. Every sequence $S(f)$ has the name of true Boolean function $f(x)$.

Hamming distance $DH(f,g)$ forms also a function of correlation $C(f,g)$ for two Boolean functions $f(x)$ and $g(x)$, that is:

$$\begin{aligned} C(f,g) &= 0{,}5^n\left[2^n - DH(f,g)\right] - 0{,}5^n\left[2^n - DH(f,\overline{g})\right] = \\ &= 0{,}5^n\left[DH(f,\overline{g}) - DH(f,g)\right] = 1 - 0{,}5^{n-1} DH(f,g). \end{aligned} \tag{2}$$

The following expression is called the linearization of Boolean function $f(x)$:

$$L(f) = \max_{\forall f_{lin}} \left|C(f, f_{lin})\right|, \tag{3}$$

in which the correlation system $C(f,g)$ of Boolean function $f(x)$ is determined by the following dependence [1]:

$$\begin{aligned} C(f, f_{lin}) &= \Pr_X[f(X) = f_{lin}(X)] - \Pr_X[f(X) \neq f_{lin}(X)] = \\ &= 2\Pr_X[f(X) = \alpha \cdot X] - 1 = 0{,}5^n S^*(f) \cdot S^*(\alpha \cdot X) = 0{,}5^n U^*_\alpha(f), \end{aligned} \tag{4}$$

where $(\alpha \cdot X)$ – scalar product of vectors.

The linearization and nonlinearization of Boolean functions $f(x)$ are joined together by expressions:

$$N(f) = 2^{n-1}(1 - L(f)); \qquad L(f) = 1 - 2^{n-1} N(f). \tag{5}$$

The basic apparatus for research of properties at crypto graphical primitives is Walsh Hadamard transformation (TWH) of real function $f(X) \in GF(2)$ by vector $\alpha; \left(X, \alpha \in GF(2)^n\right)$ that corresponds to the formula:

$$U_\alpha(f) = \sum_{X \in GF(2)^n} f(X) \cdot (-1)^{\alpha \cdot X}. \tag{7}$$

Inverse TWH is written by [1]:

$$f(X) = \frac{1}{2^n} \sum_{\alpha \in GF(X)^n} U_\alpha(f) \cdot (-1)^{\alpha \cdot X}; \quad f^*(X) = \frac{1}{2^n} \sum_{\alpha \in GF(X)^n} U^*_\alpha(f) \cdot (-1)^{\alpha \cdot X}. \tag{8}$$

If 2^n value of characteristic sequence $S^*(f)$ in the function $f^*(x)$ and 2^n values of real function $U^*_\alpha(f)$ are written in the form of graphs $[S^*(f)]$ and $[U^*_\alpha(f)]$, so these graphs are defined by the matrix of Walsh Hadamard H_n, namely: $[U^*_\alpha(f)] = H_n[S^*(f)]$. Every characteristic sequence $S^*(f_{lin})$ of lineal function from n variables is the line in matrix H_n.

Methodology for differential cryptanalysis.

With aim to define the mechanisms for influence of cryptographic primitives on resistance of block ciphers to DCA let's examine ths methodology for performance of DCA for DES – similar block algorithms, which have the paired size of data blocks n, which transform and perform r – round transformation that is provides in work of Feistel [1, 4, 5].

In accordance with this algorithm, «i» is the round transformation due to Feistel methodology and is determined by the following function:

$$X(i) = E(X(i-1), k_i) = [F(X_L(i-1), k_i) \oplus X_R(i-1)] \| X_L(i-1). \tag{9}$$

Within this example and hereinafter, the following definitions are important: the differences between two blocks X and X^* or Y and Y^* are defined by formulas $\Delta X = X \circ \left(X^*\right)^{-1}$ $\Delta Y = Y \circ \left(Y^*\right)^{-1}$.

Written function (9) corresponds to the method for influence of round key k_i on the home block (open text) X_L in round function $F(X_L(i-1), k_i)$. As appears from the algorithm of Feistel, the operation "⊕" is characteristic most of all for DES and other block ciphers, for which the differences may be expressed by:

$$\Delta X = X \oplus X^* = \Delta X_L \| \Delta X_R; \quad \Delta Y = Y \oplus Y^* = \Delta Y_L \| \Delta Y_R.$$

The introduction of algorithm «i» defines the belonging to concrete round transformation. i.e.:

$$\Delta Y(i) = Y(i) \oplus Y^*(i) = \Delta Y_L(i) \| \Delta Y_R(i). \tag{10}$$

If only one round of transformation takes place, then the mark $F(X_L, K)$ is used for the round function and for one round transformation itself $E(X, K)$ [1] is written.

The definition "characteristic of block ciphers" is used in DCA process. Thus ths following expression for sequence is called s round characteristic of block cipher:

$$\{\Delta X, \Delta Y(1), \Delta Y(2), ..., \Delta Y(s)\}, \tag{11}$$

$$\forall i \in \overline{1,s} \Delta X, \Delta Y(i) \in GF(2)^n; s \le r.$$

And this following pair of expressions is called s – round difference (differential):

$$\{\Delta X, \Delta Y(s)\};\ \Delta X, \Delta Y(s) \in GF(2)^n; s \le r. \tag{12}$$

Hereby s – round difference (s – round characteristic (11)) is considered performed (true) for blocks X, X^* and round keys $K_s = \{k_1, k_2, ..., k_s\}$, if in process of intermediate round transformations ΔX is reflected in $\Delta Y(s)$, consistently taking ths values $\Delta Y(1), \Delta Y(2), ..., \Delta Y(s)$.

The possibility for performance of s – round characteristic (11) and s – round difference (12), using round keys K, may be considered as conditional probability with X:

$$\Pr_X(\Delta Y(s), ..., \Delta Y(1)/\Delta X, K_s);\ \Pr_X(\Delta Y(s)/\Delta X, K_s),$$

Which due to the formula for total probability correspond to:

$$\Pr_X(\Delta Y(s)/\Delta X, K_s) = \sum_{\forall \Delta Y(1), ..., \Delta Y(s-1) \in GF(2)^n} \Pr_X(\Delta Y(s), ..., \Delta Y(1)/\Delta X, K_s), \tag{13}$$

In accordance to [1] the great role for performance of DCA is played by the hypothesis about stochastic equivalence, which is considered to be true, if:

$$\forall s \in \overline{1,r} \Pr_X(\Delta Y(s)/\Delta X, K_s) \approx \Pr_{X,K}(\Delta Y(s)/\Delta X).$$

For the majority of round keys K_S (consistent distribution of probability by X and by the majority of keys K_s under the condition of ΔX is considered).

The round transformation $E(X(i-1), k_i)$, present in algorithm of Feistel, is weak, if it is possible to define the round key k_i due to known data $Y(i), Y^*(i)$ and $\Delta X(i-1)$.

The possibility for performance of DCA is connected with the presence $(r-1)$ – of round difference $\{\Delta X, \Delta Y(r-1)\}$ (or characteristic $\{\Delta X, \Delta Y(1), ..., \Delta Y(r-1)\}$), for which the condition $\Pr_X(\Delta Y(r-1)/\Delta X) > 1/2^n$ must be true.

If the hypothesis about stochastic equivalence is true and weak round transformation is available, the following basic algorithm DCA is used that is a variety of cryptographic attack on the basis of chosen opened texts:

1. $(r-1)$ – round difference $\{\Delta X, \Delta Y(r-1)\}$ or corresponding characteristic, which has maximum conditional probability $p_{r-1} = \Pr_X(\Delta Y(r-1)/\Delta X) > 1/2^n$ or similar to it, is taken. At the same time the vectors ΔX with minor Hamming weight are used to simplify the calculation.
2. The initial (opened) text $X \in GF(2)^n$ is chosen accidentally and equally probable (or specially) and other text $X^* = X \oplus \Delta X$ is formed.
3. Texts X, X^* are transformed by the block cipher in ciphered texts $Y(r), Y^*(r)$ with unknown round keys $K = (k_1, ..., k_r)$.
4. Using the weakness of round transformation $E(X(r-1), k_r)$ and providing that $\Delta Y(r-1)$ is known with probability p_{r-1}, with available texts $Y(r), Y^*(r)$, the set $K(X, \Delta X, \Delta Y(r-1))$ of all possible values for round key K_r is analytically defined. The accumulation of those values in the set $K^*(\Delta X, \Delta Y(r-1)) = \bigcup_{X \in GF(2)^n} K(X, \Delta X, \Delta Y(r-1))$. is made for every chosen X.
5. Steps 1-4 are repeated until the set $K^*(\Delta X, \Delta Y(r-1))$ will have the local maximum for one value or limited set for values of round key K_r, among which there is its true value.

6. After removing the influence of last r round, steps 1-5 are repeated for weakened $(r-1)$ round transformation until receiving the key K_{r-1} and in such manner the operations are continued until receiving K_1. In some cases, for example DES, the rest of round keys may be received by the total search, based on methods of their formation.

If the value of complexity $M_D(r)$ for DCA of block cipher, which consists of r rounds, is taken as the necessary amount of pairs for ingoing and outgoing data blocks to determine the round key K_r, then the following evaluation can be true:

$$M_D(r) \geq 1/p_{r-1}^{(\max)}, \tag{14}$$

where $p_{r-1}^{(\max)} = \max\limits_{\forall\Delta X;\forall\Delta Y(r-1)} p_{r-1}$.

Thus, with $p_{r-1}^{(\max)}$ that approach to $1/2^n$, the value of complexity $M_D(r)$ will be compared or exceed the total amount of 2^n binary texts with the length of n bytes, and, accordingly, the differential analysis will become ineffective. Moreover the complicity for performance of DCA shall be assessed taking into consideration the so called ratio “signal-noise”, where the signal means the average number of replications for correct key, and noise is the average number of sudden keys in the set $K^*(\Delta X, \Delta Y(r-1))$. The signal-noise ratio is determined by the formula:

$$S/N = (mp)/\left(m\alpha\beta/2^k\right) = \left(2^k p\right)/(\alpha\beta),$$

where k is a number of bytes for the key, being calculated;

m – total amount of pairs for open texts, being researched $(X, X \oplus \Delta X)$;

p – probability of characteristic, being applied $(\Delta X, ..., \Delta Y)$;

α – average number of keys, which are received in the set $K(X, \Delta X, \Delta Y(r-1))$ for each pair $(X, X \oplus \Delta X)$;

β – ratio for amount of pairs $(X, X \oplus \Delta X)$, which at the entry result in non-contradictory difference ΔY (i.e. are not rejected) to the total number of m for pairs of open texts, being researched.

Conclusions

Thus, from the mathematical point of view, DCA is automatic correlative one, and LCA is the correlation analysis of algorithms.

The assessments, provided in this work, guarantee only necessary (but not sufficient) conditions for stability of Markov block ciphers to DCA.

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ORGANIZATION OF PRESHIFT AND INTRASHIFT ACCESS CONTROL OF ATC TO THE RESOURCES OF INFORMATION SYSTEMS

The article concerns the problem of ATC's psychophysiologic preparedness to the air traffic control. The algorithm of monitoring of PPS of human operator during passing of preshift and intrashift access control to the resources of information systems is suggested.

The quality of operation of access control systems to the resources of information systems can be improved by taking into account psychophysiologic state (PPS) of operators working particularly in transport (ATC, railway traffic controllers and so on)and energy sectors (operators of energetic systems). It is caused by the fact that unsatisfactory psychophysiologic state of operators can be the reason of accidents and emergency situations at the work place (particularly in transport and energy sectors).

In connection with the fact that PPS can substantially influence on the quality of operators' work system of access control to the resources of information systems which they work with must include elements considering their state both before work (shift) and during shift [1]. The author considers psychophysiologic state as set of psychophysiologic and psychoemotional states.

The purpose of preshift psychophysiologic control is identification of parameters of current state of human nervous system, detection of signs of organism system functioning deviations, symptoms of depression, fatigue, stressful or anxious states directly before shift (before fulfillment of functional obligations). PPS control of operators during work process is necessary for possibility of quick detection of overexertion state, fatigue, sleepiness and also heightened emotional excitement which can lead to emergency situations.

Only signs which can't be controlled by person must be selected in order to monitor operator's PPS for the purpose of efficient control of regulatory organism systems tension. The state of cardiovascular system (owing the parameters of electrocardiogram) and speech signal can be reasonably used in the capacity of such signs.

1. Application of parameters characterizing the state of operators' cardiovascular system for analysis of their PPS during passing of preshift control.

The parameters of heart rate variability (HRV) (including integral parameters such as Bayevskiy tension index) can be reasonably used in the capacity of informative parameters characterizing the state of human cardiovascular system during passing of preshift control [2]. But for some parameters exist original but still disputable treatments which must be reasoned more thoroughly.

At the present time there is portable electrocardiograph designed for convenience of electrocardiogram (ECG) readout which can readout ECG by one lead "hand-hand". Structural scheme of portable electrocardiograph includes elements which fulfill: ECG record with application of different sensors, computer digitization and noise cleaning of signal, processing and analysis of RR-intervals caused by artefacts, extrasystoles and so on, computation and analysis of parameters of spikes and ECG intervals, according which operator's PPS can be determined, temporal analysis of HRV [1]. Computation and analysis of parameters can be carried out by means of statistical analysis early suggested by Bayevskiy R.M., with the help of which the parameters of HRV are calculated, namely:

1. Heart rate HR:

$$HR = 60*1000*\frac{n}{\sum_{i=1}^{n} NNi(ms)} \text{ (per minute)},$$

where NN – set of normal intervals excluding extrasystole

2. Mean value of R-R interval $\bar{x}$:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \text{ (ms)}$$

where x_i – value of i-quantal element of function x(t), i=1,2,…,N;

3. Dispersion D:

$$D = \frac{1}{(N-1)}\sum_{i=1}^{N}(x_i - \bar{x})\text{^}2 \text{ (ms}^2\text{)}$$

4. Standard deviation σ:

$$\sigma = \sqrt{D} \text{ (ms)}$$

5. Coefficient of variation CV:

$$CV = \frac{\sigma}{\bar{x}} 100\%$$

6. Root-mean-square state of difference RMSSD:

$$RMSSD = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n-1}(NN_i - NN_{i-1})\text{^}2} \text{ (ms)}$$

PNN50 - percentage ratio of NN-intervals, difference states of which (x_i-x_{i-1})> 50 ms to total quantity of NN-intervals.

It should be taken into account that organism individual optimum doesn't always coincide with average norm because one-type adaptive reactions occur in different ways in compliance with conditions in which person is and depending on his/her individual functional reserves [2].

That is why on the basis of our research in future the program of HRV parameters calculation is outlined with the help of data received in few standard leads. Method of difference determination of potentials between two parts of body is called electrocardiographic lead. Standard electrocardiographic research includes registration of 12 leads: three standard (classic) leads, three enhanced unipolar limb leads and six chest leads. In Figure 1 (a, b) fragments of electrocardiogram read in III standard lead and aVR lead.

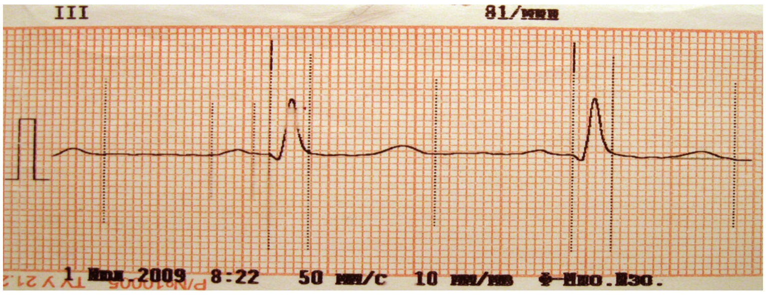
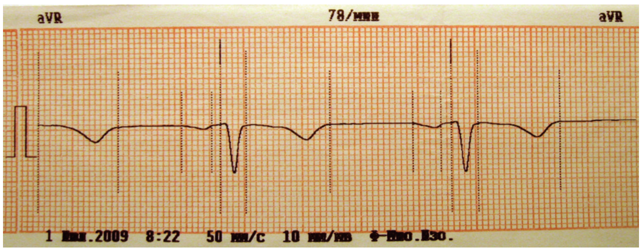


Figure 1. a) Fragment of ECG on which III standard lead is shown



b) Fragment of ECG on which aVR lead is shown

During our research parameters have been read in different leads. This fact gives possibility to describe localization process more precisely because each lead is responsible for different parts of the heart. During research ECG parameters of both physically vigorous and tired people were fixed.

2. Application of speech signal for identification of PPS during intrashift control.

Fulfillment of operators' PPS control during the shift with the help of analysis of speech signals parameters received in the process of information exchange between them is urgent. It should be noticed that under these conditions PPS analysis is carried out secretly (secretly from participants of work process). Simultaneously record of operators' (ATCs) talks during the shift may be carried out for further analysis of speech fragments recorded during off-optimum situations in order to specify their reasons.

The stay of overexertion, fatigue and sleepiness can lead to emergency situations. In the article - the analysis characterizing one of the aspects of operator's PPS, particularly – his/her emotional state.

In literature multitude of different emotions is described. But in order to carry out access control to the resources of information systems taking into account emotional state (ES) space of emotions can be divided into three classes (groups) corresponding to such emotional states as "slow response", "norm"(concentration, attention) and "excitation".

Emotional state "slow response" includes such emotions as melancholy, doubt, fear. They are connected with possible detraction, accumulated fatigue during the shift. If person is in the state "norm" he/she is concentrated, attentive, has good (heightened) working efficiency. From point of view of information systems safety protection excitation state of operator is dangerous (such emotions as anger, joy correspond to this state, person loses selfcontrol, control over emotions, becomes inattentive).

Speech material in the capacity of phrases and particular words repeated by speaker with different emotional coloring or being in different states (calm, emotional excitation and slow response) has been chosen as research object [3]. It is suggested to use prosodic features – variability of fundamental tone frequency (FTF) (irregularity from phoneme to phoneme, change range of chosen speech fragment), temporal parameters and also intensity (in the first place, vowels) as parameters of speech signal in order to identify ES. It is sufficient to carry out identification of FTF on the basis of correlated and cepstral analysis.

Comparison of influence of different phonemes on emotional coloring of speech has been made during research. The hypothesis that role of different phonemes during the formation of speech emotional coloring is not the same has been put forward and corroborated with the help of experiments. In order to test hypothesis particular phonemes from emotionally colored password phrases have been singled out and put instead of corresponding phonemes in emotionally uncolored password phrases [3]. The example of algorithm application is represented in Figure 1.

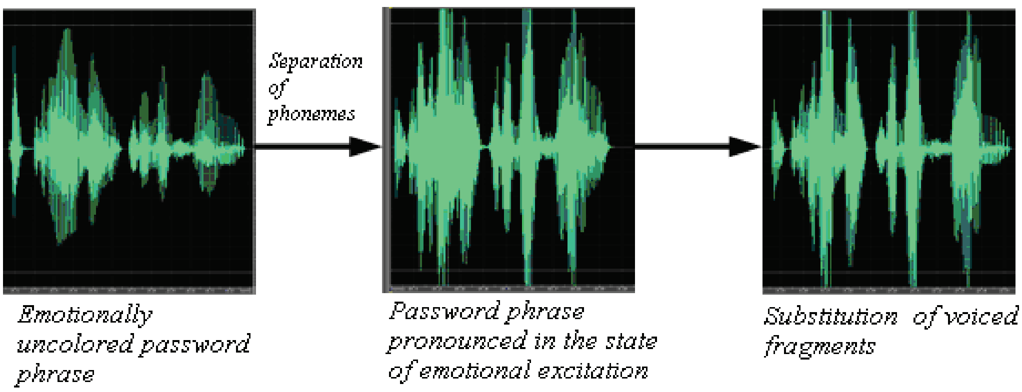


Figure 2. Separation of phonemes from emotionally colored password phrases and their substitution by them of corresponding phonemes in emotionally uncolored password phrases

Speech signals have been recorded in studio (in order to reduce of noise influence) with the help of professional equipment and specialized software used for manipulation with audio files.

Speech signals corresponding to different emotional states are characterized by different values of mentioned above parameters. According to the article state of slow response is characterized by relatively low value of parameters which describe variability of FTF, relatively low value of average FTF per speech fragment; if person is in this state he/she speaks more slowly, in lower voice (lower intensity of speech signal). The state of excitation is distinguished by heightened values of parameters which characterize FTF, person speaks more quickly and in loud voice (intensity of speech signal is raised).

Conclusions

Application of mentioned in the article research results will allow to raise quality of performance of access control systems which in turn will lead to the enhancement of work safety level of transport and energy information systems.

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EXPERIENCE WITH AUTOMATED DATA MANAGEMENT SYSTEM FOR INDUSTRIAL PURPOSES

The article describes the introduction of automated production management data within the distributed enterprise

Introduction. The experience of industrialized countries has shown that it is possible to increase the recovery from the economic recession due to intergovernmental industrial integration and cooperation. The cooperation with other partner companies, which are often located in other countries, is needed for the creation of complex high technology products. For reliable and timely exchange of information production in the project, between the parties, one must undertake a comprehensive automation of process manufacturing companies and design offices (DO) by creating an integrated automated environment (IAS). This will create a common database of partners within a project, and due to improving of the speed and quality of data exchange it will reduce product output and increase profits.

The purpose of the article. Description of the implementation of integrated automated systems for manufacturing data within geographically distributed industry enterprises, further dispersed enterprises (DE) [1].

Basic material. Traditionally, the enterprise information systems are divided into production, those related to production activities, management, providing support for administrative processes and interface responsible for the possible types of interaction of the enterprise with environment.

Production information systems cover design, planning and preparation of production and management of processes and material flows at all stages of production − from the arrival of raw materials to finished products output.

Since the efficiency of automated control of production data influences on the economic efficiency of projects on development and manufacturing of complex, knowledge-intensive products, the main focus is concentrated on technical components of this problem.

One of the most difficult tasks of constructing and DE is the integration of design offices and factories-producers, otherwise creation of the virtual geographically-distributed project-production structures.

To create the virtual geographically dispersed project-production DE the main characteristics the following conditions are needed:

− creation of command of project (fig. 1);
− targeting production processes of enterprises on joint projects;
− mobile configuration of resources involved in the project and the availability of implemented procedures of project management;
− unified information space, at least at the level of data exchange interfaces between information systems;
− unified and available for all project participants (including permissions) database system of project (a database: design and manufacturing modules, rules and regulations, materials and technological equipment, etc.);
− unified for all participants of the project model of documents and project data;
− unified model for project management on the level of processes and procedures;
− unified documentation system, regulating interaction within the virtual structure.

Building a virtual design-industrial structure of the DE should start from the development of the new product concepts for the project (fig. 2). A typical model of the new product concepts for the project, which is standard for most Western companies, is represented in this figure. Consider the main components of this concept:

− market concept − designed to specify all "external" requirements for the project, namely the assessment market and the expected volumes of the series, estimation of potential customers expectations in terms of providing after-sales service;

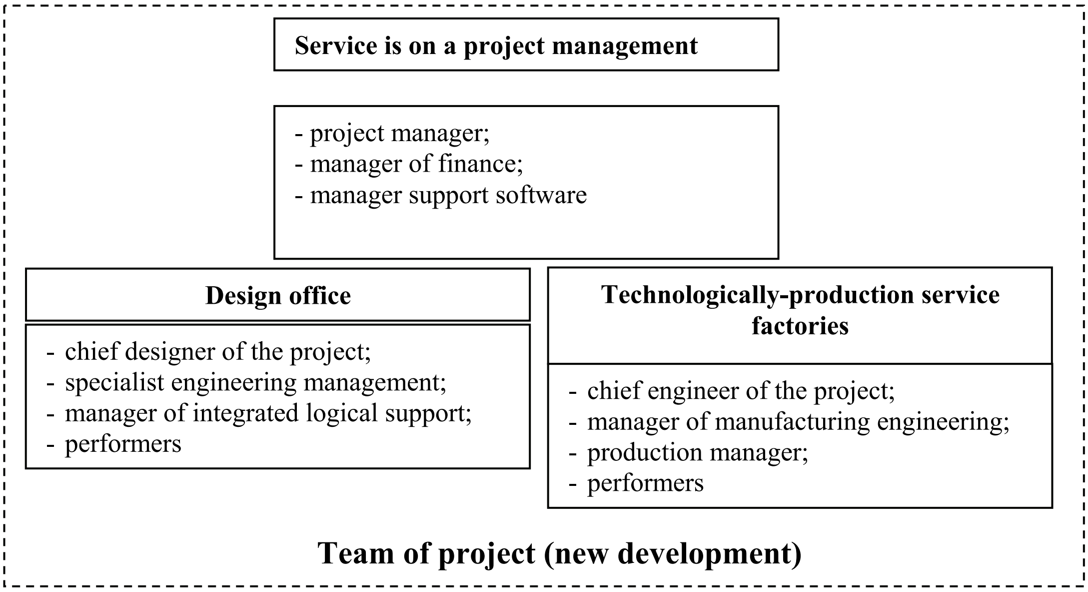

Fig. 1. Scheme of the project team's new product

- technical concept − contains technical description of the product (main series product), implementation options (options), the planned design and technological innovation, the requirements for working environment (including investments in its modernization), plans on development, quality certification, list of works on providing design for target cost;
- product concept − includes pre-production plan, estimate production costs;
- concept of suppliers − provides strategy and procurement plan components, plan management vendors (how? when? and what?).

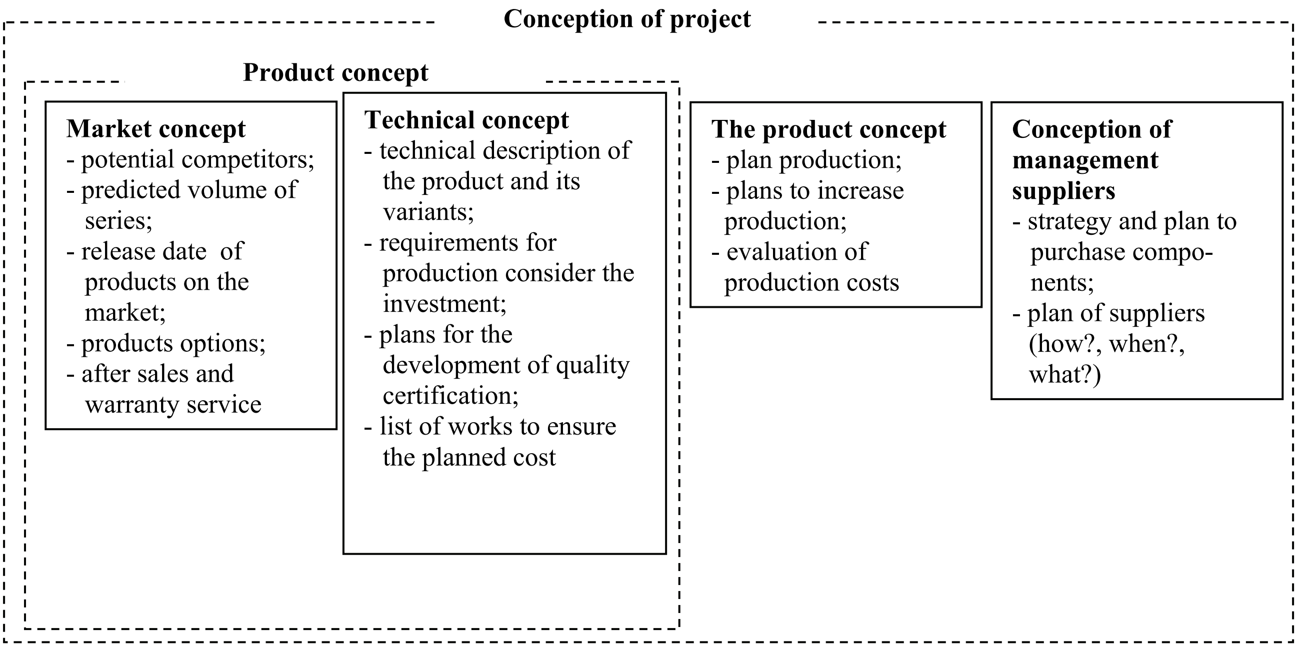

Fig. 2. Structure of the project concept of new product

It should be mentioned that all four components of the project concept of a new product are inextricably linked, directly aimed to implement the objectives of the DE and, that is why, require a common point of management. A project office can be this control center, which provides operations and supply planning, budget management and project resource and control on all aspects of the project. During the creation of the project office the main trends of modernization management technologies are to consider:

- product development approach processes and organizational structure and management of project-oriented production systems to create and support a specific project;
- development of process approach implementation of the DE as a network of production-processes related goals and objectives in general;
- development of the project approach implementation of the processes is in draft form, functional units (in this case business) delegate (emit) the performers for the period defined by the project manager.

Organization of the offered structure of project management involves the necessity to integrate project participants into the processes and procedures. It is to be mentioned that at the level of individual enterprise processes and project management procedures should be similar to the relevant processes and procedures of project office.

Another important aspect of virtual design-production system is information technology. Modern information systems of product lifecycle management (PLM-technologies) provide new functional possibilities unavailable when using "paper technology".

Designing for a given value of the product life cycle or minimizing this cost is justified clearly considers, above all, common work of designers and manufacturers of the product. In terms of information technology this task is formulated as the integration of production and projected production environment of its creation. Actually it is the problem of concurrent engineering processes at all stages of product design and manufacturing. Thus the main criterion for the effectiveness of these processes will be the minimization of the cost of the product life cycle.

Based on the above described, the requirements for the future of automated data management of industrial purposes can be formulated and types of systems to ensure compliance with these requirements can be selected [2]:

- Providing information support of modernized management process (class of PMS-Primavera, Open Plan);
- Providing information support of concurrent engineering processes (systems-class portal solution PDM-ENOVIA v.6, ENOVIA Smarteam and CAD systems-CATIA);
- Providing information support processes of organizational and technical preparation of production (class of MPM-DELMIA, Class of CAD/CAM-CATIA, class systems PDM-ENOVIA v.6, ENOVIA Smarteam);
- Providing information support of management of information (documents and data) throughout the project life cycle (of class PDM, ENOVIA v.6, ENOVIA Smarteam);
- Providing information support of resource management processes of production and after sales support of buyer (class of ERP-IFS, SAP, Oracle);
- Providing information support of management processes of development and updating interactive electronic operational documentation (class of IETM – 3D Via Composer, class systems PDM-ENOVIA v.6, ENOVIA Smarteam).

From the list is possible to see that specialized systems such as AVEVA can only be used to solve local problems and receiving of interim results (intermediate mathematical models) which will be transferred to the CATIA and construction of firm model will continue only in CATIA. This approach will allow to use specialized software that has a business and provide integrated solutions for managing the lifecycle of the product. Including merge into single information complex mathematical models of the product and production system this will allow mathematical modeling and optimization of production processes and implement a reasonable program of action for maintenance re-equipment businesses and creating new production capacities.

Work in this direction was conducted at OJSC "Industrial Investment Group transport engineering "Inter Car Group"" in 2008, where pattern of the automated production of data within the same project was established (fig. 3).

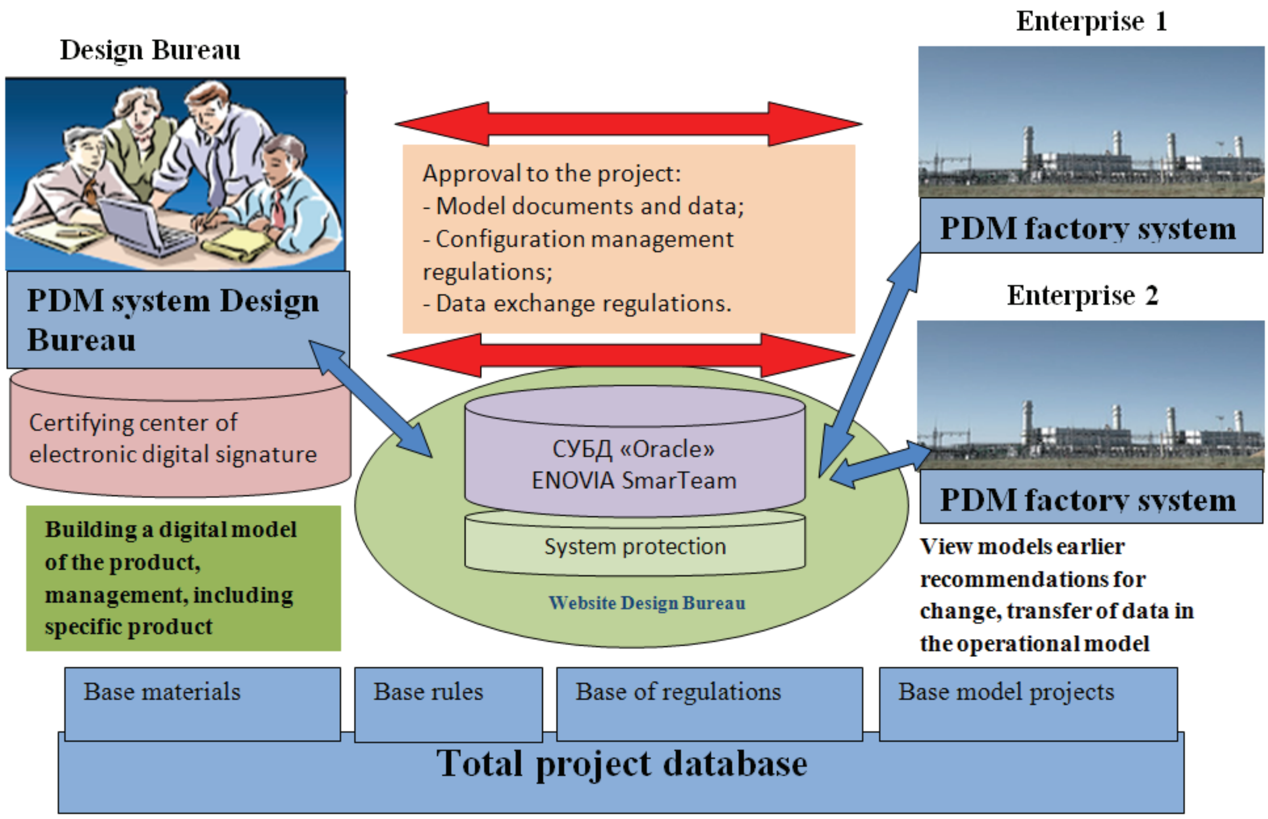

Fig. 3. Scheme of Information Exchange Bureau-Enterprise

Conclusion

The implementation of automated production management data in enterprises is an extremely important task, as it allows entering into cooperation with other enterprises and to support all stages of life cycle products with deep integration.

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SYSTEM ENGINEERING OF MANAGEMENT BY INFORMATION PROCESSES OF NATIONAL AVIATION UNIVERSITY

Questions of the conceptual analysis of automated processes and objects of university are considered. Base bases and technologies for the decision of problems of formalization and algorithmization of objects of a subject domain are presented. The method of the organization of objective system in the environment relational DBMS is described.

The problem of maintenance of complex information support of management teaching and educational, scientific, financial and administrative -economic processes of higher educational institutions (HIGH SCHOOL) still is one of actual problems[1]. Value of such automation and the requirements shown to means solving these problem, even more amplify in connection with certification of university under standard ISO 9902 (control systems of quality). Development and introduction of the modern integrated automated information system (IAIS) for university is exclusively a challenge, demands attraction of greater material and intellectual resources, application of the advanced information technologies[2].

Stages and development cycles IAIS demand the conceptual analysis of automated processes and objects and also their formalization and algorithmization. Authors represent base bases and technologies for the decision of these problems.

In communication with complexity of a subject domain, it is expedient for the analysis and a choice of design decisions to use the objective-relational approach. Because of presence of a plenty of the works, devoted to methods of objective-relational display (ORD), wide popularity was received with the tools, allowing to organize objective system on the basis of relational DBMS [4-5]. In the given work the method of the organization of objective system in DBMS MySQL environment successfully applied is described at development IAIS of National Aviation University.

Designing and realization of any program a product begins with a formulation of requirements to which there should correspond the received realization. For a method, allowing to organize objective system in the environment relational DBMS, have been made demands the following:

1. Support of an extensive metainformation;
2. Support of communication between attitudes;
3. Transformation of attitudes in classes;
4. Support of methods of data processing;
5. Support of attitudes of inheritance and an opportunity of polymorphism.

Development of the objective system meeting allocated requirements, will allow to receive following advantages:

- The unified system of abstract types of the data, promoting a reuse written before classes;
- Acceleration of process of development of appendices due to storage of the information in a uniform database that allows to create the auxiliary tools accelerating process of development IAIS;
- Simplification of process of entering of updatings which in our case represent addition of derivative classes, the announcement of new attributes, creation of new methods and change existing;
- An opportunity of program generation of methods of processing and visualization on an available metainformation.

Let's consider realization of the described principles of the organization of the objective system, meeting the allocated requirements on гипотетичном an example (fig. 1).

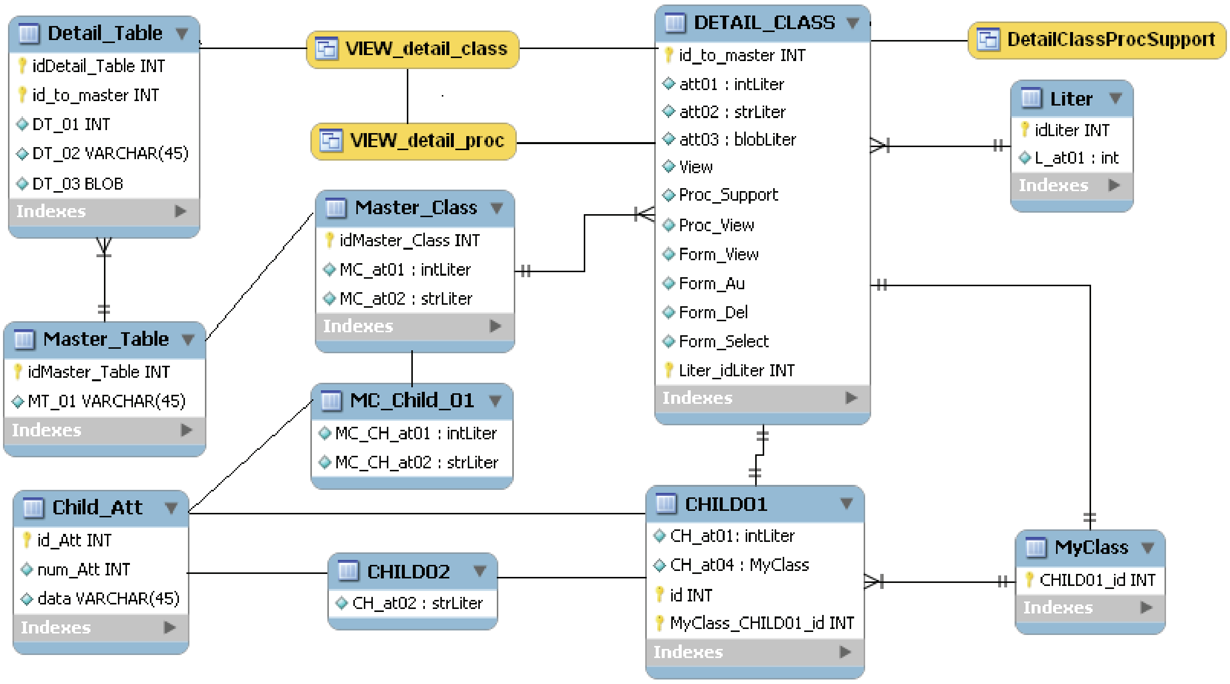

Fig. 1. Metamodel of objective system realized in the environment relational DBMS

Figure demands explanatories. In the left part of figure two tables (Master_Table (main) and Detail_Table (by the subordinate)), incorporated by communication "one-to-many" are located. For the organization of such communication in Detail_Table there is an external key id_to_master which refers to a primary key of table Master_Table (a field idMaster_Table). We shall note, that all fields of tables are described by means of the built in types of data target relational DBMS (MySQL).

According to the requirement (3) each of tables is transformed to classes. Thus each class becomes root for the hierarchy and the opportunity to declare derivative classes on demand (5) is given. An essence that all copies of hierarchy of data and derivative classes are kept in this table. Values of attributes of derivative classes are kept in one general table Child_Att. Unlike the classical realization using for preservation of values of attributes of all classes of hierarchy the uniform table, in our case in Child_Att values of attributes of derivative classes are kept only. As a result we realized a method which combines in itself architectural decisions of two known patterns ORD. Such method has following advantages:

- For extraction of values of attributes of a base class which are necessary for all classes of hierarchy, it is required to execute only one operation of sample of data from the table;
- At structure of a DB there is only one table representing hierarchy of classes that allows to group copies of similar classes physically;
- Minimization of disk space since values of the attributes which are present at all classes are stored in the base table. And in Child_Att empty values of attributes are kept not.

In the presented realization the extensive metainformation according to the requirement (1) which keeps the information both on hierarchy of atomic literal types, and on hierarchy of classes of a subject domain is supported. Key feature, in a cut of our discussion, the opportunity of the announcement of attributes for literal types and tasks for them values is. At transformation of tables in classes according to the requirement (3) each floor of the table it will be transformed to attribute of a class, thus the type of attribute is defined according to types given (classes) which are available in a metamodel. So, field DT_01 (Detail_Table) type Int is transformed to attribute att01 (DETAIL_CLASS) which type is the atomic literal intLiter. Thus the external key id_to_master (DetailTable) which also is an integer, will be transformed to attribute att01 (DETAIL_CLASS) as which type class Master_Class acts. Are in such a way realized support of communications between attitudes at a level of objective system according to the requirement (2). We shall note, that class Master_Class is received after transformation of table Master_Table. Apparently from fig. 1, there is an opportunity of the announcement of derivative classes according to the requirement (5). So, class

MC_Child_01 is inherited from class Master_Class and values of its properties are kept in table Child_Att.

Let's pass to the requirement (4) and we shall consider the methods which are present at class DETAIL_CLASS. The part of methods is represented physically with objects of a database. Method View is representation and returns values of all attributes of a class in the form of a uniform data set. In a derivative class (CHILD01) this method is redefined, as it is necessary to return values of the attributes declared in this class (CH_at01, CH_at04). Method Proc_View physically represents хранимую procedure which on the basis of the transferred filter forms the result representing set of objects. For reception of values of attributes of one concrete object and for their change procedure Proc_Support is used. For representation of several copies of classes in the graphic interface of the user method Form_View is declared; for editing - Form_AU, for removal - Form_Del. On fig. 1, at class DETAIL_CLASS there is method Form_Select which is intended for substitution of values in fields of an external key. We shall note, that all methods can be overloaded, i.e. polymorphism at a level of a database according to the requirement (5) is realized.

The general scheme of extraction of the information and its display in the client appendix is presented on fig. 2

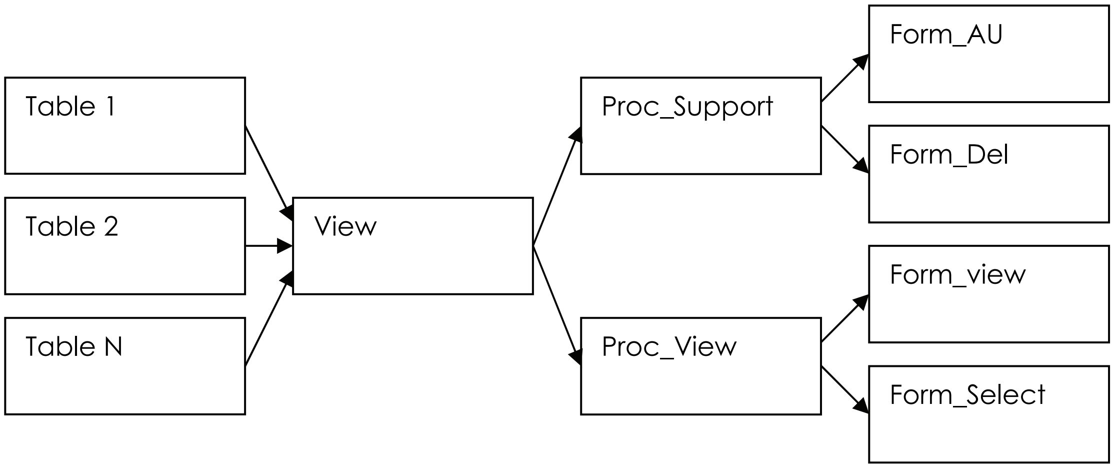

Fig. 2. - The Scheme of extraction of data

All given (elements of a metamodel and copies сущностей) are physically kept in tables of a database and taken by means of representation (View). Key advantage of representation is that on server DBMS representation is kept in откомпилированном a kind and there is an opportunity of creation of indexes on some fields. All it considerably raises speed of performance of inquiries in comparison with performance of dynamic inquiries which is applied in existing tools ORO. However it is necessary to provide an opportunity of performance of any inquiries on the basis of the transferred condition of a filtration. For these purposes are used хранимые procedures (Proc_Support, Proc_View). Finally, all data are displayed in graphic forms (Form_View, Form_AU, Form_Del, Form_Select).

At a choice of architecture of construction of an applied part of a complex is inexpedient to realize it in the form of the uniform universal "superappendix" integrating all necessary function, connected с a supply with information of university. Applied a component should represent a set of client appendices, specialized on realization of rather small set of functions precisely certain, as a rule. The part of "thin" clients should be used in the appendices intended for maintenance of functionality, connected with granting to the user of more developed interface (in sense of completeness of use of resources of a workstation, operational system). The part of "ultrathin" clients gives more simple interface which is sold by a Web-browser and not demanding use of specificity of operational system, a workstation and reports.

At such approach traditional concept « the automated workplace » (automated workplace) as the certain set of the hardware-software means realizing in advance ordered functionality in the fixed part of information system, is appreciably transformed. In the created system the equivalent of a traditional automated workplace is created dynamically, by delegation to the concrete user or groups of users of a set of the functions sold by specialized appendices required by the current moment which become for system as a whole elementary structural and resource units, alongside with elements of data. For example, at the dean and the methodologist of dean's office sets of specialized appendices offered by it and delegated access rights will differ according to their differing functional duties.

Conclusions

The described method and architecture of construction of system possesses a lot of the positive parties getting special value in existing, characteristic for university conditions of realization, support and use of a program complex of such level of complexity. The most important, in our opinion, are the following:

• independence and narrow enough functional specialization applied a component simplify their development and reduce terms of commissioning, uses for creation of such modules of less qualified developers, including students, essentially reducing the general vulnerability of system to leaving from university of experts - its developers enable;

• opportunities of development of system essentially become simpler. Escalating of its functionality is carried out by inclusion in structure of system of new applied modules or replacement become outdated without infringement of functioning of other subsystems;

• the cardinal image will facilitate introduction of system, labour input of its support will decrease;

• absence at appendices superfluous, not the functions necessary to the concrete user will essentially simplify their development by end users.

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PROVIDING OF PRECISION OF MECHANICAL PROCESSING WHICH REQUIRED ON NC MACHINES BY MEANS MODERN INFORMATION TECHNOLOGY

The problems of control automation and management precision of mechanical processing are considered on NC machines. The new method of processes verification of mechanical processing by means of integrated automated systems tools.

A problem of increase of efficiency of metal-workingness was and it remains one of main in an engineer. Large mass of wares of engineer is made in mechanical processing machine-tool modules in which a basic technological process is a cutting process, and control the system are the systems of numerical control (NC machines). One of methods of the effective use of this type of equipment is the use adaptive use of the modern computer-integrated automated systems in composition the complex of system software NC machines, which are decision-oriented wide circle of tasks.

Computer-integrated automated systems can be classified on the followings levels of automation [1]:

1. First level: automation of low-level, at which registration of technological document (strip, operating maps and other documents) and implementation of drawings drawings works is automated only (AutoCAD, VersaCAD, CADKEY).

2. Second level: automated calculation of simple technological tasks, search of optimum decision on the set criterion of optimality. The systems of this level (T-FLEX CAD, Solid Edge) are abbreviated by the terms of issue of document and time of development of projects due to automation of issue of designer and technological document, programming of 2,5-coordinate treatment of purveyances on NC machines. These systems allow to create the by volume model of good, which the inertia-mass are determined on, properties and other descriptions, the mutual location of details is controlled, all of types of mechanical processing on NC machines are designed, original appearance is processed on photorealistic images, a document is produced. In addition, a management is provided projects on the base of electronic documents calculation. An economic effect consists of frequent increase of the labour at sharp reduction of errors productivity and accordingly in the improvement of quality of wares.

3. Third level: automated calculation of intricate technological problems multilogic. The systems of this level (EDS Unigraphics, Pro/Engineer, CATIA or CADDS) provide integration of all of cycle of creation of good from planning, preparations to the production to making. They allow to construct details taking into account the features of material (plastic, metallic sheet), to conduct the dynamic analysis of assembling with the imitation of frame-clamping adaptations and instrument, to design rigging with the design of processes of making (stamping, casting, flexible), that eliminates marriage in rigging and does unnecessary making of model models, that considerably expenses and preparation time diminish to the production good. Programs of mathematical analysis such can include computer-aided design system property, kinematics and dynamic analysis. The design of mechanical processing allows to estimate quality of details from point of their deformation. The economic effect of the similar systems depends on the size of pay-envelope of designer or technologist and skills of the use computer-aided design system.

However insufficient equipped of designer and technological subdivisions modern computer-aided design system results in the incomplete working of structural and technological decisions, to the financial and temporal losses on the stage of making and during exploitation.

Therefore an increase of efficiency of cutting process is a topical scientific and technical task.

Complication of decision of problem is related to that a cutting process is characterized both unstable process with in a number of associate variables, influencing both on motion of process and on his results. Cutting terms dynamically change in time casual appearance from influence of different revolting factors: variation of allowances, variation of hardness and structure of metal of purveyances, continuously changing cuttings properties of instrument and other on the indexes of quality of treatment inflexibility and thermal deformation of elements of the technological system, character and parameters of relative vibrations of instrument, influences and flew, and others [2]. Program on NC machines can not take into account these factors, the calculation of the cutting modes is made on the worst possible variants, that provides more stable work of instrument and diminishes probability of marriage, but here scienter negatively tells on technical and economic efficiency and results in the decline of the productivity.

The problem of increase of efficiency of metal-workingness traditionally decided due to creation of the systems of the automated management metal-cutting machine-tools [1]. The systems of the automated management got the name of adaptive control the system, as allow continuously to correct the cutting modes, position of instrument, inflexibility of the system depending on the changes of terms of treatment, that enables to promote quality of making of details and productivity of treatment. Measuring strength of current in the anchor of electric motors of direct-current, machine-tools often applied in drives, it is possible easily to watch after power or twisting moment on the billow of electric motor and, consequently, after the change of technological parameters of process of metal-workingness. The method of control of instrument on power is extraordinarily simple, does not require interference with the construction of machine-tool, but effective at large enough forces of cutting and small power of idling of machine-tool [3]. At cutting considerable errors, related to the losses on a friction in the kinematics transmissions of machine-tool, appear with small forces. Because current of idling of electric motor of spindle a very little more increase of current is at cutting, for a sensitisation and exactness of work of adaptive control the system, a management is conducted on an increment of current size above the level of idling.

However interest to adaptive control the system, to functioning real-time, notedly went down for lack of mathematical models of the guided process of cutting. For the construction of exact mathematical models it is necessary to do the not alone series of experiments, that require time, materials and draws economic losses. Exact mathematical models, as a rule, are so difficult, that the rapid search of the optimum modes of cutting requires substantial vehicle expenses, results in a sharp rise in the prices of the adaptive systems and pointlessness of their use. The besides found model will have a constantly increasing error because of change of office and properties of equipment hours. A necessity to reconstruct a model from the continuously changing parameters of cutting process and determine a model structure in every case appears. The in-use presently adaptive systems have a hard structure and unchanging algorithm of functioning and, as a result, low quality of adaptation to the change of technological parameters.

Thus, becomes obviously, that the existent methods of management the indexes of exactness at treatment of details require systematization, allowing not only to choose a management method from already present but also develop the new method of management exactness if necessary [4].

Programmatic government machine-tools the determined going is underlaid near a task the trajectory of motion of instrument and cutting modes on information, to got from the draft of detail, purveyance and parameters of instrument, machine-tool. The program must provide the best approaching of the treated detail to its sizes, by the set draft, and maximal economy of output of metal [5]. However limited modern methods are that before the correction of trajectory of motion of instrument on NC machine the state of the technological system is taken into account not to a full degree.

To this time the task of providing of necessary exactness and high performance of processes of tooling is not decided in the environments of the computer-integrated automated systems. At functionality, unfar complaisant the authoritative producers of the adaptive systems, application of the computer-integrated automated systems considerably more cheap at providing of necessary authenticity of results of control of exactness of treatment.

Therefore, an author is develop the new method of verification of processes of tooling by facilities of the computer-integrated automated systems, which is based on comparing of CAD and

CAM – model to the model, got in the process of treatment taking into account information of other computer-integrated systems of the production setting. In the process of analysis takes a place concordances initial of information of «old» and «new» models, differences appear and if necessary corrections of treatment of detail is brought in on the bar of numerical control. A management processes will realize complete visualization of process of treatment: treatment of trajectories of moving of instrument and workings organs of machine-tool of elements of rigging in the mode of the real time.

An author probes the problems of verification of processes of tooling and it the effective use. Development will be realized in the informative environment of CAD/CAM/CAE – system of Catia of v6 company Dassault Systemes (France), which is ideologist of conception PLM, – decisions for most industries of industrial production.

In the stage of development independent programmatic subsystem of the automated management of tooling, which is built-in in the programmatic bar of numerical control and will allow to reduce the terms of development, improve exactness of workable operations of technological processes and control the program for an equipment with numerical control on the basis of the use of 3D-моделей and to promote efficiency of process control of tooling of details, exactness.

The of principle chart of control the system by exactness tooling and forming of executive for an equipment with numerical control is resulted on Fig. 1.

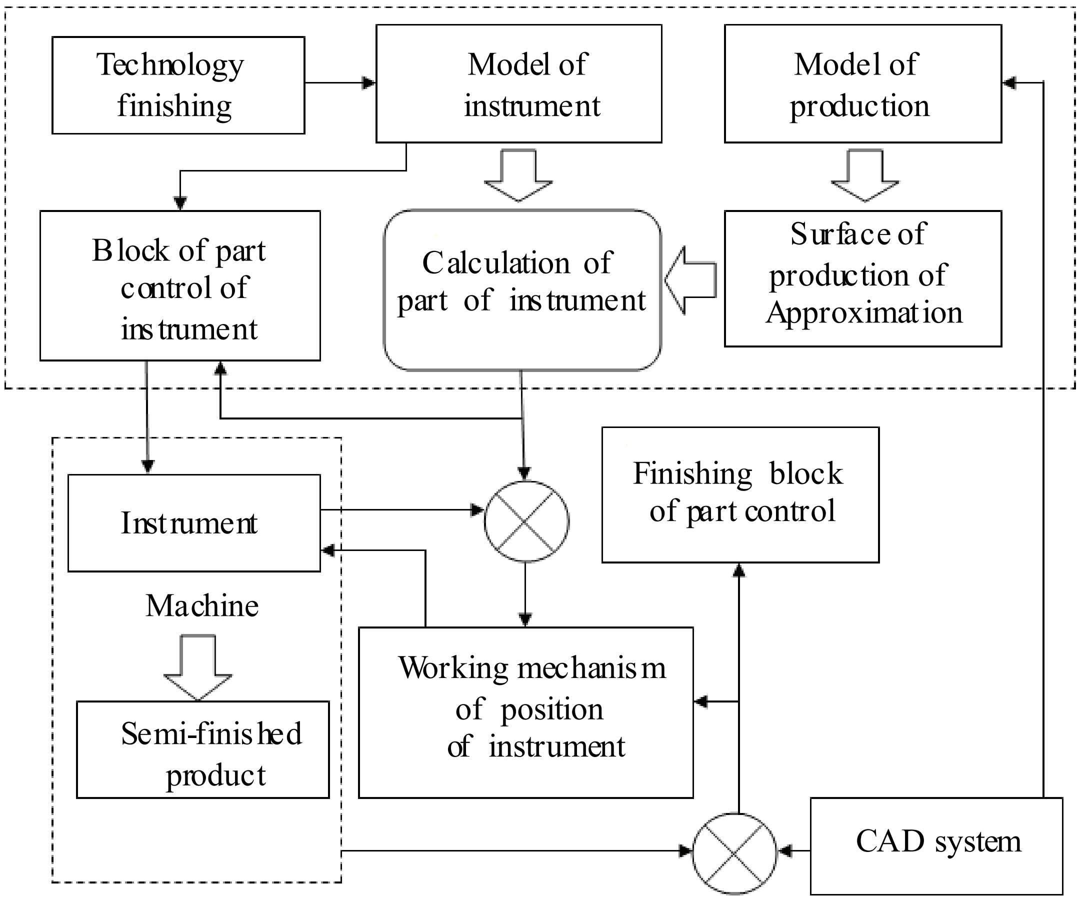

Fig.1. The principle chart of control system precision mechanical processing of good on the NC machine

Functioning of block of control of exactness of treatment is carried out in accordance with the mechanism of verification of modern CAD/CAM – systems, in basis of which comparing of initial (designer) model of detail is fixed to the model of detail which is got as a result of treatment. The estimation of exactness is a size of rejections of parameters of detail after treatment from its nominal parameters.

Conclusions

Thus, account and decision of afore-named tasks on introduction of new method of verification of processes of tooling will help to shorten the cycle of making of good facilities of the computer-integrated automated systems, decrease resource-demanding of good, decrease expenses on a production, to promote quality of good and competitiveness of enterprise.

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ANALYSIS OF THE PROCESSES OF SPECIALISTS TRAINING ON THE IMPLEMENTATION OF INDUSTRIAL INFORMATION TECHNOLOGIES

The article concerns the analysis of the process of specialists training and recurrent training on information technologies implementation into the industrial sphere. The article considers personnel training as long-term beneficial investment into the corporation prosperity.

Introduction. To provide CALS-technologies and PLM-solutions efficient implementation and utilization, competitive domestic industry has to have an ultimate number of engineers, who deal with design, construction and operation of equipment with intensive use of electronic technologies. Thus, one of the most important state targets in scientific and technical policy that identify the level of economic and national security of Ukraine in coming years, must be [1]:

- organization of wide variety of science-based and design-based researches on development and implementation of CALS-technologies, PLM-solutions and ISO Standards (hereinafter IT);
- establishing products and services market in the sphere of IT and PLM-solutions providing their efficient application in various fields of industry;
- implementation of specialists training methods on IT implementation into industrial sphere.

Purpose. The purpose of this article is to provide comprehensive analysis of the problem of qualitative enhancement of personnel training for high tech manufacturing enterprises of Ukraine by means of various training activities that promote personnel professional development.

Analysis. Enterprise personnel policy, educational policy in particular, strongly influences the financial contribution, assigned for training, as well as for methods and types of training, that are to be financed. One of the ways to persuade the employer raise financial support for training is to highlight the training as an investment, not as an irretrievable expenses. This type of approach is characterized by the notion “human capital”. It was introduced by G. Becker, human resource specialist. According to it training is considered as other investment projects.

Following such kind of approach employers would organize training and monitor gaining maximum profit from their investment. They will show great interest in managing the processes of training cost compensation, reduction of spending caused by labor turnover, specialists selection processes and personnel skill and competency relevance.

Personnel continuous training nowadays has become standardized for leading world companies. According to the forecast of a large number of analysts, 500 large companies annually devote 53 hours to average specialist training financed by the company. However, as for the present data analysis, this kind of the forecast hasn’t fully met the real requirement of the companies in training. For instance, in 1995 each specialist of “Texas Instruments” spent 40 hours on upgrading training (to compare with 1990 – 25 hours). “Motorola Company” plans to increase its standard up to 200 hours per year per specialist [2].

76% of American corporations with number of employees 500 people and more have their own programs of human resources training and recurrent training [3]. For example, “General Motors” Corporation annually spends $80 million on recurrent training of its employees.

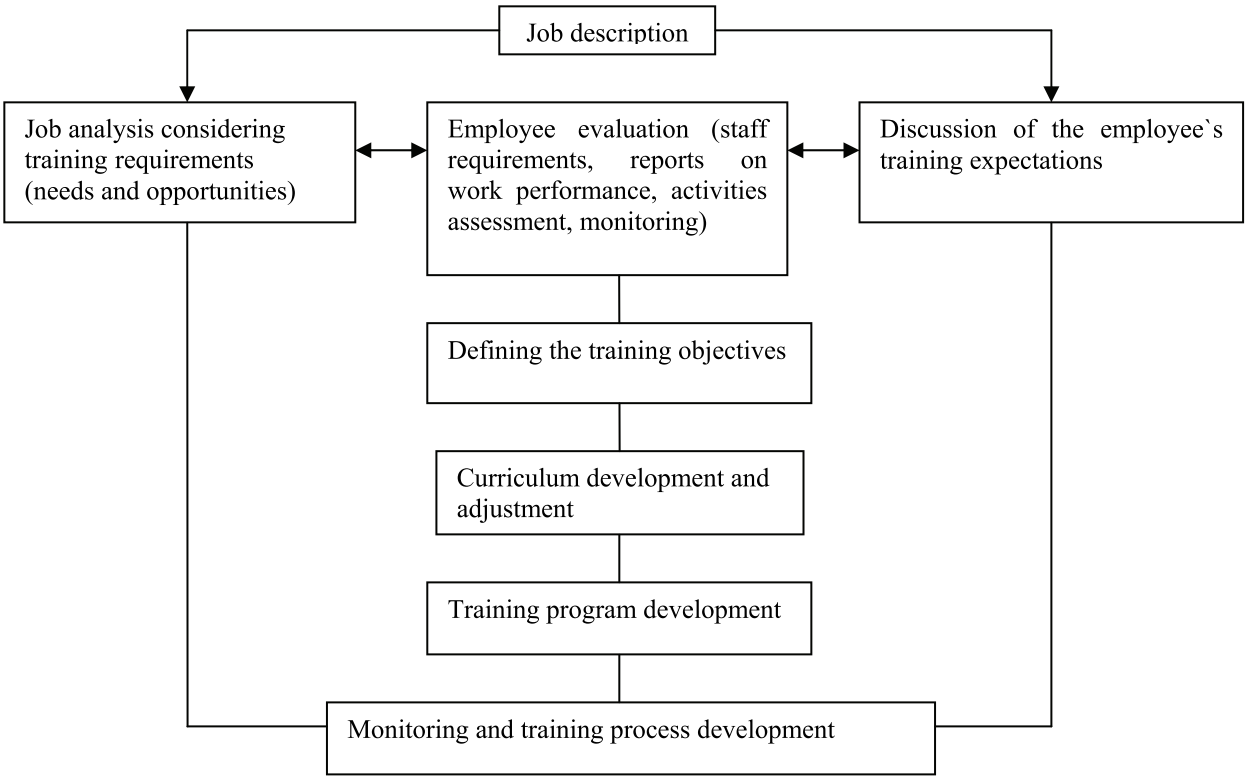

Fig.1. Stages of training process planning

Besides the direct influence of the investments on the financial results by means of professional skills development it contributes to creating the positive climate in the organization. These investments also motivate employees, increase their commitment to the organization and provide the succession in management.

Professional skills development positively influences employees as well. By raising the level of their qualification and acquiring new skills and knowledge they become more competitive in the labor market and get additional opportunities for professional advancement both in their company and beyond it [4]. This is particularly important in present-day conditions of quick moral ageing of professional knowledge. Professional training contributes to general intellectual development of a person. It broadens person`s outlook, social network and increases one`s self confidence.

Specialists training on the IT implementation is the process that includes: planning, management of functioning and training process development, monitoring and coordination.

The general scheme of specialists training is given on Fig. 2. The given scheme is of continuous development type. First of all this is connected with the rapid IT development and multitasking of these technologies implementation into commercial production.

The resulting expression that characterizes the training system as a whole is the complex function (S(z,u,n)): its parameters are variables (z, u and n) that show specialists level of knowledge, abilities and skills.

The development of specialists training system is carried out by the processes of its interaction with the environment. Environment influences the training system by means of the demand for certain specialists training as well as requirements to the level of training of these specialists (M (z',u',n')).

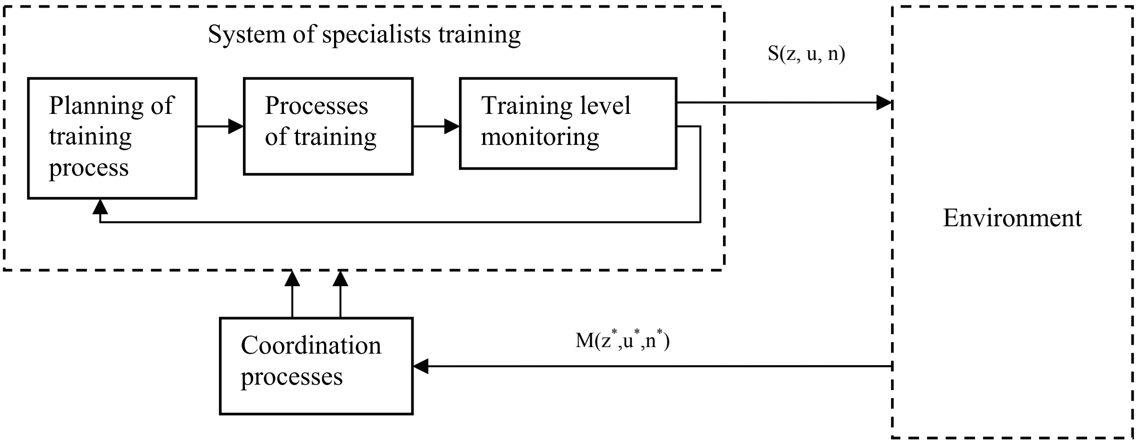

Fig. 2. General scheme of specialists training

System analysis of trainees knowledge, abilities and skills formation process allows to define the following structural elements of the training system: object, subject and training environment. The environment in its turn can be characterized by the process of knowledge, abilities and skills acquisition (Fig. 3).

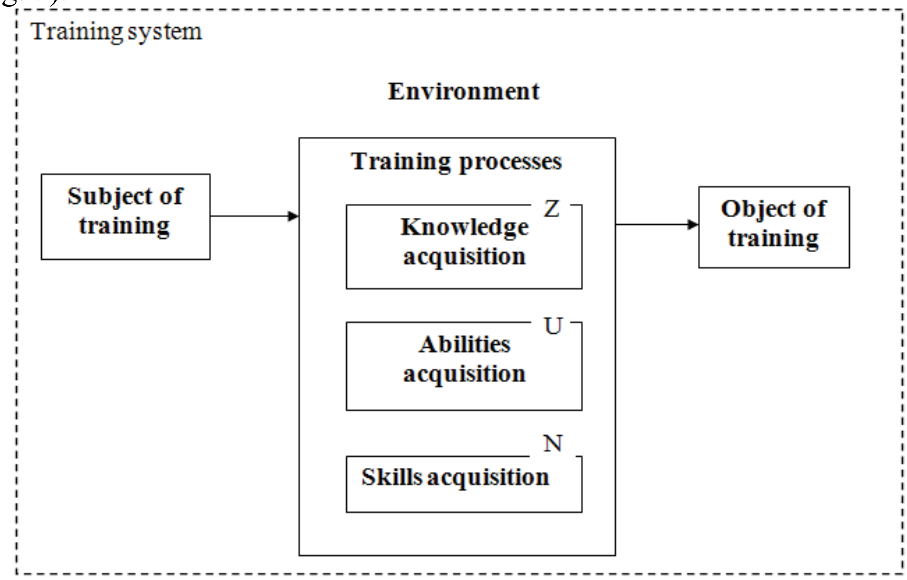

Fig. 3. Fundamental processes of specialists training

The performed analysis allows to determine the following three categories of training process results and respective facts.

Theoretical knowledge is a regulated complex of data, usually of actual or procedure nature, application of which allows to complete tasks adequately. To have knowledge does not usually mean to use it. It concerns knowledge that was acquired during theoretical studies (lectures and group work). They form the system of knowledge concerning the purpose, characteristics, principles of training discipline, methodology of its application etc.

Practical abilities are abilities required for the performance of certain function while carrying out job functions. Such abilities are regarded as those formed during practical training of completing tasks (for instance, programming ability, ability to use special software, production management ability, resources planning ability etc.). The application of certain basic knowledge is very often required for the display of these abilities.

Practical skills are skills to carry out easily and precisely actions required for qualitative work performance. As for skills it is necessary to set a certain standard which is necessary to meet for efficient work performance. This category includes skills of task performance (for instance, typing skills, hardware assembling skills, programming skills etc.) which are formed while practical and individual training.

The efficiency of IT implementation into manufacturing process depends on the level of qualification, meaning the level of knowledge, abilities and skills of specialists. The task of forming appropriate integral level of knowledge, abilities and skills must be scientifically grounded for the development of efficient training system.

The present forms of training qualified specialists take 4 years. This duration increases depending on given qualification level. Taking into consideration the necessity of introducing new specialties and specializations for the implementation of information technologies this term can be extended.

But by integration of different forms of education (training) specialists, the duration is likely to be shortened due to raise of its intensity caused by growing interest among objects of training and new training technologies.

Summary. Information technologies implementation requires new approach to training specialists who can successfully meet challenges and demands of the industry. Corporations should increase their financial and other contributions to human resources training. From the other hand methodological and pedagogical aspects of the training analysis should make training closer to the demands of the industry by the intensification of training process and efficiency of the training system, but not on the basis of the training duration increase.

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USE OF THE COMPUTER-INTEGRATED AUTOMATED SYSTEMS FOR INCREASE OF EFFICIENCY OF PRODUCTION OF ENTERPRISES OF SPACE-AIR COMPLEX OF UKRAINE

In the article the methods of increase of efficiency of production of space-air complex of Ukraine enterprises are considered due to the use of control the system, prognostication and control of dynamics of the productivity of equipment during optimization of processes of modernization and load of park of equipment.

