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NATIONAL ACADEMY OF SCIENCES OF UKRAINE
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MATHEMATICAL OPTIMIZATION MODEL OF AVIONICS COMPLEXATION PROBLEM ON EARLY STAGE OF DESIGNING

The article is the sequel of another one of this digest of authors "Approximate optimization solution by Pareto of discrete extremal problem of complexation of new generation avionics" and its development in the direction of creating optimization model and organization under synthesis of avionics structure

Vindication of optimization criteria and formation of mathematical optimization problem

The solution of integer-valued discrete programming tasks is usually realized by such methods: intercepting method, branch and bound method, dynamic programming method.

In intercepting method the additional limits are input, depending on which there is a precision of algorithms. The essential singularities of branch and bound method are: the need in creating variants tree, identification of limit value for each vertex and cutting out non-prospective vertexes. The searching of large amount of vertexes leads to increase of solution time. But when using the dual simplex-method there is a need in determine of simplex matrix for each vertex and at the same time the requirements to capacity of on-line storage gets higher. The solving of discrete programming problems is based on formally-logical scheme of consecutive variants analyses of complex system designing subject to reliability criterion [Glushkov IC NASU].

The criteria selection of multicriterion optimization was founded for aircraft instrumentation complex with known aircraft performance characteristics and operational characteristics: new variants (1…4) and basic ("B" index):

- $G_{Н}^{Б}$, $\Delta G_{К}$; $\quad \Delta G_{К} = \Delta G_{К}^{ЭК} + \Delta G_{К}^{М} + \Delta G_{К}^{Г}$;

- $\gamma_{К}^{Б}$, $\Delta \gamma_{К}$; $\quad \Delta \gamma_{К} = \Delta \gamma_{К}^{АВТ}$;

- $V_{р}^{Б}$, $\Delta V_{р}$; $\quad \Delta V_{р} = \Delta \gamma_{р}^{зорп}$;

- $T_{нал}^{Б}$, $\Delta T_{нал}$; $\quad \Delta T_{нал} = \Delta T_{нал}^{зорп} + \Delta T_{нал}^{АК}$;

- $\overline{Ц}^{Б}$, $\Delta \overline{Ц}$; $\quad \overline{Ц} = \sum_{i \in I} \left[\frac{E_{нп}}{(1+E_{нп})^{T_{si}} - 1} + E_{н} \right] x_i + k' E_{н}$;

- $C_{лч}^{Б}$, $\Delta C_{лч}$; $\quad C_{лч} = C_{лч}^{*} - \frac{P \cdot Ц_i}{T_{нал}}$;

where G_K - highest possible commercial load;

γ_K - commercial load coefficient;

V_p - average run speed;

$T_{нал}$ - annual run, h;

$З$ - reduced costs on avionics complex creation;

P - depreciation reserves of book value of avionics complex for novation;

$E_н$ - normative coefficient of investments' comparative efficacy;

$И'$ - annual maintenance costs in operation;

K' - attendant investments in civil aviation branch, penetrating the aircraft with avionics complex.

The main components of efficiency criterion use two values:

The annual aircraft work content:

$$B = G_K \cdot \gamma_K \cdot V_p \cdot T_{нал}$$

and total annual costs for one aircraft:

$$Z = З(P + E_н) + И' + E_к K'$$

In market exchange relations this criterion can be expanded and thus perform the comparative analysis of variants of avionics complexes more seriously. We use four criteria to compare the complexes cost efficiency:

- B – annual aircraft work content in tonne-kilometers;
- Z - total annual costs;
- $S = Z/B$ - first cost of 1 t·km;
- $П = B_{ts} - Z$ - annual profit, where t_s - average tariff for 1 t·km.

The formula $P_i = E_{нп}/(1+E_{нп})^{T_{oi}} - 1$ and product $З_i(P_i + E_n)$ we use, where $З_н$ - cost of purchase of specified complex is designated as $Ц$ for Z_i:

$$Z = \overline{Ц} + И',$$

where $И' = C_{лч} \cdot T_{нал}$

$$\overline{Ц} = \sum_{i \in I} Ц_i \left[\frac{E_{нп}}{(1+E_{нп})^{T_{si}} - 1} + E_н \right] + k'E_н$$

where I - ensemble of task systems;

$Ц_i$ - cost of separate complex

T_{si} - service life of complex;

x_i - variable of model, 0 – N, that means (0 – system isn't chosen, 1,2,3…N – reserve degree);

$E_{нп}$ - discounting degree;

$C_{лч}$ - first cost of flight hour without depreciation reserves for avionics novation.

$$C_{лч} = C^*_{лч} - \frac{P \cdot Ц_i}{T_{нал}}$$

The general formula for calculation of B, Z, $П$ of new variants of complex:

$$Y_a = Y_a^Б + \sum_{w=1}^{6} K_w^a \Delta x_w$$

where $a \in \{I, II, III, IV\}$ - choosing of one the indexes;

$w \in \{1...6\}$ - sequence number of criterion;

K_w^a - coefficient that is appropriate for variant (1…6) of basic one.

Since it is important to measure the changeable part when comparing, optimization criteria can be shown for new variants as:

$$Y_a = Y_a^Б + \sum_{w=1}^{6} K_w^a \Delta x_w^0 + Y_a' - Y_a^Б$$

The values of basic indexes Δx_w^0, x_w' are determined under existing method.

Classification of variable parameters for calculation of indexes of offered and basic criteria.

- Variable parameters of avionics and aircraft of basic equipment set ($G_К^Б$, $\gamma_К^Б$, $V_р^Б$, $T_{нал}^Б$, $\overline{Ц}^Б$, $C_{лч}^Б$).
- Fixed characteristics of basic aircraft ($t_р^{max}$, $\Delta g^G \%$, Δg^H, $\Delta V_{іэк}$, $g_{TЭ}$, $K_{нр}$, $Д_л^{ГСМ}$).
- Airway system characteristics of basic variant ($L_{БП}$, $Д_у$, $t_р$, μ_i, μ_2, μ_3).
- General technical and economic parameters ($З_{іэк}$, $M_{іэк}$, $\Delta M_{сл}$, K_G, M_i, $K_{ЛВ}$, C_{TOP}, $E_{нп}$, $E_н$, $K_н$).
- Maintenance characteristics of avionics (γ, $Ч_Т$, K_G, a, $a^{лаб}$, $a^{кр}$, $a^{ДМР}$, $a^к$, $a_{лаб}$, $a_{кр}$, $K_{отк}^{лаб}$, $K_{ув \cdot отк}$, $K_з$, $Ц_Т^у$, $t_{рем}$, $K_{НВ}$).
- Data assigned for basic variant ($K_{экс}^Б$, $K_{экс}$, $a_{TC}^Б$, a_{TC}, $K_T^Б$, K_T, *index difference*: $\Delta t_р^{зопр} \%$, $\Delta g^{зопр}$, $K'^Б$, K', $\Delta V_{ПНО}$, $\Delta n_{эк}$).
- Characteristics of another systems for calculation (G_i, $Ц_i$, W_i, T_{oi}, T_{si}, T_{pi}, T_{mpi}, t_{ro}, τ_i).

As the maximization task *P* is equivalent to maximization task $ln(P)$, then for greater amounts of argument *t* (while *t=3*, inaccuracy is not more than 10%), $P_{п.н}$ criterion takes the form of:

$$min\left\{(\sigma_{xDec}^2 + \sigma_{zDec}^2)(\frac{1}{a^2} + \frac{1}{в^2})\right\} = \left\{\frac{\sigma_{xDec}^2}{\frac{a^2 в^2}{a^2 + в^2}} + \frac{\sigma_{zDec}^2}{\frac{a^2 в^2}{a^2 + в^2}}\right\}$$

In model values y_i, x_i at $a^2 + в^2$ $y_i \in \{0,1\}$, $y_i \le x_i$, define the participation of parameters in criterion forming, and x_i defines the avionics reserve. For correct calculation of criterion the limitation is put into the problem situation:

$$\sum_{i \in I_p} y_i = 1$$

where I_p - system ensemble, defining P value.

Vindication of limitations in the synthesis of avionics structure.

The effectiveness of solution optimizing depends on developing software, that are peculiar. The general properties limitations are determined by indexes of: weight, cost, power consumption, error-free running time:

$\sum_{i \in I} m_i x_i \le SM$ - by weight;

$\sum_{i \in I} Ц_i x_i \le SЦ$ - by cost;

$\sum_{i \in I} W_i^G x_i \le SW^G$ - by direct current consumption;

$\sum_{i \in I} W_i^f x_i \le SW^f$ - by alternating current consumption;

$\sum_{i \in I} V_i x_i \le SV$ - by cooling consumption;

$\sum_{i \in I} \frac{1}{T_{ci}} x_i \le \frac{1}{ST}$ - by failure running time.

For each system of complex it is quite difficult to input the limitation on backup degree:

$$0 \le x_t' \le x_i^{max}$$

For synthesis of avionics structure the main limit is limitation on reliability of performing of complex functions for flight control, in terms of tolerance probability, i.e. probability of failures. Creation of "chains" is realized with usage of algorithm of aircraft functions performance.

The "chains" define the inequation:

$$0 < number < 1$$

$$DUBL > 1$$

$VV_i = V_1 V_2 ... V_k$ - realization variants, where the list $V_1 ... V_k$ - logical sum of SS_j elements.

$$V_i = SS_1 + SS_2 + ... + SS_{nj},$$

$$VV = \{\{S_0, S_j\} + \{S_2, S_3, S_4\} S_5 + \{S_6, S_7, S_8\}\}$$

For variant of system with reserve degree x_i the failure probability on flight time is:

$$Q_i(x_i) = (1 - e^{-\lambda_i t_n}) x_i, \quad \text{а при } 0 \le \lambda_i t_n << 1$$

$$Q_i(x_i) \approx (\lambda_i t_n)^{x_i};$$

$$P_i(x_i) \approx 1-(\lambda_i t_n)^{x_i},$$

where $P_i(x_i)$ - probability of functional task performing during the flight.

In examined criteria and limitation the optimal complexation of avionics task has a view:

$$\sum_{i \in I} C_i^{a^0} x_i + \sum_{w \in W} \sum_{r \in R} C_{rw}^{a^0} y_{rw} \to extr;$$
$$\sum_{r \in R} S_i y_i \to min.$$

The realization of linear model solution of optimal complexation of avionics by applications of ARM constructor.

The application package of ARM constructor includes: database (DB), interface complex, the text files block, the composition of avionics determination block, optimization programs block (fig.).

The realization of application package is performed in the following way:

- database and interface complex – by means of "FOXPro";
- filename extension, interface complex - AVIA.prg program;

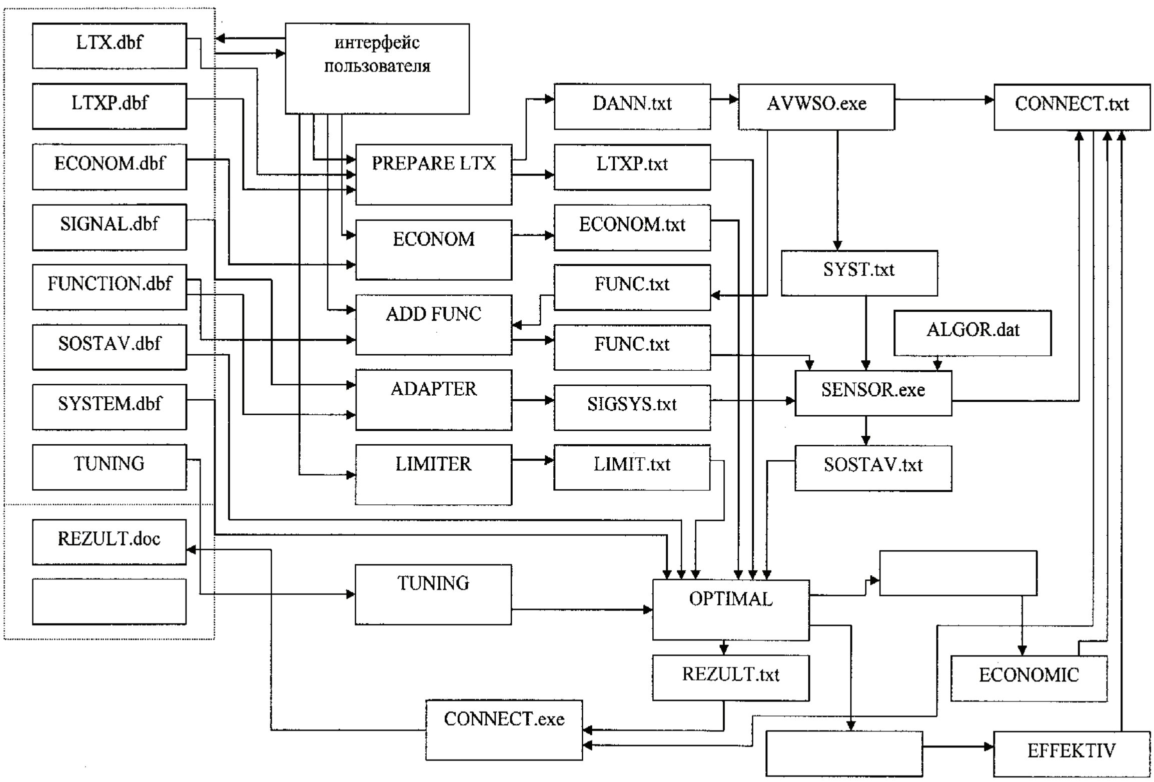

Fig. The structure chart of application package functioning of "ARM constructure"

- block of avionics programs is realized on PASCAL language with software: the list of functions AVNSO.exe; the formation of avionics variants AVIA.prg with txt-files, FUNC.txt and SOSTAV.txt; optimization of complexation - PASCAL language with software of data TASK.exe, optimization module TASK_LP.exe, results registration TASK_R.exe.

The result of task - OPTIM.res file characterizes the discovered solution or its absence (REZULT.txt file).

The database files:

- LTX.dbf – aircraft performance characteristics;
- LTXP.dbf – economic characteristics (variable and fixed);
- LTXPT.dbf – parameters of economic characteristics of aircraft;
- ECONOM.dbf – economic characteristics of environment (airway system, avionics data, accuracy estimation);
- SYSTEM.dbf – characteristic on avionics system;
- SOSTAV.dbf – structure data, weight, block dimensions;
- SIGNAL.dbf – input and output signal;
- FUNCTION.dbf – functions of systems, complexes and avionics as a whole;
- ALGORITM.dbf – signals and functions of systems for performing of avionics function;
- TUNING.dbf – optimization module tuning;
- REZULT.dbf – ARM results;
- OPERATOR.dbf – list of ARM users;
- IMVAR.dbf – description of task variant.

General resume and work results.

The multicriterion model of optimal avionics complexation task is an approximate model on criteria of maximization of technical effectiveness and minimization of reduced costs under parameters limitation. The algorithm is based on principles of decomposition of building of ε-chain of Pareto-optimal solutions for separate complexes by force of consecutive combination of solutions and sifting of not Pareto-optimal. The practical output of modeling is development and realization of application package "Automatized system of choice of optimal avionics structure".

Reference

1. ***Vorobiyov V.M., Zakharchenko V.A., Vashku G.O., Vorobiyov A.V.*** System efficiency of complex "Crew – Aircraft – Environment". Digest of studies "Cybernetics and computer technology". Vol. 126. – K.: Glushkov IC NASU, 2000, p. 48-76
2. ***Belyh T.V., Kuzmenko V.N.*** The algorithm of generation of ε-chain of compromise solutions for multicriterion integer-valued task. ASU. – K.: Glushkov IC NASU, 1994, p. 35-41
3. ***Belyh T.V., Golovnyov E.A., Kuzmenko V.N.*** Linear model of task of optimal complexation of aircraft onboard electronics // The optimal solutions theory. – K.: Glushkov IC NASU, 1994.

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DEFORMATION SURFACE RELIEF OF SINGLE- AND POLYCRYSTALS UNDER FATIGUE

Two approaches for aircraft fatigue monitoring are described: a) by the application of single crystal foil indicators; b)by the direct observation and quantitative estimation of deformation relief on the surface of alclad aluminium alloys. The evolution of such roughness has been monitored at various regimes of fatigue loading. The deformation relief under static loading is represented as well.

Introduction

Many aircraft crashes leading to considerable human losses and financial expenses are caused by metal fatigue. That is why reliable prediction of component fatigue life is critical to aircraft safety.

The current generation of civil transport aircraft has been designed for at least 20 to 25 years and for up to 80000 flights. These design service goals are exceeded by many operators of jets and turboprops. Future aircraft types are designed for at least the same purposes, but a structure with higher fatigue life and higher damage tolerance capability are required to minimize their maintenance costs and to comply with the requirements of the operator and the enhanced airworthiness regulations.

Taking into consideration the importance of the 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 analyses as a mandatory procedure for improving aircraft reliability and service life. So according to the "FAR-25, Sec. 25.571 - Damage -- tolerance and fatigue evaluation of structure", evaluation of the strength, detail design, and fabrication shows that crucial failure due to fatigue, corrosion, manufacturing defects, or accidental damage, could be avoided throughout the operational life of the airplane. This evaluation must be conducted for each part of the structure that could possibly contribute to a catastrophic failure (such as wing, empennage, control surfaces and their systems, the fuselage, engine mounting, landing gear, and their related primary attachments).

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

There are two approaches for distinction of accumulated fatigue damage: a) by application of specimen-witness; b)by direct diagnostic of material state.

A set of diagnostic methods are based on using specimen-witnesses, which are mounted on the surface of the object to be inspected. Such devices are usually called fatigue sensors or indicators of the fatigue damage. The description of the most effective device is given in [1, 2]. The indicators subjected to the operating spectrum of cyclic loads, change their state or even may be destroyed. That indicates the degree of damage accumulation in the investigated structural element.

Direct diagnostic may be performed applying non-destructive methods, such as high frequency ultra sonic test method, penetration test method, eddy current test method, etc.

Our investigations along with the other authors show that direct quantitative estimation of accumulated damage may also be conducted by surface state analysis.

1. Single crystal indicator of fatigue damage

The single-crystal indicator of fatigue damage was created at the National Aviation University [2].

The method of fatigue damage monitoring using single crystal indicators is based on the possibility of quantitative estimation of the accumulated damage using the parameters of the deformation surface relief formed on the surface of the single-crystals of plastic metals, particularly in aluminium and some of its alloys.

Two possible ways of manufacturing of the single-crystal indicators of fatigue damage are considered. Firstly, such indicator can be made of single-crystal of aluminium with cleanliness of 99.999%, which were grown up by Bridgman's method. In this case the cylindrical single-crystals of 20 mm in diameter are cut by the electric spark unit on disks of 1.0 mm wide. Then they are treated by the mechanical polishing, and on the final stage of treating by means of the electrolytic polishing their width is up to 0.2 mm. For the electrolytic treating the solution of 50%H_3PO_4 + 39%H_2SO_4 + 3%CrO_2 + 8%H_2O electrolyte is used. The magnitude of the current is 15A/dm².

The indicators are fixed on a surface of the specimen for fatigue test by means of glue based on cyanoacrylate ($C_5H_5NO_2$).

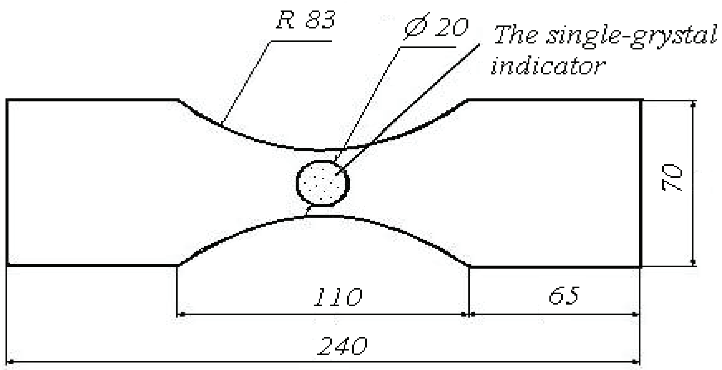

Fig.1 Specimen for fatigue test with glued single-crystal indicator

In the performed investigation the single-crystal indicators were fixed on the samples of constructional aluminium alloy D16AT.

The crystallographic orientation of the single-crystal indicators is defined by the crystallographic orientation of the axis of a cylindrical single-crystal pattern and the orientation of the indicator disc relatively to the axis of a specimen for fatigue tests.

The experiments connected with growing up of the single-crystals have shown that the most favorable orientation of a longitudinal axis of the single-crystal cylinder under growing up single-crystals by Bridgman's method is the orientation in direction <100>. In this case the surface of the discs for the indicators production coincides with the crystallographic plane {100}. In addition to all mentioned above, a possibility of manufacturing the indicators from single-crystal cylinders with axis orientation <110> and <111> was considered.

The alternative approach to growing up the single-crystals is application a method of critical deformation and annealing. The corresponding experiments were held on the samples of aluminium alloy AD-1, which is the technical aluminium. Consecutive annealing of the samples at the temperature of 500ºC , deformation till the level defined by the previous investigations and repeated annealing at the temperature of 550ºC give the possibility to get the grains of size up to 50 mm. Such a multy-crystal structure can be used for the manufacturing of single-crystal indicators. Besides, such a structure allows testing the multi-crystal samples, monitoring the state of separate grains, considering with some assumption, that the properties of separate grains are similar to the properties of single-crystals. The size of grains allows to define the crystallographic orientation of the grains using the radiographic method of Laue, the accuracy of which is not less than 2 degrees.

The testing was performed on the hydropulsating machine МУП-20.

The calculation of density of slip lines was performed by visual control of the state of a surface using the metallographic microscope MMP-4 with magnification of x400. The evolution of deformational relief of the single-crystal indicator surface was investigated under the regular cyclic loading and some regimes of the program loading. In all cases the relation between density of slip lines and number of cycles of loading and level of strain was observed.

As was shown earlier [1] the single-crystal indicators can be applied for controlling the accumulation of damage both under a cyclic and static loading. In the presented an effort was made to combine these opportunities in the program regime, while the testing is performed with sequential application of cyclic and static loads.

Fig. 2 illustrates the results of measurements of density of the slip lines on the single-crystal, the surface of which coincides with the crystallographic plane {110} and the direction [221] along the axis of loading .The cyclic loading was performed in two stages with transition from the lover level of loads (100 MPa) to the higher (180 MPa). The magnitude of static loading was 400 MPa. The graph shows that the intensity of the slip lines formation is accelerated with strain level increase. The slip lines, formed under cyclic loading, were located at the angle of 82 degrees to the axis of loading.

As a result of the static loading action, on the surface of the single-crystal the slip lines of another orientation are formed. The angle of their inclination to the axis of loading under the magnitude of the relative deformation not more then 1.7% was -57 degrees, that differ them from the lines of fatigue nature. Thus, the possibility of indication of the static overloads, acting on the background of cyclic loadings, was demonstrated.

The investigation of the single-crystal indicators with different crystallographic orientation has proved that the orientation substantially influences both the intensity of process of formation of the slip bands and the external image of the slip lines. In some cases the defected structures are formed on the surface that can not be presented quantitatively by the described technique, that is, by calculating the density of the slip lines. So during the investigation of the single-crystals with a plane of surface {100} and the direction along the sample [100] the structures are formed, for the quantitative estimation of which the methods of the fractal geometry [2] is applied.

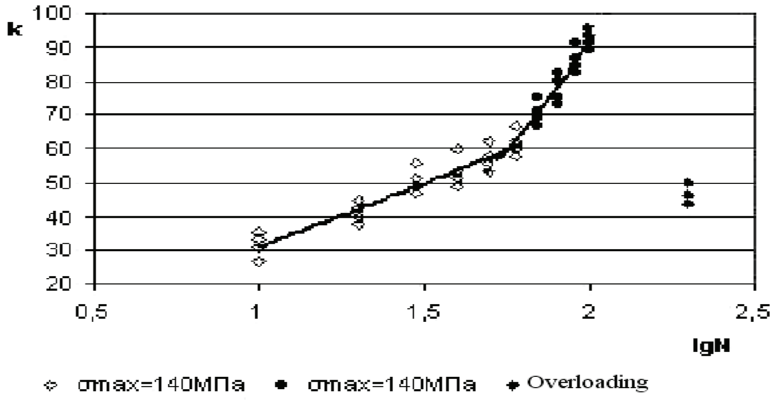

Fig.2. Evolution of PSBs density under fatigue and static overload

2. Fatigue damage analysis for alclad aluminium alloys

Studies on aluminum single crystals under fatigue [1,2] conducted at the National Aviation University and the published results of the other authors [3,4], showed a close correlation of the accumulated fatigue damage with the density of PSBs . The dependence of fractal dimension of the surface pattern on accumulated damage has been proved as well [2].These results are the basis for the proposed method. So it was proposed to use the same approach for analysis of surface state of polycrystal structural materials [5].

Aluminium alloys D16, 2024T3 and 7075T6 have been chosen for experiment. These materials are widely used for manufacturing modern aircraft skin both in Ukrainian and Western aircraft industry.

Metallographic investigation of the chosen metals was performed in conformity with the recommendation [6]. The results of investigations which may be used to determine the grain sizes are represented in the table. Grain size measurement has been conducted along with microscopic investigation.

Grain sizes of investigated alloys

Alloy designation	D-16	2024T3	7075T6
Average grain diameter in the rolling direction (μm)	41,8	83,3	42,7
Average grain diameter perpendicular to the rolling direction (μm)	39,0	66,7	41,8
Average grain area (μm^2)	$1{,}6 \cdot 10^3$	$5.6 \cdot 10^3$	$1.8 \cdot 10^3$

Flat specimens with a hole in the center (Fig.3.), in order to induce fracture localization were used in fatigue test procedure. Such stress concentrator indicates the point for checking as well.

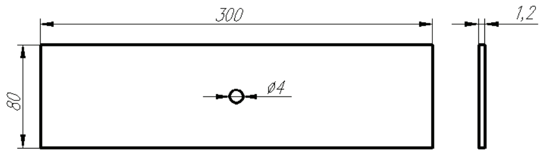

Fig. 3. Specimen for fatigue test

The thickness of the specimen is 1.5 mm and the diameter of the hole is 4 mm. These dimensions were chosen taking into account that 1.5 mm thickness sheets are used in many cases for aircraft skin production, where the 4 mm hole imitates a constructive hole for rivets.

Riveted aluminum structures are found to vary degrees on virtually all aircraft. In aircraft structures rivets are used to joint sheets of the skin, or to mount skin on frames and stringers. The number of rivets in the structure of a modern passenger airplane for 200 passengers is more than 1.5 million. Thus, such kind of stress concentrator is typical.

Cyclic deformation testing has been carried out with a hydraulic pulsating machine MUP-20. Tests have been performed under load control at frequency of 11 Hz and load ratio ($R = \sigma_{min}/\sigma_{max}$) of R = 0. The shape of loading cycle is sinusoidal.

All damage parameter measurements have been performed near the stress concentrator, where stress level is maximum.

Deformation relief under static loading has been also observed on the surface of the alloy D-16 AT specimens clad by aluminium. Used specimens have been, manufactured in accordance with the standards (Fig.4.). The test were performed on test machine for static loading FP-10.

The deformation rate was 2 mm per minute.

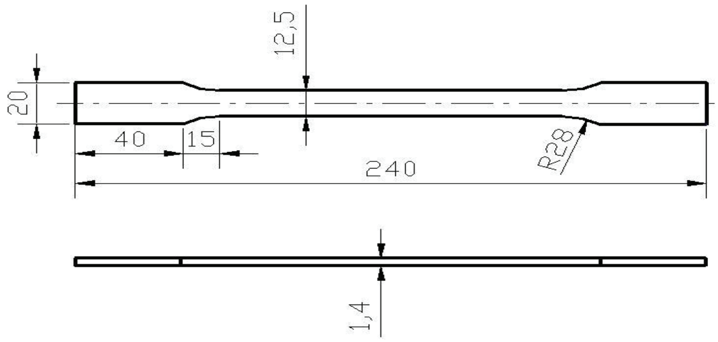

Fig.4. Specimen for static loading

Special equipment was designed for deformation roughness monitoring. The main objective was to use standardized systems which are in mass production having stable characteristics and relatively low cost. The present investigation of deformation roughness and the quantitative estimation of the accumulated fatigue damage have been conducted with the system consisting of metallographic light microscope with the enlargement about X400, digital camera with the number of pixels 1600x1200 and portable PC.

The three-dimensional character of observed roughness pattern and its correspondence to the known scheme of intrusions and extrusions formation have been confirmed by means of Scanning Electron Microscopy (SEM) investigation by using microscope Zeiss DSM950.

Images of cyclically loaded specimen surfaces have been processed by special software. The developed program saves the surface images in BMP format and gives the possibility to determine quantitatively the damage parameter "D". Such parameter is equal to the area of specimen surface with deformation tracks (PSBs) divided by total considered surface.

The researches have been carried out in the wide range of stress conditions. A set of experimental curves that express the dependence of accumulated damage parameter on the number of cycles have been obtained. All curves as well as presented below have been obtained by the approximation with exponential function. As an example the result of fatigue test of D-16 specimen and damage monitoring under the maximum stress 81,7 MPa is presented. It expresses the relationship of damage parameter "D" and current number of cycles N_c (Fig.5.). Results presented have been approximated by the function $y = 0{,}0027x^{0{,}394}$ with correlation coefficient $R^2 = 0{,}7865$.

The test was stopped after the nucleation of fatigue crack of 1.0 mm length. So a crack length of 1.0 mm has been considered as the critical state condition.

As it is seen from the graph, the minimum scatter is on the initial stage of the fatigue process, whereas the final stage of the damage accumulation process has maximum level of scattering.

The more complex situation for fatigue failure prediction is in the random action of loads. The further research plan intends to carry out testing under a wide range of loading operation regimes. Both regular and program loading regimes will be materialized in order to simulate service conditions.

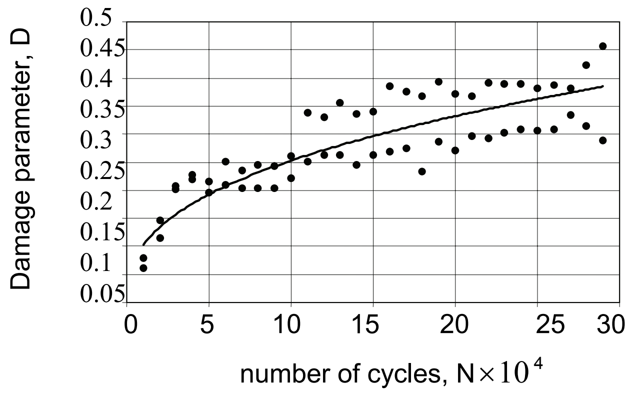

Fig.5. The dependence of damage parameter "D" on the number of load cycles

Indication of strain level under static loads is interesting for some practical task, therefore some observation of surface state under static deformation have been conducted as well.

A set of specimens of aluminium alloy D-16 have been tested under maximum relative strain 0.66; 0,83; 0,85; 1,12; 1,19; 2,15; 2,32; 5,22; 12,15 percents accordingly.

Formation and evolution of the deformation relief were observed, but in contrast to fatigue regimes surface pattern have been observed only under the relative strain of 2% and more.

So, in case of static loading deformation relief can indicate only considerably close to ultimate strain and loads.

As a result of scheduled researches, the following exemplary procedure for aircraft fatigue analysis might be proposed :

1. Operating range of loading, 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 means of generalized load researches for the particular airplane type.

2. Structure portions to be investigated are determined. The location of a possible damage can be determined by analysis or on the basis of endurance tests for the whole structure or its separate elements. If the estimation is performed by analysis, the following parameters are taken into account: a) strain measurement data for determination of places of high stresses concentration and magnitude of the concentration;

b) places where residual deformations are arisen during previous tests; c) places of possible fatigue damages defined by fatigue analysis; d) structure places which according to operation experience of similar structural elements are susceptible to fatigue.

3. Laboratory fatigue tests of structure elements (specimens) are carried out to create data base as to evolution of an element surface state.

Critical area, that is, an area responsible for destruction, is polished for microscopic investigation. Photographing of critical area is performed by a metallographic microscope equipped with a digital camera.

The data base (atlas) must contain test results under different load levels, different sequences of load application, etc. The test program is scheduled taking into account operating range of loads. For each state the factor of service life expiration is calculated as a relation of the number of cycles corresponding to a given state to cycle number to failure under given loading condition.

4.Monitoring of fatigue process of aviation structures under full-scale test is performed by means of inspection of skin clad coating in areas determined in accordance with requirements of Item 2 and by technology stated in Item 3.

5. The state evaluation of an inspected part of structure is conducted by estimation of damage parameters and comparison with those laboratory testes specimens, having the same value of damage parameter and estimated life (the factor of service life expiration). Currently, as our researches shows one of the appropriate damage parameter might be relative area of surface with deformation traces.

Conclusion

Accumulated fatigue damage of alclad aluminium alloy D-16 of Ukrainian manufacture as well as 2024T3 and 7075T6 alloys of western industry may be performed by the analysis of surface pattern, created by the cyclic loads.

As the deformation relief on the surface of cladding layer may be observed at the very first cycles of loads, the visual diagnostic of initial stages of fatigue damage is possible. The area of the surface with slip lines corresponds to the level of accumulated damage.

The new approach may be used for indication of more dangerous points of aircraft structures, for prediction of fatigue crack under full scale test of aircraft structures as well as for residual service life estimation.

References

1. ***Zasimchuk E.E., RadchenkoA.I., Karuskevich M.V.*** Single-crystals as an Indicator of Fatigue Damage//Fatigue Fract. Engng. Mater.Struct. -1992.-Vol.15, N 12. - p.1281-1283
2. ***Karuskevich M.V., Gordienko Yu., Zasimchuk E.E.*** Forecasting the critical state of deformed crystal by analysis of smart defect structure.// Fractal characteristics and percolation critical indexes. Proceedings of the seventh conference on sensors and their applications, held in Dublin, Ireland.-1995, 10-13 September.-112-117.-Dublin.:
3. ***Гурьев А.В., Савкин А.Н.*** Роль микропластических деформаций в усталости металлов//Механическая усталость металлов.- Киев: Наукова думка, 1983,-с.122-129.
4. ***Cordero L., Ahmadieh A., Mazumdar P.K.***, A comulative fatigue damage formulation for persistent slip band type materials.//Scripta Metallurgica.1988-Vol.22.-p.1761-1764.
5. ***Игнатович С.Р., Карускевич М.В., Карускевич О.М., Хижняк С.В., Якушенко О.С.*** Моніторинг втомного пошкодження алюмінієвих конструкційних сплавів, Вісник НАУ NAU, 1(19) 2004, с.88-92.
6. ***Коваленко В.С.*** Металлографические реактивы, -Москва, Металлургия, 1981,-120 с.

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APPROXIMATE OPTIMIZATION SOLUTION BY PARETO OF DISCRETE EXTREMAL PROBLEM OF COMPLEXATION OF NEW GENERATION AVIONICS.

Multicriterion optimal task solution by Pareto enables the criterion comparison of solutions quality on approximate limitation for complexation of avionics when there is an ensemble of choices and also enables to find compromise solution.

Preface of problem

There is a diversity of functional tasks should be laid on modern projected or modernized aircraft with new generation avionics. Every of task is realized by chain of system appeared in complex. Some structures must be chosen from set of complexes and systems on early design stage (beginning with phase of conception of invention). These are the structures that have the higher technical efficiency when lower reduced operational costs and that meet the certain system limitations on system resources and airworthiness requirements of aircraft.

The substantiation of social order is put into practice by aviation key personnel on sub-stage of "conception", when the main aircraft operating, trustworthy, economic attributes of prospective science intensive, competitive complex object – aircraft. Also it is realized by means of much of experience and intuition.

Modern system approaches are based on mathematical modeling, i.e. applied by man-machine system for automation making and taking decision process based on computing aids by simulation in conditions of modern information technologies [1]. Under "taking decision" we understand the tasks of choosing the proper decision by person, i.e. the chose of certain alternative when it should be taken the solution based on information on object condition, specific knowledge, criteria, limitations, also taking into account the experience and intuition.

The actuality of problem is accentuated by ever-increasing aircraft requirements [1, 2], which tend to complication of avionics, increase of physical composition and variants of integrations, i.e. equipment structure. Also these tasks should be solved on man-machine system level on early design stage (phase of conception of invention), to automate the process and provide the decision taking person (DTP) with ability to carry the dialog mode of rational variant selection of avionics. The widespread adoption into practice of science intensive engineering puts CALS-technology (Continuous Acquisition and Life Cycle Support) – the ideology of computer automation of all activity processes and kinds, connected with life-cycle support, including design, certification, manufacturing, operation, utilization, directed to increase of its efficiency. The strategy of CALS-technology [3] can be approached as standardized complex of data-operation technology that is related to the product life-cycle (with information about object, process and environment) that directed on effective joint use of this data.

Thereupon the development of application package on the problem fills the CALS conception with certain content of avionics complexation as competitive equipment being the system of open type, i.e. enables to add, change criteria, limitations, functional tasks. The use of CALS – is the implementation of new engineering culture when design and operate science intensive product, undergone the meaning from "Computer – Aided Logistics Support" to "Commerce At Light Speed". In the normative documents it is formalized that the main components in the field of CALS-technology are [4]:

- methodology of structural system analysis and design in notation IDEF/O;
- technologies of product description and documentation based on ISO10303 (STEP), ISO13584; ISO8879; ISO9735.

There are five main standards that determine CALS-technology: functional (processes and methods, formalize information about product and process), informational (data and process description), technical exchange (transceiving), guarding of information and digital signature. Most successful modern solutions are CAD/CAM/CAE/PDM systems that provide the design, manufacture, operation and interaction process control with automation.

The analysis of state of avionics complexation task.

On prime design stages (conception, planning) it is necessary to choose from variety of avionics structures the optimum alternative of group that satisfies the whole requirements: airworthiness requirements (AP-25, FAR-25, JAR); International quality standard and logistic support in the course of life-cycle; flight, operational, reliability, economic criteria in the course of life-cycle etc. The evaluation of characteristic of each alternative is a very laborious task when there are a lot of variants. Automation of this process demands the usage of economic-mathematical models that gives the opportunity to increase the efficiency of labour and to decrease the costs on life-cycle.

The penetration of new generation avionics made with use of modern aviation circuit technology IMA (Integral Module Architecture) must provide with developing new conception of project and usage of increase of economic effectiveness on the life-cycle. The minimal primary cost of aircraft with new generation avionics is provided in the course of life-cycle without preference of resource allocation on any stage. All the participants of project get their benefits: aircraft designers, avionics creators, and operators. Such benefits are improvement of aircraft performance characteristics, weight and volume reduction of construction, increase of commercial load, decrease the needs in spare equipment, simplification in service and revision procedures [5].

For aircraft designers benefits are provided by decreasing of primary costs and by maintenance costs in the course of life-cycle by means of: decrease of designing, certification and manufacturing costs; decrease of aviation power engineering weight and commercial load increase; flexibility according to the consumers needs.

For avionics suppliers the deriving of their benefits is provided by: improvements of marketing potential when scaling the market volume; product manufacture terms increase; flexibility in consumers relief

For certification bodies their benefits are due to: type certification; certification of additional type; avionics qualification.

For operators gaining their objects is provided by taking the benefits such as: improvements in aircraft operational characteristics while implementing avionics; penetration of new philosophy of maintenance: "to delay the maintenance procedure till there is no need in maintenance, when aircraft is out of base"; to decrease the number of unconfirmed blocks demounting at the expense of expansion of diagnostics features, i.e. "ability to modify the systems and addition of new functions by means of on-board loading of software".

The main global criteria when engineering is the minimum costs for aircraft with avionics on life-cycle, that can be realized during design, shock absorption, material selection, reasoning of spare equipment, weight and dimensions of avionics, aircraft performance characteristics, equipment and development costs.

The solution in problems of optimization of complexation of avionics structures assumes the rules of alternative comparison. In this case the estimation criteria or several scalar functions are used. The definition of optimality itself changes into "optimization by Pareto", and the problem of option becomes multicriterion problem [1, 6, 7]. The solution is not the certain point but the whole ensemble by Pareto or the set of effective points. Optimal solution by Pareto in case of several functions will be found if the value of any criterion can be improved only at the expense of degradation of the others [9, 10]. In the problems of mathematical programming one of ways of alternative ensemble definition can be the using of limitation system, but the problems themselves take the intermediate place between operation analyses and taking decision. This type of problems is related to semistructured problems because the trading is made by decision taking person (DTP), and the agent of decision taking is man-machine procedures (MMP).

On up-to-date stage of aircraft building evolution CALS-technology the MMP procedures are made by automatized programs CAD/CAM/CAE/PDM (design, manufacturing, operation, control) that should be filled with unique application package [3,8]. In course of iteration based on MMP [9] DTP realizes the necessity of compromise between values and simultaneously analyses the processes. The approximate optimization solution of discrete extremal problem is described in [11]. This solution is based on approximate instead of exact performance of limitations. The number of limitations is restricted. The received algorithms are polynomial as a result. The math model and algorithm of solving is shown in works [1,6,7].

"The procedures of carrying out analysis of design-technical solutions (DTS) and their ranking" of alternative evaluation for DTS to be chosen properly (including the conditions of uncertainty of initial data of aircraft) is described in [3] (425-435 p.). It is based on principles of value analysis as a method of searching and implementation of most rational technical and economic solutions to achieve maximum possible objectivity while choosing the effective DTS. The results are gotten by an impartial usage of identification of priorities principle that DTP estimate (table), and the last method shows the properties of approximate mathematical model of optimization by Pareto of such task as complexation of avionics of prospective aircrafts.

Table **Comparative analysis of alternative evaluation of DTS**

Method of alternative selection	Advantage of method	Disadvantage of method
Monocriterion optimization	The simplicity of realization. Extremely easy methods of initial data formalization.	Low accuracy of solutions; restricted usage range, because not very often one of criteria is much important than others.
Consecutive concessions	The easiness of heuristic interpretation – it's always seen which of concessions made the compromise to come. There	Not always the initial data helps to come to compromise by means of concessions variation,

	is no need in weighting coefficient.	as the most important criteria are changing continuously in optimal areas.
Gurvitz principle	The simplicity of realization; productability of solution under non-full initial data.	The ambiguity of solution, connected with uncertainty of harmonic content selecting; extremal values of criteria are practically not realized
Integral principal	Wide range of usage in different situations under sufficient solution accuracy; ability to use objective function when choosing the utility level.	Necessity of estimation normalization of every criterion alternative; the need to calculate the weighting coefficient of criteria
Graphic-analytical method	Ability of graphical performance of initial data ease their interpretation for DTP; the usage of paired comparisons method simplifies the process of initial data formalization	The accuracy of received solution comes sort of great effort; method has a restricted usage
Krylov method	High solution accuracy on quantitative assessment and alternatives to choose	Restricted usage range, because of initial background rigidity
The method of consecutive limitations	Beforehand enables to take into account the information that DTP has. It eases the later interfacing of solution with him.	Unreasonable procedure complexity consisted in necessity of DTP attraction; organizational and psychological complexity in dialog "DTP-analyst" in working process.
Method of approximate multicriteria optimization of structure by Pareto	Allows to provide methodological basis based on mathematical model, algorithm and developed application package the dialog mode for MMP. Here such problems are solved: the choice of the most rational alternative of avionics structure (generated Pareto ε-chain) on the early design stage of aircraft; initial information for limitation system can be weakly structured; ability to perform the tolerant dialog mode for choosing the efficient result by DTP and training the explorer for features that are invisible in other modes; ability to count the new equipment and estimate the competitiveness compared with the base variant.	The identification complexity of all aircraft task-functions; solution of optimization of structure by Pareto gives the approximate parameters values; difficulties of initial data and system limits forming

The mathematical statement of multicriterion task of avionics complexation.

All the aircraft equipment is allocated according to the physical components – complexes, composed of systems and apparatus modifications, with their own APC (weight, dimension, power consumption, and cost). Every aircraft function must be performed with higher probability by system chain. There is a need to integrate avionics structure: to choose the structure with higher technical effectiveness from a quantity of alternatives, but with low initial costs (operational costs) and meeting the parameters limitation requirements. The structured reserving level relatively functionally-minimal structure (FMS) is determined from condition:

$$\sum_{j \in J_l} \sum_{i \in J_j} Q_i(x_i) \le cc_l, \quad l \in L, \tag{1}$$

where $Q_i(x_i)$ - probability of failure of the chain (task), $Q_i(0) = 0$.

cc_l - required probability of l-chain task performance (commonly for the complex situation).

The limits characterizing the reserving degree are determined by resource:

$$\min_{j \in J_k \ i \in I_j} R_i \ge BR_k, \quad k \in \kappa \tag{2}$$

where R_i - resource of i-chain,

BR_k - limitation for resources of k-complex.

For every avionics complex two criteria and limitation system are assigned and thus subtask is formed in this part of model. The binding limitations for complex are in (1), but mathematical model is:

$F_{1k}(x) \to max$ (technical effectiveness criterion)

$F_{2k}(x) \to min$ (reduced costs criterion)

The system has a view:

$$\sum_{j \in J_k} \sum_{i \in I_j} M_i x_i \le BM_k \text{ , (weight)}$$

$$\sum_{j \in J_k} \sum_{i \in I_j} c_i x_i \le BC_k \text{ , (cost)}$$

$$T_{o\kappa} = \frac{1}{\sum_{j \in J_k} \sum_{i \in I_j} 1/T_{oi}(x_i)} \ge BN_k \text{ , (failure running time)} \tag{3}$$

$$\sum_{j \in J_k} \sum_{i \in I_j} E_{ri} x_i \le BE_{rk} \begin{cases} \text{direct current energy} =, & r = 1, \\ \text{alternating current energy} \sim, & r = 2 \end{cases}$$

$$\sum_{j \in J_k} \sum_{i \in I_j} w_i x_i \le BO_k \text{ (cooling)}$$

where - i-type equipment weight;

- i-type equipment costs;
- error-free running time of i-type equipment;
- power consumption of direct and alternating current of i-type equipment;

BM_k, BC_k, BN_k, BE_{rk}, BE_{rk} - limitation values for k-complex.

For every complex we choose the ensemble of alternative optimal variants by Pareto of avionics complexation. And then we solve the task for whole aircraft with multicriterion optimization method.

The algorithm of ε-chain generation of compromise solutions.

The need of design of approximate algorithm is caused by ensemble size, i.e. by large amount of complex structures of avionics. Therefore we must simplify the model of limitations (3) and approximate calculation $T_{ок}$. The limitation for exponential distributive law is:

$$\sum_{j \in J_k} \sum_{i \in I_j} \lambda_i(\tau_i) \leq BL_k, \quad k = K \ ,$$

where $\lambda_i(0) = 0$ for every *i*.

The main idea of algorithm lies in following. For every complex we input the additional criterion $F_{3k} = \sum_{j \in J_k} \sum_{i \in I_j} Q_i(\tau_i)$ and generate the ensemble of compromise solutions of F_1, F_2, F_3. On the second stage the initial task solutions are generated based on compromise ones. It is advisable to use man-machine procedure (MMP) of dialog mode here. During the calculations we get the ensemble of T_n for complex $\tau^n \in T_n$ as sub-ensemble of equivalent solutions $\overline{\tau}^n$, such, that $f(\tau^n) - \varepsilon^n \leq f(\overline{\tau}^n)$. The solution mesh for each *i* has a step not less than $\varepsilon_i^n - \varepsilon_i^{n-1}$, that is fairly for partial solution T_j. For compromise solutions on the last stage of work let us assume that $g_i(\tau^n) = 0$ for limitations, then T_n – is the unknown ensemble. The quantity if solutions are realized by ε_i choosing and ε_i^j consequence.

On the second phase the ensemble of algorithms of W_k arrangements is assigned for every *k* complex. Where every variant $w \in W_k$ complies with the functions $F_{1k}(w)$ and $F_{2k}(w)$ and limitation column (3), for which there is a convolution on *k*. At linear convolution: $\overline{F}_2 = \sum \rho_k F_{2k}$ and maximum value $\overline{F}_1 = max\{j_k F_{1k}\}$, where ρ_k and j_k - are weighting coefficients. For each *k* we need to choose the variant $w \in W$, such that point would be effective. We use the dialog mode to choose these solutions when part of work is made by machine, the rest by DTP.

The conclusion to the article

The automation of task solution on man-machine system level, beginning from conception (designing) allows to penetrate the dialog mode while choosing the rational avionics set for DTP. The creation of application package on avionics complexation tasks ensures the substance of CALS-technology conception bringing the research to standardized complex of technologies as competitive equipment.

Reference

1. ***Vorobiyov V.M., Belyh T.V., Kisilyov A.D., Zakharchenko V.A., Novikova M.V., Berezovskiy B.N.*** Mathematical model and algorithm of synthesis task of optimal avionics complexation of prospective aircrafts on conception stage. Digest of studies. "System methods of control, technology and organization of production, maintenance and operation of cars". 2005, K. NTU.

2. ***Vorobiyov V.M., Zakharchenko V.A., Kichigin A.A.*** The creation of "criterion tree" of system optimization of ergatic complexes functioning. – K.: NAU // "Production and operation of aeronautical engineering" vol. III: Materials IV ISTC "AVIA-2004", 2004., p.35.13-35.16

3. Information technologies in science intensive engineering: computer supply of industrial business / edited by A.G.Bratukhin – K.: Tekhnika, 2001 – 728 p.
4. ***Vorobiyov V.M., Zakharchenko V.A., Vashku G.O., Vorobiyov A.V.*** System efficiency of complex "Crew – Aircraft – Environment". Digest of studies "Cybernetics and computer technology". Vol. 126. – K.: Glushkov IK NASU, 2000, p. 48-76
5. ARINC – 651. "Project manual of integral module aviation electronics. Transl. USA. Maryland. 1991. – 620 p.
6. ***Belyh T.V., Kuzmenko V.N.*** The algorithm of generation of ε-chain of compromise solutions for multicriterion integer-valued task. ASU. – K.: Glushkov IK NASU, 1994, p. 35-41
7. ***Belyh T.V., Golovnyov E.A., Kuzmenko V.N.,*** Linear model of task of optimal complexation of aircraft onboard electronics // The optimal solutions theory. – K.: Glushkov IK NASU, 1994.
8. ***Vorobiyov V.M., Levkovets P.R., Kiselyov A.D., Zakharchenko V.A., Novikova M.V., Enchev S.V.*** Modern conceptions of project control of computer- integrated logistic support of virtual aircompany during its life-cycle. – K.: NAU. Digest of studies. "Information and control problems". Vol. II, 2004, p. 96-100
9. ***Benajun R., Larichev O.P., de Mongolphier G., Gerni T.*** Linear programming with many criteria. Limitation method. // Automatics and telemechanics. – 1971, - #8
10. ***Glushkov V.M., Mikhailivich V.S., Volkovich V.L., Dolenko G.A.*** The question about system optimization in multicriterion tasks of linear programming. // Cybernetics. – 1982. - #3. – p. 4 – 8
11. ***Babat L.G., Bladuz S.G.*** About approximate solution of one class of discrete extremum problem // Economics and mathematical methods. – 23, Ed. 2. M.: 1987. p. 320 – 329.

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TRIBOLOGICAL PROBLEMS OF AIRCRAFT SAFETY

Results of this work show that for failure probability reducing it is necessary to enhance tribostructure stability, i.e. to reduce their entropy. Prospects are connected with reducing of friction factor of technical tribosystems in two-three orders and approaching of this factor to the level of biological systems

Safety of an airplane as a technical object is mainly determined by its strength and tribological properties. Strength features characterize the ability of the structure to resist its destruction under permissible operational conditions. Tribological properties mean the ability of aircraft movable joints to maintain the required operational ability during given service life.

In order to ensure required safety relative to strength criteria special systems have been developed which include prior information, static and endurance calculation methods, experimental check of all engineering solutions under laboratory and working conditions beginning from initial design stages to the aircraft phasing out of operation.

The main criterion of strength is the destruction probability that can be expressed by load condition characteristics during operation and strength properties of the structure as

$$Q = \int p(X)F(X)dX,$$

where p(X) is the density of distribution of external loads during operation; F(x) is the distribution function of the structure strength.

Tribological aspects are not considered during the first stage of the process of design. In other words, at the initial stage of design prior information is used. After that on the basis of actual and operational testing the full-scale maximum load and service life are determined.

In this case required safety level is based by the application of traditional materials and constructions as well as homogeneity of tribology objects with respect to small number of failure signs. Trouble-shooting and elimination of failure reasons takes up to 80 % of all of expenditures for aircraft and aero-engines maintenance. In this case failure of tribocouplings is the main source of aircraft accidents which occur owing to technical reasons.

Lack of knowledge about contact phenomena mechanism not only keeps development and applying of new materials and constructions but also leads to fatal errors while using classic materials. For exampleit has not been taken into account in the Yak-42 stabilizer control mechanism design that under lubricant starvation the rate of bronze wear intensity is extremely high. This fact led to total wear of the bronze nut, loss of control and disaster in one hundred hours of the flight.

Complicated, multifactor, non-equilibrium contact process are the reason of the fact that the designed methods for tribocouplings have not been elaborated. In order to obtain the estimation of the processes (1) it is necessary to have multi-dimensional characteristics of materials in tribocontacts as well as operational conditions in the range of all factors influencing operation. Due to the fact that external and internal conditions of tribological objects are indefinite it is very difficult to determine all characteristics with the accuracy necessary for calculation and design. The present paper describes methods of calculation and design based on specific properties of tribosystems and triboprocesses.

Two contacting solid bodies and a lubricant (grease, oil, gaseous or combination of these) the elements of a tribosystem. In the process of relative displacement under load, the interaction of substances of tribosystem elements takes place. These substances under the action of fluctuating potential power and temperature fields rather quickly achieve final physical-chemical and aggregate condition.

During the evolution stage of running-in, the tribosystem spontaneously transfer from the state preset by technological processes to the state determined by the process itself. At this stage in the place of a contact tribological structures are being formed and later on, in these structures at stationary mode the triboprocesses are realized. Tribostructures are formed from products of interaction of all tribosystem elements that are in the final physical-chemical and aggregate state. For example, iron oxides properties are invariable up to temperature 1000° K. Oxides, sulfides, phosphates, cokes, metallorganic salts and complexes in the form of molecules, clusters, superdispersed particles are tribostructure elements and provide their resistance to external actions.

Tribosructures behavior depends upon contained energy and its distribution between free energy as well as entropy. Trend of free energy to minimum consolidates tribostructure elements. Trend of entropy to maximum, i.e. uniform substance distribution, initiates structure destruction.

In tribostructure forming mechanism randomness has the main effect. In the fluctuate potential field of the tribological contact probability peaks arise in a random way. During evolutional process the weakest peaks of potential probability correspond to abrupt peaks of concentration of transferred substance. Final molecules, clusters, superdispersed particles form structures in the form of separate portions, meshes, cells, wedge-shaped and wavy systems that can be observed at the end of the process on the elements and samples friction surfaces and can be analysed in the metastable state. During tribostructure formation entropy decrease is iteratively compensated by entropy increase during heat removal from the tribosystem. These conditions are favourable for self-organization and formation of dissipative structures.

Having been formed tribostructures operate according to nonlinear laws of synergetics in the stationary mode. Their overgrowth is limited by entropy and their low level is restrained by free energy.

Using linear approximation of Boltzman's transfer equation we can present triboprocesses as function of time in the following form

$$dy(t)/dt = -(y_0 - \langle y\rangle)/T \qquad (2)$$

$$y(t) = (y_0 - \langle y\rangle)\exp(-t/T) + \langle y\rangle \qquad (3)$$

$$Y(t) = (y_0 - \langle y\rangle)T[1 - \exp(-t/T)] + \langle y\rangle\, t \qquad (4)$$

where y_0 and $\langle y\rangle$ are initial and stationary values of the process; T is running-in time of relaxation; Y(t) is integral process.

In tribological contact friction, wear and failure processes are realized. Energy, substance and failure flows correspond to these processes. Mentioned above equations are correct for all of three flows. If we deal with friction process Y(t) corresponds to friction energy $E_{fr}(t)$ and y(t) is friction power N(t)= $dE_{fr}(t)/dt$; for wear process Y(t) corresponds to wear I(t) and y(t) is wear rate i_t = dI/dt; for failure process Y(t) is failure probability Π(t) and y(t) corresponds to failure rate π(t)= dΠ(t)/d t.

Functions presentations (3) and (4) correspond to classical curves that describe wear rate and failure rate depending upon time. Exponents of right parts characterize running-in evolutional process, running-in duration determines relaxation time T and running-in effect on integral process is characterized by function $У_0 = (y_0 - <.y>)T[1 - \exp(- t/T)]$. At this stage free energy tends to minimum, aggregation of transferred particles occurs, substance internal flows form the tribostructure and increase its volume, failure flows and substance flows from the system are reduced till they achieve stationary level. In this case tribostructure substance is in its finite state, temperature and entropy are constant, and tribostructure entropy is proportional to its volume. When the entropy effect becomes predominant tribostructure collapses. Tending to uniform distribution leads to partial destruction of the tribostructure and removing some amount of its substance from the system in the form of wear debris. In this case, the volume and the entropy of the tribostructure decrease and tend of free energy to minimum becomes predominant. Consolidation of transferred particles occurs and tribostructure recovery is observed. The cycle is repeated.

Stationary state level is determined not by all produced entropy but only by its small part that is connected with tribostructure substance. It is proportional to the volume and may either be increased or reduced. During friction process the total entropy always increases. Competition of free energy G and entropy STv generates steady periodical processes under non-equilibrium conditions. Models of Lotki – Volter, brusselator models and others correspond to these processes in G-STv coordinates.

In any tribosystem in the positive quarter of velocity range Vm/sec(X_1) and loads PΠa(X_2), where $\vec{X}$ is the predetermined coordinates, there exists an area C in every point of which there is a stationary state where friction, wear and failure process have constant in time and dispersion features (Fig.1).This area is limited by states in which failure probability is increased from zero to one.

In friction units of aircraft systems velocities and loads are changed depending upon modes of typical flight and random fluctuations. Triboprocess level is also changed together with these states. In order to choose an optimum tribosystem for the specific friction unit it is necessary to have the method to estimate friction, wear and failure under variable operational conditions.

Let us consider basic physical phenomena and mechanism of this calculation.