Presently enterprises and organizations of space-air complex (SAC) of Ukraine are in a difficult situation: high level of wear of capital assets, failing or absence of investments for his renewal, low efficiency of production, loss and obsolescence of technologies, shortage of highly skilled specialists, strong competition from the side of foreign enterprises. Such situation does vitally important the question of increase of efficiency of development and introduction of new technologies, allowing to produce competitive the high technology products at a minimum of expenses and permanent shortage of resources processes (personnel, raw material, equipment).

For the decision of these problems lately all more frequent utilize the methods of reengineering of business processes of enterprise. Correctly conducted reengineering of business processes allows on ten of percents, and sometimes and in times to increase efficiency of work of industrial enterprises, but often the projects of reengineering of business processes do not arrive at the planned results from the shortage of circulating assets and investments, that is directly related to capitalization of enterprise. We will consider possibilities of decision of these problems, coming from experience of the developed countries and possibilities of modern information technologies.

Capitalization of industrial enterprise is estimated quantitative description of efficiency of the use of his assets. In this article we examine an asset as set production equipment of enterprise and infrastructure, providing him work. Capitalization characterizes a not so much asset as thing, how many asset which works. The cost of asset can be presented as an increase of cost of the claimed product, producible an asset in time unit, on the supposed time of his functioning. The cost of domestic tangible assets comparatively with their foreign analogues is very low. At many machine-building productions of SAC market value below in dozens of one time or in general near to the zero. It is needed to modernize and replace these assets because their life cycle is closed. Replacing out-of-date assets is desirable on more effective. But it is important for the decision of problem of low cost of assets, that the modernized assets belonged to the high-quality new type which is added digitizing. Digital productive assets allow exactly to set, how many and what resources they consume on an entrance, how many products and services are given out on an output. And more main than all, digital qualities of assets provide prognostication of dynamics of their productivity. Only then bringing in of investments becomes possible on modernization projects.

The project of reengineering of business processes for the increase of capitalization of enterprise must link three various project levels at least:

- at the level of **production technologies** it is necessary due to partial, limited modernization or replacement of assets to add them additional digital quality;

- at the level of **information technologies** it is necessary to conduct such processing of these digital data, to provide monitoring and prognosis of dynamics of the productivity of our assets;

- at the level of **financial technologies** it is necessary to put the got function of the productivity of assets in the formula of capitalization. That it is needed to convert the specified prognosis of the productivity of assets in an investment project and construct the system of financial streams due to which it is possible to return on the level of production technologies and continue - in increasing volumes - modernization and replacement of productive assets.

To get investments under the project of modernization of enterprise possibly only in case if this project submits the hard standards of financial technologies, such, that a potential investor will be able expressly to count up, how many times it will be needed for returning of credit and how it will be done. In an order to do the prognosis estimation of capitalization, it is necessary foremost to digitize the productivity of production fund and build the expected dynamics of its change. It is needed to convert replacement of every unit of equipment into an attractive investment project with concrete parameters and terms of returning of facilities. For the increase of term of investments which are attracted, the prognosis of capitalization of every asset, based on the maximally exact estimation of his working resource which remains, and prognosis of dynamics of his productivity, is needed. In the developed countries of the world for drafting of such prognoses the systems of type of EAM are utilized (Enterprise Asset Management is a management the capital assets of enterprise, allow to shorten the outages of equipment, expenses on maintenance, repair and material and technical supply.).

Thus, the project of reengineering of business processes must be divided into a few stages. First stage - the shortest, he requires relatively small facilities and consists in optimization of functioning of asset. Optimization is arrived at due to setting of the special automation and software, which allow partly to digitize an asset. As a result accumulates and summarized information about the features of his functioning. The informative portrait of asset allows, improving adjusting, to attain winning in the productivity on 2-3%. The second stage is a transition from preventive-maintenance model repairs to address one, adjusted exactly on this asset. For this purpose developed or acquired the special software [1]. Due to it time of outage is abbreviated in repairs and the increase of the productivity is possible already on 10-12%. It allows yet to grow a profit, produce credit history, increase the degree of digitizing of asset. Then on the third stage becomes possible, increasing capitalization of asset, to attract facilities on the project of his modernization and complete replacement.

The second problem of enterprises of SAC is in that assets are under loaded. In an order maximally to load assets, it is necessary to go out for scopes an enterprise, construct chains, schemes, networks of production of new products and services, new cost, which an asset after it must be built-in in, that him fully to load. It means that most resources which are needed for realization of this chain, are out of enterprise: in the system of public necessities, skilled institutes, in the network of suppliers, in a transport infrastructure, organization of public safety, organs of standardization, communication networks and pr.

Activity of asset, or capital goods, it is possible to divide into some groups (to decomposition). At first, to know how he will behave farther, it is needed to understand that he is, his technical descriptions, parameters. Secondly, it is needed to understand the modes which he worked in, what events with him took a place and that is reason of these events. Under events are different sort of breakage, stop, non-extradition of regular parameters upstairs. All of these information are fixed in repair data cards, imperfect information. For every group of assets there is the detailed plan of exploitation on the basis of technical descriptions of factory-producer and history of work of every unit that, on statistics, gives the cutback of spending on technical service from two to four percents.

Thirdly, it is needed to take into account the so-called surroundings of asset, where he is. The same equipment, good in the different chain lets of production process variously influences on return of capital investments. It is necessary to take into account all of measures, related to accident prevention: it is needed to execute certain procedures at repair, in a number of cases guilty to be workers geared-up definitely. All of the transferred groups of parameters need to be known and in a comfortable on your own kind to have before eyes in an order to forecast making of asset in the nearest years. For the management of assets in obedience to the resulted method it is necessary to collect and take into account plenty of information - on work, outages, dynamics of the technical state of assets, to the charges of financial and financial resources on providing of exploitation, on carrying out of major repairs et cetera. Capture of these data hand mode, in a paper form is not possible. The use of primary facilities of automation, such as spreadsheets of Excel, does not allow to organize collection of information from a few sources. As a rule, original sources of necessary information are in different subsections of enterprise, territorial remote from a main office. Therefore the processes of collection and treatment of such information can be organized only facilities of the integrated system of management, prognostication and control (SMPC) of dynamics of productivity of the equipment, which provides single informative space for all of participants, monitoring a dynamics, regardless of place of their location, supports the comfortable system of diagnostics of technical parameters of production asset and has control the system for control all of parameters of assets.

On the basis of computer design possibility to correlate charges which are required by a that or other asset appears in such system of management, prognostication and control of dynamics of productivity of the equipment, with profits, by him producible, that will allow to correlate them and with return of capital investments of new facilities productions which appear today at the market [2-3]. If the parameters of new assets are more advantageous (low running cost, the best productivity, large return of capital investments of asset on his technical descriptions), then possibility to make the business plan of investment project on replacement of equipment appears, under which it is possible to attract money facilities, or to make an analogical business plan on repair of equipment, if in this case to repair an asset it is advantageous, what to replace. Making the informative portrait of every asset, it is possible to move him aside incomplete service or reservice, depending on his place in a technological chains. Managing these moments, it is possible again more active to manage the cost of charges on repair and technical service. The management of assets is conducted with the purpose of receipt of the set indexes of their functioning taking into account external and system of providing of capacity environments. Indexes can be reliability indicators (intensity of refuses, coefficient of readiness) and technical and economic indicators (volume of the produced products, expenses, income, profitability). The optimum term of service of asset can be certain on a minimum of specific charges which are on work machine time, a maximum of specific income, set level of profitability. The model of determination of terms of service on the minimum of specific charges and a maximum of specific income (optimum values coincide approximately) is expedient to apply in the case of presence at exploiting organization of facilities for the update of assets. The model of a minimum of level of profitability is applicable for enterprises which feel the deficit of facilities for modernization of assets [4].

Thus, the integrated system of management, prognostication and control of dynamics of productivity of the equipment must contain the programmatic modules or be computer-integrated with the systems, carrying out planning and account of measures of providing of capacity of assets, calculation of indexes in accordance with a method, optimization of business processes, including age-dating, by anchorwomen electronic catalogue of repair parts, base of these suppliers products and services, customers, personnel, market of technique et cetera. Basis for functioning of the integrated system of management, prognostication and control of dynamics of productivity of the equipment are databases, which contain information on repair parts and materials of every unit of asset, to the types of maintenance and repairs, present repair equipment, to the technical and repair document et cetera. As to every object of technical service and repair all of regulation works on him and necessary for them resources are connected, the plans of future works and requirement in repair parts and materials must be formed in automatically. On the basis of accumulated in SMPC of information and with the purpose of realization of the method described higher, analytical forms, which represent results, and also prognosis of descriptions of technical exploitation for set period of time, must be formed in the integrated system of management, prognostication and control of dynamics of productivity of the equipment, in the set subsection, on the certain type of technique et cetera. On the basis of operating information in the integrated system of management, prognostication and control of dynamics of productivity of the equipment must settle accounts also reliability indicators for every unit of asset with the use of information which characterize exploitation exactly of this unit. To other tasks of the integrated system of management, prognostication and control of dynamics of productivity of the equipment will take optimization of structure of productive assets, control and upgrading technical service and repair, realization of methods of planning of technical service and repair on work, on the technical state, for minimization of organizational financial charges at technical service and repair et cetera [4].

Conclusions

It is necessary to take into account during reengineering of business processes enterprises of space-air complex, that to one of problems, impedimental modernization of production for the increase of his efficiency, there is low capitalization of enterprises, related to incomplete loading of their assets and complication of prognostication of dynamics of the productivity of equipment. Specially developed computer-integrated automated control the system management, prognostication and control of the productivity of equipment a dynamics can help in the decision of this problem. Such the integrated system of management, prognostication and control of dynamics of productivity of the equipment is not only software or database, by but also a flexible instrument for perfection of processes of exploitation of difficult technical objects and systems, effective both for small enterprises and for large production amalgamations.

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INFORMATION TECHNOLOGY DECISION SUPPORT SOFTWARE PRODUCTION ORDERS

The article deals with formal description of the stages of information technology decision support for production orders, the use of which provides automation of analysis and assessment orders.

One of the main problems of effective functioning of the machine-building enterprises are receiving production orders and making optimal decisions regarding it. Performance decision to order depends on many factors. This, above all, reliability and efficiency of design, manufacturing and planning data that is constantly changing. Unfortunately, the machine-building enterprises of Ukraine did not solve the problem of creating an integrated information environment and ensure the exchange of data between integrated systems, automated production management ERP-systems and product data management PDM-system. Lack of such integration and automation level of technical training facilities and CAD systems CAD/CAM- TP [1].

Automation assessment task order requires information from different business units or companies mentioned above with embedded systems. That is, there is an urgent need to develop an integrated subsystem to universal automated systems for industrial purposes that could efficiently and effectively for a given company received orders to provide assessment [2]. Combining data on existing products and the company's resources and time can significantly reduce the time of product design and technological preparation of its production, as well as timely coordinate with the customer specifications through quick access to information and the optimum solution order.

Therefore an actual problem as formal design procedures for evaluating the order and presentation of the results as a method of automated analysis and evaluation of production orders, and is presented in this article.

Investigation of the analysis and evaluation of production orders for basic engineering plants showed that the decisions involved specialists of various services with diverse information. Data analysis, formulation and decision making processes algorithmization allowed to develop two interrelated methods, such as evaluation method of production order and method of correcting the parameters of the process.

Further development of design methods and procedures of the relevant development applications in integrated information environment of automated manufacturing systems and technical training at the PDM-system ENOVIA SmarTeam V6 provided the solution described above scientific and technical problems.

For further use of methods and software analysis and evaluation of production orders developed technology information support of decision making to order. In general terms this technology is presented as a sequence of steps to determine the capacity and the economic effect of production on order. Examine in detail each of these steps:

Step 1. Upon receipt of a formalized order (according to the requirements of the enterprise), a preliminary estimate of product. During the evaluation experts of marketing or other departments of the enterprise allow manufacturing feasibility of the product based on general characteristics such as product dimensions, the requirements for the quality (accuracy, stiffness, etc..), material etc..

Step 2. After receiving a positive decision sends expert input order for further processing in an integrated subsystem Orders. Subsystem includes a set of application input data order analysis, analysis and processing of existing databases and implementation methods, namely:

1. ANALOG - searches analogue technological process;
2. MARSH - sets the technological operations and their sequence;
3. RESUR - identifies necessary resources;
4. VARIAN - sets of equipment options;

5. FINAN - calculates the financial performance of manufacturing products to order;

6. RISHEN - builds ranking orders.

During the 2-nd stage is unique product-search order and the relevant existing technological processes (TP) of their production (Fig. 1).

If TP analysis of existing production equipment and other resources. In the absence of TP-analogue or model or group TP developed possible route, which generally formulated a sequence of operations and product manufacturing. This uses software module «MARSH».

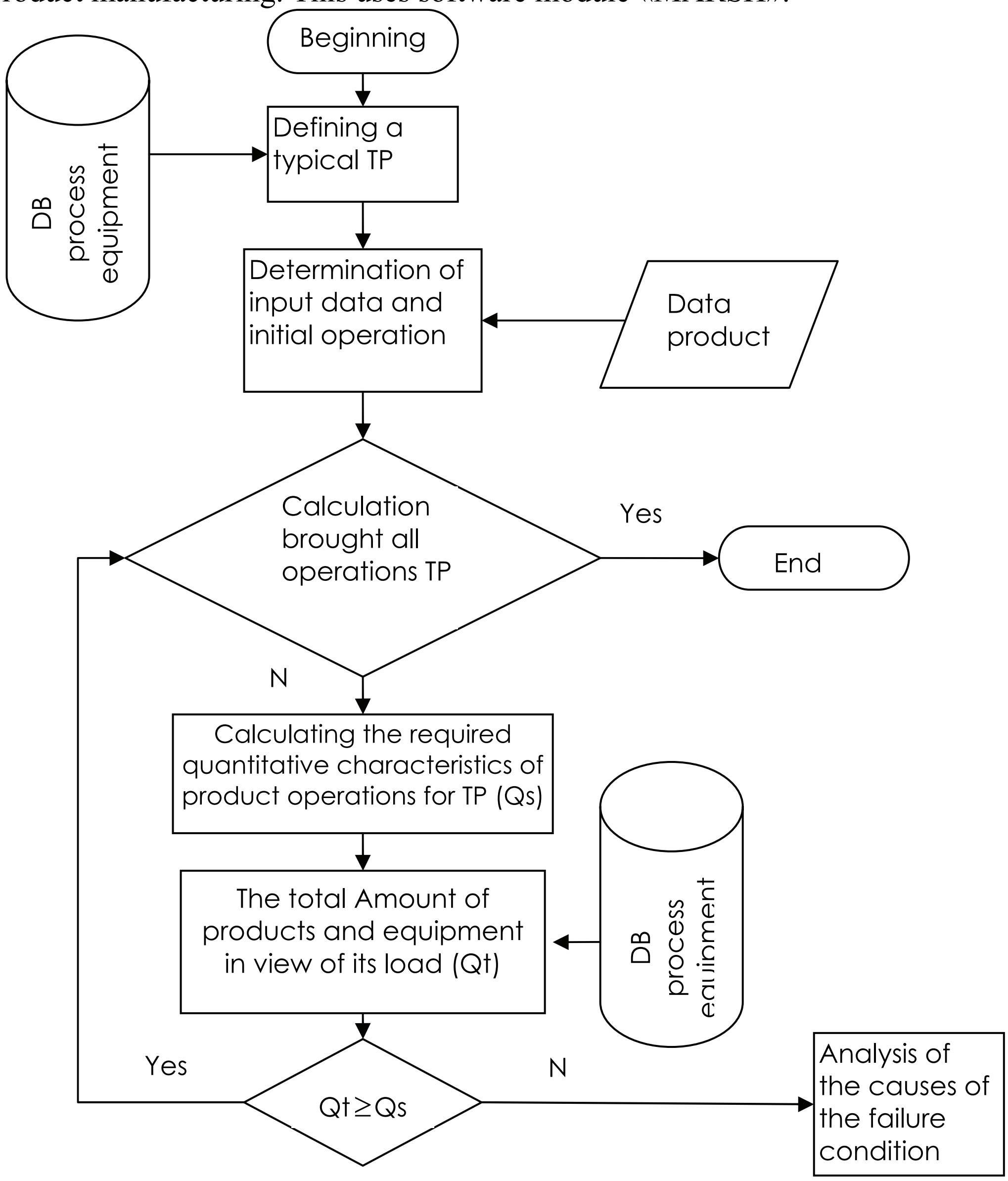

Fig.1 An algorithm for the structure determination of free TP and production capacity.

Step 3. Having the data structure of technological process of manufacturing the product, determine the capacity of free equipment, taking into account the parameters of the product and equipment, technological equipment and mode of the fund. This phase is time consuming and requires information support databases (DB) equipment and equipment.

Also available at this stage design and technological documentation for the types of physical and mechanical characteristics of products. Given the foregoing, the subsystem calculates the number of products that can be made on this equipment by the formula:

$$N = \frac{Rf - Tz}{Pt}$$

where Rf - fund custodial time;

Tz - loading equipment (time required for the manufacture of products included in the plan production for a given period);

Pt - standard time.

To evaluate the capacity issue given the number of products customized subsystem controls the amount of unfinished product at each operation TP:

$$Np = \{np_1, np_2, ..., np_o\},$$

where np_o - the estimated number of unfinished production at each production operations;

o - number of technological operations.

Thus, the technical capacity () production of these products on the number of existing industrial areas determined by the formula:

$$TP = (n_1 \geq np_1) \wedge (n_2 \geq np_2) \wedge ...(n_k \geq np_o)$$

Step 4. With information about production capacity of existing products in the enterprise resource, choose options for equipment and technological equipment, including design and technological documentation for customized products [3]. In case of failure of execution, enterprise technologists analysis of possible reasons (lack of equipment with predetermined characteristics, loading equipment, insufficient fund custodial time, etc.) and possible solutions. Information Service database and rigging equipment is a primary condition for this phase.

Step 5. Setting at the previous stage production resources required to perform production order, identify options for equipment. During their use additive selection criterion [4], which includes:

a) assessment of variable costs (fz);

b) expert evaluation of the level of complexity of equipment setup (fe);

c) the assessment technological equipment (fc);

d) evaluation of free production capacity (fi);

e) evaluating equipment (fx).

For each variant of process equipment that meets the restrictions subsystem calculates the target function and the number of products that can be made on this equipment under the existing conditions of loading and variability in the formula:

$$Fc(d) = (k_1 \times fz(d) + k_2 \times fe(d) + k_3 \times fc(d) \ ) + k_4 \times ft(d) + k_5 \times fx(d)$$

where d - variants equipment;

k_{1-5} - weights, which reflect the importance of criteria.

Step 6. Identifying options for manufacturing equipment, tools and the complexity of setting up machines and set variable costs that continue to shape the data to calculate the marginal income method [5,6].

The aim of the method of calculation of marginal revenue is determining the possible financial results of the order, which is to assess the value of profits (losses) from sales. Each product (R) is characterized by variable costs (C), price (S) and volume of sales (Q).

Profit margin (A) individual products are determined by the formula:

$$\mathrm{A}_i = \sum_{j=1}^{n} (S_j - C_j) \times Q_j$$

where n - number j - of those contracts for specific products.

Relative gross income (Av) shows marginal income share in production value:

$$\mathrm{A}v = \frac{\sum_{j=1}^{n} (S_j - C_j) \times Q_j}{\sum_{j=1}^{n} S_j \times S_j}$$

Depending on the relative value of marginal income subsystem performs formation rating products.

Step 7. After analysis and evaluation specialists order subsystem provides enterprise information support necessary for the optimum solution for this company for a particular production order. This information includes:

1. Answer questions may make this number to order products with existing enterprise resources with a light load fund equipment and mode of time.
2. In case of failure to release products in order establishes the causes and possible solutions.
3. Economic indicators of the order.

Each stage requires appropriate training and clear coordination of specialists and experts of the company.

Conclusions

Using information technology decision support customized and relevant software provides for the exchange and access to data about products, processes and resources that provides the acceleration agreement on contract obligations. Using technology to significantly reduced at short notice to answer the question: is it possible to manufacture products according to customer requirements and what economic effect it will have?

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THE PROBABILISTIC MODEL OF KEYS GENERATION OF QKD SYSTEMS

The probabilistic model of keys generation of QKD systems is proposed. The model includes all phases of keys generation starting from photons generation to states detection taking characteristics of fiber-optics components into account. The paper describes the tree of events of QKD systems. Equations are found for estimation of the effectiveness of the process of sifted keys generation as well as for bit-error probability and for the rate of private keys generation.

Nowadays, the research of quantum cryptography transforms from theoretical models to practical implementations. The quantum key distribution is a branch of quantum cryptography in which scientists reach the most of practical results [1, 2]. Id Quantque (Switzerland) [3], MagiQ Technologies (USA) [4], SmartQuantum (France) [5], Quintessence Labs (Australia) [6] commercial companies offer first on the market quantum key distribution systems.

One of the main problems of quantum key distribution is low rate of private keys generation [7]. For example, Id 3100 Clavis2 system generates raw keys with the rate of about 500 bits per second when the length of quantum channel is shorter than 25 km [8]. Rates of keys generation of QKD systems of other companies are also not too high. It should be noted, that with increase of quantum channel length the rate of keys generation decreases.

Significant difference between the rates of raw and private keys generation is an interesting fact [9]. The rate of raw keys generation depends from the rate of photon generation, coefficient of photon transmission and photon detection efficiency. The rate of private keys generation depends from the rate of raw keys generation and bit-error probability. So the main stages of keys generation process are photon generation, photon transmission, basis selection and photon detection.

The tree of events of QKD systems is constructed taking into account the main stages of keys generation process (Figure 1).

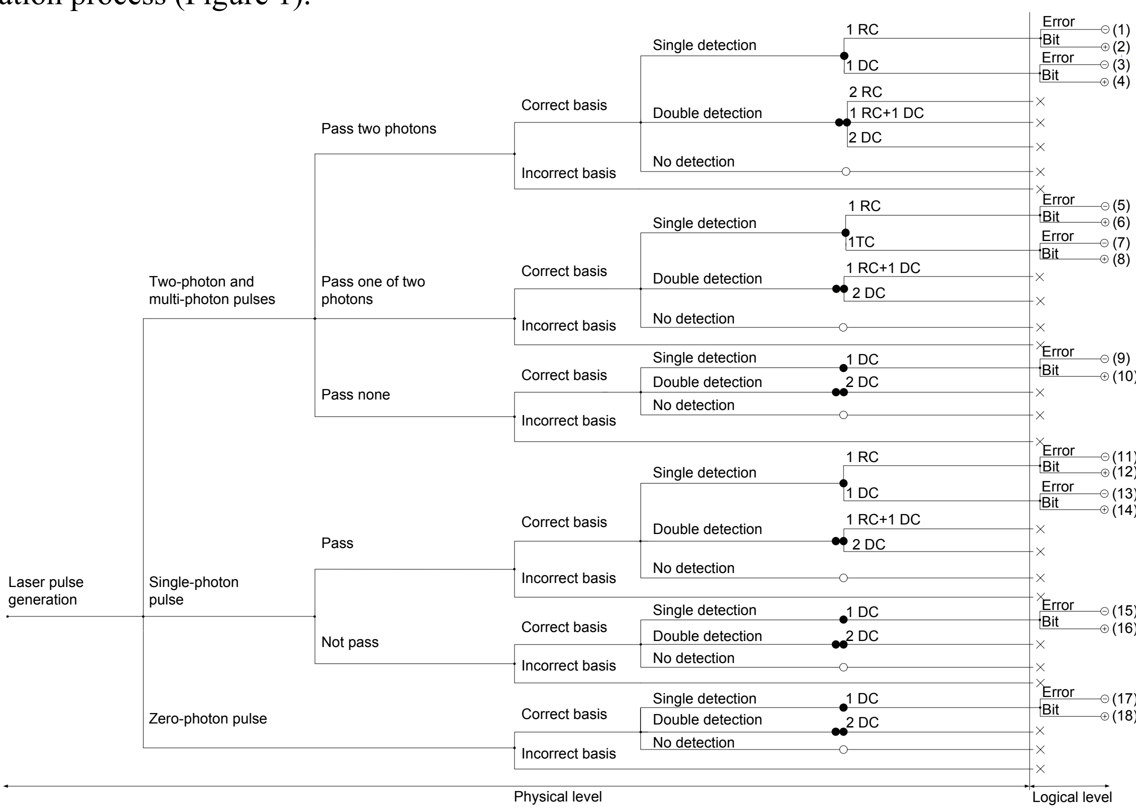

Figure 1. Tree of events of QKD systems.

The tree of events divides into physical and logical levels. The physical level consists of photon generation, photon transmission, basis selection and photon detection processes. The logical level consists of process of getting information about value of sifted keys bits and bit-error probability estimation process.

The root of tree is the event of laser pulse generation which has the probability $p_{si} = 1$. Each branch of tree corresponds to event that occurred at each stage of key generation. First junction of tree corresponds to the process of photon generation. Commercial QKD systems [3-5] use attenuated laser pulse for single photon generation. There are three branches because there are probability of zero-photon pulses $p_0(\mu)$, single-photon pulses probability $p_1(\mu)$ and two- and multi-photon pulses probability $p_2(\mu)$. $p_2(\mu)$ is combined of probabilities of pulses with two and more photons and is calculated as $p_2(\mu) = 1 - p_0(\mu) - p_1(\mu)$. For more precise calculation of the probability of multi-photon pulses expression $p_n(\mu) = \frac{\mu^n}{n!} \cdot \exp(-\mu)$ is used, where μ is average number of photons per pulse, n is a quantity of photons per pulse. The average number of photons per pulse is calculated as $\mu(\alpha_{qc}, \alpha_{voaA}, \alpha_{voaB}) = \frac{E_{lp} \cdot f(\alpha_{qc}, \alpha_{voaA}, \alpha_{voaB})}{E_p}$, where E_{lp} is energy of laser pulse, E_p is energy of single photon, α_{qc} is a transfer ratio of quantum channel, α_{voaA} is a transfer ratio of Alice's variable optical attenuator, α_{voaB} is a transfer ratio of Bob's variable optical attenuator.

The average number of photons $\mu \in (0.1, 0.5)$ is used as an optimal level in QKD systems [10]. If $\mu > 0.5$ then the probability of multi-photon pulses increases and intercept security against photon number split attack decreases. The probability $p_2(0.5) \approx 0.09$ includes the probability of two-photon pulses of 0.076, so the probability of multi-photon pulses is lesser than 0.02. Figure 1 demonstrates the tree with 3 branches of events of photon generation process.

If alternative principle of photon generation process is used in given QKD system then other function of probability distribution will be used [11, 12].

Next junction of the tree at the path of non-zero photon pulse describes the photon transmission process. For single-photon pulses there are two possible branches: pass / not pass. For two-photon pulses there are three possible branches: pass two photons / pass one of two photons / pass none. For multi-photon pulses the number of possible branches is $n+1$. The probability of each one of them is a function of number of photons per pulse $p_m(n) = C_n^m \cdot (1 - p_{qc}(\alpha_{qc}))^{n-m} \cdot p_{qc}(\alpha_{qc})^m$, where α_{qc} is transfer ratio of quantum channel and $p_{qc}(\alpha_{qc})$ is probability for the photon to pass through the quantum channel, m is quantity of transmitted photons, n is the quantity of photons per pulse.

The basis selection process is defined by quantum protocol implementation. Commercial QKD systems [3-5] are using BB84 and SARG04 protocols. The probability of correct basis selection is $p_{cb} = p\{B \mid A\} = p\{0 \mid 0\} + p\{\pi/2 \mid \pi/2\} + p\{0 \mid \pi\} + p\{\pi/2 \mid 3\pi/2\}$. Therefore, the probability of incorrect basis selection is $1 - p_{cb}$. If all $p\{A\}$ where $A \in \{0, \pi/2, \pi, 3\pi/2\}$ are equal and all $p\{B\}$ where $B \in \{0, \pi/2\}$ are equal then $p_{cb} = 0.5$. The process of basis selection is positioned at physical level because it is implemented by fiber-optic phase modulator.

Next to last junction of the tree on physical level there is the photon detection process. It is well known that commercial QKD systems have two single photon detectors based on avalanche photodiodes. So branches refer to following events: no detection / single detection / double detection. These events describe how many detectors trigger when photon pulse arrives. Events are depicted on Figure 1 with ○ for no detection events, ● for single detection events and ●● for double detection events. Next junctions of the tree are related to the cause of detection. The single photon detectors based on avalanche photodiode have two causes of triggering: a dark count or a real count.

The real count probability is $p_i(\eta_j) = 1 - \exp(-p_a \cdot \eta_j \cdot i)$ where i is the quantity of photons at entrance of single photon detector, j is the ordinal number of the detector and p_a is the probability of triggering the avalanche event that exceeds the threshold by each carrier. The dark count probability is $p(dc_j) = 1 - \exp(-p_a \cdot N_d)$ where N_d is the average number of dark carriers in the multiplication region of the j detector [13].

Only single photon detection events are processed at logical level. All other events do not contain the information about the bit value of the keys.

As the result the two branches are available at the last stage: there is a correct bit or there is an error bit. Symbol $\oplus$ denotes events which lead to the correct bit of the shifted key as the result, and symbol $\ominus$ denotes events which have the error bit of the shifted key as the result. All events at the last stage are numbered.

In accordance with the tree of events of QKD systems all outcomes are united into two groups which both consist of two sub-groups:

1. Generating of the error bit
   a. as the result of the dark count on single photon detector (events 3, 7, 9, 13, 15, 17),
   b. as the result of the real count on single photon detector (events 1, 5, 11);
2. Generating of the correct bit
   a. as the result of the dark count on single photon detector (events 4, 8, 10, 14, 16, 18),
   b. as the result of the real count on single photon detector (events 2, 6, 12).

A bit of sifted key generation is the result of processing of each event.

The expression to calculation of the probability of event numbered k is

$$p_k = p_n(\mu) \cdot p_m(n) \cdot p_{cb} \cdot f(p(dc_j), p_i(\eta_j)) \cdot f(p_{err}, p_{bit}),$$

where $f(p(dc_j), p_i(\eta_j))$ is a function that describes the cause of detection and $f(p_{err}, p_{bit})$ is a function that describes a correctness of received bit.

The effectiveness of the process of sifted keys generation is

$$p_\Sigma(\mu,\alpha_{qc},\mathrm{dc}_1,\mathrm{dc}_2,\eta_1,\eta_2) = p_{\Sigma err.dc}(\mu,\alpha_{qc},\mathrm{dc}_1,\mathrm{dc}_2,\eta_1,\eta_2) + p_{\Sigma bit.dc}(\mu,\alpha_{qc},\mathrm{dc}_1,\mathrm{dc}_2,\eta_1,\eta_2) + \\ + p_{\Sigma bit.rc}(\mu,\alpha_{qc},\mathrm{dc}_1,\mathrm{dc}_2,\eta_1,\eta_2) + p_{\Sigma err.rc}(\mu,\alpha_{qc},\mathrm{dc}_1,\mathrm{dc}_2,\eta_1,\eta_2),$$

where $p_{\Sigma err.dc}$ is sum of probabilities of 1a sub-group events, $p_{\Sigma bit.dc}$ is sum of probabilities of 2a sub-group events, $p_{\Sigma err.rc}$ is sum of probabilities of 1b sub-group events and $p_{\Sigma bit.rc}$ is sum of probabilities of 2b sub-group events.

The effectiveness of the process of sifted keys generation describes QKD system capability to form a bit of sifted key from laser pulse.

The value of bit-error probability is needed to estimate the rate of private keys generation.

The bit-error probability is

$$p_{err} = \frac{p_{\Sigma err.dc}(\mu,\alpha_{qc},\mathrm{dc}_1,\mathrm{dc}_2,\eta_1,\eta_2) + p_{\Sigma err.rc}(\mu,\alpha_{qc},\mathrm{dc}_1,\mathrm{dc}_2,\eta_1,\eta_2)}{p_\Sigma(\mu,\alpha_{qc},\mathrm{dc}_1,\mathrm{dc}_2,\eta_1,\eta_2)}.$$

So the rate of private keys generation is

$$v_\Sigma(\mu,\alpha_{qc},\mathrm{dc}_1,\mathrm{dc}_2,\eta_1,\eta_2) = v \cdot p_\Sigma(\mu,\alpha_{qc},\mathrm{dc}_1,\mathrm{dc}_2,\eta_1,\eta_2) \cdot \varepsilon(p_{err}),$$

where v is effective frequency of laser pulse generation and $\varepsilon(p_{err})$ is a c*oefficient of private keys length shortening after error correction and privacy amplification [14].*

Conclusion

All commercial QKD system structures are analysed in order to construct the tree of events of QKD systems. The tree of events represents the main stages of keys generation process in QKD systems like process of photon generation, photon transmission, basis selection and photon detection. Probabilistic model based on the tree of events is used for estimation of influence of the characteristics of fiber-optic components to QKD system characteristics. The model may be used at the development stage of new QKD system for estimation of system-limiting characteristics based on known characteristics of fiber-optic components. The model also may be used to make requirements to the fiber-optic components for customized QKD systems.

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IT PENETRATION INTO THEORETICAL AND PRACTICAL SUPPORT OF AIRCRAFT OPERATION

The task of the implementation of IT penetration for aircraft operation monitoring which is of a state importance has been formulated. The complex approach to and realization of the above mentioned task have been proposed on the basis of specific IT for development and upgrading of information and software support for aircraft, flight safety and air operations monitoring. Information security provision as well as so-called "green" information technologies have been taken into account in the process of IT application.

Introduction

Cabinet of Ministers, Ministry of Defense, Ministry of Transport and Communications of Ukraine regulatory documents set an important task of supervised utilization of safety margins and improvement of operational and maintenance workability, designed-in an aircraft for providing its serviceability. Simultaneously, the level of flight safety should not be decreased, and all the types of resources should be efficiently used during maintenance, repair and storage [1-3].

The domain of IT penetration into theoretical and practical support of an aircraft operation

The solution of the task requires development of theoretical and practical system of aircraft operation information support [4-5]. The system includes a complex of measures, taken on the research basis by the designer and/or manufacturer of an aircraft, research institutions for maintaining of required serviceability and improvement of performances and operating characteristics of aircraft.

Computers are important components of modern aircraft. Efficient monitoring of aircraft operation is impossible without automated information support, which is a key component of such process. Development of methods and means of software upgrading, creation and application of aircraft operation information support technologies are the core elements of IT penetration [6].

The tasks of investigated domain are connected with information support of the following processes (Fig.):

- maintaining of required serviceability and aircraft equipment software upgrading;
- safety management system;
- aircraft operation information support.

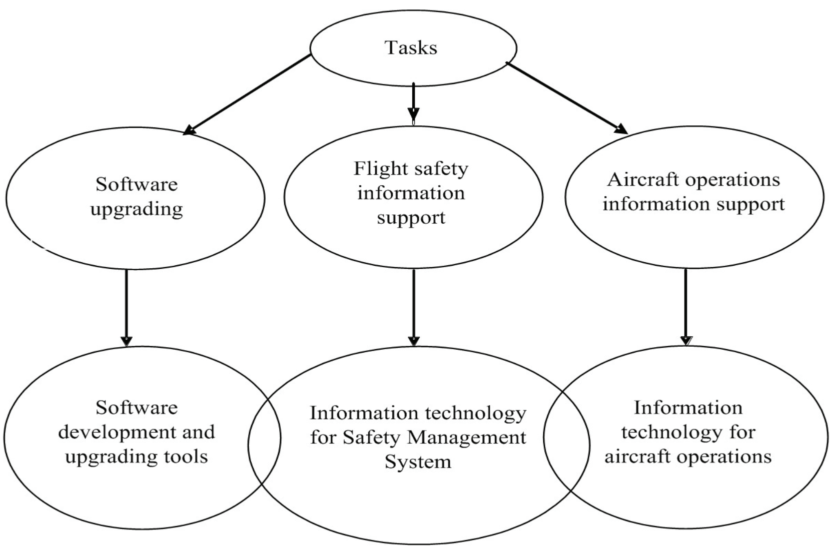

Fig. The scheme of IT penetration into theoretical and practical support of an aircraft operation

The solutions of these tasks require the development of complex approach to IT penetration. For example, the software to be ungraded is a part of safety management system, efficient functioning of which is impossible without data about current and forecasted conditions of aircraft [6].

In previous years several incidents occurred due to the absence and improper functioning of aircraft operation information support.

International best practices in aircraft operation efficiency enhancement indicate the necessity of IT implementation for the support of aircraft safety, maintenance, repair and upgrading processes in Ukraine. Such technologies are used in military and navy forces of Norway, Great Britain, France, Greece and also among the designers of aircraft and spacecraft.

Informational support and software upgrade.

For quite a long period of time computers are used as part of aircraft equipment. Their essential component is the software. In operation of aircraft the task of continuing airworthiness and service life extension arises for software as well as for other aircraft components. The data-modeling aviation complexes are the objects which have great variety of equipment working under the computers control [7]. When the task of serviceability support and service life extension appears the upgrading of equipment requires the upgrading of informational support and software. The reasonable way to implement such changes is the application of reengineering of informational support and software which has its own peculiarities connected with the aircraft performances unlike other complexes [8]. Beside it the significant part of aircraft fleet is quite aged. For example, Flight Data Recorders, Simulators require replacement by modern hardware and software, and development of new information support and software.

Flight safety information support.

Flight data analysis of Ukrainian aircraft fleet uses the information which is obtained by means of various types of on-ground decoding systems which are not integrated into single hardware/software complex [5]. The majority of systems is of outdated analog type. Diversity and obsolescence of flight data recorders and on-ground complexes for data processing, impossibility to upgrade the hardware complicate the regular and reliable data processing. That is why it is suggested to develop the safety management system taking into account problems of IT penetration and meeting new requirements:

- application of advanced methods of hardware/software development and support;
- database and knowledge formation for analysis and flight data processing;
- installation of sophisticated digital flight data recorders on aircraft.

New hardware/software complex should be comprehensive and provide decoding and analysis of flight and voice data, recorded by different types of data recorders both in the process of aircraft operation and during the investigation of incidents and accidents.

Information technology of flight safety management should provide the following :

- monitoring of flights regardless location of aircraft;
- CNS/ATM system on-ground infrastructure and appropriate airborne equipment;
- information support of aircraft on-condition operation, maintenance, inspections, incidents and accidents, voluntary reports;
- flight data analysis for promotion of safety of every flight;
- management of material resources regarding aircraft operations (logistic chains);
- administration of register of equipment installed on Ukrainian aircraft;
- administration of register of test equipment, used by aviation industry of Ukraine;
- local and global document management and planning.

Aircraft operation information support

Aircraft operations in Ukraine is nowadays characterized by the following:
- simultaneous operation of both new generation (NG) and aged aircraft;
- absence of aircraft technical condition and reliability information support;
- non-automated operational processes;
- lagging managerial decisions making.

That is why aircraft operations information support development and implementation will increase the efficiency of procedures carried out during operations. The technology development should be purposed to accomplish the following theoretical and practical tasks:

- collection, accumulation, systematization and analysis of data regarding aircraft spare parts, units and components pool;
- supervision of aircraft spare parts, units and components flow in aircraft operations;
- creation of external technical documents data base (orders, instructions, charts, drawings, forms, data sheets, etc.);
- consideration, systematization and analysis of aircraft failures and malfunctions data;
- accumulation and storage of aircraft performances and parameters values;
- data generation for aircraft technical condition analysis and reasonable decision making regarding further operations.

For solving of above mentioned tasks the aircraft operation information support technology is being developed. It is considered as a complex e-device for scaling, based on the application of sophisticated computer and telecommunication equipment and purposed for solving the tasks of IT penetration into aircraft on-condition operation information support. Herein the task of IT penetration is considered as an allocated automated document management task with «smart» analytical processing of data for appropriate decision making regarding aircraft condition, failures reasons, malfunctions and conditions of their origination. To solve the problem it is suggested to use a Web-platform, as an environment. It will provide high immediacy of collection, processing and data analysis processes and also decision making regarding volume, layout and forms of information used in information system during its functioning, on the basis of automated classifiers of aeronautical products and regulatory framework for aircraft maintenance and repair.

Methods and means of IT penetration

The information used in the processes of aircraft operation theoretical and practical support is extremely important. Informational systems complete the processes allocated in the environment, so the cryptographic defense and information security tasks become crucially valuable.

Taking into consideration the importance of known steady development concept, implementation of all aircraft operation support IT penetration means should be regarded as the green information technologies [9].

Finally, the fulfillment of IT penetration into aircraft operation theoretical and practical support tasks is impossible without appropriate personnel training. That is why initial and recurrent training shall be considered [10].

Thus, for the completion of researched tasks of aircraft operation support IT penetration the following methods should be developed:

-the domain ontology development as postulates purposed for application of domain tasks fulfillment;

-the domain analysis purposed for the search of reenterable solutions to be applied in the development of information technologies;

-reengineering of information and software support for the upgrading in the process of aircraft operation;

-assessment of aircraft technical condition;

-collection of trustworthy information regarding flight safety, actual technical condition and reliability of aircraft fleet, allocation of material resources, aircraft operation, application of life time indicators and aircraft service life;

-cryptographic defense and information security.

To implement these methods it is necessary to develop tools which provide the following:

-description and application of ontology knowledge;

-inverse and direct engineering of information and software support;

-automation of distributed document management;

-information security.

Implementation of information technologies in the system of Ukrainian aircraft operation will give the opportunity to complete an important research government task.

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METHOD OF RENEWAL OF THE LOST PACKETS AT TRANSMISSION IN COMPUTER NETWORKS

The method of renewal of informative packets is offered at their loss in computer networks, based on the use of Lagrange codes. The algorithms of calculation of check packets, transferred on a network in addition to the basic packets, and algorithms of renewal of the lost packets, are developed. The amount of operations in the finite fields and memory capacity are defined for storage of constant values during realization of these algorithms.

The large volumes of digital data, circulating in modern computer networks, require an error protection. Appearance of errors is caused by that practically in all physical environments of transmission and storage of data there are noises, resulting in distortions and losses of data. It is possible to select the followings types of environments of transmission and storage of data, in-use modern computer networks: cable and fiber lines, atmosphere, laser disks, and disk and tape stores. In a surface and satellite communication network these can be lightnings and high-voltage power lines, originative pulse noises. Atmospheric interference and space electromagnetic radiation generate Gauss noise. In cable lines there are fadings of signal because of resistance of midst, end reflections, overloads of networks. For laser disks, disk and tape stores mechanical damages and scratches are inherent.

In the computer networks of one of issues of the day are losses and delays of packets that are caused by overloads in nodes (switches, routers etc.), degradation of carrying capacity of communication data channels from the too large number of the simultaneously connected users, distortions in a packet, overload of input buffers of network devices issues etc. In the systems of data transmission and real-time network applications, the delays of packets are equivalent to the losses, as there is not possibility to halt a computational process in expectant of packet or his retransmission. In addition, requests for sending result in the additional loadings on the data channel.

One of the basic methods of information protection from errors is the antinoise encoding. Error detecting codes are used in the full-duplex channels, and it frequently is sufficient, because signaling about error detection causes the retransmission from a source. In such channels a transmitter, before to send the next packet of report, must get confirmation of rightness of reception of previous packet an addressee. Obviously, that from expectation of confirmations packets is passed with enlarged delays. In the simplex channels use correcting codes which additionally to the detection correct errors in addition.

The simplest method of detection of errors is addition of transferred packet a checksum code. As such code it is possible to use a check sum or odd-even check that is not enough reliably, especially at appearance of bursts of errors. Therefore as detecting codes more reliable cyclic codes, which are the high reliable and effective codes of CRC, belong to the number are used (Cyclic Redundancy Code). The example of correcting code is a Hamming code. However, much application of these codes for encoding of packets does not decide the problem of loss of packets.

A loss of packet actually is elimination, i.e. by an error the site of which in a report is known, but its size is unknown. It is characteristic for networks, in particular IP-networks, where through numeration of packets is used and there is possibility to define the number of the lost packet. As packets are fragments, into which a report is divided for a transmission to the addressee, then for providing of possibility of renewal of the lost packet encoding of all report is necessary. A general chart of encoding will be following.

An initial report is divided on k initial packets. Every packet is complemented by a check code and attributes for a transmission on a network. This procedure is specified in existing networks. In addition to the initial packets r packets are forming, which we name check. Forming of informative part of check packets is produced on the rules of encoding of the chosen code. The structure of check packets is analogical to the structure of initial packets, and their amount (r) is determined the by the maximal amount of packets, which must it will be recovered after a loss. The incurrence of transferred packets will make n=k+r. We will mark that forming of control packets takes place without a delay of transmission of initial packets.

As a code for encoding of transferred packets and renewal of the lost packets it is possible to use a code Lagrange, correcting eliminations. Forming of control and renewal of the lost packets will take place element wise for every packet in accordance with procedure of encoding of Lagrange code:

$$f(\beta_j) = -\sum_{i=0}^{s+j-1} f_i \prod_{l=j+1}^{r} (x_i - \beta_l)/(\beta_j - \beta_l), \qquad j = \overline{1,\ r}, \tag{1}$$

where, $\prod_{l=j+1}^{r}(x_i - \beta_l)/(\beta_j - \beta_l) = -L_{S_{j-1}}^{(i)}(\beta_j) = L_{T_j}^{(j)}(x_i)$, $S_{j-1} = S \cup \{\beta_1, \dots, \beta_{j-1}\}$,

$T_j = T \setminus \{\beta_1, \dots, \beta_j\}$, $\quad T_r = \varnothing$, $\quad x_i \in S_{j-1}$, $\quad \beta_j \in T_j$;

$f(\beta_j) = f_{s+j}$ – value of element of control (recovered) packet in j-th check (recovered) knot;

f_{s+j-1} – a value of element of check (recovered) packet is in a previous (j-1)-th check (recovered) knot;

f_s – value of element of initial (accepted not lost) packet in informative (not lost) knots.

An algorithm of calculation in accordance with a formula (1) will be following:

1. For each $i = \overline{0, s}$, setting values $l = \overline{r, 2}$, calculate values $a_{il} = x_i - \beta_l$ and determine sums: $\sum_{i=0}^{s} f_i a_{ir}$, $\sum_{i=0}^{s} (f_i a_{ir})\, a_{i,r-1}$,…, $\sum_{i=0}^{s} ((\dots(f_i a_{ir})\dots)\, a_{i3})\, a_{i2}$.

   Thus $\sum_{i=0}^{s} f_i$ also is determined separately.

2. We calculate $\gamma_j = -1/\prod_{l=j+1}^{r}(\beta_j - \beta_l)$. On the first step $j = 1$, in future each time at an address to this point increase j on 1 to (r-1).
3. We determine check characters f_{s+j}. At $j = r-1$ pass to the point 5.
4. For each $j = \overline{1, r-1}$, setting values $l = \overline{r, j+2}$, calculate products $\alpha_j^{(l)} b_{jl}$, where $\alpha_j^{(l)}$: $\alpha_j^{(r)} = f_{s+j}$, $\alpha_j^{(r-1)} = f_{s+j} b_{jr}$, … , $\alpha_j^{(j+2)} = (\dots(f_{s+j} b_{jr})\dots)\, b_{j,j+3}$; $b_{jl} = \beta_j - \beta_l$. Thus there is addition of value f_{s+j} to the sum $\sum_{i=0}^{s} f_i$. After every change j execute a point 2.
5. Summarizing f_{s+r-1} and $\sum_{i=0}^{s+r-2} f_i$, we calculate f_{s+r}.

Here, $b_{12} = \beta_1 - \beta_2$, $b_{13} = \beta_1 - \beta_3$, $b_{23} = \beta_2 - \beta_3$, … , $b_{1r} = \beta_1 - \beta_r$, $b_{2r} = \beta_2 - \beta_r$,…, $\beta_{r-1,r} = \beta_{r-1} - \beta_r$, $a_{i2} = x_i - \beta_2$, $a_{i3} = x_i - \beta_3$,…, $a_{ir} = x_i - \beta_r$, $\gamma_1 = -1/(b_{12} b_{13} \dots b_{1r})$, $\gamma_2 = -1/(b_{23} b_{24} \dots b_{2r})$,…, $\gamma_{r-1} = -1/b_{r-1,r}$.

The flow-chart of the resulting algorithm of encoding is shown on a Fig. 1.

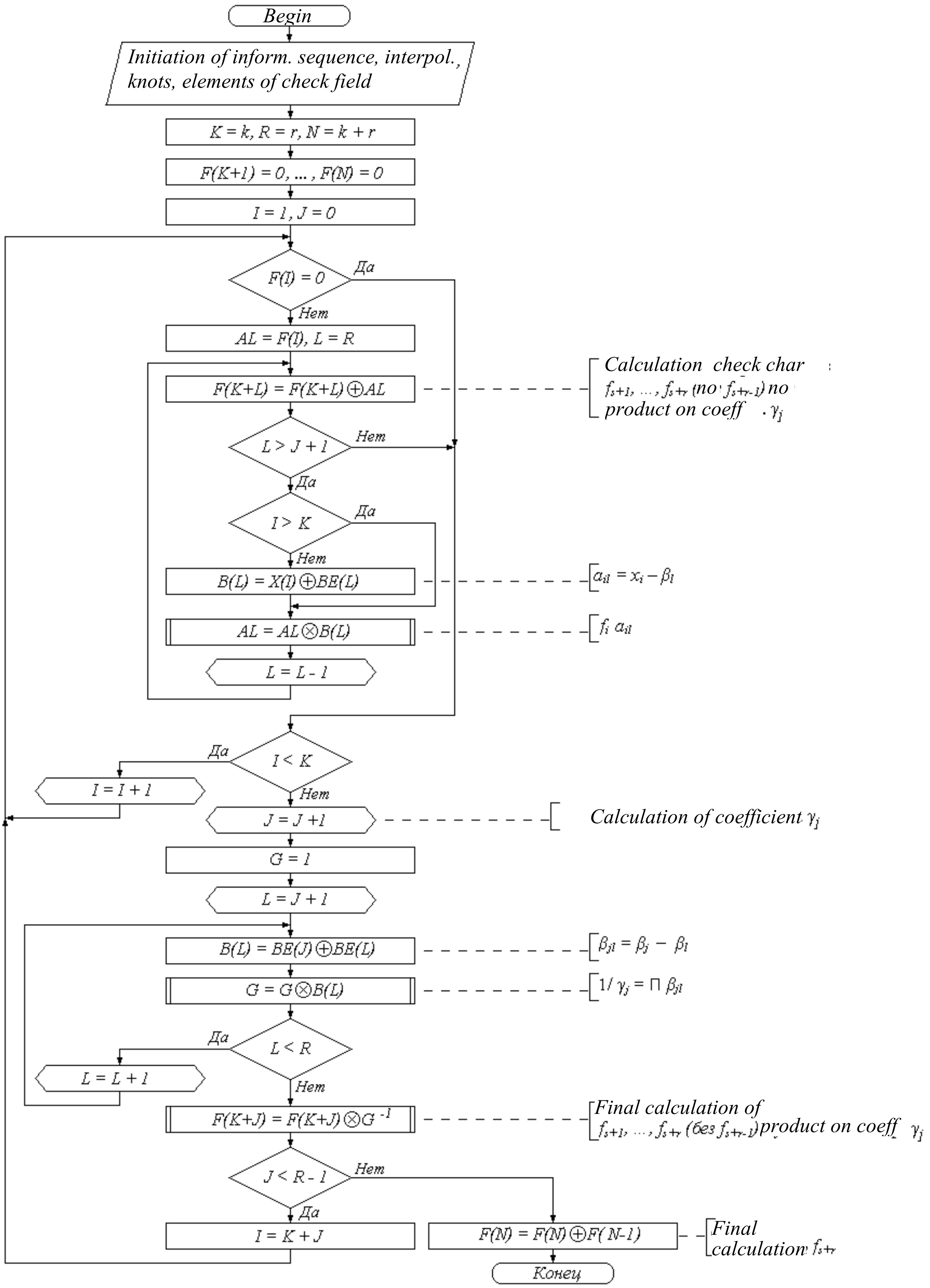

Fig. 1. Flow-chart of successive algorithm of encoding ($L^{(i)}(x)\neq$const).

The amount of operations of addition, increase and inverting in the finite fields for this algorithm is accordingly equal:

$N_{\oplus} = n(2r-1) - r(r+1)$, $\quad N_{\otimes} = (n-1)(r-1)$, $\quad N_{\circleddash} = r-1$.

The calculation of amount of operations was produced taking into account the presence $(r-1)$ of registers of memory for storage of values b_{jl}. Taking into account the presence of memory for storage of n knots of interpolation it is necessary to have ($n+r-1$) registers.

At forming of control packets of initial report for diminishing of amount of operations it is possible to take advantage of parallel and successive algorithm of encoding of Lagrange code. In this case knots of interpolation are fixed and the Lagrange fundamental polynomials $L^{(i)}(x)$ can be calculated beforehand and to keep in memory as permanent values. The values of elements of check packets in control knots are calculated on formulas:

$$f(\beta_j)=\sum_{i=0}^{s} f_i A_{ji}\ , \qquad f(\beta_r)=-[\sum_{i=0}^{s} f_i+\sum_{j=1}^{r-1} f(\beta_j)],$$

where $A_{ji}=L_S^{(i)}(\beta_j)=const$, $j=\overline{1,\ r-1}$.

At $L^{(i)}(x)=const$ the parallel and successive algorithm of encoding requires implementation of operations of addition and multiplication in the finite fields in an amount:

$$N_{\oplus}=r(n-r)-1, \qquad N_{\otimes}=(r-1)(n-r).$$

For storage of coefficients $L^{(i)}(x)$ it is necessary to have $(r-1)(n-r)$ registers.

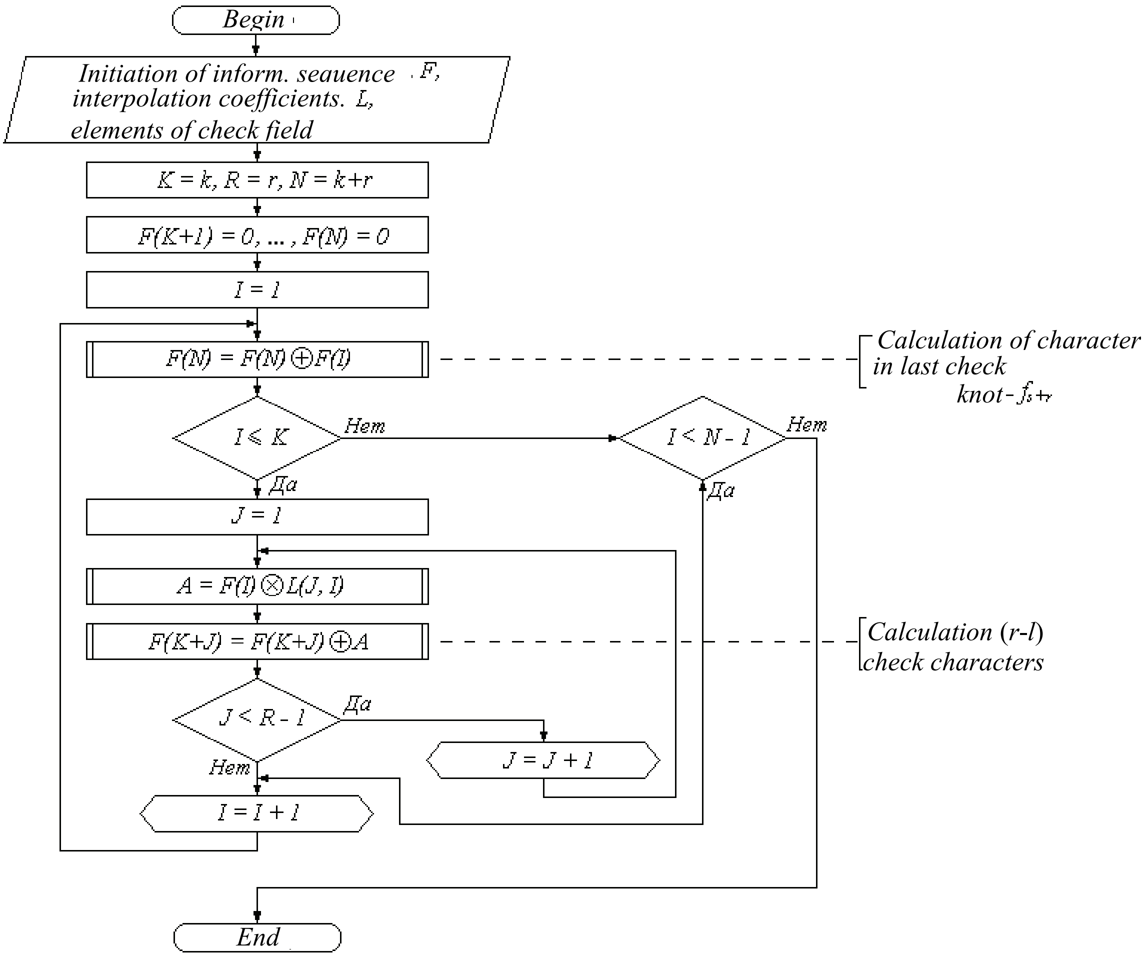

Fig. 2. Flow-chart of parallel and successive algorithm of encoding ($L^{(i)}(x)$=const)

Conclusions

The offered method does not violate the accepted procedures of communication of data in computer networks that is very important for his realization in the existent systems. It allows restoring the lost packets without a request for their retransmission. It off-loads channels of connection from unnecessary data exchanges, and also provides the capacity of network real-time applications, for which the delays of packets are equivalent to the losses, as there is not possibility to halt a computational process in expectance of packet or its retransmission.

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BROADBAND DIGITAL TELECOMMUNICATIONS SERVICE INTEGRATED COMMUNICATIONS, NAVIGATION SURVEILLANCE FOR AIR TRAFFIC CONTROL

The integrated telecommunications environment for communication, navigation and surveillance with the introduction of advanced imaging parameters of air traffic is proposed.

Introduction

The regime of "free flight", introduced the International Civil Aviation Organization (ICAO), requires a substantial increase in the capacity of airfield sites (AS) with more stringent requirements for safety [1]. A key aspect in solving this problem is a substantial modification of existing communication systems, navigation, and surveillance with increased accuracy in determining the parameters of the coordinates of the trajectories of aircraft (AC). This requires, in turn, use of digital communications (using the integrated satellite and wireless broadband), without which it cannot significantly improve the problem solving process automation control [2, 3].

For the introduction of standards and technologies of broadband digital networks, integrated services (BISDN): ATM/DWDM and WATM/WiMAX, in turn, challenges the two basic problems, namely:

- to integrate all existing and planned communications, navigation and surveillance systems based on a scalable digital imaging parameters of air traffic (VD);
- based on the proposed telecommunications environment integrated services to a substantial modification of the airborne and ground-based collegial governance, creating for them a fundamentally new multimedia service interactions in real time.

1. Integrated telecommunications environment of peer air traffic control

Based on the analysis of the problem switching to a new regime of flight is divided into four main components of the new system of CNS/ATM.

Telecommunications for communication. In the systems of CNS/ATM voice transmission should be implemented in digital networks in the band very high frequency (VHF), which will also be used to transmit digital data. The introduction of digital satellite communications system for transmitting data and voice services provide the global zone flights in conjunction with data transmission through communication channels within the band of high frequency (HF). Mode S secondary surveillance radar (SSR), which are increasingly used for surveillance in the airspace with high traffic density, as interpreted in this system that would allow the transmission of digital data between airborne and ground systems. Aeronautical communications network (ATN) will ensure the exchange of digital data between end users on different subnets communications air-ground and ground - the land. Regular use of data for the purposes of ATM significantly alters the quality of service onboard communications system and automated control systems [3].

The benefits of new telecommunication systems will implement a more direct and effective lines of communication between ground and airborne automated control systems (ABCS), used in conjunction with the communication systems between the pilot and the operator controls the AT. In essence, the digital data line may be regarded as a key element of new concepts of organization AT (ATM), aimed at achieving real benefits of real-time multimedia traffic (RT MMT).

It is important to note the effectiveness of the broadband wireless network connection (SHBSS), digital antenna arrays, which covers an area within a radius of 100 km at a speed of digital transmission MMT up to 50m / s [4-6].

Telecommunications for navigation. Improved navigation lies in the gradual introduction of area navigation equipment, as well as global navigation satellite system.

Navigational capabilities of these systems are global in nature and provide navigation for routes with a view of the implementation of precision approach. With additional functional systems and procedures, these systems will also provide the most accurate approach.

Global Navigation Satellite System, defined in the Global Air Navigation Plan, provides high-integrated, and all-weather precision-guided navigation service. The successful implementation of global navigation satellite system is fully enabling the aircraft to fly in all types of airspace. However, while away from the use of conventional radio navigation aids should be approached with caution and after a safety assessment demonstrates the capacity to withstand an acceptable level of safety and following consultation with users through a process of regional air navigation planning.

Telecommunications for monitoring. It should be noted that in the early stages would continue to be used in normal mode, with a gradual introduction of SSR Mode S in terminal areas and continental airspace with high traffic density. However, the main feature is the introduction of automatic dependent surveillance (ADS). ADS will enable Sun to automatically transmit data about its location, course, speed, and additional information, issued by the flight management system (FMS), using satellite or other communication line control center AT.

Currently being developed software that will allow ground information processing center directly use these data to detect and resolve conflict situations. Ultimately, this may lead to solutions that operators control WA will be consistent with on-board and ground-based computers with a periodic human intervention or without his participation.

The main link with the introduction BWCN (technology WATM / WiMAX) is, in turn, creating digital antenna arrays with the computer systems of the adaptive configuration of the antenna pattern (AP), supporting the specified quality parameters.

Quality of service of multimedia traffic collegial management, namely: timeliness, correctness, immunity transmission [3-6] - this is the most important and difficult problem of introduction of technologies WATM / WiMAX in an integrated telecommunications medium of communication, navigation and surveillance in the management of technological processes AT [4, 7, 8].

Thus, the introduction of the new telecommunications environment for communications, navigation, and monitoring the expected improvements will yield positive changes in ATM management and AT.

2. Multimedia services collegial management scalable visualization system parameters of air traffic

The new CNS / ATM provides greater automation of almost all the functions of ATC, which were previously handled manually. In this regard, the introduction SHBSS (WIMAX) will change the nature of interaction between operators and management of AT and pilots. For solving this problem, ICAO is developing a program to create multimedia services (MMS), which should significantly improve all the processes of organization and management of WA. However, ICAO has not claimed against the introduction of digital communication integrated services in the management of WA.

The principal difference between input MMS (as part of standard MPEG-4 and MPEG-6 on the basis of digital communication) is that the onscreen mapping displayable objects (trajectories of flights) is associated with voice communications in real time [7]. In addition, audio-visual scenarios of MPEG-4 consist of several media objects (MO), which organized hierarchical and scalable ways [7, 8].

Due to the hierarchy, you can create and implement the following media objects (MO):

– scalable chart the flight path;
– style images, finding cartographic background;
– video objects trajectories explaining to them (video and speech without background);
– sound objects as speech related to video objects.

MPEG-4 standardizes a lot of IO compatible with both natural and with synthetic types, which can be 2-dimensional (2-D) or 3-dimensional (3-D). In the functional structure of the MMC situational control center (STSU) AU-coded representation of objects of type "video and speech", or "synthetic conversation" that are associated with graphics trajectories C flights [8].

In [8] in the functional structure of the MMS management center (dispatch) AU shows the links AT and AC, according to which the audio-visual scenario is presented as a system of individual objects, and as a system, integrating the primitive MO. Primitive MO respond to requests in a descriptive tree, while the MO components cover the full sub trees.

Proposed in [8] The functional structure of the MMS enables operators to control WA and pilots in the control center airfield site to consider complex scenarios (paths C flights) with a scalable rendering them, ensuring they are displayed in a selected (scalable) versions of cartographic interface [7].

At the same time as the basic components of the functional structure of the MMC should be defined as follows [9]:

– transport platform as a telecommunications environment, which is within the MPEG-4 standard defines a transport layers, as is usual in the Reference Model Open Systems Interconnection (EM ECW). Today, in most cases, adaptation to a specific, existing transport stratum adjusts transmission of MMT in traffic flows MPEG-2, and the transfer of data to the navigation, and monitoring the RP;

– interface DMIF, as the structure of the integration of the transmitted MMT, which provides coordination between the application and transport, and this, frees the user from the need to control this traffic.

Thus, the main components of the MMC produced on the basis of integrated telecommunications environment in the framework of MPEG-4 provides the implementation of the following functions:

– accommodation MO in given coordinate system;

– changing the geometry arising MO within a given scale;

– grouping primitive MO for the formation of the specified MO (visualization scripted flight trajectories).

It can be noted that the proposed MMC significantly enhances the complex air traffic control in real time.

Conclusions:

The base components of the perspective branches of development of air traffic control systems, namely the creation and implementation of integrated services digital telecommunications processes, organization and management of AC.

The benefits of new telecommunication systems will implement a more direct and effective lines of communication between ground and airborne automated control systems (ABCS), used in conjunction with the communication systems between the pilot and the operator controls the AS. In essence, the digital data line may be regarded as a key element of the new concepts of organization AS, aimed at achieving real benefits of multimedia traffic real time.

Multimedia Service collegial management scalable visualization system parameters of air traffic can significantly improve the perception of information about the parameters of control operators AS.

The principal difference between input MMC is that the onscreen mapping displayable objects associated with real time voice communications. In addition, audio-visual scenarios MPEG-4 consists of several media objects, which are organized hierarchical and scalable ways.

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THE METHOD OF ADAPTIVE SHAPING OF THE TRAFFIC FLOWS OF CALCULATING NETWORKS

There are on the presentation a method of the adaptive forming of flows of network traffic and method of tuning of the systems managements with a non-obvious feedback, which manage parameters and structure of shaper. The mathematical models of computer networks, including models of processes of management the flows of traffic, are analysed.

Introduction

Customer demands for cheaper and more advanced technologies mean that Telecommunications Service Providers (SPs) need to constantly evaluate new and more efficient methods of delivering services to their customers. In order for SPs to provide services that generate the most revenue with the lowest operational costs their transport networks need an optimal design.

Research of characteristic properties of process is conducted forming of stream, which must be taken into account at the choice of parameters and structure of control system by the multi-speed shaper of traffic.

This discussion of the metering process has indicated that packets marked red are typically discarded. However, the immediate discarding of red-marked packets is a choice known as policing. An alternative method of dealing with non-conformant packets is known as shaping. Before explaining how shaping is carried out, it is necessary to review the mechanism where packets are queued at an egress port. Each egress port has a set of egress queues, which are allocated different priorities or weights.

The QoS mechanisms place packets into the appropriate egress queue, but the queues are of a limited length, so packets cannot be placed into them indefinitely. If the switch is congested, the queues may fill up and no more packets can be added, so even high priority packets can be dropped from the end of queues.

Developed to recommendation in relation to the choice of parameters of shapers and control system by them (necessary order of control system, structure of shapers, measuring devices of parameters of packages et cetera) depending on intensity of flows of data, are their statistical descriptions and network structure.

2. Development of the Method of Adaptive Traffic Shaping

Foremost, we'll give some important determinations.

1. The token generator TG_E throws down in the bucket of E tokens at a speed of E_{IR} in a second. If a bucket is filled, superfluous tokens are cast aside. Time of filling is $t_{fE} = E_{BS} / E_{IR}$.

2. The token generator TG_C throws down in the bucket of C tokens at a speed of CIR in a second. If a bucket is filled, superfluous tokens are cast aside. Time of filling should be corrected.

3. Tokens accumulate in the buckets of E and C. General length of temporal interval, occupied by a token in the bucket of E, is equal $\tau_e = \tau_{te} + \tau_{ge}$, where τ_{te} is duration of token in the bucket of E; τ_{ge} is duration of protect interval. General length of time interval, occupied by a token in the bucket of C, is equal $\tau_c = \tau_{tc} + \tau_{gc}$, where τ_{tc} is duration of token in the bucket of C; τ_{gc} is duration of protect interval.

The number of tokens in the bucket of E is equal, in the bucket of C equal n_c. Then the general total size of tokens in the bucket of E is equal $T_e = n_e \cdot \tau_e$, in the bucket of C is equal $T_c = n_c \cdot \tau_c$. Duration of arriving package will designate through p_s.

4. Adaptation to the change of duration of input packages can be carried out as follows:

- changing duration of token at permanent duration of protective interval;
- changing duration of protective interval at permanent duration of token.

Both in that and in other case of speed of E_{IR} and C_{IR} will change to the limits, which depend on the maximal carrying capacity of, interconnect knot.

It's reasonable to adapt to the change to middle intensity of packets by the change of speeds of E_{IR} and C_{IR}.

The load metering and packets specification procedures are shown on fig. 1.

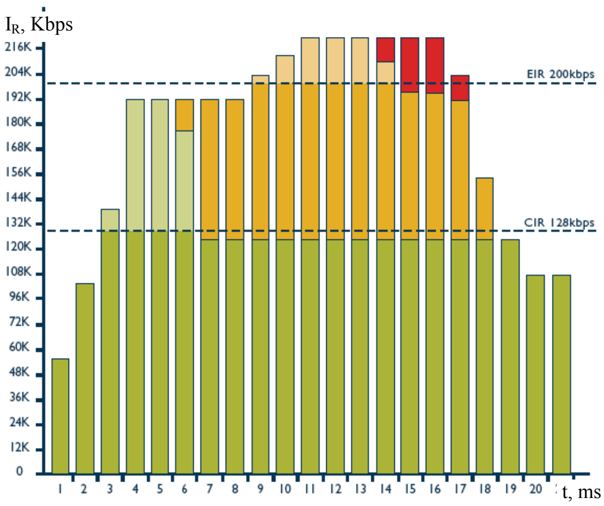

Fig. 1. Load metering and packets specification in traffic shaper. I_R – instant intensity of traffic flow. Green packets – high priority, yellow– middle, red – low (first turn dropping).