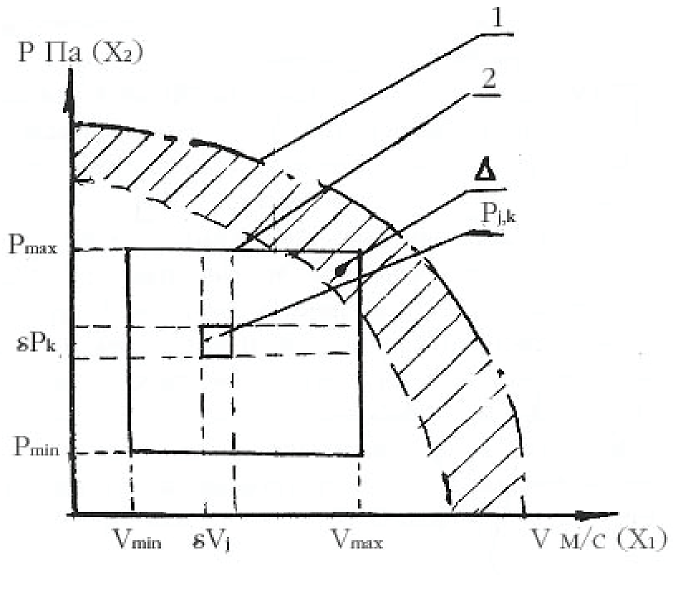

Fig 1. Preset area $\vec{X}$ tribosystem conditions
1 is boundary of area C; 2 is boundary of area of friction unit D operational states; 3 is state probability; 4 is critical operational part.

In every point of C area stationary state is an attractor. At the stage of running-in all processes tend to this state. When the system moves along area C all three processes follow to the path of motion. In this case motion is considered as changing of states in time. In other words it is motion in the area of states where the process corresponds to new state in every following point.

In the solid body mechanical signals are spread with sound speed. Tribostructures activated by friction have high relaxation ability. That is why triboprocesses follow to states without inertia up to high rate of change of loads and accelerations. Attraction of stationary states and high relaxation properties of triboprocesses allow to use superposition principle and linear summation in combining characteristics of tribosystem y(X) and medium p(X) in the form of

$$Y^{`}(t) = \int_0^t dt \int_{\vec{D}} y(X)p(X)\, dX \tag{5}$$

Inner integrals determine average values of processes and their dispersions for all states in $\vec{X}$ coordinates during time dt, Y(t) and $\sigma^2(t)$ are correspondingly integral value of the process and its dispersion during time from 0 to t. Outer integral is used for non-stationary operational conditions when contact area is increased together with wear and this fact leads to change of states probability p(X). If operational characteristic p(x) is not changed the inner integral is multiplied by the time of process realization t.

Let us consider the structure of states area $\vec{X}$ on the basis of operational conditions of the aero engine friction unit. These conditions are changed during aircraft typical flight from the ground idling condition when velocities and loads are minimal to take-off mode with maximum velocities and loads. For any part of the engine we may determine rectangle D($\vec{X}$) in $\vec{X}$ coordinates within which all its operational states are located. This rectangle has to be in limitations of stationary states area C($\vec{X}$) because outside this limitations failure probability tends to one.

After dividing this rectangle by lines which are parallel to axes and are located at equal distance we obtain a set of elementary rectangles. Identical velocity and load interval correspond to every of this elementary rectangle. During typical flight time T any time t_{tk} corresponds to every elementary part. Besides, we shall assume that value $p_{j,k}= t_{j,k}/T$ is the probability of a given state with respect to time. If we preset corresponding probability to every elementary part of D($\vec{X}$) we obtain operational characteristics of the friction unit p_t($\vec{X}$). This characteristic is a single mapping of the time line on $\vec{X}$. In this case every portion of these lines has exact place on D($\vec{X}$). Inverse mapping p($\vec{X}$) on t is ambiguous. It shows the probability with which the given state may appear at any point of the time line. In this case one elementary part D($\vec{X}$) may have several mappings on t.

Expression (5) is generalization of integral (1) for multi-dimensional spaces and non-stationary processes with respect to medium state p(X). In this case medium is functional area of velocities and loads X.

In order to find energy losses for friction, wear or failure probability per time t it is necessary to calculate integral (5) for every process. For performing this calculation we should know operational characteristic of the friction unit p(X) that is one for all of three processes as well as tribosystem characteristics for every stationary process on C such as friction factor μ(X), wear rate i(X) and failure rate π(X).

Operational characteristic of the friction unit can be obtained as a result of calculations and by means of analysis of synchronous measurements of velocities and loads during operation.

At every point of area C average values with respect to time and dispersions of processes are constant. Besides, dispersions are homogeneous on C. That is why we can use average values functions and common dispersion for every process on C as tribosystem characteristics.

Owing to stability of tribostructure properties the friction factor is usually changed lightly in the area of stationary states C. That is why it is possible to use average value and dispersion of the friction factor as characteristics of tribosystem stationary process of friction. For determination of these characteristics we have made several experiments at different points of area C.

Function i($\vec{X}$) that describes parameters of wear stationary process in all points of area C on X can be obtained in laboratory environment by means of making quite complicated and long-term experiments and analysis of their results.

Application of methods of multi-variant statistic and mathematical models of regression analysis allows to reduce essentially material and time expenditures for the experiment and to represent characteristics in the analytical form that is handy for use and storage.

Stationary processes of the wear are homogeneous in area $\vec{C}$ with respect to dispersions. Consequently, for its estimation it is enough to make several parallel experiments at one point, for example at the centre of area $\vec{C}$.

If wear is a result of partial and reversible destruction of the tribostructure the failure process occurs under partial non-reversible tribostructure destruction and after that it progresses till the final fracture. Failure process leads to serviceability loss of the frictional unit due to excessively high friction forces and comes to either seizure for example, in a cylinder and the piston group of the aircraft piston engines, in frictional units of the landing gear and other or to fire due to failure of support bearing of the gas turbine engine rotor and so on. Failure due to excessively high level of wear leads to high dynamic loads and to blades destruction of structural elements. In particular owing to wear of strip flanges blades of the gas turbine engine rotor are destructed. Such failures can be the reason of emergency and catastrophic situations. But because of the fact that for aircraft the probability of such situations can not be higher than 10^{-7} or one during 1100 years of service life we casn come to a the conclusion that the failure probability of the most responsible units approaches to zero.

The large part of the stationary state area C corresponds to these conditions. The increase of the failure probability in the marginal area is connected with stationary imbalance between energy and entropy in the tribostructure. When the entropy is excessive with respect to stationary states high mobility of tribostructure elements reduce their load-carrying ability. Direct contact of solid surfaces and cohesive separation of relatively large particles occur.

When the entropy is quite small we observe tribostructure breakdown that occurs due to low mobility of elements, direct contact of solid bodies and cohesive separation of particles. These particles form stress concentrations at the contact. They cause separation of new particles. The process is developed according to self-catalyzed mechanism and brings to non-reversible tribostructure destruction. Thus, instability of stationary states and development of failure processes are connected with appearance of self-catalyzed reactions at the contact.

As a rule, failure processes arise at the intersection of critical and operational areas Δ (Fig.1) If for a friction unit the state probability during operation is p(Δ) and the probability of appearance of the tribosystem failure process E is π(E/Δ) we can find the average failure frequency p(E) along operational area as p(E) = p(Δ) π(E/Δ). After multiplying this expression by t we obtain the analogue of the integral (5) for failure probability during time t where p(Δ) is friction unit operational characteristic and π(E/Δ) is tribosystem failure process characteristic.

Obtained relation represents existing knowledge about failure processes. Frequency of failure is uniformly distributed in time. In other words it has maximum information entropy. This information allows to localize failure process and to improve quality of forecasts in the presence of corresponding characteristics as well as to reduce the failure probability in case when characteristic features are not present. The reduction of indeterminacy as a result af diagnostics may be assumed as quantity of obtained information i.e. information is inversely proportional to indeterminacy

Information relative to failure E contained in characteristic F probability E changing from its priory value p(E) to its posteriori value p(E/F). In the information theory information amount contained in event F with respect to event E is determined as

$$I\,(E,F) = \log \{p(E/F) \,/\, P(E)\} \tag{6}$$

In this expression the base of the logarithm determines a unit of measurements of the information. When the logarithm base is 2 the information unit relative to E is obtained if p(E) is doubled; when the logarithm base is 10 the information unit corresponds to increase of p(E) in ten times.

When diagnostics is performed according to two characteristics simultaneously the property of additivity of the information amount is carried out in the following way

$$I(E;\, F_1F_F) = I(E;\, F_1) + I(E;\, F_2/F_1) \tag{7}$$

Failure appearance is always connected with tribostructure non-reversible destruction. That is why it is accompanied with identical phenomena for different tribosystems which are used as diagnostic characteristics. Among them there are changes in acoustic and vibration spectra, change of friction surfaces state, friction force fluctuation, presence of solid bodies' particles in the wear debris. Tribosystem homogeneity relative to failure characteristics permits to use very wide information basis for expert objectives and to obtain reliable estimation of priory probabilities even for very seldom events.

Conclusion

Information obtained during aircraft service life, modern means of technical diagnostics and operational inspection system allow to determine development of failure processes at an early stage. On the other hand the posteriori information and Bayesian calculation with required accuracy permit to localize a failure when the first signs appear and to reduce failure probability when they are absent to the level determined by requirements of airworthiness standards.

This level, according to which aircraft accidents rate is not grater than 10^{-7} per flight hour is not changed during fifty years. It means that classical methods of aircraft safety improvement exhaust themselves.

Results of this work show that for failure probability reducing it is necessary to enhance tribostructural stability, i.e. to reduce their entropy. Classical method consists of increasing energy flow rate from the system. Modern cooling systems attain their perfection many years ago. That is why reserves are minimal in this direction.

Prospects are connected with reduction of friction factor of technical tribosystems in two-three orders and approaching of this factor to the level of biological systems. Principal solution of this problem is connected with activation of repulsive phase states of interatomic ties in technical systems tribostructures.

In technical systems multiple reducing of friction forces simultaneously allows to solve different problems of wear, failure and ecology besides saving energy expenditure.

References

1. *Селихов А.Ф., Чижов В.М.* Вероятностные методы в расчетах прочности сасолета. – М.: Машиностроение. – 1987. – с.240

2. *Зельдович Я.Б. и др.* Перемежаемость в случайных средах. – УФН. Т.152 – Вып.1, 1987, с 33-41

3. *Пригожин И.* От существующего к возникающему. – М: Наука, Физматгиз. – 1985-с.328

4. *Кульгавый Э.А.* Триботехнические характеристики и их применение. – Проблемы трибологии.- 2003 - №3 –с.51-61

5. Нормы летной годности гражданских самолетов СССР. – МАП, МГА.-1974.- с.344

6. *Кульгавый Э.А.* Трибосистемы в случайных средах. – Проблемы трибологии . – 2004 -№3 –с.9-12

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MATHEMATICAL MODELING OF SEVERAL METHODS OF TURBULENT BOUNDARY LAYER CONTROL

Semi-empirical technique for modeling of turbulent shear flows and several methods of their control is presented. The developed methodology is based on Navier-Stokes system of governing equations and its simplified form of the boundary layer type system of equations together with several modifications of Prof. V. Movchan's algebraic model of turbulent viscosity. The possibilities of elaborated methods are illustrated on the base of comparison of predicted theoretical results with corresponding experimental data.

PREVIEW. Flow control is one of the most perspective directions of modern researches in the field of fluid-dynamics because it is closely connected with energy saving and environment protection problems. Researches in the field of drag reduction have become very intensive especially during the last quarter of the 20-th century due to intensification of energetic crisis. The state of foreign results obtained for different applications of drag reduction methodology was reflected by M. Gad-el-Hak in his extensive review (2000). In Kyiv this problem is investigated during a long period of time by the researchers of the Institute of Hydrodynamics (L. Kozlov, V. Babenko, G. Voro-payev and others). Several aspects of drag reduction and flow control problems (wall jets, resonators, suction, injection etc.) have been initiated (in sixties) and studied by team of researchers (Movchan V.T., Baskakova A.G., Trubenok V.D., Lazniuk P.S., Tokarev V.I., Maksimov V.D., Fridland V.Ya.. and others) headed by Prof. Mkhitaryan A.M. in Kyiv Institute of Civil Aviation (now National Aviation University). Flow control devices act on flow structure and modify it in required direction, so this interaction is difficult enough. It is well known fact that the different small factors like special kind of streamlined surface micro-relief (roughness, riblets) or little elements installed into boundary layer (turbulators, large eddy break up devices - LEBU) or modification of liquid properties in the vicinity of wall (polymer additives, heating) are able to modify significantly the flow properties. These factors act rather on characteristics of fluctuating turbulence motion than on mean flow properties. Turbulence is one of the most difficult physical processes, therefore the better understanding of its mechanism and behavior may be applied for development of progressive technologies of its control. As a rule, the interval of regimes for which the applied flow control method keeps its effectiveness is limited. This fact bounds the applicability of experimental me-thods of flow control investigation and optimization. That is why the implementation of mathematical modeling and development of corresponding theoretical models of flow control is a fruitful way of researches in this field.

STATEMENT OF PROBLEM. The object of this research is two-dimensional incompressible shear flows developing over wall, so-called boundary layers, with presence, possibly, some geometric phenomena like cavities. The goal of this research is to elaborate the mathematical model for this kind of shear flows based on the Reynolds-averaged Navier-Stokes system of equations or its parabolic approximation and evaluate the applicability of different turbulence models to describe correctly the diffusive processes in these flows. Several types of basic two-dimensional shear flows have been investigated. They are: orthodox boundary layers, wakes that develop inside boundary layer behind the small plate like LEBU and small airfoil-type body; near-wall jets that develop behind the jet nozzle which is tangentially attached to a streamlined surface; separated flow over a backward facing step; inhomogeneous boundary layers with the presence of devices that inject a system of polymer additives into the main flow. As a particular case a few free turbulent flows were considered, namely: free jet and wake flows behind a turbulizator. The mentioned types of flows are illustrated by the table below.

COMPUTATIONAL METHOD. In the most general case of two-dimensional shear flow it can be modeled on the base of the following Reynolds-averaged Navier-Stokes system of governing equations

$$\frac{\partial \overline{u}}{\partial \overline{x}}+\frac{\partial \overline{\upsilon}}{\partial \overline{y}}=0\,; \tag{1}$$

$$\frac{\partial \overline{u}}{\partial \overline{t}}+\frac{\partial \overline{u}^2}{\partial \overline{x}}+\frac{\partial \overline{u}\overline{\upsilon}}{\partial \overline{y}}=\frac{\partial \Gamma_u \overline{u}}{\partial \overline{x}}+\frac{\partial \Gamma_u \overline{u}}{\partial \overline{y}}-\frac{\partial \overline{p}}{\partial \overline{x}}+S_u\,; \tag{2}$$

$$\frac{\partial \overline{\upsilon}}{\partial \overline{t}}+\frac{\partial \overline{u}\overline{\upsilon}}{\partial \overline{x}}+\frac{\partial \overline{\upsilon}^2}{\partial \overline{y}}=\frac{\partial \Gamma_\upsilon \overline{\upsilon}}{\partial \overline{x}}+\frac{\partial \Gamma_\upsilon \overline{\upsilon}}{\partial \overline{y}}-\frac{\partial \overline{p}}{\partial \overline{y}}+S_\upsilon\,; \tag{3}$$

$$\frac{\partial \overline{c}}{\partial \overline{t}}+\frac{\partial \overline{u}\overline{c}}{\partial \overline{x}}+\frac{\partial \overline{\upsilon}\overline{c}}{\partial \overline{y}}=\frac{\partial \Gamma_c \overline{c}}{\partial \overline{x}}+\frac{\partial \Gamma_c \overline{c}}{\partial \overline{y}}+S_c\,, \tag{4}$$

where (1) is an equation of continuity; (2, 3) – the momentum equations for a longitudinal u and normal υ components of velocity; the equation (4) describes the transfer of scalar additive concentration c. Non-dimensional coordinates $\overline{x}$ and $\overline{y}$ are produced from dimensional coordinates x and y by using the typical size of calculated area L, so $\overline{x}=\frac{x}{L}$, $\overline{y}=\frac{y}{L}$. $\overline{p}=\frac{p}{\rho u_H^2}$ - non-dimensional pressure, ρ - density; υ – normal velocity component, $\overline{u}=\frac{u}{u_H}$, $\overline{\upsilon}=\frac{\upsilon}{u_H}$, u_H - the typical for given flow scale of velocity (for example, free stream velocity); $\bar{t}=t\frac{u_H}{L}$ - non-dimensional time. The dimensionless concentration of polymer additive $\overline{c}$ is normalized by significance of concentration c_o in an initial cross-section of ejector, that is $\overline{c}=c/c_o$. Symbols Γ denote the non-dimensional diffusive coefficients that is calculated with the use of kinematical coefficient of effective viscosity $\nu_{eff}=\nu+\nu_t$ by the expressions: $\Gamma_u=\Gamma_\upsilon=\frac{\nu_{eff}}{u_H L}$, $\Gamma_c=\frac{\nu/Sc+\nu_t/Sc_t}{u_H L}$, where ν, ν_t - kinematical coefficients of molecular and turbulent viscosity respectively, Sc and Sc_t - molecular and turbulent Schmidt's numbers that as a first approximation, in the given research were taken as constants. Symbols S in (2-4) denote the source terms, whose determination depends on problem that is under consideration (for example, an interaction between flow phases).

The set of boundary conditions for the system (1-4) is:

Streamlined surface: $\bar{u} = 0\,, \quad \bar{\upsilon} = 0\,, \quad \dfrac{\partial \bar{c}}{\partial \bar{y}} = 0\,;$ (5)

Initial cross-section $(\bar{x} = \bar{x}_o)$: $\bar{u} = f(\bar{y})\,, \quad \bar{\upsilon} = 0\,, \quad \bar{c}_o = \varphi(\bar{y})\,;$ (6)

Output boundaries of computational domain: $\dfrac{\partial \bar{u}}{\partial n} \to 0\,; \quad \dfrac{\partial \bar{\upsilon}}{\partial n} \to 0\,; \quad \dfrac{\partial \bar{c}}{\partial n} \to 0\,,$ (7)

where n is the symbol of normal coordinate to corresponding boundary of domain. Other boundary conditions depend on problem.

The function $\bar{u} = f(\bar{y})$ determines an initial velocity profile. The function $\bar{c}_o = \varphi(\bar{y})$ is determined by known concentration of a polymer solution in ejector's cross-section and other geometric characteristics of the ejector, namely, height of a disposition of its lower edge respectively streamlined surface $\bar{h}$ and dimensionless width of a slot $\bar{s}$. In case of homogeneous distribution of polymer concentration in ejector the last function may be presented by the following way

$$\bar{c} = \begin{cases} 0 & \text{if} \quad 0 \le \bar{y} < \bar{h}; \\ 1 & \text{if} \quad \bar{h} \le \bar{y} < \bar{h} + \bar{s}; \\ 0 & \text{if} \quad \bar{y} \ge \bar{h} + \bar{s}. \end{cases}$$

Mathematical model of shear flows with dominant direction spreading along surface without any geometrical phenomena can be modeled using the boundary layer type system presented, for example, in the following non-conservative form

$$\frac{\partial \bar{u}}{\partial \bar{x}} + \frac{\partial \bar{\upsilon}}{\partial \bar{y}} + \frac{\bar{u}}{u_H}\frac{du_H}{d\bar{x}} = 0\,; \tag{8}$$

$$\bar{u}\frac{\partial \bar{u}}{\partial \bar{x}} + \bar{\upsilon}\frac{\partial \bar{u}}{\partial \bar{y}} + \bar{u}^2\frac{1}{u_H}\frac{\partial u_H}{\partial \bar{y}} = -\frac{d\bar{p}}{d\bar{x}} + \frac{\partial \bar{\tau}}{\partial \bar{y}}\,; \tag{9}$$

$$\bar{u}\frac{\partial \bar{c}}{\partial \bar{x}} + \bar{\upsilon}\frac{\partial \bar{c}}{\partial \bar{y}} = \frac{\partial}{\partial \bar{y}}\left(\Gamma_c \frac{\partial \bar{c}}{\partial \bar{y}}\right). \tag{10}$$

Here the free stream velocity of outer flow u_H is considered not as a constant like in previous case but as a known function of a longitudinal coordinate *x*, the non-dimensional pressure gradient $\dfrac{d\bar{p}}{d\bar{x}}$ is determined as a function of $u_H(\bar{x})$ in accordance with Bernoulli equation $\dfrac{d\bar{p}}{d\bar{x}} = -\dfrac{1}{u_H}\dfrac{du_H}{d\bar{x}}$. The non-dimensional shear stress $\bar{\tau}$ is simulated by the Boussinesq formula

$$\bar{\tau} = \Gamma_u \frac{\partial \bar{u}}{\partial \bar{y}}\,. \tag{11}$$

Set of boundary conditions for the system (8-11) can be taken in the form given by expressions (5-7) together with dependence $\bar{u} \to u_H(\bar{x})$ determined for outer boundary of boundary layer.

TURBULENCE MODELLING. For turbulence modeling both algebraic and differential *k-ε* models of turbulence and heat conductivity have been used. These turbulence models have been modified under mentioned above circumstances. The modifications of this model by using functions of shift of logarithmic zone of velocity profile, which were proposed by author, allow accounting the influence of streamlined surface roughness (both natural and special like riblets) and injecting of polymer solution into flow.

Algebraic level of modeling is based on the model of turbulence in the form, proposed by Movchan [1, 2]. As an alternative way to algebraic approach of turbulence modeling, the k-ε model of turbulence was modified under mentioned above conditions with the use of source term change. As it was proposed by author, the modification of these models, accounting the influence of streamlined surface roughness (riblets) and blowing of polymer solution in flow, may be provided by usage the shifting functions of logarithmic zone of velocity profile.

The algebraic model of turbulent viscosity that were applied for this investigation is given by following expressions,

$$\mu_t = \chi\rho\delta^* u_H \gamma \tanh\left(\frac{\ell\sqrt{\bar{\tau}}}{\chi\Delta}\right); \tag{12}$$

$$\ell = ky_1 \tanh\frac{\sinh^2[ч_1 y_1^+]\tanh[\sinh^2(ч_2 y_1^+)]}{ky_1^+\sqrt{\bar{\phi}}}; \tag{13}$$

$$\mu_t = \begin{cases} \rho\chi_j\bar{\delta}_j & \text{if} \quad \delta_{\max} \le y \le \delta_j; \\ \rho\chi_{wk}\bar{\delta}_{wk} & \text{if} \quad \delta_j < y \le \delta, \end{cases} \tag{14}$$

where $\chi = 0.0168 - 0.0215$, $\chi_1 = 0.068 - 0.072$, $\chi_2 = 0.223$, $\chi_j = 0.009 - 0.012$, $\chi_{wk} = 0.009 - 0.012$, $k = f(c,...)$- model's coefficients for different zones of boundary layer or wall jet flow; l – length scale of near-wall turbulent motion; $\bar{\tau} = \tau(y)/\tau_w$- non-dimensional shear stresses in the vicinity of a streamlined surface, which is determined as a function of a sign of a pressure gradient $\frac{dp}{dx}$ as follows $\bar{\tau} = \begin{cases} 1 + \frac{dp}{dx}y & \text{if} \quad \frac{dp}{dx} \ge 0, \\ 1\Big/\left(1 - \frac{dp}{dx}y\right) & \text{if} \quad \frac{dp}{dx} < 0; \end{cases}$

$\Delta = \delta^* u_H^+$ - Rotta-Klauser's length parameter; y_1- the normal coordinate y shifted relatively its significance for smooth surface depending on roughness and polymer additives parameters, $y_1 = y_1^+ \nu/\upsilon_*$; $\upsilon_* = \sqrt{\tau_w/\rho}$ - shear velocity; δ^*- displacement thickness of near-wall shear flow; $\delta_{\max}$, δ_j δ - thickness of upper limits of "near-wall", "jet" and "wake" parts of velocity profile; γ - intermittency function; $u_{\min}$, $u_{\max}$ - minimum and maximum significances of velocity u in the case of non-monotonous jet profile. The magnitude y_1^+ is determined according with wall's law by: $y_1^+ = \begin{cases} 0 & \text{if} \quad s \le 0; \\ s & \text{if} \quad s > 0 \end{cases}$, where $s = y^+ + \Delta y_{rhn}^+ - \Delta y_{pol}^+$; Δy_{rhn}^+- parameter, accounting the influence of surface roughness; Δy_{pol}^+ - parameter entered into the proposed model for modeling the influence of polymeric components. The function of a shift

$\Delta y^{+}_{rhn} > 0$ allows accounting the influence of streamlined surface roughness in model of turbulence. This influence is the displacement down of a logarithmic zone of the semi-logarithmic velocity profile, concerning its position for a smooth surface by value Δu^{+}. The magnitude of Δu^{+} is a function of surface roughness parameters. This function structure and its connection with Δy^{+}_{rhn} were presented in [1, 2]. Analogically, the shifting function $\Delta y^{+}_{pol} > 0$ accounts the polymer components influence with the up displacement of a logarithmic zone of the semi-logarithmic velocity profile, concerning its position for a smooth surface by value Δu^{+}. This function may be successfully applied for modeling the influence of special kind of roughness like riblets that has the effect of drag reduction.

In the range of the presented model, the dependence between Δy^{+}_{pol} and Δu^{+} can be found in the universal form, analogically to case of roughness influence. However, the analysis of experimental data shows that it is impossible to determine universal and unequivocal dependence between Δu^{+} and parameters of the polymeric additives. Thus, the known experimental data of the concentration influence and other specific polymer characteristics should be used in each case. The empirical dependences like mentioned above for various polymers are found, for example, in [3, 4]. This information also was applied in frames of this investigation as the first approximation.

To account of heterogeneity of polymer concentration in the cross-section of calculated flow the following hypothesis has been adopted: the function Δy^{+}_{pol} in difference with the function of roughness Δy^{+}_{rhn} is not a constant in a calculated cross-section $x = const$. It should be determined in each calculated node j of y_j as a function of local concentration c_j, defined by solving of the equation (4) or (10), that is $\Delta y^{+}_{pol} = f(c, y, ...)$. In case of boundary layer modeling over surface with riblet relief the corresponding shift Δy^{+}_{riblet} is considered a function of riblet geometrical parameters (height, shape penetration) normalized in accordance with wall law scales.

COMPUTATIONAL PROCEDURE. System (8-10) together with turbulence model equations and set of boundary conditions (12-14) was solved with the use of elaborated effective marching methods of second and third orders of accuracy. This method is based on without-iteration two or three step procedures, which allow quickly running along flow direction. In case of modeling problems connected with investigations of influence between near-wall flow and wall roughness elements or other obstacles the modifications of SIMPLE iterative algorithms constructed on base of third order Leonard's and TVD Zijlema's schemes were applied. The numerical experiment have shown the workability of proposed generalizations of semi-empirical models of turbulence and effectiveness of elaborated methods of near-wall shear flows for the investigated here cases of flows.

The example of predictions of distributions for velocity, kinetic energy of turbulence and turbulent viscosity in different sections of near-wall turbulent shear flow is presented by Fig. 1 This flow is characterized by presence of a small element like LEBU inside boundary layer that modifies both structure of mean flow and turbulent motion. Points on the Fig. 1 show the results of experimental measurements of corresponding profiles that have been obtained by Tulapurkara, Ramji and Radjacekar for this type of shear flow.

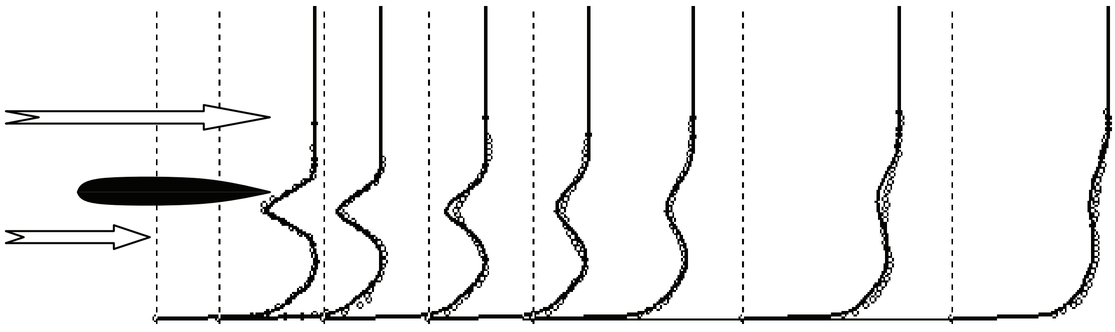

Fig .1 (a) Velocity profile distributions for boundary layer with wake that develop behind the small body of airfoil form installed inside it. Points – experimental data of Tulapurkara, Ramji and Radjacekar

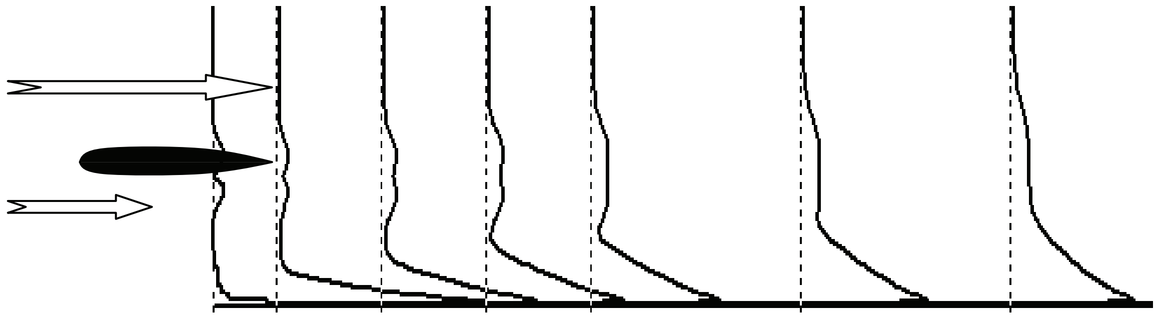

Fig .1 (b) Kinetic energy profiles for the described above flow

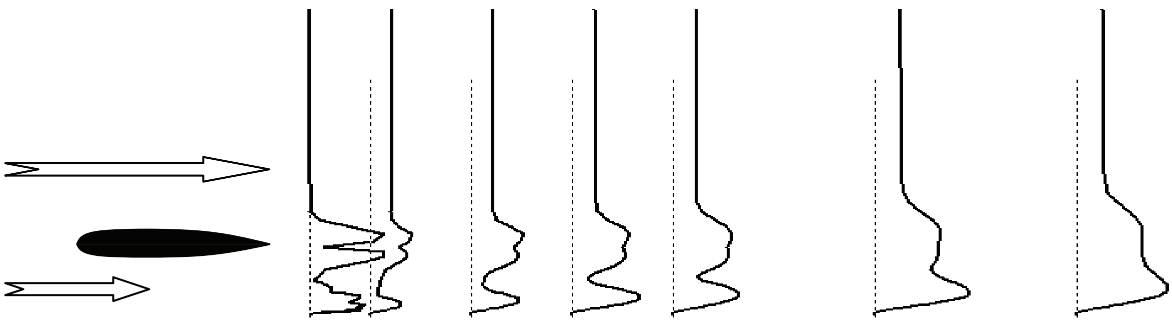

Fig. 1 (c). Turbulent viscosity coefficient profiles $\nu_t = \nu_t(y)$

Fig. 2 shows the results of integration (4) in form of velocity profiles in semi-logarithmic coordinates $u^+ = f(y^+)$. These results (lines) are compared with experimental data (points), obtained by U.F. Ivanuta & L.A. Chekalova [6] for polyethilenoxide WSR-301, wide range of polymeric concentration c=2x10^{-6}-50x10^{-6} g/cm^3. The calculated velocity distributions correspond satisfactorily with data of different experiments, as follows as presented comparisons.

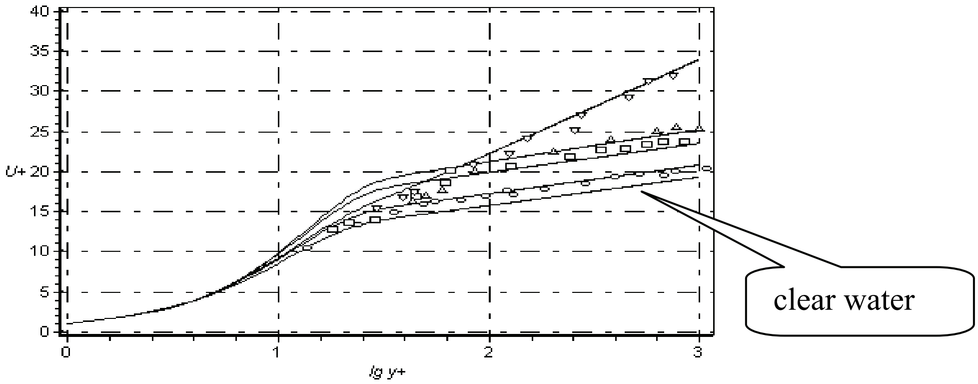

Fig. 2. Comparison of calculated velocity profiles in semi-logarithmic coordinates (lines) with experimental data (points) of U.F. Ivanuta & L.A. Chekalova (polyethilenoxide WSR-301, c=$2x10^{-6}$-$50x10^{-6}$ g/cm^3)

Fig. 3 demonstrates the example of non-homogeneous turbulent boundary layer prediction (water) with tangential injection of different concentrations of polymer addition from three nozzles located on different distances above the streamlined surface.

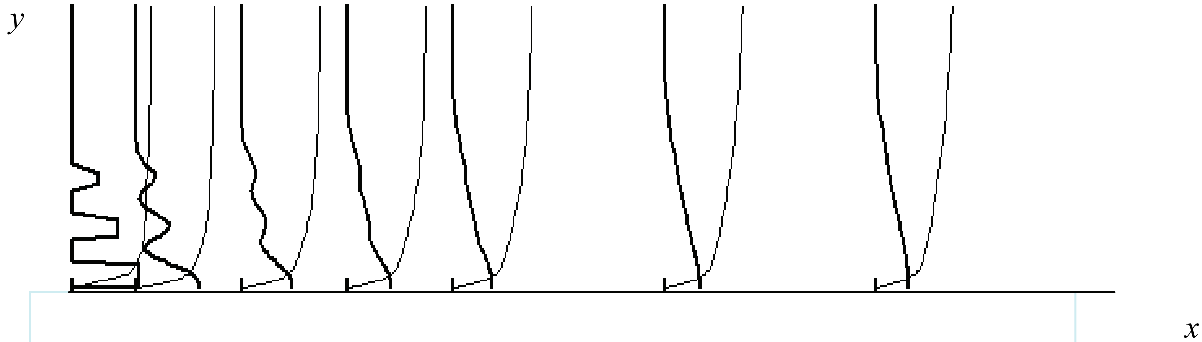

Fig. 3. Prediction of flow development with complex multi-liquid injection of polymer solutions (s=0.2δ, h=0.3δ)

Fig. 4 demonstrates distributions for velocity u, kinetic energy of turbulence k, its dissipation rate ε and turbulent viscosity coefficient ν in complicated turbulent flow which is a result of interaction between wall jet and square cavity located inside streamlined surface.

This illustration shows the effect of strong disturbance of jet flow by this cavity.

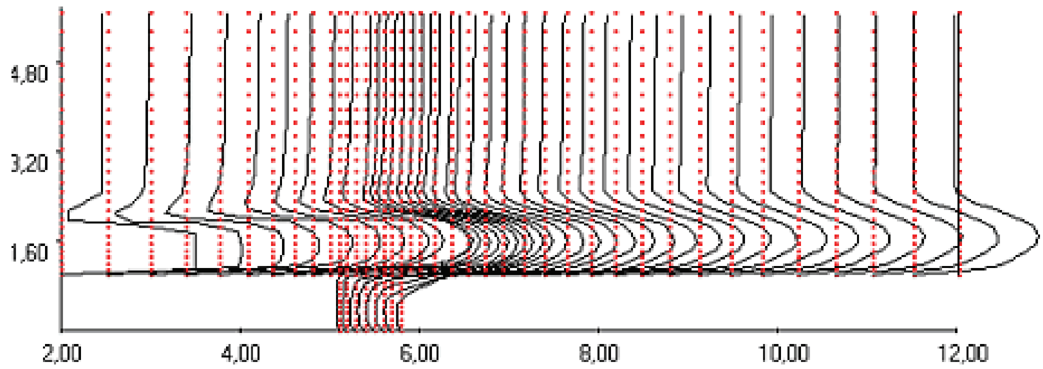

Fig. 4 (a). Predictions of the longitudinal velocity profiles $u = u(y)$ for different sections along shear flow

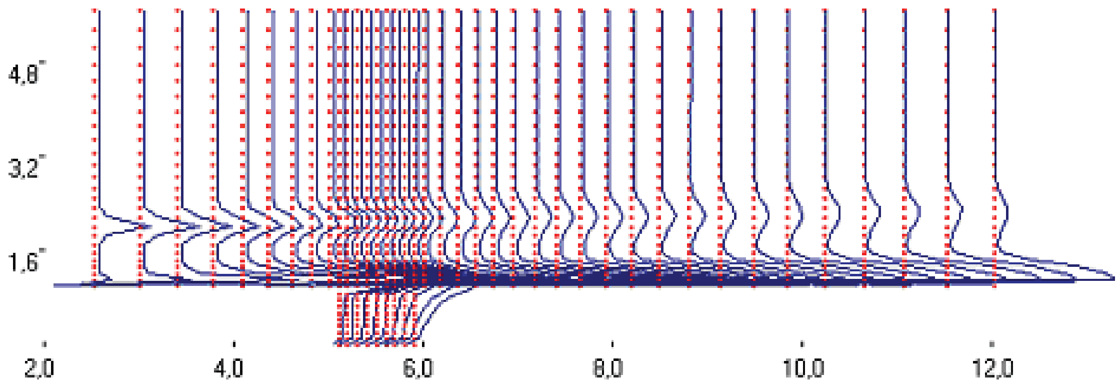

Fig. 4 (b). Kinetic energy of turbulence profiles $k = k(y)$

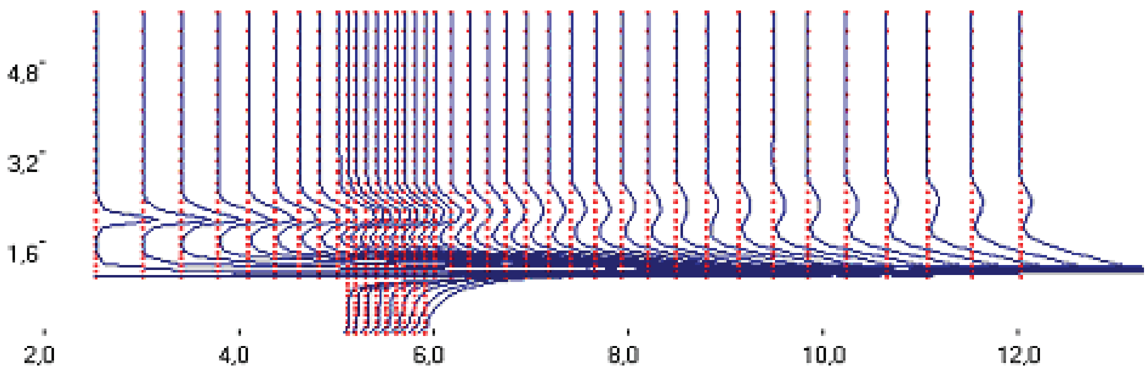

Fig. 4 (c). Dissipation rate of *k* distributions $\varepsilon = \varepsilon(y)$

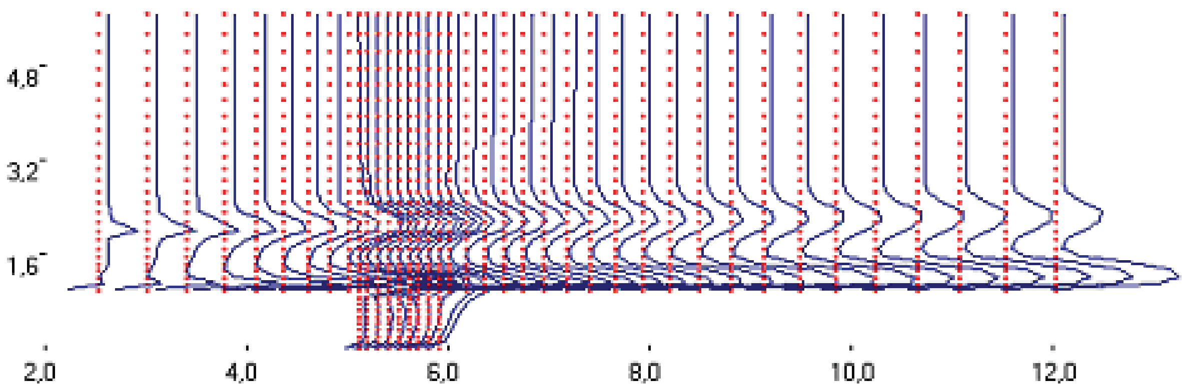

Fig. 4 (d). Turbulent viscosity coefficient profiles $\nu_t = \nu_t(y)$

CONCLUSION. The obtain results show the workability of elaborated algebraic and dif-ferential approaches for physically and numerically correct modeling of shear flows and several me-thods of their control. The analysis of comparison of the numerical results that were found on the base of developed technique with the theoretical and experimental data of the different researchers demonstrates a good agreement between them. The obtained results can be applied for optimization of a construction and regimes parameters of equipment for shear flows control. The more detailed information about author's investigations that are connected with the reflected set of problems can be found from his publications. Some of them are referred below.

REFERENCES

1. *Mkhitaryan A.M., Movchan V.T., Shkvar E.A.* **Numerical Simulation of Incompressible Turbulent Shifting Flows**, Proc. 5th European Physical Society Liquid State Conference "On Turbulence", Moscow, October, 16-21, 1989, 53-56.
2. *Movchan V.T., Mkhitaryan A.M., Shkvar E.A.* **The Simulation of Turbulent Separated Boundary Layers and Wall Jets**, Proc. IUTAM Symp. on Separated Flows and Jets, July 9-13, 1990, Novosibirsk, USSR, 1990, 799-806.
3. *Mkhitaryan A.M., Movchan V.T., Shkvar E.A.* **Mathematical and numerical modelling of turbulent boundary layer on infinite swept wing**, In book: "Applied aerodynamics" (in Russian), Kyiv, KIECA, 1993, 3-16.
4. *Movchan V.T., Shkvar E.A.* **Modeling of turbulent near-wall shear flows properties.** Proc. of AGARD Workshop on "High speed body motion in water", September 1-3, 1998, Kyiv: Institute of Hydro-mechanics. AGARD/NATO Report 827, 1998. -P. 10-1 - 10-6.
5. *Shkvar Ye.O.* **Mathematical simulation of separated flows with large zones of recirculation.** (in Ukrainian) "Visnyk Kyivskogo Mignarodnogo Universytetu Tscivilnoi Aviatscii", N 1, 1998. Pp. 280-287.
6. *Ivanuta Yu. F., Chekalova L.A.* **The experimental investigation of turbulent flow of slight polymer solutions in pipe.** // Engeneering-physical journal. - 1970. - V. 18, N 6. (in Russian)
7. *Movchan V.T., Shkvar E.A.* **Mathematical modelling of turbulent viscosity for predictions of complex turbulent flows.** (in Russian) "Bionika" N27-28, 1998, Pp. 38-41.
8. *Shkvar Ye.O.* **Mathematical modelling of turbulent flows of homogeneous polymer solutions.** (in Ukrainian) "Visnyk Lvivskogo Universitetu", Ser. Prikladnaya Mathematica i Informatika, N 1, 2000, Pp. 259-263.
9. *Shkvar E.A.* **Mathematical modelling of additives transfer by turbulent boundary layer.** (in Russian) "Prikladnaya Gidromehanika" V. 2 (74). – 2000. - C. 96-105.
10. *Shkvar E. A.* **Mathematical modelling of flows of inhomogeneous polymer solutions.** (in Russian) 8 pages, "Visnyk Natsionalnogo Aviatsiynogo Universitety", 2001, № 1, Pp. 43-49
11. *Shkvar E.A.* **Mathematical modeling of turbulent flow control by using wall jets and polymer additives.** Proc. of the 3rd International Symposium on Computational Technology (CFD) for Fluid/Thermal/Chemical Systems and Industrial Applications, ASME PVP Division Conference, July 22-26, 2001, Hyatt Regency, Atlanta, Georgia, USA.
12. *Babenko V.V., Shkvar E.A.* **Combined Method of Drag Reduction.** Proceedings of the Int. Summer Sci. School on High-Speed Hydrodynamics HSH-2002, June 16-23, 2002, Cheboksary, Russia, Pp. 30-35
13. *Shkvar E.A.* **Mathematical modeling of shear flows behind the obstacles and methods of their control.** Proc. of the World Congress "Aviation in the XXI-st Century", 14-16, 2003, Kyiv, NAU,Ukraine, P.2.41-2.45
14. *Shkvar E.A.* **Modelling of multiphase flows over surface with penetrable rough relief.** Proc. of the International NATO ASI Conference on flow and transport processes in complex obstructed geometries, Kyiv, IHM, 2004, P. 183-184

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PROBLEMS OF TURBULENT BOUNDARY LAYER OVER THE DEFORMABLE SURFACE OF VISCOELASTIC LAYER

One of the most important issues of modern hydro-aeromechanics is reduction of hydrodynamic resistance during motion of various vehicles in air and water. Vast majority of such flows are turbulent. Turbulence in a medium is a result of interacting forces of various nature in the medium and, as a rule, mandatory attribute of motion with real speeds.

The transition from laminar to turbulent regime of flow is associated with qualitative and quantitative changes in the parameters of the boundary layer formed about the surface of body in motion, among them is that friction drag and heat exchange in the same medium grow by an order or more. But despite huge financial and intellectual costs, laminar regime can not be conserved. The only achievement is increased threshold Reynolds number. But if Reynolds number exceeds some critical value, flow transits from laminar to turbulent regime that is associated with essential increase of power costs for maintaining corresponded flow speed [1,6,14].

In this connection, the emphasis of in the problem of hydrodynamic resistance reduction has shifted to the area of turbulent boundary layer. From researches in this field, including those performed in the Institute of Hydromechanics NASU, it is now well-recognized that a surface possess minimum resistance to turbulent flow is not an ideally smooth surface, but that with a regular structure which can affect boundary layer and alter characteristics of the near-wall turbulence.

A solution of the problem of turbulent near-wall flow control is associated with answering a number of questions, among them [2,8,12]:

- Is it possible to relaminarize turbulent boundary layer at Reynolds number much higher than the threshold Reynolds number?
- Is it possible to change the energy balance at given level of stress on the wall?
- Is it possible to control the level of anisotropy of Reynolds stress tensor components under stochastic turbulent flow?
- Is there a correlation between variations of spectral density of turbulent boundary layer energy, at given Reynolds number, and friction drag coefficient?

On the basis of theoretical and experimental analysis of the near-wall turbulence and mean flow field subjected to small oscillations of the surface, which do not change pressure distribution outside the boundary layer, it is possible to answer the questions.

Turbulent boundary layers over a deformable surface when the amplitudes of oscillation relative a steady surface are small in comparison with the boundary layer thickness can be attributed to such flows.

Consider a viscous flow over a deformed surface, or deformed surface under the action of disturbances in the flow. Surface deformations of an unperturbed surface are assumed to be small in comparison to the boundary layer thickness. The unperturbed surface is the contour of the body for which we know the pressure distribution or velocity of flow along the contour. The flow of viscous incompressible fluid is governed by the non-steady Navier-Stokes equations:

$$\frac{\partial \vec{\mathbf{U}}}{\partial \mathbf{t}} + (\vec{\mathbf{U}}\mathbf{grad})\vec{\mathbf{U}} = -\frac{1}{\rho}\mathbf{grad}\mathbf{P} - \nu\mathbf{rot}(\mathbf{rot}\vec{\mathbf{U}}); \qquad (1)$$

$$\mathbf{div}\vec{\mathbf{U}} = 0,$$

The motion (oscillation) of the viscoelastic layer over which the boundary layer develops is governed by the linearized momentum conservation equations:

$$\frac{\partial^2 \xi_i}{\partial t^2} = \frac{\partial \sigma_{ij}}{\partial x_j}, \qquad (2)$$

where $\sigma_{ij} = \mathbf{L}(\xi_i)$, $\mathbf{L}(\xi_i)$ is the generalized operator modeling viscoelastic medium. The boundary conditions are that velocities and pressure are equal at the interface between the two media, the lower boundary of the viscoelastic layer is fixed, and an undisturbed flow is on the outer edge of the boundary layer.

However, efforts to obtain a general solution of this classical problem at large Reynolds numbers have failed. In this connection, in this report we present the results of two solutions obtained on the basis of simplifications. First is the linearized problem modeling kinematic interaction of a disturbed flow and a deformable surface, and the second is the non-linear problem of energy interaction of TBL and DS on the basis of the Reynolds stress transport model of turbulence, realized in the form of closed problem.

We consider the near-wall area of the turbulent boundary layer over a flat surface with the velocity profile $\mathbf{U}\{\mathbf{f}(\mathbf{y}), 0, 0\}$, on which we superimpose a small nonstationary disturbance of velocity and pressure $\{u_1, u_2, u_3, p\}$, like a plane wave travelling with a slope q, skew to the direction of the mean flow. The linearized Navier-Stokes equations and equation of continuity relative to disturbances of speed and pressure are written in the form

$$\begin{aligned}
&\frac{\partial \mathbf{u}_1}{\partial \mathbf{t}} + \mathbf{f}(\mathbf{y})\frac{\partial \mathbf{u}_1}{\partial \mathbf{x}_1} + \mathbf{f}'(\mathbf{y})\mathbf{u}_2 = -\frac{1}{\rho}\frac{\partial \mathbf{p}}{\partial \mathbf{x}_1} + \nu\Delta \mathbf{u}_1;\\
&\frac{\partial \mathbf{u}_2}{\partial \mathbf{t}} + \mathbf{f}(\mathbf{y})\frac{\partial \mathbf{u}_2}{\partial \mathbf{x}_1} = -\frac{1}{\rho}\frac{\partial \mathbf{p}}{\partial \mathbf{x}_2} + \nu\Delta \mathbf{u}_2;\\
&\frac{\partial \mathbf{u}_3}{\partial \mathbf{t}} + \mathbf{f}(\mathbf{y})\frac{\partial \mathbf{u}_3}{\partial \mathbf{x}_1} = -\frac{1}{\rho}\frac{\partial \mathbf{p}}{\partial \mathbf{x}_3} + \nu\Delta \mathbf{u}_3;\\
&\frac{\partial \mathbf{u}_1}{\partial \mathbf{x}_1} + \frac{\partial \mathbf{u}_2}{\partial \mathbf{x}_2} + \frac{\partial \mathbf{u}_3}{\partial \mathbf{x}_3}.
\end{aligned} \qquad (3)$$

We search for the homogeneous solution to the system (3) in the form of plane wave travelling in the direction of the wave vector $\vec{\gamma} = \alpha\vec{\mathbf{i}} + \beta\vec{\mathbf{k}}$, of the wave [3]:

$$\begin{aligned}
&\mathbf{u}_1 = \mathbf{u}(\mathbf{x}_2)\exp(\mathbf{i}(\vec{\gamma}\cdot\vec{\mathbf{x}} - \omega\mathbf{t})); \;\; \mathbf{u}_2 = \mathbf{v}(\mathbf{x}_2)\exp(\mathbf{i}(\vec{\gamma}\cdot\vec{\mathbf{x}} - \omega\mathbf{t}));\\
&\mathbf{u}_3 = \mathbf{w}(\mathbf{x}_2)\exp(\mathbf{i}(\vec{\gamma}\cdot\vec{\mathbf{x}} - \omega\mathbf{t})); \;\; \mathbf{p} = \frac{1}{\rho}\mathbf{p}(\mathbf{x}_2)\exp(\mathbf{i}(\vec{\gamma}\cdot\vec{\mathbf{x}} - \omega\mathbf{t}));
\end{aligned} \qquad (4)$$

where $\vec{\mathbf{x}} = \mathbf{x}_1\vec{\mathbf{i}} + \mathbf{x}_3\vec{\mathbf{k}}$, and where ω is circular frequency.

We substitute (4) into the system of equations (3) and obtain the system of ordinary differential equations relative to u, v, w, which is reduced to the following system of equations:

$$\begin{aligned}
&\mathbf{v}'' - \gamma^2\mathbf{v} = \theta;\\
&\nu\theta'' - \left[\nu\gamma^2 + \mathbf{i}\alpha(\mathbf{f}(\mathbf{y}) - \mathbf{c})\right]\theta = 0;\\
&\nu\mathbf{w}'' - \left[\nu\gamma^2 + \mathbf{i}\alpha(\mathbf{f}(\mathbf{y}) - \mathbf{c})\right]\mathbf{w} =\\
&= \frac{\beta}{\gamma^2}\left[\nu\theta' - \mathbf{i}\alpha((\mathbf{f}(\mathbf{y}) - \mathbf{c})\mathbf{v}' - \mathbf{f}'(\mathbf{y})\mathbf{v})\right];\\
&\mathbf{i}\alpha\mathbf{u} + \mathbf{v}' + \mathbf{i}\beta\mathbf{w} = 0,
\end{aligned} \qquad (5)$$

where $\mathbf{c} = \dfrac{\omega}{\alpha}$ is the phase velocity of the plane wave, and where the primes correspond derivatives with respect to $\mathbf{y}$. From the impermeability and no-slip conditions we obtain the boundary conditions on the surface: $\mathbf{v} = \mathbf{v}' = \mathbf{w} = 0$ at $\mathbf{y} = 0$. (6)

At some distance from the surface, the quantities θ and q are bounded, as follows from the condition of neglecting viscosity: $\theta = 0;\quad \mathrm{w} = -\dfrac{\beta}{\gamma^2}\left(\dfrac{\mathrm{f}'(\mathrm{y})\mathrm{v}}{\mathrm{f}(\mathrm{y}) - \mathrm{c}} - \mathrm{v}'\right)$ (7)

We rewrite the system of equations (5) with the boundary conditions (6-7), describing the perturbed fields of velocity and pressure in the near-wall area of the turbulent boundary layer, in dimensionless form. If we take friction velocity $\mathbf{u}_*$ and viscous length $\ell = \dfrac{\nu}{\mathbf{u}_*}$ as scale parameters, the equations (5) will be reduced to:

$$\begin{aligned}
&\mathbf{v}'' - \gamma^2 \mathbf{v} = \theta;\\
&\theta'' - \left[\gamma^2 + \mathbf{i}\alpha(\mathbf{f}(\eta) - \mathbf{c})\right]\theta = 0;\\
&\mathbf{w}'' - \left[\gamma^2 + \mathbf{i}\alpha(\mathbf{f}(\eta) - \mathbf{c})\right]\mathbf{w} =\\
&= \frac{\beta}{\gamma^2}\left[\theta' - \mathbf{i}\alpha((\mathbf{f}(\eta) - \mathbf{c})\mathbf{v}' - \mathbf{f}'(\eta)\mathbf{v})\right],
\end{aligned} \quad (8),\ \text{where } \eta = \frac{\mathbf{y}}{\ell}.$$

Supposing that the profile of mean velocity is linear, $\mathbf{f}(\eta) = \eta$, in the near-wall area, the second equation of the system (8) can be transformed into the standard Airy equation[7]: $\theta''(\mathbf{z}) + \mathbf{z}\theta(\mathbf{z}) = 0,$ by introducing the change of variables $\mathbf{z} = \alpha^{-2/3}(\gamma^2 + \mathbf{i}\alpha(\eta - \mathbf{c}))$. From the solution of Airy equation for a complex argument, it is possible, for a fixed wave source, to construct the decaying solution that corresponds to moving away from the streamlined surface:
$\theta = \mathrm{A}_1(\mathrm{Ai}(\mathrm{z}) + \mathrm{iBi}(\mathrm{z})),$ where Ai(z) and Bi(z) are the linearly independent solutions of Airy equation, A_1 is a constant determined by the boundary conditions on the surface.

The first equation of system (8) has the solution:

$$\mathrm{v}(\eta) = \frac{1}{\gamma}\int_0^{\eta} \theta(\mathrm{t})\mathrm{sh}(\gamma(\eta - \mathrm{t}))\mathrm{dt} + \mathrm{B}_1 \mathrm{e}^{-\gamma\eta} + \mathrm{B}_2 \mathrm{e}^{\gamma\eta}. \quad (9)$$

For a flow over a rigid motionless surface $B_1 = B_2 = 0$ because v = v ' = 0 at η = 0. For a flow over an oscillating surface:

$\mathrm{v}_{\eta=0} = \dfrac{\partial \xi_2}{\partial \mathrm{t}};\ \mathrm{v}'_{\eta=0} = -\mathrm{i}\dfrac{\partial \xi_1}{\partial \mathrm{t}}(\alpha\cos\mathrm{q} + \beta\sin\mathrm{q}) + \mathrm{i}\alpha\xi_2\dfrac{\mathrm{u}_*^2}{\nu}$; or in dimensionless coordinates

$$\mathrm{v}_{\eta=0} = -\mathrm{i}\alpha\mathrm{c}\xi_2 = \mathrm{F}_1;\quad \mathrm{v}'_{\eta=0} = -\alpha\mathrm{c}\xi_1(\alpha\cos\mathrm{q} + \beta\sin\mathrm{q}) + \mathrm{i}\alpha\xi_2 = \mathrm{F}_2, \quad (10)$$

Therefore, values of constants are determined as follows:

$$\mathrm{B}_1 = (\mathrm{F}_1 + \frac{\mathrm{F}_2}{\gamma})/2;\quad \mathrm{B}_2 = (\mathrm{F}_1 - \frac{\mathrm{F}_2}{\gamma})/2.$$

The magnitude of pressure oscillations in the boundary layer is determined by expression:

$$\mathrm{p} = \frac{1}{\gamma^2}(\mathrm{A}_1\mathrm{Ai}'_1 - \mathrm{i}\alpha((\eta - \mathrm{c})\mathrm{v}' - \mathrm{v})).$$

Therefore, the disturbance of pressure on the streamlined surface is:

$$p = \frac{1}{\gamma^2}(A_1 Ai_1'(\alpha^{-2/3}(\gamma^2 - i\alpha c)) - i\alpha(cv' + v)_{\eta=0}),$$

and taking into account the boundary conditions (10) we obtain:

$$p = \frac{1}{\gamma^2}(A_1 Ai_1'(\alpha^{-2/3}(\gamma^2 - i\alpha c)) - i\alpha^2 c^2 \xi_1(\alpha \cos q + \beta \sin q)). \tag{11}$$

If do not take into account the longitudinal displacement amplitudes of a streamlined surface both on a rigid motionless and oscillating surface, the disturbances of pressure coincide, as $(cv' + v)_{\eta=0} = 0$. Thus, modelling the surface by a membrane that cannot stretch during its interaction with flow does not reflect changes of pressure oscillations in the boundary layer.

The third equation of system (8) for the amplitude of the wave solution in dynamic variables can be written as: $w''(\eta) - (\gamma^2 + i\alpha(\eta - c))w(\eta) = i\beta p.$

As similar to the solution of the equation for θ, we write its solution in the form:

$$w(\eta) = A_2 Ai_1(z(\eta)) + i\beta \int_0^{\eta} p(t) G(\eta, t) dt, \tag{12}$$

where: $G(\eta, t) = \pi(Bi(z(\eta))Ai(z(t)) - Bi(z(t))Ai(z(\eta)))$.