We consider traffic shaper with variable speeds C_{IR} and E_{IR}. They depend from speed and acceleration of intensity grows. The flow chart of multi-speed shaper is sown on fig. 2. Adaptation to variable parameters of traffic and state of network nodes input to functional transformer (FT). Output signals are used for matching parameters of shaper.

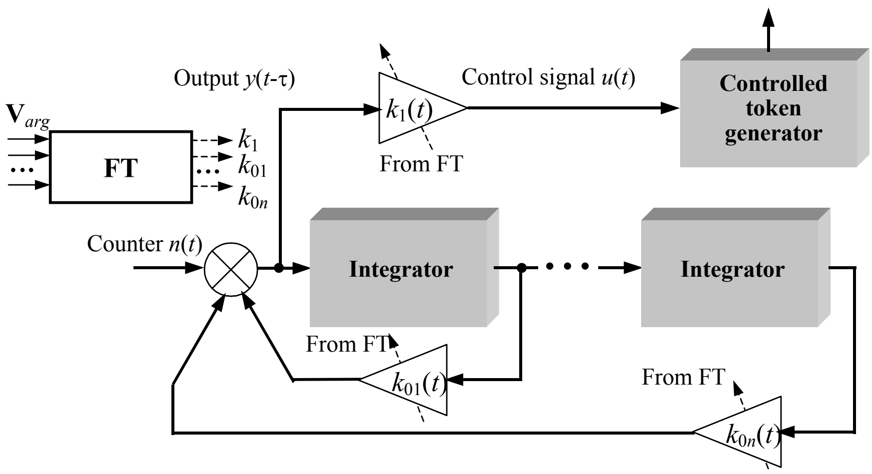

Fig. 2. Multi-speed traffic shaper.

The sensibility of adaptive device to random deviation of parameters was researched. *Relative* or *normalized* system sensibility is defined as relation of infinite small variation of system parameters to resulting relative variation of system function $J = J(\overline{x}) = J(x_1,\ x_2,\ ...,x_n)$:

$$S_n(J,x) = \lim_{\delta x \to 0} \frac{\delta J / J}{\delta x / x} = \frac{x \partial J}{J \partial x} = \frac{\partial(\ln J)}{\partial(\ln x)} = \frac{x}{J} S_d(J,x) \cdot \tag{1}$$

Multi-parameter sensibility is

$$\frac{\delta J}{J} = \sum_{i=1}^{N} \left(\frac{\partial J}{\partial x_i} \cdot \frac{x_i}{J} \right) \cdot \frac{\delta x_i}{x_i} = \sum_{i=1}^{N} S_n\left(J, x_i\right) \frac{\delta x_i}{x_i} = \sum_{i=1}^{N} \frac{\partial\left(\ln J\right)}{\partial(\ln x_i)} \delta(\ln x_i) \cdot \tag{2}$$

The models of traffic flows with non-stationary variation of instant intensity and with non-stationary expectation of instant intensity were developed:

– random flow $\xi(n)$ with quasi-harmonic law of intensity variation, $\xi(n) = \xi\left[n, \lambda(T)\right]$; $\lambda(T) = \lambda_0 \left[1 + \sum_{k=1}^{N} a_k \sin\left(2\pi nk/T\right)\right]$; λ_0 – average intensity on search interval *T*; a_k – random numbers uniformly distributed on interval $[0,\zeta]$, and $N\zeta \le \lambda_0$;

– random flow $\varsigma(n) = \varsigma\left[n, \mu(T)\right]$ with linear grow expectation in time $\mu(T) = \mu_0 + bn,\quad b = (0{,}1 \ldots 0{,}5)\mu_0 / N_T$; N_T – integer of quotient T/n.

Diagrams of sensibility functions are shown on fig. 3 and 4.

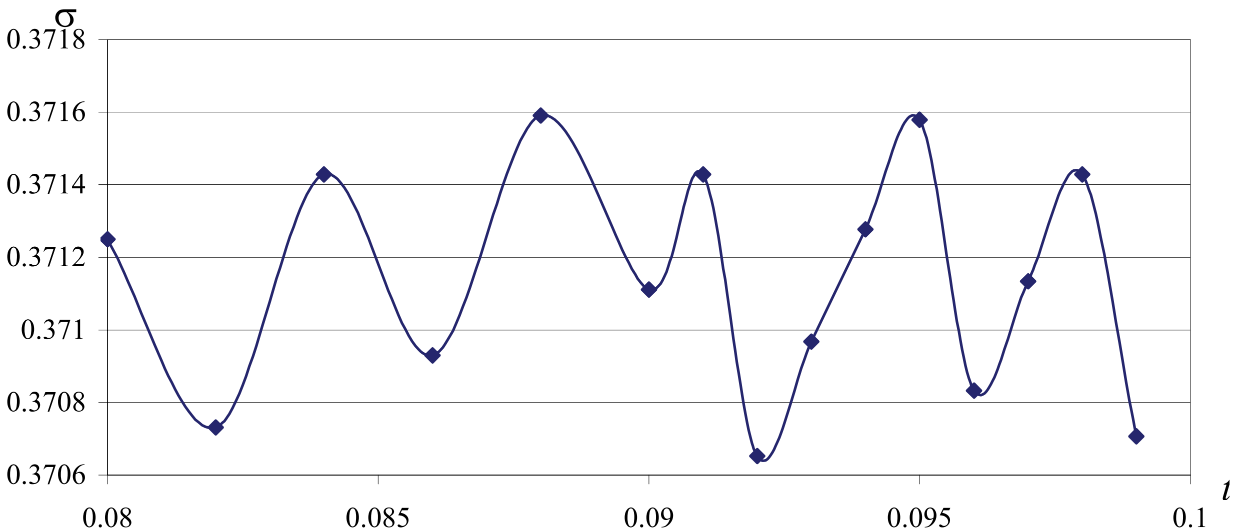

Fig. 3. Sensibility function for flow with non-stationary variation of instant relative intensity. *N*=3.

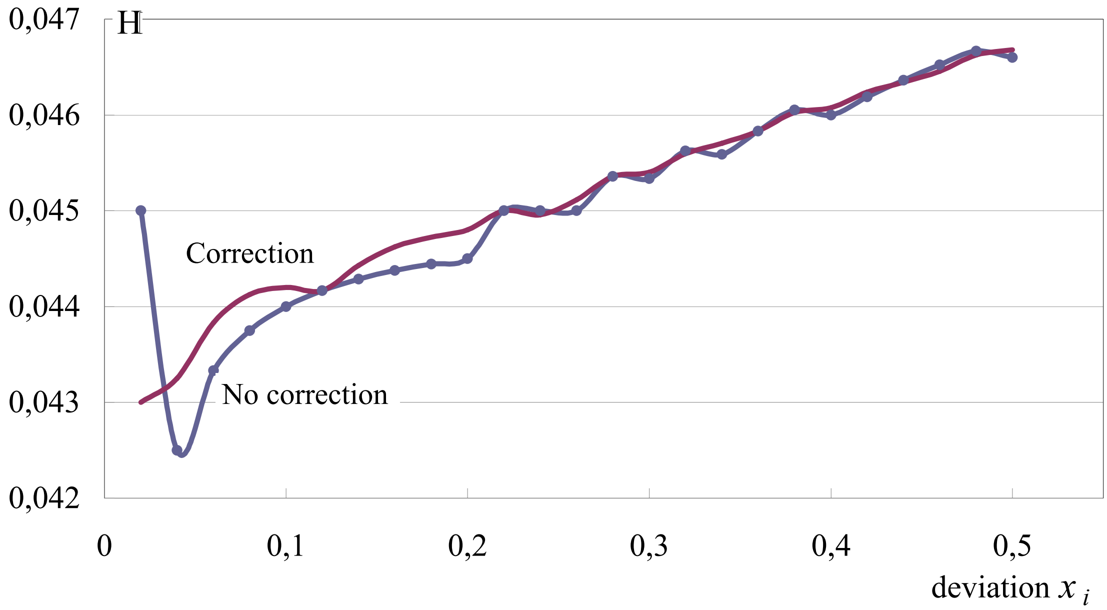

Fig. 4. Sensibility function for flow with non-stationary expectation of instant relative intensity. $b = 0,5\lambda_0 / N_T$. Correction parameters with smoothing polynomial of 3rd order.

It was established slow sensibility of developed devices to deviations both in Poisson and self-similar flows. The model generating self-similar flow was *FSNDP – fractal-shot-noise-driven Poisson process*.

The impacts oa relative frequency of token generator is rather short and quickly decreased. Overload cancellation is achieved in small time, so load swings are comparative small as well. Though both the overloads and losses of traffic controllability may have place if the duration of bursts overcomes the reserve of dynamic stability of shaper. For example if the main and additional buffers are filled in the period higher than acceptable time-out this route or network segment in general become inaccessible. Such situations have to process with the utilities of transport or higher layers.

Conclusions

Proposed procedure of traffic shaping is rather simple and efficient. The results of modeling show that it is possible to limit the frequency of token generator till such value, when all input traffic would be received and then transferred without losses and retransmissions.

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METHOD OF DECISION MAKING IN SITUATION CONTROL SYSTEM OF ELECTRICAL MOUNTING PRODUCTION

A logical-linguistic situation case frame by the electrical mounting production related to the number of difficult organizationally-technical objects is resulted. Procedure of its transformation to the canonical type of extreme combinatorial tasks is described. The algorithm of administrative decision making, realizing strategy of the directed surplus of variants is presented.

Introduction

Electrical mounting works in the system of capital building take special seat. They are the considerable on volume difficult complex of organizationally–technical processes with weak formalization of administrative tasks which require application of expert logical-linguistic case frames and algorithms of logical output proper to these frames [1]. Among the last ones the most widely distributed are the algorithms based on the known principle of the John Robynson's resolution [2]. It is known that the weak purposefulness of actions, conditioned by the presence of heuristic elements, is the basic defect of such algorithms. Hereupon in the process of analysis of logical-linguistic model the large volume of intermediate information, which in future is not used, but is sharply multiplied the expenses of machine time, is formed.

Combinatorial character of procedure of logical output, and also aspiration to give her large purposefulness stipulated an attempt to bring over the algorithm of the directed surplus of variants to decision making on the basis of expert case frames in electrical mounting production. Along with substantial reduction of volume of calculations it will give to this consulting model of management additional possibilities which this model was deprived at the use of traditional methods of logical output:

a) forming of complex administrative decisions foreseeing simultaneous realization of some set of elementary managing operations;

b) optimization of the sought administrative decisions after on the set criterion.

For realization of such approach standardization of structure of expert situation case, development of procedure of their transformation frames to the canonical type of extreme combinatorial tasks, modification of algorithm of the directed surplus of variants is needed. Exactly it is the purpose of this research, in which electrical mounting production (EMP) with the difficult technical-organizational system is a management object (MO).

Formalization of task of situation management

Offered approach to decision making in the situation control systems is based on next suppositions. Because EMP is a management object with the difficult technical-organizational system consisting of n interactive subsystems, σ_j . $j = \overline{1,n}$. The MO state at every the instant is described by the u-measured vector of values of his descriptions $z = \left(z_p;\, p = \overline{1,u}\right)$.

Expert case frame difficult EMP is built on a traditional chart <situation> → <action>. It is assumed that by the experts of electrical mounting organization the great number of most typical is beforehand certain, but enough simple anomalous (failure, nonpermanent) situations, each of which is set by belonging of values of some set of descriptions of the MO state to one or another ranges:

$$S_q : \bigwedge_{p \in P_q} \left(z_p \in Z_{qp}\right);\ q = \overline{1,v} \ ,$$

where P_q - a variety of numbers of descriptions of the MO state, the values of which are determining for the q-th situations; Z_{qp} - a variety of values the descriptions of the MO state, proper to the anomalous situation S_q.

If it is impossible quantitative measuring of one or another description of the MO state description of its values by high-quality categories is assumed. Expert situation case frame, built on the indicated chart, it is possible to express by following implication:

$$S_q \to \bigvee_{r\in R_q} \bigwedge_{i\in I_r} \bigwedge_{j\in J_{ri}} X_i(\sigma_j);\ q=\overline{1,v}, \tag{1}$$

where R_q - a variety of the elements of which identify the possible methods of influence on MO in the q-th to the nonpermanent situation;

I_r - a variety of elementary managing operations, simultaneous realization of which is foreseen by the r-th method of influence on MO;

J_{ri} - a variety of numbers of the MO subsystems, which the *i-th* managing operation in obedience to the *r-th* method of influence is used to;

$X_i(\sigma_j)$ - predicate, describing the *i-th* managing operation applied to the j-th to the MO subsystem.

The expressions (1) adapted to the concrete object of management can serve as basis of knowledge base of consulting model of situation management.

Real situations arising up in EMP, as a rule, considerably more difficult than those, which a priori are foreseen by experts. Therefore tuning of model (1) on the folded situation precedes to making of administrative decision. The structure of expressions (1) allows taking such tuning to fixing of values of components of Boolean vector $b=(b_q;\ q=\overline{1,v})$ in obedience to a formula:

$$b_q = \begin{cases} 1, \text{ if } (\forall_p \in P_q)(z_p \in Z_{qp}) \\ 0 - \text{in another case} \end{cases};\quad q=\overline{1,v}\ .$$

The use of algorithm of the directed surplus for making of administrative decision on the basis of expert model (1) requires construction of algebraic combinatorial model proper to it. For this purpose to every predicate $X_i(\sigma_j)$ is compared to the bivalent variable,

$$\text{where } m=\left|\bigcup_{q=1}^{v}\bigcup_{r\in R_q} I_r\right|;\quad J_i=\bigcup_{q=1}^{v}\bigcup_{r\in R_q} J_{ri}\ .$$

Sense of Boolean variables $x_{ij};\ i=\overline{1,m};\ j\in J_i$ is interpreted as follows: if as a result of decision of the administrative task taken to the combinatorial form, some variable $x_{i^*j^*}$ takes on a value 1, it means that in the folded situation it is necessary to realize the i^*-th managing operation in the relation to the j^*-th MO subsystem; at $x_{i^*j^*}=0$ this assertion is incorrect. Then a logical-linguistic model (1) after tuning on a situation can confront the system of algebraic equalizations of the following structure:

$$\sum_{r\in R_q}\prod_{i\in I_r}\prod_{j\in J_{ri}} x_{ij}=b;\quad q=\overline{1,v}\ . \tag{2}$$

Transition to the algebraic model gives possibility to optimize the sought administrative decision after on the set criterion. Total financial costs on realization of administrative decision, charges of material and technical resources, expense of time on returning of the EMP system in the normal state and other can come forward as such criterion. In most cases the criterion of the sought administrative decision after is expressed by the linear function of the following kind:

$$f(x)=\sum_{i=1}^{m}\sum_{j\in J_i} c_{ij}x_{ij}\to \min\ , \tag{3}$$

where c_{ij} - value, which characterizes cost of realization of the *i-th* managing operation, for example, in regard to the j-th MO subsystem.

Consequently, the task of making of administrative decision on the basis of expert model (1) is taken to finding of vector of values of Boolean variables turning in a minimum a criterion function (3) at the observance of the system of limitations (2). Task (2) – (3) behaves to the class of extreme combinatorial tasks with a nonlinear structure, unimodal matrix of coefficients and free members. It grounds to consider that for its decision it is expedient to use the algorithm of the directed surplus of variants [3], adapted under the structure of mathematical expressions (2).

Algorithmization of task of making of administrative decision

This algorithm foresees the successive crushing of initial great number G of variants of decision of task (2) – (3), producible until the optimum decision will not be found or the fact of unjoint of the system of limitations is set (2). Breaking up of great number G and subsequent it's subsets is carried out by fixing of values of the sought variables after. That subset of variants, which minimum estimation of criterion function corresponds to, gets out for the further breaking up on every stage of decision of task. Selected subsets of variants is exposed to the formal analysis on purpose maximally narrow a further search area, to shorten the volume of the processed information and the same accelerate the process of receipt of the sought result after. The complete great number G of variants of decision of the system (2) consists of 2^N vectors of values of variables, where $N = \sum_{i=1}^{m} |J_i|$.

We will suppose, to beginning of some stage of decision of task in the complete variety of variants selected λ of non-overlapping subsets containing the possible vectors of values of the sought variables after, $k = \overline{1, \lambda}$.

Disengaging oneself from physical sense of the examined task and taking into account that the sought variables after have double indexation, we will enter the following denotations:

I_k^0 and I_k^1 are the varieties of the first indexes of the sought after variables getting in the vectors of G_k subset of value 0 and 1 accordingly:

$$I_k^0 = \{i : 1 \le i \le m, \exists j[(1 \le j \le n_i) \& (x_{ij} = 0)]\}, \quad I_k^1 = \{i : 1 \le i \le m, \exists j[(1 \le j \le n_i) \& (x_{ij} = 1)]\};$$

I_k - the variety of the first indexes of the sought variables after, the values of which in the vectors of G_k subset are not fixed:

$$I_k = \{i : 1 \le i \le m, J_{ik} \ne \varnothing\};$$

J_{ik}^0 and J_{ik}^1 - the varieties of the second indexes of variables, x_{ij}, $i \in I_k^0$ and x_{ij}, $i \in I_k^1$ accordingly, getting G_k subset of the value 0 and 1 in vectors:

$$J_{ik}^0 = \{i : 1 \le j \le n, x_{ij} = 0\}, \quad i \in I_k^0; \; J_{ik}^1 = \{i : 1 \le j \le n, x_{ij} = 1\}, \quad i \in I_k^1;$$

J_{ik} - the variety of the second indexes of variables x_{ij}, $i \in I_k$, the values of which in the vectors of G_k subset are not fixed:

$$J_{ik} = \{1, \ldots, n_i\} \setminus (J_{ik}^0 \cup J_{ik}^1), \quad i \in I_k.$$

Set of values of variables x_{ij}, $i \in I_k^0 \cup I_k^1$, $j \in J_{ik}^0 \cup J_{ik}^1$ such that

$$(\forall i \in I_k^0)(\forall j \in J_{ik}^0)(x_{ij} = 0) \& (\forall i \in I_k^1)(\forall j \in J_{ik}^1)(x_{ij} = 1),$$

we will name the partial plan of the k-th subset of variants, and any set of values of variables x_{ij}, $i \in I_k$, $j \in J_{ik}$ meeting bivalent condition $x_{ij} \in \{0,1\}$ – complementary plan of this G_k subset.

Substitution of partial plan of the every k-th $(1 \le k \le \lambda)$ subset of variants in an initial model (2) –(3) will transform it to the private form proper to this subset. For presentation of such private form on the varieties R_q, I_r, J_{ri} following subsets are selected:

$$R_{qk}^0 = \{r \in R_q : (\exists i \in I_r)(J_{ri} \cap J_{ik}^0 \ne \varnothing)\}; \; R_{qk}^1 = \{r \in R_q : (\exists i \in I_r)(J_{ri} \subseteq J_{ik}^1)\};$$

$$R_{qk} = R_q \setminus \left(R^0_{qk} \cup R^1_{qk}\right); \;\; q = \overline{1,v}; \; I_{rk} = \left\{i \in I_r : J_{ri} \cap J_{ik} \neq \varnothing\right\}, \quad r \in R_{qk};$$

$$J_{rik} = J_{ri} \cap J_{ik}; \quad r \in R_{qk}, \quad i \in I_{rk}.$$

Limitation of the system (2), to which dissatisfies even one of complementary plans of subset, is named active in relation to the plans of this subset of variants. The great number Q_k of numbers of such limitations is determined in obedience to a formula:

$$Q_k = \left\{q : 1 \le q \le v; R_{qk} \neq \varnothing\right\}.$$

Taking into account the entered denotations algebraic model (2) – (3), resulted in accordance to the k-th subset of variants, it is possible to represent in the following form:

$$f_k(x) = \sum_{i \in I^1_k} \sum_{j \in J^1_{ik}} c_{ij} + \sum_{i \in I_k} \sum_{j \in J_{ik}} c_{ij} x_{ij} \to \min; \tag{4}$$

$$\sum_{r \in R_{qk}} \sum_{i \in I_{rk}} \prod_{j \in J_{rik}} x_{ij} = b_q; \quad q \in Q_k. \tag{5}$$

Algorithm of decision of extreme combinatorial task (2) – (3), realizing strategy of the directed surplus of variants, foresees implementation on every stage of calculable process of a next execution sequence.

1) Choice of the subset of variants, subject to breaking up.
2) Choice of variable, the values of which are subject to fixing.
3) Breaking up G_{k*} subset of variants.
4) Analysis of the G^0_{k*} G^0_{k*} and G^1_{k*} subsets of variants.
5) Verification of terms of ending of calculable process.

Conclusions

As compared to the existent methods of output of administrative decisions on the basis of logical-linguistic models the expounded method possesses the following advantages:

– diminishment of volume of the processed information and accordingly by reduction of duration of decision of the administrative tasks EMP;

– ability of finding of complex decisions foreseeing simultaneous realization of a few elementary managing operations;

– possibility of optimization of administrative decisions on the set criteria

The resulted algorithm of the directed surplus possesses the property of plenitude, conditioned that none of selected subsets of variants is eliminated from the field of consideration to establishment of fact of incompatibility of the system of limitations proper to him.

The described method of making of administrative decisions is oriented to the use in the situation control systems of electrical mounting enterprises. Most administrative tasks arising up on electrical mounting production are inscribed in a simple enough formal chart (1), that allows to use the algorithm of the directed surplus of variants for their decision.

Distribution of the expounded method on more difficult cases, code it is necessary to take into account the mutual influencing on each other of subsystems of object of management, is perspective direction of further researches.

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PERSPECTIVES OF SPECTRUM SLIDING ANALYSIS APPLICATIONS

The spectrum sliding analysis is a dynamic spectrum analysis in which the next analysis interval differs from the previous one by including the next signal sample and excluding the first one from the previous analysis interval. Such a spectrum analysis is necessary for time-frequency localization of analyzed signals given peculiarities. Using the well-known fast Fourier transform (FFT) towards this aim is not effective. Recursive algorithms which use only one complex multiplication for computing one spectrum sample during each analysis interval are more effective. One of such algorithms was improved so that it is possible to use only one complex multiplication for computing two, four, and even eight (for complex signals) spectrum samples simultaneously. Perspectives of spectrum sliding analysis applications are considered in the paper, particularly for speech analyzers.

Introduction

Depending on the signal form presentations, spectrum sliding analysis (SSA) may be implemented by analog, digital, or discrete-analog spectrum analyzers. Narrow band analog filters can be used to implement SSA at some points of the frequency's working band. However, such analyzers are usually designed to analyze power spectrum and are not capable of analyzing phase spectrum and complex spectrum Cartesian constituents that restricts their applications [1]. The spectrum analysis discrete-analog method uses the discrete signal formed by sampling the signal to be analyzed with an uncrossed pulse sequence, the magnitudes of which are altered in accordance with the sample values. This type of analyzer permits spectrum analysis with quality and quantity compatibility conditions, satisfying the information completeness condition [1], and it may be adapted for SSA [2, 3]. Spectrum digital analyzers [4] are the most popular.

There are two SSA spectrum methods: in one the origin of the reference function is matched with the interval analysis origin. This approach computes the sliding spectrum [5]. In many applications (e.g., speech recognition) there is no need for such matching. When this is the case the computation is called the instant spectrum [5]. Algorithms and devices implementing the two methods are considered in the following sections.

Sliding Spectrum Devices

The sliding spectrum is given by formula:

$$F_q(p) = \frac{1}{N} \sum_{k=q-N+1}^{q} f(k) W_N^{-p(k-(q-N+1))}, \quad p \in \overline{0, P-1}, \quad q = 0,\ 1,\ 2,..., \tag{1}$$

where q is an analysis interval index, k is a signal sample index in the limits of the sliding window $k \in \overline{q-N+1, q}$, N is the size of the processing extract, and $F_q(p)$ is the complex spectrum sample at the frequency $p\Delta\omega$ at the instant $q\Delta t$, $f(k)$ is the analyzed signal sample value at the instant $k\Delta t$, and W_N^{-pk} is the complex reference coefficient symbolic representation $\exp(-j2\pi pk/N)$. Δt and $\Delta\omega$ are the discrete time and frequency intervals, determined by the information completeness condition [1].

Direct computation of the functional (1) requires NP complex multiplications and $(N-1)P$ additions. FFT [6] reduces this number by $N/\log_2 N$. Further reduction is possible. The formula:

$$F_q(p) = \left(F_{q-1}(p) + (f_q - f_{q-N})/N\right) W_N^p, \quad p \in \overline{0, P-1}, \quad q = 0,\ 1,\ 2,... \tag{2}$$

leads to a recursive algorithm [7] computing the sliding spectrum samples. The computing requirements (number of complex multiplications) are considerably lower using (2) rather than (1). In (1), N complex multiplications are computed for each spectrum sample ($\log_2 N$ if FFT is used). Using (2) the same computation requires only one complex multiplication. This advantage has led to many sliding spectrum analyzers [8-10] implementing (2).

Computational stability of algorithm (2) is achieved by the appropriate rounding of twiddle factor constituents having factor modulus not exceeding unity [11]. The constituents word size should be by (1/2)$\log_2$(*number of sliding steps*) more than the signal samples word size [12]. For an unlimited number of sliding steps it is possible to use the technical decision described in [13]. While using algorithm (2) the reference function is always matched with the analysis interval origin, thereby ensuring a matched filtering [14-16].

Instant Spectrum Devices

The instant spectrum

$$F_q(p) = \frac{1}{N} \sum_{k=q-N+1}^{q} f(k) W_N^{-pk}, \quad p \in \overline{0, P-1}, \quad q = 0,\ 1,\ 2,\dots\ . \tag{3}$$

can be implemented by the following simple recursive algorithm [17, 18]

$$F_q(p) = F_{q-1}(p) + \left(f_q - f_{q-N}\right) W_N^{-pq} / N, \quad p \in \overline{0, P-1}, \quad q = 0,\ 1,\ 2,\dots\ . \tag{4}$$

This algorithm is always stable and the twiddle factors W_N^{-pq} word size is the same as the word size of signal samples. Devices [19, 20] implement (4) in conveyer mode.

This algorithm has a remarkable property which permits one to organize SSA so that one complex multiplication may be used for computing two, four and even eight (for complex signals) spectrum harmonics at once [21-23]. This may be done by presenting algorithm (4) as follows:

$$F_q(p) = F_{q-1}(p) + \Delta F_q(p), \quad p \in \overline{0, P-1}, \quad \Delta F_q(p) = \left(f_q - f_{q-N}\right) W_N^{-pq} / N. \tag{5}$$

The spectrum increments $\Delta F_q(p)$ may be used not only for spectrum harmonic *p,* but also for spectrum harmonics

$$p_i = iN/4 + p, \qquad i \in \overline{1,\ 3} \tag{6}$$

and

$$p_k = kN/4 - p, \qquad k \in \overline{1,\ 4} \tag{7}$$

using known properties of the complex exponential function. A simplified summary of (5) can be described as follows:

1. for harmonics of the form (6)

$$F_q(p_i) = F_{q-1}(p_i) + (-j)^{iq} \Delta F_q(p), \tag{8}$$

2. for harmonics of the form (7)

$$F_q(p_k) = F_{q-1}(p_k) + (-j)^{kq} \Delta F_q(-p), \tag{9}$$

where $\Delta F_q(-p)$ are complex conjugated spectrum increments $\Delta F_q(p)$, if the signal samples are real. If the signal samples are complex, the increments $\Delta F_q(-p)$ are generated by inverting the signs of the products of the signal increments $\Delta f_q = (f_q - f_{q-N})/N$ with the imaginary part of the weighting function and then forming the appropriate algebraic sums. Devices [24-28] implement (8) and (9).

Possibilities of SSA Applications

SSA may be used for FIR-filtering [29] in invariant to information shift (stationary) mode. Such filters perform signal convolution with a given impulse response

$$s(\tau) = \int_{\tau-T}^{\tau} f^*(t) g(t-\tau) dt = \int_0^T f^*(t+\tau) g(t) dt. \tag{10}$$

In accordance with Parsevol theorem (10) is equivalent to the integral

$$s(\tau) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F_\tau(\omega) G^*(\omega) d\omega, \tag{11}$$

where $G(\omega)$ is the unshifted impulse response spectrum, and $F_\tau(\omega)$ is the signal sliding spectrum in the analysis interval T. The discrete version of (11) is

$$r(q) = \sum_{p=0}^{P-1} F_q(p) G^*(p), \tag{12}$$

where $F_q(p)$ and $G^*(p)$ are samples of the spectra $F_\tau(\omega)$ and $G^*(\omega)$, P is the number of impulse response spectrum readouts.

The expression (12) is the formal description of the FIR-filtering algorithm on the basis of SSA [16]. Practical realization of the filtration procedure while processing with a set of D different impulse responses may be performed by the device, whose functional diagram is shown in Figure 1, where SSA is a spectrum sliding analyzer; MU$_i$ are multipliers, $i \in \overline{1, D}$; ROM_G$^*_i$ are complex conjugated transfer function ROMs of the spectral readouts for the appropriate filter channels; AA$_i$ are accumulating adders of the pair products.

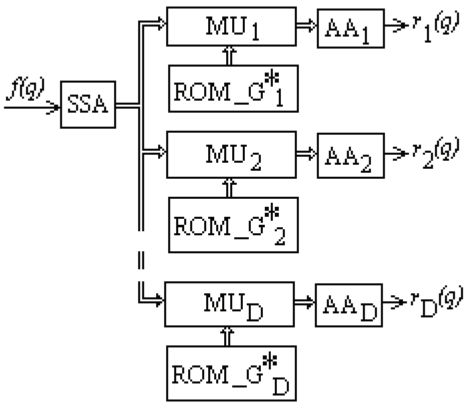

Figure 1: Varying impulse responses

The considered SSA-based multichannel filters, in each frequency channel, differ from each other only in the contents of the ROM of spectral readouts of the complex conjugate transfer function of the appropriate filtration channel. On the basis of SSA it is simple to design single-channel digital and discrete-analog filters with reconfigurable transfer functions, e.g., adaptive filters. For this purpose it is sufficient to write spectrum readouts of each possible transfer function into a set of ROMs and, after performing the next sliding step, to connect the ROM with the required characteristic to the multiplying unit input. Note, that in this case the speed of response increases *N* times as compared with the most effective filtration on the basis of FFT. It is explained by the fact that in order to change characteristic, in the latter case, it is necessary to process about 2*N* signal samples, according to which *N* filtered readouts of the output signal should be output, and only after that it is possible to change the contents of the ROM with spectral readouts. Contrary to this, while filtering on the basis of SSA, each filtered readout of the output signal is output after shifting the analysis interval by only one input signal sample. And after outputting the next output signal it is possible to immediately change the ROM contents of the spectral readouts.

Another possibility of SSA is its using for speech analyzer application. Speech analyzer function is defined as a device which does not appeal to the understanding of language message, but is capable of converting acoustic language stream in characters adequately connected to the phonetic system of the speech [30]. On the basis of such speech analyzer it can be a comparatively simple creation of different devices, speech recognition both discrete and continuous one that do not require adjustment to a particular speaker.

It is known the speech analyzer [31], which is used in speech recognition devices and include a microphone with a microphone amplifier, analog-digital converter (ADC), phoneme codes memory, phoneme codes recognition unit and source interface.

Analyses of speech with such analyzers are not consistent with the fundamental periods of the speech signal that leads to lower recognition accuracy.

In the most famous speech analyzer close to the technical essence is a utility model analyzer [32], which has a microphone with a microphone amplifier, whose output is connected to the input of low-pass filter, ADC, input control is connected to the output clock pulse generator, phoneme codes memory attached to the phonemes codes identification unit, whose output is connected to the output interface.

The drawback of the prototype is that the analysis of speech is inconsistent with the fundamental periods of the speech signal that leads to lower recognition accuracy. In addition, spectral analysis of times speech signal processor is a FFT one, implementing the so-called “jumping FFT” [29] with a jump of size equal to a quarter of the analysis window (approximately 5 ms), which does not localize the boundaries of phonemes in time with higher accuracy. Presence of these defects reduces the accuracy of phonemes recognition and the task of the utility model is to improve the accuracy.

The task is solved by the speech analyzer utility model [33] presented in Figure 2, acronyms of which have the following meanings: M - microphone, MA - microphone amplifier, LPF1, LPF2 - low-pass filters, DADL - discrete-analog delay line, ISDA – instant spectrum digital analyzer, QSADU - quasi-stationary areas determination unit, S/H - sample-and-hold circuit (analog storage device), ADC - analog-digital converter, IFPDU - instant fundamental period determination unit, PRFD - pulse repetition frequency divider, PCIU - phoneme codes identification unit, OI - output interface, CPG - clock pulses generator, and PCM - phoneme codes memory.

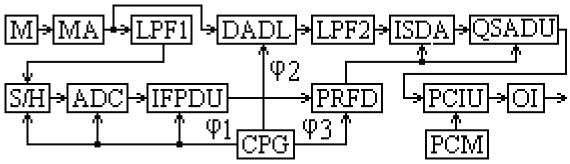

Figure 2: Speech analyzer utility model

The speech analyzer principle of operation is based on the speech signal spectrum sliding analysis [34]. When analyzing the spectrum with a sliding window which does not exceed the minimum possible duration of the quasi-stationary part of the phoneme was possible to distinguish quasi-stationary areas of phonemes in the speech signal, for almost all sounds of Russian language [35].

The input speech signal, such as from the M is given to the input of DADL via MA and, at the same time, through LPF1 to S/H information input. The purpose of LPF1 is to ensure passage to IFPDU input the part of the spectrum of the speech signal, which contains variations of the fundamental period, i.e. the bandwidth of the M-MA-LPF1 tract should be 70-450 Hz [36].

The series of strobe pulses φ1 from the first CPG output comes to the S/H, ADC, and IFPDU control inputs. The repetition period of φ1 should be equal to the permissible error in determining the instant fundamental period of the speech signal. The S/H output analog values of samples of the speech signal are fed to ADC information input. ADC converts the analog values into the digital speech signals and presents them to the input of IFPDU. Digital instant values of the fundamental period is used to fast reconfiguration PRFD, which is used for dividing frequency repetition of the series pulses φ3 from the third exit of CPG to ISDA and QSADU control inputs.

The series of strobe pulses φ2 with the sampling rate of not less than 12.5 kHz is fed from CPG second output to the control input of DADL. Preliminary experiments showed that at the lower sampling rate the high-frequency part of the acoustic signals spectrum significantly distorted, for example, after sampling sound combinations “TSE” with a sampling rate equal to 8 kHz, this sounds like a combination of sounds “PHE”. DADL intended to delay the speech signal to determine the instant fundamental period of time in IFPDU.

The output from DADL is fed to the information input of ISDA through LPF2 needed to smooth the discrete-analog signal. Clock pulses, the repetition period of which is determined by IFPDU, are given from PRFD to ISDA control input.

Indeed, ISDA analyzes the analog signal, normalized over the fundamental period of the analyzed speech signal part. Two problems are being solved in this way: the first is the exclusion of intonation variation in speech signal, depending on the emotional state [37] and the second is providing the possibility of the sliding spectrum analysis with interval analysis, equal to integer periods of the fundamental tone, in particular to one period. For this purpose CPG repetition period φ3 is chosen such that at the lowest possible fundamental period there would be possibility for ISDA definition of a spectral component of the speech signal.

ISDA performs the sliding mode with the window of analysis equal to integer of the fundamental periods, the analysis of the speech signal normalized spectrum and gives it for splitting to QSADU, which establishes the existence of such quasi-stationary areas, encodes them and gives their codes to PCIU. Its second input is associated with PCM. PCIU performs speech phoneme coding and put them to OI to interrupt whenever they are ready to pass this code (one byte) to the computer. The frequency of interrupts does not exceed 20 Hz, due to the human speech speed.

The computer with the help of appropriate software performs linguistic analysis of the relevant code tuples of phonemes, and selects from them the words and sentences, carrying the semantic interpretation of speech rights. Linguistic analysis involves the use of a knowledge base that is configured for a particular vocabulary voice person depending on the domain of use. At the same time not only the major variants of pronunciation, but also all possible future ones used by operators who are to work with this input speech device are written into the knowledge base.

Most units used here are units of computers and are familiar to specialists. For example, you can perform S/H as described in [38], providing greater accuracy and speed, ADC can be performed as described in [39] also providing greater accuracy. IFPDU can be carried out as described in [35], implementing the proposed efficient recursive algorithm. PRFD can use the device [40], and DADL can use charge-coupled devices [41]. As for ISDA, then as it is depending on the desired speed, you can choose one of the devices specified in [23].

Conclusion

The review of the spectrum sliding analysis algorithms and devices was presented in this paper, particularly their possibilities to be used in different applications. The speech analyzer utility model [33] using such SSA was described in detail.

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DESIGNING MULTI-SERVICE LOCAL AREA NETWORKS ON THE BASE OF ETHERNET SWITCH'S COMMUNICATION NET

Algorithm for design and calculation of the local multi-service network area (LAN) is described. The algorithm consists of a series of sequential steps - are: the construction of information-geometric model of the network, transforming this model into a network of ideal switches, the realization of the each ideal switch as the union of industrial switches, setting the parameters of industrial switches.

The difference between this work from previous publications. This work is a continuation of the publications [1-2], but there are differences. In [1-2] information-geometric model of the network transformed into an ideal switch, and an ideal switch is replaced with the real. Here, the Information and geometric network model is transformed into a network of ideal switches, and then a network of ideal switches is transformed into a network of industrial Ethernet-switches.

Building information-geometric model of the network. As shown in [1-2], to begin designing the network need to construct a formal description of the network as an information-geometric model, i.e., in the form of graphs and matrices (Fig. 1, a). Graph vertices correspond to network nodes (sources / consumers of information), and ribs - the information flow (traffic) and the distance between the peaks.

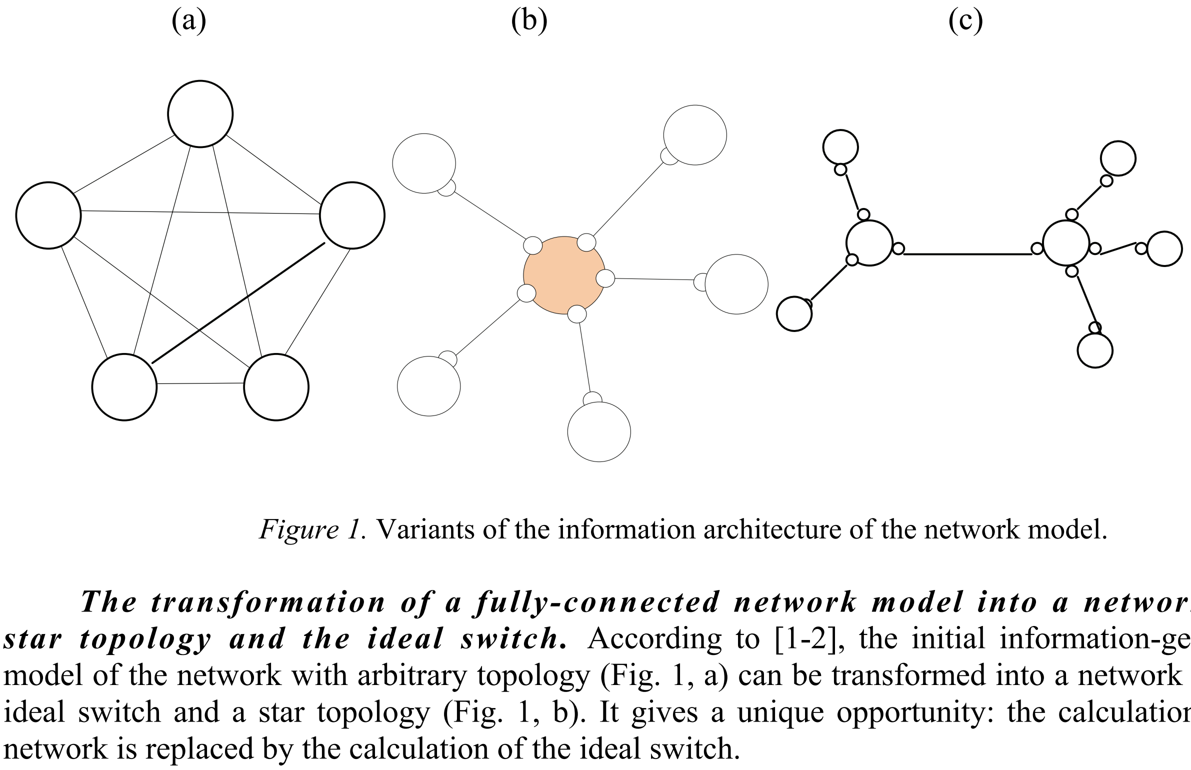

Figure 1. Variants of the information architecture of the network model.

The transformation of a fully-connected network model into a network with star topology and the ideal switch. According to [1-2], the initial information-geometric model of the network with arbitrary topology (Fig. 1, a) can be transformed into a network with an ideal switch and a star topology (Fig. 1, b). It gives a unique opportunity: the calculation of the network is replaced by the calculation of the ideal switch.

Converting an ideal switch of network to a network of ideal switches of segments. Network of (Fig. 1, b) can be divided into segments (groups of end nodes). For the grouping of nodes can use the criterion of geometric proximity (on the basis of the geometrical configuration of the network). Suppose, for example, nodes 1,5 will be treated to the first segment. Suppose that nodes 2, 3, 4 will be treated to the second segment. Then the ideal switch of the entire network (Fig. 1, b) will be replaced by two ideal switches of network segments (Fig. 1, c).

The calculation of the distribution of classes of traffic on ports ideal switch. One of the main objectives of designing a modern local area network - is to ensure the normal operation of applications with different types of traffic. To solve this problem the application is divided into classes. Number of such classes is eight.

In [1-2] is an example (Table 1) distribution of two classes of traffic ($\mathbf{H^{VO}}$ и $\mathbf{H^{BE}}$) to 34 ports of an ideal switch. In this example, the $\mathbf{H^{VO}}$ - the class of delay-sensitive traffic - a mixture of voice (VoIP) and video (Video) Traffics. $\mathbf{H^{BE}}$ - class insensitive to traffic delays - a mixture of traffic and WWW traffic FTP.

The table 1. An example of account of productivity of ports of the switch

	1	2	3	4	5	6	7-33	34	Total
	VoIP - gateway	Video - gateway	WWW-server	FTP - server	PC1	PC2	PC (3-29)	PC - 30	
$\mathbf{H^{Vo}}$	3,84	61,44	0,00	0,00	2,18	2,18	58,75	2,18	131
$\mathbf{H^{Be}}$	0,00	0,00	570,00	750,00	44,00	44,00	1188,00	44,00	2640
V	19	307	633	833	51	51	1385	51	3332

Reservation and the calculation of productivity ports of ideal switch. One of overall objectives of designing of a local network, in which the traffic consists of a mix of a vote, images and text, is to prevent damage of each of this traffic.

It is known, that the basic idea underlying all methods of maintenance of the characteristics QoS, consists in the following: the common productivity of each resource should be shared between different classes of the traffic non-uniformly. In that specific case productivity of ports of the switch also should be shared between different classes of the traffic non-uniformly.

It is known, that a primary factor influencing size of delays of packages in the switch, so, and on quality of service, is operating ratio of a resource. Therefore for maintenance of the certain quality of service it is important, that operating ratio of port of the switch did not exceed the certain size.

So, for simplification of a task all flows are shared into two classes - sensitive to delays (traffic of real time, for example voice) and elastic, admitting the large delay, but sensitive to losses of the data.

It is known ([1-2]), the limiting loading of port of the switch by the sensitive traffic should not exceed 0.2, and the limiting common loading of port by the sensitive and elastic traffic should not exceed 0.9.

In view of the accepted designations and named restrictions it is possible to define throughput of ports of the switch ($v_{i=1,\dots,N}$) for two classes of the traffic H^{VO} and H^{BE} by the following formula:

$$v_i = \max\left((h^{VO}_i + h^{BE}_i) / 0.9,\ h^{VO}_i / 0.2\right)$$

The result of account of throughput of all ports of the switch (matrix-line **V**) is given in Table 1.

Calculation of parameters of a configuration of the ideal switch. On the basis of table 1 it is possible to determine parameters of a configuration of the ideal switch (tab. 2). Here common productivity of the switch is equal to the double sum productivity of all ports of the switch.

The table 2. A configuration of the ideal switch

№	The name of parameter	Meaning
1	Quantity of ports	34
2	Common productivity of the switch (Gbit/s)	6,7
3	Number of classes of service	2
4	Configuration of ports (Mbps):	
	productivity of the port-1	19
	productivity of the port -2	307
	productivity of the port -3	633
	productivity of the port -4	833
	productivity of the port -5	51
	…	
	productivity of the port -34	51

Algorithm of realization of the ideal switch. Definition of criteria of a choice. The elementary algorithm of realization of the ideal switch can be shown to search of such industrial model of the switch, which configuration covers and is closest to a configuration of the ideal switch is, first. And, secondly, it is necessary, that the parameters of industrial model could change by the manager of a network so that after the appropriate adjustment the industrial switch was identical to the ideal switch.

Define the sequence parameters of industrial model that should be taken into account - is: the number of ports, performance switches, the number of priority queues, the number of management levels, the ability to aggregate ports, the possibility of forming ports, the ability to maintain quality of service parameters of multimedia traffic (QoS, CoS), the presence of Web- interface for configuration, manufacturer, price.

The step-by-step comparison of parameters of a configuration of the ideal switch (tab. 2) with parameters of a configuration of firm switch of a class “L3” of firm “D-link” shows, that the parameters of model DES-3852 (tab. 3) coincide or not worse than parameters of the ideal switch.

Realization of the ideal switch as a network of real switches. By combining real switches can be achieved to increase the total number of ports and overall performance. This is necessary when for the implementation of the ideal switch is not suitable real model. However, it should be remembered that by combining real switch part of their resources are spent on internal traffic.

Setup of the parameters of industrial switch and nodes of the network. The model of the switch DES-3852 has a powerful set of functions (protocols) and teams of adjustment, which allow:

- Port and link Aggregation,
- Support 802.1p priority queuing Quality of Service,
- profiling ports,
- creation of virtual networks in the form of IP-subnets.

Just note, that after the commands aggregation and profiling of ports the factory settings of the switch will be changed, and as a consequence, productivity of 34-ports of the ideal switch and the real switch will be identical.

The table 3. Structure of parameters of model of the switch DES-3852

№	Name of the parameter	The value
1	Number of ports	52
2	Common productivity of the switch (Gbit/s)	15,7
3	Configuration of ports (Mbps):	
	Quantity of ports 10/100/1000/STP	2
	Quantity of ports 10/100/1000	2
	Quantity of ports 10/100	48
4	Number of priority queues	8
5	Number of management levels	L3
6	802.3ad Link Aggregation: 32 Groups , 8 ports in the group	+
7	Bandwidth management: a step for each port 64 KB / s	+
8	QoS/CoS	+
9	Price ($)	1030

Conclusion. Algorithm for design and calculation of the local multi-service network area is described. Example of calculating the network based on Ethernet-switch gived. The algorithm can be easily programmed on the algorithmic language and complemented by an electronic directory of switches from different manufacturers to automate the calculations networks of any complexity.

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OPTIMIZATION OF PARAMETERS OF UNLOADING SYSTEM OF GYROSCOPIC FRAMES

The technique of optimization of parameters of unloading systems of gyroscopic frames of automatic control systems is considered

In automatic systems the required direction of object of management is usually sets by special gyroscopic devices. As gyroscopic sensors gyroscopic frames are used. Proceeding from the tasks, decided by automatic control systems, one-plane, two-plane or three-plane gyroscopic frames can be used in their structure. With the purpose of maintenance the accuracy of operation and indemnification of influence on a gyroscopic frame of external indignations, an unloading system enters in its structure. The effectiveness of unloading system appreciably determines quality of functioning of all automatic control system.

The block diagram of a two-plane gyroscopic frame with unloading system is resulted on Fig.1.

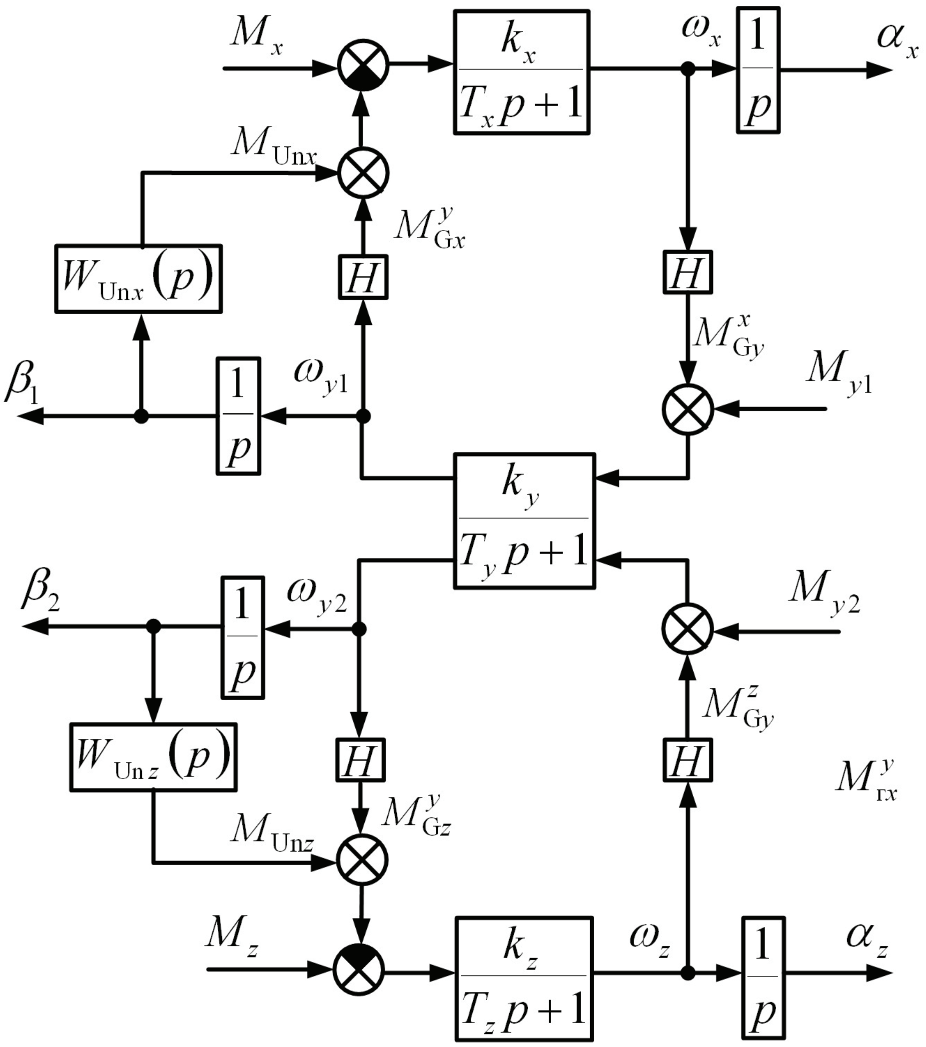

Fig.1 The block diagram of two-plane gyroscopic frame with unloading system

On the diagram the following designations are accepted: M_x, M_y, M_z - the external moments acting on the frames; α, β - corners of turning of the frames; k_x, k_y, k_z - transfer factors of frames;

$T_x, T_y.T_z$ - constants of time of frames; H - the kinetic moment of a gyroscope; $M^{y}_{Gx}, M^{y}_{Gz}.M^{x}_{Gy}.M^{z}_{Gy}$ - the gyroscopic moments; M_{Unx}, M_{Unz} - the unloading moments.

Transfer functions of unloading system $W_{Unx}(p), W_{Unz}(p)$ are shown on the block diagram in a general view and should be determined for each concrete case depending on transfer functions of the elements, which are included in system. Usually aspire to reduce maximum the inertia of unloading systems and whenever possible to increase its transfer factor in order to most full compensate actions of the external revolting moments.

Let's consider a case when the unloading system has no inertia and its transfer function looks like:

$$W_{Un}(p) = \frac{M_{Un}}{\beta} = k_{Un},$$

where k_{Un}, - transfer factor of unloading system.

Transfer functions of gyroscopic frame with the unloading system, that has no inertia, determined concerning the specified indignations and axes of stabilization, are resulted in the table.

The table.

Transfer functions of gyroscopic frame with the unloading system, which has no inertia

Stabilization of the axis X		
Impacts on the gyroframe	Reactions of the frames	
	$\alpha_x = \frac{\omega_x}{p}$	$\beta_1 = \frac{\omega_{y1}}{p}$
Moment M_x, acting on the outer frame	$\frac{f_y}{Hk_{Un}} \cdot \frac{T_y p + 1}{\frac{H}{k_{Un}} pA(p) + 1}$	$\frac{1}{k_{Un}} \cdot \frac{1}{\frac{H}{k_{Un}} pA(p) + 1}$
Moment M_{y1}, acting on the inner frame	$-\frac{1}{Hp} \cdot \frac{\frac{H}{k_{Un}} p + 1}{\frac{H}{k_{Un}} pA(p) + 1}$	$\frac{f_x}{Hk_{Un}} \cdot \frac{T_x p + 1}{\frac{H}{k_{Un}} pA(p) + 1}$
The characteristic polynomial of the gyroframe without unloading system		
$A(p) = \frac{T_x T_y}{1 + k_x k_y H^2} p^2 + \frac{T_x + T_y}{1 + k_x k_y H^2} p + 1$		
Stabilization of the axis Z		
Impacts on the gyroframe	Reactions of the frames	
	$\alpha_z = \frac{\omega_z}{p}$	$\beta_2 = \frac{\omega_{y2}}{p}$
Moment M_z, acting on the outer frame	$\frac{f_y}{Hk_{Un}} \cdot \frac{T_y p + 1}{\frac{H}{k_{Un}} pA(p) + 1}$	$\frac{1}{k_{Un}} \cdot \frac{1}{\frac{H}{k_{Un}} pA(p) + 1}$
Moment M_{y2}, acting on the inner frame	$-\frac{1}{Hp} \cdot \frac{\frac{H}{k_{Un}} p + 1}{\frac{H}{k_{Un}} pA(p) + 1}$	$\frac{f_z}{Hk_{Un}} \cdot \frac{T_z p + 1}{\frac{H}{k_{Un}} pA(p) + 1}$
The characteristic polynomial of the gyroframe without unloading system		
$A(p) = \frac{T_z T_y}{1 + k_z k_y H^2} p^2 + \frac{T_z + T_y}{1 + k_z k_y H^2} p + 1$		

The analysis of the submitted data shows, that for reduction of mistakes of a gyroscopic frame it is expedient to increase static transfer factor of unloading system. However at a choice k_{Un} it is necessary to remember, that its maximal size is limited by conditions of stability the gyroframe, which frames have definite J_x, J_y, J_z inertia.

In view of uniformity of block diagrams of gyroframe for each of planes of stabilization, we shall consider a technique of optimization of parameters of unloading system on an example of the unloading system concerning an axis X.

If to take into account, that $T_x = \frac{J_x}{f_x}$ and $T_y = \frac{J_y}{f_y}$, where f_x, f_y - factors of friction in support of frames, even at absence of inertia at unloading system gyroframe will be described by the differential equation of the third order. The characteristic multinominal of the gyroframe at presence of unloading system looks like:

$$A_{\text{г}}(p) = \frac{H}{k_{\text{Un}}} \cdot \frac{T_x T_y}{1 + k_x k_y H^2} p^3 + \frac{H}{k_{\text{Un}}} \cdot \frac{T_x + T_y}{1 + k_x k_y H^2} p^2 + \frac{H}{k_{\text{Un}}} p + 1.$$

According to Vyshnegradsky's criterion gyroscopic frame with the unloading system, which has no inertia, will be stability, if the inequality takes place

$$(T_x + T_y)H > T_x T_y k_{\text{Un}}.$$

Hence, the border of stability will be determined by the equation

$$k_{\text{Un}\max} = H\left(\frac{1}{T_x} + \frac{1}{T_y}\right).$$

At constant values of T_x and T_y, determined by the parameters of the gyroframe, the area of stability in a plane of parameters k_{Un} and H looks like resulted on fig.2a. The maximal value of transfer factor of unloading system corresponds to a point A crossings of straight lines $H_N = \text{const}$ and $H = k_{\text{Un}}\text{tg}h$. The area of stability in a plane of parameters k_{Un} and T_x (or T_y) at $H = \text{const}$ is given on fig.2b.

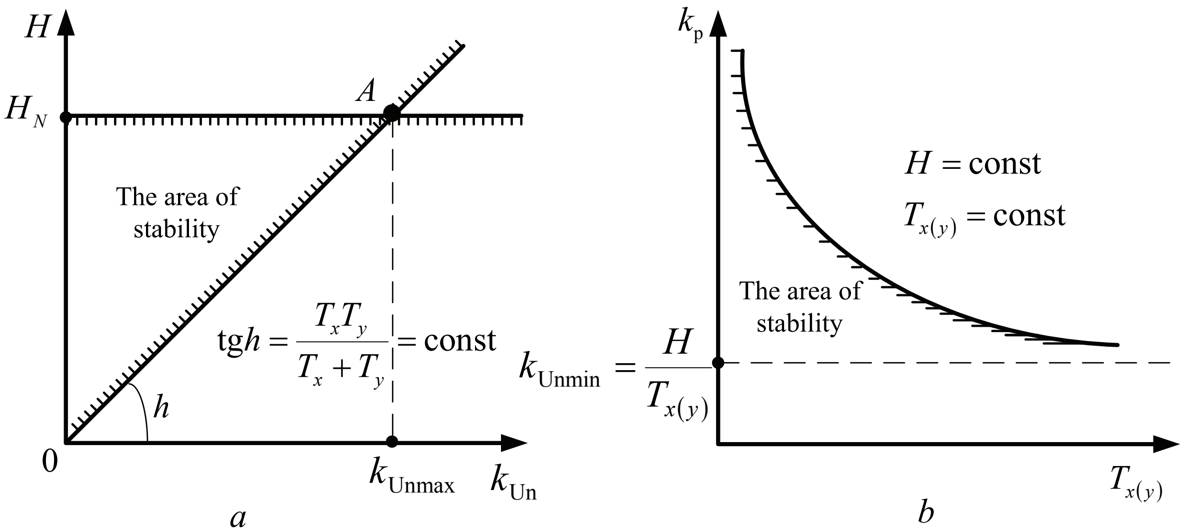

Fig.2 The areas of stability of gyroscopic frame with the unloading system, that has no inertia: *a* - in a plane $H - k_{\text{Un}}$; *b* - in a plane $k_{\text{Un}} - T_{x(y)}$

From materials of fig.2 follows, that allowable value of transfer factor of unloading system is strictly limited. Therefore, during its calculation is always necessary to check gyroframe stability. Any increasing of the the inertia of the frame or reducing of the the angular momentum of the gyromotor leads to decreasing of the area of stability. This requires a corresponding decrease in the maximum value of the transfer coefficient k_{Un} of unloading system.

Researches of the real unloading systems, which transfer functions are usually do not contain ideal differentiating and integrating parts, confirms the received results.

Analysis gyroframe with the unloading system allows to make the following conclusions:

- The established values of corners of deviation of the frames of the gyroframe with the unloading system are inversely proportional to static transfer factor of unloading system, and the compelled deviations is still significant less then the precession.
- The value of static transfer factor of unloading system is strictly limited by the conditions of stability of a gyroscopic frame. Reducing the margin of stability may cause the oscillations and vibrations. Ensuring high accuracy of gyroscopic frames can be achieved only with a rational combination of its own parameters and the parameters of the system discharge.
- Maintenance of high accuracy of job of a gyroscopic frame can be achieved only at a rational combination of its {her} own parameters and parameters of the unloading system.

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SCENARIOS ADAPTIVITY IN THE SUBSYSTEM OF ENVIRONMENT MODELLING IN THE AVIATON TRAINING SYSTEMS

The basic mathematical description of the modeled environment with it's main parts is given in this work. Different types of possible scenarios in the aviation training system are proposed, their main properties and adaptability features that can be applied to them are described. The peculiarities of each type of scenarios are analyzed.

Introduction. In the aviation training systems the subsystem of environment modelling plays the most important role. It makes possible for student to work with the copy of real environment thus allowing him to get used to some peculiarities of real environment and gain certain skills and abilities.

In some publications evolution of the aviation training systems was described [1], and some questions about their adaptability in the part of knowledge testing was risen [2,3,4] but still the question about possible scenarios and their adaptability features was not observed with required persistence.

The main goals of this work are: to give basic mathematical description of the modeled environment with it's main parts; to describe what king of different scenarios are possible in the aviation training system, what are their main properties and what adaptability features can be applied to them; to analyze the peculiarities of mathematical description of each type of scenarios.

Mathematical model. Basically the modeled environment must include the following elements:

1) The tasks those are available for solution in ATS. Their totality can be presented as set $X = \{x_1, x_2, ..., x_n\}$, where x is certain task, and n is their quantity;
2) The control elements, those are available for the student to use. Their totality can be presented as set $C = \{c_{0,} c_1, c_2, ..., c_m\}$, where c is any control element, m is their number, and c_0 is absence of action upon any of the control elements;
3) The control elements require certain set of parameters. Their totality can be presented as set $P = \{p_{0,} p_{1,} p_2, ..., p_m\}$, where p is a single parameter. If the control element is complex one and have few parameters – each part of such element will be considered separately;
4) The indicators those are available for student to analyze. Their totality can be presented as set $I = \{i_1, i_2, ..., i_r\}$, where i is single indicator and r is their quantity;
5) Each indicator has parameter to show. Their totality can be presented as set $S = \{s_{1,} s_2, ..., s_r\}$, where s is a single parameter.

The solution of each scenario is reaching the required indicator's parameter value for every indicator taken into account. This can be done by step-by-step activation of correct control elements with correct parameters. Current state of ATS can be determined by student with help of indicators and their parameters.

During the scenario solution student must execute j actions to pass j steps. j depends on the complexity of the scenario and can vary from 1 up to any number. Each action includes the use of one or more control elements, or waiting for a certain period of time. Action A includes α control elements used by student to pass current scenario step ($\alpha \le m$). Taking into account set $C' = \{c'_1, c'_2 ..., c'_\alpha\}$ as set of used control elements and set $P' = \{p'_{1,} p'_2, ..., p'_\alpha\}$ as set of their parameters ($\forall c' \in C$, $\forall p' \in P$) we can write down:

$$A = f(c'_1, c'_2, ... c'_\alpha; p'_1, p'_2, ..., p'_\alpha) \text{ or}$$
$$A = f(C', P') \text{ for } \forall A.$$

Student chooses the control elements and their parameters on the basis of the indicators parameters. Not all indicators are used but only β of them ($\beta \le r$).

$$\text{Then } A = f(I', S', C', P'), \text{ or}$$
$$C' = f(I', S')$$
$$P' = f(I', S'), \text{ where}$$
$$A = f(C', P')$$

$I' = \{i'_1, i'_2, ..., i'_\beta\}$ - is set of indicators used by the student and $S' = \{s'_{1,} s'_2, ..., s'_\beta\}$ - is set of those indicators parameters ($\forall i' \in I$, $\forall s' \in S$). Hence while solving any task student analyzes the state of imitated environment by the indicators parameters and define the correct sequences of steps required to pass the scenario. In other words he define the values j and both C', P' for each g -th step. This can be written as:

$$I'_g = f(A_g)$$
$$S'_g = f(A_g)$$
$$A_g = f(C'_g, P'_g)$$
$$C'_g = f(I'_{g-1}, S'_{g-1})$$
$$P'_g = f(I'_{g-1}, S'_{g-1})$$

Mathematical description of the environment that is given above may be applied to each of scenario types. The mathematical description of the first and second types of scenario is similar to the basic one's mathematical description while the description of third type differs a little.

The set of tasks $X = \{x_1, x_2, ..., x_n\}$ that are available for solution in ATS is the same in basic, first type and second type. In the third type of scenarios set of tasks $X = \{x_1, x_2, ..., x_n\}$ must be divided into few subsets. The reason for this is that all tasks are divided into normal ones and emergency ones. Let n_1 be the number of normal situations and n_2 be number of emergency situations. Thus the set of tasks for the third scenario type will look like $X = \{x_1, x_2, ..., x_{n_1}, x_{n_1+1}, ... x_{n_2}\}$.

The set of control elements $C = \{c_{0,} c_1, c_2, ..., c_m\}$ that are available for the student to use are the same. In all three scenario types these elements are used and there are no additional peculiarities about them. The control elements parameters also can be presented as set $P = \{p_{0,} p_{1,} p_2, ..., p_m\}$ for all three scenario types. The indicators that are available for student to analyze are presented as same set $I = \{i_1, i_2, ..., i_r\}$. Each indicator parameter also is presented as set $S = \{s_{1,} s_2, ..., s_r\}$.

The scenarios. Three different types of scenarios are proposed for the ATS modeled environment. The first one is such that imitates the finite set of predefined tasks. Each of those tasks has certain strict algorithm of solution, strict quantity of system intermediate states and limited number of imitated environment elements available for student. Student one-by-one activates required elements that influence the environment state changing it. Globally the task for the student is to complete all possible scenarios. Such task can be divided into few subtasks of certain environment states reaching. The correctness of task solution can be under influence of the parameters and time of required state reach. Each task of this type is emergency one. The example of system that uses such scenario type could be aircraft equipment repair trainer. It gives the student broken devise and student's goal is to find out the fault reason and repair the devise.

The second type of scenarios can be such that imitates the normal work of the system, with appearance of the emergency situations in random order and random time. This type of scenario differs from the previous by next:

1) Student must identify the appearance of the emergency state by the imitated environment parameters and choose correct solution for current task;
2) Few simultaneous emergency situations may occur at the same time;

3) Each new task appearance is not instantaneous process as it was in the previous scenario type. Thus the student can solve it in different stages of it's evolution. In the simplest case this can be presented as two possible states available for each task. "Potential threat" state means that this task is not in the emergency state yet and can be solved in some time later. "Emergency threat" state means that current task is in the emergency state and must be solved as soon as possible. Each task in this type of scenario is also emergency one but the main difference is that this task is not given instantly but is shown in dynamics. The example of system that uses such scenario type could be system that imitates aircraft flight. During the flight the crew has to solve some situations about changing the height, avoiding cloud fronts and others.

The process of emergency state identification is the main peculiarity in the second scenario type. This task is absent in the first scenario type and that's what makes important difference between them. Mathematically it could be described as presence of such set of values $S^+ = \{s_1^+, s_2^+, ..., s_r^+\}$ and $S^- = \{s_1^-, s_2^-, ..., s_r^-\}$ that correspond to maximal and minimal acceptable indicator values respectively. It means that the state of modeled environment is counted as one without any kind of threats until any of those limits will be crossed. The question of when the "Potential threat" becomes "Emergency threat" depends on the type of possible threats and combination of parameters that allows their indication. It's quite possible to have certain threats that will be initially similar one to another on the "Potential threat" stage but slightly different on the "Emergency threat" stage.

Few simultaneous tasks appearance with the possibility of each task progress allows to model the complicated scenarios (if modeled environment allows such scenarios), where initially two different tasks appeared almost at the same time require actions that will mutually accelerate their progress. That may put student into complex situation where all his knowledge and skills will be required.

Third type of scenarios is the one that imitates normal work of the environment where many situations of different types are appearing with certain periods of time. The student must react on each situation with corresponding actions. This type of scenarios peculiarity is that along with emergency situations student must know and be able to handle standard ones. Every standard situation is different and may have it's own level of complexity. Major part of tasks in this type is normal task that require few simple actions to solve it, and the least part of tasks are emergency ones. The example of system that uses such scenario type could be air traffic controller. During it's shift many normal flights suppose to land or take off and some of them may become emergency because of lack of fuel or other circumstances.

The adaptivity in each of scenarios is based on the variation of parameters that influence student's work. Those parameters are changed on the base of the correctness of student's actions.

Those parameters for the first type of scenario are following:

1) Task complexity. The student with better progress factors will receive composite tasks of higher complexity. In some cases composite tasks that will be made of elementary ones could be provided. This require presence of so called "simple" tasks that could be united together in different combinations and form complex task;
2) Time of task solution. The student with better progress factors will get less time to solve the task. Or the conditional time limits will be decreased for such student.

The following list will describe description of possible levels of scenarios complications as a result of adaptation to the student's high skill. List is composed taking into account two levels of task complexity and time for solution:

1) Low task complexity, big amount of time;
2) High task complexity, big amount of time or low task complexity, small amount of time. The choice between two these variants depends on the algorithms preset by system designer;
3) High task complexity, small amount of time.

Those parameters for the second type of scenario are following:

1) Task complexity. This parameter is the same as the first from previous scenario type;

2) Time of task solution. This parameter is the same as the second one from previous scenario type;
3) New tasks appearance frequency. The student with better progress factors will receive more tasks per same amount of time;
4) The task progressing rate. The student with better progress factors will receive tasks that will faster proceed from the “Potential threat” state to the “Emergency threat” state thus having less time to react and solve tasks while they are not emergency one’s yet;
5) Maximal number of simultaneous tasks. The student with better progress factors will receive new tasks before they will solve those tasks that are already given.

The parameters should be changed in the following order. The task complexity and amount of time for task solution must be changed in first and second place. The choice of first changed parameter is up to the system designer. Task progressing rate must be changed in third place. The task appearance frequency is fourth to be changed, and the last one is number of tasks at a time.

Those parameters for the third type of scenario are following:

1) Tasks variety. Since different tasks require different solutions and thus different actions – this parameter will define how many different types of the tasks will student receive during it’s work. In case student will react correctly on the most of given tasks their variety will increase with time;
2) The frequency of new situation appearance. This parameter is the same as the third one from previous scenario type. It must be calculated for every task type separately;
3) The frequency of new emergency situation appearance. This parameter is the same as the third one from previous scenario type but it concerns only non-standard situations;
4) The complexity of emergency situation. The student with better progress factors will receive more complicated emergency tasks.

Given parameters should be changed in the following order. First of all the task variety must be kept in balance with the frequency of new situation appearance. At certain tasks appearance frequency the new type of task must be added with simultaneous appearance frequency decrease. The frequency of emergency situation appearance should be changed at constant values of previous two parameters. That will allow student to adapt to the higher emergency rate without paying additional attention to the common tasks. The complexity of the emergency tasks is the last parameter to be changed.

Conclusions. As it is shown the mathematical description of proposed scenario types have a lot of common that allow the designer to use certain pattern for new training environment construction. Proposed scenario types could be applied to any type of required modeled environment. With their described order of adaptive parameters change any ATS can become adaptive one that will influence results of student work. In further works strict algorithms of adaptive processes should be defined, as well as the mathematical description of adaptive parameters with their change processes.

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UDC 519.6 : 519.21 : 511

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DYNAMICS, CODING AND ENTROPIES

Summary: *We review and investigate some new problems in the field of dynamical systems generated by iteration of maps, β-transformations, Hasse-Kloosterman maps, partitions, bundle dynamical systems and aspects of measure-theoretic, topological and metric entropies of the systems.*

Introduction. Dynamical systems have several important complexity measures among which are measure-theoretic, topological and metric entropies. A. Kolmogorov defines the complexity of a measure-preserving transformation by generators. A generator for a measure-preserving transformation T is a partition ξ with finite entropy such that the set of finite entropy partitions subordinate to some $\bigvee_{i=-n}^{n} T^{-i}(\xi)$ is dense in the set of finite entropy partitions endowed with the Rokhlin metric. For smooth dynamical systems topological entropy characterizes the total exponential complexity of the orbit structure. Metric entropy with respect to an invariant measure codes the exponential growth rate of the statistically significant orbits. In symbolic dynamics complexity of a dynamical system is measured with respect to a coding of its orbits. We review and investigate dynamical systems generated by iteration of maps, β-transformations, Hasse-Kloosterman maps, partitions, group actions and bundle dynamical systems.

Iteration of the "$\times$ 2 map" $T(x) = 2x \ (mod\ 1)$. Let $\mathcal{M}$ be the simplex of $\times$ 2-invariant Borel probability measures on $X = [0,1], b(\mu) = \int x d\mu(x)$ the barycentre of the probability measure $\mu, \mathcal{M}_\varrho = \{\mu \in \mathcal{M} : b(\mu) = \rho$. In paper [1] Jenkinson proved

Theorem [1]. For every $\varrho \in [0,1]$ the ordered set $(\mathcal{M}_\varrho, \prec)$ has a least element.This least element is the Sturmian measure S_ϱ of rotation number ϱ.

The theorem itself is a corollary of a result on C^2 convex functions: let $f: X \rightarrow \boldsymbol{R}$ be a C^2 convex function. For every $\varrho \in (0,1)$ there exists $\theta \in \boldsymbol{R}$ such that the Sturmian measure S_ϱ is a minimizing measure for the function f_θ defined by the

$$f_\theta(x) = f(x) + \theta x.$$

A number of corollaries about Sturmian measures in $\mathcal{M}_\varrho$ are also given, including facts on smaller f —integral, on smallest variance and the result that Sturmian orbit has largest geometric mean. The result on C^2convex functions comes partially from a reformulation of precondition de Sturm by T. Bousch [2]. The paper by Jenkinson [1] includes a short survey of ergodic optimization and of Sturmian measures as minimizing and maximizing measures for classes of functions.If $\mathcal{M}$ is the set of Borel probabilities on the unit circle which are invariant with respect to the mapping $T(x) = 2x \ (mod\ 1)$ then T. Bousch [2] proved that for each function $\rho_\omega(t) := \cos(2\pi(t-\omega))$, there is exactly one element $\mu \in \mathcal{M}$ which maximizes $\int \rho_\omega d\mu$, and that the support of this measure is contained in a semicircle. In particular, the image of the map $\mu \mapsto \int \exp\{2i\pi t\} d\mu$ is compact and a convex set of the complex plane which does not contain any line segments on its boundary. T. Bousch [2] also proved that the maximizing measure is periodic for every ω except on a set which has measure zero and Hausdorff dimension zero.

Baker's transformations, β-transformations and their extensions. For $\beta > 1$ and $x \in [0,1]$ let

$$T_\beta(x) = \beta x \bmod 1,$$

be the β-transformation and

$$d_\beta(x) = (x_i)_{i\geq 1}, x_i = [\beta T_\beta^{i-1}(x)],$$

the β-expansion. The symbolic dynamics of the β-transformation has investigated by A. Rénei [3] who introduced the transformation and proved that it is ergodic and by W. Perry [4] who described possible sequences that can be a β-expantion. The key role of $d_\beta(1)$ is noticed by F. Blanchard [2]. J. Alexander and J. Yorke [6] and C. Bose [7] have investigated respectively fat baker's transformations and generalized baker's transformations. The natural extensions of β-transformations have been characterized by K. Dajani, C. Kraaikamp and B. Solomyak [8]. In paper [9] the authors study the set $\mathcal{S}$ of all those β for which the natural extension of T_β can be represented by the map

$$\mathcal{T}_\beta(x,y) = \left(T_\beta x, \frac{[\beta x] + y}{\beta}\right)$$

defined on a simply connected subset of the unit square, and with invariant measure a constant multiple of the 2-dimensional Lebesgue measure on $[0,1]^2$. In paper [10] the author investigates sufficient conditions for the existence of β-transformations such that the natural extensions of the transformations can be viewed as generalized baker's transformations. He characterizes such β and studies their properties. This paper includes recent results on the symbolic dynamics of the transformations.

Measure-theoretic entropy and bundle dynamical systems. A. Kolmogorov defines the complexity of a measure-preserving transformation by generators. A generator for a measure-preserving transformation T is a partition ξ with finite entropy such that the set of finite entropy partitions subordinate to some $\bigvee_{i=-n}^{n} T^{-i}(\xi)$ is dense in the set of finite entropy partitions endowed with the Rokhlin metric. Random dynamical systems relate a partial case of bundle dynamical systems by I. Cornfeld, S. Fomin, and Ya. Sinaì [11]. In paper [12] the author investigates measure-theoretic entropy of random dynamical systems (RDS) and presents in the framework of RDS the extension of local entropy formula by M. Brin and A. Katok and the definition of the measure-theoretic entropy using spanning set by A. Katok. The main results of the paper [12] are local entropy formula and the presentation of the measure-theoretic entropy of random dynamical systems using spanning set.

Functional case of the Hasse-Kloosterman map. Let $\boldsymbol{F}_p$ be the prime finite field, $\boldsymbol{F}_p^*$ multiplicative group of $\boldsymbol{F}_p$.

Hasse component. Let

$$y^2 = f(x),\ f(x) = x^3 + cx + d,$$

be a cubic polynomial in prime finite field $\boldsymbol{F}_p$. For the number $\#C_p$ of points of the curve C: $y^2 = f(x)$ in $\boldsymbol{F}_p$ the well known formula

$$\#C_p = \sum_{x=0}^{p-1}\left(1+\left(\frac{f(x)}{p}\right)\right)$$

take place, where $\left(\frac{f(x_0)}{p}\right)$ is the Legendre symbol with a numerator which is equal to the value of the polynomial $f(x_0)$ in point $x_0 \in \boldsymbol{F}_p$. It is ease to see that $\#C_p = p - a_p$, where

$$a_p = -\sum_{x=0}^{p-1}\left(\frac{f(x)}{p}\right).$$

If C is the elliptic curve E, then the number of points $\#E(\boldsymbol{F}_p) = \#E_p$ of the projective model of the curve E in $\boldsymbol{F}_p$ is represented by the formula $\#E_p = 1 + p - a_p$, where $a_p = 2\sqrt{p} \cdot cos\varphi_p$. If C is not the elliptic curve, then the value a_p is equal 1, -1 or 0 and ease to compute. In both cases compute: $\varphi_p = \arccos\left(\frac{a_p}{2\sqrt{p}}\right)$ and reduce it to the interval [0, π].

Kloosterman component. Let $cd \not\equiv 0 \mod p$,

$$T_p(c,d) = \sum_{x=1}^{p-1} e^{2\pi i\frac{\left(cx+\frac{d}{x}\right)}{p}},$$

the Kloosterman sum. By A. Weil,

$$T_p(c,d) = 2\sqrt{p}\,\cos\theta_p(c,d).$$

Compute T_p, cos θ_p, θ_p and reduce θ_p to the interval [0, π].

Hasse-Kloosterman map. Functional case of the Hasse-Kloosterman (HK) map is defined on $(\boldsymbol{F}_p)^* \times (\boldsymbol{F}_p)^*$ with values in $\Pi = [0, \pi]\times[0, \pi]$ and has the form

$$hk(c,d) = (\varphi_p(c, d), \theta_p(c, d)).$$

As c,d runs independently the multiplicative group $(\boldsymbol{F}_p)^*$, their product is not divided by p, so the map $hk(c,d)$ is defined in all points.

Coding. Let $\mathfrak{R}_1$ and $\mathfrak{R}_2$ be two finite partitions of the same cardinality d of the interval [0, π]. We call $\mathfrak{R}_1$ horizontal, $\mathfrak{R}_2$ vertical partition of [0, π] and the pair ($\mathfrak{R}_1$, $\mathfrak{R}_2$) p-pair. Denote elements of a partition by integer numbers *0,1, …, d-1*. Functional mapping HK is coded by finite sequence $b_s b_{s-1} \dots b_1 b_0 . a_1 a_2 \dots a_r$. A value of the sequence may be interpreted as a rational number (x, y) from unit square, if we put $x = \sum_{i=1}^{r} a_i / d^i$ (respectively, $= \sum_{i=1}^{s} b_{i-1} / d^i$) for d-adic expansion of x (respectively, for y).

Conclusion

We gave a short review and present some new results in the field of dynamical systems generated by iteration of maps, β-transformations, Hasse-Kloosterman maps, partitions, bundle dynamical systems and some aspects of coding and entropies of the systems.

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COMPUTER-AIDED DESIGN OF POWER EQUIPMENT IN THE AEROSPACE INDUSTRY

Reducing the production cost, reducing the time released to the market and improving its quality while the qualities of service are competitive determinants of the industry is now and in the foreseeable future. Taking into account all these factors, especially if the product is power equipment, the successful activities of the company in the market depends on the reengineering design technology and production processes. The most radical way to solve problems of reengineering is the introduction of integrated information technology with the use of modern computer technology and networking solutions.

Industrial systems of computer aided design CAD (CAD / CAM / CAE systems).

If we talk about all aspects of CAD, then in full it is:

CAD (Computer-Aided Design) - literally translated as "computer-aided design", in fact, the term means a system of geometric modeling and CAD drawings and design work.

CAM (Computer-Aided Manufacturing) - can be translated as "production with the help of computer. The generally accepted meaning of that term now - CAD technological preparation.

CAE (Computer-Aided Engineering) - means the computer systems engineering analysis.

The world's leading producers of software for design automation, usually supplies the market with integrated universal systems that meet the requirements of designing and manufacturing of products in various industries. These systems contain the possibility of automation of all three aspects and is therefore called CAD / CAM / CAE systems.

In my opinion, the main features of the best modern CAD/CAM/CAE- systems, are recognized by the world leaders.

1. In the design phase (geometric modeling) is provided:

- Solid-state, surface and wireframe 3-dimensional modeling;
- Drawing;
- Mod "large" assemblies;
- Photorealistic mapping;
- Design and scouring of the sheet materials;
- Support of industrial graphics standards such as IGES, DXF, VDA, STEP, etc. ;
- Support of the withdrawal of documentation in all major drawing standards-ANSY, ISO, DIN, etc. ESKD
- Direct interface with other CAD / CAM / CAE systems.

2. SAM-subsystem provides:

- The efficient preparation of control programs for milling from 2,5 to 5 coordinates of all types of turning, spark erosion, as well as for gas-cutting, plasm-cutting, laser machines, presses and lathes;
- Fast generation of post-processor for various CNC systems and controllers;

3. CAE-subsystem are full-scale (i.e., solves the whole range of tasks without any restrictions) and provide all types of engineering analysis.

4. Full versions of operating systems on the main types of workstations.

The information technology development direction, is fully covering the needs of modern industry, became known as CALS (Continuous Acquisition Lifecycle Support), which refers to providing ongoing product support information throughout its lifecycle.

The key point of CALS-technologies is a paper-free, i.e. formalized on the basis of international standards for electronic submission of product information model, which includes all data on it. The effectiveness of CALS-technologies is based on their integrated application. Literate reengineering, increasing the efficiency of the implementation of CALS-technologies, leads to product success in the end user, for which the cost of operation is important, not less than the cost of the product.

Thus, CALS-technologies, providing the reduction of product cost and costs for its operation while improving the quality of its services, provide the advantage of the extended enterprise in competition.

The major components relevant to the CALS-technologies include the following systems and tools:

• CAD / CAM / CAE - systems;

• means of implementation of parallel design in the mode of group data use (Concurrent Engineering);

• controls design and engineering data (EDM - Enterprise Data Management) *(now often used and the other term for this kind of money - PDM (Product Data Management);*

• visualization and development of documentation;

• data exchange tools and standard interfaces to specialized systems;

• means to develop application software;

• method of business processes analyzing in design and technology, manufacturing and management areas for the reengineering of these processes.

With traditional techniques the implementation of complex projects produced volumes of paper documents are so large that only the necessary information search to perform the required procedure becomes a problem the solution of which can take time, comparable to the time of execution of the procedure itself.

Taking into account the cost of paper documentation and the costs of working with it is an essential part of the cost of both the product and its operation. In addition, there is always the problem of relevance of information being processed, so that users are working with already obsolete or changed data, not being able to determine their current status.

As a consequence of these problems appears the task to keep in stock a complete model of a product in electronic form, which would contain all the information necessary for the processes of its design, production or operation.

Electronic model should be integrated into the product information in all its aspects, and important is its availability of certain parts of the information contained in the model to all parts and services of enterprise through interfaces of its specific systems.

The complexity and volume of information stored in the model and the duration of the life cycle can be illustrated by the following figure.

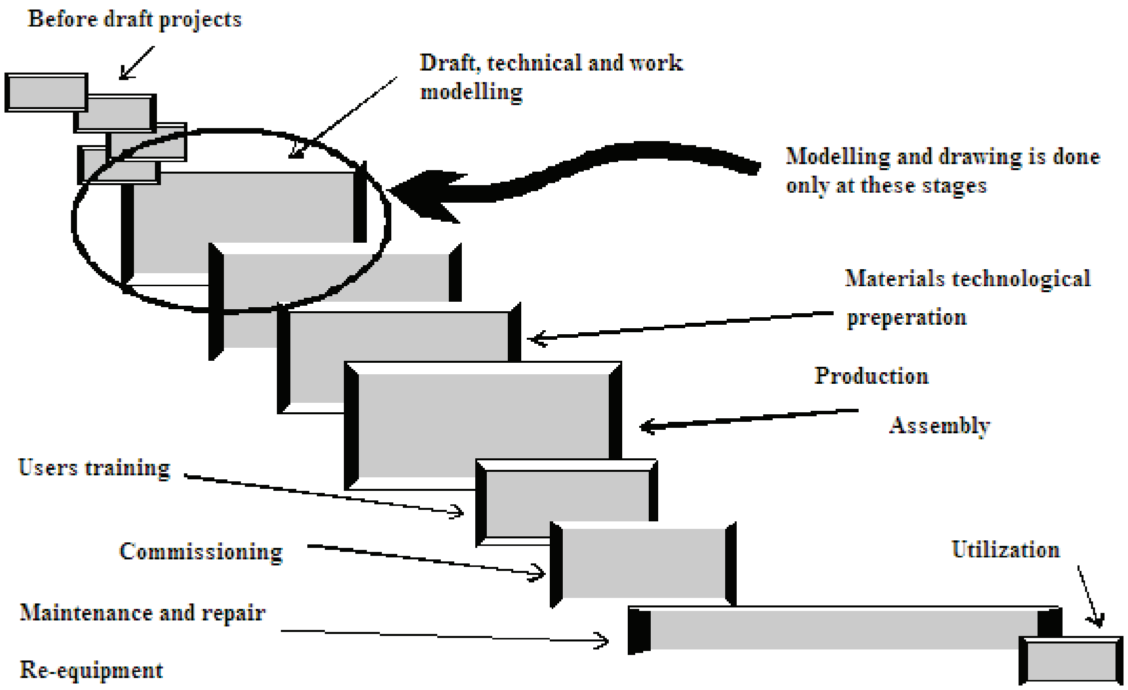

Fig. 1 Product life cycle

Means of implementation of parallel design.

About CAD / CAM / CAE-systems we already talked and about the technology of concurrent engineering also mentioned. The essence of this technology - with the introduction of CAPE, is the awareness and promotion of a new engineering design philosophy, which is the replacement of the serial (departmental) process of product development in an integrated, parallel process of its establishment on the basis of the concept of extended enterprise. Work environment involves the incorporation of the extended enterprise into a joint work of all participants - specialists in design, technological preparation of production, quality, purchasing, sales, marketing, suppliers and customers. Members of such a group, working as a closely coupled multi-disciplinary team, can make significant improvements in the overall development process.

A necessary and sufficient condition of work in the CAPE environment is the presence of software tools that allow parallel authorized access to the information model, orientation and navigation of the product structure to select the necessary geometric information or attributes pertaining to the different elements of the structure.

Conclusion

Manufacturing requirements of power equipment for the aerospace industry dictate the need for global use of information computer technologies at all stages of product life cycle: from pre-studies to the disposal of the product. The basis of information technologies in the design and manufacture of complex objects and products is now full-fledged industrial CAD (CAD / CAM / CAE – systems). In the design automation recently observed two trends in the use of CAD:

- application of full-CAD for the design and manufacture of varying complexity products;
- integration of CAD with other information technologies.

These trends suggest that in the nearest future, the efficiency of production will be largely determined by the efficiency of the enterprises producing power equipment for aerospace complex of industrial CAD.

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MODEL OF COMPUTATION FOR SCALABLE CLUSTER SYSTEMS

The problem of creation the effective program components for scalable cluster systems based on models of computation is considered in the paper. Models of computation based on C.Hoare's theory of communicating sequential processes are presented. Use models of computation for improving software and reduction design time is showed.

Today cluster architecture is considered as one of the cores at design of high-efficiency computer systems, optimal by criterion productivity/cost. Cluster system (CS) includes a set of computing nodes connected by high-speed system of links. Nodes of cluster system provide processing and data storage, internodes system provides fast transmission great volumes of data between CS nodes.

Modern CS is characterized by increase in quantity of nodes, and use of multi-core processors in nodes [1]. Cluster system with multi-core architecture is a difficult system and software engineering for such system is related with organization of calculations at two levels: between nodes and inside the node. Thus it is necessary to provide behavior each node by means of the processes mechanism (threads), and also to provide optimal on time and sizes of the transferred data interprocess communication.

Modern practice of programming for difficult computer systems is grounded on use of calculations models [4]. These models are considered as interface between architecture of system and program which realizing selected model of parallel (distributed) programming (Fig. 1). Assignment of model of calculations:

- to describe SCS architecture;
- to describe behavior of processes;
- to describe interprocess communication.

The analysis of a correctness behavior of processes and their interaction at a software product design stage will be made on the basis of model. Thus model mathematical apparatus allows establishing possible reasons of deadlocks. Besides, successfully selected model can simplify process of further creation a program.

Cluster systems are well scalable systems from the point the view of productivity increase. The cluster architecture admits almost unlimited escalating the number of nodes. Therefore the problem of software engineering for scalable cluster systems (SCS) is the important problem and demands a development of methods and tools, allowing raising quality of applications for SCS.

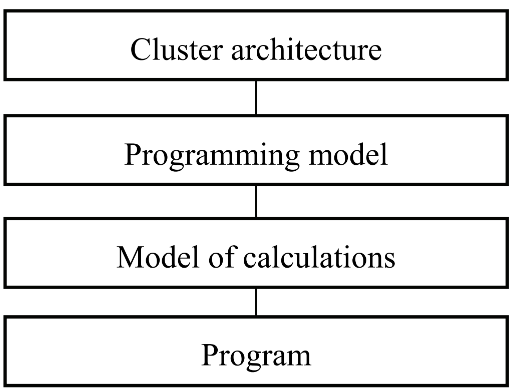

Fig.1. Model of calculation

The considered subjects are widely presented in publications. Basically, they are reduced to a choice and approach substantiation to construction the model of parallel calculations [2, 4, 5, 6, and 9]. Models of calculations can be based on Petri nets [9], the theory of finite state automations [5], CSP theory [2, 3, and 6]. The great number of various models calculations does not guarantee their adequacy to set of practical tasks which it is necessary to face by development of the distributed applications. The reason consists in inconsistency of requirements to these models and importance representation of those or other features functioning of computing systems.

In [2] use the C.Hoare's theory for construction the models of calculations for cluster systems is offered. It is shown that mathematical apparatus of CSP theory allows describing the architecture of cluster system, and also processes behavior and interprocess communication. However in operation questions of construction, implementation and usage the models of calculations on the basis of CSP theory for scaled systems are not considered. Considering that scalability is the important making computer system, solution of the problems linked to creation of the software for SCS, is the actual task. In [4] two features of the distributed calculations in SCS which define requirements to their development are selected. It is *non determinism*, meaning any sequences of creation the components of the structured data and *heterogeneity* which is linked to any structured less of the data via processes communication.

Non determinism is linked to support of unambiguity the results of calculations at which to one dialing in of the data there corresponds one dialing out of results. Heterogeneity of messages is linked by that processes can accept to (transfer) the data of any size depending on quantity of nodes in system. The choice of resources for construction the models of calculations should provide solution of the specified problems.

The purpose of the present operation is development of the approach offered in operation [2], for creation and usage of models of calculations by development of program components for scaled cluster systems with the multicore architecture.

By development of the scaled distributed programs it is necessary to provide possibility of static (dynamic) creation (generation) the set of processes, the description of their behavior, start on performance and the interaction organization.

There are various resources of the description the processes in the modern languages and libraries of parallel programming [7]. Programming languages Java, Ada allow describing process by means of special program units (classes). In language C# and library Win32 thread functions are for this purpose used. OpenMP allows to select parallel nodes of the program by means of *parallel/end parallel* operators. Library MPI creates parallel processes as main program copies.

The program for the scaled architecture should be based on possibility of creation (both statically, and dynamically) any set of processes. It is possible only by means of duplicating of the base process which parameterization will allow describing all distinctions between created copies of this process. In the languages supporting an object-oriented paradigm, it can be made by means of classes and designers, in Ada language it is for this purpose used the type with a discriminate, in MPI identifier of task automatically generated at creation of a copy of process.

The interprocess communication organization includes synchronization of processes and data exchange [6]. Interaction models thus are based on the common variables or on sending of messages.

At use of the common variables there are the mutual exclusion and synchronization tasks which solution it is necessary to provide for any number of processes. For the task of mutual exclusion it does not represent complexity as primitives of type semaphores, mutex, critical sections, also screen monitors provide the control of shared resources for any number of processes which use them. Problems can arise at solution of the task of synchronization as difficult forms of synchronization the sort here take place: process group of processes, group of processes process, and group of processes group of processes. At usage of low level primitives dynamic creation and usage of objects of synchronization is required. This problem dares by usage of monitor objects the synchronization which allows realizing the specified forms of group synchronization effectively.

At use of the mechanism of messages passing in SCS the main problem is linked to creation the size of the transferred data which can depend on quantity of dynamically created processes. Here possibility the organization of data exchange any dimension is important. In MPI it is provided with functions *MPI_Gatherv, MPI_Scatterv,* in Ada language – use of data types with specified boundaries that allows describing an input of task for transmission any size of data.

Besides, efficiency of interaction increases, if language (library) supports collective forms of interaction, both at message passing, and at synchronization. In this schedule collective operations MPI which are realized in the form in operations a multicasting (assemblage) of data *MPI_Bcast, MPI_Gather, MPI_Scatter* and operations of group synchronization *MPI_Barrier* are of interest.

Thus, it is possible to formulate the main requirements to models of calculations for scaled systems: support not determinism for unlimited number of dynamically generated processes co-operating by sending of messages any size and through group synchronization.

Let's consider possibilities the theory of C.Hoare from the point of view the implementation the formulated requirements. C.Hoare's theory allows describing behavior the consecutive not determined processes with any independent alternation of processes. It allows to describe features of operation SCS. Dynamic generation of processes without limitation their quantity is supported. Sending of messages is provided synchronous unidirectional without buffering. One form when I co-operate only two tasks is thus considered, that is exchange group operations are not used. You should not consider the common variable as a handshaking of processes, especially for group synchronization and mutual exclusion.

Thus, C.Hoare's theory can be used for construction models of calculations for SCS at its extension (finishing) in respect implementation the two-forked mechanisms of sending messages from any dimension, and also monitor-like resources for mutual exclusion and synchronization at the description of group interprocess communication.

Let's consider SCS as the difficult dynamic system which structure can vary as by change of number of nodes and links between nodes. Generally, any cluster system is fully connected as any two nodes are linked among themselves and admit base band signaling of the data among themselves. In this case scaling is realized by simple addition of new nodes. If SCS architecture is constructed by association of nodes in groups (sub-cluster) interaction is carried out between sub-clusters and in everyone sub-cluster. Usage of various communication systems for interaction between sub-clusters and in everyone sub-cluster is thus possible.

Let's consider usage of the theory of C.Hoare for construction of models of calculations for scaled cluster systems with the multicore architecture in which nodes processors are used multicore. Scalability CS at structural level it is linked to possibility the change quantity of nodes and quantities of kernels in multicore processors in the system node. C.Hoare's theory allows to consider behavior of any system in terms the object, abstracting thus from hardware or program essence of system construction the model of calculations. It allows simplifying transition from the hardware description to program implementation of model.

At model building of calculations we will recognize that it should be two-level and correspond to two levels of structure SCS. Model SCS1 describes the behavior of system linked to interaction of nodes, and model SCS2 describes behavior of system in each node.

After construction of model of calculations it can be used for the analysis a correctness of interprocess communication which is fulfilled on the basis the check of the offered rules. It will allow revealing and preventing impasses, to optimize sizes of the transferred information, to select more communications and synchronization effective remedies.

The second important side models of calculations are possibility of their application by development of the distributed applications. Usage of models allows simplifying construction algorithms of processes and their subsequent program implementation. Construction of algorithms processes is carried out in terms of events which have been defined and were used for objects of models. Algorithms completely correspond to behavior of objects in model of calculations. At model implementation it is necessary to consider that fact that the majority of the modern languages parallel programming realize the concept of the communicating sequential processes making a basis the theory of C.Hoare. It simplifies implementation of processes for objects by means of processes in the program.

The choice and implementation of objects communications and synchronization also becomes simpler, as they are developed with the registration and the analysis of various existing mechanisms of interprocess communication, such as semaphores, mutex, critical sections, locks, screen monitors, rendezvous [7].

Authors had been spent experimental researches the efficiency usage the offered models of the calculations constructed on the basis of the C.Hoare theory, for an applications programming for the real scaled cluster system equipped with four-nuclear processors. Models of calculations have allowed describing features of SCS architecture including variable number of nodes. Use of models of calculations for development of distributed applications has allowed reducing time of their programming and debugging. Programming languages With, Java, C #, Ada, library Win32, MPI were used. The developed software package was effectively fulfilled in SCS with any number of nodes, providing high-speed data transfer between nodes and a high loading factor of multicore processors in nodes.

Conclusion

The approach to construction the models of calculations for scaled cluster systems with the multicore architecture, grounded on the extension the theory of communicating sequential processes by introduction the parameterized objects of synchronization and communications is offered. Models allow describing the architecture of cluster system, behavior of processes and their interaction taking into account features of system scalability. Mathematical apparatus of CSP theory has allowed to formulate a number of requirements for optimal interprocess communication, to make the analysis a correctness of interprocess communication at both levels of cluster system at usage the model grounded on the common variables, and model, grounded on messages passing.

Usage of the offered models at designing of program SCS components will allow to raise quality of programs and to reduce time of their development.

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INTEGRATION TECHNOLOGY OF HYBRID CLOUD COMPUTING INFRASTRUCTURE OF THE UNIVERSITY TO PERFORM THE TASKS OF SCIENTIFIC RESEARCH AND EDUCATION

This article discusses the basic principles of cloud computing and the ways to integrate this technology into the infrastructure of the school of the University, which is based on innovative principles e-learning

Cloud Computing refers to the way services, where information processing or storage place on the Internet. The keyword "cloud" is essentially a large group connected to the Internet servers and personal computers to solve any problems.

Using the technology of cloud computing we get unprecedented flexibility and scalability as well as a provider of "cloud" of resources has the ability to easily extend the virtual environment the user through their virtual infrastructure, providing it with more bandwidth, or more powerful computing resources.

The concept of Cloud Computing continues ideas Utility Computing, mentioned for the first time John McCartney in 1961 and considered computing resources as utilities. In addition, Cloud Computing can be compared both with the cluster calculations (in which several machines together in a group and form a single system for high performance calculations) and with grid-computing (machine groups are usually removed from each other over long distances, but share the common task).

Figure 1 shows the history of the evolution of cloud computing

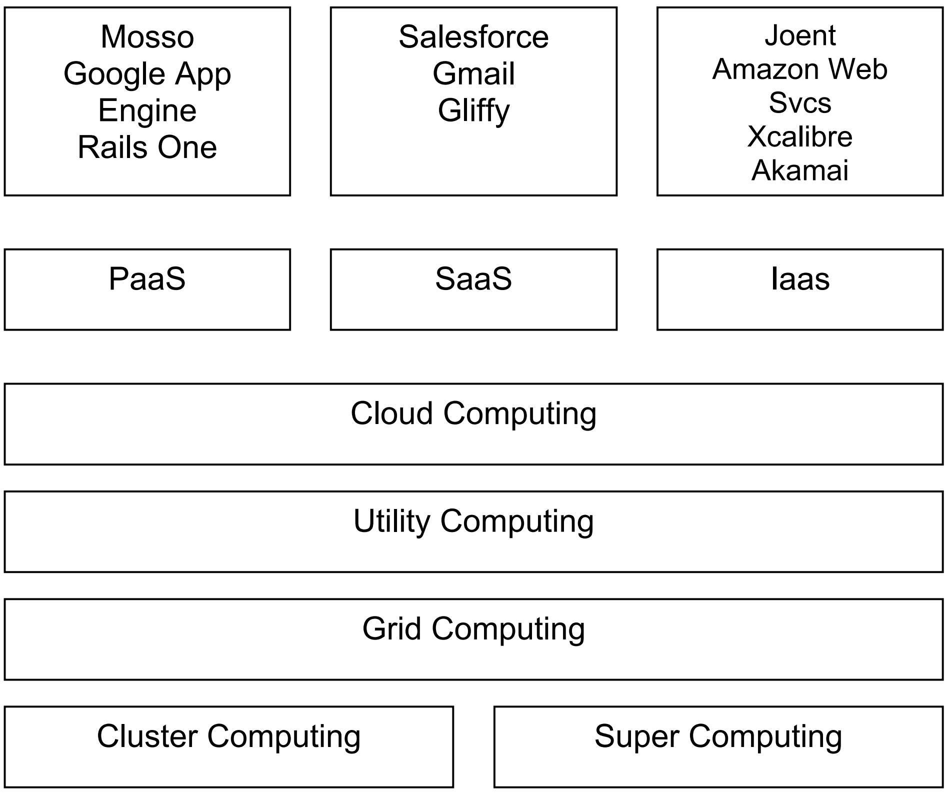

Figure 1. History of the evolution of cloud computing

As shown in Figure 2, when we look at the "cloud" is not the only service, and a set of services. Each level in this figure contributes to the provision of services.

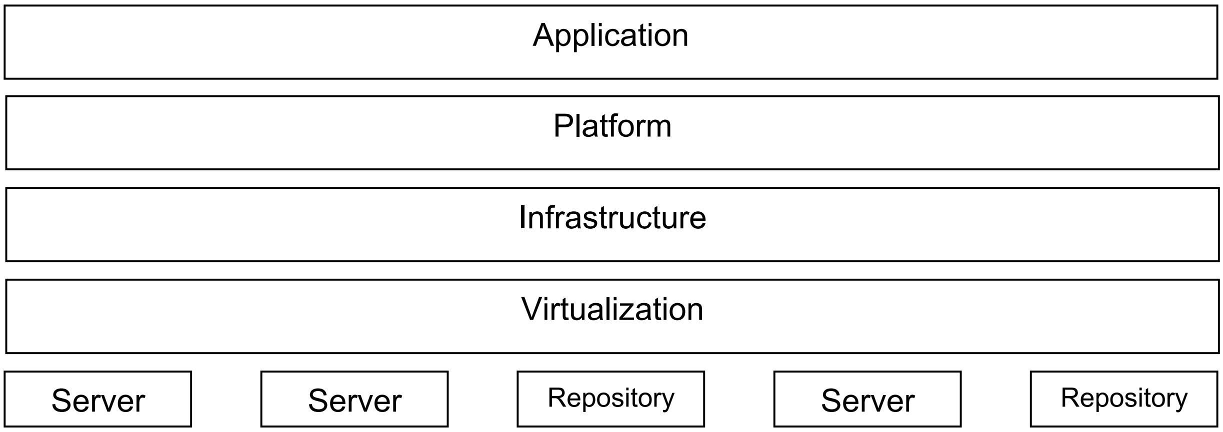

Figure 2 . The levels on which the Cloud Computing

Let's start with the lowest level, which is responsible for infrastructure (Infrastructure-as-a-Service, or IaaS, Infrastructure as a Service). IaaS is a service for renting the infrastructure, ie, computing resources and storage systems. These resources include not only the virtual servers with guaranteed computing power, but also the channels of communication bandwidth required for access to repositories of data and the Internet. In short, at this level given the opportunity to temporary use of computers or data centers with the required quality of service, with the ability to execute arbitrary operating system and programs.

The next level of service when moving up the chart - the level of the platform (Platform-as-a-Service, or PaaS, Platform as a service). PaaS is similar to the level of IaaS, but includes the operating system and related services targeted to specific applications. For example, PaaS in conjunction with virtual servers and storage systems provides some operating system and application set (usually in the form of virtual machine image, for example, the file format. Vmdk for VMWare), as well as access to various specialized local services (eg, database MySQL) . In other words, PaaS - it IaaS together a stack of applications that perform a specific task.

Finally, at the very top is the easiest-provided level - the level applications (Software-as-a-Service or SaaS, software as a service), which requires that an application from a centralized (and, possibly, remotely - from the "cloud") system to work on your computer. SaaS is measured by the service and allows both to rent an application and pay only when working with him.

At the moment one of the most promising paradigms solving research and education is the so-called virtual learning environment. Virtual Learning Environment - is a platform allows you to organize e-learning and enrich the traditional learning process on-line components.

A flexible combination of services traditional virtual learning environments and resources of the Internet makes it possible to organize an adaptive learning process based on individual advice and guidance of the teacher. This model of training is as close as the paradigm of work in the cloud (cloud computing).

Consider the main characteristics of this work:

Allocation of resources to the user from coming online.

Unlimited remote network access.

Hidden from the user the actual allocation of resources - the final the user has no idea where, how and what computational power and data storage systems it actually served.

Flexible load – system adjusts to the amount of resources requested.

Guaranteed and measured level of service. The main models of organization of computing clouds are:

- Private cloud. Created and maintained specific organization (the school).
- Community a cloud - a few members of the community divide the jointly-supported system.
- Public cloud - open service available to all consumers.
- Hybrid (mixed) cloud - a combination of closed and open.

Hybrid scheme of e-learning can be represented as follows - different clouds (closed, open and cooperative) are combined into a single system managed by the administrator, determining the role of participants in the training process, modes of security, identification procedures, etc. Closed cloud provides the resources the school (library, system testing, system of education administration, etc.), open the clouds provide access to online storage and integrated services. Cooperative cloud provides access to the resources of the educational community (eg, the association of higher educational institutions, professional community of lawyers, etc.)

The main challenges to the widespread introduction of Cloud Computing are the privacy and security. Personal data can be protected by encryption, but when "cloud" of the system is necessary due diligence. Recall that at the dawn of the emergence of electronic commerce on the Web, too, looked skeptical. Nevertheless, to date electronic transactions comprise the trillions of dollars a year, and then, Cloud Computing will adopt all the existing technologies (such as the Secure Socket Layers, SSL) protection of information on the Web.

Cloud computing is already actively used by the organizers of e-learning. However, they do not change the principles of providing educational services, but are the result of the convergence of several technologies, including virtualization, on-line services and high-speed networks.

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SYMPOSIUM 2

AERONAVIGATION

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OPERATIONAL CONCEPT OF REQUIRED COMMUNICATION PERFORMANCE

The analysis of required communication performance (RCP) as the list of parameters which will define operational requirements to communication systems at different stages of flight is given. Parameters of readiness, integrity and a continuity of functioning RCP are considered. RCP types, general process of RCP introduction and maintenance of certain ATC function are analyzed.

The absence of objective criteria for an estimation of requirements to communication characteristics has been specified at AMCP meeting (AMCP/4, Montreal, 1996). Required communication performance (RCP) was considered as the list of parameters which will define operational requirements to communication systems at different stages of flight. The meeting has agreed that it is necessary to estimate urgently different technical variants of communication systems taking into account such list of parameters.

In 1997 during consideration of the report on results of AMCP/4 meeting Air Navigation Commission has charged ADSP (which was renamed in 2000 into the commission of experts for application of data transmission lines (OP-LINKP)) to develop operational concept of RCP.

Communication can be used for information interchange between:

- The dispatcher and the pilot,
- The dispatcher and the dispatcher,
- The person and the car,
- The car and the car,
- The pilot and the pilot.

Some of these information interchange types directly provide communication realization as element of CNS/ATM system; other types are characteristic for technical communication which can be associated with any element of CNS/ATM system, including navigation and surveillance. Finally RCP concept should consider all these types of communication. Considering complexity of the questions connected with working out of the concept which could be applied for all possible types of communication, work is concentrated now on working out:

- Language communication "dispatcher-pilot" and communications in the area of data transmission;
- Flexible frameworks which can be extended to all types of communication for which certain RCP type is used.

At appearance of data transmission systems for air traffic control the voice communication systems were estimated in accordance with actual characteristics because, as a rule, it was easy to reveal deterioration of characteristics or absence of communication. For example, the dispatcher as usual can during 1-2 seconds transfer to flight crew instructions a command an acknowledgement of flight crew arrives throughout 1-2 seconds. In this case the dispatcher and crew practically at once understand a congestion or absence of channels which leads to a delay of permissions transfer. Other factors are the information on usual rush hours and reliability of components which also allows reacting ahead of time to the dispatcher to such events. At application of data transmission lines this information does not arrive behind the same scheme.

Application of digital communication equipment in CNS/ATM systems results in recognition of expediency for use of independent from technology definition method and an establishment of communication characteristics. This will allow approaching flexibly to a choice of voice communication means if they satisfy RCP.

Such approach is important for development of operational concepts taking into account appearance of new technologies. ATC function is a separate operational component of air movement service. Maintenance of airplanes echelonment, change of airplanes flight routes and flight information giving are examples of ATC functions.

RCP concept estimates transactions of operational communication in a context of ATC function taking into account interaction of people, procedures and characteristics of operational conditions.

The contribution of the person in RCP can be considerable. Communication represents reliable information transmission from the sender to the addressee which has absolutely understood to both.

A transaction of operational communication is process with the help of which the person transmits instructions, permissions, flight information and/or inquiry. The transaction is considered executed when this person is assured that this transaction is finished. RCP concept is based on "important from the operational point of view" indicators at which achievement there is a confidence that operational communication will be carried out at comprehensible safe level.

The basis of RCP concept working out is constant necessity of objective operational criteria existance in the form of RCP type for an estimation of different communication means. RCP type defines standard characteristics of operational communication transactions.

Determining RCP parametres are communication process duration, its integrity, readiness and a functioning continuity. RCP includes assignment to these parametres of minimal quantitative values for maintenance on appropriate level of operational requirements. For naming of RCP type the parametre of communication process duration presented in seconds is used. Each RCP type contains certain values for parametres of readiness, integrity and a functioning continuity.

RCP implementation

At the first stage of RCP concept application it is necessary to define ATC functions and operational conditions on which certain RCP type will be extended. After definition of ATC functions and operational conditions it is necessary to define certain RCP type which will be established. We will remind, that RCP type is defined by the number and the letter (for example, in case of RCP 180E, 180 means communication uring 180 seconds, and E - a set of parametres: integrity 10-5, readiness 0,99 and a continuity of functioning 0,99.

On the basis of RCP implementation experience there can be established and other RCP types. RCP 10 type can be applied to the dispatcher intervention with a view of echelonment maintenance in air space with radius of 5 miles.

RCP 60 type in a combination with RCP 10 type can be applied for usual communication in the area of data transmission with the purpose to unload system of language communication.

RCP 120 type can be used for intervention of the dispatcher with a view of echelontment maintenance in air space with radius of 15 miles.

RCP 240 type is studied as a basis for intervention of the dispatcher with a view of echelonment maintenance in the conditions of reduced echelonment minima application, i.e. minima of longitudinal echelonment, equal to 50 miles or less, and minima lateral echelonment, equal to 30 miles or less and application of alternative means for maintenance of standard communication ways. For example, language communication Iridium or HF-line of data transmission instead of HF-audio communications can be used. RCP 400 type can be used also for a designation of the characteristics necessary for alternative ways of communication, distinct from HF-audio communications, when the independent alternative way of communication is required in association with standard ways of communication for which established RCP 240 type.

Any ATC function can be provided with set of operational communication transactions. These communication sessions are exposed to an estimation for definition of the most important. Value of communication session parameter is based on time, necessary for ending of the major transaction.

At an estimation time necessary for safe performance of procedure with extreme character is considered, thus it can include modelling, demonstration, operational tests and the analysis of empirical data concerning time of operational communication session which is required for maintenance of certain ATC function.

Echelonment maintenance is ATC function for which communication session time can be defined with the help of collision risk modelling.

Duration time of communication process (transactions) represents the maximum term for ending of communication process. This parameter is criterion of time criticality.

Maintenance of echelonment is ATC function, for which time of operational communication transaction can be defined by modeling of collision risk. At collision risk modeling the time of operational communication transaction in the buffer of a dispatcher communication intervention is considered.

In RCP context there can be considerable the human factor. Communication represents not only transfer of a mere verbiage, signs, tones or electronic data, but an information transfer between the sender and the addressee which maintenance is easily perceived by them and clear to both of them.

The operational requirement concerning accurate acknowledgement of a two-way communication is confirmation that in the course of communication the information was transferred. In the absence of the answer the sender is not assured completely that the addressee has accepted this information. Accurate acknowledgement of communication is one of characteristic indicators of communication and is necessarily caused as an element of RCP type.

Time necessary for the person for communication process ending demands presence of the interface Human-Machine Interface (HMI) designed so that the user could react within the time parameters co-ordinated with function of communication. In this connection RCP covers all elements of communication process. Each point between separate elements of this process is meant by the letter in a triangle.

Aspects of the human factor and technical elements can be joined to RCP due to definition of RCP type for all communication process, to division and assignment of RCP type by: definition of technical communication necessary characteristics; definition of interaction time "Human-Machine"; definition of maximum admissible reaction time after message receiving.

In some cases when human processing is not supposed RCP will be limited by inclusion of only technical communication component (for example, elements D-G and M-P). They will represent Required Technical Communication Performance (RTCP) that allows formulating requirements only to technical characteristics of communication systems.

Implementation of data transmitting lines has allowed to dispatchers and pilots receive more visual information.

Integrity of a communication system is defined by probability of refusals not revealing which arise in the course of communication during time no bigger than setted. Such situation takes place in that case when the message which contains one or several errors is perceived as correct.
Readiness of a communication system is defined by probability of performance by a communication system of necessary function at initiation of communication process. The readiness parameter represents a ratio of actual and necessary system readiness times. The parameter of RCP readiness includes all elements of final and intermediate systems, networks and sub networks.

The continuity of communication system functioning is defined as probability of successive realization of communication process without not planned infringements under condition of successful initiation of communication process.

Let us consider RCP parameters. RCP concept provides using of minimum parameters values proceeding from appropriate definition of operational requirements.

It can be necessary to provide additional requirements (for example, information protection), that are beyond these parameters included in RCP type.

Duration of communication process represents the maximum term for communication process ending. This is key parameter of time criticality.

Human possibilities. RCP consider aspects of human possibilities necessary for realization of communication process. Certain flexibility in that relation is supposed.

The basic specificity of human reaction time from the RCP point of view consists in complex character of the problems necessary for successful drawing up (or a choice), sending and receiving of messages. As this parameter is defined as time necessary for successful performance of a problem, it includes any period of time necessary for correction of entrance errors. The problem choice always should be carried out by the user taking into account priorities character of specific targets.

It is necessary to specify that the basic problem is connected not with variability of separate persons or operational situations. First of all the question is about variability of reaction time specific to different systems and their interfaces, and which is a controllable and critical component of system reaction time.

The estimation of RCP components connected with duration of interaction "Human-Machine" should be based on the most comprehensible average value, received at real conditions. Representative duration of interaction process "Human-Machine" can be measured by means of modern technologies which are used in the field of applied psychology. Such measurements were spent throughout several years in different (including industrial) conditions. Differences of characteristics are presented by means of statistical values.

Reaction time extends on all additional actions necessary from the person for ending communication process (depending on a specific task reaction time can include time necessary for access to any necessary information). Thus, depending on a specific task, reaction time can be fixed the same as time of reaction "Human-Machine", or to be defined on the basis of experience of users and empirical methods.

Procedure of RCP types assignment

Assignment of RCP types is a process of determination the different meanings of RCP types for different elements of system. Result of this process is assignments of RCP types which are used for:

- Estimations of different technical means ability to satisfy operational requirements;
- Approvement of air traffic service allotment movement which is provided by communication facilities;
- Determination of time for the beginning of extreme procedures application;
- Workings out, implementation and estimations of communication service;
- Workings out, implementation, estimations and approvement of aircrafts design;
- Approvement of aircrafts operators for performance of flights on the basis of RCP;
- Operative monitoring, revealing and corrections that do not meet the requirements of characteristics.

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INFORMATION PROCESSING MODELS IN AIR TRAFFIC CONTROL

The principles of implementation of information processing models in air traffic control are considered. Generic error-modelling system, the cognitive reliability error analysis method and the contextual control model are discussed.

Introduction

The information processing tradition examines human performance by attempting to trace the information flow through several processing stages from information input to response output.

Early information processing models state that a stimulus is processed first by basic perceptual processes followed by attentional processes that transfer some of the products of the initial perceptual processing into a short-term memory store.

Rehearsal then serves to maintain information in the short-term memory store and then some of that information is transferred to a long-term memory store. However, early models omitted processes of thinking and problem-solving, and there is new evidence that the serial processing assumption was incorrect. Furthermore, the model saw the individual as inactive and therefore did not account for the role of past experience or expectations.

This early model highlights the need for a distinction between 'top-down' and 'bottom-up' processing. Bottom-up processing refers to processing directly affected by stimulus input and top-down processing refers to processing affected by aspects of context and an individual's past experience. Most cognitive activity involves both types of processing.

Later theories argued that cognitive activity consists of interactive bottom-up and top-down processes occurring at the same time. For instance, perception is affected by a person's expectations about a stimuli.

The recent information processing framework shares a number of basic characteristics. For instance, people are seen as autonomous, intentional beings who interact with the external world. Second, the mind is viewed as a limited capacity processor having both structural and resource limitations.

Generic Error-modelling System

Reason [1] proposed the conceptual framework within which to locate the origins of basic human error types - the Generic Error-Modelling System (GEMS). The method borrows Rasmussen's [2] framework to yield three basic error types:

- skill-based slips and lapses;
- rule-based mistakes;
- knowledge-based mistakes.

The dynamics of GEMS are shown in Figure 1.

Reason's [1] GEMS contains a number of 'failure modes' at the levels of skill-based slips and lapses, rule-based mistakes and knowledge-based mistake. At the skill-based level these include omissions following interruptions, reduced intentionally, repetitions, and reversals, among others.

At the rule-based level, failure modes include informational overload, rule strengths, wrong rules, inelegant rules and inadvisable rules. At the knowledge-based level, Reason represents several failure modes, including representativeness and availability heuristics, overconfidence, thematic vagabonding (cognitively 'flitting') and encystment (cognitively 'lingering').

The Generic Error-Modelling System (GEMS) goes beyond the slips/mistakes dichotomy. Skill-based errors are attributed to monitoring failures: either inattention or over-attention. Rule-based mistakes are related to a 'symptomatic search' strategy, identified by Rasmussen and Jensen [3].

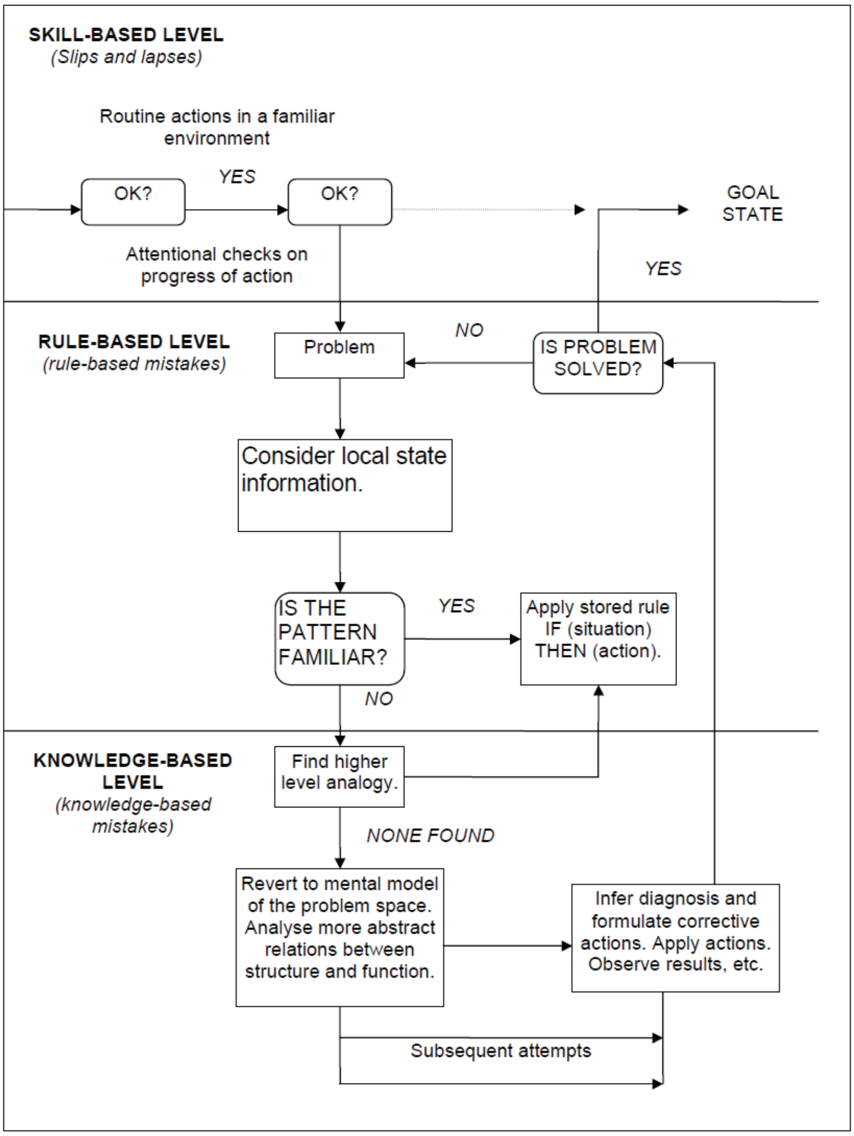

Fig. 1. The generic error-modelling system

However, a problem is identified from a match between local system cues and some stored representation of the pattern of indications of that failure state (i.e. automatic pattern-matching). If a match is found, a stored 'if-then' rule is applied. Rule-based mistakes arise either from misapplication of good rules or the application of bad rules.

Knowledge based mistakes (i.e. the lack of expertise) are related to a 'topographic search', where the diagnosis emerges from a series of good/bad judgements relating to the location and sphere of influence of each of the system components. This mode of search is dependent upon a mental model of the system. Knowledge-based mistakes originate from bounded rationality (a limited conscious workspace to display the problem space) and incorrect/incomplete knowledge.

The defining condition for both rule-based and knowledge-based mistakes is an awareness that a problem exists. The necessary condition for a slip, however, is the presence of attentional capture, associated with distraction or preoccupation. Reason further expands the basic error types with a number of failure modes. Some of these will be introduced in the subsequent coverage of error classification systems.

Reason [1] further argues for the existence of two 'computational primitives' in the cognitive system - mechanisms for knowledge retrieval that represent both a strength and a weakness of human cognition. The first primitive is similarity, or matching like-to-like on the basis of the correspondence between states of the world and the attributes of stored knowledge (the similarity-matching heuristic). The second primitive is frequency, or resolving conflicts between partially matched structures in favour of those employed frequently in the past within that particular context (the frequency-gambling heuristic).

Reason [4] extends this to posit that six error-shaping 'primaries' form most, if not all, the varieties of systematic error. These have their origins in the fundamental characteristics of human cognition, and give recognisable forms to all skill-, rule- and knowledge-based errors.

These 'primaries' are:

- Similarity bias. Errors corresponding to salient aspects of the current stimulus, to the intended actions or both.
- Frequency bias. When cognitive operations are under-specified, they tend to default to contextually appropriate and high-frequency responses.
- Bounded rationality. People have a limited conscious workspace to display problems.
- Imperfect rationality. Problem-solvers tend to violate normative decision theories (e.g. logic, subjective expected utility).
- Reluctant rationality. The need to minimise cognitive strain results in automatic parallel processing when serial processing is required.
- Incomplete/incorrect knowledge. People tend to form an incomplete model of external reality.

Consequently, although GEMS is well-known, and comprehensive, it has not been used frequently. Finally, as GEMS is tied to the framework, the user is left an underlying model of human performance that might be inappropriate for classifying human errors in ATM.

The Cognitive Reliability Error Analysis Method

The Cognitive reliability error analysis method (CREAM) [6] has been developed recently as both a means of retrospectively analysing accidents and incidents and as a predictive human error analysis methodology. The approach is intended to bridge the gap between the practical human error analysis methods which have little under-pinning theory (i.e. they are not essentially model-based), and approaches that have evolved from cognitive psychology.

The model in CREAM is a simplified version of performance that is reminiscent of Rasmussen step-ladder' model. This simplification arguably avoids some of the difficulties that the original step-ladder model has faced and the under-pinning CREAM model, called the Simple Model of Cognition (SMoC) is certainly easy to grasp (see Figure 2).

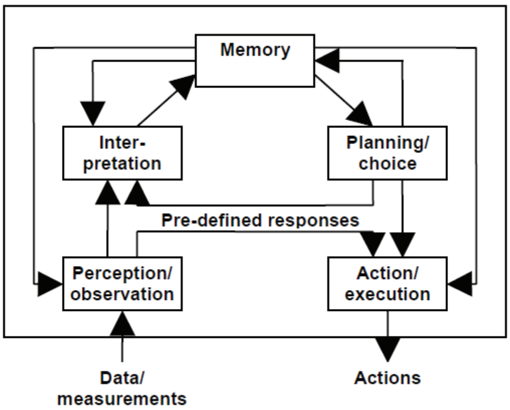

Fig. 2. CREAM's simple model of cognition

The CREAM philosophy is essentially one of multi-causality, in line with others' conclusions after two decades of incident analysis, that there is usually no single cause and, hence, no single treatment to avoid the error in the future. CREAM goes further than simply stating this, however, and attempts to investigate the interactions and likely connections between different Performance

Shaping Factors (PSFs), called Common Performance Conditions (CPCs). The main CPCs in CREAM are [7]:

- availability of procedures,
- crew coordination quality,
- adequacy of organisation,
- number of goals,
- time of day,
- adequacy of HMI,
- available time,
- working conditions,
- adequacy of training.

The Cognitive Reliability Error Analysis Method (CREAM) also has error modes associated with it, and various procedures for establishing the causes of the incident. Although the approach aims to be simple and practicable the two main texts on CREAM are relatively complex.

This is probably partly a function of the recency of the text and also the subject matter itself - trying to develop a robust cognitive framework for analysing errors, their causes, and the inter-relationships between their causes, is difficult when there is so little data from which to determine such inter-relationships. Nevertheless, CREAM represents a significant development in error models and taxonomies, and challenges other approaches to address two basic tenets about accidents: that they are multi-causal in nature, and that different factors and causes can and do interact in complex ways.

Conclusions

The control system modelling tradition uses concepts from modern control theory to understand human-machine systems. The human is seen in these models as a control or decision element in a closed-loop system, which includes monitoring, communication, supervisory situations, and manual control.

It is important to realise that cognitive science and cognitive psychology, although clearly related, do not always have the same goals. Cognitive psychologists (especially those looking for a neuropsychological [or brain] 'metaphor') want software architectures that truly represent human cognition or thinking.

However, much of cognitive science is aimed at emulating human behaviour, including human error, irrespective of whether the architecture is neuropsychologically correct or not. From this perspective such a modelling tradition remains of potential interest and utility to those involved in the investigation and prediction of human error in complex systems.

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MULTICRITERIA OPTIMIZATION OF ON-BOARD NAVIGATIONAL SYSTEM TECHNICAL MEANS COMPLEX SELECTION

The task of optimal choice of onboard technical means of the UAV navigational system was investigated. It was shown that given task can be reduced to the multicriteria optimization task. The algorithm of Pareto's set was developed.

Unmanned aerial vehicles (UAVs) have got a widespread usage at present time. The use of UAVs is caused by a number of advantages of unmanned aircraft in front of a manned one, namely: the lack of crew on board, high maneuverability, relatively minor costs of operation, mobility, ability to perform maneuvers with significant overloading, which exceed the physical capabilities, ability to work in conditions that are dangerous to human beings.

The implementation of navigation systems for UAVs involves the use of miniature low-cost microelectromechanical (MEMS) inertial sensors of low accuracy due to significant reduction in the size and cost of such systems.

However, the use of miniature autonomous gimballess inertial navigation systems (miniGINS) for MEMS sensors is not possible for long time intervals because of the rapid accumulation of errors in determining the navigation data. An effective way of solving this problem is miniGINS aggregation with external measuring devices such as GPS-receiver, magnetic compass, etc. The principle of integrated navigation systems work is the miniGINS error correction method which allows creating of integrated systems that combine the required precision and functional characteristics with the low cost and small dimensions.

A large amount of the produced inertial-satellite systems contain weakly connected systems. Leading positions in development and production of such systems hold American companies (Litton, Rockwell Collins, Applanix, Smith Aerospace, etc.). IRS production is actively developing in Russia, where can be highlighted the development of DB Ramenskoye CSRI appliance, SRI SM, LLC TeKnol "STC" Rissa ".

Performed in a single navigation unit, weakly connected IRS provide the user not only to INS / SNA information, but also independent INS and SNA data [2 – 4].

Let's consider the most popular navigation systems for microelectronics based on mechanical sensors.

Compact integrated navigation system KompaNav-2. Mince Kompanav-2, developed by Russian company LLC TeKnol", is intended to determine location coordinates and orientation angles of a moving object and a combination unit of MEMS sensors and receiver satellite navigation system with built-in antenna. In the system working process the GPS receiver provides the definition of the current location coordinates of the object. Block sensitive elements determines the parameters of angular and linear motion. Built-in power-sensitive elements of a high-speed computer calculates the orientation angles (yaw, pitch and roll), correction of location coordinates and provides information to the consumer. The system has a size of a handheld device (183 × 80 × 57 mm), weight 700 g and the accuracy is close to the classical scheme of the INS (accuracy of the roll and pitch is 0.5° ... 1°, the course - 1° ... 1.5°, and height - 5 ... 7 m). In addition KompaNav-2 has a power consumption level of 1.5 watts, which is quite high for this class of systems. Another drawback of the system - this is a high cost (several thousands of U.S. dollars) [4, 1]. Approximately the same accuracy and cost characteristics has another development of LLC TeKnol – on board complex "Aist" in which the inertial navigation system is integrated with the static pressure sensor and a receiver of the SNA [4].

Autopilot UNAV 3400. Autopilot UNAV 3400, developed by the company UNAV (USA) [5], is a fully functional tool for navigation and aircraft control, and provides:

- determination of the navigation parameters, angles of orientation and motion parameters of

UAVs;
- the navigation and management of UAV during the setted flight path;
- stabilization of the orientation angles of the UAVs

An autopilot under consideration is characterized by a small size (102 × 51 × 41 mm). The core of the autopilot is miniGINS, which is characterized by the following quality indicators: accuracy of the roll, pitch and yaw of 2 ^{o}, and height – 5 ... 6 m. Thus, the accuracy characteristics of UNAV 3400 are close to the characteristics of KompaNav-2, but it is slightly more expensive (about $ 5000 USA) and also it has high power consumption (2.7 W) [5].

Of course, there are other similar systems. The following table gives the main miniGINS characteristics nowadays presented at the market.

Nowadays, one of the most accurate inertial systems for microelectronics and mechanical sensors is a system developed by Systron Donner, however, it is about four times more expensive than other systems, and its sale outside the U.S. requires a special license. The other systems have a much higher error in the calculation of navigation parameters and thus not have a low price.

Table

Miniature gimballess inertial navigation systems

Producer	Product name	Overall dimensions, mm	Mass, g	The maximum error in measuring angles orientation in the dynamic mode (roll, pitch / yaw), deg
1	2	3	4	5
CJSC «Unmanned systems», Russia	autopilot	105×25×18	22.5	0.2 / 2
LLC «TeKnol», Russia [95]	CINS KompaNav-2	183×80×57	700	1 / 1.5
LLC «TeKnol», Russia	Onboard complex «Aist»	98×70×41	310	0.3 / 1.3
Procerus Technologies, Switzerland	autopilot Kestrel Autopilot 1.45	73×50×15	39.56	5 / 5
Xsens Technologies B.V., Netherlands [96]	miniGINS MT9	39×54×28	35	3 / 3
UNAV, USA [97]	autopilot UNAV 3400	102×51×41	84.77	2 / 2
MicroStrain, США	GINS, Inertia-Link	44×58×21	45	2 / 2
Crossbow Technology, USA	GINS, IMU 400	76.2×95.3×81.3	640	3 / 3
Systron Donner, USA	GINS, MMQ-G	64.8×47.6×47.6	227	0.3 / 0.3

Thus, a significant cost reduction of integrated miniGINS in comparison with autonomous INS allowed to expand sphere of 25 application of inertial systems. So, now, inertial systems are used not only in the long-range aviation and shipping, but also in such non-traditional areas of INS as biomechanics, animation, medicine and rehabilitation, virtual reality and robotics, miniature unmanned aerial vehicles.

However, despite of a rather high price decline of such systems in comparison with precision inertial systems, they still remain expensive.

As can be seen from the table gimballess miniature inertial navigation systems have different dimensions, weight, the maximum error in measuring of angles orientation in dynamic mode (roll, pitch, yaw) and, accordingly, the cost of which can be considered as criteria for selecting a technical means complex of on-board navigation system for a particular UAV.

Thus, we have the multiobjective optimization task, where as the restrictions the geometric dimensions of the space are proposed for the deployment of the UAV system.

The general formulation of the vector optimization problem of technical means selecting for the navigation system of the UAV can be represented as

$$A^{o} = \max_{A \in H} F(A);$$

$$(A_i)_{\min} \leq A_i \leq (A_i)_{\max}; \quad G_j^{*} \leq G_j(A) \leq G_j^{**}; \quad F_t(A) \geq F_t^{*},$$

where A^{o} – vector of optimal design parameters in the Pareto domain; H − domain of possible solutions.

Under the principle of the Edgeworth-Pareto any chosen variant should be Pareto-optimal. Due to the fact that the Pareto set is quite wide, there is a problem of narrowing of the Pareto set, associated with the choice of a particular Pareto-optimal variant as the best one.

There are some combinations of criteria by means of which it is possible to describe all the Pareto set. Then a Pareto choice can be reduced to the choice of particular combinations. The most simple and generally used among these combinations is a linear convolution of criteria $\sum_{i=1}^{m} \lambda_i f_i(x)$, where all $\lambda_i \geq 0$, very often there is also the normalization condition $\sum_{i=1}^{m} \lambda_i = 1$.

It is easy to verify that every point of maximum on the X set of linear criteria convolution if $\lambda_i > 0$, , i = 1, 2... m is Pareto-optimal. From this it follows that, choosing (or designating) within these ranges coefficients of linear convolution and maximizing its value on the set X, the result will be given by some Pareto-optimal variants. Thus the variants choice (even without a preliminary exercise to ponder the construction of the Pareto set) reduces to the choice of the coefficients of a linear convolution, which are often interpreted as a certain "weight" (or "importance coefficients") of the criteria.

This method of solution of multicriteria choice task has some drawbacks. It should be noted that the precise definition of "weighting" criteria doesn’t exists. Researchers using a linear convolution often talk about these coefficients, as the "weighting factors" that define the degree of influence of separate criteria on the final selection (final or summary evaluation): the higher the coefficient is, the greater the contribution makes its criterion. Expert or decision maker, choosing the specific values of these coefficients will base on its own understanding of these factors, since there is no strict definition of this concept. However, none of them are usually able to evaluate and numerically express in the form of coefficients the same degree of individual criteria influence on the final estimate, as was mentioned above, because the study of the linear convolution point of maximum changes, depending on its coefficients is the subject of parametric optimization theory and is a rather complex calculation task. In addition, on different sets of possible variants of X points of one and the same linear convolution, generally speaking, are different, indicating the failure of attempt to estimate the impact of coefficients for the same decision maker which uses the same criteria set, but different X-sets.

Conclusions

The necessity of microelectromechanical inertial sensors of low accuracy in onboard navigational systems of UAV was proved. The expediency of complex navigational systems was shown, which includes miniGINS and external counting devices such as GPS- receiver. The analysis of miniature gimballess inertial navigation systems showed the necessity of solving the task of technical means complex choice. It was shown in the given work that the task can be reduced to the multicriteria optimization task, which can be solved by means of the algorithm of Pareto's set narrowing.

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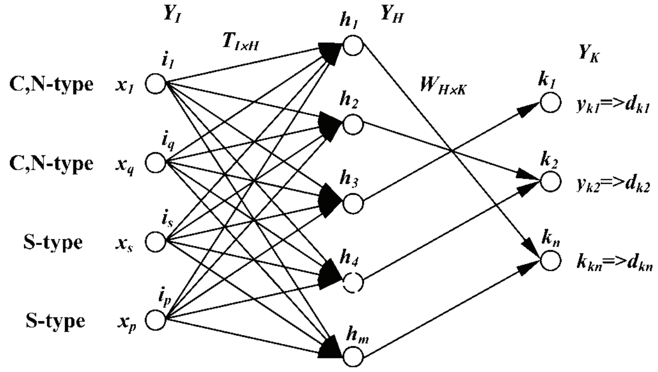
CONSTRUCTION METHODOLOGY OF INFORMATION SYSTEMS WITH INTELLIGENT DECISION SUPPORT

A self-organizing computing network based on concepts of fuzzy conditions, beliefs, probabilities, and neural networks is proposed for decision-making in intelligent systems which are required to handle data sets with a diversity of data types. A sense-function with a sense-range and fuzzy edges is defined as a transfer function for connections from the input layer to the hidden layer in the network.

In order to automatically make decisions, an intelligent system may incorporate and apply many existing techniques such as decision trees, Bayesian belief networks, evidence theory, rough set theory, fuzzy set theory, kNN (k-nearest-neighborhood) classifier, neural networks, and support vector machines. We call the technique "intelligent" if it includes three important aspects: knowledge, decision making, and learning, i.e., when an intelligent system interacts with its environment, it can automatically make correct decisions by means of its knowledge, and it can learn from instances to gain knowledge. Each intelligent technique has its own knowledge representation, decision-making, and learning mechanisms. For example, if knowledge is represented by a decision tree, the decision tree can be obtained from known instances by using the ID3 or the C4.5 algorithms [1], [2], and the decision-making is a set of tests based on the decision tree. If knowledge is represented by a feed forward neural network, the network can be trained by the back propagation algorithm with a training set, and outputs of the trained network can be applied to make decisions. Because of differing representations of knowledge and differing mechanisms of learning and decision-making, a particular intelligent technique is usually good at dealing with a specific data type. For example, neural networks are good at dealing with numeric data while decision trees are good at dealing with symbolic data.