On a deformable surface, in addition to the kinematic boundary conditions, the dynamic boundary conditions (matching of normal and shear stresses at the interface) must be satisfied:

$$\begin{aligned} &(-p + 2\mu \frac{\partial v}{\partial y})_{y=\xi_2} = \sigma_{22}; \\ &\mu(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x})_{y=\xi_2} = \sigma_{21} \end{aligned} \tag{13}$$

where σ_{ij} are components of the stress tensor in the viscoelastic layer, on the surface of which the boundary layer is formed.

For the wave solutions, the dimensionless dynamic boundary condition, linearized relative to the nonperturbed surface, is written in the form:

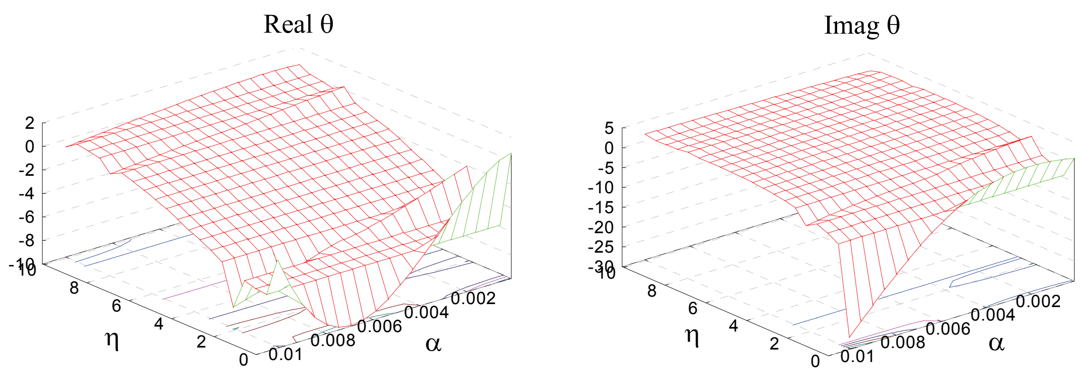


Fig.1. Dependence of Airy function on wave number α and distance from the wall η, at c=20.

$$\begin{aligned} &(-p + 2v')_{\eta=0} = \sigma_{22}, \\ &(i\alpha v + u')_{\eta=0} = \sigma_{21} \end{aligned} \tag{14}$$

The values of p, v, v' are determined on the surface. The value of u' is determined by differentiation the continuity equation.

Finally, the dynamic boundary conditions become:

$$\sigma_{21}+S_{11}\xi_1+S_{12}\xi_2=\frac{i}{\alpha}A_1Ai_1;$$
$$\sigma_{22}+S_{21}\xi_1+S_{22}\xi_2=-\frac{i\alpha^{1/3}}{\gamma^2}A_1Ai_1'. \quad (15)$$

where the constant A_1 is determined by the spectral density of pressure oscillations for a fixed wave number, where S_{ij} are functions of fixed wave numbers **α**, **β** and phase velocity **c**.

The boundary conditions (13) close the system of equations (2) for determining amplitudes of oscillation of viscoelastic layer of finite depth **h** and infinite transversal length under action of pulsative load such as travelling wave. Substituting $\vec{\xi}=\mathrm{grad}\varphi+\mathrm{rot}\vec{\psi}$, we reduce the system of equations (2) for homogeneous waves $\xi_i=\xi_i(y)\exp(i\alpha(x-ct))$ to independent Helmholtz equations for scalar and vector potentials φ,ψ [3] :

$$\Delta\varphi+\left(\frac{c\alpha}{a_\lambda}\right)^2\varphi=0;$$
$$\Delta\psi+\left(\frac{c\alpha}{a_\mu}\right)^2\psi=0, \quad (16)$$

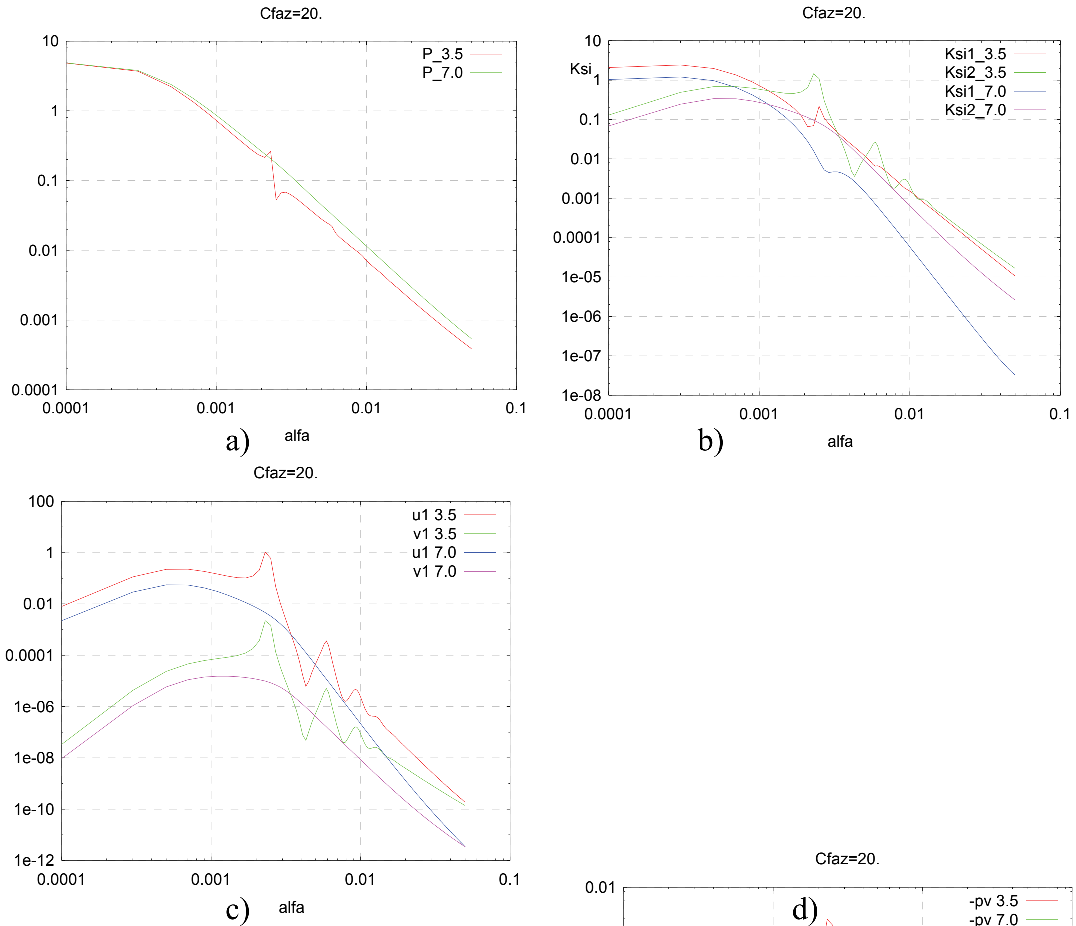
where Δ is Laplacian operator, $a_\lambda=\sqrt{(\lambda+2\mu)/\rho_s}$, $a_\mu=\sqrt{\mu/\rho_s}$, λ and μ are dynamic parameters of viscoelastic layer, and ρ_s is density of the layer material. We search for the solution to equations (16) in the form:

$$\varphi=(C_1\exp(k_\varphi y)+C_2\exp(-k_\varphi y))\exp(i\alpha(x-ct));$$
$$\psi=(C_3\exp(k_\psi y)+C_4\exp(-k_\psi y))\exp(i\alpha(x-ct)),$$

where $k_\varphi=\alpha\sqrt{(c/a_\lambda)^2-1};\ k_\psi=\alpha\sqrt{(c/a_\mu)^2-1}.$

The constants C_i are determined from the boundary conditions (13) and the condition $\xi_i=0$ at $y=-h$. The solutions obtained for the conjugate problem allow us to evaluate the magnitudes of Reynolds stresses on the surface of the viscoelastic layer and the flux of pulsation energy into viscoelastic layer. We simultaneously obtain values of deformability of the surface of the layer, evaluate the influence of viscous stresses in the flow on the amplitudes of the surface, and observe changes of the spectrum of pressure oscillations on the deforming surface of the layer. The range of wave numbers α -(0,0001-0,01) nondimensionalized by the viscous scale ν/u_*, corresponds to the energy-carrying frequency band 10Hz-1000Hz at the flow velocity of 10-15 m/s. As an example, the spectral characteristics of pressure oscillations on the surface of the layer, Reynolds stresses $\overline{u^2},\overline{v^2}$, flux of pulsation energy $\left(-\overline{pv}\right)$ into the viscoelastic layer in unit time are shown in Fig. 2a, 2b, 2c, 2d, as well as amplitudes of the surface of the viscoelastic layer at various physical properties of the viscoelastic layer material. We consider viscoelastic material with complex shear modulus smaller than the threshold value (c is phase velocity of disturbances in the flow) $\mu_0=3.5\cdot10^4\,\mathrm{Pa}$ and small relaxation time, and large complex shear modulus $\mu_0=7.0\cdot10^4\,\mathrm{Pa}$ and large relaxation time. The change in spectral concentration of pressure at low frequencies for various coatings is infinitesimal, but noticeable difference in the frequency of first proper mode of the viscoelastic layer occur when the viscosity of the material is small.

When the complex shear modulus of the layer material is greater than μ_p, the change in spectral density of the pressure on the surface of the layer can be neglected. The amplitudes of displacement of the surface are inversely proportional to the shear modulus and relaxation time of the material, but the amplitude of the surface oscillation increases sometimes near eigenfrequencies, and in this regime of wave numbers, we must account for viscous stresses in the flow. The flux of pulsation energy into the coating at natural modes also increases, but the integral flux over all ranges of wave numbers for such a layer as well as the energy of the oscillating surface is less than for a layer that has a higher complex shear modulus (Fig.2d). Under the action of a local load [8] applied instantaneously and over a finite time period on a viscoelastic layer of variable depth and finite length, wave motion appears in the layer. The



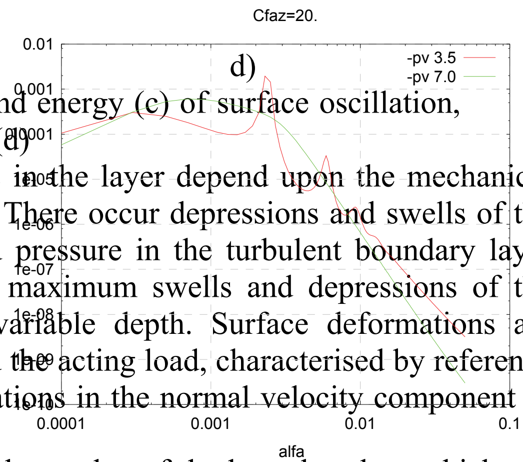


Fig.2. Pressure disturbance (a), amplitude (b) and energy (c) of surface oscillation, flux of pulsation energy into visco-elastic layer (d)

amplitudes and phases of the oscillation of points in the layer depend upon the mechanical and geometrical parameters of the layer and load. There occur depressions and swells of the surface that produce disturbances of velocity and pressure in the turbulent boundary layer [4,5]. Therefore it is very important to estimate maximum swells and depressions of the surface of viscoelastic layers of constant and variable depth. Surface deformations are determined as a function of coating parameters and the acting load, characterised by reference scales of turbulence and the most intensive fluctuations in the normal velocity component of the flow.

When Re grows due to increasing speed, absolute value of the boundary layer thickness decreases, and the intensity of turbulent pulsations increases. So, a coating with similar material properties is more compliant because amplitudes of its surface oscillations are greater and the internal dissipation rate does not change relative external disturbances. Therefore the effect of drag reduction weakens, and finally drag can even increase in comparison with the standard. When Re increases due to large dimensions of the reference body, the energy-carrying frequency of turbulent boundary layer decreses. So, for same coating thickness and relaxation time of the coating material either a reduction or increase in the effect of drag reduction can occur. But no increase in drag relative rigid smooth surface can happen, if there was a drag reduction relative rigid smooth surface at lower Reynolds number.

The considered formulation does not allow taking into account the finite surface length, or variations in properties and depth of coatings with length. In this connection, we must consider the problem of deformation of a viscoelastic layer with finite length and variable depth under the action of a nonstationary pulse source on the surface.

References

1. **Bushnell, D.M. and McGiinley, C.B.**, "Turbulent control in wall", Annual Review Fluid Mechanics, Vol. 21, 1989, pp.1-20.
2. **Chelyshkov V.S.,Grinchenko V.T. and Liu C**.," Direct numerical simulation of transitional near-wall flow", Advisory Group for Aerospace Research and Development, R-827, 1998, pp.11.1-11.8.
3. **Grinchenko V.T., Meleshko V.V.** "Harmonic oscillations and waves in elastic solids".-K.: Nauk.dumka, 1981.-283p.(in Russian).
4. **Duncan, J.H.,** "The Dynamics of Waves of the Interface between a Two-Later Viscoelastic Coating and a Fluid Flow", Journal of Fluid and Structures, Vol. 2, N1, 1988, pp.35-52.
5. **Duncan, J.H.**, "The Response of an Incompressible Viscoelastic Coating to Pressure Fluctuations in a Turbulent Boundary Layer", Journal: Fluid Mechanics, 171, 1986, pp.339-362
6. **Gad-el-Hak, M. and Blackwelder, R.F.**, "A drag reduction method for turbulent boundary layers", AIAA Paper, 87-0358, 1987
7. "Handbook of Mathematical Functions", Edited by M. Abramowitz and I. Stegun, 1964.
8. **Kim, J.,** "Turbulence structures associated with the bursting event", Journal: Physics of Fluids, Vol. 28, N1, 1985, pp.52-58.
9. **Kramer, M.O.**, "Boundary layer stabilization by distributed damping", Journal: American Society_Naval Engeneering, Vol. 72, 1960, pp.25-33.
10. **Christensen R.M**. "Theory of viscoelasticity An Introduction". –M.: Mir,1974.-338p.
11. **Rao, K.N., Narasimha, R., and Badry Narayanan, M.A.,** "The 'Bursting' Phenomenon in a Turbulent Boundary Layer", Journal: Fluid Mechanics, Vol. 48, N2, 1971, pp. 339-352.
12. **Voropayev, G.A and Popkov.V.I**. "On the interaction of compliant surface with the viscous sublayer of turbulent boundary layer". Hydromechanics, 1988, N57, pp.32-45 (in Russian).
13. **Voropayev, G.A.**, "Modeling of turbulent flows on deformable surfaces", Doctor Dissertation, Kiev, Ukraine, 1993 (in Russian).
14. **Voropayev, G.A., and Rozumnyuk, N.V.**, "Turbulent boundary layer over a compliant surface", Advisory Group for Aerospace Research and Development, R-827, 1998, pp.4.1-4.11.

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SURFACE STRENGTHENING AND RESTORATION OF AVIATION PRODUCTS BY MODERN TECHNOLOGICAL METHODS

The sophisticated technological methods of obtaining multifunctional composite coatings with an application of effective sources of energy are described. The above technology permits to form on the working surfaces the structures with predetermined physical and mechanical properties. Practical recommendations on application of the aircraft parts surface strengthening and restoration techniques, taking into account conditions of operation, are brought forward

General statement of the problem and its connection with scientific and practical tasks

The successful solution of production effectiveness tasks and state economy's transition to the intensive development are closely connected with speeding up of the scientific and technical progress. For this purpose it is necessary to create and implement into production fundamentally new types of technology and engineering, which are connected with material science. Especially it concerns parts in friction, upon which safety and durability of modern machinery, particularly aircraft depend. The problem of serviceability of aviation products (AP) is urgent in every country and first of all in the countries of CIS in connection with aging aircraft fleet and also with limited means necessary for restoration of outworn parts.

Parts of friction work under conditions of fatigue, abrasive, erosive, gas and hydro-abrasive wear, cavitation, fretting-corrosion etc. For example, turbine blades are exposed to high temperature gas flow and significant load during operation, are being worn due to propagation of erosive wear on their working surfaces.

In operation not only the wear of airfoil portion of blade can be observed, but first of all the wear of rotor blade tip shroud, which leads to extension of clearance between rotor blade tip shroud, to alternating tension in blades, resulting in break-down and failure of a blade.

Components of a landing gear are exposed to abrasive wear. Gas-abrasive wear can be observed on helicopter rotor blades operated on unpaved landing airfields and in highly dusted areas. Gas-abrasive wear is observed most distinctively on the parts of gas-air duct of helicopters gas-turbine engines. When a helicopter operates on the ground or hovering at a low altitude, dust and sand can be easily lifted into the air by air flow caused by rotating rotor; this dust cloud is kept suspended. As a result, the air, mixed with abrasive fractions, comes into the intake system of engines, promoting intensive development of gas–abrasive wear.

Mineral and artificial oils, greases, working liquids and solid lubricants are used to lubricate most parts of friction of the planes and engines.

Foreign fractions such as dust, sand, wear products come into these lubricants, which promotes development of wear processes, and sometimes can cause jamming of contacting surfaces. According to [1] 85-90per cent of planes come out of operations because of amortization of components, while expenditure of metal for spare parts manufacturing exceeds 20% of annual melting.

The problem of increasing heat and corrosion resistance of AM parts as well as fatigue strength, fretting stability etc are extremely pressing. All these factors urgently claim working out of technological methods, promoting serviceability of units of friction.

Increasing wear resistance of parts of friction units with the help of technological methods can be done in 2 directions:

1. Manufacturing of parts using wear resistant alloys and composite materials;
2. Forming on working surfaces of the parts functional coatings, the structure of which provides high tribological properties.

At present, some brands of alloyed steel such as 110Г13, ШХ15 etc are used as wear resistant steel. However the usage of these steels leads to a rise of the cost of the products. Besides the alloyed steels do not always provide the necessary tribotechnical characteristics of the parts, which work under certain conditions of contact interaction. In a number of cases it is impossible to satisfy a complex of operational requirements by application of traditional structural materials. More perspective is the creation of the functional coatings having the predetermined set physical and chemical properties. Application of such coatings does not only provide high serviceability of friction parts, but also allows to save a lot of rare alloyed materials, because in most cases thickness of coating applied on surface of the parts ranges from 5-8 up to 250-300 microns.

The purpose of the present work is monitoring of technological methods of surface strengthening and restoration of the worn out AP parts as well as determining of tribotechnical characteristics of coating, obtained by means of new technological methods.

Methods of research. A set of complex methods have been applied in research; the allow to carry out complete analysis of worn out details, subject to restoration, as well as model samples before and after the tribotechnical tests.

Condition of working surfaces has been studied with the help of metallographic and electron-microscopic analyses. The microstructures of surface layers was examined with optical microscopes of MMP-2P and Neophot-32 types. Microhardness was measured with ПМТ-3 device. The electron-microscopic research was carried out with the scanning electronic microscope named " CamScan-4 DV", the chemical structure of surface layers was determined with the help of the system called "Link-860". Phase structure has been studied by the X-ray diffractometer ДРОН-2,0. Processing of the results of the experiments was carried out by means of mathematical statistics methods.

The tests under conditions of gas-abrasive wear were carried out on installation and by means of a technique [2]. At 3000 or 6000 rpm of the rotor, the speed of the abrasive flow of 38 or 76 m/s is provided. The size of the abrasive particles has changed from 300 up to 900 microns. The tests were carried out at 15, 30, 60 and 90 degrees of angle of attach. The required angle of attack was provided by the inclination of the working surface of the sample relative to the horizontal plane. The samples sizing 20x15x4 mm have been grinded up to a roughness of the working surface Ra=0,16-0,32 microns. The quartz sand (ГОСТ 6139-70), with 0,5-0,9 mm grain size and relative moisture content not more than 0,15% has been used as abrasive material.

The wear resistance of the alloys and coatings under study with abrasive, which was not rigidly fixed, was carried out according to the mentioned method and on the installation [3].

Steels Х18Н10Т, steel 45 (hardened) and nickel based surface materials (ЭИ-893, И-625, ЭП-367, ЖС6К) were used as materials under research.

Results of research. At present the operations to provide quality and surface strength of parts of units of friction are carried out in two-directions: surface treatment, with a change of structure of the working layer without any change of a chemical composition; application of the functional coatings.

Among the methods of surface treatment there are: surface plastic deformation (SPD): mechanothermal, surface thermal, electromagnetic, magnetoimpulsive, electromechanical, laser and electron-radial processings. Each of these methods of treatment has, advantages and shortcomings and should be used in view of conditions of the operation, and also of a material of a hardenable part. So, for example, SPD method, which is one of the most widespread methods of surface hardening, promotes increasing of the surface strength of a part, hardness and wear resistance.

After SPD application the parts become less sensitive to the fatigue failure; scratches and microcracks, which have remained on a surface after the previous technological operation, disappear. Thus the limit of elasticity, fluidity and endurance grows.

The method of shot-blasting was widely used among the varieties of methods of SPD treatment. This method results in formation of cold hardening in the surface layer, providing the increasing of hardness and wear resistance. Application of the above method of hardening, allows to raise considerably the durability of such components as turbine blades, rods, springs, spring plates, stamps, etc.

Methods of traditional surface thermal treatment are carried out by heating the parts by gas flame, by high-frequency current (HFC) and by laser. The method of surface hardening by HFC found the widest application in machine building, autotractor and electrotechnical engineering. Such parts as gears, shafts, axes, cams, fingers for clutches, working under conditions of friction and wear process and subjected to dynamic, loadings are treated by this method.

As a rule, these parts have high surface hardness and wear resistance, and their core remains viscous, which provides components with high fatigue durability. Thickness of the hardened layer, which makes from 1 up to 10 mm, is adjusted by frequency of the electric current. For removal of residual pressure after hardening the details are exposed to low tempering.

More essential results are achieved by thermo-mechanical (TMT) and electromechanical (EMT) treatment, at which the durability of carbonaceous alloys considerably increases and their plasticity is not almost reduced. The given methods are based on joint effect of plastic deformation and the temperature changing in time, according to certain laws.

The varieties of TMT are high-temperature TMT and low temperature TMT methods. Application of these methods promotes the increasing of the degree of deformation up to 12%. It causes the increase of wear resistance more than 1,5 times, and wear resistance under conditions of abrasive wear process – 1,5-2 times.

The essence of EMT is that under the influence of the tool, to which the current is supplied, the partial melting and swelling-up on the edges of the working edge of the tool occurs. This method is applicable for restoration of the parts with deterioration less than 0,35 mm. Process flow diagrams of EMT are subdivided in two kinds: electromechanical smoothing (EMS) and electromechanical swelling-up (EML). The choice of technological diagram of EMT is determined by the purpose of the hardenable or restorable part and by conditions of its operation. At present research of such methods of surface processing and restoration of the worn out surfaces of the parts as electrohydroimpulsive, electromagnetic and magnetoimpulsive are carried out.

These methods could not find their wide application in industry, because systematized data of wear resistance of hardened surfaces as well as the systematized data about optimum technological mode of processing of component members were not accumulated.

Laser treatment of hardenable part is one of the prospective methods of surface machining. High speed of both heating and cooling, high temperatures, minimum time for full high temper of metal, high values of specific energy - all these cause obtaining of the necessary mechanical and physical properties at the surface layers. Laser treatment promotes increasing of wear resistance, fatigue strength as well as endurance limit of machine parts and mechanisms.

To strengthen the component members of crank – shafts, gear wheels, compression rings, distributing shafts, pistons of hydraulic engines, gas – turbine engines – the laser treatment is to be used.

The electron – ray technology [ERT] for material treatment which is intensively being developed at the Institute of Electrical Welding named after E. O. Paton which is in the framework of the National Academy of Sciences of Ukraine, belongs to the most effective science-based high technologies, which has wide prospects [4].

Such functional coatings are used for working surfaces as: galvanic and electrolytic, electromagnetic coatings, polymeric and ionized plasma, coatings, obtained by means of the methods of ion implantation; functional coatings, produced by chemicothermal treatment by means of laser and electron – ray treatment; self distributing synthesis, etc. – belong to the methods of the second group, as well as the metallization, surfacing, filling up with molten metal.

The methods of galvanic and electro-chemical coating as well as nickel plating, chrome plating, phosphate coating, cadmium plating, copper - plating, bronze - plating, etc. – are the traditional methods for restoration of worn-out parts in aviation engineering. Such methods are used at the aircraft repair plants for restoration of worn – out parts, the list of which includes more than 50 names. The coatings are used for parts, landing gears, rods of hydrocylinders, bolts, etc. The galvanic silver is an antifriction coating. And therefore, to protect the component members from setting – one of the disastrous kinds of wearing property – the galvanic silver on blade roots of compressor is to be applied.

The composite electrolytic coverings [CEC] having the second phase in their structure, which sufficiently effects mechanical and physical properties and tribological properties in particular [5], are more prospective in this connection. The distinctive feature of composite coatings is the fact, that either the coatings itself is powder, or powder medium is used to form it.

The basic method to obtain composite electrolytic coverings [CEC] is to inject the powder particles (the second phase) or simultaneously powders of some different phases into galvanic sediment. For each specific case the composition and structure of the coatings with indicated kinds of particles and matrix metals depend on technological parameters of the process, which, as the authors consider [6], includes: cathode current density; acidity; composition of electrolyte; its temperature; quantity, size and nature of the second phase; method and conditions of inserting the particles inside of electrolyte.

The composite electrolytic coatings may be obtained as a solid boron layer or solid carbide layer; or they may be obtained as eutectics in whish solid inclusions of boride and carbide layers are found or in the form of eutectics in which solid inclusions of boride and carbide will be evenly distributed in plastic matrix.

The composite electrolytic coatings may be obtained, depending on quantity and size of particles in matrix (nickel or iron in particular) as well as depending on the composition of electrolyte and parameters of the process of electrolysis. The obtaining of composite electrolytic covering also depends on duration and temperature of homogenizing.

Both coatings with hard inclusion, and the coatings with solid lubricant, which greatly improve the tribospecifications of coatings, are being obtained after heat treatment by means of simultaneous input of two or more components into the matrix during electrodeposition.

The typical microstructure of composite electrolytic coverings on the basis of nickel is shown in fig. 1.

For introduction of a proposed method for restoration of parts of aviation products there is no necessity to install special equipment, because the standard equipment of galvanic shops of aircraft plant is being used. The main advantage to obtain CEC is the fact, that being simple combination of two known and widely used methods of galvanic and thermal coating in our industry – it is provided with this equipment rather well.

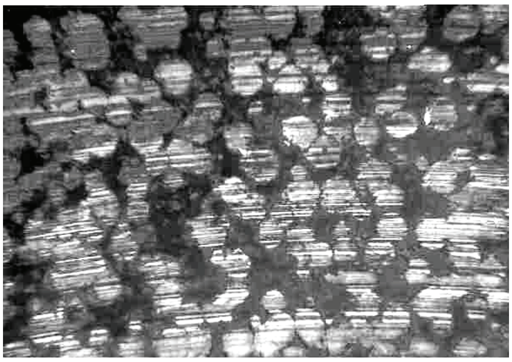


Fig1. Microstructure of CEC Ni-B after tribotechnical tests, x100

Nowadays the methods of gas thermal spraying and vacuum deposit applying refer to the number of the most actively developed directions in the field of protective coatings. Electric arc, gas flame, plasma and detonation spraying are referred to the group of industrially developed methods. They are united by one principle of forming coatings from different particles being heated and accelerated with the help of high temperature gas flow. The structure of coatings received by all these methods is laminated. It is made of more or less discrete particles with more or less distinctive boundaries of division.

In practice of aircraft repair plants all four gas thermal methods are used. Wide application of these restoration methods of worn AP parts is determined not only by physical and mechanical properties, obtained by parts after spraining, but by productivity of the process as well. Thus, the output of detonating spraining is expressed in kg/hour, of gas flame and plasma - in dozens of kg/hour, of electric arc metalization-in hundreds of kgs per hour.

Gas flame coatings are applied to the parts of gas turbine engine АИ-25 with the aim of reducing radial gap between rotor and the stator of the turbine which provides the increasing of efficiency and decreasing of specific fuel consumption. However, application of this method of gas thermal spraying is limited due to weak adhesion of the coating with the main surface, due to porosity, which ranges 5-25%, as well as due to a low coefficient of using energy during spraying (2-12%).

Plasma coatings provide higher physical and mechanical properties than gas flame ones. At aircraft repair plants these coatings are applied to the parts and they are made of steel (40Х, 30ХГСА, 30ХГСНА, Х18Н10Т) and of alloys ВЖЛ-12У, ЖС6У, ВТ3-1 etc. Powders of self fluxing alloys are used for spraying on the basis of nickel (Ni-Cr-B-Si-C) as well as the following materials ПКТСР3, ПНХАТ, ПКТХСР3.

While applying plasma coatings it is advisable to use standart equipment. Argon-nitrogen-hydrogen or propane-butane-air mixtures are recommended as power supply sources.

As for imported equipment for plasma spraying of coatings, first of all "Plasma technique AG" (Switzerland), "Metko" (USA-Italy), Kactolin-Utektic "(Switzerland) are used in our country. A modern trend in the development of equipment for spraying power is the creation of automatic complexes, including the spraying and treatment.

The computerized automatic lines with robot actuators are characterized by high accuracy of supporting and reproducing of working parameters of spraying.

Among the shortcomings of mentioned equipment is high cost, the necessity to use expensive and highly purified rare gases.

Microplasma spraying of coatings which is realized on MPP plants, is a variety of plasma technologies. This technology is used for restoration of turbine blades, details of locking armature, stamping units, press molds etc. More powerful microplasma devices are prospective including inverter and module types (Н-146, МПА-120, МТА-1).

In spite of all advantages, plasma spraying has the following distinctive shortcomings: insufficient strength of cohesion of coatings and bases, high porosity, small output of plasma jet energy use for heating powder; high noise and radiation level, relatively expensive equipment.

One can partially avoid these shortcomings, using detonation spraying. The porosity of such coatings obtained on simplier equipment makes 0,5-1,0% and the strength of cohesion of coatings and bases comes up to 160 MPa. Microstructure of detonation coating is shown in figure 2.

It is worthwhile to note that detonation method of coating is recommended for restoration of parts which have small working surfaces and don't require large amounts of coating material. This method is used for gas-turbine engine components restoration.

Compared to gas-detonation method, plasma-detonation one is more prospective. The equipment used for this method permits to introduce additional electric power into the combustion products, provides control of plasma-power density from 10^3 till 10^7 W/cm^3 and temperature control from $2 \cdot 10^3$ till 10^4 K. The equipment for plasma-detonation spraying permits to obtain high quality functional coverings for machine parts surface, the productivity of the process achieves 10 kg/h of powder at power of 10 kW.

Method of electric-spark (ESA) has great possibilities and is used for strengthening material and durability of machines, working under high temperature conditions in inert gases. This method is used to increase heat- and corrosion-resistance of surfaces; to increase durability of metal-cutting, woodworking and fitter work tools etc; for making roughness for the following galvanic coating; it is also used to facilitate soldering of hard solderable materials with usual solder (application of intermediate layer, e.g. copper); for increasing the size of machine parts during their repair, for changing surface properties of articles made of nonferrous metals and tool steels.

The essence of this process is alloying the surface layer of metal part being a cathode, with the material of electrode (anode) by spark discharge in the air. As a result of chemical reaction between alloying element and dissociated atomic nitrogen and air carbon as well as with the material of the part, the hardening structures and compound chemical combinations (e.g. high-dispersion nitrites, carbonites and carbides) are formed in surface layers, and as a result, the extremely hard and durable diffusive coating is formed. The final form of the coating obtained by ESA method, is given in fig.3. Besides craters, ridges and cavities one can see pores on the processed surface, and on the bottom of some craters one can see fused spherical particles.

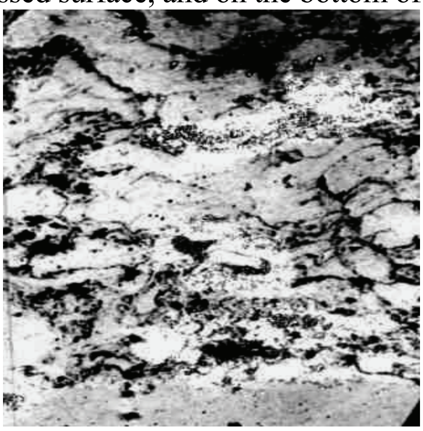


Fig. 2. Microstructure of composite detonation coating, x400

Fig. 3. Electronic photo of the coating before experiment

Under ESA method, complex physical and chemical processes take place. Firstly, the anode material is transferred to the cathode. As a result the structure and the phase in the cathode surface are changed. Secondly, the cathode material is repeatedly effected in a number of ways.

This method is noteworthy in connection with the possibility of creating multifunctional coatings of gradient and discrete structure having a wide range of physical and chemical properties. This fact is confirmed by the results of experimental tests of coatings under abrasive wear conditions (fig.4)

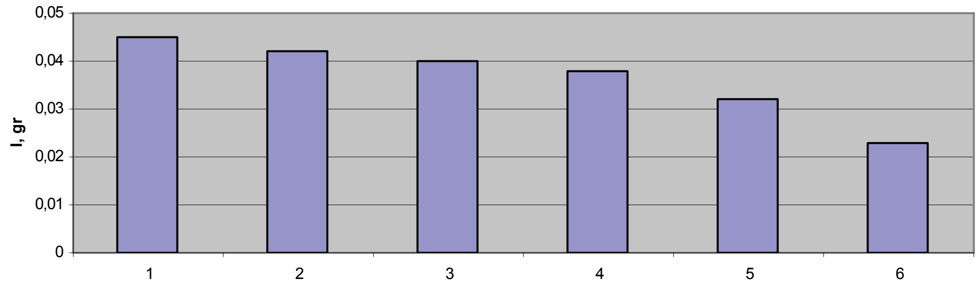


Fig.4. The steel and coatings wear under abrasive conditions ($Si0_2$): 1 -steel 30; 2 - PI8; 3 - graphite; 4 - 30ХГСА; 5-ВК8; 6 -ВК8+graphite

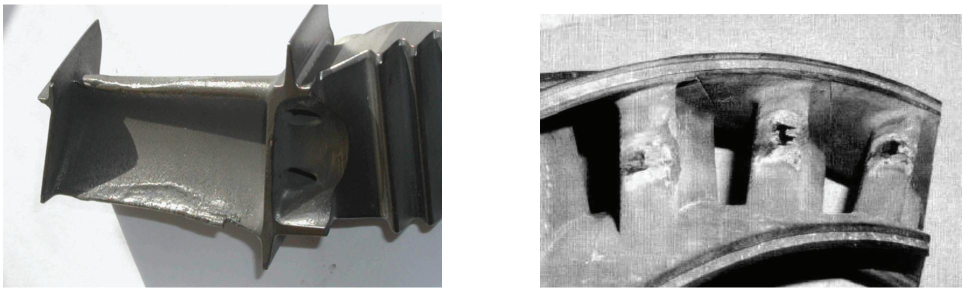
While repairing AP the ESA method is used for strengthening of such parts as cams, guides, locks, clamps, pushers, wedges and perforations of base members.

Unlimited are the possibilities of chemical and thermal method of treatment (CTT) metals and alloys. Composite diffusion coatings obtained by CTT method are particularly prospective. The data of the authors [7] testify the fact that this matter is prospective for scientific research as well as for practical use. If we take into consideration that the periodic table contains 80 elements not being rare ones, general number of systems which phases possess valuable properties, amounts to a number with 27 digits.

Numerous methods of CTT can be applied not only for surface hardening, but also for restoration of worn-out parts like high precision elements (plungers and sleeves, fuel pump needles and nozzles) serviceability of which can be effected by contaminating impurities. According to statistics, the inorganic amount of contaminating impurities contained in fuel of the engine fuel system is about 70%.

The most dangerous are solid particles, the size of which exceeds the gap of plunger pair. Ingress of abrasive particles on the functional surface of high-precision element causes its wear and results in breakdown of fuel supply; fuel consumption increases, starting and power properties of an engine become worse, overheating can also occur. Application of CTT method for hardening and restoration of plunger pair parts permits to sufficiently increase their serviceability.

Experience of operation and repair of AP showed that blades and discs are the most loaded parts of engine. While in operation, they are exposed to alternating and centrifugal loads, to extra loads caused by high-frequency vibration and raise of temperature. Their intensive wear is conditioned by high-temperature oxidizing processes of the working surfaces of the parts which stimulate the formation of oxide films and their further destruction under the effect of abrasive gas flow. Materials operate at a breaking point of their capacity due to stress, temperature and environmental factors. Effected by gas flow, abrasive particles plough the oxidized surface of the parts. They form deep scratches, tear outs and cavities. The traces of partial melting can also be observed (fig. 5a). Cracks and burn-outs may appear on the sectors of inlet vanes (fig. 5 b) and swirlers . Such parts are rejected.



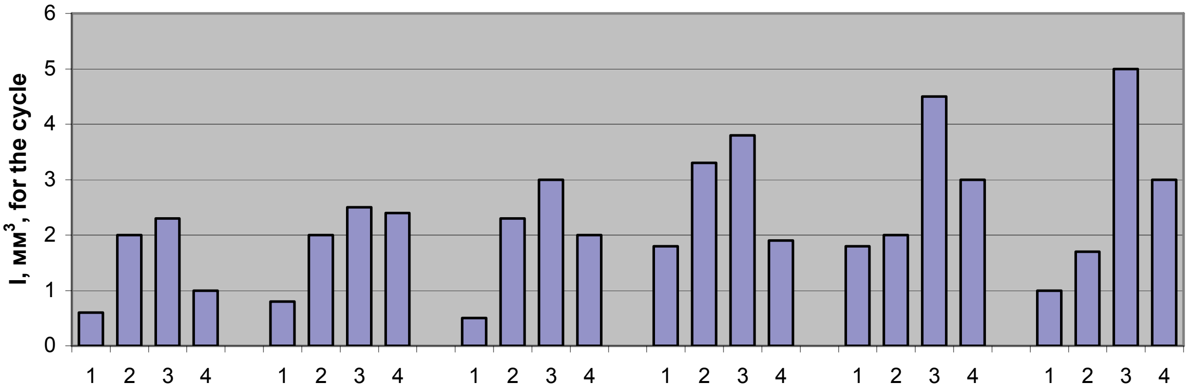
a b

Fig. 5. The blade after 8000h operating time (a) and inlet vanes sectors after 12000 h operating time (b)

Atmospheric gases (air, oxygen, carbon dioxide, nitrogen) research and their role in gas-abrasive wear was carried out for: steel X18H10T, steel 45 (hardened), surfacing materials ЭИ-893, И-625, ЭП-367, ЖС6К. The research was performed within the range of speed of abrasive particles making 38-78м/s, the size of particles being 0,5 mm. Some results of this research are given in fig. 6.

The analysis of the above data proves the fact that gas abrasive wear processes proceed more intensively in oxidizing atmosphere than in an inert one. The surfacing material ЭП-367 recommended for restoration of the worn rotor blades, is characterized by maximum wear resistance.

Lately the range of parts hardened by laser alloying has increased. When restoring the worn parts with laser surfacing the dimensions of the parts, subject to repair is reduced by the size, equal to thickness of the working layer of the coating with subsequent application of the coating, taking into consideration machining allowance in accordance with the operational sheets and process charts of laser processing. This method is used to restore the parts of the D-36 engine.



a b c d e f

Fig. 6. Diagrams of volume wear of the materials under study in different of atmospheric gases (1-nitrogen; 2-air, 3-oxygen, 4-carbon dioxide by V=38 m/s, A=0,5 mm) a-ЭП-367; b-ЭИ-893; c-ЖС6К; d-И-625; e-steel X18H10T; f-steel 45 hardened

The sphere of application of the complex method of surface hardening increases. Research directed to hardening of the parts with self-spreading high-temperature synthesis, ion implantation, electronic and ray radiation methods are being carried out.

Conclusion

Progressive methods of application of coatings will promote improvement of quality, reliability and durability of aviation products. They will also increase the period of time between repairs and decrease expenses for spare parts, which will result in saving of materials and labor resources.

References

1. *Б.И. Костецкий, И.Г. Носовский, А.К. Караулов и др.* Поверхностная прочность материалов при трении / К.: Техника, 1976. – 296с.
2. *Кудрін А.П., Лабунець В.Ф., Кучеренко В.О., Хижко В.Д.* Газоабразивне зношування жароміцних сплавів на основі нікелю // Вісник НАУ, 2002. – №4. – С. 43-45.
3. *Добровольський А.Г., Кошеленко Г.И.* Абразивная износостойкость материалов. – К.: Тэхника, 1989. – 128с.
4. *Патон К.Е.* Современные электронно-лучевые технологии Института электросварки им. Е.О. Патона НАН Украины // Автоматическая сварка, 2001. – №2. – С. 3-8.
5. *М.В. Лучка, М.В. Киндрачук, Н.И. Мельник и др.* Износостойкие диффузионно-легированные композиционные покрытия. – К.: Техніка, 1993. – 143с.
6. *Антропов И.И., Быкова М.И., Шкляная И.В.* Антифрикционные композиционные покрытия на основе никеля // Теория и практика электроосаждения металлов и сплаов. – Пенза: Приволж. кн. изд-во. Пенз. Отд-ние. – 1976. – С. 74-76.
7. *Petrow G., Lukas H.L. Z.1. Metallk-de*, 61, H.12, 877, 1970.

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ON SOME CHRACTERISTICS OF CONFORMAL MAPPINGS

Some estimates of integral moduli of smoothness satisfying Holder condition have been received for higher-order derivatives of analytic function mapping unit disk onto a simply connected domain in the complex plane.

Let G be a simply connected domain in the complex plain bounded by a smooth Jordan curve Γ, $\tau = \tau(s)$ be the angle between the tangent to Γ and the positive real axis , $s = s(w)$ be the arc length on Γ. Let $w = \varphi(z)$ be a homeomorphism of the closed unit disk $\overline{D} = \{ z : |z| \leq 1\}$ onto the closure $\overline{G}$ of the domain G, conformal in the open unit disk D.

Kellog in 1912 proved the theorem in which it had been established that if $\tau = \tau(s)$ satisfies Holder condition with index $\alpha, 0 < \alpha < 1$, then the derivative $\varphi'(e^{i\theta})$ satisfies Holder condition with the same index α. Afterwards this result was generalized in works by several authors (more detailed see [1] and [2]).In particular, generalizations and inversations of Kellog's type theorems were received by author in the terms of the uniform curvilinear, local arithmetic and integral moduli of smoothness .

The aim is to receiwe information about connection between the functions $\tau = \tau(s)$ and t $w = \varphi(z)$ in terms of the local differential moduli of smoothness.

The localization $l = l(k, E, z, \delta)$ is called the rule which to every ordered collection (k, E, z, δ), that consists of nonnegative integer k, set $E \subset C$, point $z \in C$ and positive number δ, corresponds the unique set $l(k, E, z, \delta) \subset E^{k+1}$.

Let the finite function $w = f(z)$ be defined on the set $E \subset C$. Let $l(k, E, z, \delta)$ be the maximal Euclidian localization described by nonnegative integer number k, positive number δ and point $z \in C$. Then local modulus of smoothness of order k for the function $w = f(z)$ is determined by formula

$$\omega^l_{k,E}(f, z, \delta) = \sup_{(z_0,\ldots,z_k)\in l(k,E,z,\delta)} \left|[z_0, \ldots, z_k; f, z_0]\right|,$$

where $[z_0, \ldots, z_k; f, z_0]$ is the finite difference of order k for the function $w = f(z)$.

Let consider the noncentralized local arithmetic modulus of smoothness $\omega_{k,z}(f(z), \delta)$ of order k $(k \in N)$ for the function $w = f(z)$ on a curve γ, that is

$$\omega_{k,z}(f(z), \delta) = \sup_{(z_0,\ldots,z_k)\in \gamma_{w,\delta}(N)} \left|[z_0, \ldots, z_k; f, z_0]\right|,$$

where $\gamma_{w,\delta}(N)$ is the set of collections $(z_0,...,z_k)$ such that curvilinear (with respect to the curve γ) distances between points $z_0,...,z_k \in \gamma$ satisfy the condition

$$\rho(z_i, z_{i+1}) \Big/ \rho(z_j, z_{j+1}) \le N \ (N \in [1,\infty)),$$

and

$$\rho(z_i, w) \le \delta \ (i, j = 1,...,k).$$

Theorem 1.($[2]$). If the local modulus of smoothness $\omega_k(\tau(s),\delta)$ of order k for the function $\tau(s)$ satisfies the condition

$$\omega_{k,s}(\tau(s),\delta) = O(\delta^{\alpha})(\delta \to 0),$$

then the local modulus of smoothness $\omega_{k,\theta}(\varphi'(e^{i\theta}),\delta)$ of the same order k for the derivative $\varphi'(e^{i\theta})$ of the function $\varphi(z)$ on ∂D satisfies the condition

$$\omega_{k,\theta}(\varphi'(e^{i\theta}),\delta) = O(\delta^{\alpha})(\delta \to 0).$$

Theorem 2.($[2]$). If the local modulus of smoothness $\omega_{k,\theta}(\varphi'(e^{i\theta}),\delta)$ of order k for the derivative $\varphi'(e^{i\theta})$ of the function $\varphi(z)$ satisfies the condition

$$\omega_{k,\theta}(\varphi'(e^{i\theta}),\delta) = O(\delta^{\alpha})(\delta \to 0),$$

then the local modulus of smoothness of the same order k for the function $\tau(s)$ on Γ satisfies the condition

$$\omega_{k,s}(\tau(s),\delta) = O(\delta^{\alpha})(\delta \to 0).$$

P.M. Tamrazov $[1]$ defined on rectifiable curves the local differential moduli of smoothness which are strong descriptions of smoothness and save in itself very rich information about properties about functions.

Local differential modulus of smoothness of order k for the function $w = f(z)$ is determined by formula

$$\Omega^{l}_{k,E}(f,z,\delta) = \sup_{(z_0,...,z_k)\in l(k,E,z,\delta)} \left| [z_0,...,z_k]_f \right|,$$

where $[z_0,...,z_k]_f$ is the devided difference of order k for the function $w = f(z)$.

We will consider a theorem, that generalizes the results by author $([2],[4],[5])$.

Theorem 3. Let on $\overline{D} = D \cup \partial D$ the continuous derivative $\varphi'(e^{i\theta})$ of the function $\varphi(z)$ exist and let it satisfy the condition $\varphi'(z) \ne 0$ $\overline{D}$. Let the local differential modulus of smoothness of order k for the function $\varphi'(e^{i\theta})$ satisfies the condition.

$$\Omega^{l}_{k,\theta}(\varphi'(e^{i\theta}),\delta) = O(\delta^{\alpha})(\delta \to 0). \quad (1)$$

Then the local differential modulus of smoothness $\Omega^{l}_{k,s}(\tau(s),\delta)$ of the same order k of the function $\tau(s)$ satisfies the condition

$$\Omega^{l}_{k,s}(\tau(s),\delta) = O(\delta^{\alpha})(\delta \to 0). \quad (2)$$

Proof. We will consider at first the case $k = 1$. After the wellknown Lindelof' theorem on ∂D a formula

$$\arg \varphi'(e^{i\theta}) = \tau \circ s(\theta) - \theta - \frac{\pi}{2}. \quad (3)$$

takes place.

Consequently

$$\Omega^{l}_{1,\theta}(\arg\varphi'(e^{i\theta}),\delta)=\Omega^{l}_{1,\theta}(\tau\circ s(\theta),\delta)+C_1\delta\le C_2\Omega^{l}_{1,\theta}(\tau(s),\delta)+C_3\Omega^{l}_{1,\theta}(\tau(s),\delta)\,, \tag{4}$$

where constants C_1, C_2 and C_3 do not depend on δ.

So,

$$\Omega^{l}_{1,\theta}(\arg\varphi'(e^{i\theta}),\delta)=O\left[\Omega^{l}_{1,\theta}(\tau(s),\delta)\;\right]=O(\delta^{\alpha})(\delta\to 0)\,. \tag{5}$$

As

$$\Omega^{l}_{1,\theta}(\log\varphi'(e^{i\theta}),\delta)\le C_4\int\limits_0^{2\pi}\frac{\Omega^{l}_{1,\theta}(\arg\varphi'(e^{i\theta}),t)}{t\left(1+{t}/{\delta}\right)}dt\,,$$

where constant C_4 does not depend on δ, that is

$$\Omega^{l}_{1,\theta}(\log\varphi'(e^{i\theta}),\delta)=O(\delta^{\alpha})(\delta\to 0)\,, \tag{6}$$

and

$$\Omega^{l}_{1,\theta}(\varphi'(e^{i\theta}),\delta)\le C_5\Omega^{l}_{1,\theta}(\log\varphi'(e^{i\theta}),\delta)\,,$$

where constant C_5 does not depend on δ, that is

$$\Omega^{l}_{1,\theta}(\varphi'(e^{i\theta}),\delta)=O(\delta^{\alpha})(\delta\to 0)\,, \tag{7}$$

then estimates take place for $k=1$.

We will consider now the case $k\ge 2$.

As for the local differential moduli of smoothness of the function $\tau(s)$ the estimates, that are the analogues of Marchaud inequalities, take place, then we we can apply the theorem of $[8]$:

$$\Omega^{l}_{m,s}(\tau(s),\delta)\le C_{(m)}\left(\delta^{m}+\delta^{m}\int\limits_{\delta}^{l}\frac{\Omega^{l}_{m,s}(\tau(s),t)}{t^{m+1}}dt\right), \tag{8}$$

where constants $C_{(m)}$, $(m=1,2,...,k-1)$ do not depend on δ. Thus, we have

$$\Omega^{l}_{m,s}(\tau(s),\delta)=O(\delta^{m})(\delta\to 0)\,. \tag{9}$$

Consequently, on $\overline{D}$ the continuous derivative, that does not equal to zero on $\overline{D}$, exists.

In addition, for the local differential moduli of smoothness for the function $\varphi'(e^{i\theta})$ estimates, that are the analogues of inequalities of $[8]$, take place

$$\Omega^{l}_{k,\theta}(\log\varphi'(e^{i\theta}),\delta)\le C_6\int\limits_0^{2\pi}\frac{\Omega^{l}_{k,\theta}(\arg\varphi'(e^{i\theta}),t)}{t\left(1+\left({t}/{\delta}\right)^{k}\right)}dt\,, \tag{10}$$

where constant C_6 does not depend on δ. Thus, we have

$$\Omega^{l}_{k,\theta}(\log\varphi'(e^{i\theta}),\delta)=O(\delta^{\alpha})(\delta\to 0)\,.$$

In order to get estimates of the local differential modules of smoothness for the function $\tau\circ s(\theta)$ through the local differential moduli of smoothness for the functions $\tau(s)$ and $s(\theta)$, we will apply inequality for the finite differences of superpozition of the functions of $[3]$. We receive

$\Omega^{l}_{k,s}(\tau\circ s(\theta),\delta)\le$

$$\le C_7\{\ \Omega^l_{k,s}(\tau(s),a\delta)+\delta^k\sum_{j=1}^{k-1}\Omega^l_{j,s}(\tau(s),a\delta)\delta^{-j}\times\sum_{\substack{r_1,\dots,r_j\ge 1\\ r_1+\dots+r_j=k}}\prod_{r_q=1}^{j}\Omega^l_{r_q,\theta}(s(\theta),\delta)\ \},\qquad(11)$$

where constant C_7 does not depend on δ. As

$$s'(\theta)=\left|\varphi'\left(e^{i\theta}\right)\right|,\qquad(12)$$

then it is possible to apply Marchaud inequalities for the local differential moduli of smoothness for the function $s(\theta)$

$$\Omega^l_{m,\theta}(s(\theta),\delta)\le C^{(m)}\delta\cdot\Omega^l_{m-1,\theta}(s'(\theta),\delta),\qquad(13)$$

where constants $C^{(m)},(m=1,2,...,k-1)$ do not depend on δ.

We will estimate the sum of products of the local differential moduli of smoothness for the function $s(\theta)$, placed in right-hand-side of inequality (11).

We have

$$\sum_{\substack{r_1,\dots,r_j\ge 1\\ r_1+\dots+r_j=k}}\prod_{r_q=1}^{j}\Omega^l_{r_q,\theta}(s(\theta),\delta)=\sum_{\substack{r_1,\dots,r_j\ge 1\\ r_1+\dots+r_j=k}}\prod_{\substack{q=1\\ r_q=1}}^{j}\Omega^l_{r_q,\theta}(s(\theta),\delta)\times\sum_{\substack{r_1,\dots,r_j\ge 1\\ r_1+\dots+r_j=k}}\prod_{\substack{q=1\\ r_q>1}}^{j}\Omega^l_{r_q,}(s(\theta),\delta)\le$$

$$\le C_8\delta^j\Omega^l_{k-1,\theta}(s'(\theta),\delta)\le C_8\delta^\alpha,\qquad(14)$$

where constant C_8 does not depend on δ.

Consequently, the estimate

$$\Omega^l_{k,\theta}(\tau\circ s(\theta),\delta)\le C_9\{\ \Omega^l_{k,s}(\tau(s),\delta)+\sum_{j=1}^{k-1}\Omega^l_{k-j,s}\omega_{k-j}(\tau(s),\delta)\Omega^l_{j,\theta}\omega_j(s'(\theta),a\delta)\ \},\qquad(15)$$

where constant C_9 does not depend on δ, followes the formulae (8), (13) and (14). Thus, we have $\Omega^l_{k,\theta}(\tau\circ s(\theta),\delta)=O(\delta^\alpha)(\delta\to 0)$.

The estimates (4) and (5) are proved by induction on *k* with application of the estimates (8), (9), (10) and (15).

Theorem 3 is proved.

Theorem 4..Let the local modulus of smoothness of order *k* for the derivative $\varphi'(e^{i\theta})$ of the function $\varphi(z)$ on ∂D satisfies the condition

$$\omega_{k,\theta_0}(\varphi'(e^{i\theta}),\delta)=O\left(\delta^k\log\frac{1}{\delta}\right)(\delta\to 0)\ .\qquad(16)$$

Then the local modulus of smoothness $\omega_k(\tau(s),\delta)$ of the same order *k* for the function $\tau(s)$ on the curve Γ satisfies the condition

$$\omega_{k,s}(\tau(s),\delta)=O\left(\delta^k\log\frac{1}{\delta})\right)(\delta\to 0),\qquad(17)$$

Proof. After the wellknown Lindelof' theorem on ∂D the formula (3) takes place. Then in the case $k=1$

$$\omega_{1,s}(\tau(s),\delta)=O(\delta)(\delta\to 0)$$

and тheorem is proved for $k=1$.

Let consider now the case $k\ge 2$.

Let condition of theorem are satisfied for $k \ge 2$. Then it followes from equality (3), that for all $m \ge 1$ the identity

$$\omega_{m,\theta}(\tau \circ s(e^{i\theta}),\delta) = \omega_{m,\theta}(\arg \varphi'(e^{i\theta}),\delta) \tag{18}$$

is true.

It followes from the supposition of the theorem, that

$$\omega_{k,\theta}(\arg \varphi'(e^{i\theta}),\delta) \le b_1 \delta^k ,$$

where constant b_1 does not depend on δ. So,

$$\omega_{k,\theta}(\tau \circ s(e^{i\theta}),\delta) = O(\delta^k \log\frac{1}{\delta})(\delta \to 0) .$$

Applying inequalities from $[3]$, we receive the estimates of the local modulus of smoothness $\omega_{k,s}(\tau(s),\delta)$ via the local modulus of smoothness $\omega_{k,\theta}(\tau \circ s(e^{i\theta}),\delta)$ and $\omega_{k,\theta}(s(e^{i\theta}),\delta)$. We have

$$\omega_{k,s}(\tau(s),\delta) \le \omega_{k,\theta}(\tau \circ s(e^{i\theta}),\delta) +$$
$$+ b_2 \delta^{-k(k+1)/2} \sum_{j=1}^{k-1} \omega_{j,\theta}(\tau \circ s(e^{i\theta}), b\delta) \times \sum_{\substack{r_1,\ldots,r_{k(k-1)/2} \ge 1 \\ r_1+\ldots+r_{k(k-1)/2} = k(k+1)/2-j}}^{k-1} \prod_{q=1}^{k(k-1)/2} \omega_{r_q,\theta}(s(e^{i\theta}), b\delta), \tag{19}$$

where constant b_2 does not depend on δ. We will also use inequalities of $[3]$:

$$\omega_{m,s}(\tau(s),\delta) \le b_{(m)} \left(\delta^m + \delta^m \int_\delta^l \frac{\omega_{k,s}(\tau(s),t)}{t^{m+1}} dt \right) \le B_{(m)} \cdot \delta^m , \tag{20}$$

where constants $b_{(m)}, B_{(m)}$, $(m = 1,\ldots,k-1)$, do not depend on δ.

It followes from the inequalities (19) and (20), that for all $j = 1,\ldots,k-1$ the estimates

$$\omega_{j,s}(\tau \circ s(e^{i\theta}),\delta) \le b^5{}_{(j)} \delta^j \left(1 + \int_\delta^l \frac{\omega(t)}{t^{j+1}} dt \right) \le B^5{}_{(j)} \delta^j , \tag{21}$$

where constants $b^5{}_{(m)}, B^5{}_{(m)}, (m = 1,2,\ldots,k-1)$ do not depend on δ, are true. So,

$$\omega_{k,s}\mu(\tau,\delta) \le b_8 \cdot \delta^k \log\frac{1}{\delta},$$

where constant b_8 does not depend on δ.

Theorem 4 is proved.

Theorem 5. Let the local modulus of smoothness of order *k* for the derivative $\varphi'(e^{i\theta})$ of the function $\varphi(z)$ on ∂D satisfies the condition

$$\omega_{k,\theta}(\varphi'(e^{i\theta}),\delta) = O(\omega(\delta))(\delta \to 0) \tag{22}$$

where $\omega(\delta)$ is the normal majorant satisfying the condition

$$\int_0^l \frac{\omega(t)}{t} dt < +\infty . \tag{23}$$

Then the local modulus of smoothness $\omega_k(\tau(s),\delta)$ of the same order *k* for the function $\tau(s)$ on the curve Γ satisfies the condition

$$\omega_{k,s}(\tau(s),\delta) = O(\mu(\delta))(\delta \to 0), \tag{24}$$

where

$$\mu(\delta) = \omega(\delta) + \sum_{j=1}^{k-1}\left(1+\int_{\delta}^{L}\frac{\omega(t)}{t^{j+1}}dt\right)\times\delta^k \sum_{\substack{r_1,\dots,r_{k(r-1)/2}\geq 1\\ r_1+\dots+r_{k(r-1)/2}=k(k+1)/2-j}} \prod_{q=1}^{k(k-1)/2}(1$$

$$+\int_{\delta}^{L}\frac{1}{t^{r_q+1}}(1+\int_{t}^{L}\frac{\omega(y)}{y^k}dy)dt).$$

Proof. We will consider at first the case $k=1$. After the wellknown Lindelof' theorem on ∂D the formula (3) takes place. Then

$$\omega_{1,s}(\tau(s),\delta) \leq b'\cdot\delta,$$

where constant b' does not depend on δ. It followes, that

$$\omega_{1,s}(\tau(s),\delta) = O(\omega(\delta))(\delta\to 0)$$

and теorem is proved for $k=1$.