Two classes of data, symbolic data and numeric data, are often used in an intelligent system. Symbolic data values are discrete, and relationships among the values are not explicitly indicated. It is difficult to measure a distance between a pair of symbolic data values. Furthermore, value sequences or neighborhoods are not explicitly indicated among symbolic values. For example, suppose that the data attribute *furniture* contains values: "desk," "chair," "bookshelf," "clothespress," and "bed." It is difficult to say which value is the nearest neighbor of value "clothespress." The values cannot be sorted in a descending sequence or an ascending sequence in the same way as numbers. Symbolic data are called *S-type data* in this paper. Numeric data can be classified into two types: continuous values and codes. Continuous values, which are called *C-type data* in this paper, can be addressed by mathematical functions. C-type values are not independent. There is a sequence among the values, and each pair of values can be measured with a distance. Values which are a short distance away from value A can be called the neighbors of value A. C-type data intrinsically contain knowledge about value sequences and some known relationships. Codes can be regarded as numeric labels, and they are called *N-type data* in this paper. They are usually represented by integers, for example, room numbers, ID numbers, item numbers, or other label numbers that are encoded by humans. They are somewhat similar to C-type data in that there is a sequence among N-type values, and the distance between the values can be measured. However, the distance between two values is not always significant. For example, it is not guaranteed that a student with ID = 001 and a student with ID = 002 are neighbors. The N-type data can therefore be regarded as either S-type or C-type. The choice depends on whether a distance between values is significant for decision-making.

Each intelligent technique has its own merits and shortcomings. Computational intelligent techniques, such as EfuNN [3], SOFNN [4], [5], dynamic fuzzy neural networks, kNN, neural networks, and support vector machines, are good at dealing with C-type data. The gas furnace time series data and the Mackey-Glass time series data are benchmark data sets in C-type. The EFuNN (Evolving Fuzzy Neural Network based on Tokagi-Sgeno fuzzy rules) was applied to deal with these data sets, and the errors were very small, i.e., 0.156 for the Gas-furnace case and 0.039 for the Mackey-Glass case. However, they cannot be directly applied to S-type data or to a data set with missing values. Symbolic AI techniques [1], [2], [6] are good at dealing with S-type data and data with missing values. However, if they are applied to C-type data, the C-type data have to be discretized, and the results are affected by the discretization



In the real world, an intelligent system often encounters mixed data types, incomplete information (missing values), and imprecise information (fuzzy conditions). In the UCI Machine Learning Repository, it can be seen that there are many real-world data sets with missing values and mixed data types. It is a very important challenge to enable a machine leaning or data mining approaches to deal with mixed data types. A discretizer based on class-dependence is applied to transform C-type data to S-type data and enable inductive learning and decision tree learning systems to deal with C-type data. A symbolic AI technique plus a good discretizer is the traditional machine-learning approach to handle an information system with mixed data types. However, information about distance and neighborhood in C-type data is ignored, if symbolic AI techniques treat the discretized values as symbolic values. In order to apply information about distance and neighborhoods, Multimodal Data Fusion was investigated, and difficulties in finding a measure of similarity between objects with mixed data type attributes. These difficulties are shared by machine learning in data mining approaches. To date, an effective solution has not been recorded in literature. Therefore, a novel Self-Organizing Computing Network is proposed here to deal with data sets with mixed data types. The concepts of support degree and belief in symbolic AI and concepts in fuzzy neural networks are applied to this computing network to avoid the difficulties .As this network contains many concepts that do not belong to conventional neural networks, the term *computing network,* is applied for clarity.

We shall briefly introduce basic components in a traditional fuzzy logic system (for detailed discussion, please refer to [3]), and then propose our connectionist model.

Computing network model

The standard advantages claimed for neural networks are multiple computing units, parallel processing, and adaptive learning mechanisms. However, the behavior of a single neuron in a neural network is difficult to explain. Fuzzy neural networks are an improvement in this aspect. For example, fuzzy rules can be extracted from DENFIS (Dynamic Evolving Neuro-Fuzzy Inference). Concepts of fuzzy set theory have been applied to neural networks to create fuzzy neural networks and Neuro-Fuzzy Inference Systems. In this section, the concepts in symbolic AI techniques are applied to design a self-organizing computing network so that the network is capable of dealing with mixed data types.

The self-organizing computing network as defined in this paper is constructed by means of three classes of computing cells: input cells, hidden cells, and output cells. In general, computing cells can have different computing mechanisms; for example, neuron models, mathematical functions, computer programs, or processor units. For a self-organizing computing network, input cells are defined as a set of encoders that transform different data values to the internal representation of the network. An input cell corresponds to an attribute in an instance information system [6]. Therefore, the number of input cells is equal to the number of attributes in the instance information system. Each input cell is connected to hidden cells by means of *connection transfer functions* instead of single weights. Hidden cells are self-organized by means of known instances in the instance information system. The number of hidden computing cells is determined by the self-organizing algorithm. Hidden computing cells are connected to output cells according to the decision values of known instances in the instance information system. The number of output cells is equal to the number of decision values of the decision attribute in the instance information system. The architecture shown in Fig. 1 is a self-organizing computing network for an instance information system with p attributes and n decision values.

Let $I = \{i_1, \ldots, i_q, i_s, \ldots, i_p\}$ be a set of input cells, $I_c = \{i_1, \ldots, i_q\}$ for C-type (or N-type) inputs, and $I_s = \{i_s, \ldots, i_p\}$ for S-type inputs. Let $H = \{h_1, h_2, \ldots, h_m\}$ be a set of hidden cells, $K = \{k_1, k_2, \ldots, k_n\}$ be a set of output cells. The connections from input cells to hidden cells are represented by a transfer functions matrix $T_{I\times H}$.

$$T_{I\times H} = \begin{Bmatrix} T_{i1,h1} \; T_{i1,h2} \; \ldots \; T_{i1,h_m} \\ \ldots \ldots \ldots \\ T_{i_p,h1} \; T_{i_p,h2} \; \ldots \; T_{i_p,h_m} \end{Bmatrix} = \begin{Bmatrix} T^C_{I_c\times H} \\ T^S_{I_s\times H} \end{Bmatrix}$$

$$= \begin{Bmatrix} T^C_{i1,h1} & T^C_{i1,h2} & \cdots & T^C_{i1,h_m} \\ \cdots & \cdots & \cdots & \cdots \\ T^C_{iq,h1} & T^C_{iq,h2} & \cdots & T^C_{iq,h_m} \\ T^S_{is,h1} & T^S_{is,h1} & \cdots & T^S_{is,h_m} \\ \cdots & \cdots & \cdots & \cdots \\ T^S_{ip,h1} & T^S_{ip,h1} & \cdots & T^S_{is,h_m} \end{Bmatrix}.$$

Connections between the hidden layer and the output layer are weighted connections. The weights are represented by the following matrix.

$$W_{H\times K} = \begin{Bmatrix} w_{h1,k1} \; w_{h1,k2} \; w_{h1,k_n} \\ \ldots \ldots \ldots \\ w_{h_m,k1} \; w_{h_m,k2} \; w_{h_m,k_n} \end{Bmatrix}.$$

The weights are real numbers with a range of [0, 1]. A weight in the weight matrix can be regarded as a *decision support degree* for a hidden cell. For example, weight $w_{h,k} = 1$ means that hidden cell h supports the decision corresponding to output cell k. Weight $w_{h,k} = 0$ means that hidden cell h does not support the decision corresponding to output cell k.

Input Cells—Input Data Encoders

In a computing network as shown in Fig. 1, an input cell is defined as an input data encoder that transforms input data with type diversity to the internal representation. Let $X_I = \{x_{i1}, \ldots, x_{iq}, x_{is}, \ldots, x_{ip}\}$ represent input values and $Y_I = \{y_{i1}, \ldots y_{iq}, y_{is}, \ldots, y_{ip}\}$ represent output values of the input cells. In order to transform all C-type and N-type inputs to the same value range, a computing mechanism for C-type and N-type input cells is represented by the following expressions:

$$y_i = (x_i - x_{i(\min)})s_i \quad \text{for } i \in I_c,$$

$$s_i = s_w/(x_{i(\max)} - x_{i(\min)}) \quad \text{for } i \in I_c,$$

where $[0, s_w]$ is the value range and sw can be an arbitrary integer or real number. If Xj is an S-type value, an encoding scheme is required. If the S-type data can be arranged in a significant sequence, the S-type value is converted to the order number or rank in the sequence. For example, suppose temperature has values: "hot," "warm," and "cold." The sequence "cold->warm->hot" is a significant sequence. And, it represents the temperature varying from low to high. S-type data for the temperature can be encoded with N-type data, 1 for "cold," 2 for "warm," and 3 for "hot."

Equations (3) and (4) are applied to transform these values to the internal representation of the computing network. If S-type data cannot be arranged in a significant sequence, S-type data are transformed to integer codes arbitrarily. For example, values for furniture can be encoded with 1 for "desk," 2 for "chair," 3 for "bookshelf," 4 for "clothespress," and 5 for "bed." They could also be encoded in other codes.

$$y_i = \text{code} \quad \text{for } i \in I_s, \text{ i.e., S-type inputs.}$$

In order to get a redundant integer for these codes, s_w is set to a typical value of 50. As a result of this, 50 integers within the range can be used as an internal representation for the codes of S-type data. If there are more than 50 S-type values in a single attribute, s_w can be set to a larger number. A real number within $[0, s_w]$ is applied to the internal representation of C-type and N-type input values

Conclusion

The Self-Organizing Computing Network represents a combination of symbolic AI techniques and computational intelligent approaches. In this approach, the input layer is designed as a set of data converters. The Bayes classifier is applied to input cells for converting from probabilities of symbolic data to decision support degrees. Based on the concepts of *receptive fields* and the *synapse response function* in biological neurons, a sense-function with a sense-range is defined for each connection from input cells to hidden cells. If the inputs are symbolic data, the sense-function is replaced by a support degree distribution. Each hidden cell is defined as a multiplier that combines sense functions or support degree distributions from the afferent cells. Each hidden cell responds to a fuzzy subsuperspace within the input superspace. This is similar to a biological neuron having a receptive field. Just as neural receptive fields adapt to stimuli, the fuzzy subsuperspace of a hidden cell adapts to the training set according to the self-organizing algorithms. Based on the definitions for the computing cell and its connections, each output value can be explained using symbolic AI concepts such as belief, support degree, match degree, or probability. Using this network, instance information systems with mixed data types can be handled directly. Note that preparation of input data is included in the self-organizing algorithm. Therefore, this approach has not directly given results for data reduction and aggregation, and structural and semantic heterogeneity. It may be possible to extend the cells in the hidden layer to retrieve these. This is a topic for further study.

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EGNOS INTRODUCTION TO THE EUROPEAN EASTERN REGION AS THE CHANCE FOR THE AIR REGIONAL TRANSPORT

Summary

The general idea of this project is to popularize the usage of EGNOS (European Geostationary Navigation Overlay Service) System in Central European countries. The main goal will be achieved by demonstrating key capabilities of the EGNOS System as SBAS (Satellite Based Augmentation System) APV I(Approach Procedures with Vertical guidance) – its main role. After that the National Fly Authority Agency certification procedure will be launched, EGNOS will become fully functional and operational airfield domestic system. Project consists of 4 main phases:

Phase one – Analysis of domestic airfields and Aircraft operator(s) against opportunity of EGNOS installation and utilization of capability for landing purposes;

Phase two – study of demonstrator's technical conception of EGNOS APV implementation connected with blueprint for certification process;

Phase three – on-board and airfield system installation connected with provisional certification;

Phase four – Final demonstration of overall system capabilities, followed by on-going tests, system certification and implementation of Safety Case.

The following entities participate in this project: scientific research centers, government agencies, aircraft operator and local small airfield, which guarantees general outlook analysis, clearly constructed user requirements with correct technical solutions which are in compliance with the Polish and European air traffic regulations.

Government agency will keep an eye on realizing a through airfield and aircrafts operators inspection used by research centers for analysis. Additionally government agency will be the supervisor for preparation and certification of the airfield and aircraft.

Scientific research centers will prepare technical solutions for system installation at airfield and aircraft, with certification projects and procedures, as well. This includes two types of certification: technical and fly procedures (landing procedures for aircraft and airfield). Safety of fly and Safety Case are especially taken into consideration. Aircraft operator involved in a project will perform the EGNOS system installation on the aircraft and on the airfield, using blueprint for technical solution developed in the second phase of the project, and as result of that in next phases of project will perform test and certification flights. Additionally aircraft operator is allowed to train new and current pilots, which will fully realize plan for preparing all the pilots to be familiarized with EGNOS System, and if so, this system will be widely and commonly used in aviation/air force.

All demonstration, testing and certification flights will be in participation of scientific research center and government agency, which will guarantee the test procedure correctness in accordance to flight safety regulations and rules for new equipment on board of aircraft.

Currently, differential positioning methods, such as EGNOS, ASG-EUPOS, AFREF, WAAS, MSAS, GRAS, GAGAN, SNAS, basing on global satellite navigation systems: GPS, GLONASS and also Galileo in the future, undergo dynamic development. Potential use of these techniques includes, among others, airport traffic control.

From 2007 experts representing several institutions performed aircraft flight trials of GPS receivers at the Kraków, Katowice, Mielec airfield. This was an introduction to test campaign of the EGNOS-based satellite navigation system for air traffic in international projects "EGNOS Introduction to the European Eastern Region".

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SUPPORT OF EFFICIENCY IN EXPLOITATION SYSTEMS

In a article the considered questions of support of effectiveness and efficiency of functioning of the exploitation systems of communication, navigation and surveillance devices, the methodical going is resulted for the construction of subsystem for support of effectiveness and efficiency.

Communication, navigation and surveillance (CNS) devices play an important role in support of safety and regularity of flights of airplanes of civil aviation (CA).

For providing of the reliable functioning of CNS devices the systems of exploitation (SE), which execute the considerable volume of works: the use on purpose of CNS devices, their technical service and repair, continuation of resource, etc [1]. In that time SE of technical complexes can be the object of development and perfection. In the process of usage SE possible cases of mismatch of parameters of its elements the set requirements, that can influence on a level effectiveness and efficiency SE.

An analysis shows that it is possible to consider the appeal of attention perspective direction of theory and practice of exploitation of technical complexes to SE on the whole and its component subsystems, related to application of new methods of management in SE, modern information technologies and facilities, that allows to score competition advantages at the market of services, to improve quality of grant of services and promote satisfaction of users.

Practical realization of introduction of new methods of management can be carried out by the subsystem of support of effectiveness and efficiency (SSEE) SE CNS devices, which function on the basis of principles and positions of international standards of ISO of series 9000 [2, 3]. The question of expedience of the use of SSEE was grounded in [4, 5].

The idea of creation of SSEE consists in usage of principles of international standard of ISO of series 9000, namely – to process approach in description and consideration of questions of functioning SE on the whole and its elements. Process model is the organic element of pyramid of submission of basic constituents which characterize functioning of any system (organizations or enterprises). There is subordination as: “Mission” – “Aims” – “Basic tasks” – “Basic functions” – “Processes”. In obedience to ISO processes must be guided and controlled [6].

Effectiveness of functioning of SSEE must be based on the wide use of information technologies and facilities of computer technique, which will allow in time and high-quality to collect and process the large arrays of data, form administrative decisions, etc.

The questions of synthesis and analysis of SSEE are considered not enough in scientific editions. It is therefore suggested to consider approaches to a synthesis and analysis of SSEE.

In the organizational structure of SSEE it is suggested to select the followings complexes: complex of control of parameters of stream of entrance requests and requirements to them (complex № 1), complex of control of satisfaction of users (complex № 2), complex of control of aims (complex № 3), complex of control of personnel (complex № 4), complex of control of resources (complex № 5), complex of estimation of accordance of processes the set requirements (complex № 6), complex of estimation of accordance of documents the set requirements (complex № 7), complex of monitoring of quality of functioning of facilities of CNS (complex № 8), complex of monitoring of effectiveness and efficiency SE (complex № 9), etc.

Principle of functioning of SSEE is explained by the analysis of it the generalized structure. In general case SSEE must cooperate with all structural subdivisions of SE of CNS devices and subject industry on the whole and to execute the functions on the basis of rule: “Plan” – “Actions” – “Analyse” – “Perfect”.

In general case SSEE engulfs all subjects SE. Information, what SSEE gets from these subjects, touches two aspects – requirement in relation to elements SE (informative streams of the first type I_1) and information on the current values of indexes of effectiveness and efficiency, on what set requirements (informative streams of the second type I_2). To the elements of SE, that form the informative streams of the first type, belong: users of services in aero navigation service, international organizations, organs of government control. To the elements of SE, that form the informative streams of the second type belong: organs of government control, provider of services in aero navigation service, research institutes and laboratories, suppliers of resources.

The sources of information for streams I_1 in relation to international organizations are the normative documents of ICAO, which touch facilities of CNS: Addition 10 ICAO in relation to communication, Addition 11 in relation to aero navigation service, documents of Eurocontrol ESARR 1 – 6, etc. The sources of information for streams I_1 in relation to the organs of government control are normative documents which regulate organization of technical exploitation [1] and requirements to the basic processes.

For determination of structure of every complex it is necessary to execute obligatory the followings: planning of works, direct coupled with functioning of every complex, estimation of level of achievement of the desired result, making decision, forming after a necessity and implementation of correcting (preventive) actions, – which can be examined as separate operators of processing of data.

Then typical statement description of functioning for every complex SSEE includes the followings operators: planning of works (PW), processing of data (PD) and forming of commands (FC). The generalized structure of operators of SSEE is illustrated on fig. 1.

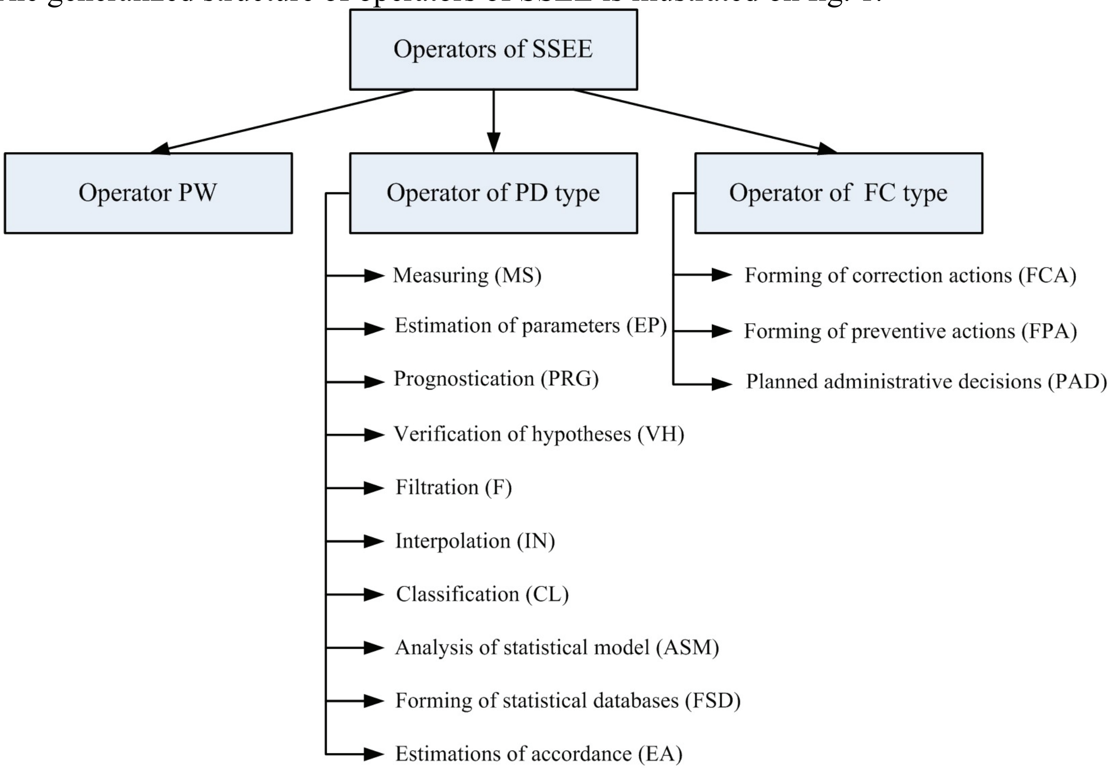

Fig. 1. Generalized structure of operators of SSEE.

On the whole it should be noted that the operator of PW and operators of FC type is related to the decisions of top management and executed on the basis of previous implementation of operators of PD. An operator of processing of data is difficult, it can includes both separate and aggregates of operators: measuring (MS), verification of hypotheses (VH), estimation of parameters (EP), prognostication (PRG), filtration (F), interpolation (IN), classification (CL), analysis of statistical model (ASM), forming of statistical databases (FSD), estimations of accordance (EA). In general case information, that subject treatment, carry casual character, that is why there is a necessity of application of operators processing of data, development of which is based on usage of methods of theory of chances, mathematical statistics, theory of casual processes, theory of evaluation, theory of statistical decisions, optimization, etc.

It is necessary to consider principle of co-operation of operators of SSEE in its separate complexes on the basis of analysis of functions of these complexes.

The complex of control of parameters of stream of entrance requests and requirements to them (complex № 1) processes entrance information on efficiency and effectiveness of facilities of CNS devices in SE. This complex includes the followings operators: EA, FPA, FCA, PAD and FSD. The entrances of this complex is information from the users of services in aero navigation service, organs of government control and international organizations of CA. This information in operator EA is compared to the set requirements which are contained in a normative and regulating document. When the amount of disparities is exceeded by a certain threshold level, an operator FCA or FPA is executed. Information about work of EA kept an operator FSD. On the finishing stage executed it is certain PAD.

The complex of control of satisfaction of users (complex № 2) executes the functions of verification of correct and timely implementation of stream of entrance requests. This complex includes the followings operators of processing of data: MS, EP, EA and FSD. Entrance information of complex are requirements of users in quality of requests, requirement of international and national standards in industries of CA, and also statistical information which characterize functioning of facilities of CNS and SE on the whole. On the basis of implementation of operators of PD can be formed operators PAD and FCA.

A complex of control of aims (complex № 3) is the analogue of the first complex and has the same statement construction, however entrance information in it is data from structural subdivisions of SE of technical complexes in relation to their executable functions and operations. Control of functions is carried out with the purpose of estimation of their accordance a general policy and aims of SE, that is examined.

Complex of control of personnel (complex № 4) has for an object establishment of level of material well-being in SE by personnel, his qualification, etc. Work of this complex foresees co-operating with higher educational establishments, by research laboratories, etc.

The complex of control of resources (complex № 5) is estimated by accordance of present resource base of SE of technical complexes to the set requirements. During work of complex the estimation of presence and state of apartments, reserve facilities of CNS devices, control and measuring apparatus, personal computers, software, etc.

The complex of estimation of accordance of processes (complex № 6) is intended for timely control of technological processes and separate technological operations with the purpose of increase of effectiveness and efficiency of functioning of SE. As requirements to technological processes are on the whole formed taking into account requirements to managing influences, resources, personnel, aims, documents and separate technological operations, this complex must summarize information, got during work of other complexes.

The complex of estimation of accordance of document (complex № 7) is checked up by accordance of normative documentation of SE to international recommendations and standards.

The complex of monitoring of quality of functioning of facilities of CNS (complex № 8) expects complex indexes of SE and includes for itself all operators of type of PD. The entrances of this complex are statistical information in relation to works and repair in facilities of CNS, descriptions of CNS devices, which are measured, information in relation to the estimation of accordance of processes. The result of PD within the limits of this complex is implementation of operators PAD, FCA, FPA and EA.

The complex of monitoring of effectiveness and efficiency of SE (complex № 9) determines numeral values of the proper indexes on the basis of the got results in the complex of monitoring of quality of functioning of CNS devices.

On the basis of information about functioning of complexes of SSEE it is possible to present the variant of co-operation of operators of SSEE of functioning of SE of CNS devices (fig. 2).

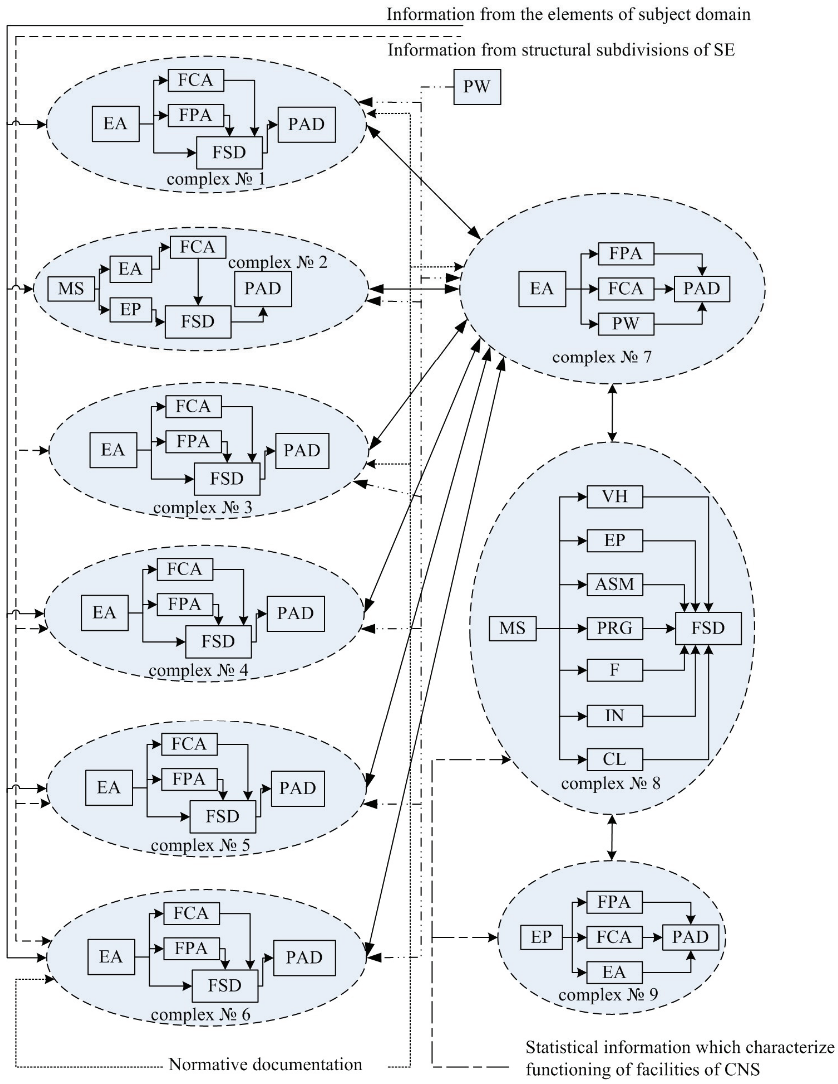

Fig. 2. Variant of co-operation of operators of SSEE.

Conclusions

The methodical going is resulted near the construction of subsystem of support of effectiveness and efficiency of the system of exploitation of technical complexes of civil aviation which is based on the substantive provisions of international standards of ISO of series 9000 and the wide use of modern information technologies and facilities, it is possible to use for creation of new and modernization of operating of SE of CNS devices.

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COMPUTER MODELLING OF ELECTROMAGNETIC COMPATIBILITY CONDITION ON AIRCRAFT FOR COMMUNICATION, NAVIGATION AND LANDING EQUIPMENT

Original computer package to model electromagnetic compatibility condition on aircraft for communication, navigation and landing radioelectronic equipment is represented. Basics of mathematical models used for calculations are described. Example of working with package is shown.

Qualitative and reliable functioning of radioelectronic equipment on aircraft is important to ensure aviation safety in common, which is impossible without guaranteeing of electromagnetic compatibility of them. Navigation, communication, landing and other functions are provided with such equipment. It is difficult to take into consideration and then to calculate all the aspects of electromagnetic effects, arising in various types and models of radioelectronic equipment and their antennas and feeder devices, placed on aircraft. In practice we could use another way to predict electromagnetic environment on aircraft while radioelectronic equipment mounting – calculating electromagnetic coupling coefficient for a pair of equipment units. This one is presented:

$$\beta_{12} = L + O_d + G_{\mathrm{t}} + G_{\mathrm{r}} + K_{\mathrm{p}} + K_{\mathrm{f1}} + K_{\mathrm{f2}} + C_1 + C_2 + Z_{\mathrm{w}}, \quad (dB), \tag{1}$$

here β_{12} – electromagnetic coupling coefficient for two antennas on disturbance's frequency; L – spatial disturbance attenuation; O_d – diffractional disturbance attenuation; $G_{\mathrm{r\ (t)}}$ — antenna gain in the line of beam, coupling two antennas; K_{p} – polarization disturbance attenuation; $K_{\mathrm{f1(2)}}$ – feeder disturbance attenuation; $C_{1(2)}$ – correction factor for antennas; Z_w – disturbance attenuation with aircraft's wings.

For each item of formula (1) calculation procedure is designed.

Computer program was designed to model different situation onboard and calculating electromagnetic coupling coefficient by formula (1). The program is designed in BorlandC++Builder and MathCAD Professional packages. Application interface includes four pages to input necessary data and showing result of calculation. All these pages are presented on figures (1 - 4) correspondingly.

The first page of computer routing is served to input parameters of antennas (type, geometric size, coordinates, directional pattern, polarization, gain coefficient), feeders (length, travelling-wave factor, attenuation constant), disturbance frequency and command buttons to save data, to calculate, to show result, to show coordinate system.

The second page of computer routing is served to input parameters of aircraft (length and radius of fuselage, wingspan, coordinates of wings, and parameters of keel). These parameters are used to be approximated with round cylinder for imitating the fuselage and with fragments of plane for imitating the wings. After approximating the getting model is shown in three dimensions.

The third page of computer routing is served to find places for antennas to mount. User can manually replace both antennas, their coordinates calculated automatically.

The fourth page of computer routing is served to get the result. It represented in a form of numerical and qualitative assessments. Numerical assessments reflect result according to formula (1), all the units are shown for understanding value of electromagnetic coupling coefficient. Qualitative assessments are used for helping engineers to estimate given situation, these characterize way of antennas interaction, for example, “receiver antenna interact throw side lobe”, “antennas are placed in powerful communication zone”, “antennas are not shaded with wings”, “disturbance frequency are not working for transmitting antenna”, “value of electromagnetic coupling coefficient within the mark” and so on.

This application has Ukrainian language interface, but it can be translated in English if necessary.

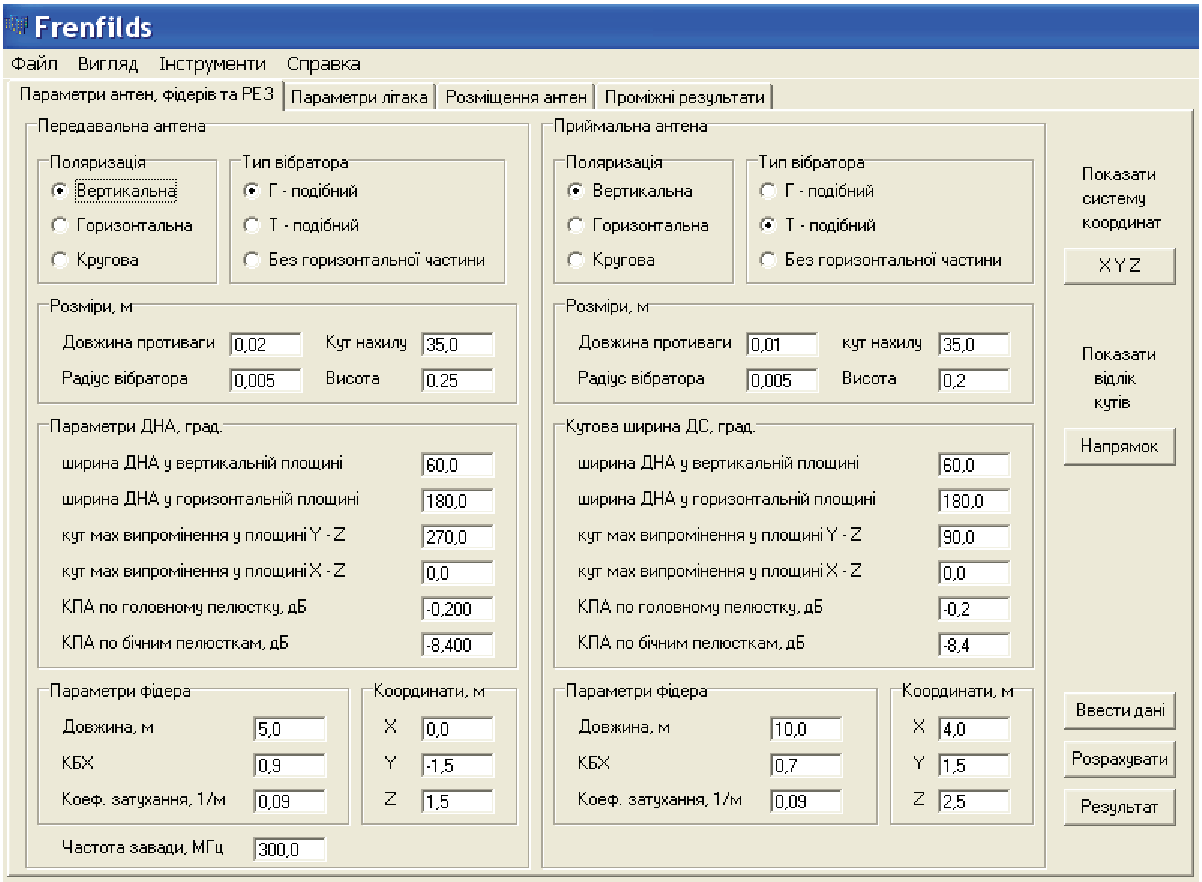

Figure 1. First page of routing – input parameters of antennas and feeders.

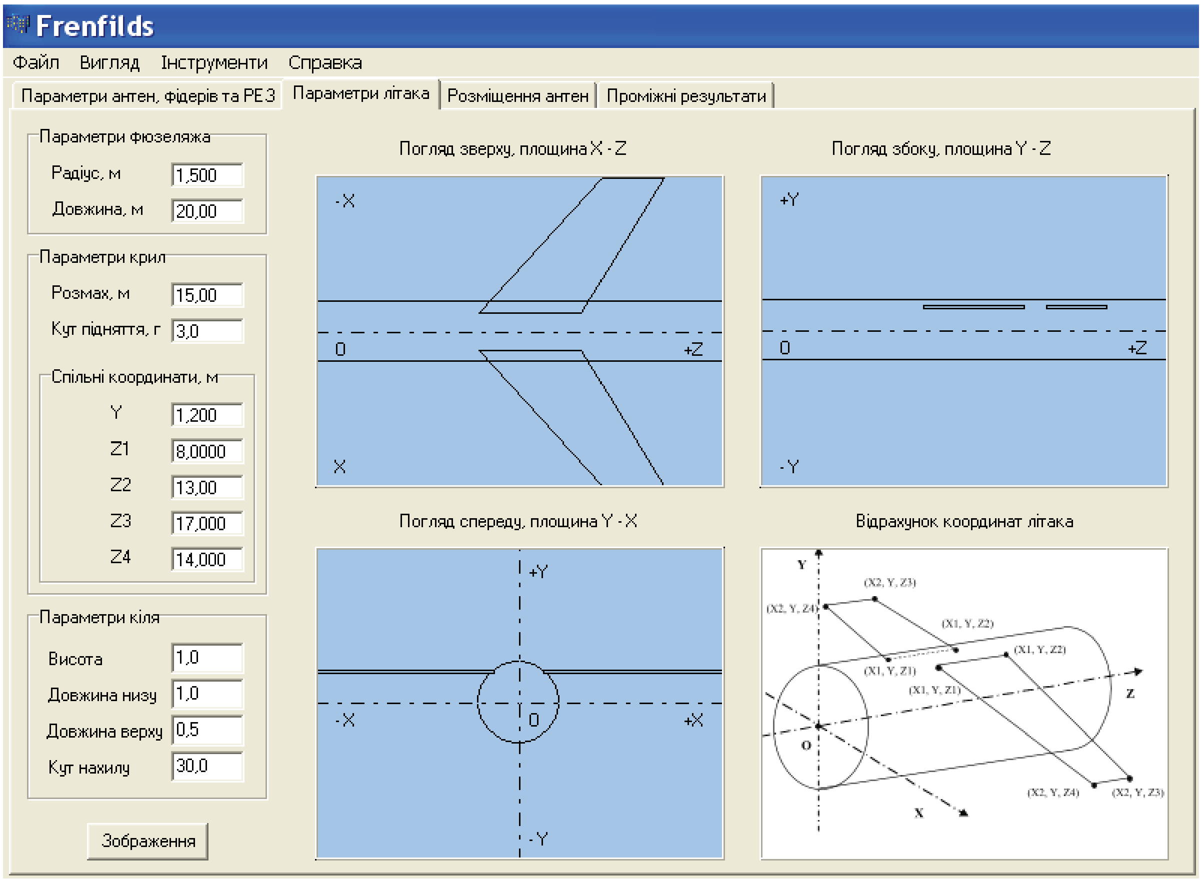

Figure 2. Second page of routing – input parameters of aircraft.

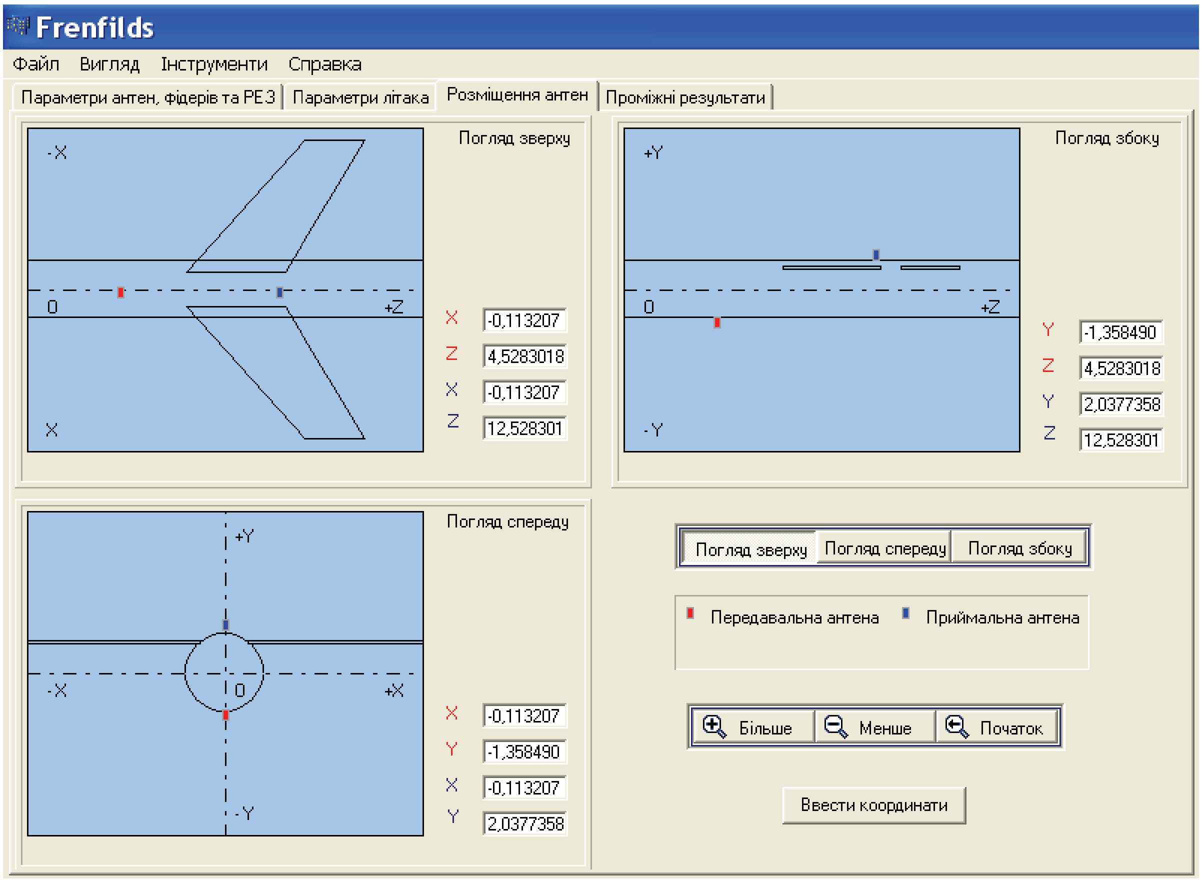

Figure 3. Third page of routing – antennas replacement.

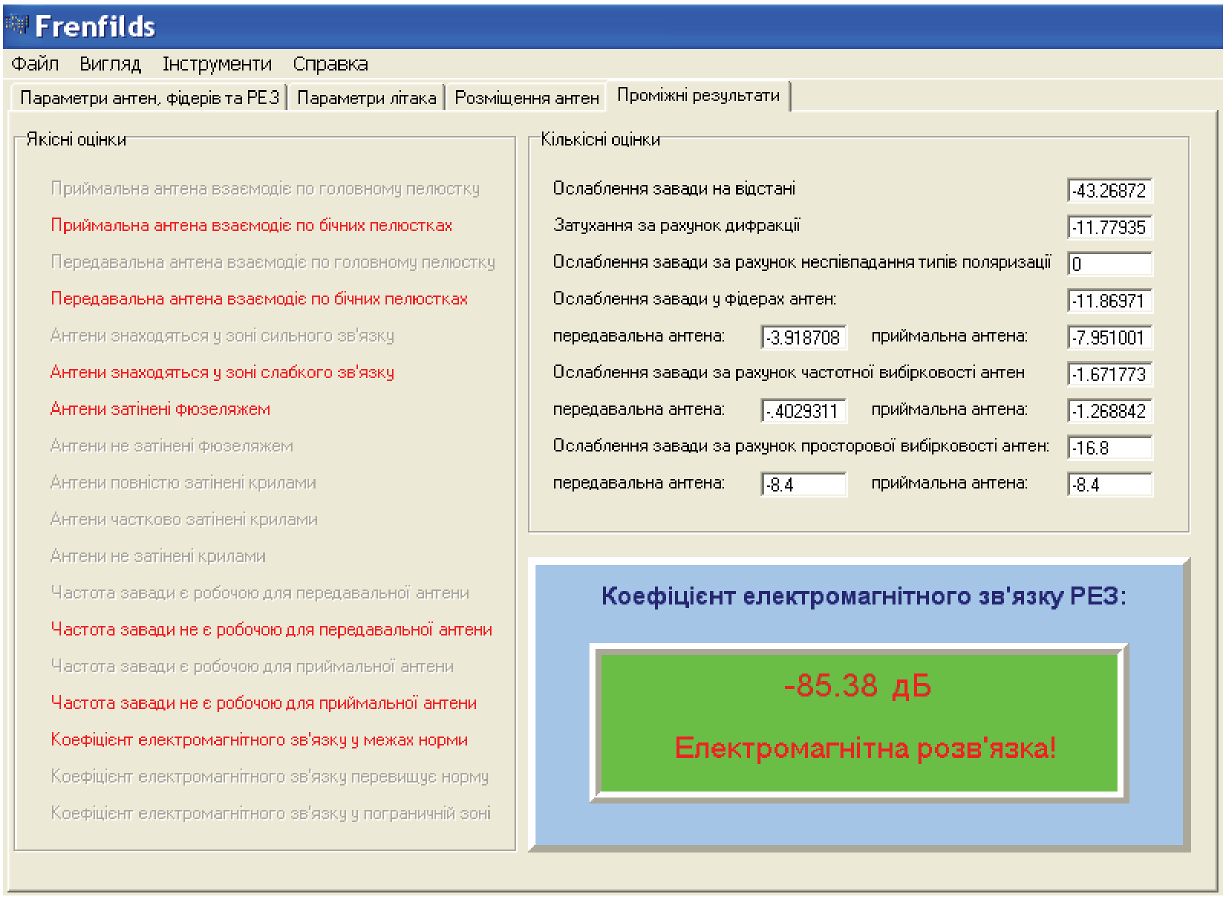

Figure 4. Forth page of routing – output results of modeling.

Conclusions:

Computer program, presented in article, is a simple and useful instrument for modeling, calculating and solving problems of electromagnetic incompatibility, arising after mounting radioequipment of communication, navigation and landing complexes on aircraft. Such a routing allows to solve a lot of possible problems without physical modeling the aircraft and numerous measuring operations, those involves engineering personal, measurement equipment and special testing laboratory.

Electromagnetic coupling coefficient was chosen as a key to the door that opens way for solving electromagnetic incompatibility problems onboard. The only criteria determines availability or absence of compatibility on the one hand, and explains the cause of incompatibility, if it takes place, on the other hand. Also, this factor prompts to engineers how to solve problem, because computer program calculated separately all including units of this coefficient, showing the numerical role each of them in forming the final result – value of electromagnetic coupling coefficient.

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DAMPING OF SCHULER'S OSCILLATIONS AS A WAY TO INCREASE THE ACCURACY INERTIAL GYRO VERTICAL

The methods of gyro vertical design are considered on rough micro-electro-mechanical (MEM) elements: sensors of angular speed and accelerometers. To increase the accuracy of MEM gyro vertical the integration with satellite navigational system is suggested. The proposed solutions allow us to increase the accuracy of computer-integrated gyro vertical, built on the basis of nano-technologies, by the newest data fusion and speed correction.

Urgency of research. Analysing the primary information sensors of existent attitude-and-heading reference system (AHRS) and strapdown inertial navigation systems (SINS) it is possible to note that they are related to the class of precision sensors, and that is why they are expensive. More over, for modern micro-satellites, microprobe, micro-space-buggy and miniature UAVS they do not satisfy the mass-proportions characteristics.

Therefore now except for precision accelerometers and sensors of angular speed in SINS, the use of rough, but microsized sensors of primary information, made on MEM (micro-electro-mechanical systems) technologies is found more and more application. These sensors are in the mass production and cost the same as other microcircuits (tens dollars). However, its basic disadvantage is low accuracy. That is why the practice of design of such information systems is formed presently and based on their data fusion with more exact, but less informative systems.

As researches show, the most perspective system for integration with SINS is a satellite navigational system(SNS). Such data fusion allows us to limit accumulation of errors in SINS and, also to decrease noise component errors of SNS, to increase the data exchange rate for users, to raise substantially the level of noise immunity. Therefore, with design of rough MEM- gyro vertical it is suggested to integrate it with SNS.

For data fusion the Kalman filtering is the most widely used and is the most attractive approach. Nevertheless, the use of Kalman filter makes certain difficulties during its practical realization aboard an aircraft. Nowadays, other data fusion techniques are used in airborne complexes for optimal estimation of the state vector, there are other methods of data fusion, in particular, methods of mutual compensation which well prove itself in practice. Basic advantage of Kalman filtering is the estimation of state vector including angular coordinates which are restored, that is the accuracy of angular orientation increases.

In our opinion the application of compensation circuit together with the circuits of speed correction gives the possibility to improve the accuracy of parameters estimation for angular orientation of rough MEM- gyro vertical.

Problem statement. The vertical line in SINS is simulated on the signals of accelerometers by an integral correction with tuning on Schuler's frequency. That's why the presence of instrumental and methodical errors of SINS causes in its structure undamped oscillations with Schuler's period (the invariance of the system to the action of horizontal linear accelerations is thus provided). These oscillations create the errors in the indication of orientation, velocity and coordinates. Thus, SINS is the oscillating systems, needing for damping. However, development of damping methods of autonomous SINS without bringing in other information results in the loss of invariance of SINS relative to linear accelerations, acted on the object.

Damping methods of SINS, built on integration with other sensors of non-inertial nature are the most widely used. Perspective methods are methods of elimination or diminishing of oscillations with the Schuler's period in SINS by its correction from the receivers of SNS.

Block diagram of data fusion SNS and strapdown inertial MEM- gyrovertical (SIMGV), realizing the method of compensation together with the correction circuit is presented in Fig.1.

Algorithm of data fusion, which uses the method of compensation, has enough simple form comparing to optimal Kalman filtering:

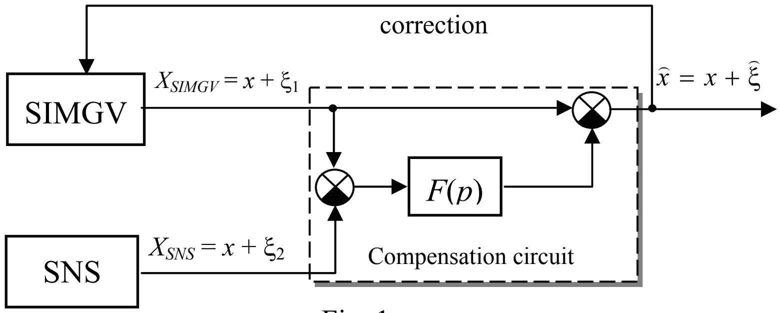

Fig. 1

$\hat{x} = x_{SIMGV} - F(p)(x_{\text{SIMGV}} - x_{\text{SNS}})$ where F(p)- dynamic filter of compensation circuit; X_{SIMGV}, X_{SNS} - navigation parameters, got from SIMGV and SNS (strapdown gyro verticals are built on the algorithms of SINS and able to form navigation parameters except for the parameters of angular orientation, in particular, constituents of ground speed); $\hat{x}$ - estimation of navigation parameter.

If filter F(p) is selected in such way, that it passes with minimum distortion the noise ξ_1 and suppresses the noise ξ_2, than an error of the complex system will be minimal, that is the error ξ diminishes depending on a difference in spectral characteristics of errors ξ_1 and ξ_2. At sufficient difference in frequency characteristics of errors the output of filter of F(p) (see Fig.1) will be completely restored the error ξ_1, that is the error of SIMGV, and the output of compensation circuit will be the estimation of navigation parameter $\hat{x}$ maximally coinciding with the measured parameter of x.

Problem statement can be formulated as follows: using in the compensation circuit the newest dynamic filter, practically not distorting the error of SIMGV, to get the estimation of ground speed maximally close to the true speed. By reproduced estimation it is necessary to form the circuit of speed correction of SIMGV (damping circuit), that will improve the accuracy of parameters estimation of angular orientation, got from rough inertial MEM- gyro vertical.

Task solution. Unlike Kalman filtering the data fusion of the inertial-satellite systems of navigation on the basis of compensation circuit has greater speed of response and is not-critical to the non-stationary random processes that include drifts of the real sensors of primary information in SINS. In addition it can be realized in the airborne processors of digital computers enough easily. The results of researches of compensation circuit [1] with the dynamic filter of the first order (aperiodic link) show that the estimation of initial parameters has the much lesser error of SINS. However, the error of compensation circuit changes in time comparing with the error of SNS. Maximum is reached during the half-time of Schuler's period. Simultaneously the error is approximately twice much and exceeds the error of the reference system (SNS). It is explained that the error of SINS caused by the error of angular speed sensor, has two components: a component, changing with the Schuler's period, and a component which increases proportionally in time. The LF filter of the first order is effective only for constant, not time-varying errors. However, more difficult filter of the third order with the following form:

$$F(p) = \frac{3Tp+1}{(Tp+1)(Tp+1)(Tp+1)},$$

already doesn't pass not only the constant constituent of SINS error, but also error, which changes according to laws of the first and second orders. It also provides good filter properties of data fusion circuit and enough high precision characteristics of estimation of current coordinates, not worse, than circuit of optimal Kalman filtering [1]. Exactly these estimations are used in the damping circuit of inertial MEM- gyro vertical.

For the researches of speed correction circuits the simple single-component circuit of inertial MEM- gyro vertical was used. Inertial AHRS is built on same algorithms as the algorithms of SINS, therefore for simplified algorithms of single-component inertial vertical the known algorithms of SINS were used [2]. The algorithms of three-component SINS were simplified and taken to measuring only pitch angle and northern component of ground speed, and it was supposed that the heading of aircraft is equal to zero. The simplified kinematic equations of single-component inertial vertical look like:

$$\dot{V}_N = a_N\,;\;\; a_N = a_y \sin\vartheta - a_x \cos\vartheta;\,;\;\; \dot{\vartheta} = \omega_{y_\Sigma} = \omega_{z_{ЛА}} - \omega_{z_{NHE}}\,;\quad \omega_{z_{NHE}} = -\frac{V_N}{R_з} = -\dot{B};$$

where is V_N is the true northern component of ground speed of aircraft; a_N - projection of apparent acceleration of aircraft, measured by accelerometers (signals a_x, a_y), on the axis of ON of navigation trihedron; ϑ – pitch angle; ω_z - angular speed of aircraft rotation on pitch angle; B -geographical latitude; R_E -radius of Earth;

The circuit of single-component inertial MEM- gyro vertical with a speed correction is represented in fig. 2.

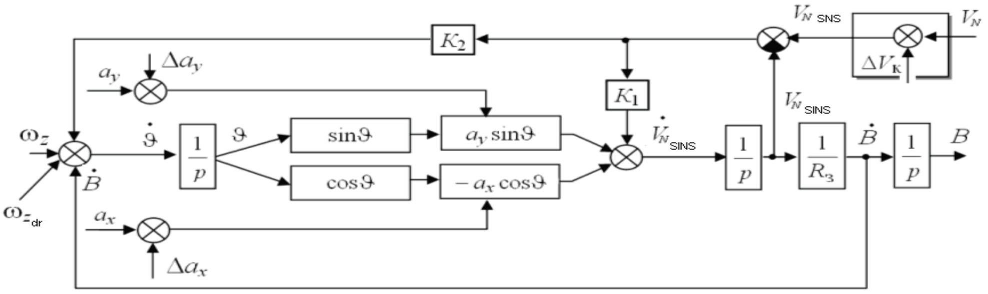

Fig.2

The realization of damping circuit in SINS differs from realization in platform INS by additional contour of K_1 that included not in the circuit of output signal of accelerometer, but in the circuit of acceleration, resulted to the geographical moving basis.

Signals Δa_x, Δa_y and $\omega_{z_{др}}$ are the most sufficient sources of MEM-vertical errors. A single-component gyro vertical circuit is a contour with the negative feedback. Presence in the contour of two integrating links testifies to structural instability of such contour. At the action of errors Δa_x, Δa_y and $\omega_{z_{др}}$ on such contour the undamped oscillations appear with eigen frequency $\sqrt{g(R)^{-1}}$. The structural analysis of contour shows that presence of constant error of accelerometers Δa_x, Δa_y,, will cause the error of vertical reproducing (pitch angle ϑ), and at presence of constant drift of angular speed sensor $\omega_{z_{др}}$ the vertical is simulated without constant error, but has the periodic error. The typical graphs of change of errors of vertical reproducing at presence of constant error of accelerometer and drift of angular speed sensor are represented in the form of sine oscillations.

The analysis of contour of corrected gyro vertical is done. Let's designate the error of speed determination of SINS as $\Delta V_{N_{\text{SINS}}} = V_{N_{\text{SINS}}} - V_N$, where $\Delta\dot{V}_{N_{SINS}} = \dot{V}_{N_{SINS}} - \dot{V}_N$, $V_{N_{\text{SINS}}}$ is a northern component of ground speed, measured by SINS; V_N is a true northern component of aircraft ground speed.

Let's suppose the flight is horizontal, then it is possible to assume that the angular speed ω_z of aircraft for spherical Earth is the following:

$$\omega_z = -V_N / R_з\,.$$

From the circuit the error of pitch change is written as follows:

$$\Delta\dot{\vartheta} = \omega_{z\,др} + \frac{1}{R_з}\Delta V_{N_{SINS}} - K_2\left(\Delta V_к - \Delta V_{N_{SINS}}\right).$$

In horizontal flight the aircraft acceleration change only in horizontal plane, that accelerometers taking into account own errors give such readings: $a_x = \dot{V}_N + \Delta a_x$, $a_y = g + \Delta a_y$ (here g is an acceleration of gravity force). Considering that at small angles $\sin\Delta\vartheta = \Delta\vartheta$, a $\cos\Delta\vartheta = 1$, let's write down equation for the right summator of structural circuit:

$$\dot{V}_{N_{SINS}} = \dot{V}_N + \Delta a_x - g\Delta\vartheta + K_1\left(\Delta V_к - \Delta V_{N_{SINS}}\right).$$

After transformation of this system we will get the system of equations which describes the errors of SINS in an operator form:

$$p\Delta\vartheta(p)-\left(\frac{1}{R}+K_2\right)\Delta V_{N_{SINS}}(p)=\omega_{z_{\text{др}}}(p)-K_2\Delta V_{\text{к}}(p);g\Delta\vartheta(p)+\left(K_1+p\right)\Delta V_{N_{SINS}}(p)=\Delta a_x(p)+K_1\Delta V_{\text{к}}(p).$$

The characteristic determinant of this system can be written as follows:

$$A(p)=p^2+K_1p+g\left(\frac{1}{R}+K_2\right)..$$

Analyzing the characteristic equation, it is possible to mark that including of correction contour with gain factor K_2 decreases the own period of system, and including of correction contour with gain factor K_1 provides the damping of oscillations in the system.

The proposed circuit was realized on the basis of GPS-receiver (GPS-Module-BR355) and rough flight sensors from autopilot (angular speed sensor (ДУСМ –АВАРЗ), and two sensors of g-load (БДЛУ-3)). The developed system was integrated with programming environment Labview. For the imitation of angular orientation change the blocks of strapdown sensors were mounted on a turn table which allow us to change the angular position of sensors block within 0,01˚ .

Graphs of errors change of vertical reproducing at including of speed correction contour, obtained by mathematical design of examined single-component circuit of SIMGV, is shown in Fig. 3. During experiments with a model the accuracy of orientation measurement was estimated with a correction from SNS and without it. The graphs of error changes of vertical reproducing at presence of accelerometer constant error and drift of angular speed sensor at presence of correction from SNS is shown in Fig. 4.

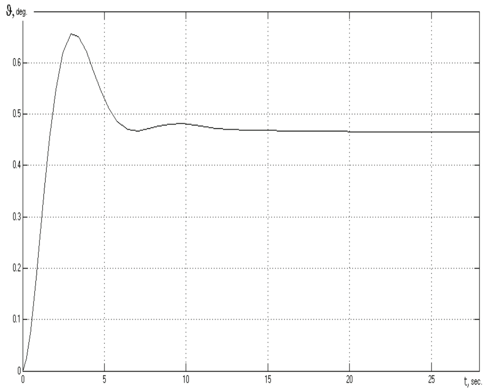

Fig.3

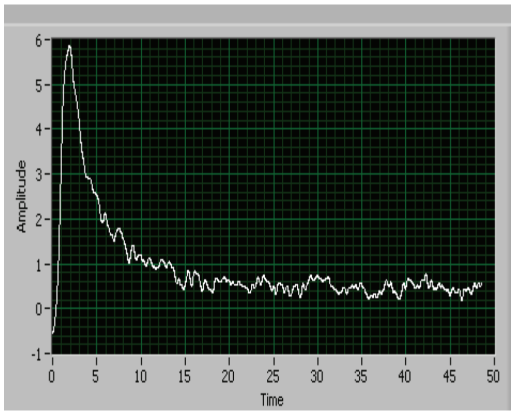

Fig.4

Value of constant error of vertical reproducing Δϑ depends on pitch angle ϑ and on constant component of accelerometers errors Δa_x, $\Delta a_в$, and it can be described be expression:

$$\Delta\vartheta=\arcsin\frac{\Delta a_y\sin\vartheta-\Delta a_x\cos\vartheta}{g}$$

The micro-mechanical accelerometer ADXL 150 of Analog Devices firm has error in the form of zero drift and equals 0,01g. Reproducing error of vertical is 0,5˚, that satisfies the requirements to existent precision gyro verticals.

Conclusions. The solutions offered in the articles let us to increase the accuracy of integrated gyro vertical operation which built on the basis of nanotechnology, by the new data fusion technique and speed correction, and which can be easily realized on aircraft.

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QUALITY ESTIMATION OF UNMANNED AERIAL VEHICLES AUTOMATED DESIGN

The problem of automated design of unmanned aerial vehicles is considered. The solution of the problem has been tried to solve by means of the multiobjective optimization. The criteria of selection the optimal shape of aircraft is the criteria of vehicle and high-speed perfection.

In today's world is fostering the development of unmanned aerial vehicles (UAV), the English version of unmanned air vehicles (UAV), which are part of unmanned aircraft complexes (UAC). Application of UAC have several advantages of unmanned aircraft to a manned one, namely: the lack of crew on board, high maneuverability, relatively minor costs of operation, mobility, ability to perform maneuvers with large accelerations, which exceed the physical abilities, the possibility of working in conditions that are hazardous for a man.

The structure and design characteristics of the UAV are determined by successive solutions of particular design problems. The choice of design solutions of particular problems is carried out under the accepted criteria for them, constituting the set of individual quality criteria of investigated UAV.

Partial criteria of quality represent some characteristics of the UAV (defined in the tactical and technical specification (TTS), or defined in the design process), which are used to compare their options. Other characteristics of the UAV are used as constraints that define the range of permissible decisions.

Aggregative functional appearance of aircraft in the class of ATS can be defined by two criteria of energy perfection, also based on two objective groups: to ensure high energy efficiency of the payload (PL) transport process and minimize the time of its delivery or approaching to the target.

Transport perfection criterion [1, 2] in relation to the aircraft aerodynamic class, based on generally accepted data formats, available for analysis, and is expedient submit in the following form:

$$K_m = \frac{DM_{ПН}P}{M_{ЛА}M_T Hu}, \tag{1}$$

where $M_{ПН}$, $M_{ЛА}$, M_m – weight: payload, starting and fuel; D – range; Hu – lower calorific value of fuel, P – the engine thrust.

Criterion of speed perfection [2] exceeds when the achievement of high velocities is the main task of designing:

$$K_V = \frac{DM_{ПН^{V^2}}}{M_{ЛА^{2Hu}}}, \tag{2}$$

where V – speed of flight. In the case of transport aircraft criterion (2) is not paramount, but is always optional, as delivery time is under project restrictions.

High-speed regime of viscous flow is characterized by Reynolds number:

$$\mathrm{Re} = \frac{VL_{ЛА}}{v}, \tag{3}$$

where V – flight speed of a given mode; $L_{ЛА}$ – characteristic linear size of an aircraft; v – coefficient of kinematic viscosity for the corresponding altitude. For energy estimates of ATS Reynolds number is used:

$$\mathrm{Re}_{np} = \mathrm{Re}\frac{M_{ЛА} g}{P} = \frac{V L_{ЛА} M_{ЛА} g}{\nu P}, \tag{4}$$

characterizes the relationship between the flow of kinetic energy spent on maintenance of aircraft in the field of gravitational forces (in the numerator) and the flow of energy spent on overcoming the resistance horizontal flight (in the denominator). Also possible the other modifications of known criteria of similarity, adapted to the practical problems of analysis and the formation of the energy aspect of ATS.

General problem setting of UAV vector optimization can be represented as:

$$A^{o} = \max_{A \in H} F(A);$$

$$(A_i)_{\min} \le A_i \le (A_i)_{\max}; \quad G_j^{*} \le G_j(A) \le G_j^{**}; \quad F_t(A) \ge F_t^{*}, \tag{5}$$

where A^{o} – vector of optimal design parameters in the Pareto domain; H – domain of admissible solutions.

Solution of the optimization problem (5) is done by means of the method based on a systematic scanning (probing) of multidimensional domains by the points of the sequence, uniformly distributed in the parameter space.

Constructing of the set of acceptable and Pareto-optimal solutions is made as follows.

Limitations $(A_i)_{\min} \le A_i \le (A_i)_{\max}$ are expressed in n – dimensional parameter space of the box Π.

Limitations $G_j^{*} \le G_j(A) \le G_j^{**}$ are expressed in the box Π some subset –, in which the variants of vector A are found, which satisfy parametric and functional limitations. Assuming that the volume of a subset $J > 0$, so restrictions $F_t(A) \ge F_t^{*}$ allows to express on the domain J some subset H, for which $H \subset J \subset \Pi$. It is obvious that a subset H contains a set of unimproved variants of designed object by the Pareto.

A solution of problem (5) is to determine the vector of design parameters A^{o} on the Pareto set P ($A^{o} \in P$), which is the most preferable.

Vector $A^{o} = (A_1^{o}, \ldots, A_m^{o})^{T}$, where m – number of efficient by Pareto solutions, which include a set of equivalent (in the sense of unimproving the criteria) solutions. The only solution in the Pareto domain is reduced to finding the extremum of the modulus of the vector criterion in the Pareto domain.

The problem of determining a unique solution in the Pareto domain A * can be represented as follows

$$A^{*} = \arg\max \sqrt{F_1^2(A^{o}) + F_2^2(A^{o}) + \ldots + F_k^2(A^{o})}. \tag{6}$$

The meaning of problem (6) is to select from a set by means of Pareto A^{o} a variant of solution A *, for which the sum of the squares of the partial criteria would reach a maximum. If this sum of squares will be the largest, then the criteria themselves will be the largest in their absolute values.

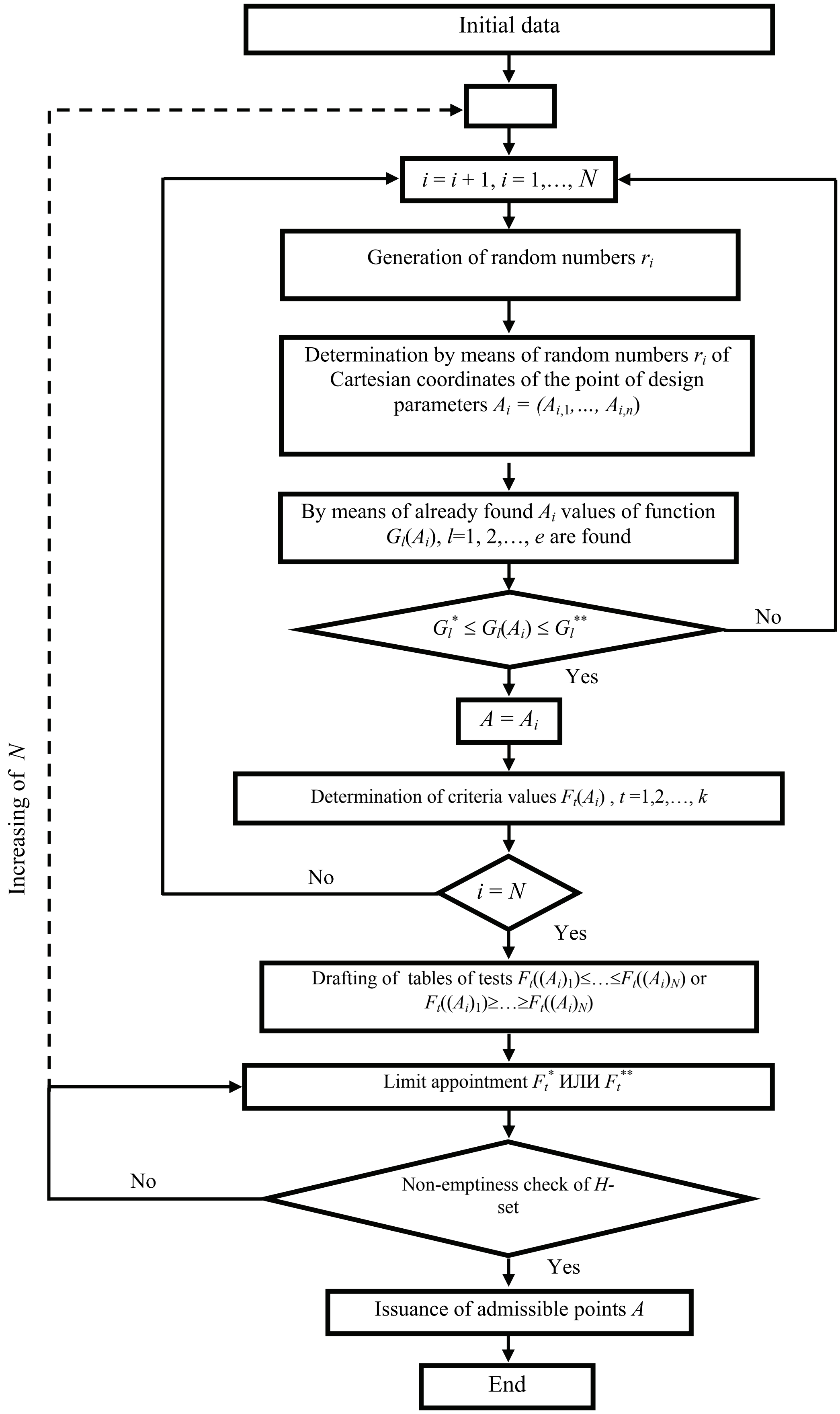
Solving of optimization problem (5) can be found using a method based on a systematic scanning (probing) of multidimensional domains by points of the sequence of uniformly distributed parameters in the space, as it is shown in the works [3 – 6], and block diagram is shown in the figure.

The easiest way to generate trial points is based on the following formula

$$x_i = (x_i)_{\min} + r_i((x_i)_{\max} - (x_i)_{\min}) \quad \text{at} \quad i = 1, \ldots, N, \tag{7}$$

where x_i – trial point; r_i – random numbers uniformly distributed on the interval (0,1); $(x_i)_{\max}$ – upper limit of the point x_i; $(x_i)_{\min}$ – lower limit of the point x_i; N – number of trial points.

The use of random numbers of high-density distribution at the given interval can help to obtain relatively complete information about the researched object as a result of effective viewing of parameter space and computing the values of the criteria in the trial points.



Block scheme of multicriteria parametric optimization process

Preference for choosing this method is relative simplicity, getting of the desired result in time, the minimum requirements to the smoothness of areas of functional limitations and criteria, the possibility of automation of the numerical algorithm.

The model of the parameter optimization process by multiple criteria can be represented as an algorithm.

According to the represented block scheme the first stage of parameter optimization by means of computer a finite number N of trial points A_i, …, A_N evenly spaced in the n - dimensional region J is selected. The restriction on the choice of N is the account time.

For selection of trial points the random number generator can be used, for each address to which returns a random number which is uniformly distributed on the interval (0,1). The Cartesian coordinates of the point A_i, which belongs to the box Π, are determined by the formula (7) as follows

$$A_{i,j} = (A_j)_{\min} + r_i((A_j)_{\max} - (A_j)_{\min}) \text{ при } j = 1, \dots, n,$$

where $A_{i,j}$ – Cartesian coordinates of a point A_i; r_i – random numbers, uniformly distributed on the interval (0,1); $(A_j)_{\max}$ – upper limit of a point A_i; $(A_j)_{\min}$ – lower limit of a point A_i; n – number of design parameters.

Conclusions

In this work a new approach for constructing a new image of an unmanned air vehicle based on the solution of the criteria optimization task was proposed. As the criteria of optimality the vehicle and speed perfection criteria were selected.

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METHOD AND MEASURING DEVICE OF PHASES DIFFERENCE OF INFRA- AND LOW - FREQUENCY RANGES

A new method of measuring of phase difference of electromagnetic signals by a photopolarimetric method is offered in this work. The advantage of offered method before the known ones of phase measuring is shown

Ways of measuring of phase difference of electrical signals are well - known: a method of phase detection, medium - pulse, digital (based on the measurement of time interval of required counting pulses), heterodyne, compensation and so on. A digital method of measuring of the initial phase is the most accurate. His error is caused due to the phase signal, which creates countable pulses, fluctuates relative to phase of measured signal and the error of defining moments of time when amplitude of measured t_c and reference t_{on} signal is equal to zero [1-4].

Magnetooptical optron [6] is suggested to use for measuring the phase difference of electrical signals.

Two signals served on the entry of optron according to [7] : measured signal, the initial phase φ_0 of which should be measured

$$u_\omega = u_{0\omega}\sin(\omega t - \varphi_0), \tag{1}$$

and calculating signal, also called infill signal

$$u_\Omega = u_{0\Omega}\sin\Omega t . \tag{2}$$

Output optron signal will be:

$$u_{\text{out}} = u_0\cos^2\left[\Theta_0 + \Theta_{0\omega}\sin(\omega t - \varphi_0) + \Theta_{0\Omega}\sin\Omega t\right], \tag{3}$$

where Θ_0 - initial azimuth between the planes of the largest transmission of polarizer and analyzer; $\Theta_{0\omega} = ku_{0\omega}, \Theta_{0\Omega} = ku_{0\Omega}$ - initial amplitude of rocking angle of the plane of polarization of light by signals u_ω i u_Ω; k - voltage conversion ratio applied to the modulator of optron, the angle of the plane of light polarization.

Let's consider the option when $\Theta_0 = \frac{\pi}{2}$, that is in original condition when the modulator has no incoming signals u_ω, u_Ω, while the output voltage of optron is zero. In this case the spectral decomposition of formula (3) has the form (similar to [7]):

$$u = u_0\left\{1 - [j_0(2\Theta_{0\omega}) + 2\sum_{p=1}^{\infty} j_{2p}(2\Theta_{0\omega})\times\cos 2p(\omega t - \varphi_0)]\times[j_0(2\Theta_{0\Omega}) + 2\sum_{p'=1}^{\infty} j_{2p}(2\Theta_{0\Omega})\times\right.$$
$$\left.\times\cos 2p'\Omega t] + +4\sum_{p''=1}^{\infty} j_{(2''-1)}(2\Theta_{0\omega})\sin(2p''-1)\times(\omega t - \varphi_0)\sum_{p'''-1}^{\infty} j_{p'''-1}(2\Theta_{0\Omega})\sin(2p'''-1)\Omega t\right\}, \tag{4}$$

where $j_i(2\Theta)$ - Bessel function of order.

Circulation condition Ω >> ω: frequency of reading (infill) signal is much more bigger than frequency of measurable signal.

Let's select the range of frequency signals in the frequency range Ω - ω to Ω + ω. It will be a signal that will carry information on the initial phase φ_0

$$u_{out} = 2u_0 j_1(2\Theta_{0\omega}) j_1(2\Theta_{0\Omega})\sin(\omega t - \varphi_0)\times\sin\Omega t = u_{0out}\sin(\omega t - \varphi_0)\sin\Omega t, \tag{5}$$

де $u_{0out} = 2u_0 j_1(2\Theta_{0\omega}) j_1(2\Theta_{0\Omega})$.

From expression (5) follows that when the azimuth plane orientation of the largest bandwidth relating to analyzer $\left(\Theta_0 = \frac{\pi}{2}\right)$ hardware feature of optron tends to multiplying signals (Figure 1)

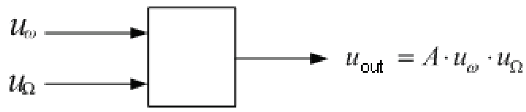

Fig. 1. The principle of multiplying signals in optron

It should be noted that multiplication of signals by magnetooptical optron has one important feature in contrast to traditional methods of multiplication: output signal is absent if there is no at least one input signal.Thus, these devices have (potentially) precision characteristics.

Typical radio methods can not create a device with ideal multiplication function. Because of the absence of one signal, the other will be greatly impaired.

By using (the) above considered ability of optron to multiply together signals, the method of measuring of initial phase is offered.

The new method of measuring of initial phase is represented in Fig. 2.

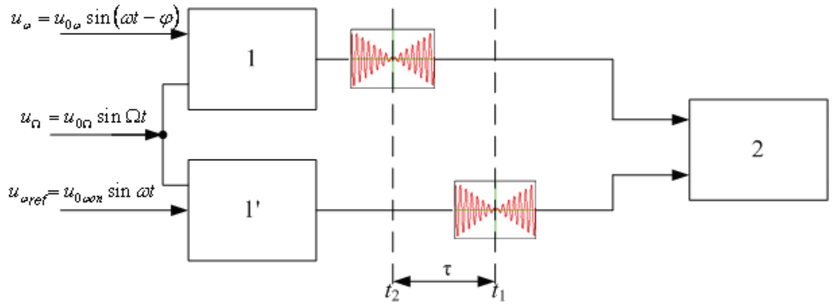

Fig.2. Photopolarimetric phase meter:

where *1*, *1'* are optrons for signal u_ω and reference signal $u_{\omega ref}$; *2* is the digital microprocessor of the interval measurement τ

The measuring signal u_ω, reference signal $u_{\omega ref}$ and infill signal (reading signal) u_Ω are defined by expressions

$$u_\omega = u_{0\omega}\sin(\omega t - \varphi_0 - \varphi_{ref}); \quad (6a)$$

$$u_{\omega ref} = u_{0\omega ref}\sin(\omega t - \varphi_{ref}); \quad (6b)$$

$$u_\Omega = u_{0\Omega}\sin\Omega t\,. \quad (6c)$$

The infill signal has value zero of initial phase, as it is tied to standard current time, which is counted for this signal. The frequency Ω must be constant, standard.

Let's determine the points of time, when measuring and reference signals are equal to zero

$$\omega t_c - \varphi_0 - \varphi_{ref} = n'\pi, \quad (7a)$$

where $n' = 0, 1, 2, \ldots$;

$$\omega t_{ref} - \varphi_{ref} = n''\pi, \quad (7b)$$

where $n'' = 0, 1, 2, \ldots$

Let's consider, that phase displacement φ_0 is not superior to 2π, viz. $n' = n''$.

We will get from formulas (7a i 7b) :

$$\omega(t_c - t_{ref}) = \varphi_0, \quad (8)$$

where t_c i t_{ref} – points of time, when amplitudes of measuring and reference signals are equal to zero.

The infill signal cycle T_Ω must be a multiple of measuring signal cycle T_ω

$$T_\omega = NT_\Omega, \quad (9)$$

where N – is integral number.

From (9) flows out that

$$N = \frac{\Omega}{\omega}. \quad (10a)$$

Absolute and relative errors of determination of N number are bound with instability of frequency of reference signal (accordingly and frequencies of measureable signal)and infill signal generators:

$$\Delta N = \frac{\Delta\Omega}{\omega} + \frac{\Omega\Delta\omega}{\omega^2}; \quad (10b)$$

$$\Delta N = \frac{\Delta\Omega}{\Omega} + \frac{\Delta\omega}{\omega}. \quad (10c)$$

Relative exactness of *N*, viz multipleness of frequencies ω and Ω, is determined by instability of frequency of generators of supporting signal and infill signal:

$$t_c - t_{ref} = n''' T_\Omega + \Delta t_c + \Delta t_{ref}, \quad (11)$$

where n''' is integral number ($n \le$ N); Δt_c and Δt_{ref} – errors of determination of moments of time t_c and t_{ref}.

Total error of determination of moments of time t_c and t_{ref} will be designated as $\Delta t_0 = \Delta t_c + \Delta t_{ref}$. We can also define this time and therefore reduce an error $\Delta t_{0\max} = T_\Omega$. Let's mark that $\Delta t_{0\max} \le 2T_\Omega$, in spite of the fact that we carry out measuring in two points.

Thus, an initial phase and error of its determination are equal to:

$$\varphi_0 = \omega n T_\Omega + \omega\Delta t_0 = \omega n T_\Omega + \xi = 2\pi\frac{\omega}{\Omega}n + 2\pi\frac{\omega}{\Omega}\frac{\Delta t_0}{T_\Omega} = 2\pi\frac{n}{N} + 2\pi\frac{1}{N}k = \frac{2\pi}{N}(n+k), \quad (12)$$

де $n = 0, 1, 2, \ldots, N$; $\xi = \omega\Delta t_0$; $k = \frac{\Delta t}{T_\Omega}$.

Taking into account that *n* is quantity of signal cycles u_Ω in a time slot $t_c - t_{on}$, and k – is additional part of time in relation to the period of filling. Discreteness of phase measuring is equal to

$$\psi_{\mathrm{n}} = \varphi_n - \varphi_{n-1} = \frac{2\pi}{N}. \quad (13)$$

Now then we should increase N for the increase of exactness.

Fig. 3 shows a block diagram of a phase meter, the method and principle of measurement is shown in [5].

Photopolarimetric phase meter contains a fill-in signal generator *1*, magneto optical optrons *2* and *6*, measured signal meter, *3* meter of multiple signal periods *4*, adder *5*, *7* meter of reference signal, reference signal generator *8*, phase shifter *9*. Blocks *3*, *4*, *5*, *7* are integral parts of the microprocessor *10*. Exit *5* is the adder output device.

Phase meter works as follows. Signal u_ω with measurable initial phase served on magnetooptical optron 1 *2*, which is also served to fill u_Ω signal from a signal generator is required *1*. Required signal u_Ω is also served on magnetooptical optron 2 *6* with a reference signal u_{ref} from the generator of reference signal controlled phase shifter *8* through *9*. The initial phase of the reference signal phase shifter *9* moves so that in the output of optron was a signal, which would be of force, shown in Fig. 4, which corresponds to zero phase difference between reference signal and the required signal.

This point is fixed by reference signal meter *7*. This signal is given to control the phase shift of the reference signal to phase shifter *9*. Measuring range phase shift does not exceed the discreteness step (quantum) measurement phase $\frac{2\pi}{N}\left(\frac{360^\circ}{N}\right)$. At this point reference signal meter *7* reveals the number of discrete steps of measuring the phase *4*. Meter measured signal *3* through magnetooptical optron 1 *2* analyses signal measured by registering the end of discrete steps, and gives a signal to close the meter multiple signal periods *4* from signal required. In addition, the reference signal meter *7* gives information about the size of additional phases ξ, which remained after discrete account. Adder *5* counts the number of discrete phases and portions, making them more value from the phase ξ, gives values measured phase φ_0.

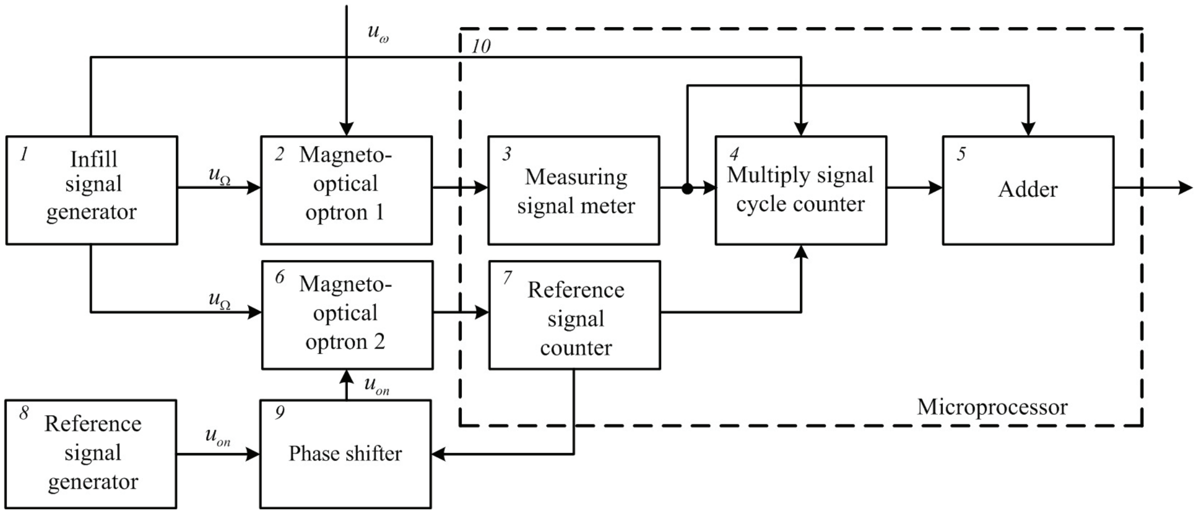

Fig. 3. Block-scheme of photopolarimetric phase meter

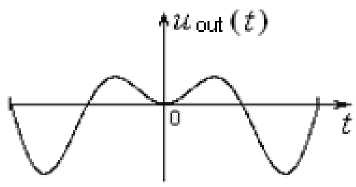

Fig. 4. Output optron signal

Conclusion

The use of this measuring method allows to create high accuracy devices for measuring of phase difference of signals of infra- and low-frequency ranges, and to use this method in radio-technical systems and complexes; for example, in distance meter, location finder, radar systems and radio navigation systems. The offered method will be also competitive with famous methods of multiplying frequency according to sensibility and will find application in digital and calculating techniques.

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MODEL OF THE PLANAR TRANSISTOR FOR MODELLING OF ACTION OF THE PENETRATING RADIATION

For modeling of radiating changes of characteristics of transistor schemes the transistor model which equivalent scheme is resulted on fig. 1 can be used. As model basis the model of the epitaksialno-planar transistor offered in work [1] and representing updating of model of Ebersa-Molla which equivalent scheme is resulted on fig. 1 serves.

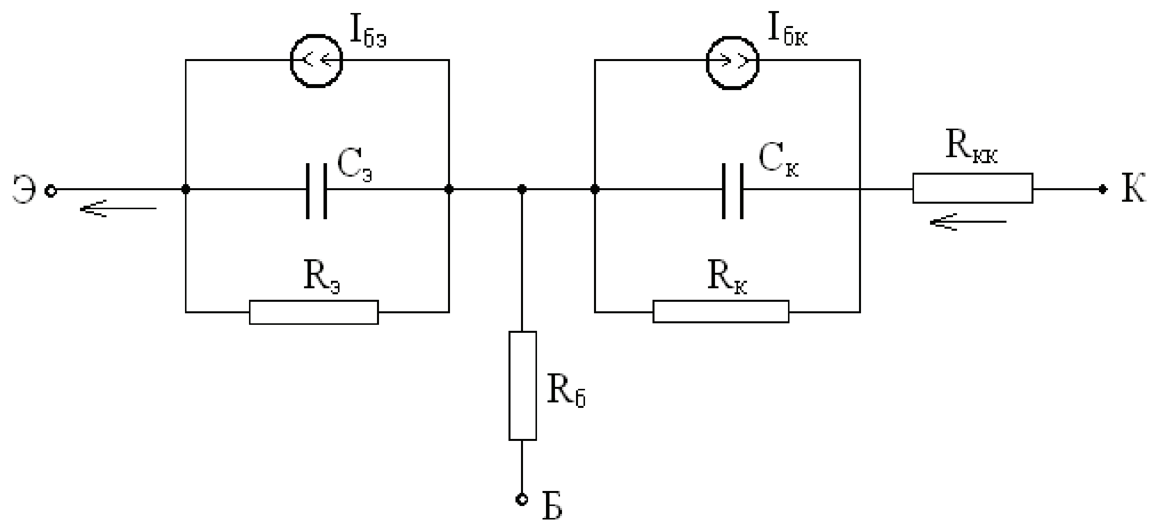


Fig.1.

For modeling of action of a getting irradiation in offered model expression [2] is used.

$$B_{N\Phi} = \frac{1}{\frac{1}{B_{N0}} + \frac{1}{2\pi f_T} K_T \Phi} \qquad (1)$$

where B_{NO}- factor of transfer of a current of base of the transistor to an irradiation;
f_T- Boundary frequency, at which $|B_N| = 1$;
K_τ – a constant of radiating change of time of life of carriers in the base of the transistor;
Φ – an integrated stream of radiation.

Comparison of experimental results from the curve calculated on given expression for silicon epitaksialno-planar transistors KT315V is resulted on fig. 2.

The irradiation of transistors was spent γ - quanta of cobalt installation K-100000. The temperature of an irradiation didn't exceed 300 ^{o} K. At various integrated streams of radiation dependences $I_б$ $(U_{эб})$ and Iк $(U_{эб})$ acted in $U_{кб}\approx 0$. These dependences have allowed to construct schedules B_N (Iэ) and B_N (Uэб). And use of the last has allowed to construct dependences of relative change of factor of transfer of a current of base on an integrated stream of radiation (fig. 2).

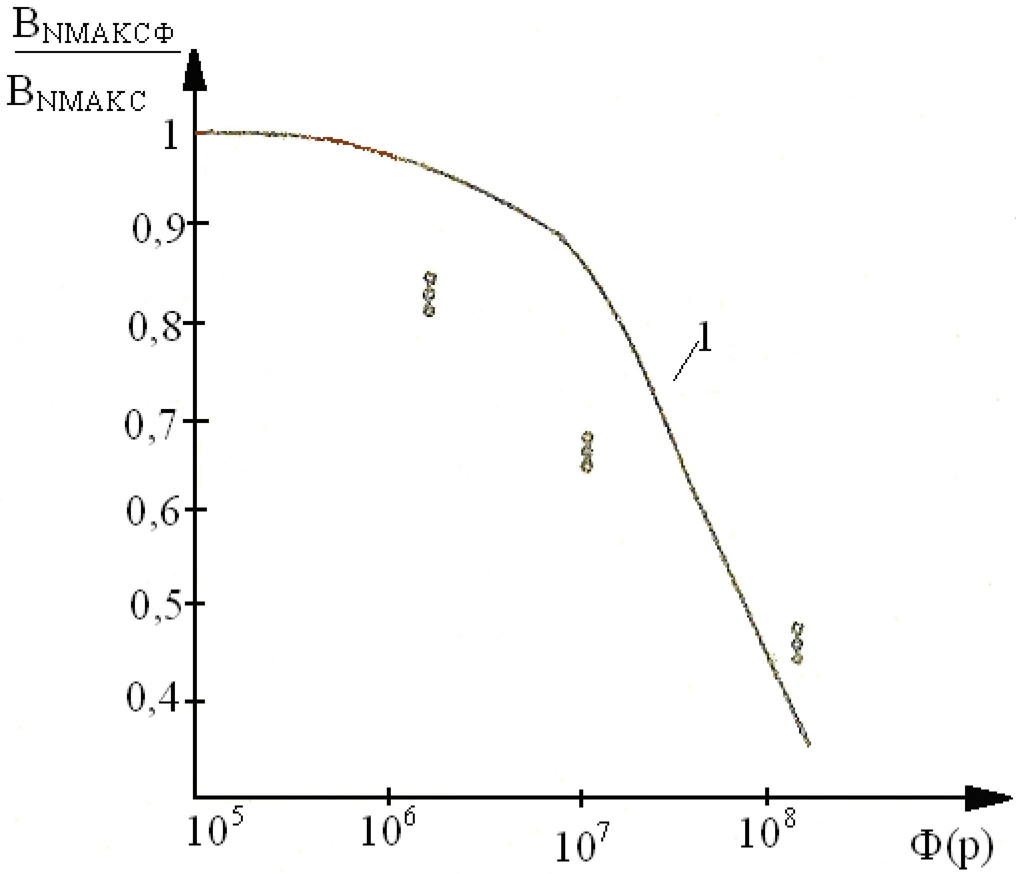


Fig.2.

For definition K_τ single-level model [3] has been used. Average value K_τ for area p – bases at low levels of injection has turned out equal $1{,}2 \bullet 10^{-10}\left(\frac{\gamma - кв.*c}{см^2}\right)^{-1}$.

From fig. 2 it is visible that there is a divergence between a settlement curve and experimental results. This divergence speaks that in expression (1) influence of change of a superficial component of time of life of the visitors playing especially appreciable role at small levels of an irradiation isn't considered, i.e. in the beginning of a curve 1, and at the big integrated streams of radiation reduction of time of flight of carriers through base area, i.e. improvement of frequency properties of the transistor isn't considered. However despite some discrepancy, expression (1) it is rather convenient to use for forecasting of reduction of factor of transfer of a current of base of the transistor at an irradiation.

Thus, generators of currents in model $I_{бэ}$, $I_{бк}$ are set by following equations:

$$I_{бэ} = \frac{I_N}{B_N} + I_N - I_I \quad ,$$

$$I_{бк} = \frac{I_I}{B_I} + I_I + I_{Dбб} - I_N \quad ,$$

where

$$I_N = I_S[\exp\frac{U_э}{m_э\varphi_T} - 1], \quad I_I = I_s[\exp\frac{U_к}{m_к\varphi_T} - 1],$$

$$I_{Дбк} = I_{Дбко}[\exp\frac{U_К}{\varphi_T} - 1]$$

B_N – factor of transfer of a current of base at normal inclusion;

B_I – factor of transfer of a current of base at inverse inclusion;
$m_э$, $m_к$, I_S, $I_{Дбко}$, $I_δ$ – constants вольтамперных characteristics.

In model it is offered to approximate experimental dependences $B_N(U_{эб})$. It allows to model precisely work of the transistor in the field of small working currents, average and big currents. Characteristic dependence B_N ($U_{эб}$) is resulted on fig. 3. This dependence can be approximated as follows:

at $0 \le U_{эб} \le U_{эб1}$

$$B_N = \exp(U_{эб} / x) - 1,$$

where

$$x = U_{эб1} / \ln(B_{NМАКСФ} + 1);$$

at $U_{эб1} < U_{эб} < U_{эб2}$

$$B_N = B_{NМАКСФ};$$

where $U_{эб} \ge U_{эб2}$

$$B_N = \exp\{[U_{эб1} - (U_{эб} - U_{эб2})] / x\} - 1.$$

At an irradiation $B_{NМАКСФ}$ will decrease according to expression

$$B_{NМАКСФ} = \frac{1}{\dfrac{1}{B_{NМАКС}} + \dfrac{1}{2\pi f_T} K_T Ф},$$

where $B_{NМАКС}$ – the maximum value of factor of transfer of a current of base at Ф=0.

On fig. 4 characteristic experimental dependences B_N ($U_{эб}$), the radiations received at various integrated streams are resulted.

The inverse factor of strengthening BI is very small on size and accuracy of modeling poorly influences.

Capacities of transitions in model can be defined from expressions [1]

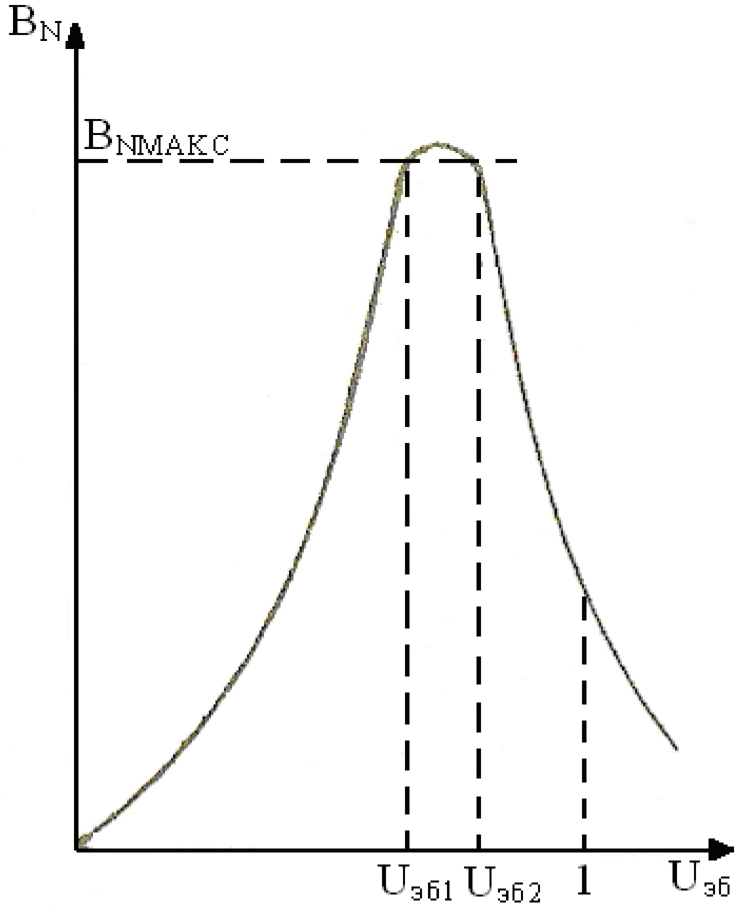
$$C_э = \frac{C_{бэо}}{(1 - U_э / \Delta\varphi_{оэ})^{1/2}} + \frac{\tau_N (I_N + I_S)}{m_э \varphi_T}$$

$$C_K = \frac{C_{бко}}{(1 - U_K / \Delta\varphi_{OK})^{1/3}} + \frac{\tau_I (I_I + I_\delta)}{m_K \varphi_T} + \frac{\tau_{ркф} (I_{Дбк} + I_{Дбко})}{\varphi_T},$$

where τ_N и τ_I - time constants equal on size to average time flight of carriers through base area in normal and inverse directions;

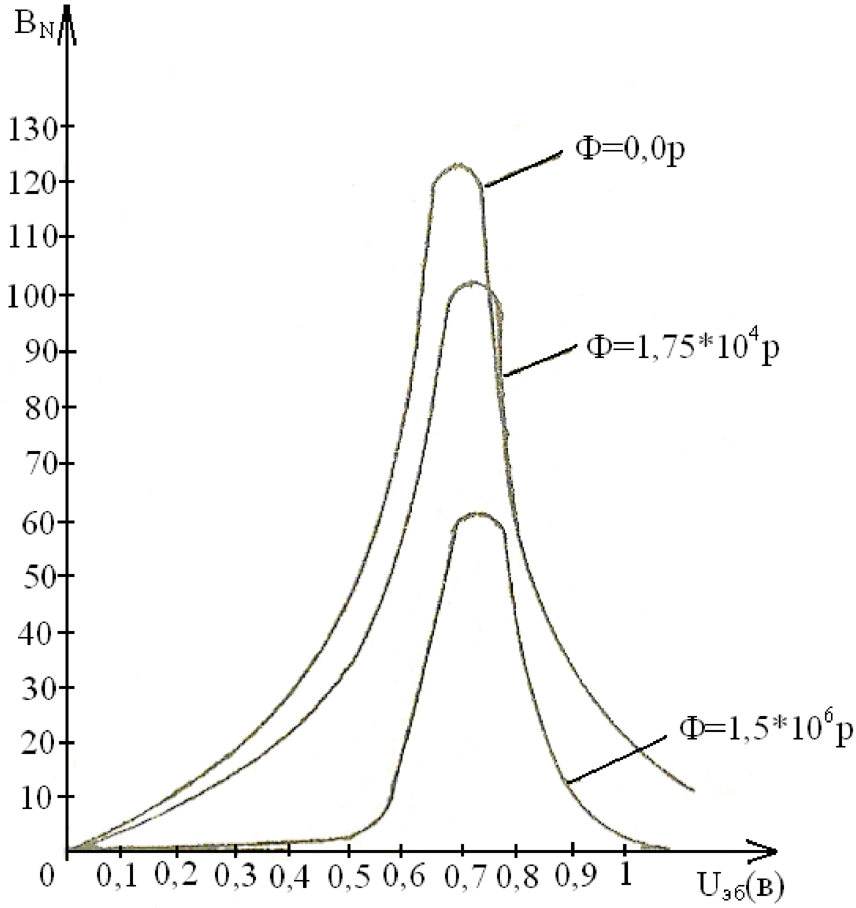
$\tau_{ркф}$ - time of life of carriers in a collector, which at an irradiation decreases according to expression [3]

$$\frac{1}{\tau_{ркф}} = \frac{1}{\tau_{рк}} + K_{\tau к} Ф.$$



B_N
B_NМАКС
U_эб1
U_эб2
1
U_эб

Fig.3.



B_N
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1
U_эб(в)
Ф=0,0р
Ф=1,75*10^4р
Ф=1,5*10^6р

Fig.4.

Model lack is that in it the increase in return currents p-n transitions isn't considered at an irradiation. The account of the last represents rather labor-consuming problem. For the decision of this problem fuller modeling of all radiating processes in semi-conductor structure is necessary: reduction of time of life of carriers, concentration of the basic carriers, mobility of carriers in various areas of the transistor, increase in specific resistance of quasineutral areas which in turn conduct to change of a considerable quantity of secondary parameters, such, as generative and diffusive components of return currents p-n transitions, average times of flight of carriers through base area, factors of carrying over of carriers, barrier and diffusive capacities p-n transitions etc. For realization of the specified purpose it is necessary to go by the way of development of physical models of the semi-conductor devices [4] which parameters are based on internal electrophysical and geometrical characteristics of semi-conductor structures.

However numerous experiments show that return currents p-n transitions in the silicon devices made on epitaksialno-planar technology, at an irradiation change slightly up to high doses when the factor of transfer of a current of base BN decreases several times. It is possible to explain it compensating influence of reduction of a contact potential difference, concentration of the basic carriers, and the increase in volume resistance of quasineutral areas conducts to that at the same put pressure to transistor conclusions, after an irradiation on p-n transitions smaller pressure falls. Therefore, as show experimental results, to integrated streams of radiation at which factors of transfer of currents of bases of transistors decrease approximately in three, four times, it is possible with sufficient degree of accuracy to use offered model.

The further perfection of models of transistors for modeling of action of a penetrating radiation is connected with development of the physical models which parameters are based on internal electrophysical and geometrical characteristics of semi-conductor structures

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MATHEMATICAL MODEL OF INERTIALLY STABILIZED PLATFORM FOR AIRCRAFT OBSERVATION EQUIPMENT

The mathematical model of the inertially stabilized platform for the aircraft observation equipment is created and the platform stabilization condition is analyzed. The expressions for control moments are derived. The simulation results on the basis of the obtained model are represented.

Statement of problem. Usage of the inertially stabilized platforms for stabilization of the different type payload is actual problem of today [1]. The studied system is assigned for control by the attitude of the observation equipment, which may be used at the aircraft. The studied system has some specific features. In the first place, it is based on the platform stabilization that is stabilization of the payload in whole but not its separate parts. In the second place, the system of control by the attitude of the observation equipment operates in some modes such as alignment of the platform relative to the horizon plane, alignment of the platform relative to the given angles of the yaw, pitch and roll and stabilization of the platform relative to the aligned attitude. In the third place, the system must provide turns at the angles of the yaw, pitch and roll in the wide range with high accuracy.

Both the observation equipment and such inertial sensors as three angular rate gyro instruments and two accelerometers are mounted at the platform. The measuring axes of the gyros are orthogonal and at the initial instant of time coincide with the aircraft yaw, pitch and roll axes. The measuring axes of accelerometers at the initial instant of time coincide with the pitch and roll axes. The pick-off is mounted at every axis of the gimbals frame relative which the turns at the angles of the yaw, pitch and roll are implemented.

Mathematical model of the inertially stabilized platform for the aircraft observation equipment. The mathematical model of the inertially stabilized platform for the observation equipment may be created on the basis of the equations of the platform motion in the inertial space. The control moments are formed on the basis of the calculated relative angular rate components determined by the stabilization object measured angular rate.

The dynamic of the stabilization object that is the platform with mounted on it payload and measuring instruments may be described by the system of the differential equations [2]

$$J_x\dot{\omega}_{xp} - J_{xy}\dot{\omega}_{yp} - J_{xz}\dot{\omega}_{zp} + (J_z - J_y)\omega_{yp}\omega_{zp} + J_{yz}(\omega_{zp}^2 - \omega_{yp}^2) + J_{xy}\omega_{xp}\omega_{zp} - J_{xz}\omega_{xp}\omega_{yp} = M_{xp};$$

$$J_y\dot{\omega}_{yp} - J_{zy}\dot{\omega}_{zp} - J_{xy}\dot{\omega}_{xp} + (J_x - J_z)\omega_{xp}\omega_{z\text{п}} - f_x\omega_{xp} + J_{yz}(\omega_{zp}^2 - \omega_{yp}^2) + J_{xy}\omega_{xp}\omega_{zp} -$$
$$- J_{xz}\omega_{xp}\omega_{yp} = M_{xp};$$

$$J_z\dot{\omega}_{zp} - J_{xz}\dot{\omega}_{xp} - J_{yz}\dot{\omega}_{yp} + (J_y - J_x)\omega_{xp}\omega_{yp} + J_{xy}(\omega_{yp}^2 - \omega_{xp}^2) + J_{xz}\omega_{yp}\omega_{zp} - J_{yz}\omega_{xp}\omega_{zp} = M_{zp},$$

where J_x, J_y, J_z are the axial inertia moments of the platform relative its proper axes; J_{xy}, J_{xz}, J_{yz} are the centrifugal inertia moments of the platform.

Attitude of the system of coordinates connected with the platform stabilized in the inertial space $\mathrm{O}X_pY_pZ_p$ relative to the reference system of coordinates $\mathrm{O}X_hY_hZ_h$ is defined by the set of turns at the angles of yaw, pitch, roll ψ, ϑ, γ, as it is shown in fig. 1. The set of the platform gimbals axes turns during stabilization process is represented in fig. 2.

Determination of the platform angular rates which are produced by the stabilization system is carried out in the following way. If $\boldsymbol{\omega}$ is the angular rate of the gimbaled platform, on which the observation equipment and sensors for measurement of the object angular rate in the inertial space are mounted, and $\boldsymbol{\Omega}$ is the platform angular rate under action of the control moments determined by the stabilization system and acting along the gimbals frames axes, the condition of the accurate stabilization becomes [3]

$$\mathbf{\Omega} + \boldsymbol{\omega} = 0 . \quad (1)$$

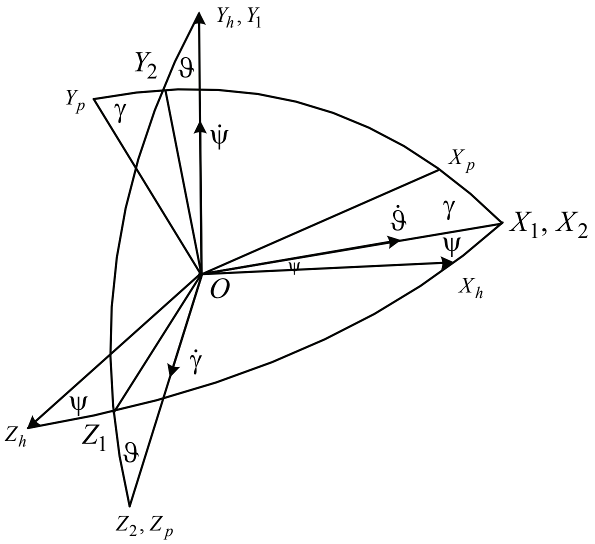

Fig. 1. Set of turns that define attitude of the aircraft stabilized platform

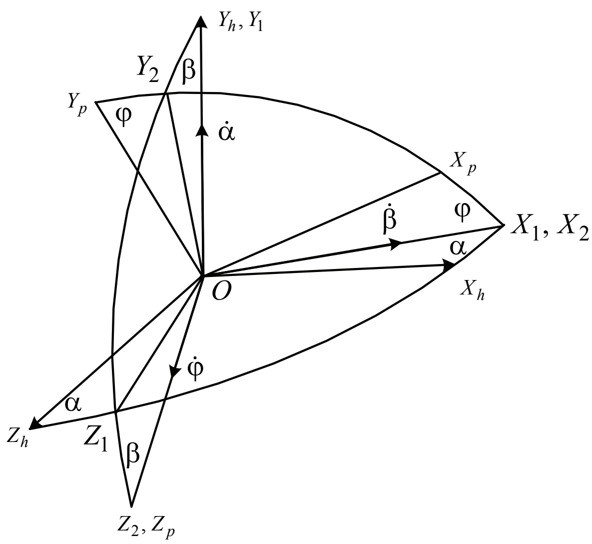

Fig. 2. Set of the stabilized platform gimbals axes turns

Taking into consideration that the angular rate of the object, at which the inertially stabilized platform with the payload and measuring instruments is mounted, is defined by the expression $\boldsymbol{\omega}_a = \omega_x \mathbf{X}_h + \omega_y \mathbf{Y}_h + \omega_z \mathbf{Z}_h$, transition to the new attitude of the inertially stabilized platform in the inertial space is implemented by the successive turns at the angles ψ, ϑ, γ in correspondence with fig. 1 and the angular rates of the platform onto its proper axes may be defined in the following way

$$\begin{bmatrix} \omega_{xp} \\ \omega_{yp} \\ \omega_{zp} \end{bmatrix} = \mathbf{A}^{\mathrm{T}} \begin{bmatrix} \omega_x \\ \omega_y \\ \omega_z \end{bmatrix} + \begin{bmatrix} \dot\vartheta \cos\gamma + \dot\psi \cos\vartheta \sin\gamma \\ -\dot\vartheta \sin\gamma + \dot\psi \cos\vartheta \cos\gamma \\ \dot\gamma - \dot\psi \sin\vartheta \end{bmatrix},$$

where $\omega_x, \omega_y, \omega_z$ are the angular rates of the aircraft, at which the platform with installed at it payload is used, $\mathbf{A}$ is the matrix of the directional cosines between axes of the systems of coordinates $Ox_h y_h z_h$ and $Ox_p y_p z_p$, which may be determined in accordance with fig. 1.

The first component of the obtained formula represents the vector of projections of the aircraft angular rate onto the platform axes that is the appropriate projections of the platform relative angular rate. Worth noting that for the studied system the aircraft axes are believed to coincide with the axes of the inertially stabilized platform gimbals.

Results of simulation of the inertially stabilized platform for the observation equipment attitude control in the different modes of its operation are represented in fig. 3.

In correspondence with fig. 2 the vector of the stabilization angular rate will be defined by the expression

$$\mathbf{\Omega} = \dot\alpha \mathbf{Y}_p + \dot\beta \mathbf{X}_1 + \dot\varphi \mathbf{Z}_2 ,$$

where $\dot\alpha, \dot\beta, \dot\varphi$ are the angular rates of the turns of the external and internal gimbals frames and the platform correspondingly.

In correspondence with the relationship (1) the condition of the accurate stabilization in projections of the platform axes looks like

$$\Omega_{x_p} + \omega_{x_p} = 0 ; \;\; \Omega_{y_p} + \omega_{y_p} = 0 ; \;\; \Omega_{z_p} + \omega_{z_p} = 0 . \quad (2)$$

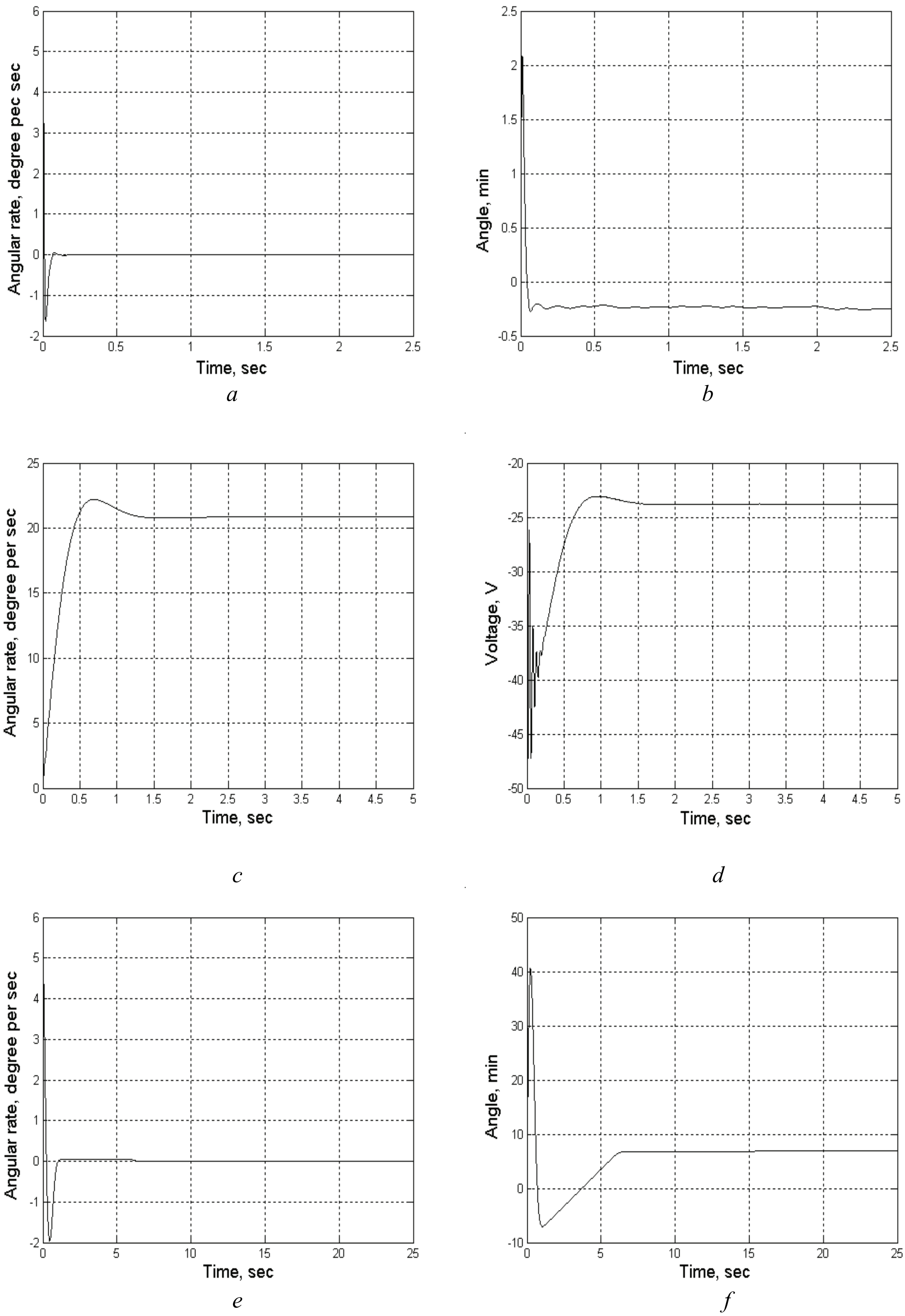

Fig. 3. Results of the stabilization and tracking simulation: – tracking of the given angular rate in the yaw channel (*a*) and error of the attitude determination (*b*) in the stabilization mode; tracking of the given angular rate (*c*) and appropriate control signal (*d*) in the mode of alignment in the space; tracking of the given angular rate in the yaw channel (*e*) and error of the attitude determination (*f*) in the mode of the platform alignment relative to the horizon plane

During creation of the gimbaled platform it is necessary to take into consideration that control moments act relative to frames of the yaw, pitch, roll correspondingly but the considered platform model is defined relative to the angular rate projections onto its proper axes. Expressions for the control moments determination may be defined after the following transformations

$$\begin{bmatrix} M_{xp} \\ M_{yp} \\ M_{zp} \end{bmatrix} = \mathbf{A}_3^{\mathrm{T}} \begin{bmatrix} 0 \\ 0 \\ M_{z\gamma} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ M_{z\gamma} \end{bmatrix}; \begin{bmatrix} M_{xp} \\ M_{yp} \\ M_{zp} \end{bmatrix} = \mathbf{A}_3^{\mathrm{T}} \mathbf{A}_2^{\mathrm{T}} \begin{bmatrix} M_{x\vartheta} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} \cos\gamma M_{x\vartheta} \\ -\sin\gamma M_{x\vartheta} \\ 0 \end{bmatrix};$$

$$\begin{bmatrix} M_{xp} \\ M_{yp} \\ M_{zp} \end{bmatrix} = \mathbf{A}_3^{\mathrm{T}} \mathbf{A}_2^{\mathrm{T}} \mathbf{A}_1^{\mathrm{T}} \begin{bmatrix} 0 \\ M_{y\psi} \\ 0 \end{bmatrix} = \begin{bmatrix} \cos\vartheta \sin\gamma M_{y\psi} \\ \cos\vartheta \cos\gamma M_{y\psi} \\ -\sin\vartheta M_{y\psi} \end{bmatrix}.$$

So, using the obtained expressions it is possible to represent the formulas for the control moments as projections onto the platform proper axes in the following way

$$M_{xp} = \cos\gamma M_{x\vartheta} + \cos\vartheta \sin\gamma M_{y\psi}; \quad M_{yp} = -\sin\gamma M_{x\vartheta} + \cos\vartheta \cos\gamma M_{y\psi};$$

$$M_{zp} = M_{z\gamma} - \sin\vartheta M_{y\psi}.$$

Control signals in the studied system are formed on the basis of the stabilized object absolute angular rate gyro sensor signals. The regulator output signals enter to the pulse-width modulator. The output signals of the last device enter to the torque motor winding. The projections of the stabilization angular rates in correspondence with fig. 2 may be defined by the expressions

$$\begin{aligned} \Omega_{x_p} &= \dot\beta \cos\gamma + \dot\alpha \cos\vartheta \sin\gamma; \\ \Omega_{y_p} &= -\dot\beta \sin\gamma + \dot\alpha \cos\vartheta \cos\gamma; \\ \Omega_{z_p} &= \dot\varphi - \dot\alpha \sin\vartheta. \end{aligned} \tag{3}$$

Based on the expressions (3) and taking into consideration the equations (2) it is possible to define formulas for determination of the platform angular rates in the following way

$$\begin{aligned} \omega_{x_p} &= -\dot\beta \cos\gamma - \dot\alpha \cos\vartheta \sin\gamma; \\ \omega_{y_p} &= \dot\beta \sin\gamma - \dot\alpha \cos\vartheta \cos\gamma; \\ \omega_{z_p} &= \dot\alpha \sin\vartheta - \dot\varphi. \end{aligned} \tag{4}$$

Based on the expression (4) it is possible to obtain the following differential equations

$$\dot\alpha = -\frac{1}{\cos\vartheta}(\omega_{xp} \sin\gamma + \omega_{yp} \cos\gamma); \quad \dot\beta = -\omega_{xp} \cos\gamma + \omega_{yp} \sin\gamma;$$

$$\dot\varphi = \frac{\sin\vartheta}{\cos\vartheta}(\omega_{xp} \sin\gamma + \omega_{yp} \cos\gamma) - \omega_{zp},$$

that describe angular motion of the stabilized platform gimbals frame axes.

Conclusion

The mathematical model of the inertially stabilized platform for the aircraft observation equipment was created and its simulation was carried out. The expressions for platform control moments were derived.

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ASSESSMENT OF DYNAMIC CHARACTERISTIC OF UNSTABLE OBJECT AT CONSTANT REGIME

It is propound a new method of assessment casual parameters of complex, unstable, moveable object (helicopter with cargo suspension) for problems with structural identification of own object and synthesis of optimal, by structure, object stabilization system.

Preface

As the analysis of world aviation shows systematic increase in competition in circle of major aircraft equipment, manufacturers makes constantly seek new methods and technology processes to achieve optimal quality of aircraft. Solution of such problems for processes of navigation and flight control requires significant financial and human resources, now, becomes evident the need to modernize some existing aircraft designs, such as helicopters with external cargo suspension.

Complexity of navigation and control of the helicopter cargo suspension linked as dynamic features of the object management and with different stochastic properties of revolting factors in flight. The mode of being helicopter in the air with cargo suspension is one of complex, insufficiently studied and responsible. Creation of hard stabilization helicopter, especially with cargo suspension, is with special interest. As it is known, helicopters - a fundamentally unstable multidimensional dynamic objects [1; 2], and dynamics models of such object stabilization and influences used in practice, not give a chance of achieving a high degree of stabilization in specific, responsible far-flight modes. In stabilization problems with the helicopter cargo suspension situation even more complicating. Expediency of studies in this area is conditioned by the wide use and polyhedral of helicopters in almost all spheres of human activity (mining, agriculture, construction, cargo transportation, passengers transportation, the study of minerals, etc.). The problem of automatic rigid stabilization of the helicopter with cargo suspension in mode of being in the air reasonable to split into separate stages:

1. Experimental evaluation of dynamic characteristics of stochastic-flight helicopter navigation parameters that characterize the "input-output" of the helicopter cargo suspension as object of stabilization.
2. Structural identification of helicopter dynamics model as the object of stabilization and acting on him uncontrollable stochastic perturbation in mode of being in the air.
3. Synthesis of optimal structure and parameters of the stabilization of the helicopter cargo suspension in mode of being in the air.

Describing the problem

Known from literature [1;2] examples of solving stabilization of the helicopter usually does not take into the real nature of stochastic perturbations, acting on it in different modes of flight, and the fact unstable object. All this leads the need to find means of solving the problem discussed in the preface. One of these tools can be a synthesis of optimal structures of stabilization of an object based on known tests with models of the object dynamics and stochastic perturbations acting on it in real flight. Analyzing operation methods of flying device [1;2], can be said that they do not include the whole range of influences that operate on aircraft flying in standard mode. Consider the situation of operation a helicopter with cargo suspension in mode of being in air, when there are additional forces and moments on the motion of the external cargo suspension, causing additional instability of the helicopter. The reasons for this instability of helicopter in the standard mode flight, as with external cargo suspension, and without it, today, are not known, so to set in possibility of high accurate stabilization of the helicopter in the standard mode of cargo flight suspension is problematic. One of the reason for the instability of the helicopter cargo suspension is a glidering features of helicopter [1;2] (no symmetry, rudder screw). Its role in instability is playing external perturbation, as from cargo suspension, so and from environmental perturbations that have stochastic character.

In this article will review the first phase of solution rigid stabilization problem, namely evaluation received during special tests of dynamic stochastic characteristics flying-navigation parameters of helicopter that characterizes the "input-output" of the helicopter with cargo suspension as the stabilization object.

Solution of described problem

Let's introduce the concept of "Helicopter - Pilot - Cargo - ENVIRONMENT (HPCE) diagram of such object shown in Fig. 1.

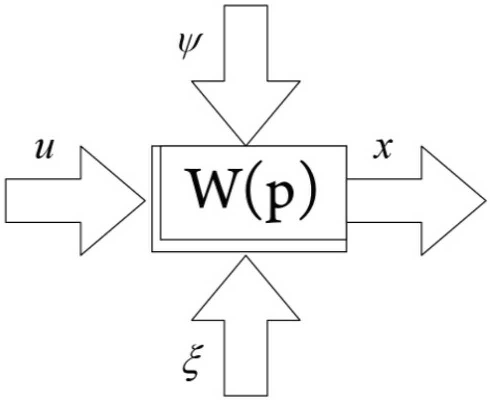

Fig. 1. Diagram of (HPCE).

where u -m-dimensional vector of controlling stochastic influences (influence of a pilot autopilot); ξ - n-dimensional vector controlled stochastic perturbation, caused by movement of cargo; ψ - n-dimensional vector of uncontrollable external stochastic perturbation, acting on a helicopter with a cargo in mode of being in the air (e.g., turbulent wind); x - n-dimensional vector of reaction helicopter on controlled ξ, uncontrolled ψ disturbance and leading influence of a pilot u. Under investigation case of motion of helicopter might write transposed by Laplace or Fourier system of ordinary differential equations look

$$Px = Mu + \xi + \psi \,, \tag{1}$$

where P and M - matrix dimensions respectively, and whose elements are polynomials of the arguments (Laplace) or (Fourier). The system of equations (1) fully describes the system HPCE as stabilization object. In the studied case unknown matrices P and M, and dynamic models of vectors u, x, ξ and ψ. Signal vectors can be fixed in the process of model experiment.

Analyzing the helicopter control one can fix the structure vectors of system HPCE that is necessary to evaluate in process and determine their structure (2-3) for necessary tests.

$$u' = \left| \delta_\vartheta \;\; \delta_\gamma \;\; \delta_\varphi \;\; \delta_g \right| ; \tag{2}$$

$$\xi' = \left| \vartheta_g \;\; \gamma_g \right| ; \tag{3}$$

$$x' = \left[x \;\; y \;\; z \;\; \vartheta \;\; \gamma \;\; \varphi \right] , \tag{4}$$

where $\boldsymbol{\delta_\vartheta}$ - longitudinal deviation of control knob, δ_γ - lumbar deviation of control knob, $\boldsymbol{\delta_\varphi}$ - deviation angle of pedals; $\boldsymbol{\delta_g}$ - deviation of gas; x -linear deviation of the helicopter in longitudinal plane; y - linear deviation of the helicopter in the transverse plane; z - linear deviation of the helicopter in height; ϑ - helicopter pitch angle; γ - angle of roll of the helicopter; φ - helicopter's angle of yaw; ϑ_g - pitch angle of cargo oscillation; γ_g - angle of roll cargo oscillation.

Stages of successful solution of the dynamic characteristics of vector's stochastic signals HPCE define this way:

1) separation of the arrays variable deterministic signals and random stationary ergodic components of signals, received during a special mode testing;
2) accounting known regulations of theory of random ergodic processes determining the correlation and mutual correlation functions centered random components of the investigated signals;
3) using Fourier transform correlation and mutual correlation functions, spectral determination of the mutual spectral density of the investigated signals;
4) graphical representation of the computer calculated the mutual spectral density of the investigated spectral signals using special software;
5) based on generalized method of image approximation logarithmic characteristics of the spectral dependence and mutual spectral densities shortened mathematical expressions;
6) determination of structures of the investigated vector signals *u, x* and ξ;
7) using the theorem of Wiener-Hinchyna definition of matrix structure of spectral densities and mutual spectral vectors study of random signals;
8) fill the mathematical elements of the matrix spectral and mutual spectral density, which elements are spectral and the mutual spectral density of the investigated signals.

For the special mode tests is developed a special technique which has the following form:

1) choice of preparation and measurement platform for the helicopter (kinoteodolity are established, marks center of area, marks the helicopter center of mass);
2) installation of special equipment on helicopter to measure deviations cargo suspension;
3) selection of cargo suspension spherical shape (typical load, with parameters of mass about 10 - 15% of the mass of the helicopter).

This method of conducting a special mode testing was tested and used for the helicopter Mi-8 MTV with cargo suspension in mode of being in the air. Offered method of conducting special tests has a meaning and in the case of studying of any other helicopter with cargo suspension in mode of being in the air and assistance to obtain all the necessary incoming information that characterizes the state of stochastic systems HPCE.

During the mode test has been received vector components of stochastic signals that determine the "input-output" as the subject of helicopter stabilization. All registered signals have stochastic character (and deterministic, and random components), so expression (2 - 4) can be written as:

$$u = u_0 + u^0 = \begin{bmatrix} \delta_\vartheta \\ \delta_\gamma \\ \delta_\varphi \\ \delta_g \end{bmatrix} = \begin{bmatrix} \delta_{0\vartheta} \\ \delta_{0\gamma} \\ \delta_{0\varphi} \\ \delta_{0g} \end{bmatrix} + \begin{bmatrix} \delta^0{}_\vartheta \\ \delta^0{}_\gamma \\ \delta^0{}_\varphi \\ \delta^0{}_g \end{bmatrix}; \quad (5) \qquad \xi = \xi^0 + \xi_0 = \begin{bmatrix} \vartheta_g \\ \gamma_g \end{bmatrix} = \begin{bmatrix} \vartheta^0{}_g \\ \gamma^0{}_g \end{bmatrix} + \begin{bmatrix} \vartheta_{0g} \\ \gamma_{0g} \end{bmatrix}; \quad (6)$$

$$x = x^0 + x_0 = \begin{bmatrix} x \\ y \\ z \\ \vartheta \\ \gamma \\ \varphi \end{bmatrix} = \begin{bmatrix} x_0 \\ y_0 \\ z_0 \\ \vartheta_0 \\ \gamma_0 \\ \varphi_0 \end{bmatrix} + \begin{bmatrix} x^0 \\ y^0 \\ z^0 \\ \vartheta^0 \\ \gamma^0 \\ \varphi^0 \end{bmatrix}. \quad (7)$$

Using known methods of separating signal for deterministic and random components [3, 4] one have to do the initial processing of all registered signals.Using only the random component defining not random characteristics of random signals such as spectral and mutually-spectral density investigated signals.Using expressions (2 - 4) and theorem Wiener-Hinchyna, composed matrix of spectral and mutual spectral densities investigated vectors:

$$S=\begin{bmatrix}
S_{\delta_\vartheta\delta_\vartheta} & S_{\delta_\gamma\delta_\vartheta} & S_{\delta_\varphi\delta_\vartheta} & S_{\delta_g\delta_\vartheta} & S_{\vartheta_g\delta_\vartheta} & S_{\gamma_g\delta_\vartheta} & S_{x\delta_\vartheta} & S_{y\delta_\vartheta} & S_{z\delta_\vartheta} & S_{\vartheta\delta_\vartheta} & S_{\gamma\delta_\vartheta} & S_{\varphi\delta_\vartheta} \\
S_{\delta_\vartheta\delta_\gamma} & S_{\delta_\gamma\delta_\gamma} & S_{\delta_\varphi\delta_\gamma} & S_{\delta_g\delta_\gamma} & S_{\vartheta_g\delta_\gamma} & S_{\gamma_g\delta_\gamma} & S_{x\delta_\gamma} & S_{y\delta_\gamma} & S_{z\delta_\gamma} & S_{\vartheta\delta_\gamma} & S_{\gamma\delta_\gamma} & S_{\varphi\delta_\gamma} \\
S_{\delta_\vartheta\delta_\varphi} & S_{\delta_\gamma\delta_\varphi} & S_{\delta_\varphi\delta_\varphi} & S_{\delta_g\delta_\varphi} & S_{\vartheta_g\delta_\varphi} & S_{\gamma_g\delta_\varphi} & S_{x\delta_\varphi} & S_{y\delta_\varphi} & S_{z\delta_\varphi} & S_{\vartheta\delta_\varphi} & S_{\gamma\delta_\varphi} & S_{\varphi\delta_\varphi} \\
S_{\delta_\vartheta\delta_g} & S_{\delta_\gamma\delta_g} & S_{\delta_\varphi\delta_g} & S_{\delta_g\delta_g} & S_{\vartheta_g\delta_g} & S_{\gamma_g\delta_g} & S_{x\delta_g} & S_{y\delta_g} & S_{z\delta_g} & S_{\vartheta\delta_g} & S_{\gamma\delta_g} & S_{\varphi\delta_g} \\
S_{\delta_\vartheta\vartheta_g} & S_{\delta_\gamma\vartheta_g} & S_{\delta_\varphi\vartheta_g} & S_{\delta_g\vartheta_g} & S_{\vartheta_g\vartheta_g} & S_{\vartheta_g\gamma_g} & S_{x\vartheta_g} & S_{y\vartheta_g} & S_{z\vartheta_g} & S_{\vartheta\vartheta_g} & S_{\gamma\vartheta_g} & S_{\varphi\vartheta_g} \\
S_{\delta_\vartheta\gamma_g} & S_{\delta_\gamma\gamma_g} & S_{\delta_\varphi\gamma_g} & S_{\delta_g\gamma_g} & S_{\gamma_g\vartheta_g} & S_{\gamma_g\gamma_g} & S_{x\gamma_g} & S_{y\gamma_g} & S_{z\gamma_g} & S_{\vartheta\gamma_g} & S_{\gamma\gamma_g} & S_{\varphi\gamma_g} \\
S_{\delta_\vartheta x} & S_{\delta_\gamma x} & S_{\delta_\varphi x} & S_{\delta_g x} & S_{\vartheta_g x} & S_{\gamma_g x} & S_{xx} & S_{yx} & S_{zx} & S_{\vartheta x} & S_{\gamma x} & S_{\varphi x} \\
S_{\delta_\vartheta y} & S_{\delta_\gamma y} & S_{\delta_\varphi y} & S_{\delta_g y} & S_{\vartheta_g y} & S_{\gamma_g y} & S_{xy} & S_{yy} & S_{zy} & S_{\vartheta y} & S_{\gamma y} & S_{\varphi y} \\
S_{\delta_\vartheta z} & S_{\delta_\gamma z} & S_{\delta_\varphi z} & S_{\delta_g z} & S_{\vartheta_g z} & S_{\gamma_g z} & S_{xz} & S_{yz} & S_{zz} & S_{\vartheta z} & S_{\gamma z} & S_{\varphi z} \\
S_{\delta_\vartheta\vartheta} & S_{\delta_\gamma\vartheta} & S_{\delta_\varphi\vartheta} & S_{\delta_g\vartheta} & S_{\vartheta_g\vartheta} & S_{\gamma_g\vartheta} & S_{x\vartheta} & S_{y\vartheta} & S_{z\vartheta} & S_{\vartheta\vartheta} & S_{\gamma\vartheta} & S_{\varphi\vartheta} \\
S_{\delta_\vartheta\gamma} & S_{\delta_\gamma\gamma} & S_{\delta_\varphi\gamma} & S_{\delta_g\gamma} & S_{\vartheta_g\gamma} & S_{\gamma_g\gamma} & S_{x\gamma} & S_{y\gamma} & S_{z\gamma} & S_{\vartheta\gamma} & S_{\gamma\gamma} & S_{\varphi\gamma} \\
S_{\delta_\vartheta\varphi} & S_{\delta_\gamma\varphi} & S_{\delta_\varphi\varphi} & S_{\delta_g\varphi} & S_{\vartheta_g\varphi} & S_{\gamma_g\varphi} & S_{x\varphi} & S_{y\varphi} & S_{z\varphi} & S_{\vartheta\varphi} & S_{\gamma\varphi} & S_{\varphi\varphi}
\end{bmatrix} \qquad (6)$$

Thus, the task of evaluation of dynamic characteristics of stochastic influences controlled perturbation of cargo suspensions, and reactions on them of the helicopter was reduced to the creation of analytical models, which determine the matrix and spectral elements of matrix and the mutual spectral densities [3 - 5].

The basis of spectral estimates and mutual spectral densities of signals laid determine the correlation and mutual correlation functions of random processes, with further Fourier transformation.

Using the method of generalized logarithmic frequency characteristics, one can create analytical models of all elements above the matrix.

Conclusion

Thus, methods of evaluation of dynamic characteristics, suggested in this work enables to consider the problem of stabilizing a moving objects with a qualitatively new way, identifying the real stochastic disturbing influences, acting on the helicopter with the cargo suspension in mode of being in the air. Using obtained spectral and mutual spectral density, the possibility in the future to get the optimal structure for stabilizing the helicopter with the cargo suspension in mode of being in the air, conducting identification procedures and synthesis of stabilization system.

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THE AUTOMATION OF RADAR SIMULATION: PRINCIPLES OF CONSTRUCTION, THE OPTIMIZATION OF STRUCTURE AND FUNCTIONING OF SIMULATION SOFTWARE

In report some questions of the creation of information system (problem-oriented software complex) intended for obtaining of various information with using computer experiment for radar research and designing of radar and its elements, for education in this subject area are considered

Complexity of modern radars, a variety of their operation conditions, necessity of improvement of technical solutions and corresponding devices, strict resources restrictions of designing are an important factors which influence on the realization of continuity principle of designing. This principle directly depend on information maintenance of designing and research, from the cumulating of technical decisions used in last and new radars to scientific and technical forecasting of methods and means of processing of radar signals and data [1,2].

From this point of view, *integrated informational environment (**IIE**)* which allows optimally using same software, methodical information and data for a realization of the research programs for radars and their elements is interesting for practical applications [3]. Important ***IIE*** components are problem-oriented modelling software complexes (computer laboratories (***CL***)) which are information software systems for obtaining qualitative information with using of computer experiment

In this report, the problems of the creation and functioning (principles, the optimization of the structure and the operation) of such information system ***S*** intended for support of radar research and designing are considered.

First of all, under ***S*** creation it is necessary to determine the purposes, realization, functions, the class, efficiency criterions and quality indexes, the structure etc. The main purpose of ***S*** creation is determined as essential resources reduction for research and designing, with guaranteed quality of works. Main ***S*** function is the function *G* of obtaining of the information about given object with using computer experiment and the presentation of this information in accordance with the requirements of research program (multitude ***W***). The system ***S*** is in a class of dialogue software information systems according to modern tendencies on an individualization and intellectualization of computer work.

Let's consider following indexes for estimation of quality of obtained information [3, 4]:

solutions quality

◊ $\overline{\pi}$ (accuracy, complexity, reliability of obtained solutions);

the quality of output information presentation

◊ $\overline{\partial}$ (information completeness, visualization, expressive adequacy of output information);

***S** operation quality*

◊ the time t_{proc} for execution of all operations for information obtaining of required quality;

◊ the volume of required software V_p;

◊ $\overline{\wp}$ (conceptual clearness, reliability, realization simplicity, user's convenience as the requirements to «user-computer» dialogue).

The problem of optimal ***S*** designing is difficult enough for formalization therefore we consider some simplified variant of its statement which may be used on practice.

We assume that required solution may be computed with using ***S*** then the time t_{proc} of obtaining of the information required quality $\{\overline{\pi}, \overline{\partial}\}$ is chosen as optimized parameter of information required quality $\{\overline{\pi}, \overline{\partial}\}$. In this case, optimization problem is determined as the minimization t_{proc} for restrictions $\overline{\wp}_0$, V_{p0} on indexes $\overline{\wp}$, V_p:

$$t_{proc} \to \min \tag{1}$$

$$\overline{\wp} \geq \overline{\wp}_0, \qquad V_p \leq V_{p0}.$$

By definition t_{proc} for effective operation ***S***, it is necessary to minimize or restrict all components of the index t_{proc}. This result may be achieved by corresponding choice of information maintenance of ***S*** (mathematical models, models of information presentation, modelling algorithms and calculation algorithms etc.) and of ***S*** structure. For synthesis of optimal ***S*** structure, we have to determine all ***S*** elements, elements interactions, the connection between ***S*** elements and their characteristics, control by their operation (modes of ***S*** functioning). Optimal result under solving (1) we can obtain for distributed ***S*** structure which may be achieved by way of the decomposition of research problems multitude ***W*** on *J* classes. In this case, the function *G* is decomposing, too.

Let's consider basic assumptions used for ***S*** structure definition on the base of processes of the statement and solving of research problems and the presentation of the information, required under radar designing. We can consider a radar and-or radar input influence, n-th radar element and-or input influence of n-th radar element as object(s) under research, n=1,…N. In dependence on problem requirements, the results of ***S*** operation may include different forms of the description of radar or of its elements (formula, functional schemas etc.), statistical and determined characteristics of input influence or its components, different quality indexes and characteristics of functioning of radar and its elements $\{\overline{\gamma}_n\}_0^N$.

Note, that the partition for radar (as for any complex technical system) isn't determined uniquely. In accordance with basic functions of radar we have as result the partition with one or many levels. Let's consider as radar elements (multitude O_R) the subsystem of processing of radar signals (SPRS), the subsystem of processing of radar data (SPRD), the channels of space and temporary processing of signals, the channels of detection and tracking of trajectories, devices and algorithms of radar information processing with their parametrical definition [1,3]. As rule, the catalogue (multitude) ΘM_R of mathematical models, of modelling algorithms and other information are used for mathematical description of chosen objects under research. As computer experiment may be executed by using analytic expressions, numerical methods, simulation and the combinations of these methods, we can consider the multitude of versions $\{\upsilon_l\}_1^L$ of calculation methods of each solution and $\Theta M_R = \bigcup_1^L \Theta M_{Rl}$.

The ***S*** functioning is effective if all stages of problem statement (the definition of initial data, calculation methods and the presentation of solutions, requirements to the solution) are executed with required quality and resources. Multitude W is characterized by enough large volume and non-uniform therefore ***S*** software and the execution of condition (1) essentially complicates. In this connection, for achievement of quality and resource requirements we have to determine classified attributes $\{\lambda_m\}$ and to decompose multitude W and the function *G* by such way that to reduce the execution time of problem statement, its solving and obtaining of output information.

Depending on the number of chosen attributes, we have following *W* partition accordance in a hierarchical principle:

one level
$$W = \bigcup_1^J W_j, \tag{2}$$

two levels
$$W = \bigcup_1^J \bigcup_1^{L_j} W_{jl} \quad \text{or} \quad W = \bigcup_1^J \bigcup_1^{M_j} W_{jm}, \tag{3}$$

$$\textit{three levels} \qquad W = \bigcup_{1}^{J}\bigcup_{1}^{L_i}\bigcup_{1}^{M_i} W_{jlm} \quad \text{or} \quad W = \bigcup_{1}^{J}\bigcup_{1}^{M_i}\bigcup_{1}^{L_i} W_{jml}\,, \qquad (4)$$

where W_j, W_{jl}, W_{jm}, W_{jlm}, W_{jml} - multitude (classes) of research problems, $m = 1,...M_l$; $l = 1,...L_j$; $j = 1,...J$.

The choice of classified attributes, number and forming of problems classes and distribution structure depends on radar type, exist information about radar functioning, used methods and their realization. Let's use the attributes λ_1, λ_2, λ_3 determined elements of problems statement and related to the choice of:

- the object under research (the radar, radar elements, input influence) - attribute λ_1;
- the version of the method of solution calculation - attribute λ_2;
- the form(s) of output information presentation - attribute λ_3.