Let consider now the case $k\geq 2$.

Let conditions of theorem are satisfied for $k\geq 2$. Then it followes from equality (3), that for all $m\geq 1$ the identity

$$\omega_{m,\theta}(\tau\circ s(e^{i\theta}),\delta) = \omega_{m,\theta}(\arg\varphi'(e^{i\theta}),\delta)$$

is true.

It followes from the supposition of the theorem, that

$$\omega_{k,\theta}(\arg\varphi'(e^{i\theta}),\delta)\leq b_1'\delta,$$

where constant b_1' does not depend on δ. So,

$$\omega_{k,\theta}(\tau\circ s(e^{i\theta}),\delta) = O(\omega(\delta))(\delta\to 0).$$

Applying inequalities from $[3]$, we receive the estimates of the local modulus of smoothness $\omega_{k,s}(\tau(s),\delta)$ via the local moduli of smoothness $\omega_{k,\theta}(\tau\circ s(e^{i\theta}),\delta)$ and $\omega_{k,\theta}(s(e^{i\theta}),\delta)$. We have

$$\omega_{k,s}(\tau(s),\delta)\leq\omega_{k,\theta}(\tau\circ s(e^{i\theta}),\delta)+$$
$$+b_2'\delta^{-k(k+1)/2}\sum_{j=1}^{k-1}\omega_{j,\theta}(\tau\circ s(e^{i\theta}),b\delta)\times\sum_{\substack{r_1,\dots,r_{k(k-1)/2}\geq 1\\ r_1+\dots+r_{k(k-1)/2}=k(k+1)/2-j}}^{k-1}\prod_{q=1}^{k(k-1)/2}\omega_{r_q,\theta}(s(e^{i\theta}),b\delta), \tag{25}$$

where constant b_2' does not depend on δ. We will also use inequalities of $[3]$:

$$\omega_{m,s}(\tau(s),\delta)\leq b'_{(m)}\left(\delta^m+\delta^m\int_{\delta}^{l}\frac{\omega_{k,s}(\tau(s),t)}{t^{m+1}}dt\right), \tag{26}$$

where constants $b'_{(m)}$, $(m=1,\dots,k-1)$, do not depend on δ.

It followes from the inequalities (15) and (26), that for all $j=1,\dots,k-1$ the estimates

$$\omega_{j,s}(\tau\circ s(e^{i\theta}),\delta)\leq b^9{}_{(j)}\delta^j\left(1+\int_{\delta}^{l}\frac{\omega(t)}{t^{j+1}}dt\right), \tag{27}$$

where constants $b^9{}_{(m)}, (m=1,2,\dots,k-1)$ do not depend on δ, are true. Besides it followes from enequalities (20) and (21) that

$$\omega_{k-1,\theta}(\varphi'(e^{i\theta}),\delta) \le b_{10}\delta^{k-1}\left(1+\int_{\delta}^{l}\frac{\omega(t)}{t^k}dt\right),$$

where constant b_{10} does not depend on δ .As,

$$\omega_{k,\theta}(s(\theta),\delta) \le b_{11}\delta^{k}\left(1+\int_{\delta}^{l}\frac{\omega(t)}{t^k}dt\right), \tag{28}$$

where constant b_{11} does not depend on δ, then it followes from enequalities (26) and (27) that

$$\omega_{k,s}\mu(\tau,\delta) \le b_{12}\Big(\ \omega(\delta) + \delta^k \sum_{j=1}^{k-1}\left(1+\int_{\delta}^{L}\frac{\omega(t)}{t^{j+1}}dt\right)\times$$

$$\times \sum_{\substack{r_1,\dots,r_{k(r-1)/2}\ge 1 \\ r_1+\dots+r_{k(r-1)/2}=k(k+1)/2-j}} \prod_{q=1}^{k(k-1)/2}(1++\int_{\delta}^{L}\frac{1}{t^{r_q+1}}(1+\int_{t}^{L}\frac{\omega(y)}{y^k}dy)dt),$$

where constant b_{12} does not depend on δ .

Theorem 5 is proved.

References

1. *Тамразов П. М.* Гладкости и полиномиальные приближения. Наукова думка. Киев. 1975.- 274 с.

2. *Каруну О. В.* О модулях гладкости конформных отображений.//Укр. матем. журн., т. 30, №4, 1978, с.540-545.

3. *Тамразов П. М.* Конечно-разностные тождества и оценки модулей гладкости суперпозиций функций. Препринт Ин-та математики АН УССР ,77.5, К., 1977, 24 с.

4. *Каруну О. В.* Про деякі властивості модулів гладкості конформних відображень. //Праці Ін-ту математики НАН України, т. 31, Київ 2000, с.237-243.

5. *Karupu O. W.* On some finite difference properties of conformal mapping // International workshop on Potential Theory and Free Boundary Flows, Ukraine, Kiev, 19-27 August, 2003, Abstracts, Kiev, 2003, p.21.

6. *Karupu O. W.* On some properties of local moduli of smoothness of conformal homeomorphisms// Тези доповідей конференції "Функціональні методи в теорії наближень, теорії операторів, стохастичному аналізі і статистиці." Київ, 1- 5 жовтня 2004, с. 51.

7. *Warschavski S. E.* On differentiability at the boundary in conformal mappings.// Proc. Amer. Math. Soc., 1961, v.12 N 4, p. 614-620.

8. *Бари Н. Л., Стечкин С. Б.* Наилучшие приближения и дифференциальные свойства двух сопряженных функций. Труды Моск. мат. общества, 1956, т.5, с. 483-522..

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NONLINEAR OSCILLATIONS OF LIQUID IN RESERVOIR OF REVOLUTION

Introduction. We consider the problem about oscillations of ideal incompressible vortex free liquid with a free surface in a cavity of arbitrary geometrical shape. This type of problems is frequently met in transport engineering (cisterns, rockets, some types of airplanes).

In the case when the tank cavity represents a cylindrical domain one succeeded to resolve the equation of the free surface relative to the variable z, which corresponds to vertical direction. Then the equation of a free surface takes the form of $\eta(x,y,z,t) = z - \xi(x,y,t) = 0$, where z is the vertical coordinate, x, y are coordinates in the horizontal plane, t is time. In this case the corresponding linear problems admit analytical solution on the basis of the method of variables separation, and the nonlinear problem becomes essentially simpler. In the case of cylindrical domains occupied by liquid it is possible to construct effective algorithms for solving nonlinear problems of dynamics tanks with liquid with a free surface, including the case of translational and rotational motion of the carrying body [1–4]. The most substantial results in this direction were obtained on the basis of variation algorithms of statement and solving of nonlinear problems of dynamics of tanks with liquid. Thus, for tanks of cylindrical shapes various problems of dynamics of steady and transient modes of motion of reservoirs with liquid were investigated.

Further attempts of solving problems of dynamics of liquid in tanks of non-cylindrical shapes showed that there is a number of unqualified problems, which fundamentally make difficult solving of the problem. Most clearly this becomes apparent on application of methods of formal point-wise discrimination, when during one period of oscillations violation of laws of mass and energy conservation was about 20%. Taking into account that laws of conservation of mass and energy are not only physically evident for this class of problems, but they practically coincide with the mathematical condition of solvability of the nonlinear problem, these methods as well as some analytical methods collapse even for small time intervals. Moreover, most frequently methods of point wise approximation are applied for nonlinear 2D or axis-symmetrical problems, because they are based on essential usage of limited computer resources, which is insufficient for investigation of most complicated nonlinear processes.

For further progress is solving applied problems of this class it is necessary to analyze deeper mechanical and mathematical essence of the problem. This analysis is done from the point of view of further application of the variational method of solving the problem, which is based on formulation of the mechanical problem on the basis of the Hamilton variational principle. The mechanical analysis of this approach shows that a part of the problem's conditions (kinematical constraints) should be satisfied before solving the variational problem on the stage of construction of decompositions of desired variables, and dynamic boundary conditions and motion equations for the carrying body are obtained from the variational relation. It is significant to note that in the subsequent procedure of problem solving no other increase of accuracy takes place in satisfying kinematical requirements of the problem. For cylindrical domains the solvability condition of the Neumann problem for the Laplace equation is equivalent to requirement of conservation of a liquid volume in its perturbed motion. The analysis conducted in the present article shows that simple transfer of this form of the solvability condition on the case of oscillations of liquid in non-cylindrical cavities is insufficient. Hence, construction of a nonlinear discrete resolving model for the problem about oscillations of ideal liquid with a free surface in a tank of non-cylindrical shape is done according to the following scheme.

- Analysis of the solvability condition.
- Construction of decompositions of desired variables, which hold linear kinematic boundary conditions coupled with solvability conditions.
- Construction of decompositions of desired variables, which hold nonlinear kinematic boundary conditions.
- Construction of a resolving system of motion equations relative to amplitude parameters of liquid motion and parameters of translational motion of the carrying body.

Problem statement. We consider a problem about oscillations of liquid with a free surface in a reservoir, which cavity is of revolution shape. The reservoir is supposed to be movable and it can perform finite translational movements. Basic denotations are shown in Figure 1.

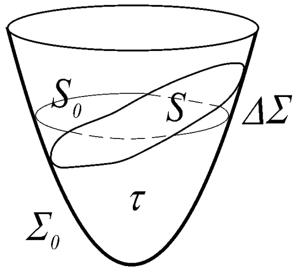

Figure 1. General scheme of denotations.

For specification of liquid motion we introduce non-Cartesian parametrization of the domain, occupied by liquid, according to the following scheme $\alpha = \dfrac{r}{f(z)}$; $\quad \beta = \dfrac{z}{H}$, where $r = f(z)$ is the equation of the generatrix of a body of revolution, H is filling depth of liquid. At that we suppose that the origin of the reference frame is in the center of the undisturbed free surface of liquid, the axis Oz is directed upward, (r, θ, z) is the system of cylindrical coordinates, which according to the relations (5) is substituted for the new non-Cartesian system of coordinates (α, θ, β) state $\beta \in [-1, 0]$. For the accepted system of parametrization the domain of liquid takes cylindrical shape and the equation of a free surface can be resolved relative to the coordinate β and it takes the form of $\beta = \frac{1}{H}\xi(\alpha,\theta,t)$.

Analysis of the solvability condition of the problem. Taking into account that the nonlinear problem as well as the corresponding linear boundary problem [3, 4] has no exact analytical solution for arbitrary cavities of revolution, we must come from the fact that boundary conditions of the problem are realized approximately. According to the general theory of solvability of the Neumann boundary problems for the Laplace equation the solvability condition for the nonlinear problem can be given in the following form

$$\int_{\Sigma_0} \frac{\partial\varphi}{\partial n} d\Sigma + \int_{\Delta\Sigma} \frac{\partial\varphi}{\partial n} d\Sigma + \int_{S} \frac{\partial\varphi}{\partial n} dS = 0$$

Let us analyze term by turn the expression for the solvability condition. The first addend represents requirement of satisfying (in wea+k sense) the non-flowing condition on an unperturbed boundary of contact of liquid with tank walls Σ_0. Therefore, holding this boundary condition of non-flowing on Σ_0 should be performed with improved accuracy. In our appearance on realization of different procedures of solving this class of problems insufficient attention was paid to this question. Sometimes natural modes of oscillations with errors of satisfying of boundary non-flowing condition about 20% and more were applied for numerical realization. Correspondingly, such violation of the non-flowing conditions, and therefore the solvability condition, results in instability of realization of numerical procedures. The second addend corresponds to the requirement of realization in weak sense of the non-flowing condition on the boundary $\Delta\Sigma$, i.e., on wave crests of liquid over level of the undisturbed free surface. This physically evident kinematic boundary condition is not consequence of statement of the linear problem about oscillations of liquid in a tank, which is usually applied for construction of decompositions of desired variables. Normally this condition is not taken at all into consideration on analysis of nonlinear oscillations of liquid in tanks of non-cylindrical shape, although we suppose that this condition is the dominant one in the analysis of the physical sense of the considered problem. In accordance with the maximum principle for harmonic functions the solution tends to violate realization of non-flowing condition, and this corresponds to overflow of liquid through the tank walls (namely this causes "loss" of liquid in methods of pointwise discretization). In spite of the property that this condition is expressed by a linear mathematical relation, according to its nature it is nonlinear, because it corresponds to realization of the kinematic condition on a nonlinear perturbed surface, and it is evident that this condition does not enter the linear statement of the problem. The third addend in the solvability condition corresponds to the requirement of the liquid volume conservation in its perturbed motion. Realization of this requirement will be considered below, where we shall show that realization of the requirement of liquid volume conservation for every separately taken natural mode of liquid oscillation, which corresponds to linearized requirement, is not sufficient for realization on a whole of the requirement of volume conservation in its perturbed motion.

Construction of decompositions of desired variables, which hold linear kinematic boundary conditions. Traditionally the problem about determination of this system of coordinate functions was identified with the classical problem about determination of natural frequencies and modes of oscillations of ideal liquid with a free surface in cavities of different geometrical shape. As it follows from the mentioned above analysis the system of coordinate functions for solving the nonlinear problem does not coincide with natural modes of oscillations, since it must supplementary satisfy nonflowing conditions on $\Delta\Sigma$. At the same time the problem about determination of natural frequencies and modes of oscillations of liquid with a free surface has independent theoretical and applied significance.

It is evident that in the general case solutions of the classical linear problem do not hold this requirements, since the initial statement of the boundary problem admits only conditions with differential operators of the first order. In this connection it is expedient to certain extent to refuse from the traditional problem of determination of natural frequencies and modes and to construct approximately the system of coordinate functions close to solutions of the classical problem with correspondingly close frequency parameters, but which in addition holds with high accuracy nonflowing condition on Σ_0 and on the surface $\Delta\Sigma$.

For realization of this goal we suggest new technique, i.e., the method of an auxiliary domain for reduction of influence of the singular points on behavior of the solution. Hence, we propose to solve the problem about searching the coordinate functions close to natural modes of oscillations, but having the mentioned above supplementary properties in the following way. We solve the problem for the domain increased up to level of possible wave crests reaching with taking into account validity range of the nonlinear theory. Later we use values of the obtained solution on the cross-section, which corresponds to real level of liquid filling, as the determined solution (their frequency parameters are determined by the Rayleigh method). On the basis of the analysis of errors of realization of non-flowing condition it is possible to note that the solution obtained by the method of auxiliary domain with the acceptable accuracy "follows" the contour above the free surface and values of errors on Σ_0 decrease about 1000 times in comparison with the classical approach. Here difference of frequencies does not exceed 0.2%.

For solving the nonlinear problem of dynamics of combined motion of a reservoir and liquid, which partially fills its cavity of revolution, we applied the following discretization parameters $N_1 = 10$, $N_2 = 6$, $N_3 = 3$ [1]. The suggested technique of determination of coordinate functions is based on solving the linear problem, but it is supplemented by a number of requirements, which lie outside the scope of the linear statement of the problem and reflect a part of kinematic requirements and solvability conditions of the nonlinear problem. Finally this makes it possible to construct the system of coordinate functions, which in improved way hold the non-flowing condition on the perturbed moisten boundary of the domain occupied by liquid. Further this system of functions was successfully used for solving the nonlinear problem.

Construction of decompositions of desired variables, which hold nonlinear kinematic boundary conditions. Realization of the procedure of elimination of the kinematic boundary condition on a free surface is similar to the procedure for a cylindrical tank [1–4]. Distinction of this procedure consists in the property that in derivations it is necessary to keep some additional terms caused by geometrical properties.

Construction of a resolving system of motion equations relative to amplitude parameters of liquid motion and parameters of translational motion of the carrying body. We derive the motion equations of the system on the basis of the Hamilton–Ostrogradsky variational principle applied to dynamics of bounded liquid volume and a rigid body with cavity of revolution. For transition from continuum structure of the initial model of the system rigid body–liquid to its discrete model we make use of the Kantorovich method. Basic stages of numerical realization of the suggested approach mainly coincide with the case of cylindrical tank. However, distinction consists in the property that approximate determination of coordinate functions close to natural modes of oscillations becomes significant component of the procedure. Numerical results showed that application of these new coordinate functions increases stability of numerical solution.

Numerical examples. For determination of peculiarities of development of wave generation on a free surface of liquid and influence of liquid mobility on motion of the carrying body we consider the problem of forced oscillations of liquid in movable conic tanks, which can perform translational motion in the horizontal plane, caused by sudden application of rectangular force impulse to the quiescent system.

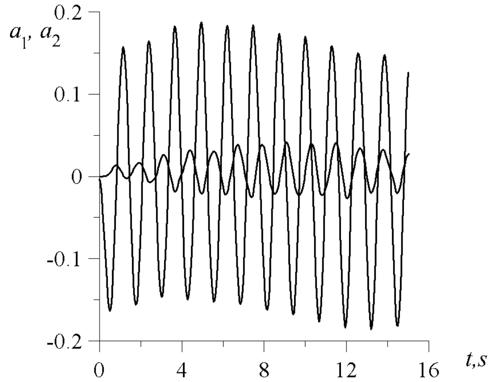

Figure 2. Variation in time of two first amplitudes.

Figures 2 shows dependence in time of two fist amplitudes of normal modes. Law of variation of amplitudes a_1 (larger amplitude excursion) and a_2 (lower amplitude excursion) shows that it is different from the linear law. Moreover, the amplitude a_2 is excited only owing to nonlinear mechanism.

Conclusions. The suggested procedure was realized for modes of free and forced oscillations. The obtained results about wave generation of a free surface, alteration of the tank velocity and dynamic interaction of liquid with tank walls are evidence of good reflection of general regularities of the system behavior.

References

1. Limarchenko O.S, Yasinsky V.V. Nonlinear dynamics of structures with liquid. – Kiev: National Technical University of Ukraine "KPI", 1997, 338 p. [in Russian]
2. Limarchenko O. Nonlinear properties for dynamic behavior of liquid with a free surface in a rigid moving tank, International Journal of Nonlinear Sciences and Numerical Simulation, 2000, v. 1, N 22, P. 105–118.
3. Limarchenko O.S, Matarazzo G., Yasinsky V.V. Dynamics of rotational structures with liquid. – FADA Ltd, Kiev, 2003, 286p.
4. Narimanov G.S., Dokuchaev L.V., Lukovsky I.A. Nonlinear dynamics of a spacecraft with liquid. – Moscow: Mashinostroenie, 1977. – 208 p. [in Russian]

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THE NON-PILOT AIRPLANE – SAFETY FLY IN TURBULENCJE

Introduction

The problem of the exact fulfillment of the given trajectory by a small, non-pilot flying object in conditions of stormy weather was being solved by many different science institutes. In connection with a great progress in electronics – especially the development of computers and micromechanics – new solutions and possibilities of use occur. Elimination of quickly-changeable interruptions caused by turbulence with the use of additional systems, situated in a flying object, allows to improve the results of the given assignment.

Conducted by Institute Lotnictwa researches of non-pilot flying objects had resulted with a preparation and verification, in exploitation conditions of balloon platform, of aerostat. Destiny of the project was to create a system of controlling and space observation of the great fire risk forest and city communication areas.

One of the research elements during working over the project was the balance and dynamic stability analysis. The object's reactions caused by wind blows were examined.

Calculations presented in the article were to situate the aerostat with the carrying rope in space because of its eventual contact with other objects, according to wind blows, also the evaluation of upper values of oscillation frequency occurring during the movement in turbulence.

The evaluation of the frequency was necessary to determine working conditions of the observation camera stabilization system, also of the automaton keeping the object in a constant position, simultaneously to horizon.

The mass, geometrical and aerodynamic characteristics were taken from the study [1].

1. The mathematic model

Calculations of the balance conditions concern geometrical values and loads occurring in an attachment system to the carrying rope – the system of two front ropes of constant length, one rope of variable length (according to weather conditions) attached to two ropes on the fuselage, behind the mass center and a coiling mechanism, that all ropes are attached to.

The coiling machine is to establish ropes' length, so that the fuselage had a constant simultaneous to the horizon position.

In the calculations it was established that the system is made of two rigid elements, on the top attached to the symmetry plane of the fuselage and on the bottom – to the linking point of the carrying rope.

Calculations of stability and dynamics were made for two rope lengths: l=100 m and l=300 m. For l=100 m the air density was taken as for 0 height according to model atmosphere (AW), which is: $\rho_p = 1.2263$ kg/m^3,
but for l=300 m as for 300 m height AW, which is: $\rho_p = 1.1909$ kg/m^3.
The above data, used in calculations, were also presented in titles of tables 1 and 2.
All calculations were made for the wind speed Vo=0, 5, 10, 15 and 20 m/s.

Table 1.

Warunki opływu		Lina l = 100 m, d_c = .007 m, ρ_c = .085 kg/m (z kablem zasilającym), ρ_p = 1.2263 kg/m^3, W = 572 N, m_b = 41.7 kg					Lina l = 300 m, d_c = .005 m, ρ_c = .015 kg/m (bez kabla zasilającego), ρ_p = 1.1909 kg/m^3, W = 556 N, m_b = 40.1 kg				
l.p.	***Paramet r***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1.	**V_0 [m/s]**	**0**	**5**	**10**	**15**	**20**	**0**	**5**	**10**	**15**	**20**
2.	δ_1 [°]	**37.5**	**42.9**	**60.9**	**89.4**	**117.2**	**37.5**	**42.8**	**60.2**	**88.1**	**115.8**
3.	δ_2 [°]	**49.4**	**49.5**	**46.5**	**37.5**	**26.7**	**49.4**	**49.5**	**46.7**	**38.0**	**27.2**
4.	**N_1 [N]**	**106.1**	**96.0**	**77.7**	**72.1**	**87.7**	**106.1**	**96.3**	**78.1**	**71.9**	**86.2**
5.	**N_2 [N]**	**129.5**	**128.3**	**130.9**	**149.2**	**189.2**	**129.5**	**128.3**	**130.7**	**148.0**	**186.4**
6.	**P_x [N]**	**0**	**13.1**	**52.3**	**117.6**	**209.1**	**0**	**12.7**	**50.8**	**114.3**	**203.2**
7.	**l_2 [m]**	**2.74**	**3.07**	**4.12**	**5.62**	**6.78**	**2.74**	**3.06**	**4.08**	**5.56**	**6.73**

2. **Dynamic stability of the flying object**

The system of equations of the movement of "small interruptions" was created according to [2].

It was assumed the rigidity of the flying object together with its connection to the carrying rope and non-flexibility of the rope, with its division for n elements and the beginning of the current co-ordinate "s" in the point of the attachment to the ground.

Other weather, geometrical and mass conditions were taken as for stability calculations, but the value of inertia moment of the object according to the transverse axle in the system of its mass centre, taken as in [1] $I_y = 325$ kgm^2.

The movement of the carrying rope in the plane XOY can by described as a equation:

$$\mathbf{a}\,\mathrm{dm} = \mathbf{A}\,\mathrm{ds} + \mathbf{G}\,\mathrm{ds} + \frac{\partial}{\partial s}(\mathrm{Tt})\mathrm{ds} \tag{1}$$

System of equations for small interruptions:

$$\dot{\mathbf{x}} = \mathbf{S} \cdot \mathbf{x} \tag{2}$$

Solution of equations system:

$$\dot{\mathbf{x}} - \mathbf{S} \cdot \mathbf{x} = 0 \tag{3}$$

and the characteristic equation of matrix for S:

$$|\lambda \cdot \mathbf{I} - \mathbf{S}| = 0 \tag{4}$$

we get the general solution of the system (76) as:

$$\mathbf{x} = \mathbf{x}_k\ e^{\lambda \cdot t} \tag{5}$$

Table 2.

Warunki opływu		Lina l = 100 m, d_c = .007 m, ρ_c = .085 kg/m (z kablem zasilającym), ρ_p = 1.2263 kg/m^3, W = 572 N, m_b = 41.7 kg					Lina l = 300 m, d_c = .005 m, ρ_c = .015 kg/m (bez kabla zasilającego), ρ_p = 1.1909 kg/m^3, W = 556 N, m_b = 40.1 kg				
l.p	Parametr	1	2	3	4	5	6	7	8	9	10
1.	V_0 [m/s]	0	5	10	15	20	0	5	10	15	20
2.	T_1 [s]	5.47	5.43	5.26	4.55	3.77	6.20	5.24	5.32	4.24	2.98
3.	ς_1 [-]	0	.2502	.3830	.3675	.3001	0	.5332	.8280	.7843	.6515
4.	$T_1(1/2)$ [s]	∞	2.32	1.40	1.27	1.32	∞	.916	.400	.370	.382
5.	fn_1 [Hz]	.183	.190	.206	.236	.278	.161	.226	.335	.381	.443
6.	T_7 [s]	.794	.791	.749	.654	.548	.916	.925	.910	.719	.611
7.	ς_7 [-]	0	.0350	.0554	.0523	.0417	0	.1585	.2512	.1916	.1755
8.	$T_7(1/2)$ [s]	∞	2.49	1.49	1.38	1.32	∞	.635	.387	.363	.378
9.	fn_7 [Hz]	1.259	1.265	1.338	1.530	1.827	1.092	1.095	1.136	1.584	1.662
10	T_p [s]	$4.41_{(sw)}$	-	-	-	-	$4.52_{(sw)}$	-	-	-	-
11	$\varsigma_p\,\omega_{np}$ [1/s]	0	1.382	2.950	4.575	6.159	0	1.337	2.871	4.508	6.075
12	$T_p(1/2)$ [s]	∞	.50	.23	.15	.11	∞	.518	.241	.154	.114
13	fn_p [Hz]	.227	-	-	-	-	.221	-	-	-	-
14	T_w [s]	39.05	43.33	40.56	31.14	27.81	60.53	132.52	48.18	38.50	34.85
15	ς_w [-]	0	.4878	.7575	.7989	.8340	0	.9321	.9072	.8794	.9004
16	$T_w(1/2)$ [s]	∞	8.56	3.85	2.59	2.03	∞	5.89	2.46	2.30	1.86
17	fn_w [Hz]	.026	.026	.038	.053	.065	.017	.201	.055	.066	.066
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18	Tap(1/2)	-	-	-	23.8 h	14.9 h	-	-	-	9.6 h	-
19	Tp	-	-	245.1 s	95.7 s	78.0 s	-	-	-	50.8 s	40.6 s
20	Tp(1/2)	-	-	67.2 s	28.3 s	28.0 s	-	-	-	78.8 s	324.3 s

In the above table values with indexes "1" and "7" concern first and seventh harmonic oscillation of transverses, values with indexes "p" – fast oscillations, with "z" indexes –

swinging oscillation in gravity field. Index "sw" means freely swinging of the flying object around the attachment to the carrying rope, with the wind speed Vo=0.

3. Results of calculations and conclusions

Calculations of states concerning parameters of attachment system of the flying object to carrying rope, as well as bending of the carrying rope caused by changing wind speed confirmed construction expectations as for reactions of these elements in stable conditions.

Especially results for the side stream are similar to those described in p.2.2 of the article [6] in very stable state that occurred during researches outside, with the wind speed about 5 m/s and 70-meters long carrying rope, when the object came to the side position to the incoming wind direction. A great deviation of rope's position was observed and the object was a dozen or so meters up in the air, just above tree tops. In the same time there occurred some difficulties with taking the object down because of the great tightening of the rope close to the ground.

Results of calculations for side position confirm what was observed during field researches because for the 5 m/s speed in calculations the tightening to the ground was 40 daN and the object was 20 m above the ground. In addition we can avoid this kind of object's behaviour by keeping the horizontal position and keeping the stream in small angles of side-slip by using the special automaton. As the research had shown, the object has good direction stability in a horizontal position.

There were some disstabilities in calculations results, the solution

$Re(\lambda) > 0$. As was mentioned before, in the table 2. they were all mentioned.

Identification has shown the greatest role of the movement with unstable own values in vertical movements of the rope near the ground. These movements are very slow and have almost non influence on the object's reactions.

Together with the increase of the wind speed there was also noticed a increase of frequency of free and disturbed oscillation and also interruption of the carrying rope concerning its non-flexible material. But with the wind speed Vo=20 m/s there is a small decrease of the interruption. It can be explained that in these conditions there is a small decrease of the resistance Cx that influences interruptions. There is a decrease of Cz of the rope which has a different result.

So called "fast oscillations" of the object don't occur, except for the wind speed Vo=0 (free movement) because there is an asymptotic disappear of bending. It is caused not only by an aerodynamic stability but also by reactions of an object with its carrying rope together with the same effect of draught power.

Results of calculations show very characteristic behaviour of the system in swinging oscillations. There is a regular increase of free frequency and decrease of the time of amplitude's division together with the increase of the wind speed, but the time of these changes, especially for the rope l=300 m is very irregular concerning speed. For the rope l=100 m the coefficient of interruptions increases together with the speed. On the other hand periods of changes in both cases first increase from Vo=0 to about Vo=6 m/s, but then decerase with greater speed. In case of l=300 m for the speed about 6 m/s there is a critical interruption (c>=1 where c is confirmed in function of wind's speed which increases up to Vo=6 m/s but later it decreases) and oscillations of swinging disappear (Tw - $\rightarrow \infty$) which is not happening for l=100m.

All in all we can say that calculations confirmed expected satisfying characteristics of dynamic stability of the system that were observed during researches of a real object in the air. But still, these calculations should be treated only as a first stadium of creating a mathematical model of this system. Summary

Non-pilot aerostat – controlling in the air. The analyses of balance states and dynamic stability .

In the article there was shown a piece of work [10] respecting matching of balance states and dynamic stability of aerostat at tether attachment.
A computable aerostat model was used with computer stimulation of predicted external hums affecting the model. During following parts of counting project, some modifying statements of the system were approached by mathematical models. Results of these actions were put into tables and graphics. Gained computable materials was the basis for the continuation of works, where the subject was real aerostat. The experimental aerostat at tether attachment projected in the Institute of Aviation as "Blimps platform" was built and checked in exploitation conditions.

References

[1]. Sprawozdanie nr I-26/BP/2000 – „Geometria mas i charakterystyki stateczności aerostatu obserwacyjnego"; Ilot, Warszawa 2000.
[2]. B.Etkin – „Stability of a Towed Body"; Journal of Aircraft, Vol. 35, No 2, March-April1998.
[3]. A.W.Babister – „Aircraft Stability and Control"; Pergamon Press, 1961.
[4]. C.H.Wolowicz, R.B.Yancey – „Longitudinal Aerodynamic Characteristics of Light, Twin-Engine, Propeler – Driven Airplanes"; NASA TN D-6800, 1972.
[5]. B.Etkin – „Dynamics of Flight"; John Wiley & Sons, Inc., 1959.
[6]. Sprawozdanie nr I-26/31b/BP/2001 – „Platforma balonowa I-26. Nosiciel systemów obserwacyjnych"; Ilot, Warszawa, czerwiec 2001.
[7]. W.Fiszdon – „Mechanika lotu"; PWN, Warszawa 1961.
[8]. J.Maryniak – „Dynamiczna teoria obiektów ruchomych"; WPW, 1976.
[9]. Z.Goraj – „Obliczenia sterowności, równowagi i stateczności samolotu w zakresie poddźwiękowym"; MEiL, Warszawa 1984.
[10] Sprawozdanie nr I-26/26/BP/2002 – „Platforma balonowa I-26. Nosiciel systemów obserwacyjnych"; Ilot, Warszawa, czerwiec 2002.

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DESIGN OF SUBOPTIMAL ROBUST FLIGHT CONTROL SYSTEMS FOR SMALL UAV.

The report is devoted to the design of the robust flight control systems for small UAV, which have to satisfy contradictory requirements of performance and robustness from one hand and low cost and simplicity from other hand. In this report two approaches of flight control law design pursuing aforementioned goal are proposed: the first is based on the application of the separation theorem for control law synthesis with further robustization and simplification of obtained solution, the second is based on the fuzzy control law learning using robust prototype.

Introduction. Flight control of the small UAV doesn't afford expensive on-board computers and navigational sensors. From other hand their successful operation requires high level of robustness towards the uncertainty of their aerodynamic models' parameters and high level of performance in the presence of turbulent wind. That is why well-known PID-controllers are applied as the main mean for UAV flight control in the majority of autopilots, which are serially manufactured by various companies all over the world. Using "nominal performance-robust stability"(NPRS) approach [1], it is possible to find such adjustment of PID-controller's parameters, which delivers a reasonable trade-off between contradictory conditions of the control system performance and robustness. This goal could be achieved using mixed H_2/H_∞ control of multi-model plants [1-4], which is based on the minimization of the complex cost function incorporating deterministic as well as stochastic criteria, based on the correspondent H_2-norms, and H_∞-norms of the complementary sensitivity functions of the set of closed loop systems for different plant models. The set of plant's models includes all parametrically disturbed models in the different conditions of flight, which cover all flight envelopes of the given aircraft. So far as H_2-norms determine the performance of control system and H_∞-norm determine the robustness, the minimization of this complex cost function can achieve aforementioned compromise on the basis of the weighting coefficients, assigned to each component of the complex cost function. This approach was successfully applied for parametric optimization of the analog and digital flight control systems of small UAV with given PID and PD structures [2-4]. The software proposed in these publications can be recommended for robust tuning of the serial UAV autopilots.

However nowadays there is some tendency to optimize the UAV aerodynamic properties in order to perfectly accomplish the ultimate goals of its specific flight mission. This tendency must be reflected in the flight control law synthesis, when requirements to performance have to be increased, meanwhile the requirements to robustness must preserve at least the same level as in the aforementioned case of PID-controllers. In this case at the first stage of the design procedure the structure of controller must be chosen on the basis of the optimal stochastic control theory (separation theorem) [5]. At the second stage of this procedure the parameters of autopilot's structure are chosen to satisfy the robustness requirements using aforementioned NPRS approach [6,7]. Another way of the robust UAV autopilots design is the application of the fuzzy logic in the control law. As it was stated in the recent publications [8-10], fuzzy autopilots possess high level of robustness, because they use the knowledge-based (expert) control. It "uses reasoning mechanisms for determining the control action from the knowledge stored in the system and the available measurements"[8]. The robust sub optimal control could be used as such an "expert" for tuning the membership functions of the fuzzy controller, thus achieving the compromise between robustness and performance of the flight control system as the ultimate goal of the robust control. The paper is devoted to the description of these two basic approaches for the UAV autopilots design.

Structure-parametrical synthesis of the sub optimal robust control. Consider the 1st stage of the design procedure – the synthesis of the optimal stochastic controller on the basis of the separation theorem [5]. The standard block-diagram, which illustrates this problem of the synthesis, is represented at the Fig.1. Let, $\mathbf{A} \in R^{n\times n}, \mathbf{B} \in R^{n\times m}, \mathbf{C} \in R^{l\times m}, l < n, m < n$, would be the quadruple of matrices of the state space of the controlled plant (UAV):

$$\dot{x} = \mathbf{A}x + \mathbf{B}u + \omega_1 \tag{1}$$

$$y = \mathbf{C}x + \omega_2 \tag{2}$$

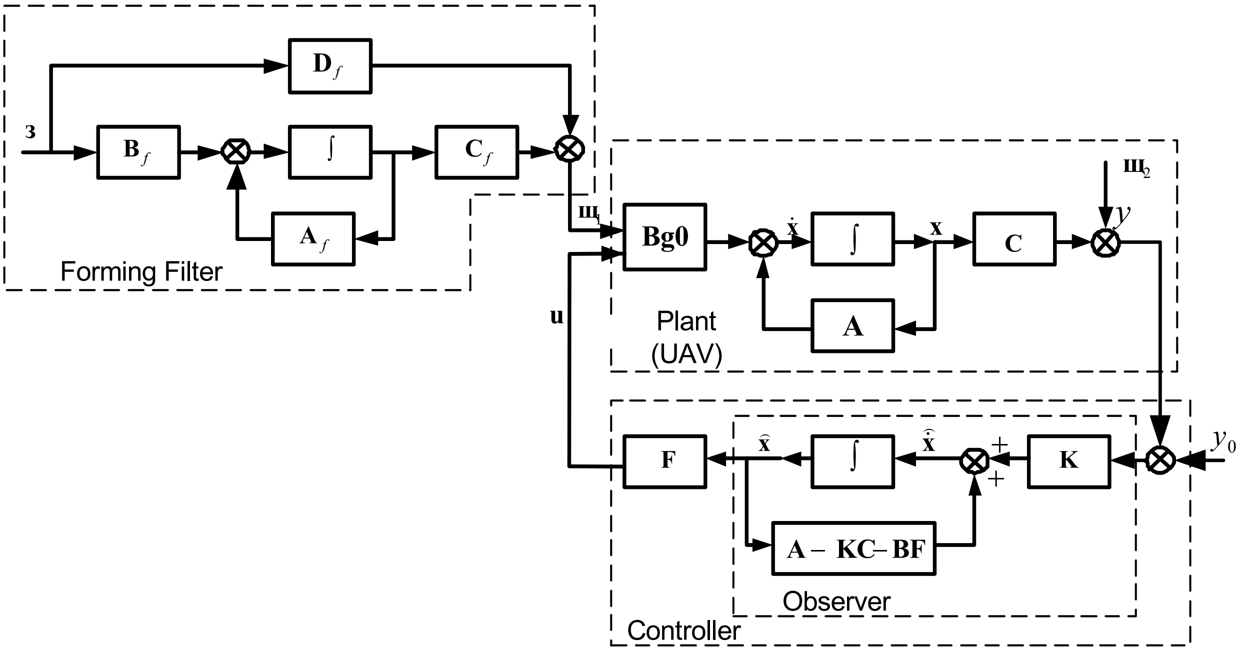


Fig.1. Optimal stochastic control system.

where ω_1- is the model of turbulent wind with spectral densities described by the Dryden model, ω_2- are the sensors white noises with covariance matrix V_2. Let the quadruple of matrices $\left[\mathbf{A}_f \in R^{p\times p}, \mathbf{B}_f \in R^{p\times s}, \mathbf{C}_f \in R^{r\times p}, \mathbf{D}_f \in R^{r\times s}\right]$ describes the forming filter, which forms the random vector with entries having Dryden power spectral densities (PSD) from the input white noises vector η with unit covariance matrix V_1. State space model of Dryden forming filter $\left[\mathbf{A}_f, \mathbf{B}_f, \mathbf{C}_f, \mathbf{D}_f\right]$ is described in [11] and its concrete form for this particular case would be represented later. In order to represent this task in the standard form ready to be solved using the separation theorem [6], it is necessary to incorporate the state space model of the Dryden filter into the state space description of the controlled plant (1,2). The series connection of the Dryden filter and UAV models produces extended state space model with extended state space vector X_{ex} = [X_f, X]' and the following quadruple of matrices $\left[\mathbf{A}_{ex} \in R^{(p+n)\times(p+n)}, \mathbf{B}_{ez} \in R^{(p+n)\times(r+s)}, \mathbf{C}_{ex} \in R^{l\times(p+n)}, \mathbf{D}_{ex} \in R^{l\times(r+s)}\right]$, where

$$\left[\begin{array}{c|c} \mathbf{A}_{ex} & \mathbf{B}_{ex} \\ \hline \mathbf{C}_{ex} & \mathbf{D}_{ex} \end{array}\right] = \left[\begin{array}{cc|c} \mathbf{A}_f & \mathbf{0}_{p\times n} & \mathbf{B}_f \\ \mathbf{B}_g\mathbf{C}_f & \mathbf{A} & \mathbf{B}_g\mathbf{D}_f \\ \hline \mathbf{0}_{l\times p} & \mathbf{C} & \mathbf{0}_{l\times s} \end{array}\right] \tag{3}$$

Entries of matrix $\mathbf{B}_g \in R^{n\times r}$ are connected with the forming filter's outputs, which disturb corresponding state space variables of the controlled plant. The matrix B_{g0} presented at the Fig.1 is equal: $\mathbf{B}_{g0} = [\mathbf{B}_g, \mathbf{B}]$. After this transformation the extended state space description would have the following form

$$\begin{aligned} \dot{x}_{ex} &= \mathbf{A}_{ex}x_{ex} + \mathbf{B}_{ex}x_{ex} + \begin{bmatrix} 0_{r\times m} \\ \mathbf{B} \end{bmatrix} u + \eta \\ y &= \mathbf{C}_{ex}x_{ex} + \mathbf{D}_{ex}x_{ex} + \omega_2 \end{aligned} \tag{4}$$

where η and ω_2 are the white noises of state space disturbances and measurement errors. The dimension of the matrix $\mathbf{C}_{ex}$ shows that numbers of available measurements are much less than the dimension of the state space vector $\mathbf{X}_{ex}$: l < n < n + p.
Now it is possible to apply the separation theorem and the first of all to find the optimal observer (Kalman filter) to restore the complete state space vector X_{ex}. In accordance with [5] the optimal observer, minimizing the quadratic norm of the error between state space variables of the real plant and its model $\varepsilon = x_{ex} - \hat{x}$, is defined by the following expressions:

$$\dot{\hat{x}} = \mathbf{A}\hat{x} + \mathbf{B}u + \mathbf{K}\left[y - \mathbf{C}\hat{x}\right], \tag{5}$$

where Kalman gain matrix is determined from the following expression:

$$\mathbf{K} = \mathbf{P}_2\mathbf{C}^T\mathbf{V}_2^{-1} \tag{6}$$

and covariance matrix P_2 of the state variables X_{ex} is defined from the algebraic Riccati equation (ARE):

$$0 = \mathbf{V}_1 - \mathbf{P}_2\mathbf{C}^T\mathbf{V}_2^{-1}\mathbf{C}\mathbf{P}_2 + \mathbf{A}\mathbf{P}_2 + \mathbf{P}_2\mathbf{A}^T. \tag{7}$$

Using completely restored state vector $\hat{x}$ it is possible to find optimal deterministic controller minimizing quadratic functional

$$J_d = \int_0^\infty (x^T Q x + u^T R u)dt\,, \tag{8}$$

where Q, R are the diagonal matrices, weighting each state and control variables respectively in the common performance index (8). This controller uses output static feedback:

$$u = -\mathbf{F}\hat{x}, \tag{9}$$

where gain matrix F is determined from the following expression:

$$\mathbf{F} = \mathbf{R}^{-1}\mathbf{B}^T\mathbf{P}_1 \tag{11}$$

and positively defined matrix P_1 is the solution of the following ARE:

$$0 = \mathbf{D}^T\mathbf{R}_2\mathbf{D} - \mathbf{P}_1\mathbf{B}\mathbf{Q}^{-1}\mathbf{B}^T\mathbf{P}_1 + \mathbf{A}^T\mathbf{P}_1 + \mathbf{P}_1\mathbf{A}. \tag{11}$$

The order of the closed loop system, shown at the Fig.1, is equal $2(n+p)$ (where n, p are the dimensions of the controlled plant's and Dryden filter's models respectively) and its equation has the following form:

$$\begin{pmatrix} \dot{x} \\ \dot{\hat{x}} \end{pmatrix} = \begin{pmatrix} \mathbf{A} & -\mathbf{BF} \\ \mathbf{KC} & \mathbf{A} - \mathbf{KC} - \mathbf{BF} \end{pmatrix} \begin{pmatrix} x \\ \hat{x} \end{pmatrix} \tag{13}$$

This procedure concludes the 1st stage of the flight control system design.

The 2nd stage is the robustization of the previously obtained optimal flight control system. For the sake of brevity and without loss of generality we consider two plant's models: nominal and perturbed, which are represented by two quadruples of matrices [A, B, C, D] and [A_p, B_p, C_p, D_p] respectively [2,3]. Number of perturbed models could be increased to any appropriate value, if information about all them is available. The problem is to find the same control law for these two models appropriate from the viewpoint of stability and performance. The solution of this problem can be achieved by the convex optimization procedure using composite performance index (CPI), consisting from estimations of performance and robustness for the nominal and perturbed systems with corresponding LaGrange factors, weighting the contribution of each estimation in the CPI [2-4]. The entries of the controller and observer gain matrices F from (9) and K from (6) can be used as the variables of the optimization procedure. The optimal values of these entries achieved at the 1st stage of design for the nominal system could be used as the initial values for starting the optimization procedure. Running optimization procedure several times with different LaGrange factors allows finding the desirable trade-off between performance and robustness. Therefore it is necessary to define the estimations of performance and robustness of the closed loop system presented at the Fig.1.It is known [5,12], that the performance of system could be estimated by H_2-norm for deterministic as well as for stochastic cases. We shall consider both this cases because it is important to stabilize flight of UAV under turbulent wind during long time as well as to execute exactly deterministic commands y_0 for changing altitude, course, track and so on. The NPRS approach allows incorporating into CPI the H_2- norms for stochastic case, when the Dryden forming filter is included in the state space model of closed loop system, and simultaneously the same norms for deterministic case without aforementioned filter with corresponding weight coefficients. Such approach allows achieving the trade-off between the performances in the stochastic and deterministic cases [1-4]. So it is necessary to determine the following components of the CPI defining the performance of nominal and perturbed closed loop systems:

1. H_2-norm for nominal and perturbed systems in the deterministic case:

$$J_d = \sqrt{\int_0^\infty \left[\mathbf{X}^{\mathrm{T}}\mathbf{Q}\mathbf{X} + \mathbf{U}^{\mathrm{T}}\mathbf{R}\mathbf{U}\right]dt} \tag{14}$$

with corresponding diagonal weight functions Q, R for each state space and control variables;

2. H_2-norm for nominal and perturbed systems in the stochastic case:

$$J_d = \sqrt{E_M \int_0^\infty \left[\mathbf{X}^{\mathrm{T}}\mathbf{Q}\mathbf{X} + \mathbf{U}^{\mathrm{T}}\mathbf{R}\mathbf{U}\right]dt} \tag{15}$$

where E_M is the symbol of the expectation operator, produced by the ensemble averaging.

The estimation of robustness of the closed loop nominal and perturbed closed loop systems could be done using H_∞- norm of the complementary sensitivity functions $T(j\omega)$ [12]:

$$\|T\|_\infty = \sup \bar{\sigma}(T(j\omega)),\ 0 \le \omega \le \infty \tag{16}$$

where $\bar{\sigma}(T(j\omega))$ is the maximal singular value of the matrix $T(j\omega)$ at the current frequency ω. Computation of these norms could be performed on the basis of the quadruples of matrices, which define the state-space descriptions of closed loop systems in the stochastic and deterministic cases for nominal and all perturbed models of plant. Then these matrices are used for the calculations of H_2- and H_∞- norms (14-16) to produce CPI in the following form:

$$J_\Sigma = \lambda_{dn} H_2^{dn} + \lambda_{dp} H_2^{dp} + \lambda_{sn} H_2^{sn} + \lambda_{sp} H_2^{sp} + \lambda_\infty H_{\inf}^{n} + \lambda_\infty^{p} H_{\inf}^{p} + PF \tag{17}$$

where H_2^{dn}, H_2^{sn} are H_2- norms for nominal deterministic and stochastic models respectively, H_2^{dp}, H_2^{sp} - are H_2- norms for perturbed deterministic and stochastic models respectively, $H_{\inf}^{n}, H_{\inf}^{p}$ -are H_∞-norms for perturbed deterministic and stochastic models respectively, $\lambda_{dn}, \lambda_{dp}, \lambda_{sn}, \lambda_{sp}, \lambda_\infty, \lambda_\infty^p$ -are the corresponding weight coefficients, PF is the penalty function, which restricts the location of the closed loop system poles in the prescribed domain of the complex plane [2-4,6,7]. . Increasing or decreasing the weights $\lambda_\infty, \lambda_\infty^p$ relatively to the performance components $\lambda_{dn}, \lambda_{dp}, \lambda_{sn}, \lambda_{sp}$ it is possible to reach the trade-off between the performance and robustness of system. There is also very important possibility to change the elements of weighting matrices Q and R in (14), (15), thus avoiding of exceeding the prescribed tolerance for each state space and control variable of plant's model. All components of the CPI (17) depend on the variable (adjusted) parameters of controller or entries of matrices F (deterministic controller) and K (Kalman gain matrix). These variables could be considered as the components of vector $\vec{\Theta}_n$, where n is the number of iteration of the optimization procedure. Optimization procedure must find such value of vector $\vec{\Theta}_n$, which provides the minimum of CPI (17):

$$\vec{\Theta}_{\mathbf{n}}^{*} = \arg\min J_{\Sigma} \left(\vec{\Theta}_{\mathbf{n}}\right), \ \vec{\Theta}_{\mathbf{n}} \in D_c, \tag{18}$$

where D_c is the stability domain in the parameter's space, which is defined by penalty function.

After executing optimization procedure it is expedient to reduce the order of acquired controller due to the following reason. Using Kalman filter for restoring complete state vector $\hat{X}$ increases the order of system in two times, as it could be seen from (13). So from the viewpoint of practical implementation of the control law in the airborne computers it is necessary to perform the model reduction. It is done on the basis of the balanced realization, obtained by nonsingular transformation of system (13) [6,7]. Model reduction made after aforementioned robust optimization procedure is much more effective, than before it, when it is applied directly to the system (13) just after controller design on the basis of the separation theorem. It will be illustrated in the Case Study. The last stage in the design procedure is the simulation of the acquired control system in SIMULINK, including all necessary nonlinear elements, which are immanent to the actual control systems (like saturation, dead zones and so on), and wind turbulence. These conditions guarantee the proximity of the simulation to the real flight. Such kind of simulation is the final test of efficiency of the acquired flight control law.

Case study. Consider the small UAV in the altitude-hold mode studied in [2,3,6,7]. The state space vector of its dynamic model has the following components: X = [V_t, α, ϑ, q, h]', where V_t – is the deflection of true airspeed from steady state value V_{t0}, α - is the angle of attack, ϑ - is the pitch angle, q-is the pitch rate, h- is the deflection of altitude from the steady state value. The control variable is the angle of deflection of elevator δe from its trimmed value; the thrust control is absent. Absence of the thrust control is the reason of vulnerability of aircraft model towards the constant wind speed and eventually towards the true air speed V_{t0}. The true airspeed uncertainty is defined as interval: 55 m/sec $\le V_{t0} \le$ 70 m/sec. The nominal model corresponds to the air speed V_{t0} = 70 m/sec, the perturbed one is V_{t0p} = 55 m/sec. So we have two models corresponding to these air speeds, which have the following matrices of the state space description:

$$\mathbf{A} = \begin{bmatrix} -0.0345 & 5.9942 & -9.7764 & 0 & 0 \\ -0.0041 & -1.7565 & 0 & 0.9860 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0.0033 & -25.6814 & 0 & -2.1905 & 0 \\ 0 & -Vt_0 & Vt_0 & 0 & 0 \end{bmatrix} \quad \mathbf{A}_p = \begin{bmatrix} -0.0273 & 5.9960 & -9.7764 & 0 & 0 \\ -0.0064 & -1.3927 & 0 & 0.9971 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0.0036 & -16.1243 & 0 & -1.7339 & 0 \\ 0 & -Vt_{0p} & Vt_{0p} & 0 & 0 \end{bmatrix}$$

$$\mathbf{B} = \begin{bmatrix} 0.3576 & -0.1628 & 0 & -31.1037 & 0 \end{bmatrix}^T; \ \mathbf{B}_p = \begin{bmatrix} 0.3581 & -0.1303 & 0 & -19.8857 & 0 \end{bmatrix}^T.$$

Only three variables are measured: θ, q, h, so the observation matrix has the following form:

$$\mathbf{C} = [\mathbf{0}_{3\times3}, \mathbf{I}_{3\times3}],$$

where I is the unit matrix of the corresponding dimension. The actuator can be approximated with the simplest 1st order block with transfer function $W_a(s) = \frac{1}{0.5 \cdot s + 1}$. So the model of controlled plant is the series connection of the actuator's and UAV models. . In accordance with [1] the Dryden filter for turbulence wind description has 2 inputs (horizontal and vertical wind gusts) and 3 outputs (turbulent longitudinal speed, turbulent angle of attack and turbulent pitch rate). State space description for the Dryden filter [2,3] for the nominal air speed V_{t0} = 70 m/s and r.m.s. of turbulent speed 2.5 m/s is the following:

$$\mathbf{A}_f = \begin{bmatrix} -0.096 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & -0.009 & -0.192 \end{bmatrix}; \mathbf{B}_f = \begin{bmatrix} 0.494 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix}; \mathbf{C}_f = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 6\cdot 10^{-4} & 0.011 \\ 0 & 10^{-4} & 0.0015 \end{bmatrix}; \mathbf{D}_f = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & -0.011 \end{bmatrix}.$$

The state space representation of this filter for the V_{t0p} = 55 m/s also was defined but not given here for the sake of brevity. The covariance matrices of the state variables noise and measurement noise are equal to $V_1 = I_{2\times2}$ and V_2 = diag [0.25, 0.2, 25], the entries to the last one being defined by the specifications on accuracy of corresponding sensors. The weighting matrices Q, R in (14), (15) have the following form: $Q = [0.1 \;\; 1 \;\; 1 \;\; 5 \;\; 0.1 \;\; 1 \;\; 0.01 \;\; 0.01 \;\; 0.01]$; R=1. Using these models it is possible to define the extended state space description for the stochastic case using expression (3). Model (3) has dimension 9, so it is necessary to create the Kalman observer using 3 measured variables for restoring 9×1 state space vector X. Eventually on the basis of the separation theorem the optimal gain matrix of controller having size 1×9 was defined:

$$F = [-0.0055 \;\; 23.1277 \;\; -27.5729 \;\; -1.6705 \;\; -0.5607 \;\; 1.6444 \;\; -0.0191 \;\; -0.0017 \;\; -0.0564].$$

These gains were used as the initial values for starting the Nelder-Mead optimization procedure. In order to find desirable values of the weighting coefficients λ in CPI (21), the optimization procedure was executed several times, and the weights were defined as: $\lambda_{sn} = \lambda_{sp} = 1.8$, $\lambda_{dn} = \lambda_{dp} = 0.6$, $\lambda_\infty = \lambda_\infty^p = 0.7$. After robust optimization the order of the controller was reduced. The controllability Gramian [2,4,6,7,12] of the balanced realization model was the following:

$$g = [0.0418 \;\; 0.0391 \;\; 0.0154 \;\; 0.0082 \;\; 0.0065 \;\; 0.0007 \;\; 0.0003 \;\; 0.0002 \;\; 0.0000]'.$$

Here modes 4-9 are very small and it is possible to neglect them. These modes were excluded using MATLAB operator "modred" and simplified 3rd –order controller was determined. Performance and robustness indices of the controller system with the nominal and perturbed plant are given in the Table 1.

Table 1

		Optimal Syst.	Reduced Syst.	3rd order Robust
H_2 Stoch. case	nominal	0,6796	0,6994	0,6890
	perturbed	0,5344	0,5596	0,5488
H_2 Deter. case	nominal	1,1732	1,1954	1,1349
	perturbed	1,9975	1,0185	0,9868
H_∞	nominal	1,6943	1,8257	1,4062
	perturbed	1,7227	1,8794	1,4323

Restricted volume of the paper doesn't allow demonstrating the results of the system's simulation, which also prove the efficiency of this approach for control system design. From the Table 1 it could be seen that robust optimization permits to achieve order reduction from 9 to 3 without performance degeneration not only for stochastic disturbances, but also for the deterministic commands. Comparison of the corresponding rows of the Table 1 shows that the performance and robustness indices for nominal and perturbed plants in all cases are very closed. In this paper the analog autopilot was considered. The application of the described approach for the case of discrete time is made in [7].

Fuzzy robust control. As it was stated in [8,9], the most successful structure of fuzzy autopilot could be obtained as a result of combination of elements of the "crisp" (classical) and the fuzzy autopilots. In particular it is proposed to use the dynamic feedbacks containing integrals and derivatives with those coefficients, which were inherited from the "crisp" prototype, meanwhile the static feedbacks (gains) must be replaced with the fuzzy blocks. On the basis of this conception we can propose the following structure of the control law for the UAV altitude-hold mode, which is shown at the Fig.2. At this figure

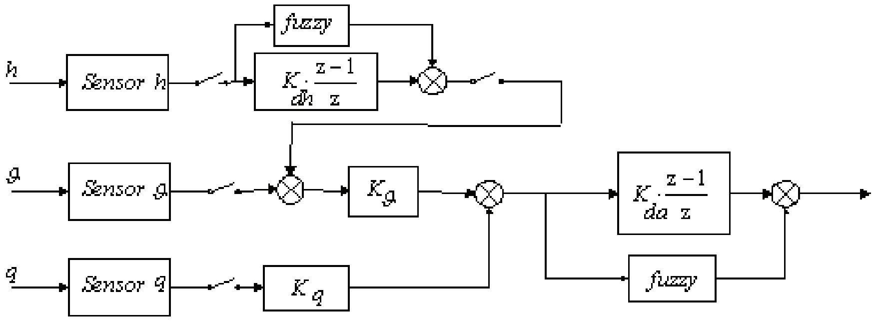


Fig. 2. Structure of the combined (fuzzy and "crisp") autopilot.

the measured components of the state vector h, ϑ, q are the same as in the previous example, K_q, K_ϑ, K_h are the corresponding gains, K_{da}, K_{dh} corresponding derivatives coefficients for angular and altitude stabilization loops respectively. In the altitude-hold mode coefficients K_q, K_ϑ could be considered as derivatives towards the altitude h. So we have two main gains K_h, K_a for altitude and angular stabilization loops, which must be replaced with fuzzy blocks, as it is shown at the Fig.2. Other coefficients $K_q, K_\vartheta, K_h, K_{da}, K_{dh}$ could be determined from the vector $\overrightarrow{\Theta}^*$ (see (18)). As it is known, the fuzzy blocks contain the following elements (see Fig.3): scale coefficients SC_1, SC_2 for matching

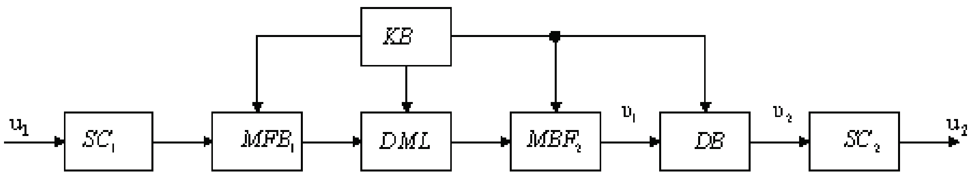


Fig. 3. Structure of the autopilot's fuzzy logic block.

the input and output signals u_1, u_2 with outputs of previous and inputs of further blocks of the autopilot (input-output normalization), the input membership functions block MFB_1 and output membership functions block MFB_2, decision-making logic (DML) and defuzzification block (DB). The knowledge base (KB) comprises knowledge of application domain (basic principles of flight control) and control goals to pursue (performance, robustness etc.). As it was recommended in [8,9], the membership functions MF were chosen as triangular ones and the Mamdani rules [10] were used for DNL inference engine. The universe of discourse is continuous in this case and the term set consists of 7 terms $d_j(1,...,7)$: *NB*, *NM, NS* – are negative big, medium and small altitude (or pitch angle) errors respectively; *ZE* stands for zero error, *PS, PM, PB* are positive small, medium and big errors respectively. The analytical expressions for membership functions are the following:

$$\mu(u;a,b,c)=\begin{cases}0, & u<a_i\\ \dfrac{u-a_i}{b_i-a_i}, & a_i\le u<b_i\\ 1, & u=b_i\\ \dfrac{c_i-u}{c_i-b_i}, & b_i<u\le c_i\\ 0, & u>c_i\end{cases}, \tag{19}$$

where i = 1,…,7 is a number of a membership function. The grade of the membership of the variable u to the fuzzy term d_j is determined by the following expression:

$$\mu_{d_j}(u)=\max\left\{\min_i\left[\frac{u-a_i}{b_i-a_i},1,\frac{c_i-u}{c_i-b_i}\right],0\right\}, \tag{20}$$

Parameters of the membership functions

Table 2

Term	Param	Input	Output	Param	Input	Output	Param	Input	Output
NB	a_1	-1.3	-1	b_1	-1	-0.7	c_1	-0.7	-0.5
NM	a_2	-1	-0.7	b_2	-0.7	-0.5	c_2	-0.1	-0.2
NS	a_3	-0.7	-0.5	b_3	-0.1	-0.2	c_3	0	-0.1
ZE	a_4	-0.1	-0.1	b_4	0	0	c_4	0.1	0.1
PS	a_5	0	0.1	b_5	0.1	0.2	c_5	0.7	0.5
PM	a_6	0.1	0.2	b_6	0.7	0.5	c_6	1	0.7
PB	a_7	0.7	0.5	b_7	1	0.7	c_7	1.3	1

Parameters a_i, b_i, c_i of the membership functions (19) are represented in the Table 2. They were chosen on the basis of the proximity of transient processes in the "crisp" and fuzzy systems, the first one being used as the knowledge base for the fuzzy system.

Decision making block is described by the Mamdani rules [10, 13]: if (AE is NB) then (PA is NB) (1), if (AE is NM) then (PA is NB) (1), if (AE is NS) then (PA is NM) (1), if (AE is ZE) then (PA is ZE) (1), if (AE is PS) then (PA is PM) (1), if (AE is PM) then (PA is PB) (1), if (AE is PB) then (PA is PB) (1) , where AE is the altitude error, PA is the pitch angle.

Defuzzification uses the center of area method:

$$\upsilon_2=\frac{\int_{\underline{\upsilon}_1}^{\overline{\upsilon}_1}\upsilon\mu_0(\upsilon_1)d\upsilon_1}{\int_{\underline{\upsilon}_1}^{\overline{\upsilon}_1}\mu_0(\upsilon_1)d\upsilon_1} \tag{21}$$

where $\underline{\upsilon}_1, \overline{\upsilon}_1$ are minimal and maximal values of the output variable υ_1 for the set of the output membership functions of MFB$_2$ (see Fig. 3), $\mu_0(\upsilon_1)$ is the set of the output membership functions. Comparison of the dynamic properties of crisp and fuzzy autopilots were made on example of longitudinal motion control of the same UAV, which was considered in the previous chapter using the simulation of the same nominal and parametrically disturbed plant's model under deterministic and stochastic disturbances. Results of this simulation of

fuzzy autopilot are shown at the Fig.4; meanwhile the comparison of the dynamic properties is represented in the Tables 3 (for the step responses) and 4 (for the stochastic disturbance).
Fig.4. Transient processes in the UAV altitude-hold control loop for the nominal (left) and perturbed (right) plant's models.

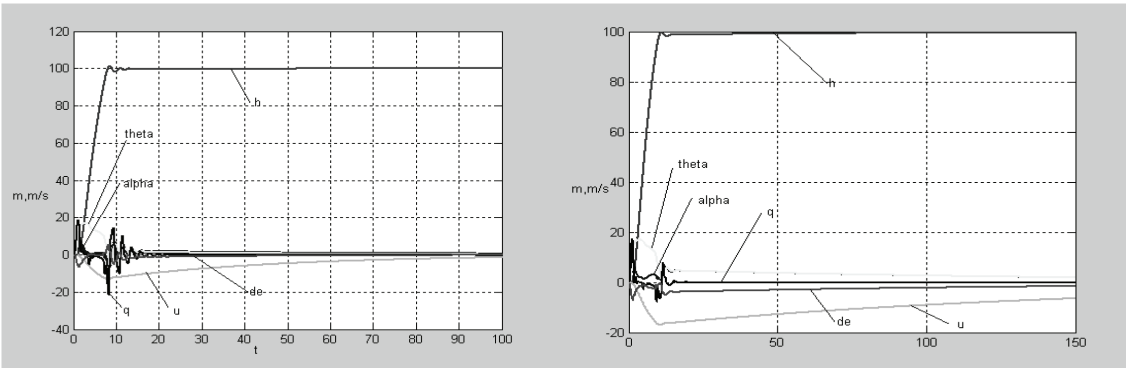
Comparison of the fuzzy and crisp systems' step responses

Table 3

System	Settling time, s	Overshoot h, %	Maximal deflection.				
			u, m/s	б, deg.,	ϑ,град.	q,град/с.	δe,град.
Fuzzy nominal.	12.	1.4	13	7.65	17	21	6.6
Crisp nominal	15	10	14.2	8.85	17.1	27.6	8.1
Fuzzy perturb.	13	1.8	16.9	8.4	16.9	17.35	7
Crisp perturb.	16	5	17.8	9.2	17	28	8.2

Comparison of the state variables' r.m.s. of the fuzzy and crisp systems

Table 4



Система	y_h m	y_u m/s	$y_б$ deg	y_ϑ deg	y_q deg/s	$y_{\delta e}$ deg
Fuzzy nominal	0.195	2.7897	1.0847	0.9462	2.5273	0.7397
Crisp nominal	3.593	7.1538	3.0791	4.4520	6.1054	2.0939
Fuzzy perturb.	0.435	3.2506	1.5431	1.4110	1.8687	1.2025
Crisp perturb.	5.878	11.9290	4.5465	5.9787	4.8389	3.1954

This comparison shows that using the fuzzy autopilots it is possible to find such tuning of parameters of the membership functions, which provides the same level of robustness (accepted parameter uncertainty) and even some small improvement of performance for the deterministic disturbances and better suppression of the random errors under deterministic disturbances. In the same time the crisp autopilots are simpler than the fuzzy ones. This advantage is more pronounced taking into account the aforementioned controller's order reduction, which could be made after procedure of optimal controller robustization.

References

1.***E.Schoemig, M. Sznaier***. Mixed H_2/H_∞ Control of Multi-model Plants// Journal of Guidance, Control and Dynamics, No.3, May-June, 1995, p.p. 525-531.
2. ***A.A.Tunik, E.A.Abramovich***. Parametric Robust Optimization of the Digital Flight Control Systems. Вісник НАУ, №2, 2003, стор. 31-37, Київ
3. ***I.K.Ahn, H.Ryu, V.B.Larin, A.A.Tunik.*** Integrated Navigation, Guidance and Control Systems for Small Unmanned Aerial Vehicles. The World Congress "Aviation in the XXXI-st Century", NAU, Kyiv, 2003, pp.5.15 –5.25.
4. ***A.A.Tunik, H.Ryu, H.C. Lee.*** Parametric Optimization Procedure for Robust Flight Control System Design. KSAS International Journal. Vol. 2, No. 2, Nov. 2001, pp.95-107.
5. ***H.Kwakernaak, R. Sivan.*** Linear Optimal Control Theory. New York, John Wiley & Sons, 1972, 464 c.
6. ***A.A.Tunik, T.A.Galaguz.*** Robust Stabilization and Nominal Performance of the Flight Control System for Small UAV. Applied& Computational Math. Vol.3, No.1, 2004, pp.34-45.

7. ***А.А.Тунік, Т.А.Галагуз.*** Структурно-параметричний синтез цифрової робастної системи управління. Вісник НАУ, №4, 2004, стор. 8-16, Київ.
8. ***Schram, G., Kaymak, U., Verbruggen, H.B.*** Fuzzy Logic Control. Chapter 13. "Robust Flight Control. Design Challenge". Springer-Verlag.- Berlin, Heidelberg, New York.
9. ***G. Schram, H.B.Verbruggen.*** A Fuzzy Control Approach. Chapter 26 in the same issue. - P. 397-419.
10**. *Lin C.F.*** Advanced Control Systems Design. PTR Prentice Hall Inc., Englewood Cliffs, New Jersey, 1994. - 664 p.
11**. *D. McLean.*** Automatic Flight Control Systems. Prentice Hall Inc., Englewood Cliffs, 1990, 593p.
12. ***S. Skogestad, I. Postlethwaite.*** Multivariable Feedback Control. Analysis and Design. John Wiley & Sons, 1997, 559p.
13. ***D. Driankov , H. Hellendoor , M. Reinfrank.*** An Introduction to Fuzzy Control. Springer-Verlag, Berlin, Heidelberg, New York. - 1993. -316 p.

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THE IMPACT OF METALLIC-CERAMIC SURFACE LAYERS CHARACTERISTICS ON ACOUSTIC EMISSION

The paper deals with the research of idle time impact on operational properties of friction pairs with metallic-ceramic surface layer. The application of AE information for inspection and diagnostics of complicated trybotechnical systems directly in the process of operation has been proposed

Introduction

The use of tryboretrofitting mixes TRM is one of the ways of service life duration of modern technological units. Introducing of TRM is directed to the recovery of trybotechnical friction surfaces without carrying out labor-taking operations which are connected with units dismantling after their repair [1,2,3]. Hence, present requirements for the TRM application do not take into account specific conditions of real friction pairs operation. For example, gas turbine engine GTE transmission gearing can operate both under stationary and non-stationary conditions. During time of their operation there can be rather long intervals of time when the friction pairs are not engaged into operation [4]. It is natural, that such a range of modes of operation will impact on physico-mechanical characteristics of metallic-ceramic layers (MCL) which are originated on the friction surface due to TRM application and also due to their stressed condition. It is evident that changes in MCL properties will also impact on the GTE service life.

For the study of friction pairs properties different methods of research have been used, fractographical surface analysis, electrical, electromechanical methods of wear intensivity estimation are among them. At the same time the methods which allow to obtain information about kinetics of processes which take place in the surface layers of materials at the moments of their dynamic contact interaction are more widely used. The acoustic emission (AE) [5, 6, 7, 8] is one of them. This method has a high sensitivity to the change of an element wearing mechanisms which are due to physico-mechanical processes taking place on the boundary of materials surface layers separation [6,7,8]. This fact allows applying AE information for the elaboration of estimation method of friction pair conditions with the detection of the materials wearing stage.

This paper will show that as a result of a long idle time of friction pairs with TRM, their properties are changed which is connected with the relaxation of internal strains in the system "the basic material – "MCL". This process leads to the intensification of elements surface wearing are put into operation after the long idle time period. It will be also determined that main regularities of the changes of acoustic radiation which can be used for the development of methods of estimation of surface friction under operational conditions.

Materials and methods

Three pairs of samples made of ШХ-15 and 12Х2Н4А steels have been prepared. The samples of he first friction pair were covered with MCL a month later after its application. The samples of the second friction pair have a 10 day delay, while the MCL of the third friction pair was applied on the friction surface just in the [rocess of research i.e. without any delay. The MCL for all friction pairs samples was obtained by means of the adding of „ИТП-300" "Gel-revitalisant for reduction gears" to the reduction gear oil (TRM produced by the ХАДО firm). The methods for obtaining of MCL which is formed in the process of friction with TRM are described in [9]. The choice of these materials for friction pair under investigation and the lubricant environment is reasoned by their wide use in aircraft GTE transmissions.

Testing of samples has been performed with the help of universal friction machine CMT-1 on the "disk-disk" scheme. Accordingly to this arrangement one disk was stationary while the other was rotating on the spindle of the friction machine. During tests the mode of rolling friction with 20% of slipping was realized. Samples dimensions were: diameter D_{sam}=25mm, thickness h=15mm. Speed of rotation of the friction machine transmission shaft was chosen as close as possible to the condition of operation of modeling units and it was equal to 500 rpm.

The tests were performed during two stages. Firstly, friction pairs were tested under loading with the determination of the time of their steady 'quasiwearless" work mode of operation. The applied loading which was transferred after calculation into account the dimensions of tested samples was taken equal to σ_{max} = 1000MPa. Methods of stress calculation are given in [10]. During the second stage when the friction pairs achieved the steady mode of operation the sudden oil suction out of lubrication bath was performed. After that the friction pair worked up to the time of a scratch appearing under the condition when samples were lubricated with oil which was left on their surfaces. The value of applied stress was constant and was not changed during experiment. Moment of friction and samples weights which were determined according to the methods described in [11] were considered as the main parameters characterizing wear resistance of samples.

In the process of friction AE signals recording and processing were performed. Acoustic emission unit included the AE 109M unit which had the output of information into two recording devices of H306 type and the PC. Primary transformation of information was made by means of transducer made of pieso-ceramics of ЦТС-19 type. The transducer was placed on the waveguide which had a rigid contract with the stationary part of the friction pair. Transducer output signal was too week to be processed by electronic devices. The signal was amplified and selected from noise with the help of a preliminary amplifier. The frequency range of recorded AE signals was between 500 kcps- 1mcps.

Average amplitude, average power and average accumulated power were among processing AE signal parameters which were recorded. Time of averaging is equal to 0.2s. This time was taken because it was necessary to harmonize the AE device and the speed of its processing by the recording AE signals took some time which corresponded with the time of test, it was necessary for control of information output to apply in AE devices two levels of limitations: amplitude limitation and power limitation.

In case when AE parameter reached the limited level, for example, of accumulated power, automatic disconnection of an integrated chain took place. After this the process of power accumulation was repeated. As a result of this, the process of AE signal average power accumulation can be presented as saw-line curves with different angles of slope.

In the process of research the analysis of structural and chemical composition of MCL was carried out. It was performed with the help of raster electronic microscope-analyzer of CamScan-4DV at magnification x3500

Results of research

Results of carried out research have shown the following. In the process of contact interaction of friction pairs under the stress equal to 1000 MPa we can observe the transition of friction pairs into the stage of stable wear which is detected by the changes in recorded parameters (Fig.1). Fig. 1 demonstrates dependence of change of the moment of friction for the first (curve 1, Fig.1) and the second (curve 2, Fig 1) pairs of samples as well as the dependence of change of AE signals averaged power corresponding, curves 1' and 2' (Fig.1). Points A and A_1 in Fig.1 denote the moment of transmission from the mode of the secondary running-in into "quasiwearless" stable mode.

Points B and B_1 show the moment of the scratch appearing for the first pair of samples, which was recorded on the moment of friction and averaged power of AE signal (w). Points C and C_1 in Fig.1 indicate the moment of scratch appearing for the second pair of samples which was recorded at the moment of friction (M_{fr}) and AE signal averaged power (W).

The mode of stable wearing is characterized by the stable meaning of M_{fr} for all tested pairs of samples when $M_{fr} \approx 4.6$ Nm (point A_1 Fig.1) At the moment of samples transition to "quasiwearless" mode of work the oil was sucked out of the bath. Then, the work of friction pairs was going on up to a scratch appearing.

The obtained results show that the duration of "quasiwearless" mode of friction up to the time of a scratch appearing was different for all friction pairs under investigation. For the first pair of samples this time period which was determined at moment of friction was equal approximately to ≈ 18 min (point B, fig.1) while for the second pair of friction was equal to 6 hours (point C, fig. 1).

For the second pair of samples duration of "quasiwearless" mode was equal to the duration of the friction pair work with MCL which was applied at the time of the experiment. At the same time, the determination of the moment of a scratch appearing for the tested pairs of samples was performed by means of AE signals and was equal to 14 min (point B, Fig.1) and 5.9 hours (point C, Fig1) correspondently.

The obtained results have also shown that the second and third pairs of samples have the same time of running-in, it is different from that of the first pair of samples , which was achieved not due to the change of the pair of friction but due to the change of the AE signal averaged power. For the first pair of samples it was equal to $W=14.2x10^{-8}$ B (pint F, fig.1) while for the second and the third pairs of samples it was approximately equal to $W=5.8x10^{-8}$ B (pont D, fig.1).

The higher value of AE averaged power for the first pair of samples demonstrated higher intensity of wearing which corresponded well to the results given in [6]. It is worth to note that the moment of time of a scratch appearing is recorded by 15-20% earlier on the basis of AE signals than by the moment of friction method.

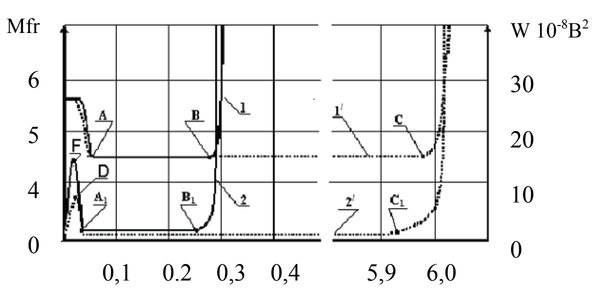
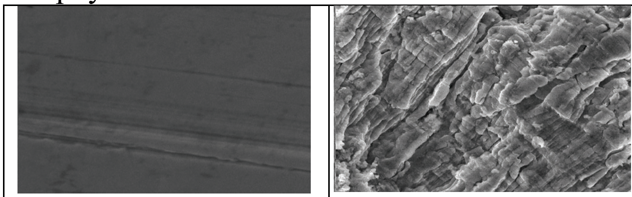


Fig1 Time changes of the friction moment M_{fr} (1, 1') and AE averaged power W (2, 2'): 1, 2 – a sample with 30 day delay; 1', 2' - a sample with 10 day delay; *AA' – transition moment into quasiwearless mode of friction; B_1B' – a scratch appearing moment of time.*

The AE signal power was essentially averaged and this fact was recorded. The shorter duration of a "quasiwearless" mode of operation, shorter period to the fixing of the moment of a scratch appearing proved the low MCL stability with a 30 day delay. This was possibly connected with the relaxation of internal stress in the MCL boundary layer which impacted on its physico-mechanical characteristics.



a b

Fig 2. Fractography of MCL surface: a - sample with 10 day delay; b - sample with 30 day delay.

Metallographic investigation of the MCL boundary layer after its development demonstrated a smooth structure (Fig.2, a). It looked like glass which is reinforced with debris due to the wear process, the corundum Al_2O_3 being the main part of them (Table 1). At the same time after a 30 day delay the surface structure was changed. It had a complicated crest-like form (Fig.2b). The sample surface was characterized with a specific direction of macroplastic shift which coincided with the replacement of the friction pair moving part. At the same time different size microcracks appeared on the sample surface. Chemical analysis of a tested MCL surface layer demonstrated changes in its composition. The Al was the main element observed on the sample layer (Table 1). The changes which were registered on MCL surface were probably connected with destruction of its boundary layer (glass) which could be reasoned by internal stress relaxation with taking into account concentrators in the form of wearness product which could be found in surface layer.

Table 1

MCL Chemical composition			
10-day delay sample		30-day delay sample	
Element	%	Element	%
Si	82,747	Al	95,747
Al	9,943	Si	2,943
Fe	2,548	Fe	0,548
Cu	1,762	Cu	0,762
Total 100%		Total 100%	

It is true, that the friction process was accompanied by high mechanical twisting scratching stresses, compression and continuous bending which was resulted in high temperatures. The latter as it wasshown in [12] had non-uniform distribution in the thickness of a material boundary layer. That is why in the process of cooling the internal left stress [13] could be found.

Their relaxation in time together with the concentrators of stresses in the form of wear particles could tend to the cracking of MCL surface layer (glass) and the following breakage. Besides, relaxation of stress was the reason of microcracks if the MCL surface layer is more plastic when the main component of it is Al. This could be well observed on the surface of friction pair (Fig. 2,b).

If a good adhesive catching of an intermediate layer was observed, Al was the main element in the composition of friction pair material. In this case the development of microcracks in the intermediate layer could result in a scratch or microcracks development in the basic material. Such kind of MCL sample surface layer structure damage could lead to the fact that in case of repetitive friction under conditions of large loading the scratch appeared much earlier than in samples where structure was not damaged. The scratch registration was performed according to the results of the friction moment as well as the averaged AE signal power (Fig.2) recording. But if we use AE the recording of the scratch could be done much earlier.

Conclusion

Results of the carried out research have shown that in case of a long idle time of friction pairs covered with MCL their operational properties are changed i.e. their resistance to the stretch appearing becomes less. It is connected with the fact that in case of a long idle time of friction pairs the destruction of their MCL surface layer (glass) is observed and it is possible to find microcracks in the subsurface plastic layer. Such changes of a surface layer can be as a result of relaxation of remaining internal stress of "basic material – MCL" system which can appears due to high ambient air temperatures. The analysis of relations of friction moment and the averaged AE power signals have shown that the AE method is much more sensitive to intensity of friction pairs wearing. The generation and development of a scratch is registered much earlier by AE method than by a friction moment determination. This allows using of the AE information for inspection and diagnostics of complicated tribological systems directly in the process of their operation.

References

1. *Аратский П.Б., Капсаров А.Г.* Применение геомодификаторов трения для увеличения ресурса работы металлообрабатывающего инструмента.— лектронный журнал «Трение, износ, смазка», 2001, т. 3, №1.

2. *Половинкин В.Н., Лянной В.Б., Аратский П.Б.* Применение геомодификаторов трения для восстановления изношенных поверхностей узлов трения при эксплуатации.—Электронный журнал «Трение, износ, мазка», 2000, т. 2, №2.

3. Babak V.P., Stadnichenko V.V. "Application of revitalisants for extension of resource and restoring of worn-out friction units of aviation axial-piston hydromachines". Aviation, Vol. VIII, #1, p.8-12 (Vilnius, Lithuania).

4. *Максимов Н.А., В.А. Секистов.* Двигатели самолётов и вертолётов. Основы устройства и лётной эксплуатации. М., Воениздат, 1977г. – 343с.

5. *Свиридёнок А.И., Калмыкова Т.Ф., Холодилов О.В.* Исследование фактической площади фрикционного контакта полимер-металл с помощью акустических колебаний //Трение и износ, 1980, т.1, № 5, с.898-907.

6. *Свиридёнок А.И., Мышкин Н.К.* /Под редакцией Белого В.А./ Акустические и электрические методы в триботехнике. - Мн.: Наука и техника, 1987. - 280 с.

7. *Стадниченко В.М., Стадниченко М.Г. Джус Р.М., Чотій Л.Ю.* Вибір інформативних параметрів АЕ для структурної побудови автоматизованої системи контролю процесів зношування. // Вопросы проектирования и производства ЛА: Сб. науч. тр. Нац. аэрокосмич. ун-та им. Н.Е. Жуковского "ХАИ". Вып. 34(3). – Харьков: НАКУ, 2003. – С. 96-103.

8. Бабак В.П., Стадниченко В.М., Філоненко С.Ф. „Дослідження пар тертя з трибовідновлювальними сумішами методом акустичної емісії", „Вісник НАУ" №3(21) 2004., стр. 3-8.

9. *Опис. изобр.* к пат. РФ: RU 2135638 C1, 6 C 23 C 26/00, C 10 M 125/00. Способ образования защитного покрытия, избирательно компенсирующего износ поверхностей трения и контакта деталей машин. Никитин И.В. 26.11.98. – 10 с.

10. *Справочник* по триботехнике. / Под общ. ред. Чичинадзе А.В.: В 3 т. – М.: Машиностроение, 1989.– Т. 1: Теоретические основы. – 400 с.

11. *Гаркунов Д.Н.* Триботехника. – 2-е изд., – М.: Машиностроение, 1989. – 328 с.

12. *Кащеев В.Н. Процеси в зоне фрикционного контакта металлов. – М.: Машиностроение, 1978. – 213 с.*

UDC 531.7

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INTELLECTUAL SYSTEM OF COMPLEX AIRCRAFT UNITS SURFACES MEASUREMENT

The structure of intellectual measuring system for measurement of complex spatial surfaces of the aviation units, including a laser hardware-software complex is developed. Measurement of a surface structure is made by triangulable method that allows to raise accuracy and speed of system.

Introduction. Modern aviation engines are complex technical objects which have incorporated new information technologies of science and engineering. Precision process of measurement at the stage of manufacturing of the aviation engine allows to carry out its effective operation on condition.

High complexity of aircraft units is connected with many parameters, a majority of forms and arrangements of surfaces. All this assumes necessity of new methods and techniques for the decision of problems of measurement and diagnostics inspection of parameters of aircraft units. The demand of accuracy limits for measured parameters of separate aircraft units is high enough. Integration of standard and intellectual quality monitoring of many metrological problems essentially raises efficiency of the control and quality of making decisions.

With development of new information technologies the urgency of creation of computer systems for realization of complex forms object geometrical parameters measurement in aviation industry [1, 2] grows.

Under these conditions application of the neural networks approach represents a perspective direction. On the basis of results of measurements of input and target parameters of intellectual measuring system the causal interrelations of the gauge of measurement and the object are established, and according to some analytical criteria which determine deviation of forms and surface position, measurements error and mean square deviation are defined.

The present stage of development of instrument manufacturing is characterized by essentially new approach to design of precision intellectual measuring systems objects dimentions. The concept of the new approach assumes that the intellectual measuring system should be designed as a unit. Necessity of such approach is dictated by two principal reasons: the first is an opportunity to realize at the present stage in manufacturing instrument development of the integration caused first of all by occurrence of new generation computers with high capacity and second is the struggle against destabilizing factors of a various nature [3, 4].

Intellectual systems should carry out measurements and process their results with recording system, three-dimensional visualization, documenting and keeping results of measurements in a database and their transfer to a computer network.

Problem definition. To develop intellectual system for the control of geometrical parameters of the complex form products, including gas turbine engines component. For the adequate statistical description of intellectual measuring system, it is necessary to develop such procedure which would allow to define its random errors taking into account a real spectrum of external interferences.

Problem solving. Methods of structural, algorithmic or functional designs which are widely used in instrument making allow to receive models adequate to all attributes of well organized systems. However, the methods of design based on algorithmic decomposition have no mechanisms which would reflect generality of behaviour and structures of selected abstraction.

Accuracy of objects dimensions measurement with the help of intellectual measuring system is limited by continuously existing random interferences the character of which essentially depends on conditions of measurement system operation and its location. For intellectual measuring system built - in flexible industrial systems vibrations and noise act as main sources of interference. External cases, causing fluctuations of a sensitive element of measuring system, form random errors which value can be determined by the statistical description of a deviation from the geometrical sizes of object as dynamic system.

Random interference spectra in both industrial and laboratory measuring systems frequently differ from spectrum of white noise, remaining at the same time Gausses random process. Besides the specified statistical description should allow to find analytical expressions for dispersion of random fluctuations of a system sensitive element, which takes into account real kind of a spectrum of external interferences, that, in it is turn, provides an opportunity to realizy optimization of parameters of the initial transformations with the purpose of random errors of level reducton.

In the process of sophisticated intellectual measurement devices design the system analysis of problems settled by this system is carried out together with the decomposition of these problems in accordance with some features and the generalization of functional components into different multilevel complex problems on the basis of systematization, unification, establishment of rational connections, application of modular-hierarchical methodology.

At the system problem analysis of the target problems, which are main of content during mechanical measurements of objects with complicated spatial surfaces are determined.

On the basis of the analysis of functional problems of intellectual measuring system and use of the object-oriented approach the object-oriented structure which is submitted in Fig.1 is developed.

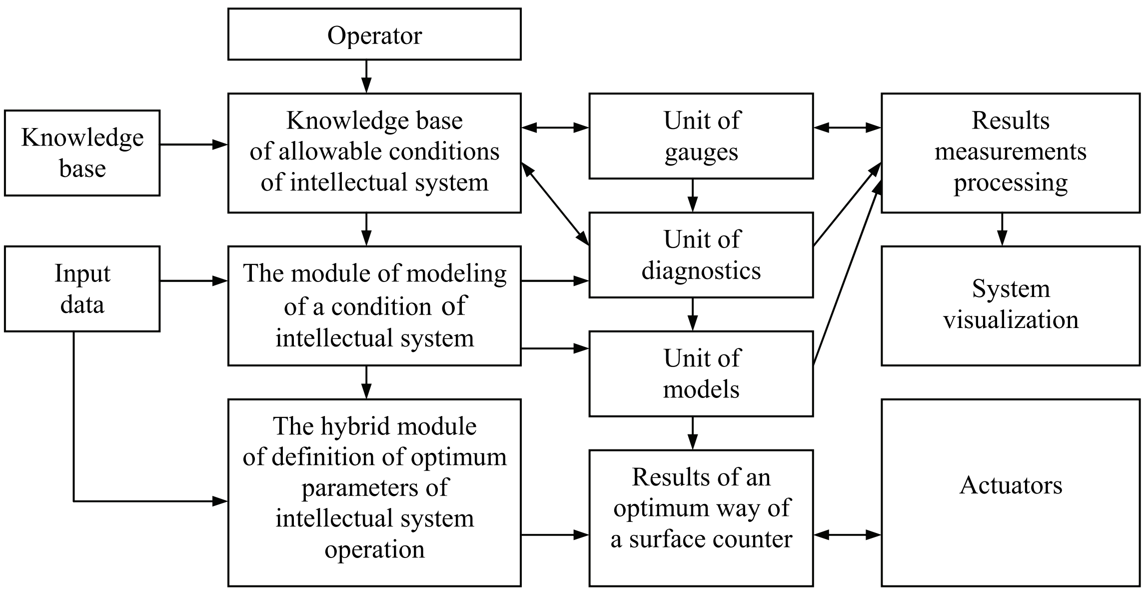

Fig. 1. Structure of intellectual measuring system of aircraft elements

Intellectual system includes a laser hardware-software complex for measurements of aircraft units dimensions and industrial equipment.

The given system consists of optoelectronic measuring sensor, the electronic unit, the laser scanning optic-mechanical system, a special software for the control of geometry of the complex form of products. The special software allows in real time carry out processing, displaying, recording of measurements results and their visualization.

Scanning box incorporates coordinate and rotary tables controlled from the computer. Optoelectronic sensors principle of action is based on application of shadow, triangulable and other methods of measurements with use of semi-conductor scanning photodetectors [4, 5]. The electronic unit of the device provides development of a target signal of an integrated multielement photodetector and the appropriate processing of video signal for allocation of the information on a projection of images in a required dynamic range of intensity variations.

High speed of measurements provides an opportunity of realization of practically continuous measurements even at simultaneous movement of optoelectronic sensor and a controllable product.

One of the important kind of measurements results processing is an actual three-dimensional surface recombination on the measured data. For this purpose the splaine approximation method is used according to which the triangles connecting nearest points of a surface (top of triangles) are constructed. Then, splaine approximation is achieved by simplex method [6, 7]. The splaine-function which is used is defined by the formula

$$f(Q)=\sum_{i=1}^{N} a_i m_i(Q)+\sum_{j=1}^{M} b_j n_j(Q), \qquad (1)$$

where Q - an approximated point; a_i, b_j – splaine approximation factors; $m_i(Q)$ – the square-law polynom connected to a vertex of angle of an elementary triangle approximating a three-dimensional surface; $n_j(Q)$ – the square-law polynom connected to an average point of an edge of approximating triangle; i – number of top of a simplex; N - quantity of tops of approximating triangles; j - number of a simplex edge; M - quantity of edges of approximating triangles.

The controllable surface of products can have various color, roughness and a wide range of corners of an inclination concerning a beam of the laser of the measuring head.

The error of the control of geometry of products is defined by a range of measurements and depends on roughness and corners of an inclination of surface points. For reduction of an error (constructive and electronic) both program methods and measurements, including computer calibrations are applied. All this allows to receive an error of measurements of metal products with roughness R_a from 3.0 up to 0.32 within the limits of 1-2 microns.

At measurements of a surface structure by a triangulable method the error reaches 5 microns, and at measurements of a contour and edges of products a shadow way makes 2-3 microns.

The given systems allow to measure and optimize the form and radii of input and target edges of products, displacement or turns of structures and to present these values in text and graphic forms.

The intellectual system allows to carry out the control of width and position of a shadow from an element in the given section. Scanning is performed by means of laser sensor of the optical-mechanical unit replacement relative to measured products and turn of the laser head with two laser sensors with fixed corners.

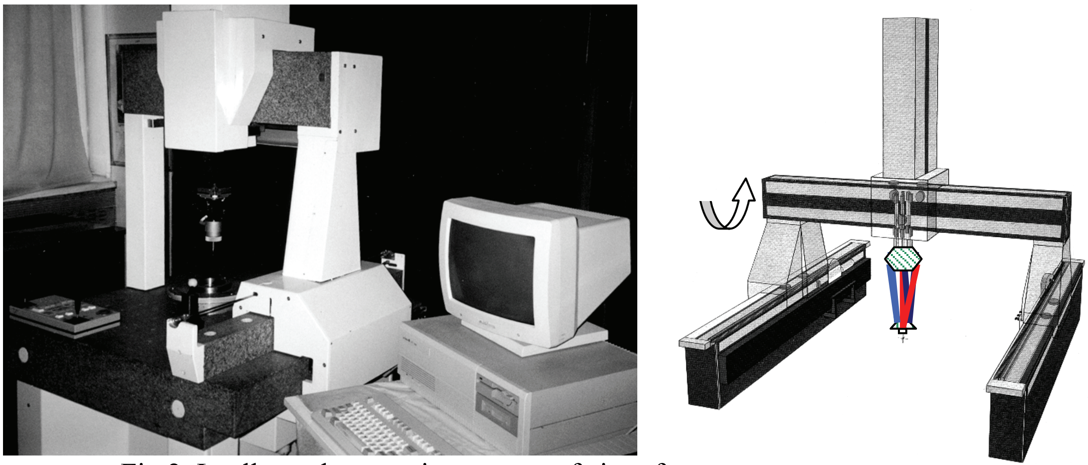

Fig.2. Intellectual measuring system of aircraft units of complex form

The basic problems of measurement results processing connecting to complex spatial surfaces consist of the following:

First, it is exact installation of a model on a rotary table of intellectual measuring system. The model fixing is limited by the accuracy of manufacturing and location of these bases relativity to bases of a controllable surface, and also by accuracy of their shighting during measurements.

Second, direct measurements of coordinates of controllable points of an object surface can be established only indirectly on the basis of many measurements in their vicinity.

Thirdly, at application of sensors with the inductive transdusers, the final geometry tracer, touching measured surfaces allows to estimate coordinates only indirectly. The coordinates of the bottom point of the tracer gauge or its centre are authentically fixed.

The number of measuring points N is determined on a surface of an aircraft unit. Their location depends on the concrete form of a model and is defined depending on accuracy of measurement.

In case of one-dimension space p=1,in the process of p=1, in the process of optimization we minimize the total volume p of training and control samples which are necessary for the detection of the object and obtaining of the predetermined level of measurement truthfulness at the probability level of errors α and β and their upper limits $б_0$ and $в_0$. The normalized difference between average values of the aggregate $(a_2 - a_1)/\sigma$ should be not less of this difference in the real system.

In table №1, you can see the value of capacity of points of measurements of the training m and control n samples for achievement of required truthfulness of measurement , which minimize the criterion of the summary capacity of the selection

$$\rho = 2m + n \to \min$$

Table 1

Values of optimum volumes of m and n sampling

$1-\alpha_0$	$a_e = 0.1$		$a_e = 0.05$		$a_e = 0,01$	
$1-\beta_0$	m	n	m	n	m	n
0,9	42	61	130	269	440	610
0,99	130	182	410	658	1320	1850

When an object and its mathematical model coincide, the beginning of systems of coordinates of object O and models O^1 are shifted along vector P. Besides, system O^1 is turned on axes OX, OY, OZ systems of O by α, β, and γ corners.

It is required to find transformation R, which would transfer system O^1 into system O in such a way that the sum of squares of distances from the transformed measured points $c^i = R(b_i)$ up to the points of appropriate mathematical model them can be minimal

$$\sum_{i=1}^{N}\left[\left(a_x^i - c_x^i\right)^2 + \left(a_y^i - c_y^i\right)^2 + \left(a_z^i - c_z^i\right)^2\right] = \min . \qquad (2)$$

Transformation for the measured point b_i in the coordinate form looks as follows:

$$C = \begin{bmatrix} c_x \\ c_y \\ c_z \end{bmatrix} = \begin{bmatrix} P_x + b_x - b_y \text{г} + b_z \text{в} \\ P_y + b_x \text{г} + b_y + b_z \text{б} \\ P_z - b_x \text{в} + b_y \text{б} + b_z \end{bmatrix}.$$

Having substituted values c_x, c_y and c_z in the expression for the sum of squares of distances (2), we receive expression for Lagrang function.

$$J = \sum_{i=1}^{N}\left(a_x^i - b_x^i - P_x + b_y^i \text{г} - b_z^i \text{в}\right)^2 + \sum_{i=1}^{N}\left(a_y^i - b_y^i - P_y + b_z^i \text{б} - b_x^i \text{г}\right)^2$$
$$+ \sum_{i=1}^{N}\left(a_z^i - b_z^i - P_z - b_y^i \text{б} + b_x^i \text{в}\right)^2 .$$

If we make expressions for partial derivatives equal to zero and having grouped similar members, we receive system of the linear equations

Having realised system of the equations (3), we receive required values P_x, P_y, P_z,, α, β and γ, for R transformation.

The certain values of linear and angular displacement (P_x, P_y, P_z, α, β and γ) give the initial information for the operator - metrologist of intellectual measuring system with the purpose of updating system of coordinates of measuring unit.

$$\begin{bmatrix} d_{11} & . & . & . & d_{16} \\ . & . & & & . \\ . & & . & & . \\ . & & & . & . \\ d_{61} & . & . & . & d_{66} \end{bmatrix} \times \begin{bmatrix} P_x \\ P_y \\ P_z \\ \text{б} \\ \text{в} \\ \text{г} \end{bmatrix} = \begin{bmatrix} h_1 \\ . \\ . \\ . \\ h_6 \end{bmatrix}. \qquad (3)$$

Conclusions. The developed structure of intellectual measuring system of aircraft units allows to raise accuracy, reliability, speed of realization of measurements in real time. The intellectual system enables to automate scientific researches and the experiments connected with a form of a unit surface, with processing of results of measurements and visualization.

Key words: Intellectual measuring system, measurement of aircraft units, optoelectronic sensors.

References

1. *Бабак В.П., Білецький А.Я.* Детерміновані сигнали і спектри. – К.: Техніка, 2003. – 456 с.
2. *Бабак В.П., Хадецький В.С., Шрюфер Е.* Обробка сигналів. – К.: Либідь, 1999. – 496 с.
3. *Битюцкий О. И., Вертопрахов В. В., Гущина А. А. и др.* Трехмерный бесконтактный контроль геометрических параметров дистанционирующих решеток ядерных реакторов // Автометрия.2003.39, № 5. С.4.
4. *Гостелоу Дж.* Аэродинамика решеток турбомашин: Пер. с англ. М.: Мир, 1987.
5. *Cardew-Hall M., Cosmas J., Ristic M*. Automated proof inspection of turbine blades The Intern, Journ. of Advanced Manufacturing Technology. 1988. 3, N 2, P. 67.
6. *Galiulin R. M*. Optoelectronic computer-aided measuring "OPTEL" systems //Proc. SPIE. 2002. 4900.P. 486.
7. *Galiulin Rav. M., Galiulin Rish. M., Bakirov J. M*. et al. Mobile "OPTEL-CW system for Optoelectronic measurements of contact wire (CW) parameters in railways // Proc. SPIE. 2002.4900.P. 935.

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IDENTIFICATION OF DYNAMIC OBJECTS PARAMETERS IN THE TECHNICAL DIAGNOSTICS SYSTEMS

The objective of a given paper is to analyze the test-signal method of identification in technical diagnostic systems, described by ordinary differential equations with unknown coefficients. Developed method allows, after solving the system of equations, obtain unknown parameters with any given accuracy. Results will be useful in elaboration of dynamic objects parameters identification in the systems of technical diagnostics and in control of dynamic systems, including flying objects.

Quality of operation and safety of modern technical systems, in particular of aircraft, determine additional requirements to effectiveness and reliability of technical systems diagnostic parameters. The diagnostic is one of main methods for determination technical systems reliability, which allows to define parameters of object with required accuracy [1].

The system identification problem is to estimate a model of a system based on observed input-output data. Several ways to describe a system and to estimate such descriptions exist. This paper gives a brief account of important approaches. The identification process amounts to repeatedly selecting a model structure, computing the best model in the structure, and evaluating this model properties to see if they are satisfactory.

Special attention to problems of experimental determination (identification) of control systems dynamic models is recently given. The problem of development and research of dynamic objects model with the aim of determination of this object parameters on the basis of experimentally obtained input-output data is quite principal [2].

In engineering and mathematics, a dynamic system is described as a deterministic process in which functions value changes in time according to a rule that is defined in terms of the functions current value. A dynamic system is called discrete if time is measured in discrete steps; these are modelled as recursive relations, where t denotes the discrete time steps and x is the variable that changes in time. If time is measured continuously, the resulting continuous dynamic systems are expressed by ordinary differential equations.

For linear continuous systems, the Laplace transformation method can also be used to write the differential equation in the algebraic form.

Traditionally, the formal modelling of systems can be done in mathematical form. This process allows to find analytical solutions to problems which enable to predict the system behaviour on the bases of a set of parameters and initial conditions. Computer simulations are useful addition to purely mathematical models in science and technology.

Computer models can be classified according to several criteria including:

- stochastic or deterministic (and as a special case of deterministic, chaotic);
- continuous or discrete (an important special case of discrete models, discrete event models);
- local or distributed (simulations).

Stochastic models use random number generators to model of random events; they are also called Monte Carlo simulations.

A discrete event simulation manages events in time. Most computer, logic-test and fault-tree simulations are of this type. In this type of simulation, the simulator maintains a queue of events sorted by the simulated time they should occur. The simulator reads the queue and triggers new events as each event is processed. It is not important to execute the simulation in real time. It is often more important to be able to access the data produced by the simulation, to discover logic defects in the design, or the sequence of events.

A continuous simulation is based on differential equations (either partial or ordinary), and on numerical methods. The system of modelling allows dynamically adjust the state of system depending on input signal value change.

Mathematical models describe relationships between measured signals. The output signals are then partly determined by the input signals. In case of an airplane where the inputs would be the different control surfaces, ailerons, elevators, and the like, while the outputs would be the airplane orientation and position.

In the theory of automatic systems [3] identification is the process of determination of partial or ordinary differential equation which describes physical phenomena in accordance with predetermined criterium. The known analytical methods of identification in technical systems of diagnostics are based on transient analysis, frequency and static characteristics of input and output signals.

The research of analytical identification methods in technical diagnostic systems is of large practical interest.

Let us consider diagnostic model parameters of a dynamic object as n-order differential equation on the basis of analytical methods of identification.

The process of dynamic objects parameters diagnostics offers the method of the test-signal [4]. The signals as pulses of the specific shape acted on an input of a technical system. The response of a system under research is diagnosed with the help of monitoring measurements and the output signal representing a response of the system (Fig.1) is fixed. The kind and the order of a linear differential equation is defined as a result of an identification process on the basis of information after measurement.

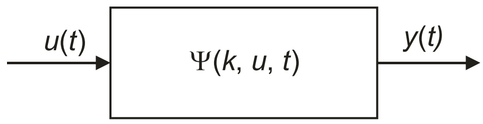

Fig.1. Model of an object identification

If the proposed order of a differential equation is as result of solution of a system of algebraic equations one or several coefficients of a left-hand part will be equal to zero [3]. At underestimation of the order the equation system has no solution.

If the test - signal $u(t)$ is submitted to an input of a diagnostics system (Fig.1) we can measure and fix values of output $y(t)$ and it derivatives at the given time during predetermined interval

Let us consider process of object parameters diagnostics on the basis of identification model of dynamic object as a second-order differential equation.

$$k_2 \frac{d^2\ y(t)}{dt^2} + k_1 \frac{d\ y(t)}{dt} + k_0\ y(t) = k\ u(t)\,,$$

where $y(t)$ - the value of output signal, which is measured, $u(t)$ – initial input signal (test - signal), k_i $(i = 0, 1, 2)$ – system parameters.

Input signal $u(t)$ is a rectangular pulse (Fig.2), which is described by the following function:

$$u(t)=\begin{cases}1, \text{ if } 0<t\le t_0\\ 0, \text{ if } t_0<t<\infty\end{cases}.$$

The decision of the differential equations with the right part in the form of a rectangular pulse is connected with the problems in computation and the difficulty of formal presentation.

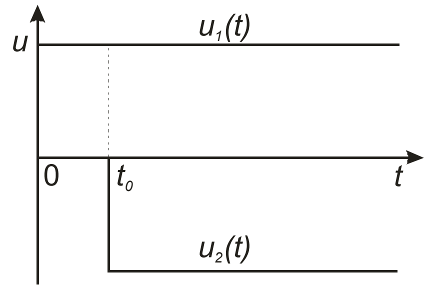

Fig.2. Input pulse

In order to find the required function we shall present function *u(t)* as the sum of a step function $u(t)=u_1(t)+u_2(t)$,

where

$$u_1(t)=\begin{cases}1, \text{ if } 0<t\le t_0\\ 0, \text{ if } t>t_0\end{cases},$$

$$u_2(t)=\begin{cases}1, \text{ if } t>t_0\\ 0, \text{ if } 0<t\le t_0\end{cases}.$$

Let input signal $u(t)$ is the test-signal in the form of rectangular pulse on the time interval $t-t_0$. The output signal $y(t)$ is characterized by the following parameters: initial value of a measured signal - $y_0(t_0)$, speed of a signal change - $y'(t_0)$ and derivative of a signal - $y''(t_0)$.

For parametric synthesis of a dynamic system we shall generate a system of algebraic equations in the matrix form:

$$\begin{bmatrix} y''(t_1) & y'(t_1) & y(t_1) \\ y''(t_2) & y'(t_2) & y(t_2) \\ y''(t_3) & y'(t_3) & y(t_3) \end{bmatrix}\cdot\begin{bmatrix} k_0 \\ k_1 \\ k_2 \end{bmatrix}=\begin{bmatrix} u(t_1) \\ u(t_2) \\ u(t_3) \end{bmatrix}.$$

For calculation of system parameters we have to fix values of a function $y(t)$ and its derivatives in boundary points of subprocesses. Solving a system of equations, we find value of vector $[k_0,\ k_1,\ k_2]$, and disign mathematical model of a dynamic object as a differential equation, that allows to organize control and to predict behaviour of an output signal.

Let us assume, that the object or dynamic system as a whole is described by the linear differential equations with the identified coefficients. k_i (i = 0,1 ...n) and the form of measured signal corresponds to non periodical process.

Let us consider the time interval $0 < t \le t_0$ with initial conditions for the time $t = 0$:

$$y(0) = 0, \qquad y'(0) = v.$$

After that we can find roots of the characteristic equation:

$$p_{1,2} = \frac{-k_1 \pm \sqrt{k_1^{\,2} - 4k_0 k_2}}{2k_1}.$$

In the given scientific work we apply the theory of Lyapunov's , namely, 2-nd Lyapunov's theorem. The necessary and complete condition of dynamic system stability is positive determined function. In the case if all values of function variable are greater than zero (except one point, where all variables are equal to zero), and its first derivative with respect to time and in accordance to the system is less than zero we can state that such system of equations will be stable.

The output measured signal is given as:

$$y_1(t) = \frac{k}{k_2 p_1 p_2} + \frac{k + k_2 p_1 v}{k_2 p_1 (p_1 - p_2)} e^{p_1 t} + \frac{k + k_2 p_2 v}{k_2 p_2 (p_2 - p_1)} e^{p_2 t}.$$

In a case when the initial value of an output signal is not equal to zero $y\ (0) = y_0$, function $y_1(t)$ looks like:

$$y_1(t) = \frac{k}{k_2 p_1 p_2} + \frac{k + k_2 p_1 (v + y_0 p_1) + y_0 p_1 k_1}{k_2 p_1 (p_1 - p_2)} e^{p_1 t} + \frac{k + k_2 p_2 (v + y_0 p_2) + y_0 p_2 k_1}{k_2 p_2 (p_2 - p_1)} e^{p_2 t}.$$

The resulted analytical conclusions allow to present model in the following way (Fig.3):

$$y(t) = y_1(t) + y_2(t),$$

where $y_2(t)$ - the output signal after the test-signal action stops.

For interval $t_0 < t < t_1$ with initial condition: $y(0) = y_0,\ y'(0) = 0$:

$$y_2(t) = \frac{-k}{k_2 p_1 p_2} + \frac{-k + y_0 p_1 (k_1 + k_2)}{k_2 p_1 (p_1 - p_2)} e^{p_1 (t - t_0)} + \frac{-k + y_0 p_2 (k_1 + k_2)}{k_2 p_2 (p_2 - p_1)} e^{p_2 (t - t_0)}.$$

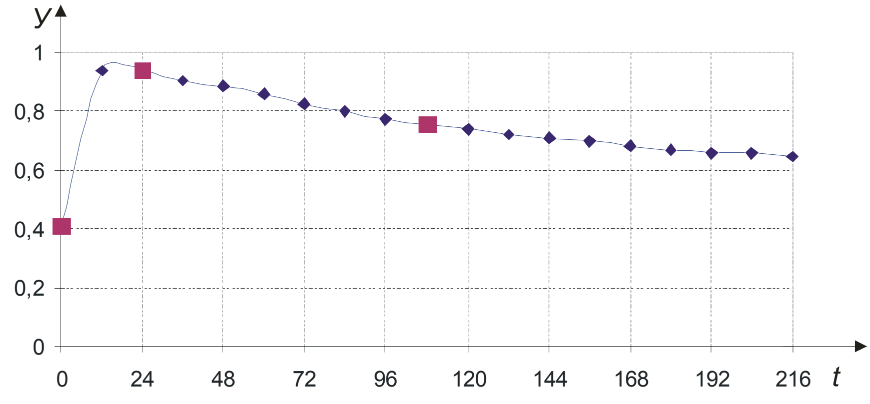

Fig.3. Measured and calculated $y(t)$ signals

Conclusion

Developed method allows, after solving the system of differential equations, to find unknown parameters with any given accuracy. Results will be useful in elaboration of dynamic objects parameters identification in the systems of technical diagnostics and in control of dynamic systems, including flying objects.

References:

1.ДСТУ 2389-94. Технічне діагностування та контроль технічного стану. Терміни та визначення. – Чинний від 01.01.95. – К.: Держстандарт України. – 1994. – 24 с.

2.*Бабак В.П., Хандецкий В.С., Шрюфер Е.* Обробка сигналів – К.: Либидь. – 1996. – 389 с.

3.Цыпкин Я.З. Основы информационной теории идентификации.– М.: Наука. – 1984. – 320с.

4.*Шибицкая Н.Н.* Метод идентификации объектов в эргатической системе управления процессом обучения // Кибернетика и вычислительная техника. Вып. № 121 – К.:–1999. – С.52-58.

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INTELLECTUAL SYSTEM OF DIAGNOSTIC PARAMETERS DETERMINATION OF COORDINATE MEASURING MACHINES

The structural system of diagnostic parameters determination of co-ordinate measuring machine is developed in the given work , that allows to promote exactness, authenticity, fast-acting of measuring conducting in the real time Obtained results will be useful in elaboration of dynamic objects parameters identification in the systems of technical diagnostics and in control of dynamic systems, including flying objects.

Introduction. The modern state of technical equipment, computer and information technologies have created preconditions of transition to full intellectualization of process of objects measurement. Rapid development of information technologies has provided an opportunity of creation of essentially new direction in metrological maintenance of manufacture - intellectual coordinate -measuring machines (CMM) [1, 2].

The major problems of modern metrology are development of methods and new intellectual means of measurement with high accuracy and speed. The decision of this complex problem demands development of principles of maintenance of precision measurement, speed, expansion of their adaptable opportunities and intellectualization of processes of processing of the information in continuously changing conditions, and also methods of definition of diagnostic parameters of coordinate -measuring machines. Feature of measuring robots and coordinate -measuring machines consists that they are used not only in laboratory, but also in real conditions with various revolting factors of an environment. On this way the problem of the intellectual management CMM, described following feature-development of new methods and means of measurement with high accuracy and speed in view of various revolting factors of an environment is central [3, 4].

Technical diagnostics provides search of defects at an operation phase, and also definition of diagnostic parameters on a design stage with a view of maintenance of a product reliability.

Problem definition. To develop intellectual system of definition of diagnostic parameters of coordinate -measuring machines and variety of the account of diagnostic elements. In structure of this system steady attitudes on set of elements of system which allow to make the analysis of diagnostic parameters are set and to spread out in an equivalent number of the interconnected parameters.

Problem solving. It is necessary to consider as the diagnostic block such part in which defects are possible. We shall define diagnostic block CMM as accessible to the control and repair a functional part of object of functioning.

First of all we allocate problems of a special-purpose designation at the system analysis of problems which are the basic maintenance at mechanical measurements of objects with complex spatial surfaces.

The variety of potential diagnostic blocks is materialized in a subset of real diagnostic blocks by the task from the outside depths of search which, on the one hand, is the structural characteristic of object of diagnosing, and with another, it characterizes accepted for the given object of diagnosing system of maintenance of reliability.

Data of object of diagnosing includes the basic functional block, attitudes which subdivide into two aspects. The first are such attitudes which define purpose of each part in relation to other parts. Thus, any part of object of diagnosing is in functional attitudes with one or several other parts. The second are attitudes on set of functional diagnostic blocks, and they define sequence of transfer of the information, substance, energy in functional processes. Malfunction of functional diagnostic blocks with necessity attracts malfunction of object of diagnosing. The following criterion of classification of diagnostic blocks is a technological opportunity of realization of assembly operations [4, 5].

Each diagnostic block by definition has nonempty set of possible defects. Physical display of elements of this set defines transition of the given diagnostic block from area serviceable in area faulty. Malfunction of one or several diagnostic blocks causes malfunction of object of diagnosing as a whole. If the degree of malfunction of diagnosing object in a present situation is recognized inadmissible the decision on its restoration can be accepted.

Physically diagnostic experiment represents the certain sequence of diagnostic checks. This sequence can be ordered (conditional) or disorder (combinational). The result of each check generally, establishes the fact of serviceability or malfunction of a nonempty subset of the diagnostic block. If this one element subset check we shall name a straight line, otherwise - indirect. Direct check can fix the fact of serviceability of the unique diagnostic block and is its{his} essential diagnostic characteristic in the sense that logic complexity of the given check is determined by complexity of the corresponding diagnostic block.

Structural complexity of the auxiliary diagnostic block (ADB) is defined only R_{rs} and can be quantitatively estimated by capacity, that is number of pairs, formed by taking for pieces assembly operations of data ADB. Clearly, that for not folding ADB $|R_{rs}| = 0$ the parameter $|R_{rs}|$ sets the attitude of the partial order on the functional diagnostic devices (FDD) set in which not folding ADB takes of the first position. Structural complexity is a complexity of internal character [5–7].

Except for internal complexity, functional diagnostic device (FDD) in addition possesses external complexity. Conditionally external complexity we shall spread out on two components - logic and alarm. Logic complexity is defined by three level hierarchy presented on fig. 2. Alarm complexity we shall characterize a parity of a continuity and step-type behavior of signals on entrance and target channels FDD.

The quantitative estimation of logic complexity is defined by a three (N, M, q), where N, M - are the number of entrance and target channels accordingly; q - is a number of inwardnesses. Alarm complexity, basically, is quantitatively characterized by pairs $(n_i, m_i)$where n_i - is a capacity of set of pieces of splitting of a signal (admissions) on *i*-th entrance channel, m_i - it is similar, on i-th target channel.

Let's enter restrictions on a class of investigated technical objects. Such objects are characterized by presence in them of one or several functional processes (processes of transfer or transformation of the information, energy or substance).

The problem of construction of trajectories of movements of the robot, including mobile or the manipulator, till now has no standard decision. Common fault of existing global or local approaches is the contradiction between reception of the satisfactory decision of a problem and speed.

The new approach consisting overlapping of local both global methods and based on components is offered in article:

- initial procedure of construction of a suboptimum trajectory on time in space of the generalized coordinates, in view of cinematic and dynamic restrictions, but without taking into account obstacles in a working zone;

- the compact description of obstacles in the form of hierarchical system of areas of the simple form and definition of the fact of crossing of the robot with obstacles during movement;
- tables of known correct (not crossed with obstacles) trajectories, before constructed by system at the fixed set of obstacles;
- a method of a choice of an intermediate point in case of crossing an initial trajectory with an obstacle and absence of a trajectory in the table of correct trajectories;
- the expert system used at a stage of decision-making in case of presence of collisions.