In accordance with chosen attributes λ_1, λ_2, λ_3 we can consider different variants of the definition of multitudes W_j, W_{jl}, W_{jm}, W_{jlm}, W_{jml}.

The attribute λ_1 is traditionally used for system research when expression (3) is used and we have *variant 1* of problems statement execution as autonomous research of *each j-th object* from O_R, *j=1,...J.* For this variant method of solutions calculation and the form(s) of output information presentation are defined as initial data and aren't chosen by user.

Increasing attributes numbers we have multilevel construction. Thus, for combination $\{\lambda_1, \lambda_2\}$ and *variant 2* of *W* decomposition according to expression (4), we control the version of the method of solution calculation (can consider different methods) *for each j-th object* from O_R, while the form(s) of output information presentation are fixed, *j=1,...J. Variant 3* of *W* decomposition is oriented on the combination $\{\lambda_1, \lambda_3\}$ when *for each j-th object* from O_R the form(s) of output information presentation are chosen, but method of solution calculation is defined by initial data, *j=1,...J. Variant 4* for the combination $\{\lambda_1, \lambda_2, \lambda_3\}$ is most control by user, therefore *for each j-th object* from O_R the research program is executed with the choice of methods of solution calculation and presentation forms, *j=1,...J.*

The graphs described the variants 1, 2, 4 of *W* decomposition are presented in Fig.1a,..1c.

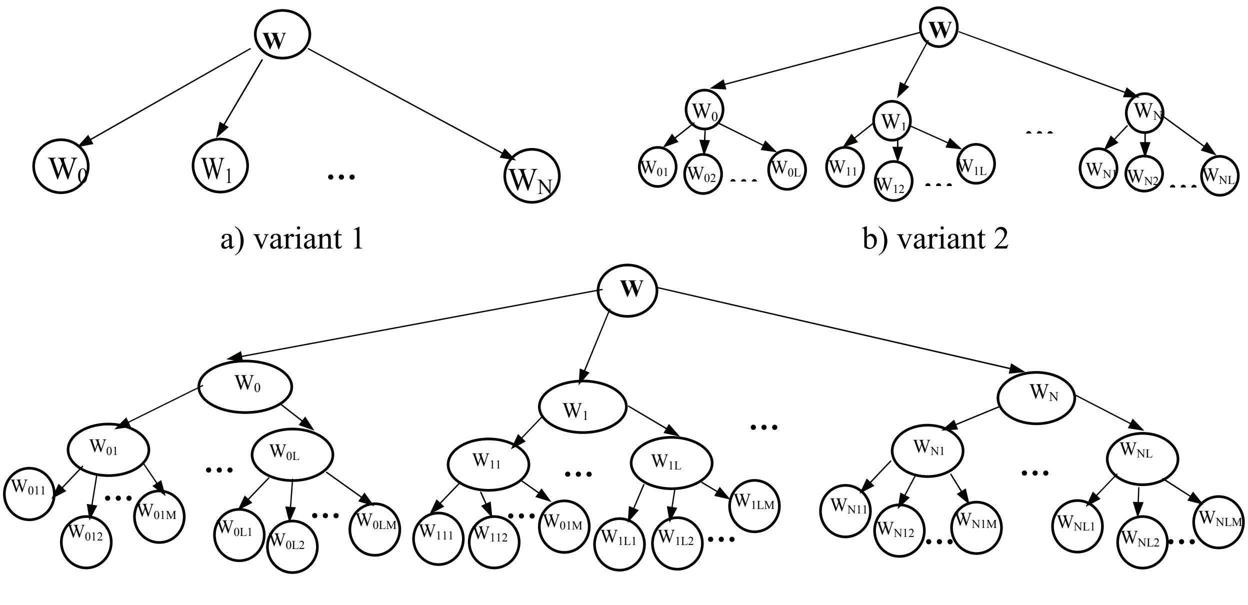


Fig.1. Variants of *W* decomposition

The W decomposition is connected with the decomposition of function G of system $\boldsymbol{S}$. We can consider different variants of distributed $\boldsymbol{S}$ structure in accordance with W decomposition. The example of simple $\boldsymbol{S}$ partition related to *variant 1* by the separation of J elements of $\boldsymbol{S}$ ($\mathbf{S}_0$ for radar research (object $o_{R0} \in \mathrm{O}_R$) and $\boldsymbol{S}_1,..\boldsymbol{S}_N$ for research of N radar elements (objects $\{o_{Rn}\}_1^N \in \mathrm{O}_R$), $J=N+1$) is presented in Fig.2a. Each subsystem among $\{\mathbf{S}_j\}_0^N$ may be independent, if, in addition, to stipulate ways of its realization in such aggregated kind

Other variants of $\boldsymbol{S}$ structure may use the separation on less aggregated elements or the definition of control (mode) by subsystems operation. In particular, the schema relating to *variant 1* in Fig.2a determines J subsystems $\{\mathbf{S}_j\}_0^N$ intended for research of objects $\{o_{Rj}\}_0^N \in \mathrm{O}_R$, $J=N+1$. We can get the schema related *variant 2* in Fig.2b if to add L_j subsystems $\{\{\mathbf{S}_{jl}\}_1^{L_j}\}_0^N$ determined by different methods of solutions calculation, $J=\sum_{j=0}^{N} L_j$. Next variant of functions distribution in $\boldsymbol{S}$ is oriented to the definition of $\boldsymbol{S}$ elements related to the object under research, to choice of the method of solutions calculation $\{\{\mathbf{S}_{jl}\}_1^{L_j}\}_0^N$ and to presentation form(s) $\{\{\{\mathbf{S}_{jlm}\}_1^{M_l}\}_1^{L_j}\}_0^N$; $m=1,...M_l$; $l=1,...L_j$; $j=0,...N$.

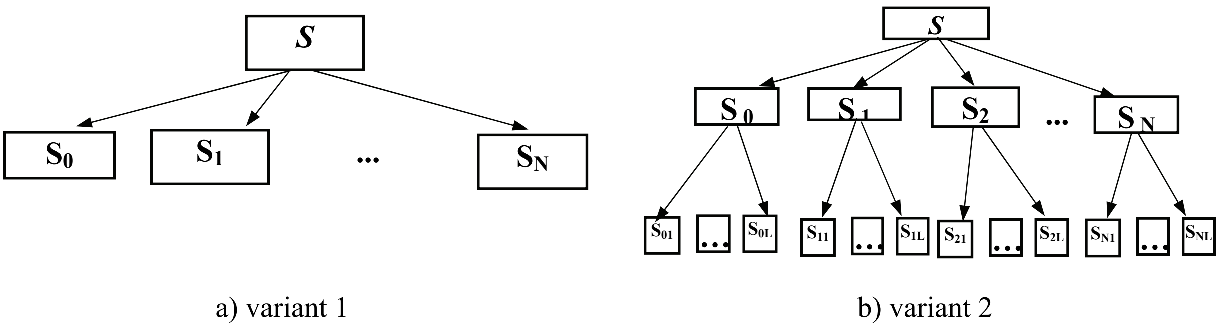


Fig.2. The examples of $\boldsymbol{S}$ structure

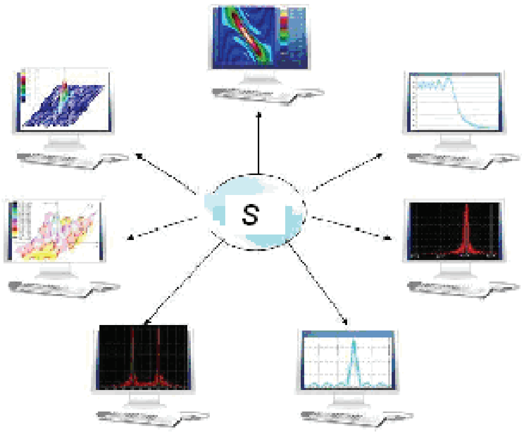
Such approach to $\boldsymbol{S}$ creation on practice may be presented by some problem-oriented software complexes – *computer laboratories*, intended for research support of radar, the channels of processing of radar information, different devices and algorithms of processing of radar signals and data [3,…8]. Objects under research are determined with using their structure-parametrical definition on the base of given catalogue of algorithms and devices of processing of radar information.

Let's consider as example the variant with a choice of the forms of output information presentation (given multitude Φ) when this information is obtained with using chosen method of computer experiment realization for appropriate mode of $\boldsymbol{S}$ functioning. Multitude Φ is formed on the base of different characteristics and quality indexes of radar information processing and data about various variants of input influence. The examples of Φ definition for forming and processing of radar signals, for the estimation of radar visibility in various weather conditions and for simulation of trajectories of air objects movement are presented in Fig.3a,…d.

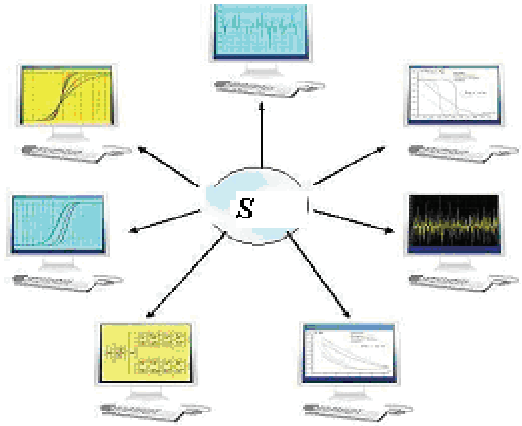
In this case, the user can analyze solutions presented by various way and cover different aspects of functioning of chosen research object.

If optimization problem (1) is solved by way of $\boldsymbol{S}$ structure choice, then centralized control by $\boldsymbol{S}$ is absent for optimal variant of $\boldsymbol{S}$ structure and we have a free access to each element and self-sufficiency of each element. However such approach essentially increases the software volume V_p by high level of the concurrence of information part, by the duplications of some operations of reception and processing used for different problems classes. In common case, such approach is applied only in absence of restrictions on V_p or in absence of similarity relation between $\boldsymbol{S}$

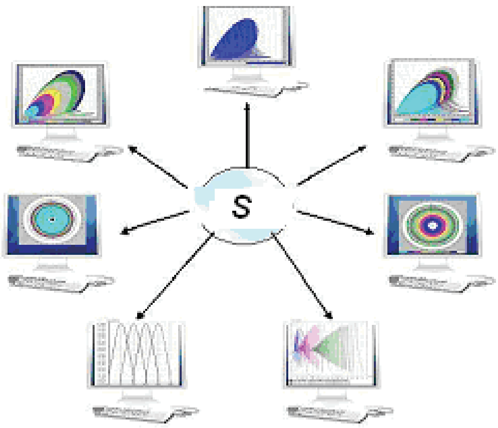
elements. (We understand as similarity relation between problems (or problems classes) full or partial concurrence of statement problem operations, of problem solving and output information presentation in $\boldsymbol{S}$).



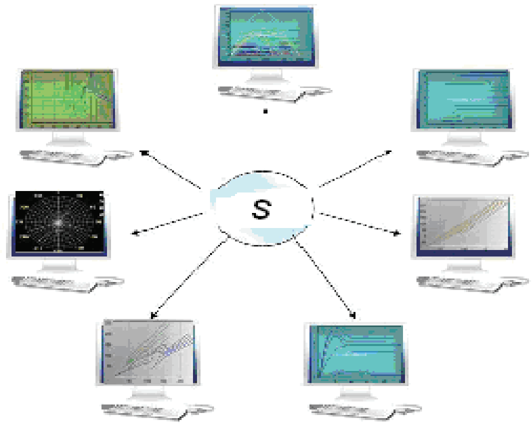
a) the forming and processing of radar signals



b) the detection of radar signals



c) radar visibility estimation



d) simulation of trajectories of air objects movement

Fig.3. The examples of Φ definition

The number of subsystems in $\boldsymbol{S}$ may be reduced by using of separate functioning modes if classes of similar problems are defined. The solution of optimization problem (1) for restriction on V_p is obtained according to features of concrete object and research program. Note, that the distributed system $\boldsymbol{S}$ allow to use advantages of a computer network, to reduce the requirements to V_p, and independently to consider separate W submultitudes included in information environment with users' free access to $\boldsymbol{S}$. We can consider other variants of $\boldsymbol{S}$ creation using the information about radar type, requirements to problem solving for all designing stages, methods of research problems solving and of research program execution etc.

$\boldsymbol{S}$ efficiency may be increased by using of $\boldsymbol{S}$ software or service information (for example, data, scripts of input influence, algorithms and programs, etc.) for solving of other problems (software of radar simulators, complexes of radar equipment testing, education).

For improvement of indexes $\overline{\wp}$ we chose the professional language for the dialogue with user and its support based on semantic model. Modern software, advantages of computer networks and other service opportunities allow to use programming means for the execution of different functions of system $\boldsymbol{S}$ and to consider $\boldsymbol{S}$ as a system of support of radar research and designing.

Conclusions

- for optimal $\boldsymbol{S}$ creation it is necessary to use different variants of the decomposition of research problems multitude W for chosen object (radar and its elements) with using of a hierarchical principle or on the base of similarity relation between classes and with using of computer networks;
- the level of aprioristic definiteness of the information needed for solutions obtaining is defined in hierarchical model of $\boldsymbol{S}$ by the choice of classified attributes (object under study, requirements to solutions quality, methods of solutions obtaining and forms of output information presentation);
- the system $\boldsymbol{S}$, its elements and software may be effectively used for radar research and designing, simulation, testing of technical solutions used for radar designing and education in given subject area.

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GASDYNAMIC METHOD OF UAV LANDING

It is offered the landing method of aircraft. This method can be used for landing of air ship or without an undercarriage in the set district. In the landing method of aircraft, after which turn off the engines of aircraft and brake it in the set district of landing by the additionally created artificial current of air.

Analysis of problem and problem statement.

An unmanned aerial vehicle (UAV) is an aircraft that flies without human crew. UAVs are a key element within the concept of information dominance. Historically the greatest use of UAVs has been in the areas of intelligence surveillance and reconnaissance. While UAVs play an increasing role in these mission areas, we are just beginning to understand the operational impact of multiple UAV operations and their importance to 21st century air power needs.

UAVs are defined as powered, aerial vehicles that do not carry a human operator, use aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload. UAVs have been used in a reconnaissance and intelligence-gathering role since the 1950s, and more challenging roles are envisioned, including combat missions. UAVs have been referred to in many ways: Remotely piloted vehicle, drone, robot plane, and pilotless aircraft are a few such names.

Their largest uses are in military applications. To distinguish UAVs from missiles, a UAV is defined as a reusable, uncrewed vehicle capable of controlled, sustained, level flight and powered by a jet or reciprocating engine. Therefore, cruise missiles are not considered UAVs, because, like many other guided missiles, the vehicle itself is a weapon that is not reused, even though it is also unmanned and in some cases remotely guided.

There is a wide variety of UAV shapes, sizes, configurations, and characteristics. Historically, UAVs were simple drones (remotely piloted aircraft), but autonomous control is increasingly being employed in UAVs. UAVs come in two varieties: some are controlled from a remote location, and others fly autonomously based on pre-programmed flight plans using more complex dynamic automation systems.

Statement of problem

Today, there are many types of UAVs landing. The most common practices are landing with parachute, landing on a air-cushion support, landing on recovery net and landing on rope using hook, typical landing procedure. There are a lot of disadvantages of mentioned above methods, so there is a need for a convenient system. In this thesis there was researched the feasibility of a new method - the gasdynamic method of landing of unmanned aerial vehicles.

Problem solving

The device of landing researched herein is to be used for landing unmanned aerial vehicles. The device of landing an aircraft is mounted on a carrier platform, for example a truck. It consists of two spherical supports and a gasdynamic installation. The load platform of the landing device includes two perforated plates, an upper and a lower one that are connected to one side of a rack with a single hinge and a hydraulic elevator, and on the other side, by a second hydraulic lift. The front edge of the upper perforated plate contains a gasdynamic installation, which is the main element featured in this thesis paper. Each of the items is fastened and the fastening elements are designed as an elastic beam on hinges. The lower perforated plate is placed above two inflatable cylinders, and above this surface, an additional gasdynamic installation is placed.

Schemes of this method are demonstrated in the fig. 1.

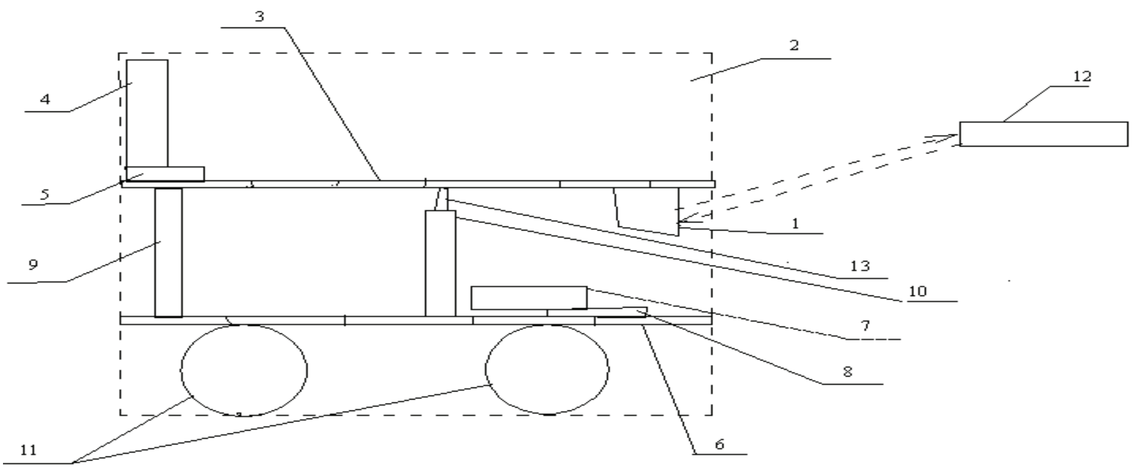

Fig. 1. The functional diagram of the landing device

The aircraft landing device includes a control system that is connected with bearing platform 2 which includes the upper perforated plate 3; the main gasdynamic construction (for example a fan) 4; the dynamic element 5; the lower perforated plate 6; an additional gasdynamic construction (another fan) 7; a dynamic driving gear 8; hydraulic lifts 9 and 10; and pneumatic cylinders 11. In addition, the control system has a radio connection with the aircraft 12. The perforated plates 3 and 6 are linked by a hydraulic lift 9 and the hydraulic lift 10 with a hinge 13 from the top. The lower perforated plate 6 is fixed on pneumatic cylinders 11.

There was researched the influence of ground effect (fig. 2). It increases the closer to the ground that a wing operates. As indicated in the plot shown below, ground effect typically does not exist when a plane operates more than one wingspan above the surface. At an altitude of 1/10 wingspan, however, induced drag is decreased by half.

So, it works against the landing process, as it causes the aircraft to seem to take off, instead of landing. In this case to eradicate ground effect, the landing bay is perforated to decrease the pressure caused by the wings of the aircraft.

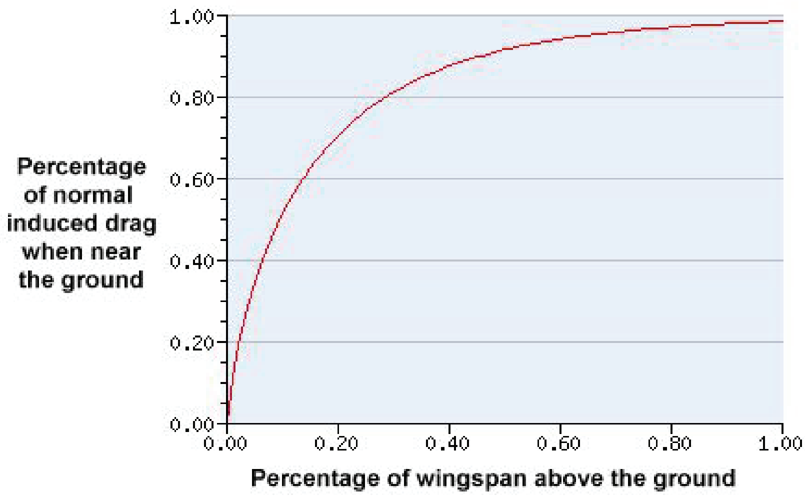

Fig 2. Influence of ground effect

Determination of the necessary energy gasdynamic installation. Assessment of the necessary energy gasdynamic installation can be carried out based on equations used to calculate the energy (power) wind tunnel (WT) with an open working part because the problem in both cases the same - creating the songs even and consistent flow at a given speed (Mach number M). Power plant WT is given by [4], which includes the similarity of M and Re (Reynolds number).

But we can to estimate the power required and useful based on physical considerations: It is necessary provide the air flow with fixing velocity and the given cross-section.

On figure 3 is shown necessary power of the flow from the area, where the q is ram air in kg*m/sec. On figure 4 is shown necessary power of the flow on the speed.

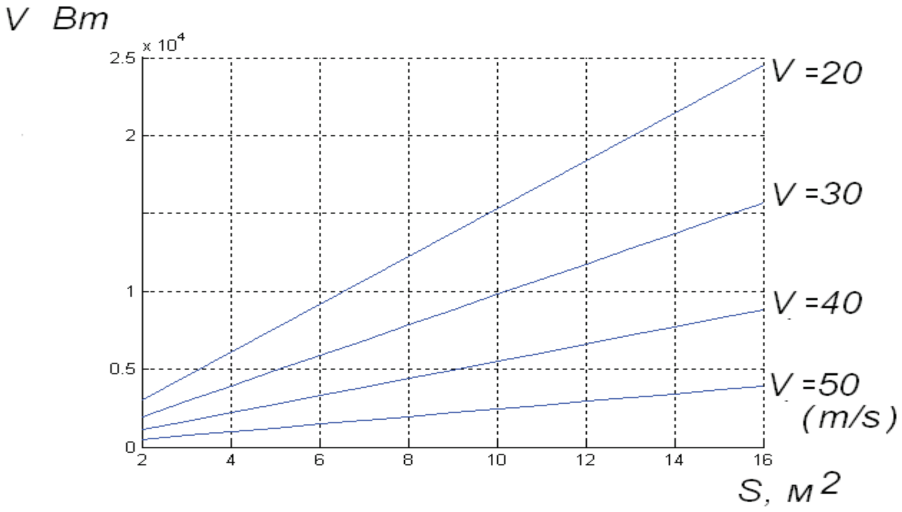

Fig 4. Dependence of the power flow from the area

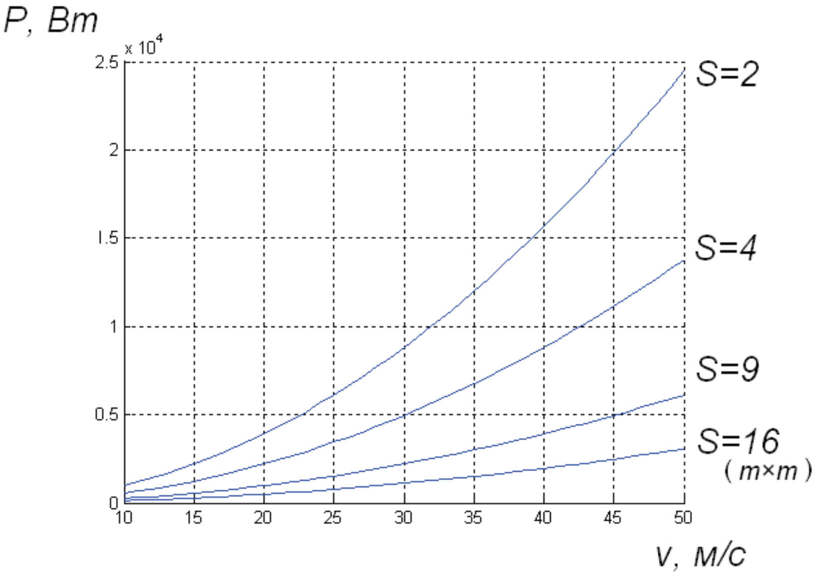

Fig 5. Dependence of the power flow on the speed

Conclusion

During approach, the aircraft gradually shifts from an area of free air movement to one with an artificial air stream created by the main gasdynamic installation. This opposing force created will reduce the horizontal airspeed of the aircraft to zero. The final aircraft trajectory coincides with the axis of the artificial air flow, because in this is the most efficient use of the energy produced by the artificial air flow. The artificial air flow of the additional gasdynamic installation causes the aircraft to gradually slow down as it gently touches a given area and fixed landing.

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THE COMBINED METHOD OF COORDINATE DETERMINATIONS USING GNSS

In this work are presented design and modeling of correction method coordinate measurements in the combined mode

Quality and reliability of functioning of aviation transport largely depend on descriptions of navigation system which allows real-time to get information about co-ordinates. Accuracy of co-ordinates determination of object or point of earthly surface using signals of navigation satellites of global satellite navigation systems mainly depends on measuring accuracy of users receivers pseudodistances to navigation satellites.

Thus considerable role in measuring pseudo distances play methods which use for measuring.

One of methods which provide high-fidelity co-ordinate determinations there is the so-called static mode.

The standard statistical mode provides high-fidelity co-ordinate determinations on condition that GNSS a transceiver in the process of measuring is immobile.

The static mode of GNSS of geodesic survey is technology of relative co-ordinates determination, which is based mainly on measuring of phase bearing of signals of navigation satellites. In the static mode used minimum two stationary GNSS of transceivers which simultaneously look after one the same navigation satellites. One of GNSS transceivers, which is usually named base or reference, is set in a point with the exactly known co-ordinates, and second in a point with unknown co-ordinates, on distances at which simultaneously there is all GNSS receivers of constellation from minimum 5 identical navigation satellites.

The static mode of high-fidelity co-ordinate determinations consists in accumulated results of simultaneously executable reference GNSS receiver and GNSS receiver in the measureable point of measuring of phase of signals and code pseudo distances of the looked after navigation satellites, postprocessing pseudo distances provides the high-fidelity estimation of co-ordinates of measureable point.

At presence of flow line for transfer results of measuring of reference GNSS receiver in GNSS receiver which is set in a measureable point, the estimation of co-ordinates of measureable point comes true practically in the real time.

A time of supervisions (observations) of navigation satellites domain is scope from ten of minutes to a few hours depending on quality of GNSS receivers, distances between a measureable point and reference GNSS receiver, number of observable navigation satellites and level of the signals of navigation satellites removed from local objects. Measuring usually come true with an interval 15 seconds.

Unlike the static mode in the kinematics mode high-frequency co-ordinate determinations come true during motion of user GNSS receiver, which is essentially measuring of co-ordinates of trajectory on which a platform moves from GNSS receiver.

In practice distinguish continuous kinematics mode and so-called RTK (Real Time Kinematic) mode. By the obligatory stage of both variants of the kinematics mode like with the statistical mode there is the stage of initialising, that is determining the amount of complete cycles of phase of signals of navigation satellites. And in the statistical mode and in the kinematics mode after integer distinction of phase ambiguity the high-frequency estimation of co-ordinates values will be realized on one chart. Co-ordinates are determined by a decision with the help of standard least-squares method of the system of equalizations for the double difference of phase of signals of navigation satellites:

$$\nabla\Delta\Phi_{1,2}^{kl} = \nabla\Delta \mathrm{P}_{1,2}^{kl} + \lambda\nabla\Delta \mathrm{M}_{1,2}^{kl}, \tag{1}$$

values $\nabla\Delta\mathrm{M}_{1,2}^{kl}$ are put in which, calculation on the stage of initialization.

Continuous kinematic mode realizes co-ordinate determinations in the process of motion of GNSS receiver after the stage of initializing, which immobile GNSS receiver usually use one of two approaches a receiver for realization of initialising, namely: placing of user GNSS receiver in a point with the known co-ordinates or swapping procedure of aerials.

The combination method is combination of the static and kinematics modes of high-fidelity co-ordinate determinations.

The combination method of correction of time and coordinate high-fidelity measurements is used in the modes which are usually named "stop and go" and reokulatsiyi.

In the mode the " stop and go " initialising of movable GNSS receiver comes to beginning of moving of user GNSS receiver on the set trajectory. During motion, shadowing comes true after navigation satellites, there is a known integer value of phase ambiguities of navigation satellites observable constellation in any moment. But co-ordinate determinations measure only in the separate points of trajectory of motion and here immobile GNSS receiver that stipulated the name of the mode of high-fidelity determinations of co-ordinates in the real time.

Initialising of movable GNSS receiver in the mode of "stop and go" measure with the use of method of correction characteristic or for the static mode, or for the mode of rapid statics, or for the kinematics mode depending on present software and descriptions of used movable GNSS receiver. Unlike the static mode and mode of rapid statics in the process of moving of GNSS receiver of user shadowing after navigation satellites and monitoring of absence of loss of surveillance. Monitoring of loss of surveillance is based on the use of combinations of double differences, calculated for bearing L1 and L2.

Monitoring of absence of loss of surveillance effectively will be realized by the analysis of values of the continuously calculated values of combination of L4.

Monitoring of values of loss of surveillance is possible and by the use of values of wide band (L5) and narrowly band (L6) combinations. Wide band and narrowly band to combination designed by next equalizations.

$$\Phi(L_5) = \frac{\Phi(L_1)}{\lambda_1} - \frac{\Phi(L_2)}{\lambda_2} = \rho + \frac{\lambda_2}{\lambda_1} d_{ionL1} + d_{trop} + \lambda_5 \cdot N_5, \tag{2}$$

$$\Phi(L_6) = \frac{\Phi(L_1)}{\lambda_1} - \frac{\Phi(L_2)}{\lambda_2} = \rho + \frac{\lambda_2}{\lambda_1} d_{ionL1} + d_{trop} + \lambda_6 \cdot N_6, \tag{3}$$

where $\Phi(L_1), \Phi(L_2), \Phi(L_5), \Phi(L_6)$ - measured phase value (in meters) in the case of bearing L_1, L_2, L_5, L_6 respectively; $\lambda_1, \lambda_2, \lambda_5, \lambda_6$ - wavelength L_1, L_2, L_5, L_6 respectively; d_{ionL1} - ionosphere error (delay) for the L1 carrier;

d_{trop} - ionosphere error (delay); N_5, N_6 – integer value of phase ambiguity in the case of bearing L5 and L6 respectively. So the difference is described by the following expression: $\Phi(L_5) - \Phi(L_6)$:

$$\Phi(L_5) - \Phi(L_6) = 2\frac{f_1}{f_2} d_{ionL1} + \lambda_5 \cdot N_5 - \lambda_6 \cdot N_6, \tag{4}$$

Value λ_5 and λ_6 are constants, value N_5 and N_6 remain unchanging in default of loss of surveillance thus values $\Phi(L_5) - \Phi(L_6)$ are determined by the change of ionosphere error in the process of moving of user GNSS receiver. As a value of error d_{ionL1} changes very slowly, then different change of value $\Phi(L_5)-\Phi(L_6)$ possibly only at the change of values N_5 and N_6, that is at the loss of surveillance even after one navigation satellites of the observable constellation.

After realization of the second stage of measuring results of measuring, that is value of double differences of phase bearing of signals of navigation satellites and code pseudo distances jointly processed with the help of least-squares method and with the use of data averaging. The increased exactness of co-ordinate determinations is arrived at due to that drawn on the results of measuring for substantially excellent constellations of navigation satellites.

In the mode of the reokulyatsiyi measuring of co-ordinates of object comes true with an interruption in time about hour in two receptions. It provides the high degree of results of measuring, and also allows to apply more simple measuring technique and software.

On the stage of preliminary estimate of close values of measuring point co-ordinates by initial data measured to the code pseudo distances and co-ordinates of reference GNSS receiver. In consideration of that amount of navigation satellites not less than 5 and spatial correlation of atmospheric effects takes place. The preliminary estimate of close values of co-ordinates in the geocentric system comes true as follows.

A navigation satellite is determined as base with the maximal value of elevation angle. The values of double differences of code are calculated pseudo distances $\nabla\Delta \mathrm{P}_{12}^{kl}$ in relation to a base satellite. So as an amount of unknown (co-ordinates of measureable point) less amount of equalizations for a code pseudo distances, then the estimation of close values of co-ordinates comes true concordantly:

$$X=(A^T PA)^{-1}A^T Py, \tag{5}$$

where A – estimated matrix size (n-1)x3;

n – number of satellites in the observed constellation;

$$P=\frac{1}{2(n-1)}\begin{bmatrix}(n-1)(-1)...(-1)\\ ....\\ (-1)(-1)....(n-1)\end{bmatrix}$$ - weighting matrix;

y - (n-1) dimensional vector elements are the double difference of measured pseudo code and distances calculated using the coordinates measured as a reference point coordinates GNSS receiver.

x – three-dimensional vector measured point.

The estimations of close values of co-ordinates and their dispersion as consistent with above-described procedure during the row of epochs. Thus beginning from the second epoch, smoothing of code will be realized pseudo distances by a phase. For a к-th epoch smoothed out by a phase pseudo distance $\hat{\mathrm{P}}_k$ is determined by expression:

$$\hat{P}=W_{p_k}P_k+W_{\Phi_k}\left\{\hat{P}_{k-1}+(\Phi_k-\Phi_{k-1})\right\}, \tag{6}$$

where $W_{\mathrm{P}_k}=W_{\mathrm{P}_{k-1}}-0.01$ $(0.01\le W_{\mathrm{P}_k}\le 1.00)$,

$W_{\Phi_k}=W_{\Phi_{k-1}}-0.01$ $(0.01\le \Phi_{\Phi_k}\le 1.00)$,

P_k - pseudo distance measured in k-th epoch;

$\Phi_k=\lambda\Psi_k$,

λ - wavelength carrier;

Ψ_k - phase carrier in k-th epoch;

$\hat{\mathrm{P}}_1=\mathrm{P}_1$

The results of estimations of approximate values of co-ordinates and their dispersions average with the use of expressions:

$$\bar{X}^{n+1} = \frac{n}{n+1} \cdot \bar{X}^{n} + \frac{1}{n+1} \cdot X_{n+1}, \quad (7)$$

On the stage of additional estimation of approximate values of co-ordinates of measurable point the higher described procedure recurs and the middle estimation of approximate values of co-ordinates and their dispersions is determined on the basis of results of the stage of preliminary estimate and stage of additional estimation.

Conclusion

Realization of the offered method will provide the grant of objective information about parameters and descriptions of the navigation-sentinel field which is formed by the systems of GPS/ГЛОНАСС/GALILEO and them by differential additions.

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THE ALGORITHM OF AVAILABILITY DETERMINATION OF NAVIGATION SATELLITES ON A FLIGHT PATTERN

Availability is the probability that a navigation system meets the accuracy and integrity requirements.

The initial data of forecasting of availability are existential coordinates of the aircraft and nanosecond. For reception of existential coordinates of the aircraft it is possible to use Flight plan or specialized program Jeppesen. The initial data of existential coordinates of navigating satellites are the almanac which is possible for receiving from the satellite navigating receiver or from logic files of the almanac from sites of providers of navigation systems.

In connection with that the almanac is given on the certain moment of time (Time of Applicability) the algorithm of prediction provides calculation of coordinates at the moment of time corresponding to existential coordinates of the aircraft.

The coordinates of satellites is calculation accordingly interface monitoring documents GPS and GLONASS. Existential coordinates of the aircraft are set in geographical coordinate system (B, L, h, t -a latitude, a longitude, an altitude, time), and the almanac of navigational satellites in orbital and geocentric coordinate system ($e, t_{oa}, i_o, \dot{\Omega}, \sqrt{A}, \Omega_o, \omega, M_o$ -an eccentricity of orbit, time on which created almanac, inclination of orbit, speed of change of right ascension, root square of the aircraft of orbit, a longitude of an ascending node of orbit, argument of a perigee of orbit, mean anomaly).

In this connection at calculation of geometrical factors it is necessary to use the general coordinate system as such geocentric mobile coordinate system ECEF can be used. After definition of aircraft and satellites coordinates in coordinate system ECEF visual range angles of satellites concerning the consumer in coordinate system the east - the north - a normal to a tangent plane in a point of arrangement of the consumer are determined, the basic geometrical factors of accuracy depreciation are estimated.

Then with the help to values of factors accuracy depreciation is determined the ability to use of satellite navigation, as source of the navigating information.

The generalized definition algorithm GNSS availability is resulted in figure 1.

Let's consider algorithm of availability definition of navigational satellites on flight pattern of the aircraft on equal interactions of input units and initial data (databases), program modules and the basic program functions of a hardware-software complex of availability definition.

For availability definition CHC on flight pattern of the aircraft it is necessary to develop the following basic algorithms and functions:

- Algorithms of transformation of coordinates: algorithm of transition from absolute coordinate system to systems WGS-84 and the Software 90 and back, algorithms of transition in topocentric coordinate system, algorithms of transition from coordinate system WGS-84 in the Software 90 and back;

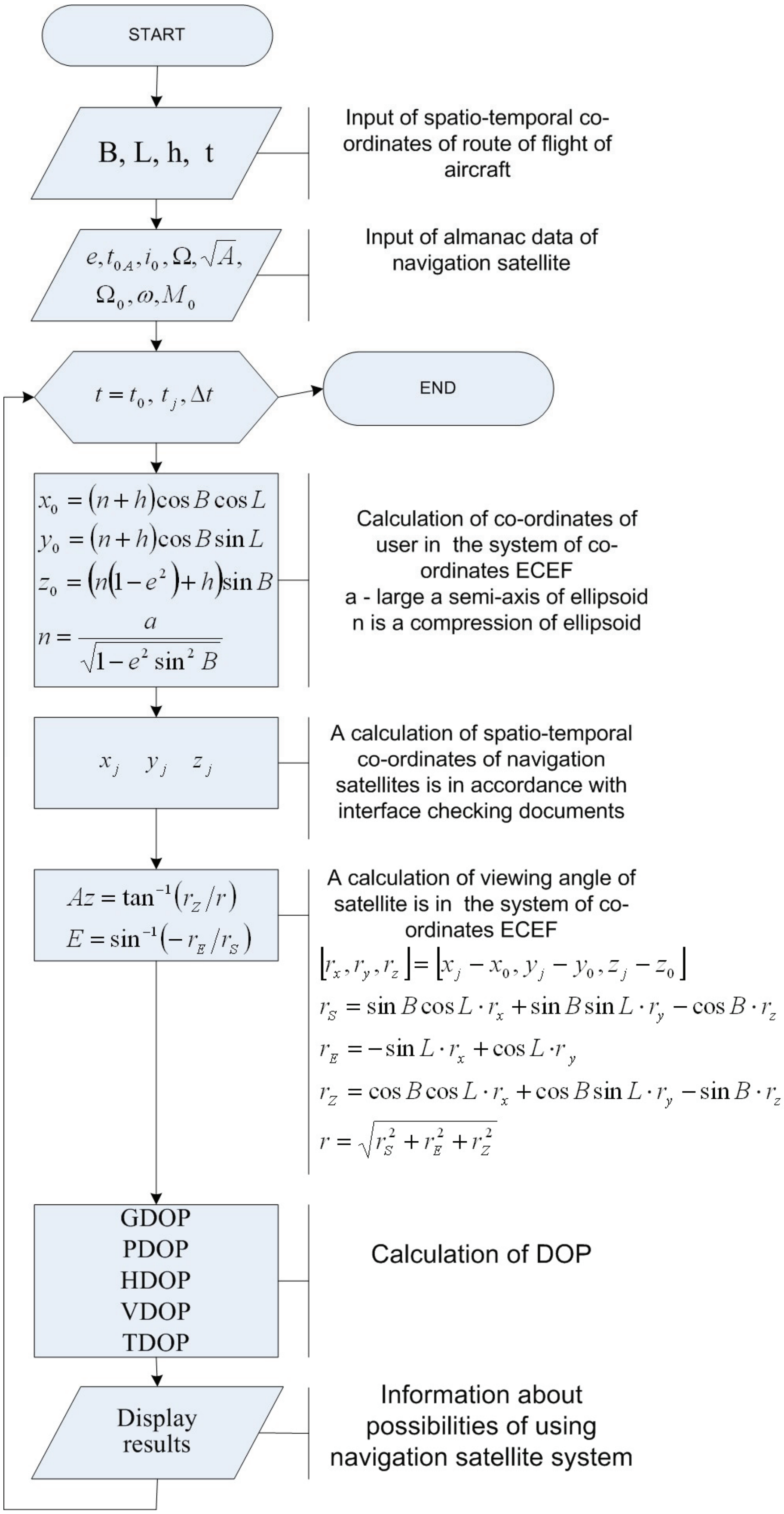

Fig. 1 The generalized definition algorithm GNSS availability

- Calculation algorithms of coordinates of navigational satellites GPS and GLONASS on any moment of time;

- Algorithms of timing GPS and GLONASS systems, and the apparent sidereal time on greenwich meridian;

- Calculation algorithms of ionospheric correction;

- Calculation algorithms of coordinates user, geometrical factors, visual range angles of navigational satellites GPS and GLONASS.

Besides it is necessary to realize as programs a series of specific methods, in particular a method of least squares, Runge-Kutta method, solving systems of nonlinear and linear problem methods, etc.

Control of separate program modules in algorithm complex of availability definition to realize the control program which displays operation algorithm complex of availability definition.

The time scale to which GPS signals are referenced is referred to as GPS time. GPS time is derived from a composite or "paper" clock that consists of all operational monitor station and satellite atomic clocks. Over the long run, it is steered to keep it within about $1\mu s$ of UTC, as maintained by the master clock at the U.S. Naval Observatory, ignoring the UTC leap seconds. At the integer second level, GPS time equalled UTC in 1980. However, due to the leap seconds that have been inserted into UTC, GPS time was ahead of UTC by 10 s in April 2000.

The parameters needed to calculate UTC from GPS time are found in subframe 4 of the navigation data message. This data includes a notice to the user regarding the scheduled future or recent past (relative to the navigation message upload) value of the delta time due to leap seconds Δt_{LSF}, together with the week number WN_{LSF} and the day number DN at the end of which the leap second becomes effective. The latter two quantities are known as the effectivity time of the leap second. "Day one" is defined as the first day relative to the end/start of a week and the WN_{LSF} value consists of the eight least significant bits (LSBs) of the full week number.

Three different UTC/GPS time relationships exist, depending on the relationship of the effectivity time to the user's current GPS time:

1. First Case. Whenever the effectivity time indicated by the WN_{LSF} and WN values is not in the past relative to the user's present GPS time, and the user's present time does not fall in the timespan starting at $DN + \frac{3}{4}$ and ending at $DN + \frac{5}{4}$, the UTC time is calculated as:

$$t_{UTC} = \left(t_E - \Delta t_{UTC}\right) \ (\text{mod}\,ulo \ \ 86400)s\,, \tag{1}$$

where Δt_{UTC} is in seconds and

$$\Delta t_{UTC} = \Delta t_{LS} + A_0 + A_1\left[t_E - t_{0t} + 60.4800(WN - WN_t)\right]s\,, \tag{2}$$

where

$t_E =$ user GPS time from start of week (s);

$\Delta t_{LS} =$ the delta time due to leap seconds;

$A_0 =$ a constant polynomial term from the ephemeris message;

$A_1 =$ a first-order polynomial term from the ephemeris message;

$t_{0t} =$ reference time for UTC data;

$WN =$ current week number derived from subframe 1;

$WN_t =$ UTC reference week number.

The user GPS time t_E is in seconds relative to the end/start of the week, and the reference time t_{0t} for UTC data is referenced to the start of that week, whose number WN_t is given in word eight of page 18 in subframe 4. The WN_t value consists of the eight LSBs of the full week number. Thus, the user must account for the truncated nature of this parameter as well as truncation of WN, WN_t and WN_{LSF} due to rollover of the full week number. These parameters are managed by the

GPS control segment so that the absolute value of the difference between the untruncated WN , and WN_t values does not exceed 127.

2 Second Case. Whenever the user's current GPS time falls within the timespan of $DN+\frac{3}{4}$ to $DN+\frac{5}{4}$, proper accommodation of the leap second event with a possible week number transition is provided by the following expression for UTC:

$$t_{UTC} = W \quad [\mathrm{mod}\,ulo\,(86.400 + \Delta \mathrm{t}_{\mathrm{LSE}} - \Delta t_{LS})] \quad s, \tag{3}$$

where

$$W = (t_E - \Delta t_{UTC} - 43.200) \quad (\mathrm{mod}\,ulo\ 86.400) + 43.200 \quad s, \tag{4}$$

and the definition of Δt_{UTC} previously given applies throughout the transition period.

3. Third Case. Whenever the effectivity time of the leap second event, as indicated by the WN_{LSF} and DN values, is in the past relative to the user's current GPS time, the expression given for t_{UTC} in the first case above is valid except that the value of Δt_{LSF} is used instead of Δt_{LS}. The GPS control segment coordinates the update of UTC parameters at a future upload in order to maintain a proper continuity of the t_{UTC} time scale.

Conclusion

Using this algorithm it is possible to realize as programs a series of specific methods, in particular a method of least squares, Runge-Kutta method, solving systems of nonlinear and linear problem methods, etc.

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MAINTENANCE OF QUALITY OF SERVICE IN THE COMMUNICATION NETWORK OF THE FOLLOWING GENERATION

The review of a communication network of following generation (NGN) is done, also specifications and advantages of NGN ore explained. The analysis of mechanisms of maintenance of quality of service is carried done. The model of the Network with connection and without a connection is researched.

In the beginning of XXI-st century radical changes of those conceptual positions which define the basic directions of the subsequent development of telecommunication system have begun. The idea of construction known on abbreviation NGN (Next Generation Network) was generated. The majority of experts consider idea NGN as the cleverest concept of the subsequent development infocommunicational systems - to telecommunication and computer science symbiosis. There are some basic features and advantages: decreasing the working costs; Networks NGN give the opportunity to realize new services which are sources of additional incomes; scalability; possibility of granting of package deals; decreasing the expenses counting on port; standard interfaces are opened; Possibility of introduction of the new services created by extraneous suppliers; simplicity of installation and network service; consolidation of networks; VoIP-telephony; voice mail; IP-Centrex, virtual private networks; Date transmission services, multimedia services, video conferences, the home manager; services of system of the interactive language answer, the virtual reality is distributed; an instant messaging; the unified exchange of messages; services of the contact center; interactive games and others.

Introduction NGN at the aviation enterprises can provide a number of value added services, provide high speeds of data sending, operative reaction and intervention which will raise safety of flights.

Theoretically concept NGN can be realized in development of any network of telecommunication maintained: telephone, a data interchange, a cable television. It is hypothetically possible to consider idea of creation of one more - new - a network completely corresponding to concept NGN. However from the practical point of view interest represents only that way of construction NGN which is based on purposeful development of a telephone system of the general using (TSGU). At construction NGN it is necessary to consider a number of specific properties of system of telecommunication. Among changes in TSGU it is necessary to allocate transition to package technologies of transfer and the switching, new principles of construction of the network, which working out stimulating. One of the major tasks, promoting formation and realization of these principles, - working out of methods of calculation of characteristics which allow to analyze quality of service of traffic in NGN as a whole, and also in its separate fragments.

NGN shows the universal multi-purpose network intended for transfer of language, images and the data with use of switching of packages. At a transition stage to NGN there is a number of the tasks, one of which, a choice of a principle of upgrade TSGU, the analysis and calculation of characteristics of quality of service of traffic in NGN.

CHARACTERISTICS OF QUALITY OF SERVICE OF TRAFFIC IN NGN

As network NGN is based on principles of transfer of packages the IP-technology, mechanisms of support of quality of service QOS, the transfer environment; reliability of the switching equipment will be primary factors which define reliability of a network, but other. One of primary factors for NGN networks are support of quality of service of users, after all it is one of the major qualities NGN.

Mechanisms of QOS support

The basic mechanisms of QOS support (Quality of Service) is:

1. Packet data transmission.

NGN as the network with switching of packages responds model of system with expectation (RMSC responds model of system with loss of calls). The demand which has arrived at the moment of employment of all channels, will not leave system, and will be put in turn. Time of clearing of system to start processing of the demand from turns is less, than time necessary on recall of services. Besides, packet voice spends a pass-band much more prudently - at silence of subscribers the information is not transferred.

2. Presence of "a time stock".

The measurements done by experts of the International union of telecommunication (IUT) and the European institute of telecommunication standards have shown that the delay results in decrease in quality of telecommunication from above 150 ms. Let’s designate time of delivery of the information in a network from the site And to the site B. Then the hour stock is a difference between critical time of delivery of the information to the subscriber and real time of passage of packages through a network:

$$Ts = T_{cr} - T_0 .$$

The hour stock which in traditional communication networks is despised, in NGN is given to other additions that as a whole is well reflected in parameters QOS.

3. Physical and logic branch of transfer and routing of packages from devices and logicians of management of services. Given the architectural decision allows using unique program intelligence of processing of calls for networks of different types (traditional, package, hybrid) with different formats of language packages and with different physical transport, and also raises degree of controllability processes and in parameters QOS in a network of following generation.

4. The application of limiting controllers of sessions SBC (Session Border Controller). The given device is focused on a considerable quantity of services of real time (video, multimedia, Instant Messaging), realized in Ip-net, and involved for tracing of merit figures of service in NGN. To traffic which is passed through SBC, service quality management, is provided with safety, a pass-band. For interaction of networks simultaneous use of both kinds of the equipment - Softswitch and SBC is necessary.

5. Technology use multiprotocol switching on labels MPLS (Multiprotocol Label Switching). Technology MPLS is focused on routing process optimization traffic so that to provide as much as possible favorable combination of all mechanisms QOS involved in a network. Routing process is replaced with process of switching which is carried out on the basis of labels. Essential improvement of quality of work (audio and the video information is transferred by switchboards MPLS with accuracy, comparable work with results from direct connection) is reached for instructions in a label of carrying capacity which should be reserved.

Function MPLS Fast Reroute that operatively reacts (no more than for 50 ms) on breakages of communication and resends information highways on safe sites of a network, does NGN more reliable, than networks SDH.

Definition of characteristics of quality of service

It is necessary to notice that RMSC, the network with switching of channels, is reference at an estimation of quality of transfer of language in other networks. To improve quality of service there were technologies which emulate switching of channels in a network with switching of packages. Report TCP of stack IP and reports SIP, H.323, Megaco/H.248, MGCP which operate audio- and video conferences and provide interaction between devices NgN-nets, is the reports focused on an establishment of connection.

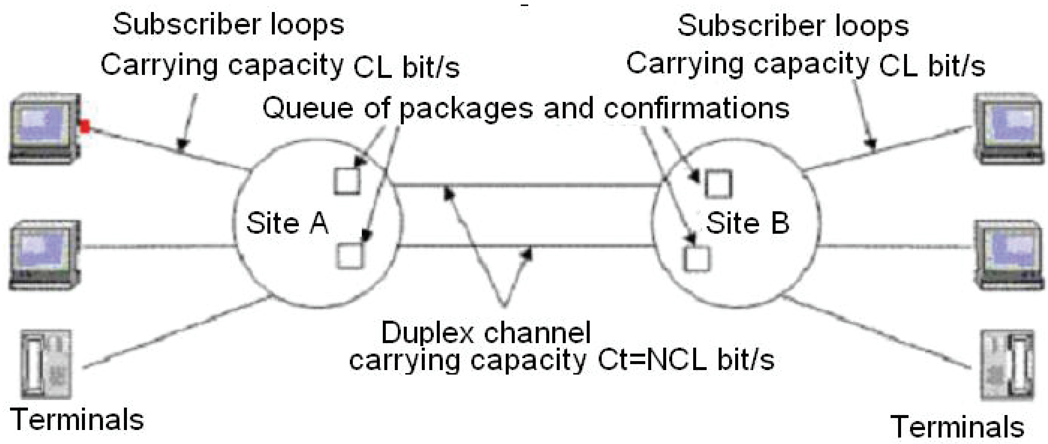
The carried out analysis of different researches allows drawing a conclusion that normalized time of a response of a network is one of important parameters of quality of service for networks with switching of packages.

For research and the analysis of normalized time of a response of a network, it is necessary to untie following tasks: to construct model of a network with switching of packages; to investigate normalized time of the answer for networks with an establishment and without an establishment of connection and different ways of transfer of confirmations; to investigate dependence of normalized time of the answer on a parity between length office and information water a package.

Network without a connection.

On pic. 1 we see the fragment of a network. We will designate intensity of a stream in the entrance site, carrying capacity of the duplex channel between sites where the size defines the maximum speed of access to the site. Two scenarios of transfer of acknowledgement are possible:

1. Confirmations are transferred in separate packages;
2. Confirmations are transferred in special fields of information packages of a backward direction.



Pic. 1 Model of a network with switching of packages without a connection.

Let's put the task to find average time of a response from the site to the site, as loading function in a network, lengths of office and information packages and intensity of message transfer.

In the first case time of a response of a network will consist of lag time in turn of an information traffic of the site A, lag time in turn of a stream of acknowledgement of the site B, average time of transfer of an information package (considering the title) and transfer time.

In the second case time of a response of a network will decrease for a waiting time in turn of time of transfer of a stream of confirmations (in the form of absence such).

$T_D = t_m + 2t_h + 2W$

Where - average duration of transfer of information fields of packages;

t_h- Duration of transfer of office fields of packages and packages of a stream ofconfirmationst;

W - average value of expectation of a package which in system of type M/G/1 is defined under the formula of Poljacheka-Hinchina and depends on the second moment of distribution of a holding time.

Network with a connection.

This network is built on model M/M/n. Also as well as in a network without a connection two cases are possible:

1. The stuff information necessary for an establishment of connection, is transferred on the same channel, as the data;
2. The stuff information is transferred on the separate channel.

Generally time of an establishment of connection of the site A with the site B (from the moment of transfer of the message of inquiry by the time of acceptance of the message on the transfer beginning) consists of a parcel of a call the site A - expectation of clearing of the channel which is defined by times taking into account the second formula of Erlanga and the formula of Littla. - The site message In about reception of a parcel of a call - parcels the site In the message on readiness for connection - and answers of the site A about message reception-.

$$T_c = 4T_S + W .$$

It is necessary to consider that a waiting time of service for system with transfer alarm Information from the separate channel will be less, than for system with transfer alarm and a pay load on one channel at the expense of absence of expectation of clearing of the channel from alarm messages. Applying the technique described above, we will find normalized time of a response as:

- For model with transfer office and the helpful information on one channel

$$\frac{T_C}{T_M} = 4k + \frac{(8k+1)*C(N,A)}{N(1-\rho_M(1+8k))}, \tag{1}$$

- For model with transfer of the office information on the separate channel

$$\frac{T_C}{T_M} = 4k + \frac{C(N,A)}{N(1-\rho_M)} \ . \tag{2}$$

As well as in the previous case we will examine situations when the relation of volume of the office information to the useful is 0,1.

The limiting factor of useful use of the channel for each system can be

Found from living conditions (1) and (2):

- In the first case:

$$\rho_{M_{MAX}} = \frac{1}{1+8k} \tag{3}$$

At k=0.1 M=0.56;

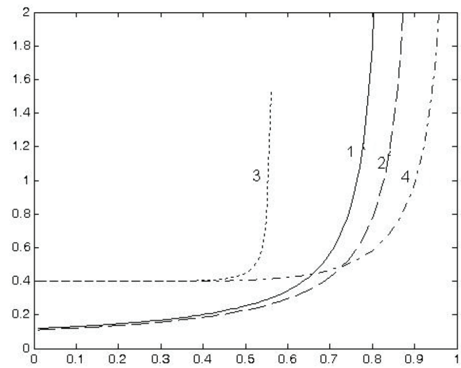
In the second case:

$\rho_M = 0.999$,

At any k.

Dependences are brought on picture 2.

Despite of that the system with a connection has a bit worst parameters, than system without a connection, at the first increase in factor of useful use of the channel (that is the increase in loading at the channel) does not increase time of a response which does this system of the priority multimedia information for pass to networks NGN.



Pic 2. Normalized time of response of packet net with k=1

1 - Confirmations in model without a connection establishment are transferred by a separate stream;

2 - Confirmations in model without a connection establishment are transferred in special fields of information packages of a backward direction;

3 - Stuff information necessary for an establishment of connection is transferred on the same channel, as the data;

4 - The stuff information necessary for an establishment of connection, is transferred on the separate channel.

Character of a curve which responds a network with a connection establishment, shows that at increase in loading time of a response of a network does not increase. Therefore such network is capable to satisfy requirements multimedia traffic to a delay.

Thus, network NGN provides high quality of transfer of all types traffic, optimizing its distribution to real time and considering pass-band reservation, carrying capacity and current loading of channels, traffic priority.

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ALGORITHM OF DEFINITION OF ZONES OF SERVICE OF ACCESS POINTS OF STANDARD IEEE 802.11

Presented algorithm of calculating the areas of service access points, the standard IEEE 802.11.It allows you to effectively design the location of access points for construction of local networks Wi-Fi.

Article purpose is minimization of expenses on construction of a wireless network by definition of radius of zones of service of points of access to resources of network Wi-Fi for the set amount of subscribers in which limits necessary level QOS is provided. It is necessary to construct mathematical model of distribution of radio-waves within many-stored buildings and on the basis of this model to develop a technique of definition of radius of zones of service of points of access to resources of network Wi-Fi. By working out of the given model to consider following factors: quantity and character of obstacles within a building, ambient temperature, speed of the data through a network, quantity of subscribers, capacity of the transmitter of a point of access and sensitivity of the receiver of the equipment of subscribers of a network.

In the process of the analysis of existing theoretical materials and practical researches the conclusion has been drawn on expediency of use within the limits of the given task of model of distribution of radio-waves indoors that offered in [2]. This model is named as model the House for internal to the scenario of distribution of electromagnetic radiation (when the receiver and the transmitter are located within a many-stored building). The given model describes radio signal attenuation on a way of distribution of radio-waves within buildings; however it is fair only for a range of frequencies to 2 GHz.

Analytical expression for model the House generally has the following appearance:

$$L = L_{fc} + L_c + \sum h \cdot L_{\omega i} + k_f^{\frac{k_f + 2 - b\times(k_f+1)}{k_f+1}} \cdot L_f \,, \tag{1}$$

Where:

$L_{fc}L_{fc}$ - loosing of distributions to a free space;

$L_c L_c$ - Constant losses (it is defined experimentally);

$k_f k_f$ - Amount of finished levels on a distribution way;

$L_{\omega i} L_{\omega i}$ - Losses on a wall type i (where i - type of a building material of a barrier);

$L_f L_f$ - Losses between adjacent surfaces;

b - empirical parameter (b=0,46 [2]).

Quality of service of subscribers QOS essentially depends on speed of processing, quantities of wrongly accepted packages, reliability of connection with a point of access [1]. But the given characteristics are defined by level a signal/noise on a receiver input. The more this relation, the less packages are deformed and higher speed of processing the data through a network probably to provide.

The relation a signal-noise has the big practical value from the point of view of support stability, as speed of occurrence of erroneous bits is descending function of the given relation [3]. It is necessary to notice that for preservation of necessary value a signal-noise at fall forward of date transmission R it will be necessary to increase capacity of a signal of the transmitter of a point of access.

In networks of standard IEEE802.11g transmitters change modulation type simultaneously with falling of the relation a signal-noise during communication system functioning in such a manner that speed of processing the data decreases and the relation a signal-noise raises automatically .

In the following frame the data concerning speed of processing and type of modulation which are normalized by specifications of technology IEEE802.11g [4] :

Table 1

Parameters of the transmitter of standard IEEE 802.11g

Speed of Date transmissions (Mbit/s)	Modulation type	Speed of convolutional codings	Number of channel bits on subbearing	Number of channel bits on a symbol	Number of bits of the data on symbol OFDM
6, (9)	BPSK	1/2, (3/4)	1	48	24, (48)
12, (18)	QPSK	1/2, (3/4)	2	96	48, (72)
24, (36)	16-QAM	1/2, (3/4)	4	192	96,(144)
48, (54)	64-QAM	2/3, (3/4)	6	288	192, (216)

According to table 1, depending on speed of processing the data through a network, in actual practice equipment uses is chosen automatically by corresponding type of modulation, and, hence, changes the relation a signal/noise on necessary [3,4].

For capacity of a signal:

$$S = P_{c/ш} \cdot kTR, \quad (2)$$

Or in decibels:

$$S_{дБ} = 10\lg(P_{c/ш} \cdot kTR) \quad (3)$$

On the other hand, capacity of a signal on a receiver input is defined as

$$S_{дБ} = P_{прд} - L \quad (4)$$

$$S_{дБ\min} = P_{прм\min},$$

- Sensitivity of the receiver.

Substituting (1) in (4), we have:

$$S_{дБ} = P_{прд} - \left[32{,}4 + 20\log\left(\frac{d}{1000}\right) + 20\lg(f) + L_c + \sum \frac{h_i \cdot k_i}{\cos(\alpha_i)} + k_f^{\frac{k_f + 2 - b\times(k_f+1)}{k_f+1}} \cdot L_f\right] \quad (6)$$

Having considered (5), we get:

$$10\lg(P_{c/ш} \cdot kTR) = P_{прд} - (32{,}4 + 20\log\left(\frac{d}{1000}\right) + 20\lg(f) + L_c + \sum \frac{h_i \cdot k_i}{\cos(\alpha_i)} + k_f^{\frac{k_f + 2 - b\times(k_f+1)}{k_f+1}} \cdot L_f) \quad (7)$$

From expression (7) by elementary transformations of algebraism it is received:

$$d = 10^{\frac{P_{прд} - \left[32{,}4 + 20\lg(f) + L_c + \sum \frac{h_i \cdot k_i}{\cos(\alpha_i)} + k_f^{\frac{k_f + 2 - b\times(k_f+1)}{k_f+1}} \cdot L_f + 10\lg(P_{c/ш} \cdot kTR)\right] + 30}{20}} \quad (8)$$

Thus, for the maximum radius of a service zone:

$$d_{\max} = 10^{\frac{P_{прд} - \left[32{,}4 + 20\lg(f) + L_c + \sum \frac{h_i \cdot k_i}{\cos(\alpha_i)} + k_f^{\frac{k_f + 2 - b\times(k_f+1)}{k_f+1}} \cdot L_f + 10\lg(P_{c/ш} \cdot kTR_{\min})\right] + 30}{20}} \quad (9)$$

In expressions (8) and (9) following designations are accepted: $P_{прд} P_{прд}$ - Capacity of the transmitter of a point of access:;

$L_c = 35 - 37$ dBm - constant losses;

f - nominal frequency of working range for concrete system;

Ps/sh - The necessary relation a signal-noise on a receiver input;

k=1,38h10-23 Dzh/to - constant of Boltzmann;

$h_i h_i$ - thickness of i barrier;

$k_i k_i$ - Attenuation factor of i barriers;;

$\alpha_i \alpha_i$ - A corner between a beam of falling of a radio-wave barrier and the normal lead to the given barrier;;

$k_f k_f$ Amount of passed adjacent surfaces by the radio-wave;;

$L_f L_f$ - Losses on passed adjacent surfaces for the set frequency range;;

T - absolute temperature in Calvin (average temperature in premises under normal conditions T = 20°C = 293K);

Rmin - is minimum admissible speed of transferrableness of the data for the exact application.

The relation a signal-noise gets out of expressions which are received for probabilities of errors depending on type of modulation and the coding of the information [3].

As much as possible admissible probability of errors is usually displayed in the documentation to concrete device Wi-Fi.

On the basis of the received results that stated above, the algorithm of calculation of radius of a zone of service of a network of standard IEEE 802.11 (fig. 2) is developed.

In the given algorithm of definition of necessary value the signal/noise is carried out by external transformations from expressions for values of probability of occurrence of a bit error for the set kind of modulation (BPSK, QPSK, 16-QAM, 64-QAM)..

Conclusions

Thus, in the course of researches the algorithm of calculation of the maximum radius of a zone of service of a point of access Wi-Fi within premises which considers the minimum admissible speed of processing the data, type of modulation which is used thus, temperature of premises, losses on overcoming of adjacent surfaces, the obstacles of a different thickness made of a different material, capacity of the transmitter and sensitivity of receivers, and also quantity of subscribers which have got access to a network has been developed.

The given model gives the chance to calculate amount of subscribers of a network which are in radius of a zone of service of points of access of network Wi-Fi.

The developed model gives possibility to spend optimization of a wireless segment of corporate networks, and also small local networks behind criterion of a minimum of expenses on network expansion.

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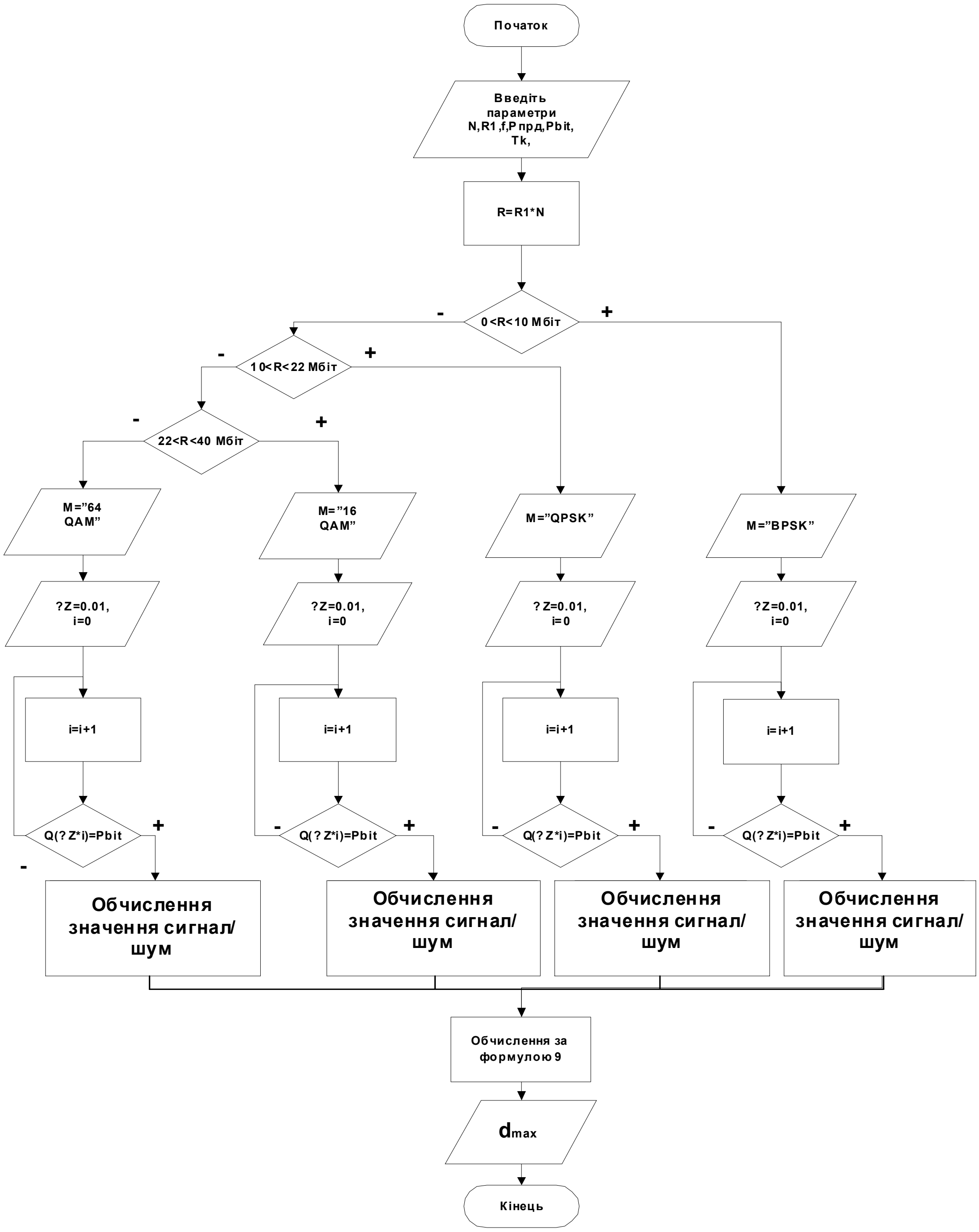

Fig. 1. Algorithm of calculation of the maximum radius of a zone of service of a point of access of standard IEEE 802.11

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CALCULATION OF RADIUS OF ACTION OF HIDDEN RADIO-TRANSMITTING DEVICES

In given article the technique of calculation of radius of action of radio mortgage devices in many-stored premises with a considerable quantity of obstacles is brought

In article materials «Modeling of technical channels of information leakage in office accommodations» [1] mathematical models of laws of change of level of signals which are information mediums with fixed access have been examined, different models of diffraction (different scenarios of distribution) are constructed, main principles, approaches and restriction at construction of mathematical laws of change of level of signals and the made answers calculations are generated.

In the course of the analysis of theoretical materials and practical researches there was a developed model of distribution of radio-waves indoors - model the House for internally internal to the scenario of distribution of electromagnetic radiation. This model almost completely describes radio signal attenuation on a way of distribution of radio-waves, however there are considerable lacks as it is not fair for all range of frequencies. Analytical expression for modernized model the House in a general view has the following appearance:

$$L = L_{fc} + L_c + \sum h \cdot L_{\omega i} + k_f^{\frac{k_f + 2 - b \times (k_f + 1)}{k_f + 1}} \cdot L_f, \quad (1)$$

Where:

$L_{fc} L_{fc}$ - Losses in a free space;

$L_c L_c$ - Constant losses;

$k_f k_f$ - Amount of passed levels;

$L_{\omega i} L_{\omega i}$ - Expenses type i wall

$L_f L_f$ - Losses between adjacent surfaces

b - empirical parameter.

In a problem on improvement of the modified model the House the basic tasks were defined to loss factor between adjacent surfaces L_f,to loss factor in a wall of type and, angular to loss factor at passage through obstacles. For each exact case it was necessary to make necessary experiments. However working out of a technique of definition of a controllable zone generally was the purpose of the given work.