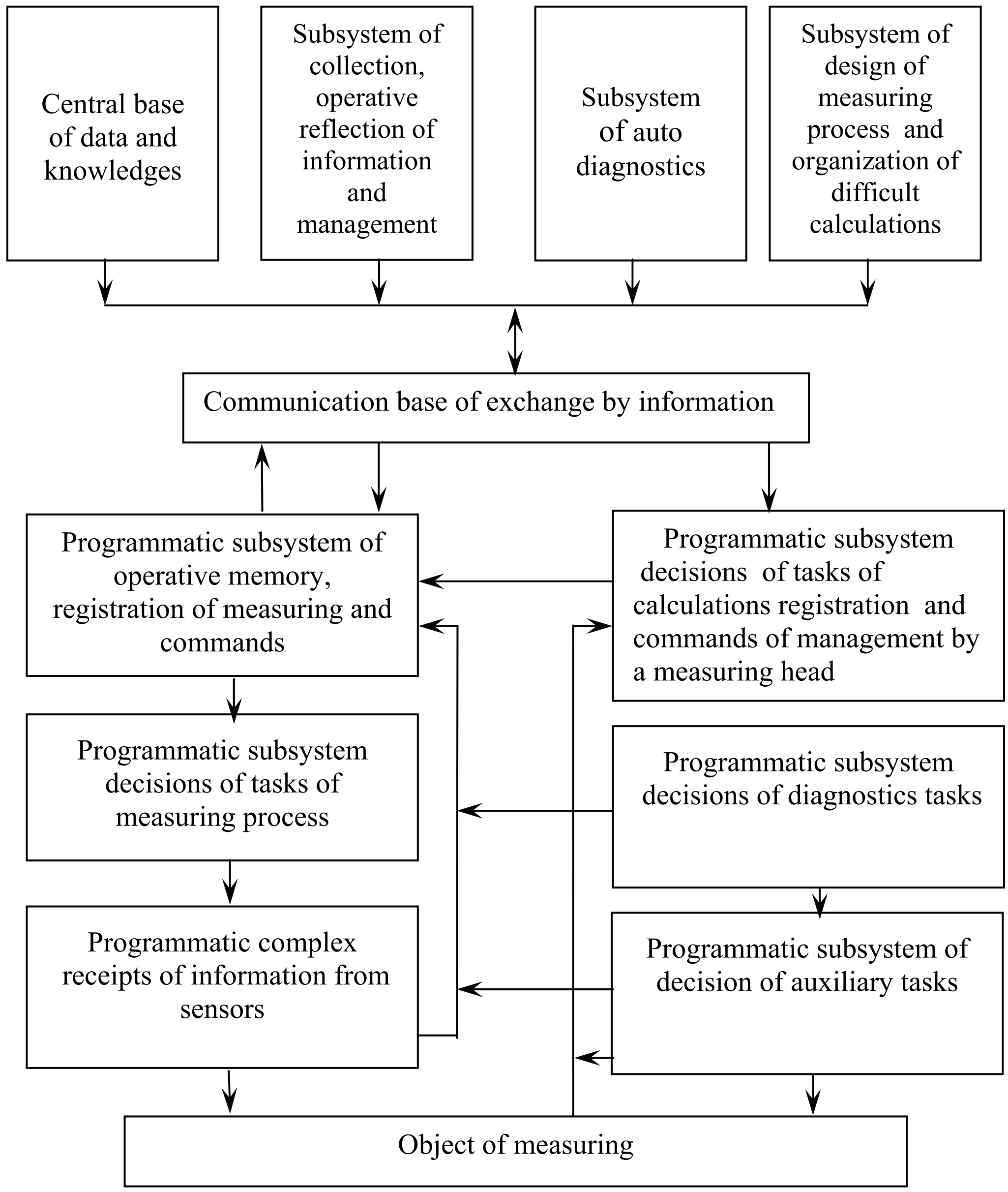

Fig. 1. Block diagram of CMM with the block of self-diagnostics

Initially the program trajectory in space of the generalized coordinates Q^n, where n – is a number of coordinates, according to the procedure using parameterization of a long arch in this Riemannian space is under construction suboptimum on time, in view of dynamic restrictions. As natural criterion of an optimality of a geometrical curve (without taking into account parameterization in time) the minimum of length of trajectories in Riemannian space Q^n, of the generalized coordinates gets out

$$J = \min \int_{s_0}^{s_T} \left(\frac{dq}{ds} \right)^2 ds.$$

First of all we shall describe obstacles in the form of areas $\overset{€}{G}_i \in W \subset R^m, i = 1, ..., n_W$, in robot technical zone W (also areas) of Eucledean spaces $R^m, m = 2, 3$, for a flat or spatial problem accordingly. Similarly we shall describe the robot $G_i = G_i(q) \in W \subset R^m, i = 1, ..., n_{R1}$, allocating in it design the separate elements G_i considered as absolutely firm body (for example, the basis of the mobile robot or parts of the manipulator). Then the prohibited zone of obstacles set looks like as $\overset{€}{G} = \bigcup_{i=1,n_W} \overset{€}{G}_i \in W \subset R^m$, and the robot- $G = G(q) = \bigcup_{i=1,n_R} G_i(q) \in W \subset R^m$.

With each area we shall connect system of coordinates $\overset{€}{O}_i \overset{€}{x}_i \overset{€}{y}_i \overset{€}{z}_i, i = 1,..., n_W$ or $O_i x_i y_i z_i, i = 1,..., n_R$. For example, it can be connected with parts of the manipulator widely known as systems of Denavit - Hartenbeg's co-ordinates or systems of co-ordinates of ellipsoid inertia of area.

Let's compare each area $\overset{€}{G}_i(G_i)$ its "standard" $\overset{€}{G}_i(\widetilde{G}_i)$ from which it turns out by movement of Eucledean space, transforming the base system of coordinates R^m - $O_0 x_0 y_0 z_0$ to the system of coordinates of area: $e : R^m \to R^m, e(\widetilde{G}_i) = G_i, e \in E(R^m)$ - the movement transforming the standard in area ($E(R^m)$ - group of movements R^m).

The solved problem consists in construction of a program trajectory of movement $q_p(s) \in Q^n \subseteq Q^n, s \in [s_0, s_T]$, from an initial configuration $q_0 \in Q^n$ to a final configuration $q_T \in Q^n$ in space of the generalized coordinates Q^n, where Q^n - area in Q^n in view of constructive restrictions on the generalized coordinates, and s - parameter, for example, length of an arch in Q^n or time. The condition of absence of crossings with obstacles looks like

$$\overset{€}{G} \cap \left(\bigcap_{i=1,n_R} G_i(q) \right) = \varnothing.$$

Conclusions. The developed structure of diagnostic parameters definition of CMM allows to raise accuracy, reliability, speed of carrying out of measurements in real time. The intellectual system enables to automate scientific researches and the experiments connected with carrying out CMM diagnostics, including processing of results of measurements and visualization.

Keywords. Intellectual measuring system, the coordinate-measuring machine, diagnostic parameters.

References

1. Методы компьютерной обработки изображений / Под ред. В.А. Сойфера.– М.:Физматлит.–2004.–282 с.
2. *Воронин В.В.* Продукционные правила для диагностических проверок // Информатика и системы управления.–2003.–№2.–С.79-88.
3. *Попов В.Н., Зайков А.Л.* Диагностика текущего состояния первичных измерителей информационно – измерительных систем // Контроль. Диагностика.–2001.–№11.–С.40-44.
4. *Бергер И.А.* Техническая диагностика // М.:Машиностроение.–1978.–240с.
5. *Данилюк С.*Г. Вероятностный подход к автоматизации процесса диагностирования на основе структурно–параметрической математической модели // Контроль. Диагностика.–2001.–№6.–С. 36-42.
6. *Данилюк С.*Г., *Товстыко К.М., Ермаков О.Н., Лебедькова Н.Н.* Применение технологии искусственного интеллекта в системах диагностирования сложных технических объектов // Контроль. Диагностика.–№12.–2004.–С. 46-49.
7. *Gromakovsky D.G., Malyarov A.N., Samarin V.P.* Modelling and Wear Calculation on Friction. Abstracts of Papers of the World Tribology Congress Bath:Bookcraft Limited.–1997.–462p.

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AUTOMATED CONTROL SYSTEM OF AIRCRAFT ENGINE PARTS BY A SAMPLE

The automated control system of aviation details in conditions of external indignations action, and also mathematical model is developed at the control of details with the standard model. The block diagram of the automated control system of aviation details with the standard model is offered. As model of the standard can be built in the control computing system coordinate-measuring machine (CMM), located on a rotor of the linear engine with two dividers of a beam on coordinate y and coordinate z.

Introduction. The modern level of a science and engineering development is characterized by universal distribution of complex technical objects. For managing and control of such objects are widely applied measurements of details with the help of CMM. Especially it concerns to measurement of output parameters of the processes accessible to direct measurements, but dependent on the big number of factors, that demands their account in model of object measurement and conducts to a significant methodical error. Frequently measuring systems (MS) have is unacceptable big resulting error because of low-frequency components.

An effective means of low-frequency errors exception is the periodic parametrical adaptation of the MS due to structural redundancy by complecsening of the MS In the numerous works devoted to parametrical adaptation, the main attention is given to algorithms of adaptation (algorithms of values search of adapted parameters). The problem of a choice of optimum value of the adaptation period and other characteristics of the adaptation mode until recently remained outside of a field of vision.

One of directions of the automated control systems perfection by the processes of measurement and the control of details of aviation devices on the CMM is connected with the use of synergetic theories of management. In a basis of construction of such systems lays varieties of trajectories of form-building three-dimensional motions in the conditions space providing given parameters of the details quality and being natural and asymptotically steady for a given, controlled set of technological modes.

The analysis of practice of the complex monitoring systems management shows an absolute necessity of the creation of automation management means as the complete process proceeding in real time. The analysis of managerial processes by the automated control systems of aviation engines has shown, that especially important stages are an estimation of the situations, forecasting of its development and decision making on a situation.

The essence of work of the details automated control systems consists that alongside with system of regulation there is the standard model of the closed system, which have desirable dynamic characteristics. The error of a mismatch between movement of system and standard model serves as the basic information for reorganization of a factors regulator with the purpose of approximation of the system dynamic properties to the properties of standard model.

The present work is devoted to synthesis of the generalized algorithms of the adaptation using a error of a mismatch between output coordinates of the system and model and their derivatives with the purpose to deliver to the system the property of stability of its movement concerning movement of model and simultaneously to provide stability of the change processes of the reorganized factors of closed system, which considered as auxiliary coordinates, concerning the appropriate factors of model.

The analysis of references has shown, that mathematical modelling evolutionary converters is executed at measurement of details in aviation engineering [1,2], and also on the basis of Lyapunov direct method made a synthesis of the generalized algorithms of factors reorganization of a regulator in system of details measurement with model [3] is carried out, but is not offered the method of construction of adaptive management and the control with standard model at external indignations.

Statement of a problem. The purpose of work is the development of the automated control system of aviation details in conditions of action of the external indignations, and also development of mathematical model at the control of details with the standard model.

The task is to find algorithm of factors adaptation of a regulator such, that, since some moment of time t_N difference of $e(t)$ of the object and standard model satisfied to the requirement $|e(t)| \le e^* + e(t_N)$, $t \ge t_N$ to the accuracy of tracking (e^* - given number, $e(t_N)$ - the number, dependent from t_N, which module is less e^*).

The decision. Let's consider a detail described by the differential equation

$$y^{(n)} + d_{n-1}y^{(n-1)} + \ldots + d_0 y = k_p u^{(p)} + \ldots + k_0 u + f \,, \quad p < n, t \ge t_0 \,, \tag{1}$$

where $y(t), u(t), f(t)$ - measured output of the object, management and external indignation accordingly, $y^{(i)}, u^{(j)} (i = \overline{1,n}, j = \overline{1,p})$ - derivatives of an output and management, $d_i, k_j (i = \overline{0,n-1}, j = \overline{0,p})$ - unknown numbers, n and p - are known. Further for simplicity, $p = n-1$, indignation $f(t)$ - limited, unmeasured, polyharmonious function

$$f(t) = \sum_{i=1}^{\infty} f_i \sin(\omega_i^f t + \phi_i^f) \,, \tag{2}$$

in which $\omega_i^f, \phi_i^f (i = \overline{1,\infty})$ - unknown frequencies and phases, and amplitudes $f_i (i = \overline{1,\infty})$ - the unknown numbers satisfying an inequality

$$\sum_{i=1}^{\infty} |f_i| \le f^* \,, \tag{3}$$

where f^* - known number.

The reference model is described by the equation

$$y_m^{(n_m)} + d_{m,(n_m-1)} y_m^{(n_m-1)} + \ldots + d_{m,0} y_m = k_{m,p_m} r^{(p_m)} + \ldots + k_{m,0} r \,, \tag{4}$$

where $d_{m,i}$ and $k_{m,j} (i = \overline{0, n_m - 1}, j = \overline{0, p_m})$ - known numbers, $r(t)$ - measured specifying influence which also is polyharmonious function.

The purpose of management $u(t)$ is, that a difference $e(t) = y(t) - y_m(t)$ outputs of a detail (1) and standard model (4) satisfied, since some moment of time $t_N > t_0$, the requirement

$$|e(t)| \le e^* + e(t_N) \,, \; t \ge t_N \,, \tag{5}$$

where e^* - given number, $e(t_N)$ - dependent from t_N the number, which module is less then e^*

The management $u(t)$ is formed by a regulator described by the differential equation

$$d_{c,n_c}u^{(n_c)} + d_{c,n_c-1}u^{(n_c-1)} + \ldots + d_{c,0}u = k_{c,p_c}e^{(p_c)} + \ldots + k_{c,0}e, \qquad p_c \le n_c, \qquad t \ge t_N. \quad (6)$$

Let factors of the equation of a detail (1) are known. We shall construct a regulator (6) providing the requirement to accuracy of tracking (5).

Let's transform the equations (1), (4), (6) on Laplass at zero entry conditions. Then they will become

$$d(s)y = k(s)u + f, \qquad d_m(s)y_m = k_m(s)r \quad (7)$$

$$d_c(s)y = k_c(s)e, \quad (8)$$

where $d(s) = s^n + \sum_{i=0}^{n-1} d_i s^i$, $k(s) = \sum_{i=0}^{p} k_i s^i$, $d_m(s) = s^{n_m} + \sum_{i=0}^{n_m-1} d_{m,i}s^i$

$$k_m(s) = \sum_{i=0}^{p_m} k_{m,i}s^i, \qquad d_c(s) = \sum_{i=0}^{n_c} d_{c,i}s^i, \qquad k_c(s) = \sum_{i=0}^{p_c} k_{c,i}s^i.$$

Having increased first of the equations (7) on $d_m(s)$, and the second on $d(s)$ and, after their subtraction, we shall receive the equation of the expanded object. It describes a difference of movements of a detail (1) and standard model (4).

Using the equation of a regulator (8), we shall exclude a variable $u(t)$ from this equation and also we shall receive the equation of the closed system

$$d_z(s)e = h_z(s)r + m_z(s)f. \quad (9)$$

Let's write the equation (9) as

$$e = T_{er}(s)r + T_{ef}(s)f, \quad (10)$$

where $T_{er}(s), T_{ef}(s)$ - the transfer functions connecting a error of tracking with specifying and revolting influence.

The relation of numerators of these transfer functions satisfy to one of inequalities

$$\frac{|k_m(j\omega)d(j\omega)|}{|d_m(j\omega)|} \ge \frac{f^*}{r^*}, 0 \le \omega < \infty \quad (11)$$

or

$$\max_{0\le\omega<\infty} \frac{|k_m(j\omega)d(j\omega)|}{|d_m(j\omega)|} \le \frac{f^*}{r^*}. \quad (12)$$

Let the object and standard model are those that the inequality (11) is carried out. We shall consider a regulator (8) with polynoms

$$d_c(s) = k(s)d_m(s), \qquad k_c(s) = d(s)d_m(s) - \delta_1(s), \quad (13)$$

where $\delta_1(s)$ - a Hurvits polynom which is finding from identity

$$\delta_1(-s)\delta_1(s) = d(-s)d(s)[d_m(-s)d_m(s) + q_{11}k_m(-s)k_m(s)], \tag{14}$$

where q_{11} - some positive number.

If a detail (1) and standard model (4) have property (11), and factor q_{11} in identity (13) satisfies to a condition $q_{11} \geq \frac{4r^{*2}}{e^{*2}}$, the difference of outputs of the object and standard model satisfy the requirement (5).

Let the inequality (12) is executed. We shall consider a regulator (8) with polynoms

$$d_c(s) = k(s), \quad k_c(s) = d(s) - \delta_2(s), \tag{15}$$

where $\delta_2(s)$ a Hurvits polynom which is finding from identity

$$\delta_2(-s)\delta_2(s) = d(-s)d(s) + q_{22}, \tag{16}$$

in which q_{22} - some positive number.

If the detail and standard model have the property (12), and factor q_{22} in identity (15) satisfies a condition $q_{22} \geq \frac{4r^{*2}}{e^{*2}}$, the difference of outputs of the object and standard model satisfy the requirement (5) to accuracy of tracking.

On the basis is higher told it is possible to construct a regulator solving a task if factors (1) are known. When they are not known, it is necessary to identify them and construct the polynoms (13) and (15) of the required regulators, using estimations of these factors.

Let's describe filter Fur'e and frequency equations of identification, which underlie algorithm.

Filter Fur'e looks like

$$\alpha_{л}{}^{\eta}(\tau) = \frac{2}{p_k \tau} \int_{t_F}^{t_F+\tau} e^{\lambda(t-t_0)} \eta(t) \sin \omega_k (t - t_0) dt,$$

$$\alpha_{\gamma+л}{}^{\eta}(\tau) = \frac{2}{p_k \tau} \int_{t_F}^{t_F+\tau} e^{\lambda(t-t_0)} \eta(t) \cos \omega_k (t - t_0) dt, \ (k = \overline{1,\gamma}).$$

Frequency equations of identification look like

$$-[\alpha_k{}^{\eta}(\tau) + j\alpha^{\eta}{}_{\gamma+k}(\tau)]\sum_{i=1}^{\gamma} s_k{}^{\gamma-i}\theta_i(\tau) + \sum_{i=0}^{\nu} s_k{}^{\nu-i}\theta_{\gamma+i+1}(\tau) = [\alpha_k{}^{\eta}(\tau) + j\alpha^{\eta}{}_{\gamma+k}(\tau)]s_k{}^{\gamma}, s = \lambda + j\omega_k, k = \overline{1,\gamma}$$

The process of identification comes to an end at the moment of time in which necessary conditions of its convergence are satisfied.

For convergence of a process of asymptotically steady object adaptation there is enough expansibility of adaptation intervals and strict ΦΦ-filterability of indignation $f(t)$, s under these conditions any accuracy of identification of object (1) can be achieved.

The structure of the offered automated control system of aviation details with the standard model is submitted on fig.1.

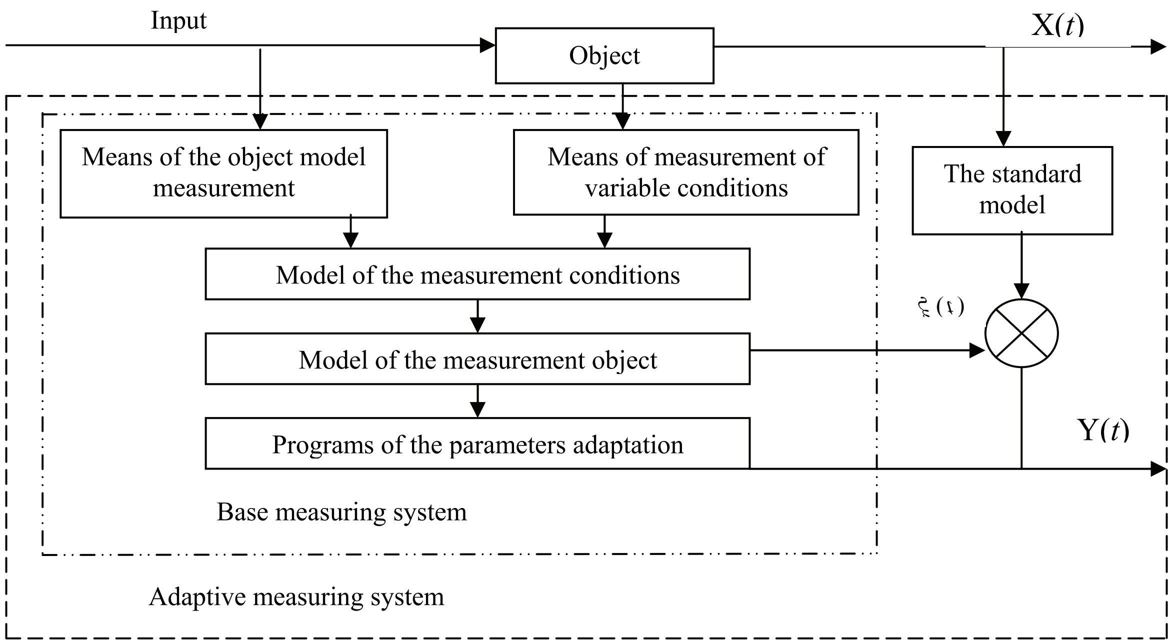

Fig.1. Structure of adaptive measuring system with the model - standard

As model of the standard can be built - in the managing computing system the CMM, located on a rotor of the linear engine with two dividers of a beam on coordinate y and coordinate z.

Conclusion. Summing up above told it is possible to note, that we develop the automated control system of aviation details in conditions of action of external indignations, and also mathematical model at the control of details with the standard model. The approach to the construction of system is based on identification of object and the closed system with the help of a method certainly - frequency identification and procedures of a regulator synthesis at the external indignation being the sum of unlimited number of harmonics. The block diagram of the automated control system of aviation details with the standard model also is offered.

References

1. Современная прикладная теория управления / Под ред. А.А. Колесникова. Том 3. – Москва – Таганрог: Изд-во ТРТУ, 2000.
2. *Колесников А.А.* Синергетическая теория управления. – М.: Энергоатомиздат, 1994.
3. *Земляков С.Д., Рутковский В.Ю.* О синтезе самонастраивающейся системы управления с эталонной моделью. Автоматика и телемеханика, №3, 1966.
4. *Hiza T.C., Li C.C.* Analitical Synthesis of a Class of Model-Reference Time-Varying Control Systems. IEEE Trans. Appl. And Ind.,№.69, 1963.
5. *Bonjiorno Joseph T. Tr.* Stability and Convergence Properties of Model Reference Adaptive Control Systems. IRE Trans. Aut.Contr., №3, 1962.
6. *Parks P.C. Lypunov*. Redesign of Model Reference Adaptive Control System // IEEE Automat. Control. 1966. V. AC-11. № 3.
7. *Narendra K.C., Annaswamy F.M.* Robast Adaptive Control in the presence of Bounded Disturbance // IEEE Automat. Control. 1986. V. AC-31. № 4.

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THE CONCEPTUAL NEURONET APPROACH TO DIAGNOSTICS OF DEFECTS IN TECHNICAL SYSTEMS

The structure of the informational-program environment in which the systems realizing various methods are incorporated has been developed. The new direction for diagnostics and measurements of details of aviation devices based on the use of the coordinate-measuring machine on neuronet networks has been offered.

High operational characteristics of technical systems, including flying devices during life cycle of a product stipulated by the rules, are achieved by measurement of diagnostic parameters, including the control of wide scale of parameters at all stages of technological processes.

In these conditions the application of the device of neuronets represents a perspective direction.

Artificial neuronets (NN) now have received a wide distribution at construction of recognizing and diagnostic systems, they are the convenient tool for construction of numerical models [1].

The complexity of diagnostic systems is determined by the complexity of objects of diagnosing [2]. Therefore the technical diagnostic systems, including the elements of hybrid, dynamic and in some cases distributed expert systems are the most complex. Problems related to such systems are connected not only with uncertainty and discrepancy of knowledge, but also with dimension of a subject domain. Thus, the restriction of search space of decisions by definition of area of diagnostics is not always possible.

The creation of hybrid expert systems (integration of expert systems with information systems, systems of search and optimization), allows to use them as the external managing program which calls the necessary package according to the kind of the being solved task, and thus expands a subject domain and functionalities of the whole system.

Therefore, in the development of architecture of such systems it is necessary to use principles of construction of the dynamic systems, allowing to model dynamic subject domains. The changes which occurred in such areas, after the beginning of the decision of the task, influence the final conclusion and consequently should be taken into account directly during a conclusion that enables realization of some tasks of monitoring.

During the process of development of diagnosing variants in conditions of uncertainty and discrepancy of the data, an attempt to model process of deterioration of the control of details in real conditions of operation is usually made. Experts use the so-called "direct" conclusion (direct transition from the description of the task to its decision without sorting numerous variants), that is characterized by the speed of the decision of the task and small number of mistakes. Difficulty of creation of the systems trying to model a course of reasoning of the expert, is explained by the fact that getting information from highly skilled experts is a complex and not always feasible task (frequently the expert can not explain how the decision was found).

Fast development of modern technical and tool means has caused some advantages of computer processing of information over thinking of the expert. Even the application of the most universal method of search of decisions - the method of sorting, on the basis of the newest means can be more effective in some cases, than the use of means of an artificial intellect. Application of methods of sorting acceleration, methods of mathematical statistics, Boolean mathematics on the basis of the newest tool means can considerably reduce time of development of similar systems and solve some tasks of diagnostics. At the same time the use of only such means can lower both quality of diagnostics, and the abilities of intellectual systems as a whole. Therefore at the given stage of researches at construction of intellectual diagnostic systems there appeared a problem of full use of advantages not only of computer processing of the information but also of methods modeling expert's reasoning. Such target setting during the process of development of intellectual systems structure demands essentially new approaches. Similar systems should use various methods of diagnostics, carry out the intellectual analysis of the data and give the user full information for decision making. The architecture of the given systems should be constructed according to the principle of hybrid systems whose essence of work consists in functional association of the systems realizing various methods and system carrying out analysis of decisions and organizing interaction of the user with the expert system.

Application of hybrid systems is limited to some subject domains and use of concrete algorithms of decisions making for given areas [3].

In the given work the structure of the uniform information and program environment is developed in which the systems realizing various methods are incorporated.

Designing of technical systems we shall consider by an example of coordinate-measuring engineering which is characterized by a high level of intellectualization of diagnostics of defects, considerably differs from designing the automated systems of high accuracy. A perspective direction of development of the coordinate-measuring machine for diagnostics and measurements of details of aviation devices is the use of artificial neuronets the research of which began in 60th years, due to the bionic direction in cybernetics.

NN are the systems the elements of which constitute the basic processor elements (artificial neurons). Artificial NN can change the behaviour depending on internal and external influences and are used by the solving tasks of recognition and classification, processing of images and signals of gauges, systems of identification and management of movement, planning of a route, navigation etc.

As discriminantal function of neuron it is possible to use the weighed sum

$$\varphi(x,w)=\sum_{i=1}^{N} w_i x_i + w_0,$$

where $\varphi(x,w)$ - discriminantal function of neuron, x_i - value of a signal on i-th input of neuron ($i=1,2,...,N$), N - quantity of inputs of neuron, $w=\{w_0,w_1,w_2,...,w_N\}$ - a set of weight factors of neuron.

As a function of activation we shall apply threshold function

$$\psi(\alpha)=\begin{cases}0, & \alpha \le 0,\\ 1, & \alpha > 0,\end{cases}$$

where $\psi(\alpha)$ - function of neuron activation.

The artificial NN, they are complex structures representing a set of neurons connected in a certain manner are constructed on the basis of neuro elements.

The ability to be trained in approximation of multivariate nonlinear dependences on the dot data is their major property. However, the majority of methods of training and synthesis of NN do not meet such requirements, as a logic transparency of a network, accuracy of training on training sample, a minimum of redundancy of a network, a minimum of time and iterations of training, adequacy of topology and structure of the modeled task. A minimum of redundancy of a network it's a condition, minimizing the quantity of parameters NN of the model, its weight factors. Criterion which demands that NN-model contained as few as possible layers of neurons, neurons in a layer, connections between neurons. The degree to which settlement values on an output of a network differ from actual values of numbers of the classes compared with copies of training sample determines accuracy of training of a network by the training sample [1].

The minimum of time and iterations of training of a network assumes as fast construction of NN-model and whenever it is possible without the adjustment of weights. Adequacy of topology and structure of a decided task demands conformity of structure of NN-model and structure of the decided task.

But, the majority of known methods of construction of NN-models can not simultaneously satisfy considered criteria [1].

Application of NN by processing the information received as a result of diagnostics of defects allows to proceed from search of rules of the decision of tasks to training a network using examples. By measurement NN are used for solving the tasks of classification, recognition, search of the necessary information. In a spectrum of modern information technologies, the technology of information processing using neuronets takes the important place.

For the development, realization and applications of NN-information technologies neurocomputers are used that is the software package realizing NN algorithms. Usual computers, more often personal which can contain special hardware for acceleration of work, serve as a platform for realization of neurocomputer [4]. The Block of selection of a class should give out by an output of a network binary number of one of two classes for recognized copy depending on that, to one of the clasters of which class the given copy is closer in sense of a used measure. The given block can be realized on the basis of one neuron, having two inputs: x_1 and x_2, on which compared minimal distances up to classes of clasters 0 both 1, accordingly, and one input act y.

The block of interaction of the basic modules of system is submitted on fig. 1.

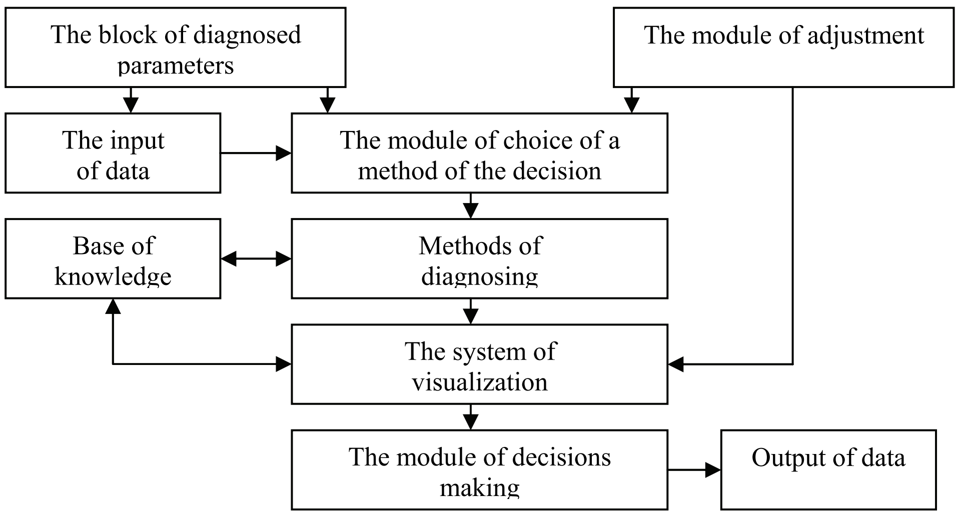

Fig. 1. The basic modules of intellectual system of diagnosing

The weights of neurons of the first layer are adjusted in an iterative mode during synthesis of a network. Weights of neurons of all other layers are adjusted in a different mode.

The first layer of neurons realizes blocks of clusterization, the last layer - the block of selection of a class, and internal layers - the block of selection of a class. Parameters of a network, such as quantity of neurons in a layer, quantity and topology of connections between neurons in a network are formed automatically, that makes the process of construction of neuronet models not dependent on the user and proves the certain level of universality of an offered technique.

The system is problematic-dependent and is intended for work in the field of diagnostics of defects in technical systems.

Approximately the process of diagnostics of object can be presented in two stages:

– The restriction of space of diagnosing.

– Application of some strategy of diagnostics for identification of object which is most adequate to attributes.

At realization of diagnosing of objects the use of various methods is stipulated: mathematical statistics, an artificial intellect, direct sorting. The Process of formation of knowledge is not finished at the development cycle of system and formation of a database and base of knowledge. In the process of service systems "corrects mistakes", thus the system accumulates experience [3].

As it has already been specified above, in the system at realization of search of the decision it is possible to use various methods included in process of diagnosing at adjustment of system.

NN, received as a result of synthesis and training on the basis of the developed technique are logically transparent. Due to the fact that the computing circuit of work of the network trained according to the developed method is very simple, neurons of all layers of NN, except the first one, have only two inputs, one of operands at multiplication is in most cases equal 1 or-1, and functions of activation of neurons are linear or threshold, NN, synthesized and trained on the basis of the considered method, can be realized by the hardware or by the user on the computer with parallel architecture.

Accuracy of classification and speed of training NN, generated on the basis of the considered technique, are high enough for the majority of applied tasks of diagnostics and recognition of images.

Conclusions. The conceptual approach to diagnostics of defects in technical systems and principles of neuronet approach to diagnostics of defects in the aviation industry has been developed. Use of the coordinate-measuring machine on NN for diagnostics and measurements of details of aviation devices is shown.

References

1. *Дубровин В.И., Субботин С.А.* Методика синтеза и обучения многослойной нейронной сети классификации образов // Радіелектроніка. Інформатика. Управління. – 2002. – №2. – С. 80-87.
2. *Kwater T.* Mathematical Modelling and Diagnostics of Working Elements in Air Mechanics // Искусственный интеллект. – 2004. – №4. – С. 530-538.
3. *Гридин В.Н., Тарасова О.Б.* Построение интеллектуальных диагностических систем в медицинских приложениях // Информационные технологии. – 2003. – №7. – С. 54-58.
4. *Гриценко В.И., Мисуно И.С., Рачковский Е.Г., Ревунова Е.Г., Слипченко С.В., Соколов А.М.* Концепция и архитектура программного нейрокомпьютера SNC // Управляющие системы и машины. – 2004. – №3. – С. 3-14.

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INTELLECTUAL SYSTEM FOR AUTOMATIC CONTROL OF TRAVEL DRIVES BASED ON LINEAR ENGINES WITH AEROSTATIC SUPPORTS

The article presents a systemic approach to the analysis of features of travel drives used in precision machines and measuring robots. Advantages of drives based on linear engines with aerostatic supports are demonstrated. The work provides an analysis of factors affecting the precision and dynamic parameters of control drives based on linear engines. A method is offered for the development of an advanced-precision digital electric drive. The effectiveness of the method is tested and confirmed by a mathematical model simulating dynamic processes in the drive

Introduction. Production of parts with high-precision automated machines and control of geometrical parameters of produced units require drives that ensure a high precision of the working organ travel. The task of improvement of the drives is aimed at the perfection of their static and dynamic characteristics. The drives must satisfy the following requirements: ensure high precision of the working organ positioning, deliver the prescribed quality of dynamic processes, ensure the precision of travel when alternating loads are applied at the working organ.

The development of the new generation of machines and measuring robots has necessitated the adoption of new technical solutions in the design of the travel drives. The application of gapless mechanical transmissions, linear engines, hydraulic and aerostatic supports has provided the opportunity to achieve high levels of the speed stability and the smoothness of change in various conditions, including the operation at minimum speeds and at the start and the end of working organ travel [1, 2]. The effectiveness of the application of highly sensitive feedback sensors increases.

The different types of tasks to be solved determine the use of a proper mathematical model. For theoretical calculations of precision and dynamic characteristics of drives, deterministic models are usually used. Experimental researches are most often based on probabilistic correlations. The research of drives usually comes to measuring the following characteristics: precision of the working organ positioning, operating speed, rigidity of the drive, the output effort, smoothness of the working organ travel. The research uses methods supplied by the theory of fluctuations and automatic control, technical diagnosis, metrology and other disciplines. The effectiveness of the development and realization of methods that improve the reliability of precision drives is ensured by combining of theoretical and experimental research methods with the practical experience of production and operation of the drives.

The precision of a control system is measured by static and dynamic errors. A static error is caused by discontinuities of the feedback sensor, errors of mechanical transmission, and the influence of perturbations upon the executive link of the drive. A dynamic error is related to the transitional processes caused by the change of speed or the stop of the working organ.

Modern high-precision machines widely employ linear precision electric drives. Drives of this type use linear engines as executive devices and avoid application of the kinematical transformation, which causes nonlinear and resilient errors in the channel of motion transmission to the working organ.

Electric drives of this type are distinguished by a high precision of positioning, adjustable by fractions of a micron, and a wide range of speed adjustment. The stability of low speeds is ensured by the nonlinear dependence of the engine effort on the control current and the co-ordinate of the mobile part. This effect is caused by the properties of the electromagnetic system of the engine and the power electric part. At high speeds the decline of the drive effort is strongly affected by the iron loss and the satiation of the inverting element.

Nonlinear mathematical description of the electric drive reduces the efficiency of the traditional approach to the system control based on vectorial algorithms with the transformation of the co-ordinates [3]. A greater effect is achieved by the control in real co-ordinates, adjusted to nonlinear effects. This type of control requires the application of complicated control algorithms, which can be realized only by high-performance signal processors [4].

The essentials of the development of a digital control system for linear engines are demonstrated below by the example of a specific task.

Problem definition. Design a working organ travel drive for a co-ordinate measuring robot with linear electric engines on aerostatic supports, satisfying the following requirements:

- speed range – 0,2 mm/sec to 500 mm/sec
- deviation from the average at the speed of 1 mm/sec - not more than 0,05 mm/sec;
- positioning precision - not worse then ±0,5 µm.

Basic technical characteristics of the employed engine:

- nominal current of the phase I_n = 5 A;
- nominal static effort T_n = 100 N;
- effort ripple $\Delta T/T$ = 10 %;
- tooth division X_z = 1,28 mm;
- average phase inductance L_{ph} = 5 mHn;
- phase resistance R_{ph} = 1,5 Ohm;
- mobile part mass m_i = 1,0 kg.

The system employs a linear two-phase synchronous engine with the winding placed on the mobile part, and an immobile excitation system on field magnets.

Problem solution. During the concept design of the drive with the named parameters the following principle tasks have to be addressed:

- in order to achieve a high travel smoothness at a wide range of speeds, the drive should possess a high bandwidth threshold frequency both for the control action and for the external perturbations;
- dynamic characteristics of the drive should remain stable at the entire range of speeds;
- in order to achieve the prescribed positioning precision, a high-sensitivity position sensor should be used.

The practical realization of the statements above is demonstrated in the structure chart Fig. 1.

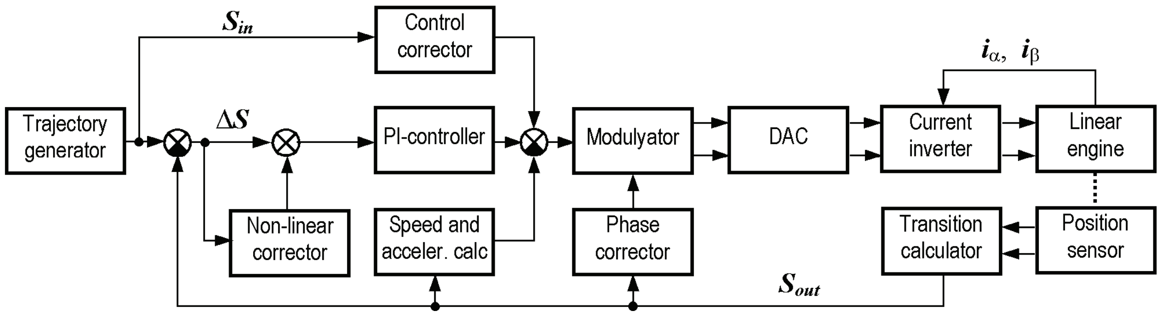


Fig. 1. Structural chart of digital watching drive

The digital control system is based on a signal processor, where the following functional nodes are realized:

- a trajectory generator, which forms smoothly changing positioning tasks and adjusts for limitations on the acceleration of the drive's and its derivative, thus minimizing control errors;
- a calculator of speed and acceleration of the mobile part travel, based on signals from the position sensor;
- a PI-controller in the positioning mode;
- a control corrector that analyses the closed-loop drive dynamics and adjusts the speed parameter of the control signal, thus minimizing errors related to the input task modification
- a switching non-linear corrector that improves the quality of transitional processes during the feeding of the working organ to the position;
- a corrector of the task of the engine winding currents that compensates the ripple of the generated effort, caused by the non-linearity of the magnetic circuit and materialized in the form of a parasitic clamp pulse as an alternating perturbation;
- a driver circuit of sine-cosine control signals for currents of the engine's winding.

The digital control signal formed by the signal processor is converted by the digital-analog converter into an analog form. The signal proceeds to the two-channel inverter, which works in the valve mode and forms the prescribed currents in the winding of the linear engine as a function from the position of the mobile part.

The current inverter is built according to the pulse-width modulation (PWM) principle of voltage feeding the converter. The law of electronic switching of currents of the synchronous engine winding is formulated as follows:

$$i_\alpha = i_m \sin\theta, \quad i_\beta = i_m \cos\theta, \tag{1}$$

where i_α , i_β – are currents of the engine's phases, i_m – the total amplitude of the current; θ – electric co-ordinate of the mobile part. The control law (1) in its general form does not take into account the ripple of the clump impulse. The processor compensates this perturbation by adjusting the input currents i_α and i_β.

The amplitude of the alternating voltage U_m, necessary for the achievement of the boundary speed X_m in the mode of the effort source, omitting the voltage drop in the winding and the key elements, can be determined by means of the synchronous machine equation

$$U_m \geq X_m \frac{2\pi}{T_z}\sqrt{\left(L_{ph} I_{mn}\right)^2 + \left(T_n T_z / 2\pi I_{mn}\right)^2} \tag{2}$$

where T_z – tooth kink, L_{ph} – average phase inductance, T_n – nominal static effort, I_{mn} – nominal current amplitude. For the given parameters of the engine and the maximum speed X_m = 500 mm/sec the sought voltage is $U_m = 65\ B$.

The current inverter faces the highest requirements to the speed of forming the engine momentum in order to deliver a wide bandwidth of the whole drive. The task is solved by introducing the current feedback [5]. The transfer function of this inverter, omitting the PWM lag, is formulated as follows:

$$K_i(s) = k_c \frac{1 + s/2\zeta\omega_0}{1 + 2\zeta s/\omega_0 + s^2/\omega_0^2} \tag{3}$$

where k_c – the static coefficient of the current circuit transmission., ω_0 – the resonance frequency,
ζ – the fading coefficient.

The minimum inverter bandwidth is determined by the requirement to realize the entire range of speeds in the mode of the current source without the inverter's satiation. At the maximum drive speed X_m = 500 mm/sec the frequency of the sine-cosine currents $f_{max} = X_m/T_z$ will amount to 400 Hz. The bandwidth reserve has to amount to at least two times. The order of magnitude of the PWM frequency should be increased by one, in order to annul the influence of the signal time sampling.

An optical incremental encoder with a 0,2 μm raster period and a digital output is used as a position sensor. It ensures the prescribed positioning precision and refreshing of the speed signal at the minimum travel speed with a sufficient frequency within the boundaries of the drive bandwidth.

The selection of the processor takes into account the requirements to the realization of complex control algorithms with a wide range of fluctuation of state vector components. The control system software implements the control cycle consisting of a drive control subroutine, an interpreter of instructions of control computer, and a subroutine for emergency processing.

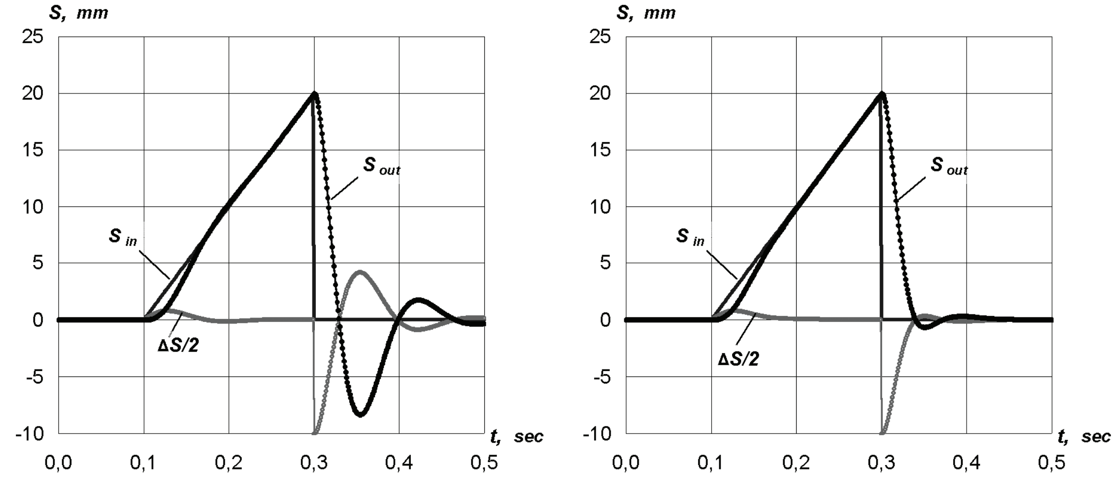
The regulation is carried out in the state space with the use of a state vector. The vector's components are the positioning error, the speed error, the perturbation action and its first derivative. The positioning error is measured directly, and the remaining components of the vector are computed.

The synthesis of the control system parameters has been analytically performed for a linearized drive description in the state space, with the account of quantification period and conversion time. Additional research has been conducted by means of modeling the drive and considering adjustments for non-linearity as well as the time sampling and amplitude quantization.

In addition to a series of nodes and compensating linkages, which ensure advanced control possibilities (a trajectory generator, a control corrector, a phase corrector), the structure of the drive incorporates an additional link for non-linear correction. This element provides for a high robustness of the control system, both when the other compensating mechanisms are used and when they are conditionally disabled or not functioning properly.

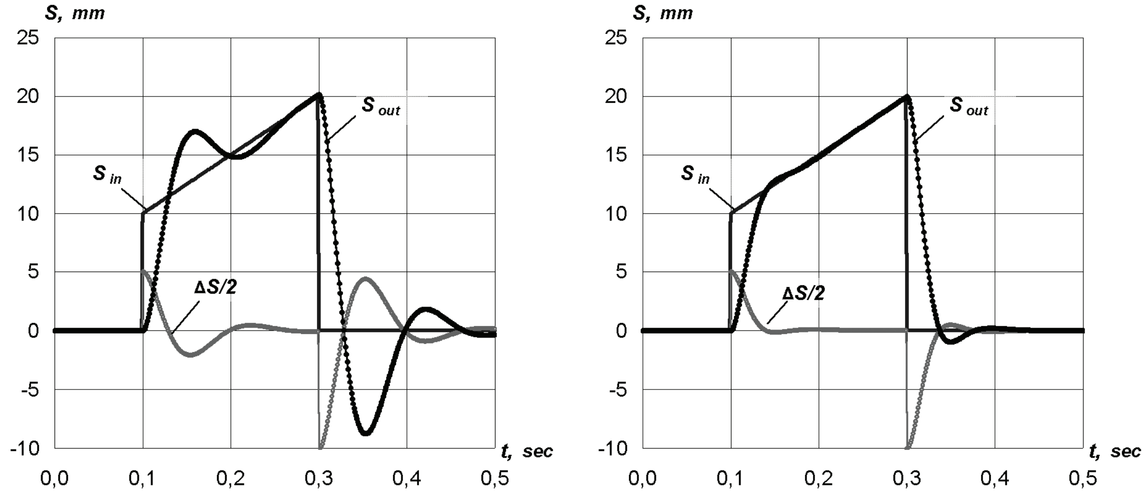
The non-linear link is a commutable discrepancy signal differentiator basing on location, and it is controlled depending on the current combination of signs of the discrepancy signal and its derivative. The effect of the application of the correcting link is observed below in more detail.

Figures 2 – 5 demonstrate a comparative analysis of the mathematical modeling of the drive's reaction upon various input actions, as observed in a system without (*a*) and with (*b*) the compensating link.



a *b*

Fig. 2. Comparison of transitional characteristics of drives having the conventional structure (*a*) and a structure incorporating a commutable differentiating link (*b*)



a *b*

Fig. 3. Comparison of transitional characteristics of the drive

The slightest input action is shown in Figure 2. It is a steady-speed start followed by a return to the initial position. The effect of the non-linear corrector is demonstrated by a substantial reduction of the oscillation of the system and becomes most apparent in the spasmodic phase of the input action.

A stronger input action is the movement from a distant location in the direction opposite to the initial position. Fig. 3 demonstrates the apparent advantages of drives with a commutable link (*b*) compared to drives having the conventional structure (*a*).

Additional evidence is provided by the results shown in Figures 4 and 5. The input actions are described as follows: the movement from a distant location in the direction of the initial position with a spasmodic finish of the process (Fig. 4) and with a smooth finish in the zero position (Fig. 5). In the both cases the beginning of the process is characterized by a considerable start discrepancy with a subsequent transition to the steady-speed movement in the reverse direction.

The need to cope with such input actions can arise in the process of controlling measurement robots during measuring of geometric objects of complicated shapes, as well as in the process of controlling the actuating element of the machine that produces such objects. The implementation of a commutable link (Fig. 4, *b* and Fig. 5, *b*) enables minimization of the discrepancies at the beginning spasmodic section of the trajectory, coherent to the drives having the conventional structure (Fig. 4, *a* and Fig. 5, *a*).

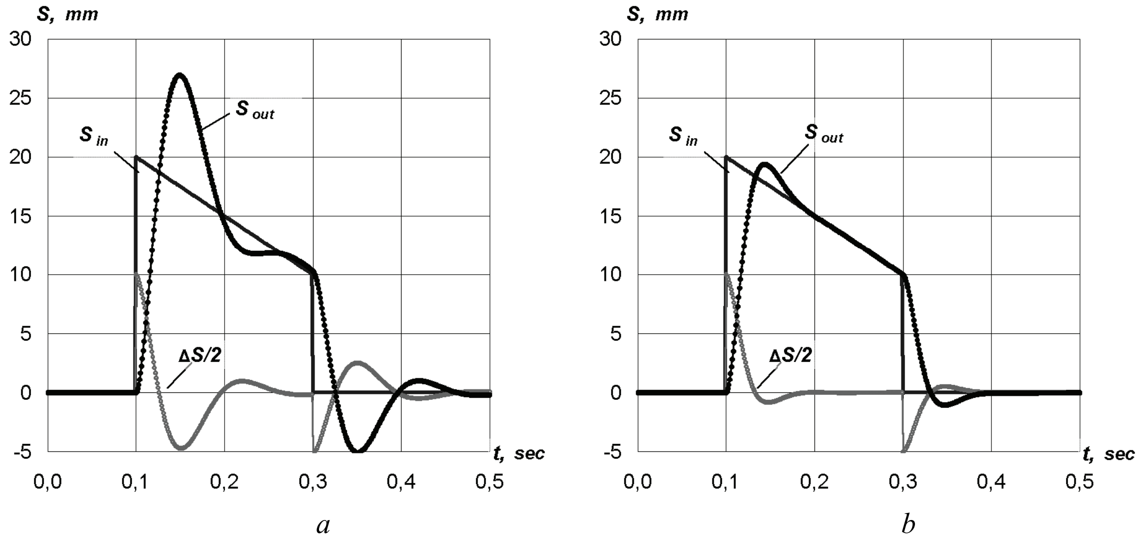


Fig. 4. Comparison of transitional characteristics of the drive

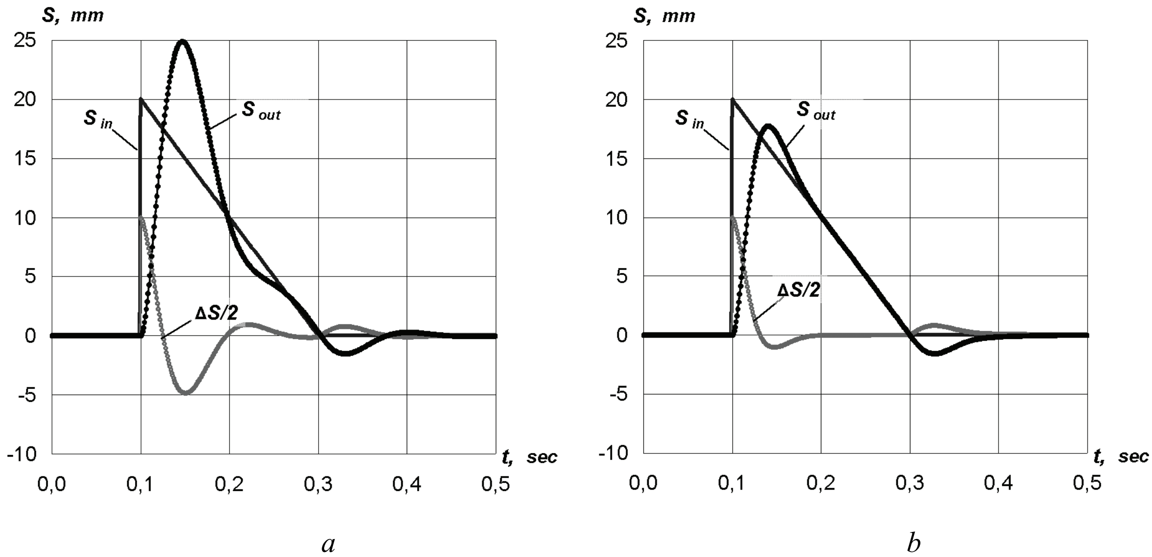


Fig. 5. Comparison of transitional characteristics of the drive

The testing of the developed control system was conducted with the consideration of actual characteristics of its components, as well as for additional types of the input action. The results are common in the fact that the usage of the commutable link provides for a considerable improvement of the drive's parameters. A comparative analysis of the most typical results is presented in Figures 2 – 5.

An integrated application of the described technical solutions, represented in the structural scheme in Figure 1 allows to develop a digital control drive based on linear engines, characterized by a high precision and operating speed. A multiprocessor system controlling identical drives on three and above coordinates has proved to be the most effective solution from the practical point of view. Automated coordinate machines and measuring robots, incorporating such drives, can form the basis of intelligent production complexes, which enable the manufacturing of high quality of the product at a high production rate.

Conclusions. The conducted analysis of factors influencing the precision and dynamic parameters of control drives of precision machines and measuring robots has demonstrated the advantages of the application of linear engines on aerostatic supports. The offered method of the digital drive design as well as the results of the mathematical modeling of the dynamic processes confirm the effectiveness of the proposed solution.

Drives of this structure can be effectively applied in other mechanisms, where high-precision programmed travel is necessary, especially in such areas as laser technologies, medical equipment, microelectronics, production of printing circuit cards, etc.

References

1. *Пуш А. В.* Основные принципы проектирования прецизионных и сверхпрецизионных станков // СТИН. – 1999. – № 3. С. 12-14.
2. *Бржозовский Б. М., Виноградов М. В., Игнатьев А. А.* Исследование точностных характеристик приводов подач прецизионных токарных модулей // Известия вузов. Машиностроение. – 1990. – № 3. С. 132-135.
3. A Tutorial in AC Induction and Permanent Magnet Synchronous Motors. Vector Control with Digital Signal Processors, Analog Devices Inc., Brochure, 1994.
4. *Корнеев В., Киселев А.* Современные микропроцессоры. М.: Нолидж. 2000.
5. L6258. PWM controlled-high current DMOS universal motor driver. SGS-Thomson Data sheet, 1996.

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USING OF MODERN INFORMATION TECHNOLOGIES IN THE DIAGNOSTIC TASKS OF ROBOTOTECHNICAL COMPLEXES

Is developed measuring robototechnical a complex with use of modern information technologies allowing to make measurements with high accuracy and speed at complete automation technological.

Introduction. Modern information technologies manufactures of flying devices functioning in sphere have not only traditional properties, such as speed, accuracy, reliability, but also a number of others. So-called systems concern to them with an artificial intellect [1] which have ability to be reconstructed under varied technological conditions.

For last years in connection with rough development of computer engineering robototechnical complexes have undergone the significant updating concerning first of all a control system. robototechnical complexes allow to perform various work in heavy conditions with the purpose of decrease of physical work working.

Information technologies in robototechnical are based complexes on the theory of automatic control at which use full automation of technological process is reached under the control of system of automatic control.

As basic criteria system of automatic control serve:

- A supply to object of measurement with simultaneous removal of the information,
- accuracy of positioning with given confidential probability,
- an opportunity of recurrence of exact movements of mechanisms,
- use of the mechanism of the decision of a concrete measuring problem.

Modern means of the analysis and synthesis system of automatic control carry out the decision of a measuring problem is automated under the control of commands of the user, carrying out a sequence of the certain programs and algorithms. In robototechnical complexes it is important to estimate process of machining or measurement of the geometrical sizes of details to lead an estimation of quality of work and to choose strategy of management from alternative variants.

Statement of a problem. To develop measuring robototechnical a complex with use of modern information technologies allowing to make measurements with high accuracy and speed at full automation of technological process. At performance of each detour on measuring details the result should be estimated and compared with previous and also be made an estimation of approachibility of this purpose on the basis of the forecast in view of destabilizing factors.

The decision of a problem. Robototechnical measuring complexes work by a principle of acceptance of decisions [2] proceeding from multilevel hierarchical structure. Process of measurement is defined not only set measuring surfaces, but also recurrence of these measurements. They has ability to adapt to varied operating conditions and consist of set of subsystems:

- the search system, is based on application of various gauges which can include technical sight;
- the system of recognition, is based on identification of object;

- system directly conducting the measurements, processing results of measurement, and also a subsystem of visualization.

Taking into account hierarchical structure it is possible to divide robototechnical a complex into three levels:
I - databases and knowledge,
II - estimations of a condition and management of system,
III - direct measurement.

The first level - databases, includes measuring object, the block of switching communication, block entrance influences.

The second level - estimations, includes a direct estimation of a condition of system and the block of diagnosing, the block of management of gauges and a control system of agencies. Problems of this level include processing of the acting information from gauges established in robototechnical to system, management of a measuring tip at a supply to measurement details, and also decision making. It realizes management of movement of parts robototechnical a complex.

At the third level the block of measurement makes a choice of the further strategy of system. The block of monitoring which is part of this level, carries out program adjustment of movement of working bodies, measures and identifies parameters. The new chosen strategy of actions is under construction on the basis of expert generalization of the situation, sold by expert system in the block of an estimation [2].
The block diagram of an information control system robototechnical is submitted by measuring complexes on fig. 1.

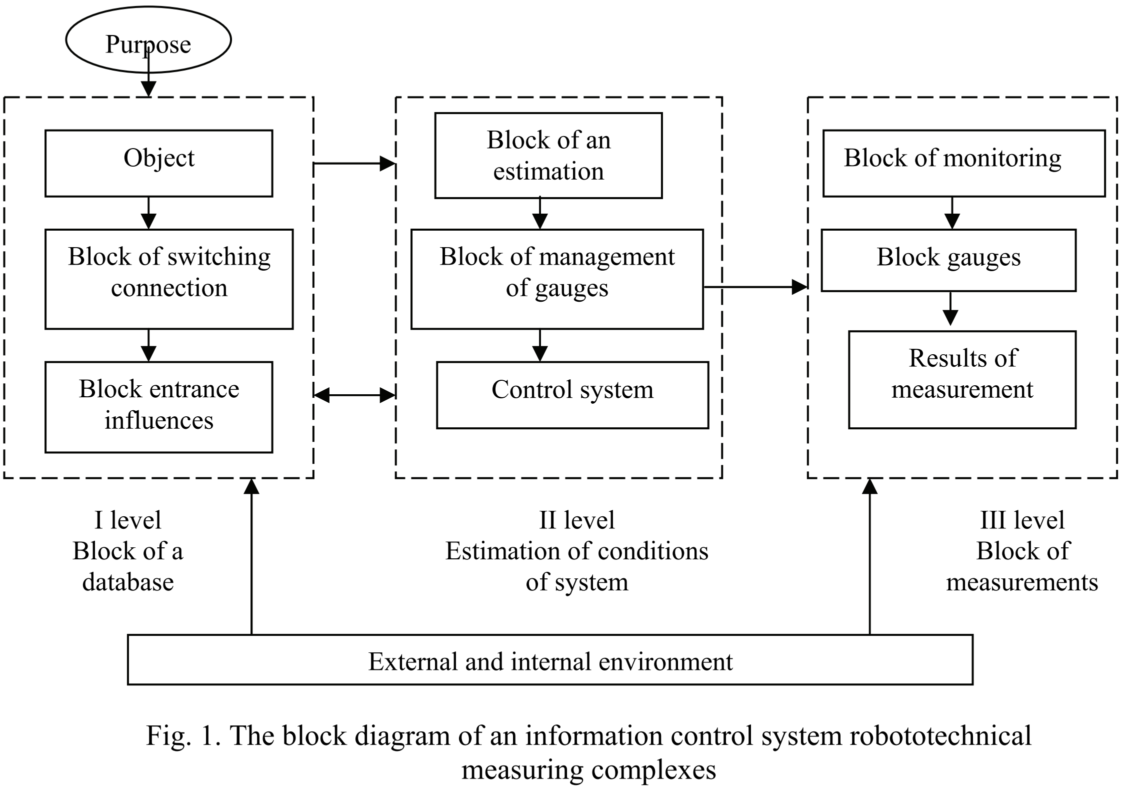

Fig. 1. The block diagram of an information control system robototechnical measuring complexes

The hierarchical structure has advantages before other structures. Features of her consist in that that [3]:
- the researched system works in interaction with all blocks,
- provides stability and reliability at interaction internal and an environment,

- it is supported by the software for processing results of measurement.

Continuous increase of [4] requirements to modern systems of automatic control regarding accuracy, speed, a range of change of variables and parameters results in essential complication of managing algorithms.

Capacity of modern computer facilities allows to model very uneasy systems about enough high accuracy of calculation in real time, that provides operative intervention in process of modelling in case of need and research of reaction of modelled system on action of the operator, and at connection of the computer through transitive devices to real physical object - research of properties and parameters of this object.

Thus, depending on areas and the purposes of use required parameters, characteristics of systems of automatics should be optimum, and also are universal, that will increase a spectrum of controlled objects. All this will allow to lower cost of created means of automatics.

We shall consider a linear problem of management of modes of measuring system. The general problem of optimum control can be written down as follows:

$$\dot{X} = A(t)X(t) + B(t)U(t) + G(t)v(t), \tag{1}$$

where $X(t) = [\Delta x_1, \Delta x_2, \Delta x_3, \varphi, \dot{\varphi}, \Delta t, \Delta K, \omega_1, \omega_2]$ – vector - column of a condition of system, $\Delta x_i, i = 1,2,3$ – a mistake of linear measurements on three coordinates, φ – a corner of turn of a mobile platform of coordinate x_3, $\dot{\varphi}$ – angular speed of a measuring tip, Δt - temperature error, ΔK – a mistake of basing of object of measurement on a rotary table, ω_1 – linear acceleration, ω_2 – angular speed of a rotary table, $v(t)$ – a vector of casual entrance indignations, $A(t)$ – a matrix of a condition of system, $B(t)$ – a matrix of management, $G(t)$ – a matrix of the output, consisting of the appropriate factors of the differential equations of the first order which describe dynamics of measuring system.

Synthesis of optimum control can be carried out by the decision of algebraic matrix equation Ricatti with use of criterion of an optimality:

$$J = 1/2\int_0^t (x'Qx + u'Ru)dt \tag{2}$$

where Q – positively halfcertain a matrix, R – positively certain matrix.

Elements of matrixes Q and R get out so that to reflect allowable limits variable conditions and managements u. Thus $Q = C^T C + A^T C^T T_з^2 CA$, $R = B^T C^T T_з^2 CB$, where T – transposing, $T_з$ – a constant of time of transient of the closed system.

Thus the law of optimum control will look like:

$$u(t) = -kx(t), \tag{3}$$

where $-k = R^{-1}B^t P$ – a matrix of factors of a regulator.

The matrix P is the decision of algebraic matrix equation Ricatti :

$$PA + A^t P - PBR^{-1} B^t P + Q = 0 . \qquad (4)$$

In this case all variable conditions x should be accessible to measurement as management is carried out on all variable x.

However his practical realization [5] is connected to the known difficulties caused basically by the big dimension of a decided problem . Quantity of operations which are necessary for executing for calculation of factors of a regulator k, approximately proportionally n^6. Definition of optimum control in practice is connected to calculation of parameters of a regulator at each change of a mode robototechnical a complex which causes respective alterations of factors of matrixes A and B models. Therefore with a view of optimum control robototechnical a measuring complex application of effective methods of decomposition of initial systems is required. In the given work calculations on full models robototechnical a complex which results are accepted as reference are used. Thus accuracy of the decided approached problems of optimum control and their speed are analyzed.

In a class of allowable managements we shall include any measuring values of a vector function u dimension m at each moment of time, satisfying the requirement $u \in U$.

Values of phase variables also are limited to allowable areas $x_1 \in X_1$ and $x_2 \in X_2$ dimensions accordingly n_1 and n_2. At $\varepsilon \to 0$ we receive:

$$\frac{dx_{1x}}{dt} = A_{11} x_{1s} + A_{12} x_{2s} + B_1 u,$$
$$0 = A_{21} x_2 + A_{22} x_{2s} + B_2 u . \qquad (5)$$

Having expressed from the second level $x_{2s} = -A_{22}(A_{21} x_{1s} + B_2 u)$, we shall receive model of a slow subsystem:

$$\frac{dx_s}{dt} = A_s x_s + B_{s1} u, \text{ at } x_{1s} = x_s , \qquad (6)$$

Change of fast management can be presented [6]: $u = u_f - u_s$.

Hence the model of a fast subsystem will look like:

$$\varepsilon \frac{d(x_2 - x_{2s})}{dt} = A_{21}(x_1 - x_{1s}) + A_{22}(x_2 - x_{2s}) + B_2(u - u_s)$$

or $$\varepsilon \frac{dx_f}{dt} = A_{22} x_f + B_2 u_f . \qquad (7)$$

Thus it is taken into account, that $x_1 - x_{1s} = x_1 - x_s \approx 0$.

Dynamics of a slow subsystem can be described also in the stretched time scale: $\tau = (t - t_0)/\varepsilon$.

As on an interval t it is accepted $x_1 = x_s = const$, $u_s = const$, system (7) can be written down as:

$$\frac{dx_1}{d\tau} = \varepsilon(A_{11}x_1 + A_{12}x_2 + B_1u),$$
$$\frac{dx_2}{d\tau} = \varepsilon(A_{21}x_1 + A_{22}x_2 + B_2u).$$

Thus, phase variable initial system can be with accuracy: $x_1(t) = x_s(t) + 0(\varepsilon)$,

$$x_2(t) = x_{2s}(t) + x_f + 0(\varepsilon) = -A_{22}^{-1}A_{21}x_s(t) + x_f\left(\frac{t-t_0}{\varepsilon}\right) + 0(\varepsilon). \quad (8)$$

It is necessary [6] to define small positive parameters. Basic difficulties of introduction of small parameters in system of the differential equations are well-known. There is no yet theoretically proved uniform point of view at the choice of small parameter.

In the received expressions it is supposed, that dimension of managing influence of each of subsystems u_s and u_f remains to equal dimension of managing influence of full model which can be presented as:

$$u(t) = u_s(t) + u_f + 0(\varepsilon). \quad (9)$$

Hence generally the control system can have both slow, and fast management.

The conclusion. The block diagram of an information control system is developed on the basis of modern information technologies which is applied in robototechnical complexes allows to reach maximum exact measurement of geometrical parameters of object. Process of measurement in given robototechnical a complex consists not only in repeated measurement of surfaces, but also provides at performance of each detour of details to estimate result and his comparison with previous.

References

1. *Поспелов Г.С.* Искусственный интеллект – основа новой информационной технологии. – М.: Наука, 1988. – 246 с.
2. *Тугенгольд А.К., Носенков Д.А., Коротков О.Е.* Организация интеллектуального управления технологической системы // СТИН.– 2001.– №11. – С.3-8.
3. *Лукьянов А.А.* Реализация распределенной системы управления для интеллектуального мобильного робота // Приборы и системы. Управление, контроль, диагностика. – 2004.– №10. – С.13- 19.
4. *J.Robert, D.K. Tran.* Modelling & Simulation of Electrical Machines & Power System / Elsevier Science Publishers B.V. (North-Holland). IMACS, 1988.
5. *Богатырев Л.Л.* Диагностика аварийных состояний электроэнергетических систем. СУПИ, 1983.
6. *Карелин А.Н.* Применение современных математических методов для синтеза субоптимального закона управления в РМВ // Приборы и системы. Управление, контроль, диагностика. – 2000.– №7. – С.29- 33.

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ADJUSTMENT OF TECHNICAL SIGHT SYSTEM WITH THE USE OF REFERENCE POINTS REFLECTION FROM MIRROR SURFACE

Introduction

Modern robotics is unthinkable without the tools of intellect and adaptation. The given tools allow to be oriented to the robotics complex in space and chosen the most optimum trajectory of approach to the set detail. System of Technical Sight is the most main component part of the given system (STS). As is generally known STS consists of three basic parts of the TV camera, firmware complex, processing software.

The TV camera executes the role of commentator of working stage and also sends a television signal in a computer. A firmware complex is symbiosis of hardware solutions(vehicle decisions) such as pays of video capture and so specially developed software products. Last of peat-time of transformation it is the specialized programmatic decisions, directed on treatment, analysis of the got image and also selection of the required objects.

Most application of System of Technical Sight was got wherein artificial perception and determination of their geometrical parameters is needed.

Determination of geometry (it is ordinary sizes and distances) takes place as follows. On the recognized object getting in the area of review of the TV camera, certain characteristic points (they can be the beforehand marked, for example specially created markers) distances between which are known are selected. Further, on a corner from which these elements are visible to the TV camera (I.e. actually these corners are proportional to distance from the center of photosensitive PSZ-matrix in the TV camera to the point the image of the selected element of frame got in which), it is possible, deciding the system of equalizations with limitations, to find distance to the object. It allows finding the matrix of the transition "TV camera- object". It is then necessary to conduct transformation of co-ordinates by the matrix of transition "capture the equipment- TV camera" and we get a having a special purpose point for motion.

Target setting

There is a plenty of methods and algorithms of analysis of images and pattern recognition, different by the variety of approaches to the decision of this problem, used mathematical vehicle, by complication of calculable procedures, different degree of practical realized. Each of such methods and algorithms possesses the dignities and failings, region and terms of application. Therefore in practice a priori choice of concrete approach appears very difficult.

Taking into account possibility of receipt of multispectral and multiperespektive information, it is suggested to form the high-informing looked images (by interconnecting entrance data) after and generalized functions of likeness (by joint treatment of set of the systems of signs). Within the framework of the first problem it is necessary to promote informing of each of channels (above all things, spectral) by potochechnih transformations of type of normalization of histograms, increase of contrast, removal of noises by means of a different type of filtration, and also local transformations for underlining of contours and forming of graphic data.

It is expedient to carry out the further adding up of multispectral images in the proportion determined is adaptive on the basis of analysis of informing of fragments of got from the proper channels. Thus the basic requirement consists of that the resulting synthesized image maximally displayed the information got from the sensors of every channel, and, at the same time, the form of displaying was usual for a statement

Fig.1 Basic procedures and methods of pattern recognition.

Other approach is possible at the same time, basic on ability of man to select from the field of supervision (videoframes) fragments proper to the certain criteria and parameters.

In particular, the multicolour is possible, line-after-line, dotted, frequency-modulated, and also other presentation of initial multichannel information.

Task solution

At the decision of the given problem it is necessary to analyze the data (images) arrays, got different systems of supervision (including in different spectral ranges) for determination of location and class of objects being in eyeshot of. Thus, dynamic information from the set of various sensors about the looked three-dimensional stage after is entrance data, and spatial co-ordinates (it is possible also scale, orientation and etc.) and classes of objects being in the field of supervision must be a weekend . Decisions consists of a few stages:

1 Registration of data arrays, got from the sets of sensors, their preliminary treatment with the purpose of correction, attachments to edge to the system of co-ordinates and dr. (forming of the primary system of signs);
2 Forming of set of the second systems of signs on the basis of joint treatment of initial (primary system of signs) and standard information;
3 Interconnecting second systems of signs on the basis of joint treatment of initial (primary system of signs) and standard information;
4 Interconnecting of the second systems of signs for determination of the generalized function of likeness of reference patterns recognizable and;
5 Estimation of measure of likeness and decision-making of about belonging of objects in the field of supervision to some one from the set classes.

We will consider the case of fragment treatment of initial information, not accenting attention on a spatial surplus on the field of supervision. The registered multidimensional data array depends in general case from two-dimensional spatial co-ordinates in the field of sight, foreshortenings of supervision, time, spectral range.

Without limitation of community in future we will leave dependence only on discrete bidirectional spatial co-ordinates r_i . Then after preliminary treatment of the fragment of n digital representation of the field of supervision centered on an arbitrary object we get the system of primary signs $f_n(r_i)$. Standard information of class *k* to also appears as values of counting out of digital representation of $h_k(r_i)$.

Forming of the systems of the second signs is offered to carry out by five methods:

1. Correlation of images $g_{kn}^{(1)}$ of the processed fragment $f_n^{(1)}(r_i)$ and standard $h_k^{(1)}(r_i)$

$$g^{i}_{kn} = \sum_{i=1}^{N} G^{(1)}\left[f^{(1)}_{n}(r_i), h^{(1)}_{k}(r_i)\right] = \sum_{i=1}^{N} f_n(r_i) * h_k(r_i) \quad (1)$$

where the N is the number of images.

2. Correlation of over falls of brightness $g^{(2)}_{kn}$ of the processed fragment $f^{(1)}_{n}(r_i)$ and standard $h^{2}_{k}(r_i)$ got as a result of differential treatment, accordingly $f_n(r_{i)}), h_k(r_i)$.
3. Correlation of contour images $g^{(3)}_{kn}$ of the processed fragment $f^{(3)}_{n}(r_i)$ and standard $h^{(3)}_{k}(r_i)$, got accordingly from $f^{(2)}_{n}(r_i)$, $h^{(2)}_{k}(r_i)$ as a result adaptive threshold treatment on the local isotropic neighbouring of every counting out r_i.
4. Correlation of contour images $g^{(4)}_{kn}$ of the processed fragment $f^{(4)}_{n}(r_i)$ and standard $h^{(4)}_{k}(r_i)$, got accordingly, from $f^{(2)}_{n}(r_i), h^{(2)}_{k}(r_i)$ as a result adaptive threshold treatment on the local anisotropic neighbouring of every counting out r_i in the direction of maximal overfall of brightness $f_n(r_i)$, $h_k(r_i)$. Unlike ordinary isotropic threshold treatment, including adaptive, a similar anisotropic procedure allows to select the points of maximal overfall of brightness of images exactly, that provides high coherent and stability of scope lines.
5. Logical comparison of the fields of directions is maximal overfall of brightness of the processed fragment and standard

$$g^{(5)}_{kn} = \sum_{i=1}^{N} G^{(5)}\left[f^{(5)}_{n}(r_i), h^{(5)}_{k}(r_i)\right] \quad (2)$$

where - $f^{(5)}_{n}(r_i)$, $h^{(5)}_{k}(r_i)$ monogradiating images every counting out of which characterizes direction of maximal overfall of brightness in neighbouring of proper pixels $f_n(r_i)$, $h_k(r_i)$.

Further interconnecting of second signs, as it was already marked, directed on determination of the generalized function of likeness of reference patterns recognizable and, steady to a different kind to distortions, noises and hindrances, on the basis of two approaches. Joint logical (or algebraic) comparison of values of a few (in the given work the two) systems of the second signs is carried out in first case

$$p^{(1,m)}_{kn} = Q^{(1)}\left[g^{(l)}_{kn}, g^{(m)}_{kn}\right], \text{ где } 1 \le 1 \ne \text{m} \le 5 \quad (3)$$

In second case - comparative analysis to adding up of counting out of regenerate images of the processed fragment and standard

$$q^{(1,m)}_{kn} = \sum_{i=1}^{N} Q^{2}\left[G^{(l)}\left[f^{(l)}_{n}(r_i), h^{(l)}_{k}(r_i)\right], G^{(m)}\left[f^{(m)}_{n}(r_i), h^{(m)}_{k}(r_i)\right]\right] \quad (4)$$

Concrete the generalized functions 3 and 4 at the fixed site of fragment in the field of supervision (fixed value of parameter of n) are the proper measure of closeness of reference patterns recognizable and.

The offered methods of pattern recognition are approved on the example of the low-sized image processing of three classes. On the basis of developed in accordance with a 1-4 programmatic-algorithmic providing the measures of closeness and generalized measures of closeness are certain. For estimation of efficiency of different functions of likeness the mean values and standard deviations of measures of closeness are calculated, accordingly, for objects belonging (n=k) and not belonging to the sought class after. These sizes characterize the location and size of ranges of definition of classes of objects in space of signs. It is natural, that discriminate properties of deciding functions, in same queue, are characterized by the relations $r_{kn}^{(1)} = m_{kk} / m_{kn}$ and $r_{kn}^{(2)} = (m_{kk} - m_{kn})/(\sigma_{kk} + \sigma_{kn})$.

Value of the given parameters are represented below (Table 1):

Table 1

	m_{kk}	m_{kn}	σ_{kk}	σ_{kn}	$r_{kn}^{(1)}$	$r_{kn}^{(1)}$
$g_{kn}^{(1)}$	0.95	0.86	0.025	0.002	1.10	3.29
$g_{kn}^{(2)}$	0.72	0.60	0.024	0.021	1.19	2.48
$g_{kn}^{(3)}$	0.65	0.55	0.010	0.014	1.19	4.33
$g_{kn}^{(4)}$	0.43	0.35	0.002	0.023	1.22	3.0
$g_{kn}^{(5)}$	0.45	0.34	0.018	0.009	1.30	4.08
$g_{kn}^{(1.5)}$	0.68	0.30	0.41	0.012	1.40	4.85
$g_{kn}^{(4.5)}$	0.3	0.23	0.006	0.01	1.33	4.75

Conclusions

Thus application of differential adaptive treatment, is special taking into account directions of overfalls of brightness of images of the looked stages after, allows to form steady to different distortions, noises and hindrances of the system of the second signs. The offered methods of forming of the generalized functions of likeness on the basis of joint treatment of values of the systems of the second signs provided the substantial increase of discriminate properties of deciding functions at recognition of the real small objects.

References

1. Kovalevskiy V.A. Methods of optimum decisions in artificial perception.- M.: Science, 1976
2. Pratt W. Digital Image Processing - Wiley - Interscience, New York, 1978. - Vol. 2.
3. Borzov S.M., Kozik V. I., Potaturkin O.I. Image Representation in the Form of Lines of Maximal Brightness Jumps in Pattern Recognition Problems.

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INTELLECTUAL CONTROL SYSTEM OF FOCUSING HEAD TURNING DRIVE IN THE SYSTEM OF LASER TWO-BEAM WELDING ON THE VARIOUS PATH

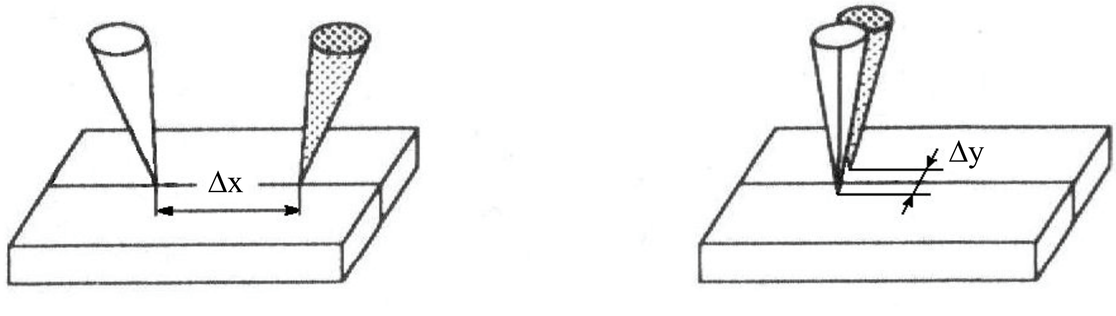
The way of welding by the two-beam laser on a curvilinear contour of metals of different thickness is offered. Formation of two-beams of the laser, and also updating of position of beams of the laser is shown. The control system of focusing head turning drive is developed. Technological features of two-beam laser welding on distribution of energy in a welding bath are submitted.

Introduction. Unique properties of laser radiation - high monochromaticity and coherence, low divergence have allowed to create a perspective kind high concentrated a thermal energy source. A beam of the laser as the welding energy source, has opened new technological opportunities in the theory and practice of welding processes. Now the laser is a unique accessible welding energy source which under atmospheric conditions allows to generate density of capacity more than 10^6 W/sm^2 realizing a mode deep welding. [1,2]

One of directions of development of hybrid laser technologies of processing of materials is the technology of two-beam laser processing of materials, i.e. such way of welding at which formation of a welding bath occurs at simultaneous influence of two beams of the laser.

Statement of task. To develop an intellectual control system of a drive of focusing head of a laser technological complex at high-speed welding thin sheet materials and details with various thickness on a curvilinear contour.

The decision of task. There are some ways of material processing two beams consecutive (fig.1,a) and parallel (fig.1,b) which are determined by various geometrical arrangements of two beams of the laser be relative each other and performance of various functional tasks at laser processing materials [3, 4].

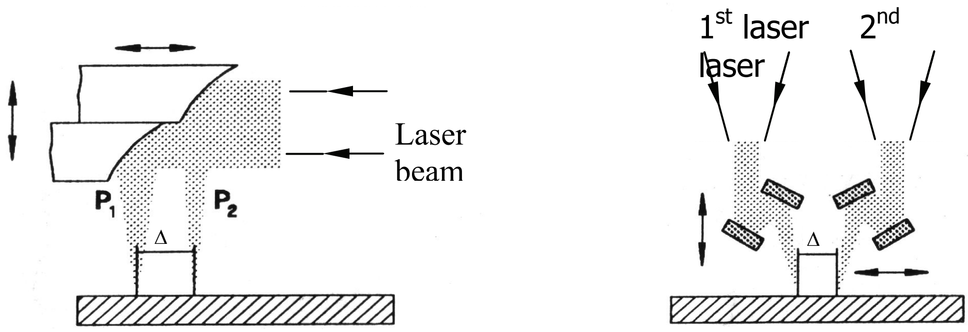


a) b)

Fig.1. Various kinds of two-beam laser processing
a) Consecutive laser processing; b) parallel laser processing

The choice of a way of processing by two laser beams is defined(determined) by a particular kind of laser technology - welding, surfacing, heat treatment and the technological tasks facing to welding.

Formation of two laser beams can be realized by various ways (fig.2).



a) b)

Fig.2. Function charts of formation of two laser beams
a) One laser is used; b) two lasers are used

Now technological lasers are developed, on an output from which resonator there are simultaneously two laser beams.

Technological features of two-beam laser welding

The two parallel beams welding. The two parallel laser beams welding is used for welding details with different thickness (fig. 3) to reduce pore-formation, to eliminate burn-throughs.

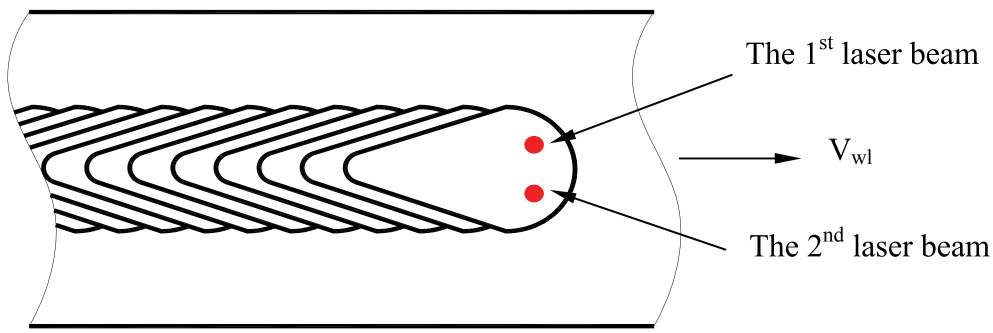


Fig.3. Laser welding with use of two parallel laser beams

At welding materials with different thickness (fig.4), capacity of the second beam can be much lower than capacity of the first beam that reduces probability of burn-through formation.

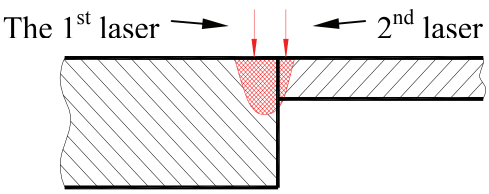


Fig.4. Laser welding materials with different thickness by two parallel beams

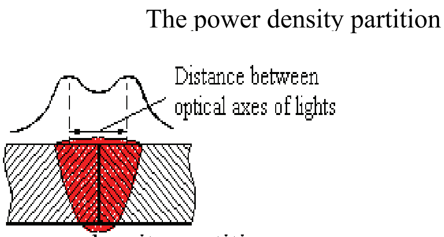


Fig.5. The power density partition

The two parallel laser beams welding becomes especially effective, when it is necessary to reduce a high-intensity central part of a welding thermal source (for example, shit-mill materials butt welding due to change of distance between optical axes of the laser beams (fig. 5).

The power density cut partition of a welding seam which is a result of the synchronous two parallel laser beams operation renders positive effect on a seam formation, especial while the welding of shit-mill materials.

The two consecutive laser beams welding

The welded seams formed at high speeds of welding, do not always meet all welding connection quality requirements, owing to existence of process instabilities. At the high speeds of welding when there is a hydrodynamic instability of a liquid phase of a surface of a melt bath, resulting formation of "hump" or occurrence of defects, it is possible to use consecutive beam influence of various capacity (fig.6).

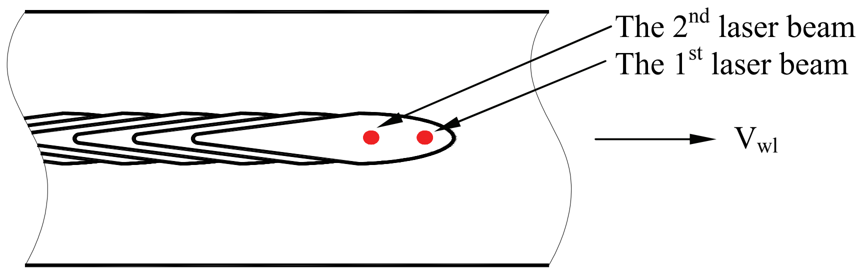
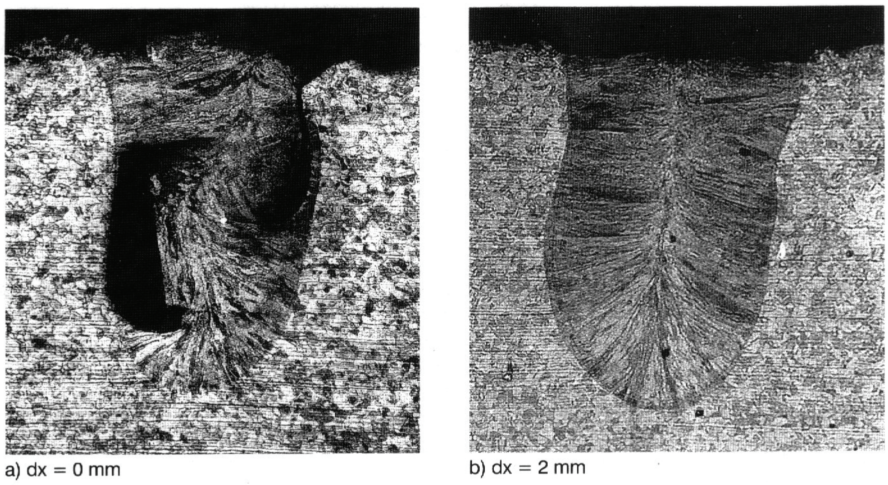


Fig. 6. Two consecutive laser beams welding

The distance Δx (the distance between centers of beam diameters) influences on the fusion process dynamics during two consecutive laser beams welding. Optimization Δx allows to increase the maximal speed of welding on 50 % at which faultless welded connections can be received. On rice 7 images macrostructure seams of steel 10X6CrNiTi18, received are submitted by two-beam laser welding by consecutive beams; at speed of welding V_{wl} = 433 mm / sec and total capacity P_L = 7kw ($P1 = P2$ = 3,5 kw).



a) b)

Rice 7. the macrostructure of seams of steel 10X6CrNiTi18,
a) Δx = 0 mm; b) Δx = 2 mm

Feature of two-beam processing at movement on a random contour is necessity of position correction of the laser beams at a processing course direction changes.

For correction of the position of beams the additional engine established on system of laser beams focusing which makes turn of focusing head is used in such a manner that position of laser beams corresponds to a direction of processing.

For definition of focusing head rotation signals of the task of position for coordinates *X* and *Y* are used. The signals of the task act on the arithmetic-logic device (ALD) which calculates the task signal of the focusing head rotation in real time. The block diagram of turning focusing head control is submitted by a drive on fig.8.

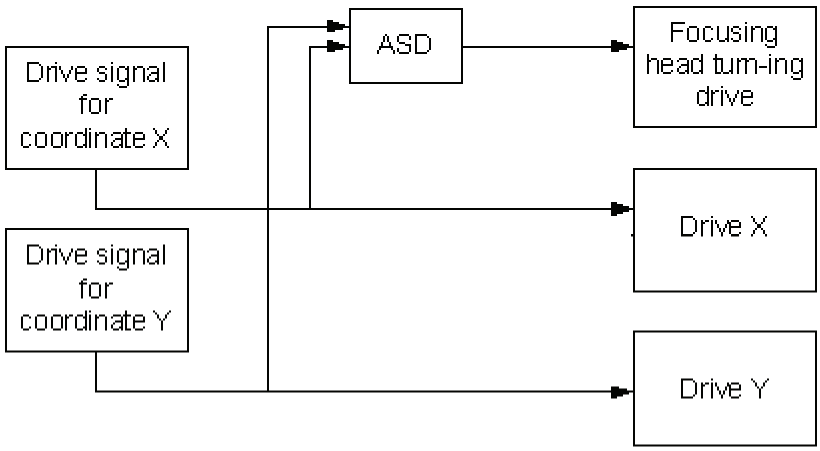


Fig.8. A control system of a drive of turn of focusing head

Quantization frequency of generating of adjusting task is determined by speed of processing and a steepness of change of a trajectory of the head movement.

Conclusions. In given article the method of laser two-beam welding on a random contour is developed at welding details of various thickness. The control system of the executive mechanism of turn of focusing head is given. Application of the given method allows to receive a better welded seam of an any contour at high-speed welding thin metals, welding of materials with different thickness and deep welding of thick materials.

Keywords: Laser two-beam welding, a curvilinear contour, control of the focusing head turn.

References

1. *Григорьянц А.Г., Шиганов И.Н.* Лазерная сварка металлов. – М.: Высшая школа.-1988. – 207с.
2. *Дьюли У.* Лазерная технология и анализ материалов. - М.: Мир.-1986.-488 с.
3. *Григорьянц А.Г.* Основы лазерной обработки металлов. М.: Машиностроение.-1989.-301с.
4. *Григорьянц А.Г., Шиганов И.Н., Чирков А.М.* Гибридные технологии лазерной сварки. М.: Изд-во МГТУ им. Н.Э. Баумана.-2004.-48с.
5. *Visitin, A.*, Mathematical models of solid-solid phase transitions in steel, IMA J. Appl. Math.39.-1987.

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USE OF INDUCTIVE TRANSDUCERS IN THE LOW-FREQUENCY OSCILLATION SECTION OF BRIDGE CONSTRUCTIONS

The inductive transducers work used for study of mechanical vibrations of large-sized constructions is considered. Is shown, that the adjusting of a conversion coefficient allows using inductive transducers at registration of the constructions oscillations on frequencies below than resonance frequency of transducers. Thus transformation of oscillations speed to displacement provides a capability to recover an original signal displacement on a noise background and increases the veracity of definition of construction the dynamical characteristics in conditions of their exploitation.

Introduction

Builders of bridge constructions face one of the basic problems – the maintaining of reliability and durability. This problem should fix while the project is in process and after, when the exploitation has begun. During the exploitation the regular check-up and technical analysis are provided, the condition is evaluated and the decisions about the further exploitation are made. The technical analysis of bridge-type constructions requires range of different researches and check-ups, including static and dynamic testing. The research of dynamic characteristics of large-sized constructions reflects not only scientific interest but also an important application technical task. During the exploitation the constructions have to undergo at first different dynamic loads. If the frequency of those loads is equal to the frequency of the constructions, this may result to an anticipatory loss of careered capacity, because of the uncontrolled increase of amplitude for forced oscillation. Hence the recommendations for the exploitation regime are based on the results of dynamic testing of constructions and it enables us to reach a maximum reduce for the influence of dynamic loading of the unwanted range of frequencies [2, 5]. Besides that the numeric values of the dynamic characteristics of constructions give the important information about their technical condition [7]. For instance, in order to get the evaluations of intensive-deformed condition of bridge-like constructions [3, 7] the parameters of natural and forced oscillation of constructions (amplitudes, periods, frequencies, logarithmic decrement of loading, etc) are registered and analyzed.

During check-ups and dynamic research of constructions, the registration of forced mechanic frequencies is made using variable transducers: inductive, piezoceramic, capacitive etc [6, 7]. However, conditions of research conducts give the restriction for their using, especially in cases of wide range of mechanic biases (displacements). This is related to the fact that all types of transducers have different characteristics of exploitation, as sensity, frequencial and dynamic range of transformation of mechanic values into electric signal. Usually high-sensitive transducers have an insignificant dynamic range of transformation, if the dynamic range is wide – the sensity of transducers is very low. In the same time the results of processing for a signal of low-frequency oscillation is highly influenced by irregularity of their frequency characteristic. Regarding the final values of amplitude of new natural mechanic oscillation depending on correlation of its frequency and resonant frequency of the current transducer, non-lineal effects may arise and affect the results of processing of the spectrum of the registered signal.

One of the transducer types that are used for the registration of mechanical low-frequency oscillation is a speed seismic inductive transducers. Their analysis was made in article [1]. The calculations were made and they were showed that if the measuring system is situated on the surface of the object the measured electromotive power (EMP) is proportional to the speed of the current surface oscillating. In the same time the results of modeling state allowed to conclude that almost all frequency range is acceptable for taking measurements of the frequencies of oscillation, including section of natural resonance of the measuring system. However, if the oscillation develops with high amplitude, the influence of non-linear section of amplitude-frequency characteristic of measuring system will take place.

It is showed in the fixation of additional frequencies in the spectrum of oscillations, which are multiple to natural frequency of oscillation of the researched surface. In the current study the possibility of the inductive transducers application for frequencies lower than their natural resonant frequency is shown. The extension method of the frequency range of transducers transformation correction coefficient will be developed, taking into consideration the preliminary knowledge of resonant vacillating frequency of the construction.

Results

The research of the inductive transducers which was held in work [1] helped us to obtain the expression for EMP that arises in the output of the transducer, which is situated on the surface of the vacillating item (product). It was shown that the coefficient of the proportionality between the amplitude of speed of the surface and the amplitude of EMP, which depends on the frequency, is described as:

$$P(\omega) = \frac{\lambda\omega^2}{\sqrt{(\Omega^2 - \omega^2)^2 + 4\alpha^2\omega^2}}, \tag{1}$$

where λ is a coefficient defined by the constructive features of the sensor; Ω signifies natural vacillating frequencies of the measuring system; α signifies the coefficient of the fading of the measuring system; ω signifies the vacillating frequency of the current surface.

This leads us to further statement: if the measuring system has a significant fading then its conversional speed of oscillation of the moving surface within AMF at the frequencies starting from the resonance frequency and higher, will be almost equal. However, there will be some deviations if the frequency is lower than the resonant.

The main task of the research [8] is the improvement of method dynamic constructional characteristics determination during which the preliminary dynamic loading helps to define the frequencies of arising oscillation and further adjustment of conversion coefficient of preliminary converter according to the defined frequency. Than the corrected conversion coefficient after the process of secondary dynamic loading of construction took place within the characteristics definition of the natural (free) and forced frequencies. The latter reduces errors (lapses) of the measurement of dynamic constructional characteristics and of constituting decisions about the condition. Hence the complexity, duration and research expenses are reduced but the manufacturability induces. This cause-and-effect relation between the compounds, which depend on technical results as well, is further explained. At dynamic loading influences the construction the oscillation take place. It is well-known that the parameters of the frequencies that are used to determine dynamic characteristics of construction can be determined with minimal error in this case: when the frequency of the registered oscillation equals the frequencies in the linear section of amplitude-frequency characteristic of preliminary converter (transformer) which covers higher frequency range than its resonant frequency and its transformation coefficient has constant value (K_m).

In the case when vacillating frequency of constructions is higher or equal to resonant frequency ($f \geq f_m$), the electrical signal in the output of the transformer (for instance, inductive transformer of speed) is described as:

$$U(t) = K_m \cdot v(t), \quad f \geq f_m \quad , \tag{2}$$

where K_m = const – coefficient for transformation of frequencies which is equal or higher than the resonant frequency; $v(t)$ – speed of frequency changing in time.

Formula (2) enables us to determine the speed of constructional frequency time at its dynamic loading:

$$v(t) = \frac{U(t)}{K_m}, \qquad f \geq f_m . \tag{3}$$

For lower resonant frequencies of preliminary transformer its amplitude-frequency characteristic has a non-linear character, hence the coefficient of transformation depends on the frequency. Both theoretical and empirical (experimental) studies of inductive transformers of speed proved that the transformation coefficient (K_f) in section of amplitude-frequency characteristic lower than resonance frequency and it is described by the following formula

$$K_f = kf^2, \quad 0 < f \leq f_m , \tag{4}$$

where k is a coefficient of proportionality, which doesn't dependant on the frequency;
f_m - is a resonant frequency of the inductive transformer.

For frequencies $0 < f \leq f_m$ formula (4) may be written as

$$K_p = \frac{K_{pm}}{f_m^2} f^2 , \quad 0 < f \leq f_m^2 \tag{5}$$

From formula (5) we can state that for frequencies lower than the resonant frequency of transformer the correction of amplitude-frequency characteristic of transformation coefficient may be added. Equalization can be made when frequencies are lower than the resonant frequency; hence the correction of the amplitude of the registered signal for natural (free) and forced frequencies is possible during the dynamic loading of constructions.

In case of repeated loading the electric signal in the output of the transformer (f.e. inductive speed transformer) for frequencies lower than resonant frequencies ($0 < f \leq f_m$) within correction of transformation coefficient equals

$$U(t) = K_f \cdot v(t), \quad 0 < f \leq f_m \quad , \tag{6}$$

or

$$U(t) = \frac{K_m}{f_m^2} f^2 v(t), \quad 0 < f \leq f_m \quad . \tag{7}$$

Formulas (6) and (7) help to determine the alteration of speed of construction oscillation the dynamic loading within the actual value of transformation coefficient

$$v(t) = U(t) \frac{f_m^2}{K_m f^2}, \quad 0 < f \leq f_m ,$$

or
$$v(t) = \frac{U(t)}{K_f}\ ,\ 0 < f \le f_m\ . \qquad (8)$$

At registration of forced and natural oscillation of constructions with determination of frequency and correction of transformation coefficient within preliminary loading it is possible to reduce significantly the error of determination of dynamic characteristics of constructions during the registration and processing of vacillations from the secondary dynamic loading. Hence it will help to reduce errors in formulating decisions about the condition and about the careered ability of constructions.

Undoubtedly, the use of preliminary dynamic loading of constructions within determination of frequencies of new oscillations and within the coefficient correction to a certain frequency, is an efficient method of reducing errors of determinating characteristics of constructions. This method improves the manufacturability while it requires fewer technical equipment, less labor input, and less expenses invested in research.

Conclusion

The current study has shown that coefficient of correction for transformation of inductive transducer enables to use it for researching natural and forced oscillations within frequency which is lower than the resonant frequency of measuring system (the transducers). The correction is done while taking into consideration the transformation coefficient of sensor within the resonant frequency and character of changes in transformation coefficient within the frequencies lower than the resonant. As it was shown above, the transformation coefficient within frequencies lower than the resonant depends the frequency. Hence if we determine the resonant frequency of construction oscillation before, it gives us an opportunity to determine the real transformation coefficient of the current resonant frequency. Knowing the real transformation coefficient enables to reproduce exactly all the characteristics of construction oscillation, like amplitude of speed, amplitude of bias, etc.

References

1. *Бабак В.П., Филоненко С.Ф., Калита В.М.* Моделирование динамических характеристик крупногабаритных конструкций //Технологические системы. - № 2(22), 2004.- с.31-36
2. Барашиков *А.Я., Малышев А.М.* Оценка технического состояния строительных конструкций, зданий и сооружений .- К.: НМЦ Держнаглядохоронпраці України, 1998.-232 с.
3. *Барченков А.Г.* Динамический расчет автодорожных мостов.-М.: Транспорт, 1976.-199 с.
4. *ГОСТ 28134-89 Е.* Сейсмоприемники электродинамические. Типы, основные параметры и технические требования.-М.: Изд-во стандартов, 1989.- 5 с.
5. *Делидзе Д.Е.* Испытания конструкций и сооружений.-М.:Высшая школа, 1975.- 252 с.
6. *Злочевский А.Б.* Методы регистрации и обработки результатов динамических испытаний конструкций.-М.: МИСИ, 1977.-84 с.
7. *Лучко Й.Й., Коваль П.М., Дем'ян М.Л.* Методи дослідження та випробувань будівельних матеріалів і конструкцій.-Львів: Каменяр, 2001.- 436 с.
8. *Бабак В.П., Филоненко С.Ф., Калита В.М., Корниенко – Мифтахова И.К.* Информативность параметров сигналов низкочастотных колебаний при использовании индукционных датчиков скорости //Технологические системы. - № 2(28), 2005.-с.19-23

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THE METHOD OF CONTROL OF FUEL EXPENSE OF AIRCRAFT BY USING OF A MAGNETOELASTIC TRANSFORMERS

In the article described the method of determination of fuel expense of aircraft from the condition of motion of solid in relation to the center of the masses considered. Using intellectual measuring elements based of magnetoelastic transformers builded in the construction of the controlled structural module as single whole, measure their state of loading and identify mass of object in a present moment of time, and by the known sizes of component aggregates of rocket, the location of resulting resultant rocket (center of the masses) determined in relation to the controlled axis of symmetry.

Actuality. In a process of aircraft designing, for example rockets, depending on a kind fuels is calculated a value of traction force and specific impulse.

The traction force (F) of engine equal to work of the pressure created by exhausting gases, on the area of output section of nozzle, instead of force of pressure of environment on that area. Efficiency of engine is estimated by his specific impulse I_{sp}, which has a few different units of measuring. One of the units is the traction divided by the complete of fuel expense per second (w), I.e.

$$I_{sp} = \frac{F}{w}$$

Another is effective speed of expiration C, divided by acceleration of gravity g, in this case

$$I_{sp} = \frac{C}{g}$$

A specific impulse is usually expressed in seconds (in the system of SI I_{sp} is measured in H s/kg or m/s), and in this case its value is equal to the number of kilograms of the traction which is obtained at combustion of one kilogram of fuel. The I_{sp} value depends on the factors row, mainly on the energy, selected at combustion of fuel, and efficiency of the use of this energy, in an engine.

The measurement of values of operating forces with the purpose of determination of result of co-operation bodies entering in the complement of aircraft is absent.

$$r_C = \frac{1}{m}\sum m_i r_i\,, \qquad m = \sum_i m_i\,.,$$

where i - number of material point,

m - mass of point.

The coordinates of center of the masses are the generalized coordinates for all systems. The impulse of the system of material points equal to product of sum of the masses by a speed of center. In general case a motion of body is determined as motion of his center of the masses and the motion of body in relation to the system of coordinates with beginning in the center of the masses and with axes parallel to the axes of the basic system of co-ordinates (in relation to the center of the masses). The number of strengths of a different fortitude, which stipulated a systems motion, can be great.

All these values are taken into account for developing of aircraft.

In real flights it is necessary to control an accordance of these parameters to the calculation (theoretical) values within the limits of possible declinations for providing of safety. It is comfortably to search resultant, attached in the center of the masses for a freely locomotive body, in relation to which determined a total moment.

analysis of existent decisions. We will take a rocket as object of research. It consists of the motive setting (engine and fuel compartment), control systems and guidance system, actual load and some auxiliary systems.

On the third law of Newton every action has opposite and equal on a size counteraction Mathematically this law expressed as equality of amounts of the *MV* motion = *mv*. From here obvious, that mass and speed are the informing parameters.

Complete dirigibility by an aircraft can be attained, if the dynamics of the system will be controlled. The well-known theses of dynamics of the system are based in laws: linear momentum, motion of center of the masses, moments of amount of motion, areas, manpowers (kinetic energy). At different assumptions can be the possible methods of control based on principle of Dalambert, consisting that at motion of the system in every moment of time of force of inertia of points of the system, active forces operating on the points of the system, and forces of reaction of communications are in an equilibrium, that:

$$\sum\left(-m_\gamma a_\gamma + P_\gamma + R_\gamma\right) = 0;$$
$$\sum M_0\left(-m_\gamma a_\gamma + R_\gamma\right) = 0.$$

where $-\boldsymbol{m}_\gamma$ are forces of inertia, $\boldsymbol{P}_\gamma$ - are active forces, $\boldsymbol{R}_\gamma$ - are reactions of communications.

With the use of the Dalambert-Lagrangs equalization principle of the possible points moving of of the system is taken into account

$$\sum\left(X_\gamma - m_\gamma \frac{d^2x_\gamma}{dt^2}\right)\delta x_\gamma + \sum\left(\mathrm{Y}_\gamma - m_\gamma \frac{\mathrm{d}^2\mathrm{y}_\gamma}{\mathrm{dt}^2}\right)\delta \mathrm{y}_\gamma + \sum\left(\mathrm{Z}_\gamma - \mathrm{m}_\gamma \frac{\mathrm{d}^2 z_\gamma}{dt^2}\right)\delta z_\gamma$$

where $\delta\boldsymbol{x}_\gamma$, $\delta\boldsymbol{y}_\gamma$, $\delta\boldsymbol{z}_\gamma$ - - possible moving of points of the system.

With the use of the Hamiltons principle, the impulse of the system of material points is taken into account

By using of the equation, an impulse of the system of material points is taken into account.

Under an elementary impulse of a force (P) for an interval of time (*dt)* make a vector equal to product of force by an interval of time, i.e.: $\boldsymbol{Pdt}$. In accordance with the law of motion the differential of amount a motion of point for the interval of time (*dt*) equal to the elementary impulse for that interval of time of all forces operating on a point.

$$d(m\upsilon) = Pdt$$

or in projections on the axis of coordinates

$$d(m\upsilon_x) = Xdt,\ \mathrm{d}(\mathrm{m}\upsilon_y) = Ydt,\ \mathrm{d}(\mathrm{m}\upsilon_z) = Zdt,$$

where R- resultant all forces operating on a point.

The analysis shows that one of initials values for the decision of these equalizations is mass of the controlled object. To define this size in the difficult conditions of action of different forces it is necessary to control every component part of aircraft separately, because action of the same force on different bodies is different because bodies in regard to such influence possess a different quality. This quality is named the heaviness of bodies. Then mass of body is the measure of his heaviness.

Existent checking systems, for example, guidance system, determines position and course of rocket and gives out to the control system necessary information for the management by its flight. The flight control carried out by small steering engines or by changing of direction of vector of traction of basic engine.

In the system are usually used of guidance gyroscopes for measuring of changes in the orientation of rocket, acceleration sensors for measuring of changes of speed, radio equipment for determination of position of rocket and airborne computer for making of commands of management by flight. It is developed the laser gyroscopes, in which used the Dopplers effect for measuring of rotations and accelerations.

Unresolved problems. It is missed now the control of change a mass of fuel, center of the masses, site of resultants of rocket is absent in the existent systems, that a few are reduced by exactness of control and management by the orientation of rocket, implementation of to change direction of motion of space vehicle. In a process of flight the environment change continuously, at planning of rocket to the designers not having the real measurements of the indicated changes, it is necessary to settle for compromises.

Target setting. On the example of decision of task of control of expense of fuel to explore possibility of increase of efficiency of control of change of the loaded state of component parts and rocket on the whole in the process of flight.

Statement of basic material. Obviously, that the decision of set problem is possible only at building of sensible elements in turning pins, in gimbal suspension or in other force passing constructions of aircraft as single whole. The optimization of structural elements of sensors of force from standpoint of minimization of the error conditioned by reverse influence on an object is thus executed. It is achieved the increase of informing due to optimization of the measuring magnetoelastic module, consisting of the sensible element oriented in any direction, processor block and specialized intrinsically safe source giving the power only to the sensors active for this direction of rocket by an intellectual switchboard.

The value of the controlled size is determined by particular solutions of the Cramer equations on condition that sensible elements do not require the additional calibrating [1, 2]. These conditions allow to optimize the measuring system from standpoint of set of elements, their weight and self-descriptiveness.

So, for example, for large rocket engines, at which connection of rocket airframe and nozzle executed from the great number of thin layers of steal and heat-resistant rubber, it is necessary to set identical in all directions to sensors special construction. At the turn of nozzle on a few degrees in any direction the entering force will get a sensor of force which proper to this change. He will carry out measurement, which the expense of fuel and direction of vector of traction is determined on the basis of.

It is known that the feature of absolutely solid is that the point of force application operating on him can be carried in any other point on a line which the vector of force (line of action of force) belongs to, and the result of action of force will not change here.

The point of force application can be carried also in direction, perpendicular to the line of action of the force, attached in a former point, and force attached in a new point and directed in an opposite side. By such transfers there are all forces, operating on a solid, except for the forces included in pair, can be taken in one point.

Then it can add vectorially them and get resultant.

As a rocket is not absolutely a solid, it is expedient in the process of flight by the measuring system to determine the location and value of resultants of every its component part. For a freely locomotive body – rocket on the whole - it is comfortably to search resultant, attached in the center of the masses, in relation to which to determine a total moment.

Because the total moment of forces of gravitation in the homogeneous field in relation to the center of the masses is equal to the zero, the determined center of the masses will be the centre of gravity also.

On a fig. 1 on the chart of illustrating the process of creation of traction by a with jet solid-rocket engine a supposed places of setting of sensors are shown $1Д_1$, $2Д_1$, $3Д_1$ – $1Д_n$, $2Д_n$, $3Д_n$.

On a picture marked: F is a value of traction, is determined by equation

$$F = mY_e + A_e(p_e - p_a),$$

where $\boldsymbol{m}$ - second expense of gaseous products of combustion, $\boldsymbol{Y_e}$ and $\boldsymbol{p_e}$ - it is speed and pressure of gases on the cut of nozzle, $\boldsymbol{A_e}$ it is area of output section of nozzle, $\boldsymbol{p_a}$ - it is external (atmospheric) pressure, $\boldsymbol{A_{кр}}$ - it is area of critical section of nozzle, $1Д_1$, $2Д_1$, $3Д_1$ – $1Д_n$, $2Д_n$, $3Д_n$ – magnetoelastic sensors of force.

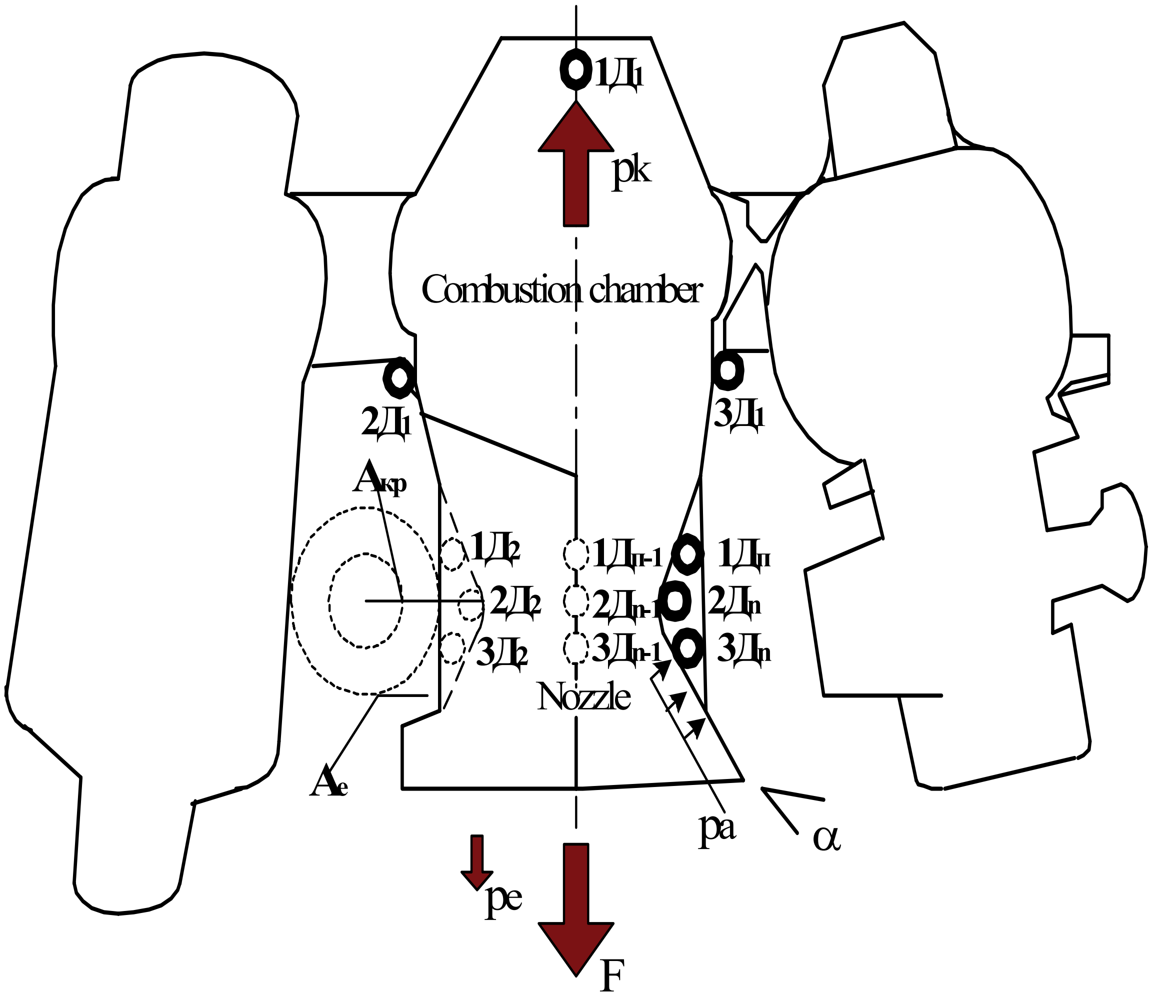

Fig1. Layout of sensors chart and illustration of tractions creation

Conclusions. Thus, in the process of flight by the offered method including the intellectual magnetoelastic sensors of force, it is possible to check up the capacity of engine, to measure the traction, loadings on a rocket airframe, value and location of resultant forces and to determine a values necessary on a flight. It will allow during flight more precisely to check up all possible operating mode, including unforeseen, that will allow to promote safety of flight.

References

1.*Ларин В.Ю., Зори А.А*., Унифицированные устройства для организации ИИС контроля технологических параметров. // Материалы всероссийской научно-технической конференции с международным участием. "Компьютерные технологии в инженерной и управленческой деятельности". Таганрог. – 1999. – С. 213–220.

2.*Ларин В.Ю*. Оценка погрешностей, возникающих за счёт вариации и линеаризации статических характеристик измерительных средств // Наук. пр. Донецького держ. техн. університету Серія: "Обчислювальна техніка та автоматизація". Вип. 25. - Донецьк: ДонДТУ, 2001. – С. 214–222.

3. *Sutton G*., Rockets Propulsion Elements (Wiley, 1999)

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THE MATHEMATICAL MODEL OF CONSTRUCTING THE ADAPTIVE SYSTEM OF MECHANICAL VALUE MEASUREMENTS

This article gives the analysis of the suppression of vibration influence at preliminary processing the results of measurements in control and measurement machines under conditions of the large level of industrial vibration interferences.

Introduction. The modern technologies of aviation manufacture demand the continuous control and diagnostics of many parameters of the production equipment and measuring devices under the conditions of actual production. The similar control is necessary in other spheres too: in machine- building, automotive industry, power engineering etc. The measurements of mechanical parameters occupy the important place among the controlled parameters. The control and measurement machines (CMM) take the leading position among the systems of the operative measurement of mechanical parameters. Therefore the study of external factors influencing the measuring system and reliability of the measurement results is considered highly topical. Vibrodisplacement (the amplitude of vibration) and vibrospeed (frequency of vibration) are some of these factors.

The passive damping devices are widely used for elimination of vibration influence in technique everywhere and in measuring systems in particular. Besides the usual passive vibroinsulation which doesn't demand additional power sources the following approaches are applied:

- the static and dynamic balancing, selection of the inertial and elastic parameters which exclude the work in resonance zones;
- the introduction of damping elements when the work far from the resonance area is impossible;
- the dynamic cancellation of vibration by way of connection of specially adjusted vibration devices;
- the installation of gyroscopes for cancellation of angular fluctuations;
- the means of active vibroinsulation (automatic suppression of fluctuations).

Such devices on account of their narrow bandwidth can't reduce effectively and proportionally the vibration influences within broad bandwidth. This constitutes their drawback.

The analysis of publications devoted to compensation of vibration influences shows that as a rule the complex measuring systems constructed on CMM are initially designed for operation in laboratory environment. The reduction of vibration influence on them is made with the help of the elastic passive supports. At the stage of preprocessing of measurement results the elimination of inaccuracies and interferences introduced by measuring path and equipment as well as external influences is performed. Many methods applied for preprocessing are described in the work [1], but in some cases (including this one) more qualitative elimination is required.

Problem definition. The task is to eliminate the vibration influence upon the results of CMM measurements at measuring complex spatial surfaces under actual workshop conditions of flexible industrial systems.

Problem solution. It is offered to use active controlled elastic element (CEE) as the supports of CMM which will eliminate the vibration influence on the measurement results by way of cancellation of its vibrational amplitude. The vibration frequency of the linear mechanical system coincides with the frequency of exciting force. If several exciting forces with different frequencies operate in the system simultaneously, the resultant vibration will be equal to the sum of vibrations on each frequency. Under such conditions the resultant time realization of fluctuation won't be sinusoidal and may turned out to be very complex. That is typical for practically all modern industrial workshops, where high- and low-frequency vibrations of operating equipment are imposed on each other and create the complex time realization.

The most widespread kinds of vibrational drive of working devices of technological facilities under production conditions are centrifugal, exciting fluctuations up to 600 Hz, electromagnetic (50..100 Hz), piston (5…80 Hz) and connecting rod (1..20 Hz) [2]. Figure 1 presents the spectrum of vibration signal received while conducting measurements in workshop conditions.