Conditions of distribution of radio-waves indoors much more difficult, than in a free space.

First, through presence of walls and massive subjects of a life. Walls and wooden overlappings, synthetic materials make low impact on distribution of radio-waves; obstacles from glass, a brick, concrete - average; Ferro-concrete and walls with foil heater is high. Metal walls and overlappings essentially influence range, leading at a given time to full loss of connection. Influence non-capital drywalls - from low to very high depending on a lattice design in its basis is ambiguous - and in some cases can fluctuate at humidity change indoors.

Secondly, interference character of an electromagnetic field in premises (at the expense of reusable reflection from subjects) is expressed more sharply. There is it in reduction of intensity of a field and to change of an initial plane of polarization of waves.

In most of premises it is possible to face with so-called "dead zones" in which signal reception is the complicated. Such situation is possible, even if the transmitter and the receiver are in direct visibility. Formation of "dead zones" is connected by that a signal to pass on ways of different length, being reflected from metal objects, such as steel designs, concrete walls, metal doors, windows, ceilings and so on "Dead zone" appears, if lengths of ways of distribution effectively disperse on unpaired amount of half waves. But «absolutely dead zones» usually very local and can be eliminated by small moving of aerials of the receiver or the transmitter.

Theoretically it proves to be true parity:

$$\frac{E_b}{N_0} = \frac{S/R}{N_0} = \frac{S}{kTR} \tag{2}$$

Where - the relation a signal noise, S - capacity of a signal, R - transit velocity of the data, T - the temperature in Calvin, k=1,3803*10 - became Boltzmann.

It is known that in a free space capacity of electromagnetic waves decreases as distance in a square between the transmitter and the receiver or in the linear form, attenuation in a free space is described by the formula:

$$L_{fc} = \frac{\lambda^2}{4\pi d^2} \tag{3}$$

The equation can be written down also in the logarithmic form:

$$L_{fc} = -32{,}4 - 20\log(\frac{d}{1000}) - 20\lg(f) \tag{4}$$

Where - losses in a free space; - distance between the transmitter and the receiver, in meters; - frequency of a signal, at MHz

For the majority of cases taking into account all parameters we can average that value dB

From expression (2). we have expression for capacity of a signal:

$S = P_{c/ш} \cdot kTR$, In decibels:

$$S_{дБ} = 10\lg(P_{c/ш} \cdot kTR) \tag{5}$$

On the other hand capacity of a signal on a receiver input:

$$S_{дБ} = P_{прд} - L \tag{6}$$

$$S_{дБ\,\min} = P_{прм\,\min}, \tag{7}$$

Where

- Sensitivity of the receiver.

$$S_{дБ} = P_{прд} - \left[32{,}4 + 20\log\left(\frac{d}{1000}\right) + 20\lg(f) + L_c + \sum\frac{h_i \cdot k_i}{\cos(\alpha_i)} + k_f^{\frac{k_f+2-b\times(k_f+1)}{k_f+1}} \cdot L_f\right] \tag{8}$$

Having considered (7), we have:

$$10\lg(P_{c/ш} \cdot kTR) = P_{прд} - (32{,}4 + 20\log\left(\frac{d}{1000}\right) + 20\lg(f) + L_c + \sum\frac{h_i \cdot k_i}{\cos(\alpha_i)} + k_f^{\frac{k_f+2-b\times(k_f+1)}{k_f+1}} \cdot L_f) \tag{9}$$

From expression (9) by elementary transformations algebraizm:

$$d = 10^{\frac{P_{прд} - \left[32{,}4 + 20\lg(f) + L_c + \sum\frac{h_i \cdot k_i}{\cos(\alpha_i)} + k_f^{\frac{k_f+2-b\times(k_f+1)}{k_f+1}} \cdot L_f + 10\lg(P_{c/ш} \cdot kTR)\right] + 30}{20}} \tag{10}$$

For the maximum radius of a zone of service we have:

$$d_{\max} = 10^{\frac{P_{прд} - \left[32{,}4 + 20\lg(f) + L_c + \sum\frac{h_i \cdot k_i}{\cos(\alpha_i)} + k_f^{\frac{k_f+2-b\times(k_f+1)}{k_f+1}} \cdot L_f + 10\lg(P_{c/ш} \cdot kTR_{\min})\right] + 30}{20}} \tag{11}$$

In last expression (11)

- Capacity of the transmitter of an access point

$L_c = 35 - 37$ dBm - constant losses;

f - frequency of working range for the concrete radio mortgage device;
Ps/sh - The necessary relation a signal-noise on a receiver input;
k=1,38h10-23 Dzh/to - there was Boltzmann;
And;
$h_i h_i$ - thickness of the i barrier;
$k_i k_i$ - Attenuation factor i barriers;
$\alpha_i \alpha_i$ - A corner between a beam of falling of a radio-wave to i barrier and the normal spent to the given barrier;
$k_f k_f$ - Amount passed adjacent surfaces by the radio-wave;
$L_f L_f$ - Expenses on passing of adjacent surfaces for set frequency range
T - absolute temperature in Calvin (average temperature in premises under normal conditions T = 20°C = 293K);
Rmin - is minimum possible speed of processing the data for a concrete case.

The relation a signal-noise gets out of expressions for probabilities of errors, depending on type of modulation and the information coding.

Hence, apparently from expression (11) for definition of a controllable zone of the radio mortgage device it is necessary for following sequence of actions to adhere:

1. Definition of amount and character of obstacles in a way of distribution of a radio signal;
2. Definition of descent angle of radio-waves to i obstacle;
3. Definition of conditions of distribution of radio-waves (absolute temperature, humidity and so forth);
4. Definition of minimum possible for a exact case of transit velocity of the data;
5. The Choice of working frequency;
6. Definition of the necessary relation a signal/obstacle on an input of a radio receiver that capacities of the transmitter;
7. Calculation of the maximum radius of a controllable zone of the hidden radio-transmitting devices

Conclusions

During lead and described above researches there was developed technique of an estimation of a controllable zone of the *hidden radio-transmitting devices* which work on different frequency in premises which considers physical conditions, transit velocity of the data, probability of an error, amount and character of obstacles. The developed mathematical model allows to spend with enough split-hair accuracy estimations of radius of action of radio devices in the conditions of city building. The given model also can be used by working out of actions from increase of protection in premises from unapproved loss of the information. One more application field of a technique is definition of radius of zones of service of base stations of specialized radio systems (for example, devices of standard IEEE 802.11 g). The stated material is a basis for c arrying out of experimental researches for confirmation of the given updating of model. Therefore in the chosen direction of this article it is necessary to consider the subsequent researches expedient.

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EFFECTIVENESS OF ADAPTIVE ARRAY UNDER INFLUENCE OF DIFFERENT INTERFERENCES

The researches have been conducted devoted to efficiency of suppression of sinusoidal and wideband interference. A variant of design of the adaptive antenna has been examined.

Great attention is paid to the problem of noise immunity of satellite navigation system from the beginning of its creation to the present time. Expert group of ICAO have reported, that countries, which implement GNSS for needs of aviation, should analyze the problem of influence of noise (interference) and to produce solutions for increasing of noise immunity.

The most effective way of suppression of noise today is application of adaptive antennas (AA) on base of the adaptive arrays. Construction of adaptive antenna essentially depends on a type of suppressed interference.

Studies which were conducted in this area are not enough described in the literature. This work is devoted to research of influence of frequency shift of sinusoidal and frequency bandwidth of noise-type interference on efficiency of their suppression.

The dependence of suppression ratio on change of frequency of a sinusoidal interference for two types of AA is under consideration.

Let’s model adaptive antenna with algorithms of definition of weighting coefficient on Wiener-Hopf.

$$W = \Phi^{-1} * \mathrm{S},$$

where W- vector of weighting coefficients, B - correlation matrix of interferences, S - vector of phasors of input signals, and according to the formula

$$W = \Phi^{-1} * \mathrm{B},$$

where Φ- matrix of phasors of amplitude-phase distribution of signals and interferences through the adaptive array, B - vector with unit elements for the signal lines and zero for the noises lines.

The coefficient of noise suppression for linear adaptive array is defined by expression

$$K_p = 20\lg G(\theta) - 20\lg G(\alpha),$$

where G(*) – directivity diagrams of AA in direction of angle of arrival of a noise θ, and signal α.

Initial data for the experiment. The number of adaptive array elements – 4, interelement distance – 0.2 m, bandwidth central frequency AA – f_0=1.5 GHz, noise-to-signal ratio – 30 dB, angle of arrival of noise – 50 degrees, angle of arrival of a signal – 20 degrees.

The frequency of the sinusoidal interference changes according to the expression:

$$f_1 = f_0 + \Delta * 10^6\, Hz$$

The results of modelling for the AA, according to (1) and (2), respectively, as variants A and B, are given in Table 1.

Table 1.

Δ / K_p	-10	-5	-3	-2	-1	0	1	2	3	5	10
A	-34	-34	-46	-57	-57	-54	-58	-58	-49	-51	-40
B	-50	-56	-60	-62	-66	-74	-82	-69	-64	-59	-52

Analysis of the data given in Table 1, shows that the suppression of sinusoidal interference while tuning out its frequency from f0,

- for AA of the variant B changes monotonically, and at the shift of 10 MHz decreases on 24 dB,

- for AA of the variant A the dependence Kp=F(d) is not monotonic and at the shift of 10 MHz Kp decreases on 20 dB,
- maximums of Kp for both variants are shifted relatively to f0, which can be because of to instrumental error in the simulation.

Now we investigate the influence of wideband operation of interference on effectiveness of adaptive array.

Let's represent the model of a wideband interference for *к* th channel of adaptive array in the form of

$$P\kappa = U_0 \sum_n \exp(-j\frac{2\Pi * d * k}{\lambda_n} * \sin\partial + Fn)$$

where U_0 – random normally distributed variable with parameters[μp,δp] , F_n – uniformly distributed random variable with parameters[].

Multiplier n is chosen from a row of numbers [-1,-2,-3,-5,0,1,2,3,5]. The combination of [-1,0,1] corresponds to the conditional frequency band B = 2 MHz, the full range – B = 10MHz.

The results of modelling are represented in Table 2. The taken data is similar to the first experiment.

Table 2.

B, MHz					
K_p, dB	A	-106	-97	-91	-85
	B	-70	-67	-65	-62

As it is seen from table 2, with increasing of wideband suppression of interference becomes worse, it is more noticeable for the variant A.

The monograph [4] contains an expression for the dependence of suppression coefficient K from the frequency band B for AA, synthesized with respect to the criterion of minimum of output interference power.

$$K = 1 - \sin^2(\Pi * B * Z)/(\Pi * B * Z)^2$$

K – ratio of powers at the input and on the output of AA, $Z = (d * \sin\theta)/c$, c - speed of light

The results of calculation according to (3) for θ = 50 deg are shown in Table 3.

Table 3.

B, MHz	2	4	6	10
K, dB	-61	-49	-45	-41

According to the data in Table 3 the coefficient of interference suppression decreases as frequency bandwidth of interference increases with steepness similar in the variant A.

Researches have shown that the efficiency of adaptive antennas decreases as with increasing the bandwidth of wideband interference, so as with biasing of the frequency of sinusoidal interference from the intermediate bandwidth of antenna array.

The transversal filters are used for increasing the effectiveness of AA in the presence of wideband interference. But this increases the number of elements that form the diagram.

Below is given the scheme of construction of AA with the spectrum analyzer and digital tunable filters (Fig. 1)

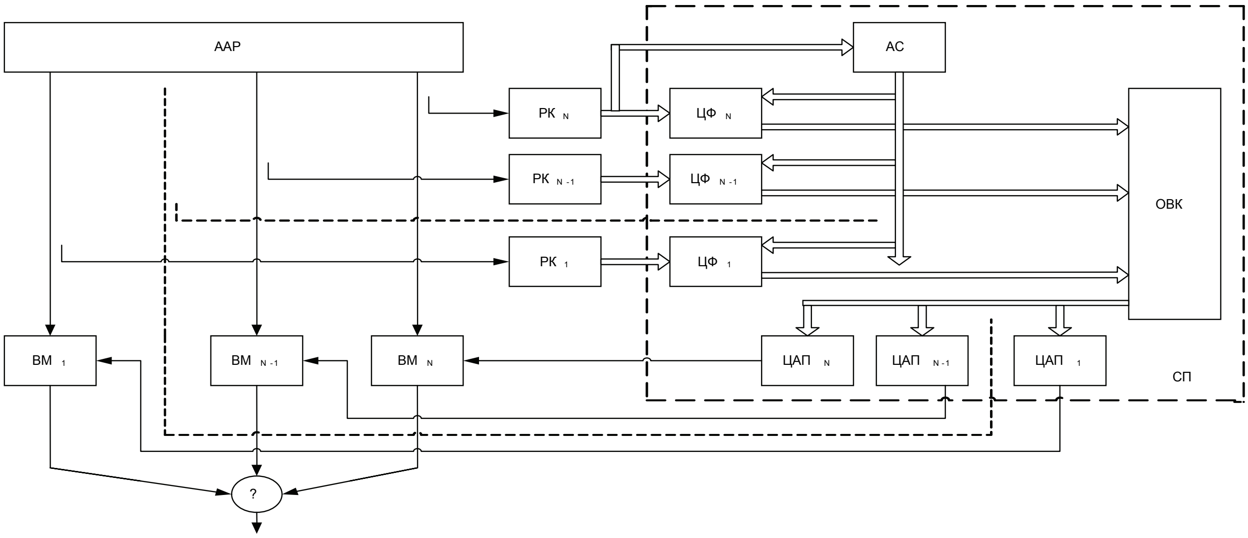

Figure 1. Adaptive array

AA consists of: radiochannels, vector modulators, computer of weighting coefficients, analog-to-digital converter, and signal processor.
Spectrum analyzer in the AA is used to regulate the frequency of narrow-band ADC.
For construction of spectrum analyzer with the help of program the FFT (fast Fourier transform) can be used. But, the frequency characteristic of individual bean of FFT has the form sin(x)/x, because of what its frequency bandwidth is not flat, the side lobes are significant, the main lobes of neighboring beans overlap. The level of side lobes can be reduced with the help of windows, but this leads to widening of the main lobe, and, hence, to the decrease in resolution ability.

Monograph (5) contains the solution of this problem. It is based on the following property of the RBF (range bandpass filter).

Let's consider the sequence x(n) of length M. It's M-points' RBF is equal to

$$X(n) = \sum_{n=0}^{M-1} x(n) * e^{\frac{-j2\Pi nm}{N}}$$

If to divide the sequence x(n) into P sub-sequences of length N and to add them element by element, we obtain a new sequence y(n) of length N. Its N-point RBF is equal to

$$Y(m) = \sum_{n=0}^{N-1} y(n) * e^{\frac{-j2\Pi nm}{N}}$$

$$|Y(m)| = |x(Pm)|$$

Using (4) we can formulate the principle of construction of a spectrum analyzer. Let's form the sequence x(k). Then weight this sequence with the help of a window. Now let's split the weighing sequence into P sub-sequences and generate the sequence y(n), and perform N-point FFT. The task consists in definition of values M, N, P and type of a window.
Let's perform modelling. Let's assume that the signal x(t) has carrier frequency 40 MHz and is digitized with the frequency 160 MHz.

Researches have shown, that the most acceptable model of spectrum analyzer is that with parameters M=5120, P=5, N=1024 and Hamming window.
The results of measuring the frequency of sinusoidal signal are shown in Table 4, where f – frequency of sinusoid, Δ – measurement error.

Table 4

f_z	35	36	37	38	39	40
		10,62	10,62	11,25	12,25	11,87
Δ	0,01	0,05	0,04	0,02	0,08	0,01

Adding of interference to a sinusoidal signal up to the level of 0 dB does not influence on the results of the analysis.
Figure 2 illustrates the resolution of two sinusoidal signals of frequencies 35 MHz and 37 MHz.

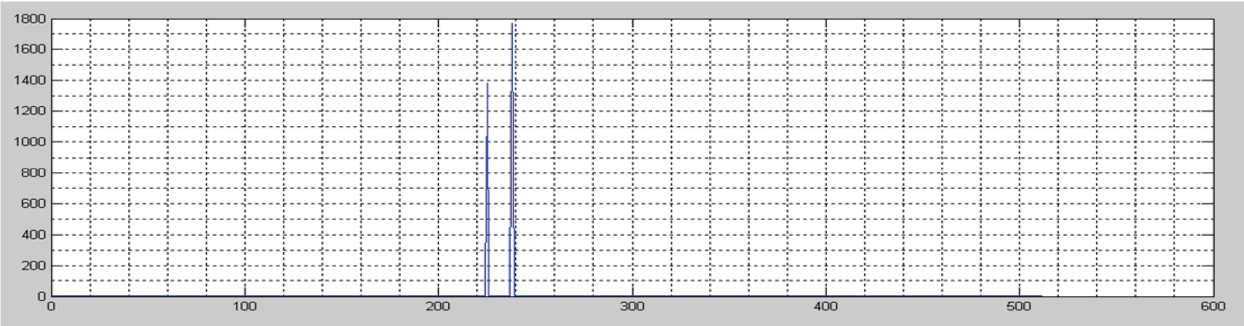

Figure 2.

Analysis of the received results shows that the principle of construction and parameters of spectrum analyzer provide the measurement of frequency of sinusoidal signal on the bandwidth of 10 MHz with an error 0.08 MHz and resolution of sinusoidal signals separated by frequency of 1 MHz, even in the presence of level of interference of 20 dB relatively to the level of the signal.

Comparison of principles of construction and characteristics of a bandpass filters shows that for the problem under consideration the digital filters with the final impulse characteristic (FIC) are the best solution.
This is primarily due to the fact that the FIC filters ensure linear PFC, which is the essence for an adaptive antenna. To another advantage of this filters we can add very low probability of overflow, the guaranteed stability, simple hardware handling.

The results obtained in the work [6] allow us to recommend the FIC filter of 25order, which should ensure the filter pass band of 2 MHz with an average frequency of 40MHz. Levels of the maximum ripples in this case should not exceed 0.018.
As shows the analysis the existing microelement baseline makes it possible to realise the spectrum analyzer and digital filter.

Conclusions

Experiments that were held showed the need for providing measures to improve the efficiency of adaptive antennas during the suppression of wideband and sinusoidal interferences.
The proposed principle of modification of adaptive antennas by introducing into their structure spectrum analyzer and tuneable digital filter will allow to increase the quality of interference suppression. Performed modelling of spectrum analyzer and analysis of construction of digital filter showed has shown the performability of the proposed approach.

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UDC 62.50

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THE APPROACH TO FORMATION OF INFORMATION-CONTROLLING SYSTEM STRUCTURE SYNTHESIS OF OPERATION SUPPORT OF DIFFICULT TECHNICAL SYSTEMS

The system approach to formation of a functional-structural level of the information-controlling systems intended for support of operation of difficult technical systems on the expanded interval of an operational stage of their life cycle is offered.

Difficult economic processes which flow in the economy of many countries of the world are reason of impossibility or they are not economic inexpediency of replacement of the morally old-fashioned difficult technical systems (DTS) on new. An objective necessity of the DTS use on the expanded interval of the operating stage of life cycle is consequence of it.

The basic measures, directed on the increase of duration of DTS operation without conducting of labor-consuming repairs (capital) repairs, it is been:

–introduction of progressive, economic advantageous strategies of DTS operation, basis of which are conceptual principles of exploitation on the state;

–researches on determination of capabilities of increase of the set terms of operation and elements operation time of DTS;

–modernization of DTS with the purpose of efficiency indexes increase;

–creation information-controlling system (ICS), automatically deciding the tracking tasks of DTS exploitation.

ICS, on the functional and structural characteristics, must answer requirements:

–to have effective control contours of reliability, and also of the parameters of the functional and technical state of DTS;

–to have an opportunity to carry out the forecast of change of technical and functional states of DTS;

–at formation of controlling influences to take into account the of long-life (slow) evolution processes of the technical and functional states of DTS on all of interval of the operating stage of their life cycle;

–to possess properties of flexible adaptation or invariance to the volumes changes of financing of the accompaniment system of DTS operation;

–to function continuously on all of interval of the operating stage of DTS life cycle;

–to provide the guaranteed controlling, allowing to arrive at the set indexes of functional efficiency of DTS.

Providing of effective work of ICS first of all depends on correctness and sufficiency structure of model kernel structure [1], which must include:

–integrated information models of DTS, reflecting their purpose;

–informative evolution models of the technical and functional states of DTS on all of interval of the operating stage of their life cycle;

–industrial and operating environment models.

The lacks of these models are their separation, passive and fragmentary character, inability to reflect the most general, fundamental laws of change of technical and functional state of DTS, in coordination with the of storage, operation and functional application of DTS [2].

Thus, there is a requirement in structure development of information-controlling systems of maintenance of DTS operating, based on single model formulation of dynamic evolutional processes, flowing on all of interval of the operating stage of life cycle of DTS.

Formalization consideration of the dynamic processes proceeding in classical technical system, leads to formation of the uniform approach to synthesis ICS for DTS on the basis of the description of changes in time of technical systems characteristics into account power components. Most full such description is given the canonical Hamiltonian differential equations system [2].

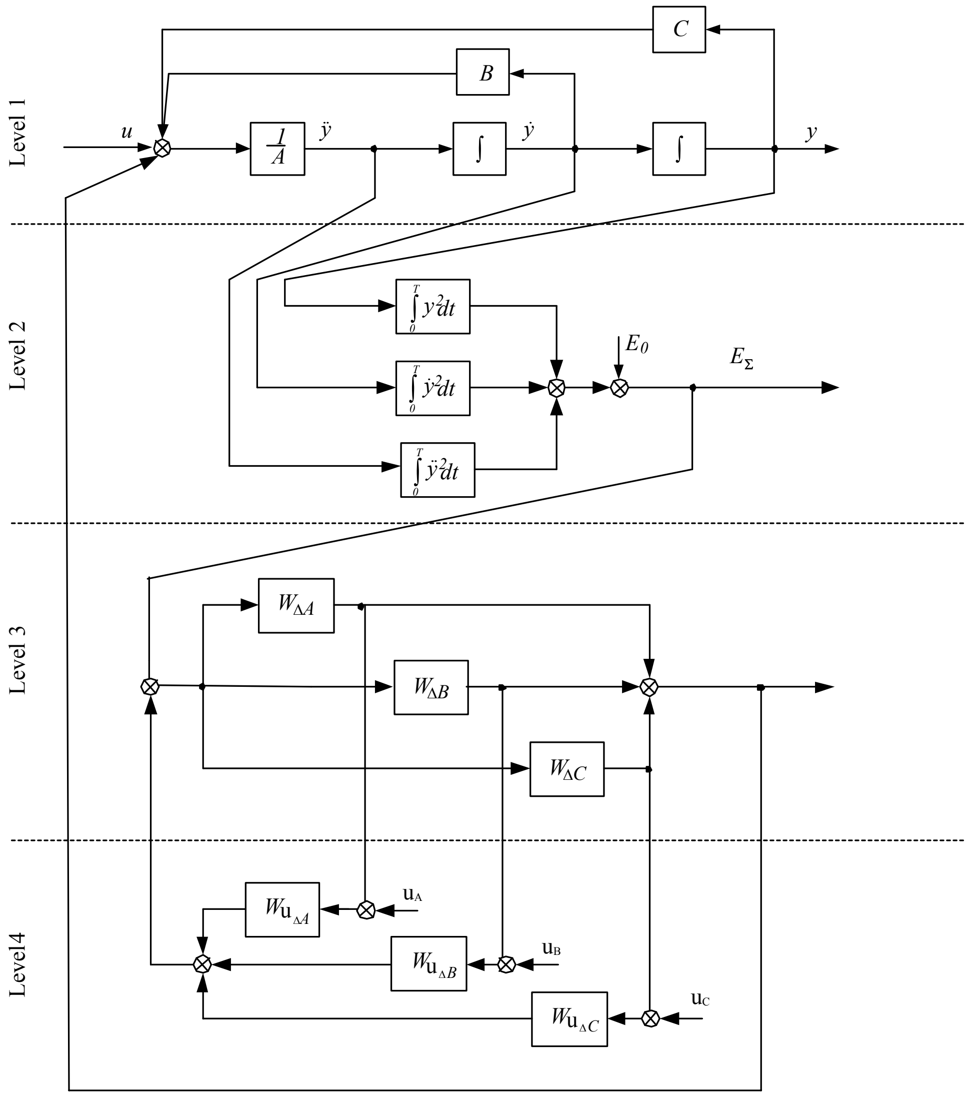

Fig. 1. ICS structural representation

The Hamiltonian equations system is easily led to initial form Koshy. By exception p this equations system the to be reduced to one equation of the second order.

The received equations are the system of usual differential second-order equations. Similar expressions can be easily got and for the systems, based on other physical principles: electric, electromagnetic, electromechanics et cetera. In case, expressions of coefficients A, B and C are accordingly dependences on kinetic, dissipative and potential energies coefficients. At the same time, these coefficients are functions of the parameters of DTS elements that Hamiltonian equations allow to connect together power and parametrical (informative) characteristics of evolutional processes, flowing in the technical system together.

The analysis of the received equations system shows that it can be as a structural fractal. As is known [4, 5], the basic fractals property is their structural invariance (self-similarity) at every level of DTS. Structural fractal, for example, for the system with three degrees of freedom, it is possible to as a flow diagram. However such representation does not give full understanding of evolutionary change processes of the technical and functional state, flowing in DTC.

For the elimination of this lack it is offered to expand state space, entering in the system model an additional level, reflecting power processes, flowing in DTS. Power influences on DTS can be divided on revolting and directed on support of their purpose functioning. In the process of DTS exploitation these processes cause the change of their physical parameters. At the use of classic chart of representation of structural fractal, the physical parameters change corresponds the coefficients increments g_{ij} of DTS elements model. Power level Addition results in structural fractal transformation in multipole. This structure can be transformed to more compact kind.

For DTS a power level can be represented as separate strata. Multidimensional vector of initial values of energy E_0 designed-in the DTS construction and vector of energy which is transformed in the DTS construction in the process of functioning by the operator $W_{E_0 y}$, go on its entrance. Total energy, producible DTS is the power strata return.

Power level introduction to the generalized dynamic DTS model allows to form the ICS structure, and also to define a role and place of controlling the technical and functional DTS state at its functioning on the complete interval of life cycle (fig. 1).

Conclusion

Thus, the got ICS structure consists of two parts – power and informative and contains four basic levels:

- level 1, including the ordered hierarchical models structure of dynamic modes of behavior of DTS component;
- energy transformation surveillance level 2 in the DTS functioning process;
- DTS parameters "virtual moving" level 3;
- DTS parameters "virtual moving" controlling level 4.

The ICS structure synthesized thus allows to decide the basic tasks of informative arrays synthesis, synthesis of transformation procedures of one arrays in other, of rational variants of separate parts and all ICS on the whole, formation of entrance and output information arrays in DTS and other.

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UDC 656.71.06:629.7.08 (045)

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CONSTRUCTION OF OBTAINING OPTICAL IMAGE ANALYTICAL MODELS OF INTERNAL STRUCTURE CONTROLLED OBJECTS

The analytical models of optical control object's internal structure image obtaining were considered, and on their basis distortions, appearing in image depending on visualization system's parameters and emitting source type, were analyzed

Introduction and problem statement. For aviation securities of hardware design engineer problem statement increase of effectiveness-reliable useful signal determination from noise stock - this research facilities. Signal determination process is based on statistical technology utilization and filtration methods of signals processing. This methods are based on electronic simulation methods. The aim of the article analytical model development for acquisition of multivariate shades of translucent objects for further processing.

Development of mathematical apparatus. It is arguable that all the methods of straight visualization possess one and the same type of operation: such as irradiation of controlled object primary illumination (in case of active method), second reception (scattered illumination or that one which pass as through object) illumination, transformation of it in electric signal, processing and transformation of electric signal in optical signal. Then such systems should given the same general arrangement. Emission source - Controlled object (CO)- Transformation of electric signal - Transformation of electric signal in optical image.

Naturally, that the greatest exactness of visualization is given by the sources of EM transmitter_(electromagnetic measurement) of x-ray range, actually for which the worked out is stated below theory. But it is absolutely applied and for the sources of other ranges: such as submillimeter, millimetric, infra-red and other. Only obligatory implementation of linear condition distribution of EM, so sizes of local heterogeneities must be considerably less after a wave-length.

For simplification of description of the CO visualization structure will accept it's two-dimensional. Actual spatial distribution of parameter, the image of which is formed is described by the function of *f(x, y)*, which will consider the function of initial image of OK. On the indicator of transmition and introscope systems get an optical image which differs from a weekend and is distribution of brightness of image

$$g(\xi,\eta) = \iint\limits_{xy} f(x,y)h(\xi,\eta,x,y)dxdy \quad + n(\xi,\eta)$$

where *h*-is an operator of transformation; *x, y*-are spatial coordinates of CO; *f(x, y)*-is the real spatial distribution visualization to the parameter which is good for worked out models; ξ, η-are coordinates of three-dimensional optical image of underlying structure of KO and noises are added in the treatment of signal processing with distribution of probability of $n(\xi, \eta)$.

An operator $h(\xi,\eta,x,y)$ or instrument room function describes the diagrams of orientation and detector of radiation. An instrument room function depends on the geometrical parameters of radiant which rayed CO. Geometry of beam radiation but as a consequence and instrument room function considerably influencing on dividing ability of detector. As a result of infidelity of instrument room function $h(\xi,\eta,x,y)$ the optical image of g(ξ, η) turns out distorted: with changed proportions, blurred. Exactly these distortions for CO of various geometrical forms are evidently demonstrated in worked out in-process models of x-raying of objects. These distortions are the disadvantages of modern technology Inspection. For their removal the possible use two fundamentally different ways.

The first is an attempt to get a instrument room function $h(\xi,\eta,x,y)$ as possible more near to ideal.

The second method is to transform the function *g (ξ, η)* for recovery (formation of) of source (original) image *f (x, y)* using mathematical operations. It is carried out by digital treatment of signals in computer.

For embodiment of the last method it is necessary to foresee mathematical descriptions of processes, which cause infidelity of gravimetric function. This paper describes the mathematical processes that occur when you convert the original image *f (x, y)* in the optical *g (ξ, η)* CO for a known geometry in other words, having previously known spatial distribution seen a real parameter *f (x, y)*.

Every CO has an enormous amount of parameters which characterize his structure density, resistance and others. In general case actual spatial distribution certain to the parameter is three-dimensional *(x, y, z)*. However, for analytical models will describe some simplification and productive function to of valid parameter space and as follows: suppose there is some function f (x, y) it which is in volume limited of schedule this function is valid spatial constant parameter α. Outside this volume α = 0.

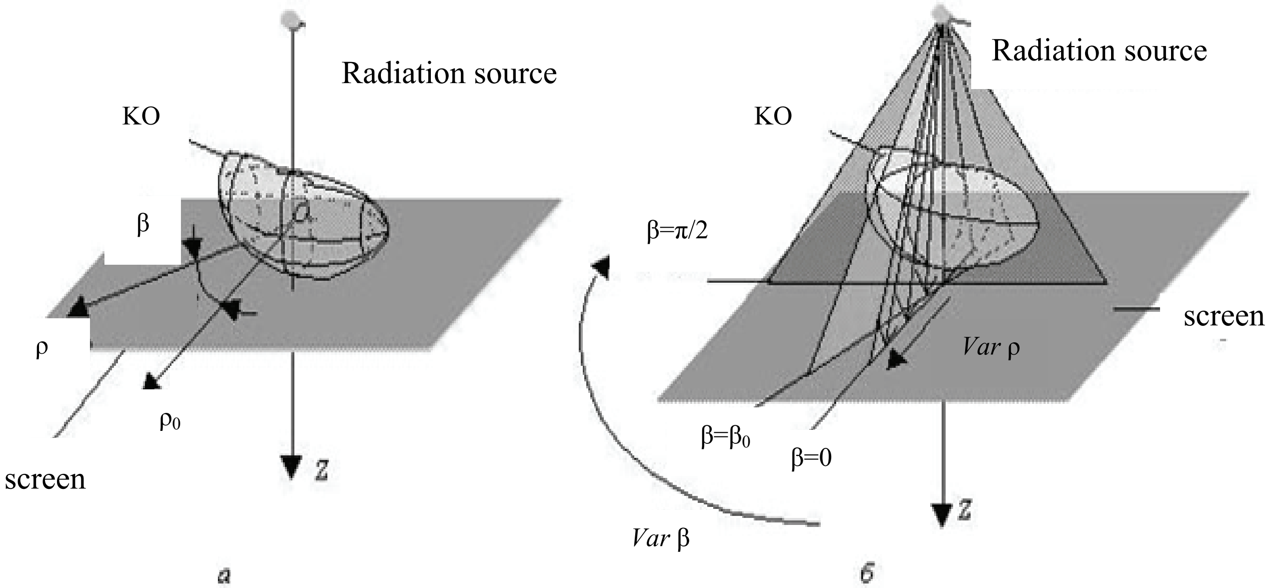


Fig.1 Scanning CO: α-coordinate system of cylinder; b-scanning beam position

Scanning CO With the use of radiant of point geometry for position-finding of radiant, CO and screen expedient is work in the cylindrical system of coordinates which is inflicted on rice.1, α.

Position of point in this system is determined by a size, set aside after an axis 0Z, by a corner between a zero and set direction of shads which belongs to the plane of z = 0, and size which is put aside after an axis ρ. Controlled object will dispose thus that beginning of coordinates took place in the middle it. The plane of screen will place in half-space of z > 0 and athwart axes 0Z radiant in half-space of z < 0 on wasp 0Z.

Will accept the method of CO what expedient for the use of source of radiant of point geometry [1] when some value of corner β is determine position of plane the ray of scanning (rice. 1, б) moves in which. Then concrete position of ray is determined coordinate ρ of the inflicted cylindrical system id est. a ray will scan space with the successive change of values β and ρ.

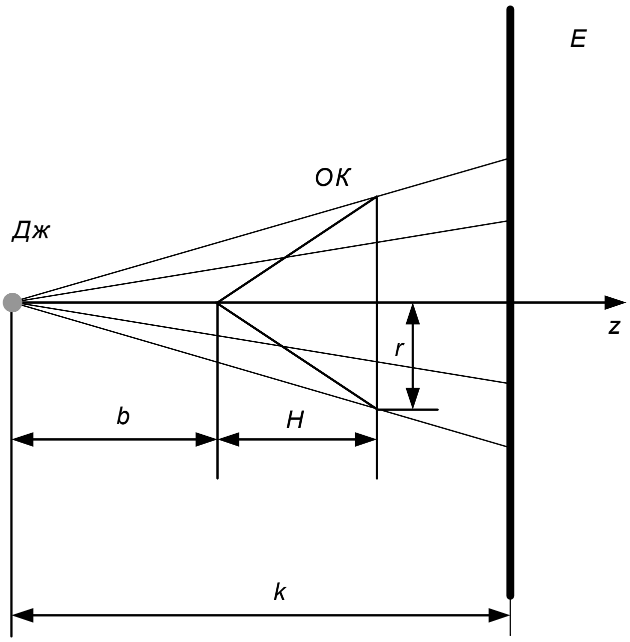
This type of scanning will define as a scanning after a circular trajectory.

1. Construction of analytical model of optical image receipt of internal structures object of control the geometrical form of which is a cone, made from homogenous material.

Let CO be cone made from one material. Thus, within the limits of it cone a fading coefficient is a permanent. Outside it a cone a fading coefficient equals to the zero. Will construction analytical model of receipt of optical image of underlying structure of this KO in the environment of MathCAD.

Will inflict the geometrical parameters of the system.

The function of $g(\rho, \beta)$ for a permanent value β is determined by work to the index of absorption of radiations α and by distance which was passed by a ray in material of CO. On rice.2 case is illustrated for $\alpha = 1$. After some transformations obsessed of formula of dependence of function of g from co-ordinates ξ and η:



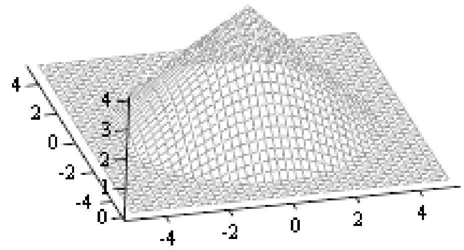


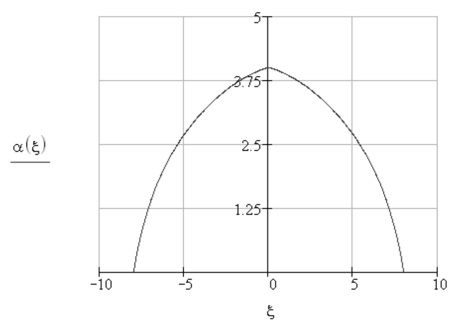
Fig.2 Fig.3

If CO is a cone made from one material, then imaginary spatial distribution to the traced parameter is calculated on a formula

$$g(\rho,\beta)=\begin{cases}\alpha\cos\left(arctg\dfrac{|\rho|}{k}\right)\left(H-\dfrac{b|\rho|H}{rk-|\rho|H}\right), at\ \rho\in\left(-\dfrac{rk}{b+H};\dfrac{rk}{b+H}\right)\\ 0,\ at\ \rho\notin\left(-\dfrac{rk}{b+H};\dfrac{rk}{b+H}\right)\end{cases}$$

The example of two-dimensional chart of this distribution for $\beta = 0$ is represented on fig.3.

Image of underlying structure of control object which it is been by a cone with the inflicted meters of pairing the three-dimensional type of lines.



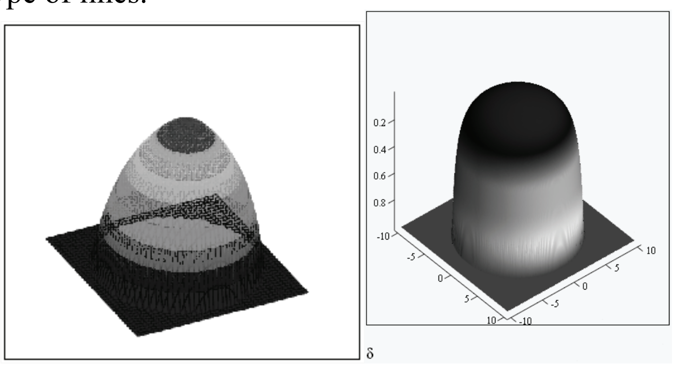


Fig.4 Fig.5

2. Construction of analytical model of receipt of optical image of internal structures object of control, the geometrical form of which is cylinder, made from homogeneous material.

When CO is a cylinder, forming of image of it underlying structure place is taken like a case, when KO is a cone. An only difference is that at forming of certain cut of scanning at any size of corner β this cut has the appearance of rectangle with parties of d and 2 - r, where r is a radius

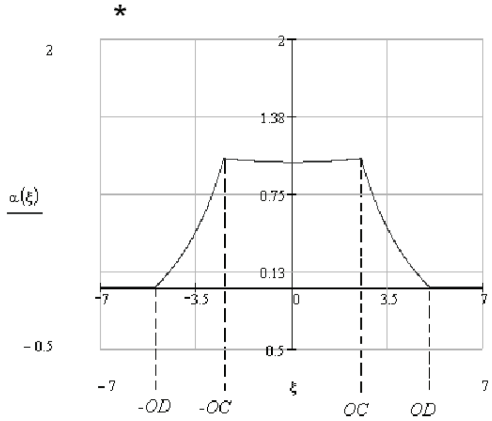


Fig.6

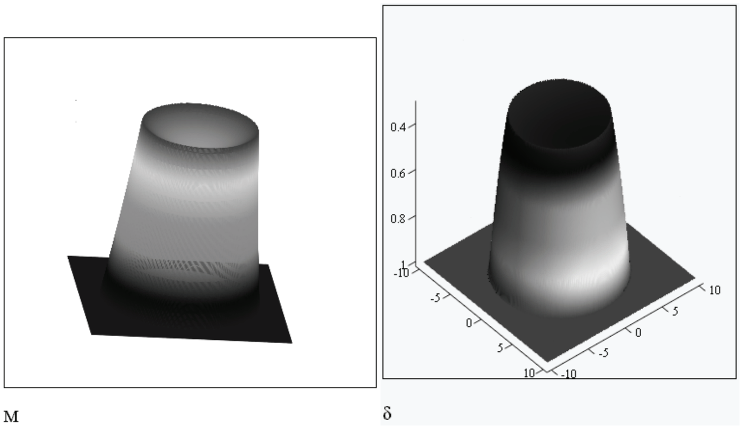


Fig.7

Conclusions. Expressions and programs of forming of multidimensional shade of semilucent CO are got allow to design the processes of visualization of CO underlying structure in the trasmission introscope systems. A design shows that the simplest bodies have shades with transitional by descriptions, by penumbras by distortions as a crater wherein in general flat exposed to irradiated planes. The change of foreshortening of irradiation changes shade to the unrecognizability. For the clear reliable exposure of predictable CO it is necessary to automatize the process of recognition of shades taking into account the possible between of distances by a source CO and screen - by a transceiver, foreshortening of irradiation and others like that.

The described methods are applicable in the traced processes of the radial approaching, id est without the diffraction, interference phenomena.

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MONITORING OF PRIVATE AVIATION FLYING

Two different ways of aircraft flight monitoring in the bottom airspace have been represented. Wireless communication network based conception has been proposed to use for control and navigation.

Introduction

Today general aviation is very fast changing and progressive part of aviation industry. A lot of advantages make general aviation very useful and popular. Nowadays small airplane or helicopter costs like a good new car therefore more and more people use it in their life. So, quantity of helicopters and small airplane is increased rapidly every year.

General aviation in Ukraine also is developed. One year ago our government and Prime minister were changed some regulation documents in aviation. Some changes have been made in documents which regulate flight space using. The main here is that nowadays pilots don't need make request for flight if they are going to flight in the bottom airspace (up to 1500 m under sea level).

It has been first small, but very important step to develop private aviation in Ukrainian airspace. It is very good because nowadays a lot of municipal services can use it. For example air ambulance, police air patrols, crop dusting, rescue team, forest fire fighting and many other services use it. But also we have some problems in this context.

General aviation flying in the bottom airspace must guarantee very high level of safety. Safety fly of general aviation is very important. General aviation accidents statistic data do not look good for counties where many private and commercial aircrafts flight every day. On fig.1 is represented number of general aviation accidents for USA during 1996-2005 years [1]. It shows decreasing tendency but it contains more than enough number of accidents every year.

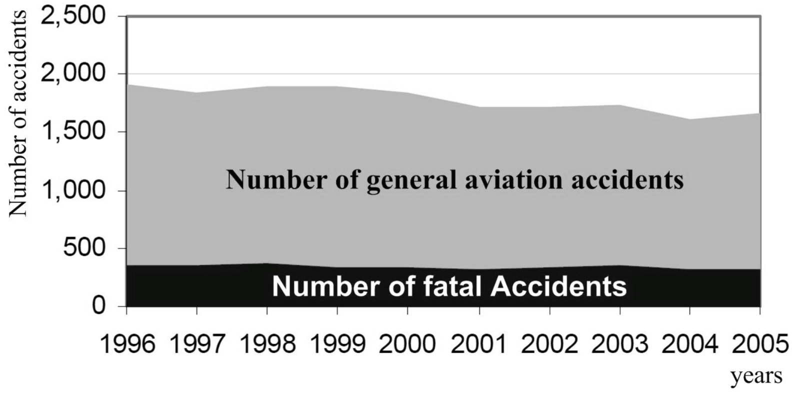

Fig.1. Number of general aviation accidents for USA during 1996-2005 years

One of the big problem which has been connected with general aviation that bottom airspace is not possible to be controlled. It is uncontrolled any radar service and air traffic service. Current radar and secondary radar systems can't cover bottom airspace. It has some technical aspects and depends on reflected ability radio signals from ground.

ADS-B conception

Automatic dependence surveillance broadcast (ADS-B) conception helps here. ADS-B is a cooperative surveillance technique for air traffic control and related applications being developed as part of the Next Generation Air Transportation System.

An ADS-B-equipped aircraft determines its own position using a global navigation satellite system and periodically broadcasts this position and other relevant information to potential ground stations and other aircraft with ADS-B equipment (fig.2). ADS-B can be used over several different data link technologies, including Mode-S, Universal Access Transceiver, and VHF data link (VDL Mode 4)[2].

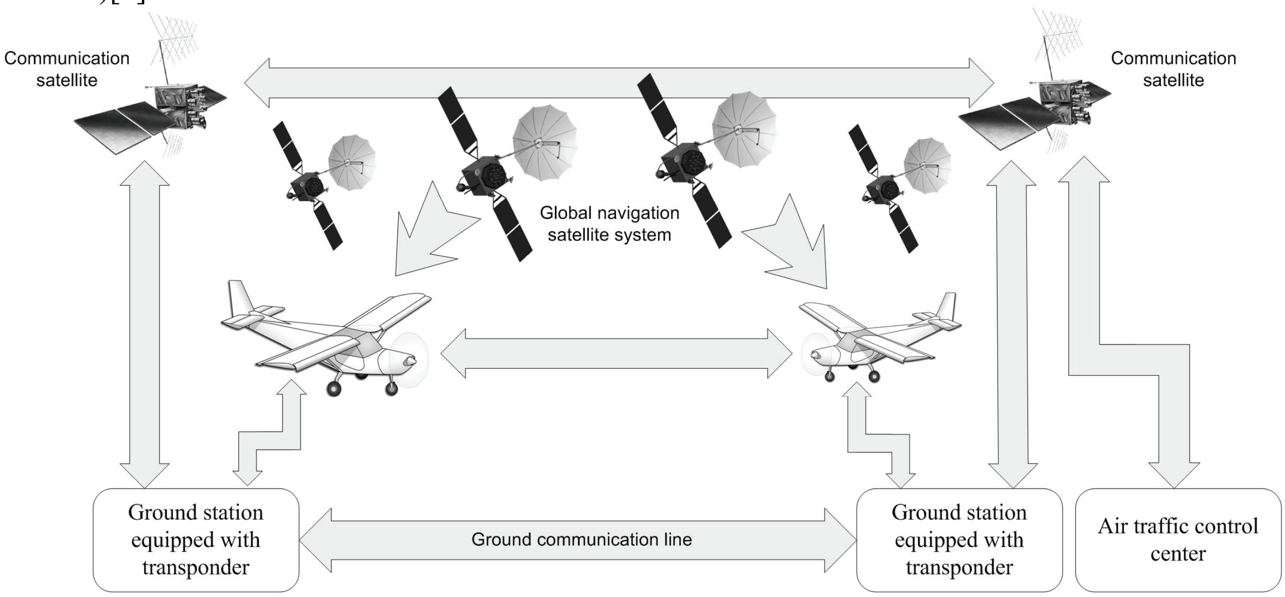

Fig.2. ADS-B conception structure

ADS-B provides accurate information and frequent updates to airspace users and controllers, and hence supports improved use of airspace, reduced ceiling/visibility restrictions, improved surface surveillance, and enhanced safety, for example through conflict management.

ADS-B is the best solution for improve safety of flight not only for general aviation. But development and technical realization of this conception are very expensive and need some time.

Wireless communication networks

Other way to solve the problem of low altitude flying aircraft control is usage of ground wireless communication networks. Nowadays wireless communication networks develop rapidly. Companies which are provided communication service cover more than 98% territory of Ukraine. Cell phone service is very popular and rapidly changing.

Cover area of airspace makes possible to use cell phone system on board of aircraft if the altitude isn't very big. Typical equipment is used to transmit aircraft position and other data to air traffic control (ATC) center by wireless communication ground networks [3-5] (fig.3). Many aviation services may be represented for owners of aircraft on board:

- weather broadcast;
- map information;
- airport information (SID, STAR, Approach procedures);
- communication;
- surveillances data and many other information.

Wireless communication networks are possible to realize navigation function. Different methods will be used to estimate aircraft location in cell organization network. The basic methods are:

- Cell of Origin;
- Signal Strength;
- Time of Arrival;
- Time Difference of Arrival;
- Enhanced Observed Time Difference.

This different methods combination will produce good accuracy of coordinates' estimation. Accuracy of this depends on location of aircraft and base station configuration. If airplane equipped with special devises to work with ground cell based network flies, service provider will estimate coordinates information about location of airplane. Then coordinates of each airplane will be compared with closed airspace areas location. If the service is recognized illegal crossing of the closed airspace frontier, owner of airplane will be responsible for it.

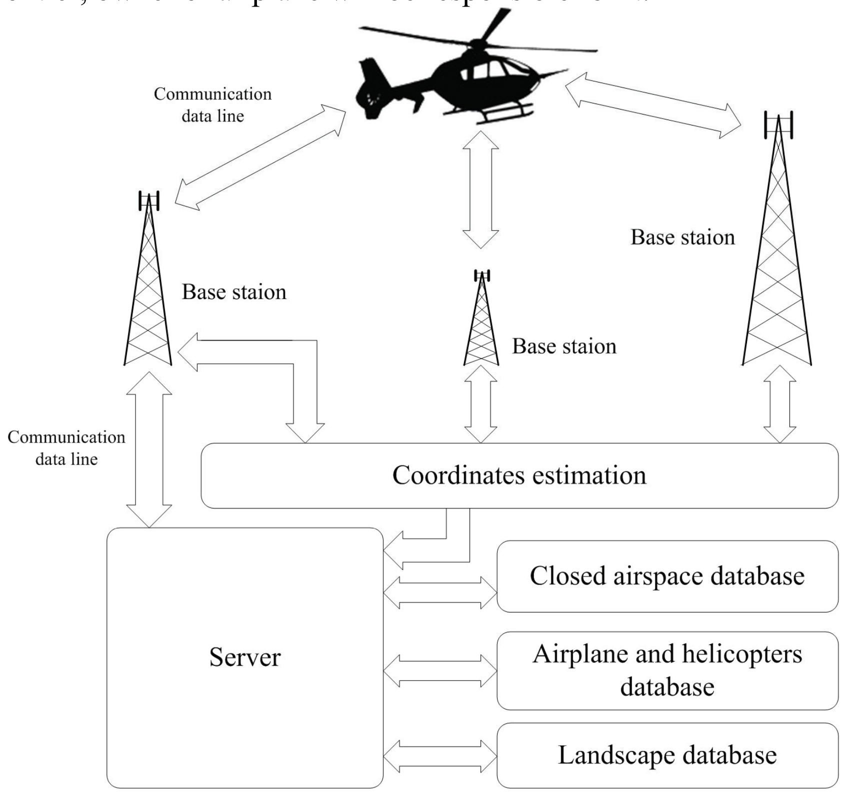

Fig.3. ATC conception based on wireless communication networks

Conclusion

ADS-B conception is the best solution for aircraft control in bottom part of airspace, but it's very expensive and needs time for practical realization in Ukraine area. Wireless communication network has already covered the whole territory but needs an agreement with service provider. Wireless communication network provides communication, high speed data line and positioning therefore realization of this conception is more suitable for our country.

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UDC 551.509

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WEATHER WEB SERVICE

New Weather Web Service which can be used for education and flight operation support has been represented. It collects information from different weather servers and current information from weather station in suitable form for pilots.

Introduction

Aviation meteorology is an essential element of the complex system that constitutes Air Traffic Management (ATM) in its broadest sense. Weather conditions impact the operations of ATM by variations in head and tail-wind components, through changes in pressure and temperature values at airports, and in imposing low visibility operating conditions. Adverse meteorological conditions have the greatest impact on the ATM system creating disruption and the consequent problems of disturbed flow rates, lost capacity and induced additional costs. It is important for air crews to understand the implications of weather on their flight plan as well as their aircraft.

Meteorological information

On-board meteorological information can be given by flight management system (FMS) for pilot operation.

This system helps pilots to guide and control aircraft during the flight. One of it's subsystem provides optimum operation and control of air-to-ground, two-way datalink communications with your selected ground-based service provider. Communications may be routed through the aircraft's VHF, satcom or airborne telephone systems (fig.1). It is also included for ACARS messaging over VDL Mode 2 along with growth capability to support the Aeronautical Telecommunications Network.

It makes opportunities for messaging, flight plan up-loading, pre-departure and other clearances, automatic position reporting, digital ATIS and text weather information such as TAF, METAR, SIGMETS, winds aloft and TWIP and others. All of this information with weather graphics is indicated for pilot on FMS and through Electronic Flight Instrument System. Represented information can include displays of composite radar, tops and movements, IR satellite images, significant weather, winds aloft as well as icing and turbulence potentials.

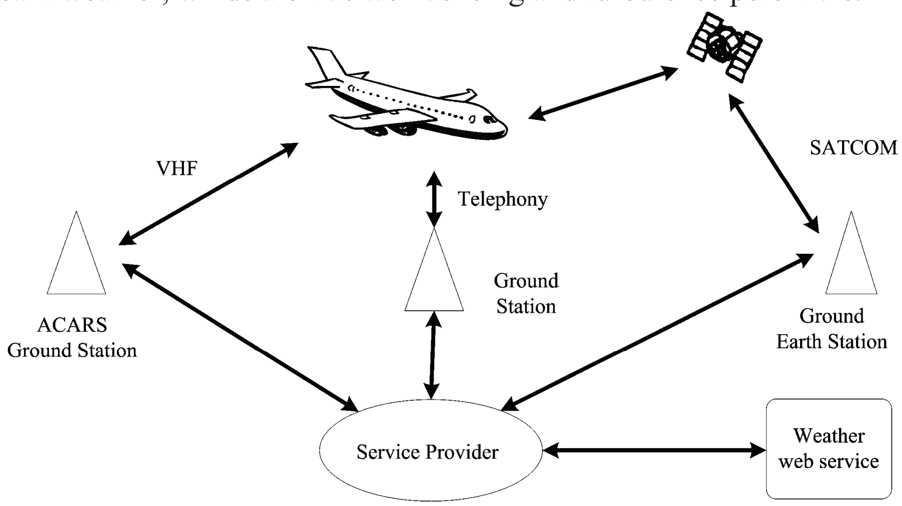

Fig.1. Communication conception aircraft-service provider

During the flight FMS connects with Ground Service Provider and download from it's computer servers all of this information.

Weather Web Service

For education process' supporting a special Weather Web Service was created at the department web site www.ANS.nau.edu.ua. This Weather Web Service collects all the data that a pilot also can get from the FMS on-board.

Weather Web Service includes:

- METAR, TAF, SIGMET information;
- Image of different weather conditions;
- Astronomical information about Sun and Moon;
- Current weather

Current and recent METAR and TAF reports from around the world are taken from public noaa service [1]. So, the information presented on these pages is considered public information and may be distributed or copied. The servers automatically collect information for site management and for statistical purposes, which are used for such purposes as assessing what information is of most and least interest, determining technical design specifications, and identifying system performance or problem areas.

To display the most recent METAR and TAF reports for one ore more observing locations, it is necessary to enter the four-character ICAO code (almost all of the world airports are set in the database).

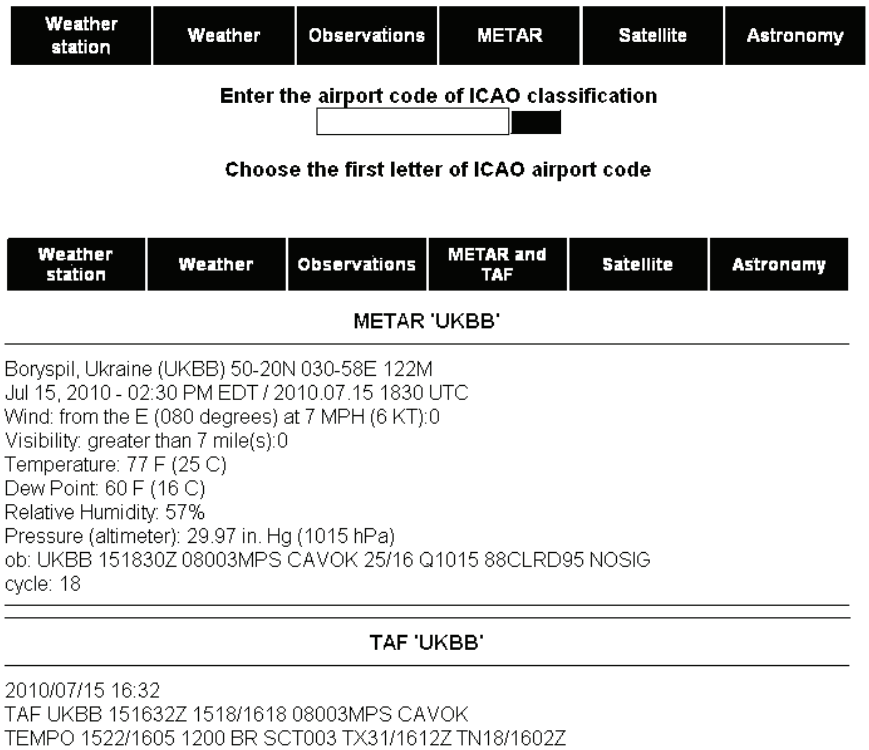

Fig.2. METAR and TAF information

Due to the big amount of satellites NASA can provide a lot of visual weather information of different electronic types.

Example of image provided by NASA service you can found in Fig.3.

It's mosaic picture that is continuously updated with images from MODIS TERRA satellite, which has almost global daily coverage. This layer is the most current, near-global image of the earth available. New images are added on top of the old data, in the order in which they become available. In general, the latest images are between 6 and 24 hour old.

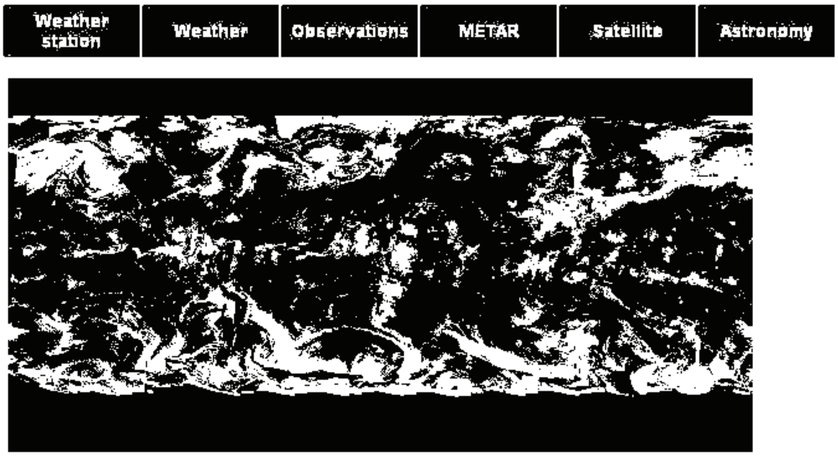

Fig.3. Image of the Earth surface and weather from the meteorological satellite for current day

For pilot it is necessary to know astronomical information about Sun and Moon position, sunrise/sunset time and day duration that helps him to plan flight in the given area.

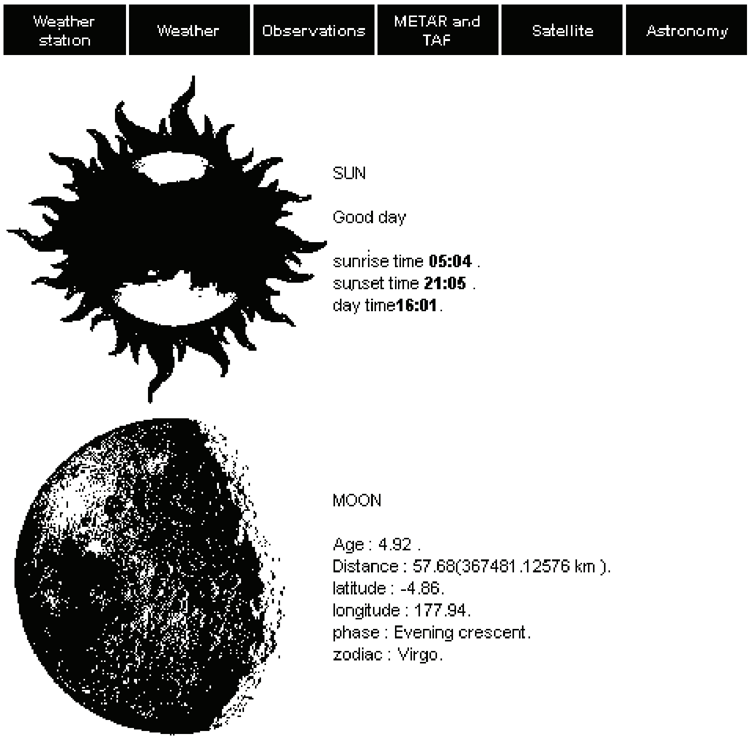

Fig.4. Astronomical information about Sun and Moon position

Current weather information has been provided by the Weather Transmitter which has been mounted at the department's building. This system measures and saves this information in a special weather department server. It works 7 days per week, 24 hours per day. The Weather Transmitter measures wind speed and direction, precipitation, barometric pressure, temperature, and relative humidity.

Wind speed and direction are determined by measuring the time it takes for the ultrasonic signal of one transducer to travel to the other transducers. Wind direction is not calculated when the wind speed drops below 0.05 m/s. In this case, the last calculated direction output remains until wind speed increases. The computed wind speeds are independent of altitude, temperature, and humidity.

This system uses the sensitive Sensor to measure accumulated rainfall, rain intensity, and rain duration. Precipitation is measured one raindrop at a time. Whenever a raindrop hits the precipitation sensor, an electrical signal is produced that is proportional to the volume of the drop.

The sensor is also capable of distinguishing hail stones from raindrops. The measured rain and hail parameters are cumulative amounts of rain or hail, rain or hail intensity, and the duration of a shower.

For indication of this data special software which works on-line has been developed. Web interfaces of this system have been represented in Fig.4.

To avoid the system overloading the current weather data renewal appears each 2 seconds.

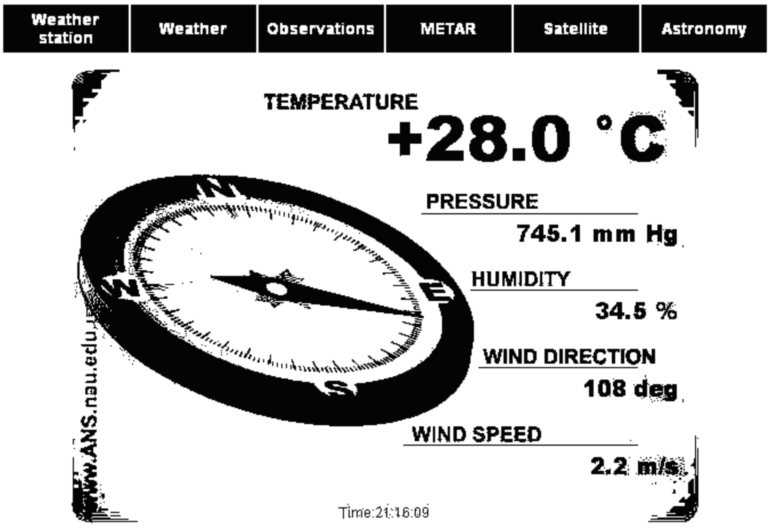

Fig.4. Weather station information interface

For flight guidance pilot needs information about cloudiness. For cloudiness determination the dew point deficit and pressure dependence is used.

Dew point deficit Δ – difference between air temperature T and dew point Td: $\Delta=T\text{-}Td$

Dew point is determined by formula [3]:

$Td = (235\cdot\beta)/(7.45-\beta);$

$\beta = \lg(RH) + (7.45\cdot T/235+T) -2,$

where RH – relative air humidity [%], T – air temperature [°C]

Determined dew point deficit will be compared with it's limits and cloudiness will be determined.

Conclusion

Developed Weather Web Service supports the educational process and can serve as on-board FMS system. Data given at the Weather Web Service can be used by everyone who needs to know weather and astronomy information.

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COMPUTER ANALYSIS OF BRAIN CHARACTERISTICS FROM DATABASES IN NETWORKS

Some problems of computer analysis of the data obtained during investigations of the brain in neurophysiology and medicine are discussed basing on concept of network databases.

Introduction. The tasks of construction of database (DB) with information about the brain, characteristics of its elements of different hierarchical levels attract an attention of engineers and investigators in whole world today. Some contemporary DB's include different images – at the level of whole brain, optical slices from different parts of the brain (colored or no; ones that are marked by radioactive or other marks, magnetic resonance images (MRI) etc.). In such DB may be included results of experiments with optical registration of processes in neurons, neuron assembles, etc. At contemporary level of technologies such DB may be constructed as de-concentrated in computer networks DB. Examples of practical problem solutions (electronic brain atlases on the base of DB images, others) are discussed, some recommendations for such works continuation are given.

Actuality of investigations. Actuality of the works for construction of DB in brain sciences and in medicine is caused by the specificity of objects in these branches, that stimulated the search of new approaches and development of new methods for construction of DB with characteristics of brain elements (that include also images of brain elements). Such DB today usually realized as de-concentrated in computer networks. Due to the invention and use of some contemporary approaches in computer sciences and technique became possible to solve of some important practical tasks in biology and medicine, including development of new methods of diagnostics of psychological and neurological disorders.

Main part. *Development of electronic DB with brain images.* Visual methods of diagnostics rank traditionally prior place among other methods in medicine. In contemporary medical practice traditional visual diagnostics evolve naturally in direction to computer methods application. For example, widely spread today noninvasive methods for making of electronic images of the brain, inner human organs, skin etc. for patients as well as for healthy people. Such images may be input into the structured DB that is included into the network of contemporary electronic information system (IS). With brain images may be done all operations possible for elements in such DB: sorting according to different characteristics, analysis, input and\or output of them to\of DB, their transmission in network to other user etc.

All abovementioned demonstrates the real expansion of possibilities for contemporary doctor. For example, transmission of images in clinic network gives the possibility for quick, distant, and confidential discussion with other doctors-colleagues some cases of pathological complications, surgery operations planning etc. From other side, for analysis of such images necessary to be aware in design of specific algorithms of brain image processing. So, traditional notion of image analysis become more complicated today because of appearing of possibility for computer comparison of great number of images, up to few hundred. Such analysis gives also the possibility of disease diagnostic at initial stages, at stages of changes in cells or groups of cells that is extremely important, for example, for successful treatment in oncology [1].

Methods of visualization and analysis of neuroimages continue to improve today; quality of the data is continually upgraded. That is why quality of brain investigation is also continually upgraded due to post-experimental analysis and understanding of experimental data taken from individual investigations or due to meta- analysis of series of experimental results. Such practice is enough successful today because DB with neuroimages are accessible for wide circles of people, for example, through Internet, for the aim of functional diagnostics, students studying etc. Some groups of investigators in Ukraine can carry out experiments with registration of brain cell optical characteristics as well as other types of cells, for example, acinary or pancreatic cells) [2-4]. Registered in such experiments series of images further are processed and analysed. In all such experiments studying are done under the control of confocal microscope, objects – cells are coloured by fluorescent dyes. In such a way experimenter can study processes, for example, of medical preparation action on the cells, metabolic processes, electrical impulse transmission etc. During such experiments dyes inside of the cells change colours, and these changes reflect inner mechanism of phenomena. Experimenter traces studied processes - make series of digital photoimages, and input them into computer memory. Analysing received datasets experimenter makes conclusion concerning studied phenomena. Obtained images advisably packed into DB constructed according to all rules of DB construction. But such powerful technique in neurophysiologic practice is used not enough today although some last investigations confirms correctness of chosen path.

Electronic atlases of the brain. With using of same technique are done electronic atlases of the brain because paper versions of brain atlases are unable to solve a lot of today tasks.

Methods of automatic segmentation and registration already have been used for generation of stochastic atlas on the base of magneto resonance investigations for majority of sub cortical structures. There was done stochastic atlas of cytoarchitectonics of somatosensore cortex from individual human brains.

Electronic IS with de-concentrated DB. Discussing abilities of de-concentrated DB (dcDB) let's study example of IS with such type of DB. dcDB consists on few fragments located in different nodes of network; they may be under the control of one or few different database management system. From the point of view of programs and users, such DB may be interpreted as one local DB.

Information about the disposition of each dcDB parts and other service information are recorded in data dictionary (DD). DD may locate in one of nodes or to be de-concentrated. For making of correct access to dcDB today is the most usable protocol (method) of two-phase commit. The sense of this method is in two-stage synchronization of all changes in all participated nodes. At the first stage in network nodes are recorded changes of records in DB (at this primary stage changes may be cancelled if necessary). Message about this is transmitted to the system component that controlling processing of de-concentrated transactions. At the second stage controlling IS component receives messages from all nodes about correctness of operations fulfillment. These messages evidence about the absence of errors and failures in apparatus–programming supply; further it transmits to all nodes commands about changes fixation. After this transaction is considered as terminated and its result – as irreversible.

The main advantage of de-concentrated BD model is that all users at nodes obtain information taking into account current changes in communications. Another advantage is saving usage of computer external memory that permit to organize DB of great dimensions. As imperfections in dcDB model may be seen tight requirements of efficacy and reliability of communication channels because of their linking for periods of transactions (for example, during intensive queries their processing in this scheme are too complicated).

Using preliminary processed input of biological and medical information in this scheme such system may be used for making of electronic atlases in neurobiology, for teaching of students at Universities, etc.

Conclusions. Methods for construction of DB with brain images permit to solve a set of problems: academic – studying of the brain by scientists and students, practical – for surgery operations planning, for diagnostics etc. There are some references [5] about successes in computer visual diagnostics of schizophrenia, Alzheimer disease. In first case during the study of computer images and analysis there were registered many changes linked with this disease at sub cortical structures. Preliminary analysis of electronic slices of schizophrenic brain also revealed visible structure anomalies. So, such studying may be used for analysis how and in what degree the structure and functions of brain may be linked with different psychiatric and neurological disorders.

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