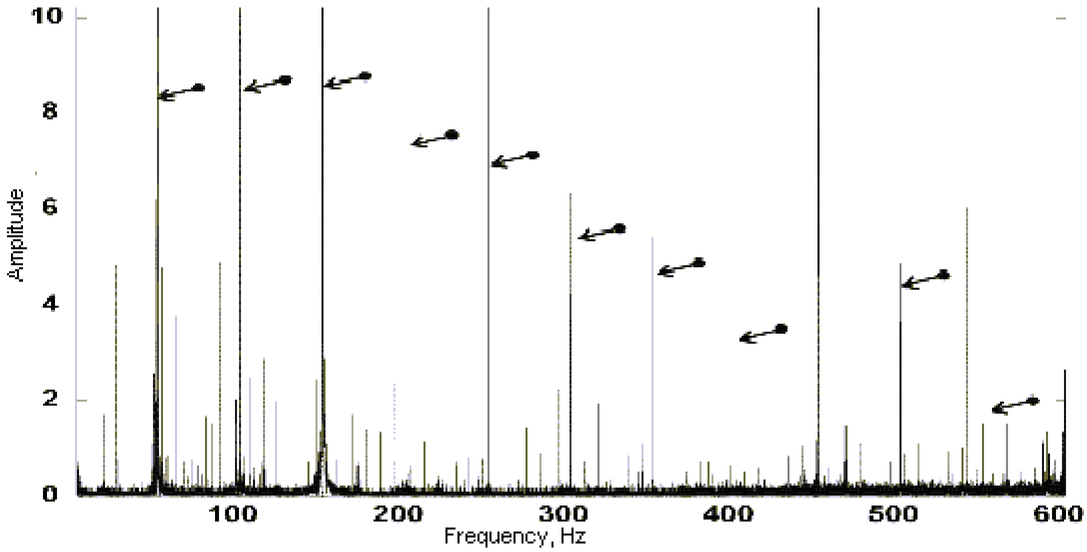

Fig.1. The spectrum of vibration signal

In figure 1 arrows point spectrum components which correspond to vibrational fluctuations.

At spectrum analysis of the vibrations excited within such frequency bandwidths a significant volume of information (contained in characteristics of each component to be included in the product) is lost. Therefore at accomplishing the task of spectrum analysis it is necessary to select those product components which carry the maximal amplitude of vibration. In most cases the first 3...5 harmonics of spectrum (all the others as a rule may be neglected) are such components in the modulated vibration signals. Therefore to define frequencies and amplitudes of separate components it is necessary to analyze the form of time schedule (time realization) of a signal.

A complex solution is suggested to eliminate the influence of vibration on the results of CMM measurements. It allows to obtain the results of measured values in working (workshop) conditions similar to the results obtained in laboratory environment.

The complex solution for the creation of the adaptive system of mechanical value measurements based on exact CMM may be divided into the following trends:

- the active means of cancellation of vibration influences in broad band;
- the exact quick-operating system of measurement, vibration analysis and development of control response;
- the algorithms of conducting, measurement processing and updating of inaccuracies of measurement results.

We will analyze the active means of cancellation of vibration fluctuations.

Any mechanical construction may be presented in form of the system of springs, weights and dampers. It has a resonance on its own typical frequency. If power is imparted to such a system it will begin fluctuating at its own frequency. The vibration amplitude will depend on the capacity of power source and on the absorption of this power, i.e. damping typical of the system itself. The proper frequency of an ideal system *weight – spring* with no damping is presented by the proportion:

$$\Omega^2 = m / k , \qquad (1),$$

where: Ω = proper frequency, k – coefficient of elasticity, m – weight.

It follows that the proper frequency changes with the change of the coefficient of elasticity.

If the system possesses damping because all real physical systems do so, the proper frequency will be a little bit lower than the value calculated according to the given above formula. The frequency will depend upon the damping value. It means that using bearings with the controlled coefficient of elasticity as the bearings of CMM it is possible to regulate proper system fluctuations and smooth the impact of vibration forces on CMM.

We will analyze the controlled elastic element (CEE) for realization of smoothing in all the frequency range of vibrations. CEE should possess a high response speed and be able to change its linear sizes in the wide frequency range under keying signal. A multilayer structure is used for the effective absorption. Each layer in such a structure will trace the absorption of fluctuation power of the certain harmonic allocated out of the spectrum of vibration signal. The measurement system operates in the real time, measures vibration action constantly, processes this action according to this or that mathematical method. The system allocates harmonics from the complex signal, analyzes and generates the dirigible signal on CEE. Adequately changing its elasticity CEE absorbs the vibration action.

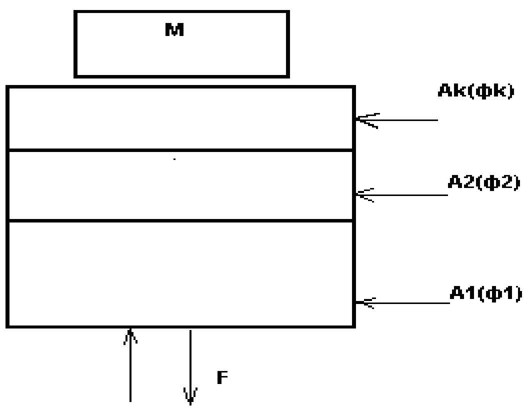

Fig. 2. Structure of the controlled elastic element

The main difficulty of the task of allocation of the disturbing vibration influence for CEE manipulation is that the frequency range of vibration is rather wide (5 …600 Hz).The usage of digital rejecter adjusted on the vibration harmonics doesn't give the acceptable results. The reasons of this are the following: firstly, it is necessary to use the filter with the finite impulse response (FIR) of the multiple of N=40000…50000 to reach suitable bandlimitedness (0,5 Hz on the level – 3 decibel) and good suppression for all 11 harmonics [3]. It leads to the completely unacceptable time of signal filtration for the real time system even on the modern high-efficiency computers. Secondly, the process of filtration brings phase deformations and delays which are unacceptable for the further signal analysis in time domain and the generation of the signal of counteraction on CEE if the system operates in real time. In principle these deformations and delays may be eliminated if an additional damping element is used together with CEE. The coefficient of elasticity of this CEE should absorb power of the small vibration amplitudes of high harmonics. Thus the range is narrowed.

We will use the piezoelectric accelerometer as the sensing device for the measurement of vibration. The accelerometer has a high response speed and a wide track of the signal measured.

An entrance path of vibration measurement (fig. 3) is executed according to the traditional scheme [4]. To reduce the time of processing of vibration input signal we use the quick-operating 12- digit analog-digital converter (ADC) with sampling frequency of 30 …40 MHz.

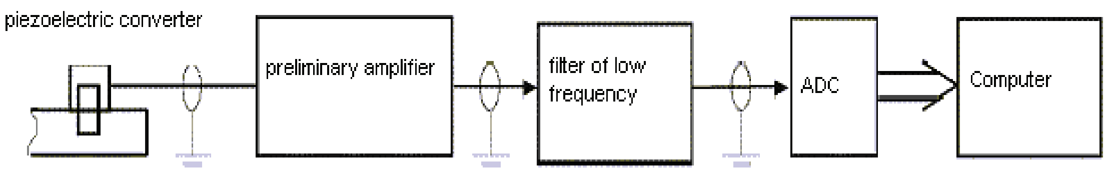

Fig. 3. Structural scheme. An entrance path of vibration measurement

After the number K of harmonics that should be cancelled is determined any method may be used for determination of A_k amplitudes and initial phases ϕ_k for the corresponding sinusoids [5]:

$$s(t) = \sum_{k=1}^{K} A_k \sin(k\Omega t + \phi_k), \tag{2}$$

The amplitudes and phases of corresponding harmonics can be determined if either Fourier coefficients for the corresponding frequencies are calculated

$$a_k = \frac{1}{N}\sum_{t=0}^{N} s[t]\cdot \sin(k\Omega t), \quad \left(b_k = \sum_{t=0}^{N} s[t]\cdot \cos(k\Omega t)\right), \quad k = \overline{1,K}, \tag{3}$$

or coefficients a_k and b_k of the following model are identified with the help of least-squares method (LSM):

$$s(t) = \sum_{k=1}^{K} \left[a_k \sin(k\Omega t) + b_k \cos(k\Omega t)\right]. \tag{4}$$

For the determination of amplitude and phase in formula (4) with LSM it is necessary to formulate a matrix of explanatory variables which look like the following for the formula (4):

$$X = \begin{pmatrix} \sin(\Omega_0 dt) & \cos(\Omega_0 dt) & \sin(2\Omega_0 dt) & \cos(2\Omega_0 dt) & \ldots & \sin(11\Omega_0 dt) & \cos(11\Omega_0 dt) \\ \sin(\Omega_0 2dt) & \cos(\Omega_0 2dt) & \sin(2\Omega_0 2dt) & \cos(2\Omega_0 2dt) & \ldots & \sin(11\Omega_0 2dt) & \cos(11\Omega_0 2dt) \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ \sin(\Omega_0 Ndt) & \cos(\Omega_0 Ndt) & \sin(2\Omega_0 Ndt) & \cos(2\Omega_0 Ndt) & \ldots & \sin(11\Omega_0 Ndt) & \cos(11\Omega_0 Ndt) \end{pmatrix} \quad (5)$$

that means it is necessary to obtain from *sin(Ωot)* function a set of functions of multiple frequencies in the form *sin(k Ωot)* and *cos(kΩot)* for all the harmonics.

The signals of influence on CEE is constructed on the basis of calculated values of amplitudes and phases.

Conclusions. The effectiveness of the work of the system depends upon the development speed of control response. The methods of processing of vibration signal contain the reserves of its increase .

The method of Fourier coefficients possesses a sufficient resolution although it is rather complicated for calculations even if a little amount of harmonics is analyzed.

The approach with LSM usage has proved to be perspective. The calculation complexity of these two methods is practically similar. At the same time the second method gives the clearly expressed minimum of variance of model residuals when the correct frequency is caught.

The analysis of mentioned methods has shown that the ways of further researches will be directed to the search of faster approaches of mathematical processing.

References

1. Kvasnikov V. The increase of precision and response speed of information-measuring systems of mechanical values of objects with the complex spatial surfaces. – Cherkasy: Cherkasy Institute of Management, 2002. – 212 p.
2. Holdin A. The vibration of rotor machines. – Moscow: Engineering, 2000. – 344 p., il.
3. Cowen K.F.N., Grant P.M. Adaptive filters. – Moscow: Mir, 1988. – 184p.
4. Max J. The methods and technique of the signal processing in physical measurements. v 1. – Moscow: Mir, 1983. – 312 p.
5. Bendat D., Peersal A. The usage of the correlation analysis and spectrum analysis. – Moscow: Mir, 1982. – 362 p.

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FORMALIZATION METHODS OF TECHNOLOGICAL EXPERTISE IN THE EXPERT SYSTEMS

The results of multiagent technologies researches for modeling and formalization of technological expertise are presented. They are used for construction of the automated system of technological preparation of industrial production of a discrete type.

Introduction. Information technologies, which are used for automatization of engineering work of experts of the industrial enterprises, are based on modern methods of modeling of products, processes, resources and knowledge. Modeling of experience, traditions and design decisions, i.e. knowledge, is the most labour-consuming and the least formalized in methodology of construction of the automated systems. It concerns especially the automated systems of technological preparation of manufacture and questions of their integration.

Results of researches. While carry data from one automated system to another great labour expenditure and time consumption the repeated coding are required which results in numerous mistakes. Different systems proved "speak to different languages" and badly understand each other. Moreover paper documentation and ways of renderins of the information sum to limit opportunities of the use of modern information technologies. Thus, the three-dimensional model of a product created in modern SADES, cannot be adequately presented on a paper at all.

For overcoming these difficulties new concepts and new ideas were required. Among them the idea of information integration of stages of life cycle of production (product) which consists in refusal of " paper environment " in which traditional document circulation is carried out, and transition to the integrated information environment covering all stages of life cycle of a product became fundamental.

The essence of information integration means of that all the automated systems applied at different stages of life cycle, operate not with traditional documents or their electronic image (for example, with scanned drawings), but with the formalized information models describing a product, technologies of its manufacturing and use. These models exist in integrated information environment in the specific form of information objects. Systems to which require these or those information objects for their functions can take them from the integrated information al environment, to process, creating new objects and place the results of the work in the same integrated informational environment. These models exist in the integrated information environment in the specific form of information objects. Systems that need for work those or other information objects can take them from the integrated information environment, to process, creating new objects and to place results of the work in the same integrated information environment. To make this process possible, informational models and corresponding informational objects should be formalized [1].

Since 1998 the engineering center of the Institute of Informational-diagnostic Systems of the National Aviation University carries out scientific research of methods of formalizing technological knowledge with the purpose of constructing expert subsystems of the automated systems of technological preparation of manufacture (ASTPM). Opportunities of multiagent technologies are used as a toolkit of management resolving works by technological preparation of manufacture (TPM). The multiagent technologies are the sub-branch of the distributed artificial intellect, the main point of which is cooperative interaction of the distributed intellectual systems [1, 2]. The distributed artificial intellect is based on the classical foundation of artificial intellect taking into account the usage of the new methods of processing the distributed data and knowledge as well as the methods of decentralized management.

By 'agent' we mean an object existing in a medium where it can exert the definite actions, which is capable for interpreting a part of the medium, it can communicate with other agents and possesses the autonomous behavior that is the result of its observations, knowledge and interaction with other agents [2, 3]. A man, program subsystem or a module can act as an agent. Depending upon the proper complexity level, the agent can process the received messages as well as send them to other agents, it can deal with the target designation and with planning the actions, with coordinating the actions with other agents.

When agents act as program modules of PDM (Product Data Management) systems, their initializing can be done:

- as the result of some \`external\` act, for example, receiving the order to fulfill the work on designing an item;
- in given time intervals;
- when obtaining the messages from other agents.

The agent is characterized by the scheme and method [2]. The scheme presents the whole complex of the names, their important features – that is an agent\`s identificator, agent\`s class, input and output attributes and so on. The method defines the agent\`s behaviour and the algorithm of transforming the input attributes into output ones.

For construction of multiagents' systems the toolkit consisting of two components is necessary:

- means of development;
- environments of the agents-focused programs.

The first component is focused on support of processes of the analysis of the subject domain created multiagents' of system, and for designing agents with the certain behavior. The second - provides the effective environment for performance agents-focused programs.

The diagram of designing and realization agents-focused applications in notations of language UML (Unified Modeling Language) [4] is shown in the Fig.1. This toolkit has means for organization of a subject domain, which is formed by multiagents' system, construction tools of architecture of agents and means of formalization and representation of technological knowledge.

Processing of information by the agent includes the following main steps:

- processing of new messages;
- definition of rules of behavior which can be used in a current situation;
- performance of the actions defined by these rules;
- restoration of imitating model according to the given rules;
- planning.

Within the limits of the given model a set of rules of behaviour forms the whole set of possible responses of the agent on external inquiry. Rules of behaviour of the given model are described by designs of a kind " when - if - that " [3].

"When" - the part of rules is addressed to new events which arise in an environment of the agent and contain the new messages received from other agents. "If" - the part compares line imitating model to conditions in which corrected behaviour can be used. Samples in "If" - parts work on intentions, hypotheses, duties and opportunities which are applied in imitating model. That" - the part defines actions in reply to current events, conditions of model and an external environment.

The most promising are the multiagents' systems on the basis of the distributed artificial intellect [4] which are under construction on the basis of the systems based on rules on the basis of precedents. Each agent is considered as the system formed on knowledge with summation of components, providing safety, mobility, quality of service, interaction with other agents, network resources and users. Such multiagents' systems are characterized by the coordinated intellectual behaviour in the co-authorship with the intellectual agent.

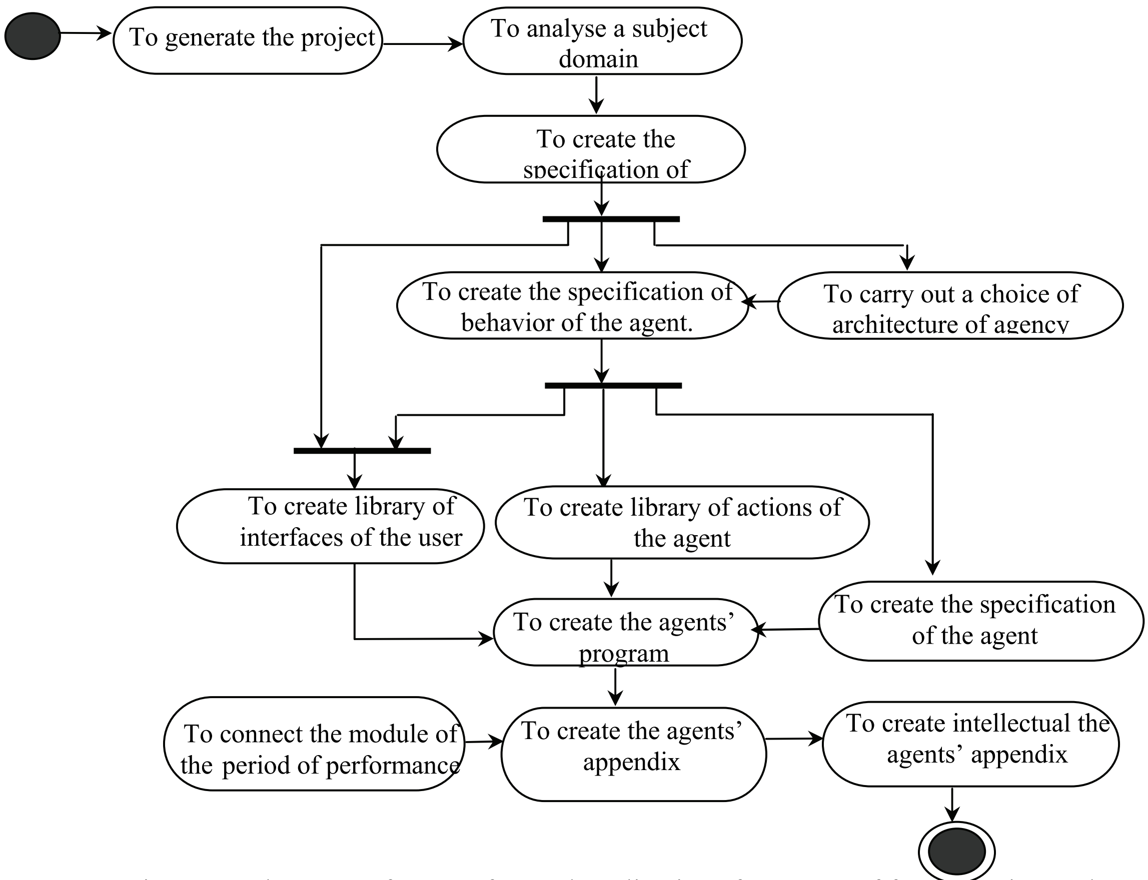

Fig.1. Development of agents-focused applications for means of formalization and representation of technological expertise

The system provides in dialogue with the dispatcher automated adjusting on investigated problem area by introduction the basic concepts, attributes, their possible values, communications by averages, and also types of possible situations, characteristic processes and interactive interaction with the user during its functioning. In system the stipulated use (adaptation) of different models of processes for investigated problem area with possible sequences of processes and interrelations between situations. The model of process is set in the form of set of situations.

The situation is referred to as a set of events. The event is establishment of the certain value or achievement of some border of value of one or several attributes of an object (objects). Thus, event is characterized by change of a condition of one or several objects. The possible sequence of course of processes is set by their sequence and the attitude of the precondition between situations. Formation of reports of information simulates process of gathering from external sources (operators of system or automatic gauges) messages on changes of investigated problem area. As a matter of fact, multiagents' systems can be considered as a set of interdependent program modules (agents), that is, fragments of the knowledge accessible to other agents. Them name " program robots " which satisfy different information and computing needs of end users. They coordinate the knowledge, the purposes, skills and plans at the decision of problems. Thus, it is possible to consider multiagents' systems as program-executive devices [1].

By means of program agents multiagents' systems search of competitors of the project is carried out, the coordination of specifications on a product, its functions and designs with the customer is spent. Multiagents' the system is connected to the automated workplaces of the director, the main designer and the main technologist through the intellectual interface integrated in PDM-system. Through this channel the information on the basis of which the final decision should make is transferred. The final decision on start of the order in manufacture, realization of cooperation with elites multiagents' system coauthors, is accepted by the director by means of own automated workplace on which all necessary information for strategic planning with CAD/CAM and ERP-systems is deduced. The decision on entering of constructive changes for a product is brought by the designer.

The software package which expands opportunities of the program, on the basis of use of elements of an artificial intellect provides performance of additional problems distributed АСТПВ. To such problems concern: optimization of loading of the equipment of the expanded enterprise; training new, retraining and improvement of professional skill of the skilled personnel; a complex of support acceptance the decision leading heads; carrying out of analytical calculations; forecasting of events and other.

For programming, languages object-oriented designing in Visual Basic environments and Delphi are used. For the description of rules (logic) of agents behavior of multiagents' expert system the functional modeling in UML environment is used.

Conclusions. Advantages of the proposed method in comparison with the methods based on using the examination systems are in greater flexibility of managing TPM and in acceleration of TPM at the expense of parallel solving the tasks by the programs-agents.

The offered methods of formalization of technological expertise are used at in developing of the expert subsystem ASTPM operating in the integrated information environment of the expanded enterprise [5].

References

1. *Евгенев Г.Б.* Системология инженерных знаний – М.: Изд-во МГТУ им. Баумана, 2001. – 376 с.
2. *Klaus Fisher, Jorg P. Muller, Ingo Heimig, August-Wilhelm Scheer* Intelligent Agents in Virtual Enterprises, Institute fur Wirtshaftsinformatik, 1997.
3. Искусственный интеллект: применение в интегрированных производственных системах: Пер. с англ. А.П. Фомина; Под ред. С. Дащенко, Е. Леввнера.– М.: Машиностроение, 1991. – 544с.
4. *Лешек А., Мацяшек В.* Анализ требований и проектирование систем. Разработка информационных систем с использованием UML:Пер. с англ. – М.: Издательский дом «Вильямс», 2002. – 432с.
5. *Бабак В.П., Павленко П.М.* Проблеми впровадження CALS-технологій у промисловість та освіту України // Матеріали V міжнародної науково-технічної конференції НАУ. 2003 –– С.11.127-11.129

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INTELLECTUAL 3D-LASER MEASURING SYSTEM OF DIAGNOSTICS

In the paper technical requirements are given to the device of the 3D-control of aircraft engine parts, the essence of the offered method, structure and the software of the laser measuring system, and also experimental results are described.

Introduction. Recently on the basis of modern informational technologies various methods of synthesis, the analysis, processing, classification and measurement of three-dimensional objects including details of flying devices are created.

The details configurations of aviation drives are a subject to three-dimensional (3D) control.

The analysis of publications shows, that today the most spreaded are two ways of scanning: laser scanning using the manual measuring machine with a laser head and optical scanning in the system ATOS by means of optical installation GOM.

Problem definition. The purpose of work is the development of 3D-laser three-dimensional scanning system for diagnostics and measurements of aviation details of the complex form which, allows to reduce a time for development of mathematical model.

Problem solving. Among existing non-contact means of the 3D-control the most perspective are optical on the basis of stereoprojection, pixel scanning of the object surface, a method of structural illumination, etc. Recently for automatic 3D-measurements the method of structural illumination is widely used. It is based on illumination of the object by a bunch of light of a known configuration, recording of the image by a video-camera and processing of the information. The form and geometrical parameters of the object surface inside of measuring volume are restored by the means of a set of the object cross-sections. The application of a traditional method of structural illumination faces the problems, concerning formation required of the light structure, perception and processing of the optical image. That's why the modified method of the 3D-control is used. This method allows quickly and non-contact to carry out automatically 3D-measurements of many objects.

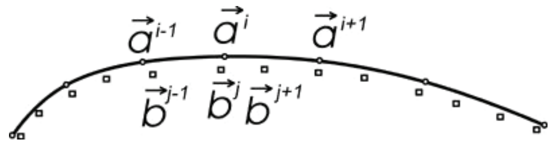

Fig.1. The circuit of points of the aviation detail control.

The number of points in section M depends on geometry of concrete section. The distances from a point a^i up to each of cuts $\left[b^i, b^{i+1}\right]$, $j = 1,...,M-1$ are sequentially defined. The point d which corresponds minimum distance, is defined from a condition of perpendicularity of a vector $\left(a^i - d\right)$ of the straight line which is passing the through points b^i and b^{i+1}. Having defined the distances from a point a^i up to each of cuts $\left[b^j, b^{j+1}\right]$, we choose that cut, the distance up to which is minimum.

The features of traditional methods of structural illumination for 3D-measurements.

First, these methods should ensure required depth of focusing of a structural light field. It means, that the light field should save the parameters at distribution of light along axis Z in the measured volume. Secondly, as the light intensity, dispersed by various parts of the object, can differ on some orders of sizes the chamber cannot simultaneously record all of the object parts with identical quality. At last, there is a problem of identification of pairs a point of a plant – point of the image at processing the image. For example, using the structural illumination in the form of an one-dimensional lattice the analyzed bordered image of the object with a smooth surface leads to indefiniteness of fields identification, i.e. to significant difficulties of the link installations between each strip of the image and a corresponding strip of a structural light field. Thus, spatial position of the object and its shape cannot be certain uniquely. This deficiency can be eliminated by sequential illumination of the object by light lattices with the various periods and an aftertreatment of all received images of the object. However it is connected with greater time expenditures on restoring 3D-object. We offered the modified method of the 3D-control using the multipoint structural illumination which is deprived mentioned above deficiencies.

The distribution of light intensity $J(\xi,\eta)$ in the pointwise structured illumination represents set of Gaussian bunches of identical intensity:

$$J(\xi,\eta) \sim A \sum_{i=-N/2}^{N/2} \sum_{\substack{j=-M/2 \\ j\neq 0}}^{M/2} \exp\left\{-\frac{\left(\xi - i\Delta_\xi\right)^2 + \left(\eta - j\Delta_\eta\right)^2}{\sigma^2}\right\}, \tag{1}$$

where ξ,η - coordinates of cross-sections of laser bunches; N,M - amount of Gaussian bunches lengthways ξ and η accordingly; Δ_ξ, Δ_η - distances between the centers of bunches; σ – halfwidth of Gaussian bunches $\sigma << \Delta_\xi$ $\sigma << \Delta_\eta$.

In this case in all range $D_x \approx N\Delta_\xi$, $D_y \approx M\Delta_\eta$ homogeneous illumination in reference points takes place and consequently appreciable differences between the intensity of the incident bunches in the center and on periphery is not observed. Owing to the small divergence of laser bunches the demanded measuring volume on depth $D_z \approx D_y \approx D_x$ is ensured.

The circuit of the experimental 3D-laser measuring system is presented on fig.2.

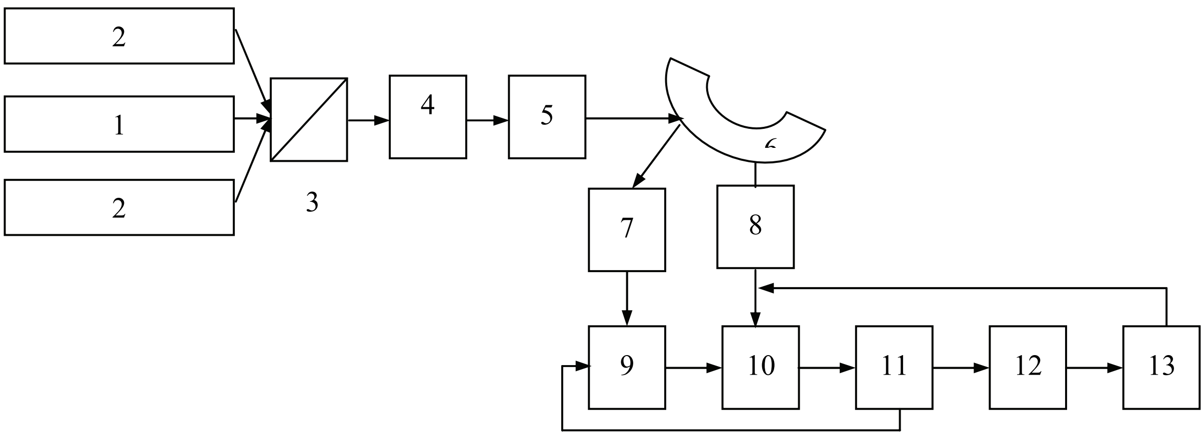

Fig.2. The circuit of the experimental 3D-laser measuring system

The circuit contains the laser measuring system 1,2 types LMS-100, a light cube 3, the electrooptical converter 4, an electrooptical chip 5, the object of measurement 6, optical filters 7, a photodetector 9, a computer 12, analog-digital recorder 11, digital-to-analog recorder 13.

Operation of the 3D-laser measuring system. The software of the measuring system includes: the basic program; the program for the analysis of the statistics collected during the measurement; the program for the device of gathering and processing of the information. The basic program written in programming language Microsoft Visual C ++ of version 5.0, works under control of operational system Windows 98. It ensures the displaying on the screen of a current condition the processes in the form convenient for the human controller. The window graphic modes is used for interaction with the human controller.

In the basic program of the 3D-laser measuring system two modes are realized. They are preparatory and working modes. The preparatory mode (with participation of the human controller) provides following operations: testing of the basic units of the measuring system, input of parameters of the inspected details and standard samples, calibration and metrology checking of the laser measuring system.

In the basic program of the laser measuring system two modes are realized: preparatory and working. The preparatory mode following operations are made: testing of the basic units of the laser measuring system, input of parameters of the inspected details and standard samples, calibration and metrology checking of the laser measuring system.

The calibration of system is executed separately for each ray from a structural bunch. We shall consider a unit ray. The image of the radiation lays on some line in a plane of a matrix of a video-camera. At the first stage we had to find the coefficients of this line in the coordinate system of a video-camera. Then under the least squares method we discover coefficients A and B for reception the dependence between coordinate of a stain on a matrix of a video-camera and 3-D coordinates of a stain on a surface of the object by means of following rational function:

$$\Delta X = A\Delta\chi(1 + B\Delta\chi)^{-1}, \qquad (2)$$

where $\Delta\chi$ – displacement of an sample of the radiation along a corresponding straight line on the chamber; ΔX – stain displacement on a surface of an inspected object along a ray. Knowing parameters of a ray in space, it is possible to calculate 3-D coordinates of a stain on a surface.

The mode of measurement allows to define automatically geometrical parameters of measurement object, and also to visualize results of measurements on each of parameters and to produce reports of measurement and control in the brief or full form.

During the measurement of the complex spatial surfaces such as aviation details the algorithm with using of the laser measuring system is developed which includes positioning of a measuring tip; gathering and transmission from three video-cameras in the operating computer complex, processing of measurement results that allows to make identification of a light stain and a surface reshaping.

As a rotary table we use coordinate table AP-400, which ensures inspected moving of measurement object in sight of the opticoelectronic measuring block in a direction of coordinates X and Y is used. Accuracy of positioning makes $2 \cdot 10^{-6}$ m. Movement on two coordinates is ensured with two linear engines which are connected with operating controllers of coordinates X and Y, linked with a computer through serial port RS-232.

Measurement technique. Reconstruction of a surface profile on intensity of light diffraction.

The flat monochromatic wave drops normally to a surface which profile is presented as $z = h(x, y)$. Distortion of a wave front at once after a surface reflecting is given in the complex form as

$$f(x, y) = |f(x, y)| \exp[i\theta(x, y)], \tag{3}$$

where $\theta(x, y) = \frac{4\pi}{\lambda} h(x, y)$ - a difference of phases, brought by an irregularity of heights on a surface, and λ - a wavelength of the radiation falling on a surface.

Let's consider the indignant wave $f(x, y)$ objective. The field of Fraungofer diffraction, received by means of a single lens, is connected with an objective wave by Fur'e-transformation

$$F(u, v) = \iint_D f(x, y) \exp[-i2\pi(ux + vy) dxdy], \tag{4}$$

where (u, v) - coordinate in frequency space.

The Fur'e-spectrum is characterized by a complex function. However the measurement of diffraction intensity $I(u, v) = |F(u, v)|^2$ gives only spectral density of an objective wave power. Definition of an objective wave on its spectral power density is possible using phase restoring.

The quality of a phase restoring is controlled by the mean of normalized square error σ_k^2 defined in the field of spatial frequencies as [3]

$$\sigma_k^2 = \frac{\iint [|F(u, v)| - |G_k(u, v)|]^2 dudv}{\iint |F(u, v)|^2 dudv}. \tag{5}$$

The measuring base formed by several gauges, is the filter of spatial frequencies. The creation of algorithms of the account of transmitting function of such a filter will allow to interpret the measured signal with greater reliability. Besides having the aprioristic information on a spectrum of object spatial frequencies, it is possible to use measuring base with the corresponding filtering properties with the purpose of information allocation on the set scales of the object profile.

Depending on a measured profile, properties of a measuring base, a way of measurement the received signal can be periodic, almost periodic or non-periodic. It causes the necessity of base filtering properties research for corresponding signals. Let's consider the peculiarities of the measuring base, formed by three transmitters, on an example of control of complex aviation three-dimensional profiles.

Let's consider the circuit of the measurement, formed by three gauges. Filter parameters are: the size of a measuring base; a corner of its inclination α, to an axis of wising; an arrangement of the average gauge. By means of a measuring base with the size b the surface, which profile is described by function $f(x, y, z)$ where x, y, z - coordinates of a measured three-dimensional plant [4] is investigated.

The output signal can be written in the form of convolution of an input signal $f(x, y, z)$ with the function of the impulse response of system $f(x, y, z, b, d)$ [5,6]

$$y'(x,b) = y(x) \otimes f(x,b), \qquad z'(y) = z(y) \otimes f_1(z,d) \tag{6}$$

Fur'e-images of input and output signals, according to the theorem of convolution, are connected by transmitting function $F(\xi)$

$$Y'(\xi) = Y(\xi)F(\xi)\; Z'(\xi) = Z(\xi)F(\xi), \tag{7}$$

where $F(\xi) \xleftarrow{F} f(x,y,z,b,d)$; ξ - spatial frequency; $\xrightarrow{F}$ means the procedure of Fur'e-transformation.

Then using the theorem of shift, we receive expression for transmitting function of system

$$F(\xi) = Y'(\xi)/Y(\xi) = 1 - \cos(\pi b \xi), \tag{8}$$

or, having used standard trigonometrical transformations, we shall receive

$$F(\xi) = 2\sin^2(\pi b \xi/2). \tag{9}$$

The size of a measuring base is a parameter of transmitting function of the filter.

On fig. 3 transmitting function of the filter of spatial frequencies $F(\xi)$ is represented.

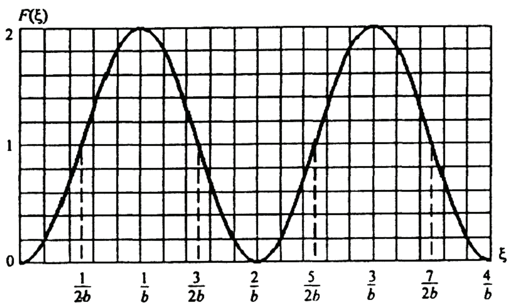

Fig. 3. Transmitting function of the filter of spatial frequencies

From figure it is possible to conclude, that the full filtration of spatial frequencies $\xi = 2n/b \;\; (n = 0,1,2,...)$ in a spatial spectrum of function $f(x,y,z)$ is carried out. With reference to the sizes it means, that the information on the details of a profile, having the sizes $b/2n$, will be lost. On the contrary, the maximal strengthening of a signal occurs on frequencies $\xi = (2n+1)/b \;\; (n = 0,1,2,...)$. From a condition $F(\xi) = 1$ we fined, that without distortions the filter passes frequencies $\xi = (n + 0{,}5)/b \;\; (n = 0,1,2,...)$.

By a choice of the size of measuring base it is possible to get maximum trustworthy information about the set scales of an examined profile of a surface. Besides the given model, allows to develop algorithms of the account of filtering properties of base for concrete cases. So, for example, at active control a surface profile of a while manufacturing a product the size of a measuring base should be chosen grounding on following criteria. The filter of spatial frequencies should realize a filtration of the frequencies connected with irregular movements of a surface owing to its transportation the measuring system. The frequencies connected with errors of a product manufacturing techniques of an article, should be passed by such a filter.

Conclusions. The technique and the block diagram of 3D-laser three-dimensional scanning system is developed for diagnostics and measurement of aviation details of the complex shape. Technical requirements are led to the device of the 3D-control of aviation details, the structure of the laser measuring system and the software of measurement of aviation details of the complex shape are described.

By a choice of the size of a proof surface it is received as much as possible a trustworthy information about the set scales of an examined profile of a surface, and also the model which allows to develop algorithms of the account of filtering properties of base for concrete cases is resulted.

Referenses

1. Битюцкий О. И., Вертопрахов В. В., Гущина А. А. и др. Трехмерный бесконтактный контроль геометрических параметров дистанционирующих решеток ядерных реакторов // Автометрия.–2003.– № 5.– С.4-8.
2. JSCTVEL nuclear fuel for power and research reactors. M.: Russian business agency, 2001.
3. Taguchi A., Miyoshi T., Takaya Y., et al. 3-D micro-profile measurement using optical inverse scattering phase method // Ann. CIPR.–2000.- № 1.- v.49, P.423.
4. В.В. Демин, В.Г. Максимов, И.Г. Половцев Фильтрующие свойства измерительной базы в задачах профилометрии // Автометрия.–2000.–№6.–С.74–81.
5. Сороко Л.М. Основы голографии и когерентной оптики. М.: Сов. радио.–1980.
6. Макс Ж. Методы и техника обработки сигналов при физических измерениях. М.: Мир.–1983.–Т.1.

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FORECASTING AND MODELING SUBSYSTEM OF UKRAINIAN GOVERNMENTAL INFORMATION AND ANALYTICAL SYSTEM ON EMERGENCY SITUATIONS

The development of Ukrainian Government Information and Analytical System on Emergency Situations (GIAS ES) was carried out since 2001 to 2005 by the request of Cabinet of Ministries of Ukraine.

The forecasting and modeling system was created as a component of allocated information structure of GIAS ES which integrates information streams originated from different sources such as Cabinet of Ministers of Ukraine, Ukrainian Hydrometeorological Centre, the Ministry of Emergency Situations of Ukraine, etc. Thus, the uniform information environment was created to provide necessary initial data for modeling and forecasting of emergency situation consequences.

The allocated geodatabase of forecasting and modeling subsystem on emergency situations (FMS ES) includes the following components:

- **DATA BASE of Messages on Emergency Situations** (Ministry of Emergency Situations and Chornobyl Affairs, Kyiv);
- **DATA BASE of the Hydrometeorological Information** (Ukrainian Hydrometeorological Centre, Kyiv);
- **Fund of Electronic Maps of Ukraine** (Interagency Centre for Digital Mapping, Kharkiv);
- **DATA BASE «The National Register of Potentially Dangerous Objects»** (Institute of Micrography, Kharkiv), etc.

System maintenance of a complex is based on a platform of a new line of ESRI software products – ArcGIS, that allows to connect new opportunities of modules ArcView 8.3 (ArcMap, ArcCatalog, Spatial and 3D Analyst) with the powerful problem-oriented modeling systems, based on the allocated spatial databases organized by means of ArcSDE on platform DBMS Informix.

Today such forecast and modelling complexes are developed and placed for beta - testing:

1. Forecasting and an evaluation of flood consequences (FMC "Flooding", Fig.1)
2. Forecasting and evaluation of mudflow consequences (FMC "Mudflow")
3. Forecasting and evaluation of consequences of dangerous chemical substances emissions to the atmosphere (FMC "Chemistry")
4. Forecasting and evaluation of geological processes consequences (FMC "Karst", "Underflooding", "Landslip")
5. Risk Assessment Subsystem

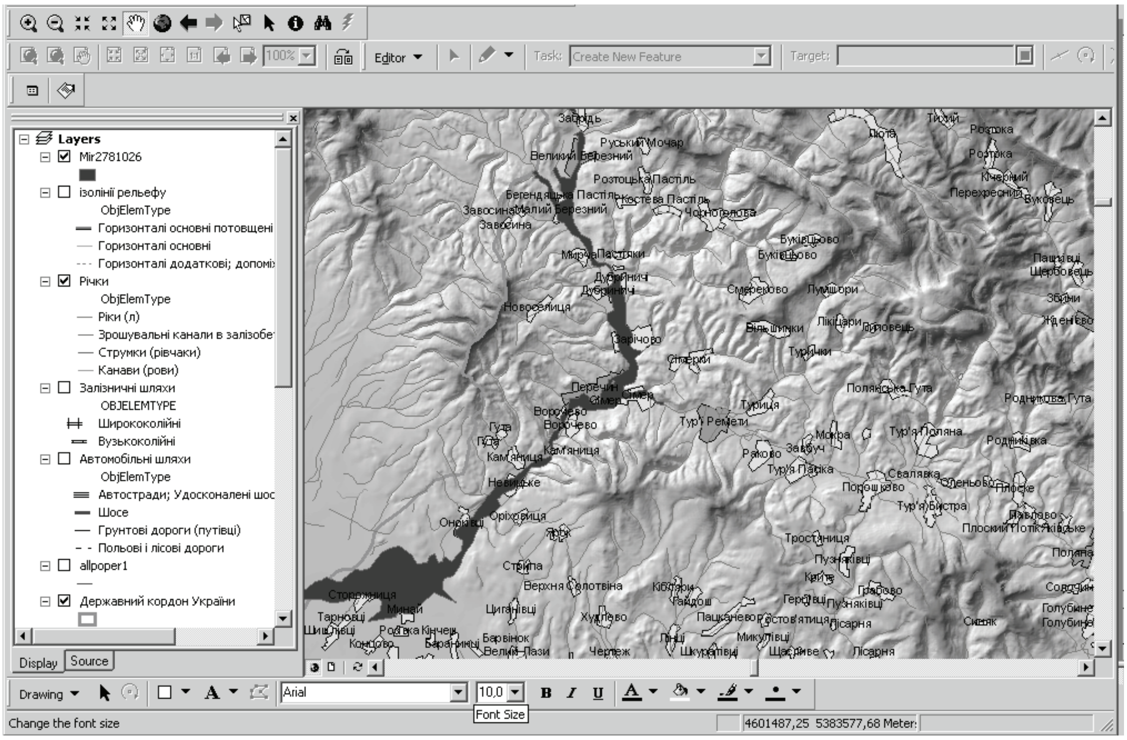

Fig. 1. Result of spatial modeling of flooding zone (FMC "Flooding").

All listed above complexes have similar structure which is defined by the following set of modules:

1. ***The manager of scripts.***
   This module defines the geoinformation environment for each type of emergencies, gives an opportunity for automated and manual data input, and also provides viewing, editing and use of the saved up scripts.
2. ***The modeling block.***
   Realizes algorithms of spatial modeling of hazard zones, using both internal GIS tools, and opportunities of integration GIS with the third-party problem-oriented modeling complexes.
3. ***Spatial analysis of emergency situations consequences.***
   GIS based spatial analysis defines the list of settlements (or their parts), the industrial enterprises, roads and railroads, and also engineering communications which are located in a hazard zone (volume of the information of a base digital map, scale 1:200 000).
4. ***The module of modeling results visualization.***
   It is intended for display on a map and in the table form the listed objects, which are located in the impacted hazard zones (a Fig. 2).

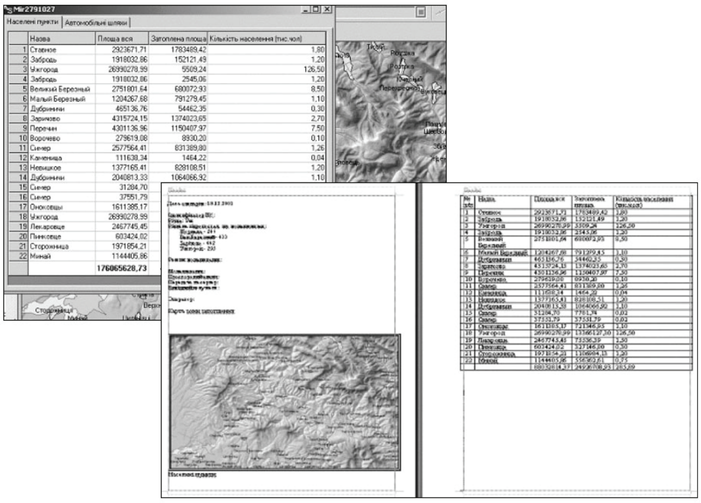

Fig. 2. The result of spatial analysis - module of visualization.

The following steps of GIAS ES Forecasting and Modeling Subsystem development are planned:

- development of Emergency and Operational Plans to Support Subsystem (EOPSS);
- development of GIS-based subsystem for viewing and spatial analysis of the simultaneous incidents (Common Operating Pictures);
- development of new GIS-based complexes for forecasting and modeling of emergency situation consequences;
- development of GIS subsystem for spatial analysis of emergency situations for distribution within Ukraine and for the control of efficiency of measures of prevention and recovery.

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OPPORTUNITIES OF GIS SPATIAL MODELING FOR ESTIMATION OF THE INTEGRATED COST OF THE PROJECTED COMMUNICATION ROUTES

When choosing the variants of projected communications lines, experts solve a lot of typical problems connected with a detailed estimation of physical, geographical, landscape, engineering-geological, etc. conditions of investigated territory. Problems include:
- definition of real length of a line considering relief;
- calculation and classification of crossings of this line with objects of hydrography, roads, etc.;
- estimation of remoteness of each site of the future construction from transport communications and settlements;
- calculation of construction cost increase depending on geological structure and land cover (sand, marshes, etc.)

and many other problems, demanding time consuming comparison of spatial positions of various objects of research territory. Complexity and tremendous labor input into process of such parameters definition forced researchers to reduce the number of investigated variants up to 2 - 3 of most obvious. Alongside with it, opportunities of spatial analysis of modern analytical systems of ArcGIS class, enable to automate such labor-consuming operations as
- calculation and classification of objects crossings,
- estimation of remoteness and expenses of distances overcoming on a road system or impassability,
- calculation of integrated construction cost, etc.

GIS tools of spatial modeling give complex estimation of each elementary part of investigated route considering of a wide spectrum of territory characteristics [6].

That is why the enterprises of oil-and-gas industry and telecommunications, find GIS practical application more and more widely. A number of publications in specialized editions prove that [1-5]. However, after the investigations of the Russian OJSC "ROSNEFTEGAZSTROJ" [5] very few researchers pay attention to opportunities of application of GIS raster analysis in this particular area. And in fact under this scheme (a cell of a grid - an element of a numerical matrix) starting from 70 - 80th years of the last century the net spatial models allowing to quantitatively estimate the influence of many factors in each point of space simultaneously were effectively applied. Modern technologies have allowed to increase the nets resolution, to automate process of data input and interpretation of results of modeling. The topic of application of GIS raster and vector analysis for creation of models of territory appropriateness is described in detail in the publication "Conceptual models of district, as the tool of a complex estimation of territories" [6]. The purpose of this publication is to take a look at methodical features of spatial modeling of the integrated cost of territory objects by means of raster analysis, based on a real project of GIS Analyst Center "selection of a projected gas line Turkmenistan-Ukraine".

Statement of a problem. Setting the problem of line selection of a projected gas line Turkmenistan-Ukraine, OJSC "Naftogasbud-Ukraine" selected GIS Analyst Center to lead a complex estimation of several variants of a line for choosing the optimal decision. The basic criteria of estimation had been the integrated pipeline construction cost, that is the cost considering the influence of the fixed set of territory characteristics.

As an area of investigation the territory containing three preliminary variants of the projected line, offered by the customer (fig.1) has been chosen: the Variant of detour of Caspian sea from the north with maximal use of existing corridors of pipelines through Turkmenia, Kazakhstan, Russia, Ukraine.

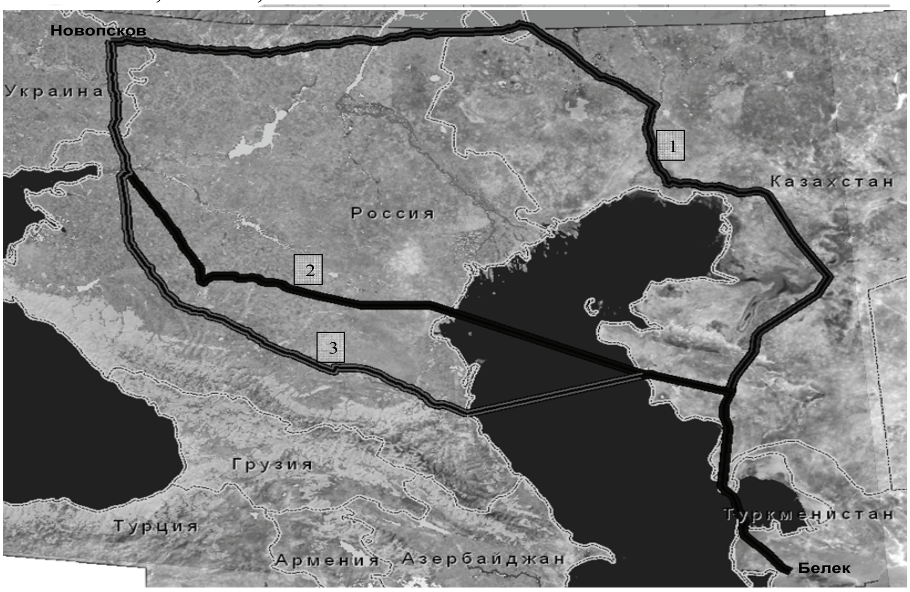


Fig.1. Variants of pipelines routes of projected gas pipeline Turkmenistan-Ukraine

- Variant of crossing the Caspian Sea with an exit to oil-gas areas and corridors of existing pipelines of Stavropol Territory.
- A variant of crossing the Caspian Sea with maximal use of existing corridors of pipelines. This variant has the main problem of passing through the territory of unstable political environment - the Chechen republic. Methodically work has been subdivided into following stages:
  - Preparation of information base to model.
  - Modeling of a surface of the integrated cost.
  - Spatial analysis of projected lines variants.

It is interesting, that the first 2 stages, being preparatory, took about 80 % of time of project realization. Taking very short, in comparison with traditional methods, period time the researcher has an opportunity to estimate practically unlimited quantity of variants.

Preparation of information base model.

Usually, the collected spatial data are in various formats. For example, the digital model of a relief (DEM) can be stored as in raster data form (GRID), and in the vector data form (TIN) models. And the results of the relief analysis (slopes, aspects, vision zones etc) are usually represented as a raster data. A similar format have such representations of continuous phenomena [7], as remote surfaces, surfaces of pollution density, depths of underground waters, etc. Other part of information consists of elements of topographical or thematic electronic maps; the data received by a vectorization, etc. This information exists in a vector format.

Preparation of information base of raster model usually includes 3 stages:

1 – gathering and systematization of spatial data;

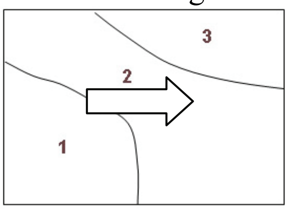
2 – putting the data to a raster format;

3 – reclassification of raster coverings for putting to a unified scale of categories.

As the first stage is an obligatory element of any GIS project and does not reflect methodical features of raster modeling, and it won't be mentioned in this publication.

Bringing Data to a Raster Format.

Two basic ways of bringing the data to a raster format are used in GIS: interpolation and converting. At all variety of interpolation methods the sense of this process in modern GIS is reduced to calculation of raster cells values of a continuous statistical surface at discrete values of vector objects (points of measurement, contours, borders or centroids of polygons). By interpolation in this project such raster coverings as digital model of relief surface and its derivative (a map of slopes) have been received; surfaces of remoteness from transport communications, the settlements, existing deposits, etc. At converting vector data into raster data we make spatial overlaying of vector coverage on an even grid (raster). Thus the values of vector coverings characteristics are automatically assigned to the pixels of raster that spatially coinside with corresponding vector object. Usually only the values of one significant field of initial coverings move into raster. For example, type of vegetation (Fig. 2).



vegetation.shp

2	2	3	3	3	3	3
2	2	2	3	3	3	3
1	2	2	2	2	2	3
1	1	1	1	2	2	2
1	1	1	1	2	2	2
1	1	1	1	2	2	2
1	1	1	1	2	2	2

vegetation.grd

Fig.2. Converting data from vector format to raster.

For solving the tasks of the project using this method the raster coverings for the following items have been obtained:

- types of vegetation and soils,
- water objects,
- transport systems and engineering communications by categories;
- corridors of the existing pipelines which are passing through the territory of Kazakhstan, the Russian Federation and Ukraine, etc.

Reclassification of raster coverings.

The purpose of reclassification is the putting all raster coverings to a unified scale of categories. For example, the categories of appropriateness or costs, as in an example above. For estimation of cost as experience show, it is much more convenient to appropriate the values of cost change coefficient to groups of pixels of corresponding category. For performance of this project the values of the coefficients have been developed by experts of Ukrgazproekt institute, in compliance with the existing construction specifications and experience of previous researches in this specific field.

It is known, for example, that construction of a line leads to the project cost increase in 1,8 times on marshy soils, and the project cost increase in 1,3 times on sand soils. Thus, in a raster covering of soils types the pixels located within the coordinates of marshy soils should receive the value of 1,8, and within the limits of sand – the value of 1,3. These transformations should be made for all raster coverings used in definition of the integrated cost of a line.

Modeling the surface of the integrated cost.

Spatial modeling was carried out by means of basic raster analysis contained in Spatial Analyst ArcGIS 8.3 appendix. The corresponding correcting coefficient, allowing to consider and operatively correct the contribution of each factor to formation of the integrated cost was appointed to each layer. The integrated cost was defined as function from initial cost of a line (the cost depending only from characteristics of communications) under the formula:

$$C\_sum.grd = C\_init.grd *(soil.grd * K_1) * (transp.grd * K_2)*.., \text{ where}$$

C_sum.grd – the result raster layer, where each pixel contains the calculated integrated cost of construction of a line in the given point;
C_init.grd - an initial raster layer, where every pixel contains initial cost of a line without taking into account factors complicating the construction;
soil.grd, transp.grd … - the raster layers containing in each pixel the information on coefficient of cost change depending on a class of objects containing in them (for example, each pixel in the area of development of sand receives value 1.3, swamp - 1.8, etc.).
K1, K2 … - the weight coefficients allowing easily correct influence of each factor on the integrated cost.

The spatial analysis of variants of projected lines.

During estimation of cost of each variant of a line it is necessary to find only the sum of pixels of result raster layer c_sum.grd which are crossed by a line of the next considered variant. Except for variant cost the researchers receive the results of spatial analysis describing various aspects of each variant of projected lines location (Table 1). Results of the spatial modeling within the limits of the project, are illustrated on picture 3. As we see, the longest variant turned out to be the cheapest.

Chart1

Influent Factors	units	Route № 1	Route № 2	Route № 3
Length of part in existing corridors	km	1420	700	1140
Maximum transport remoteness	km	15	11	12
Large water crossing length	km	4	327	302
Large river crossings number, (30-100m wide)	item	2	3	2
Small river crossings number (<30m wide)	item	15	12	10
Railway crossings	item	5	8	7
Highway crossings	item	0	6	3
Roadway crossings	item	4	10	7
Unpaved roads crossings	item	15	34	14
Length of Parts in forest	km	14	14	49
Length of Parts in marshes	km	40	39	25
Length of Parts in sands	km	544	395	285
Average slope	degree	0	1	1
Maximum slope	degree	4	5	7
Parts with slopes more than 18^o	%	0	0	0
Parts with slopes 8^o - 18^o	%	0	0	0
Parts with slopes less than 8^o	%	100	100	100
Average Height	m	73	74	88

Maximum Height	m	336	336	506
Minimum Height	m	-117	-126	-176
Length of route	km	2251,86	1881,58	2008,99

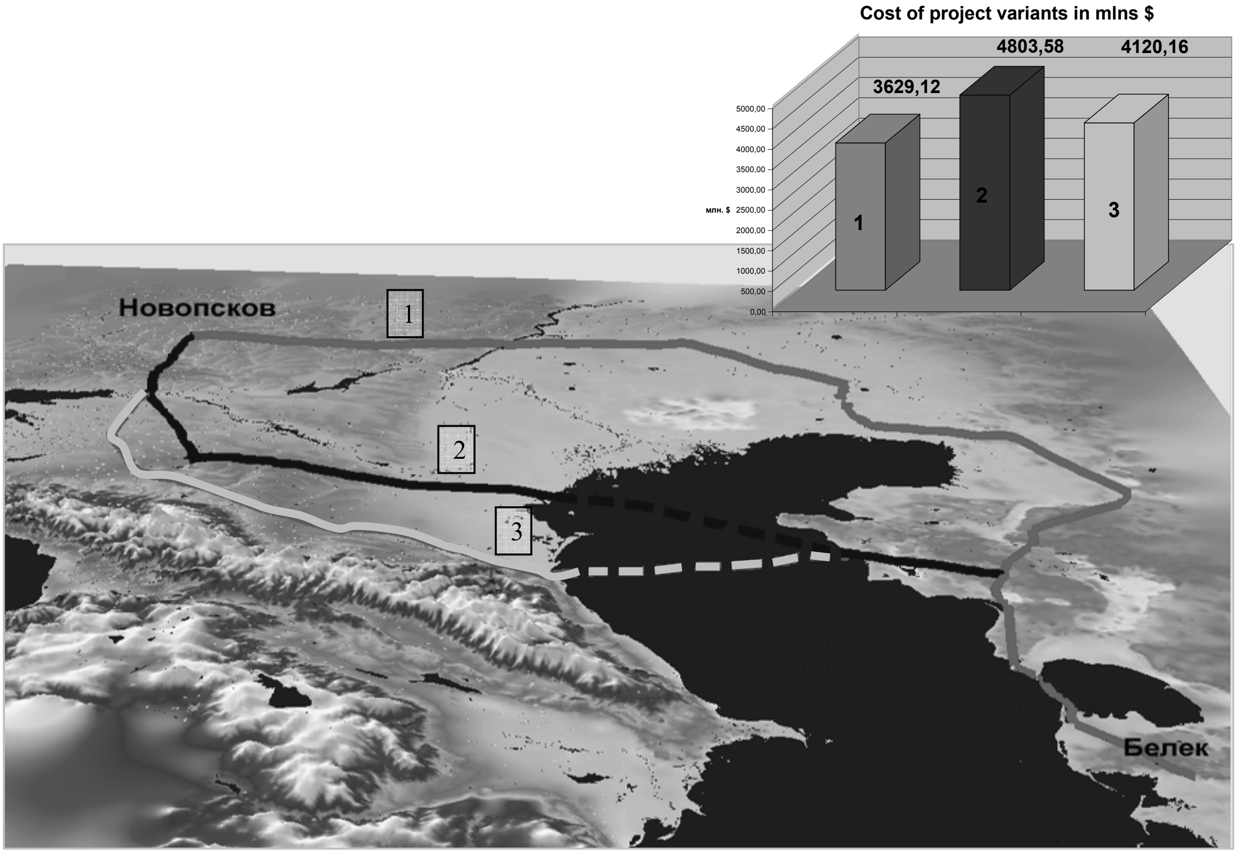


Fig.3. Cost Estimation of lines variants.

References:

1. Goncharenko S.V., Guralnik M.L., Fetman N.J., About some approaches in problem GIS and engineering networks // Information bjuleten GIS Associations of Russia ¹ 5 (12) 1997ú. - p. 28
2. Materials of the First training-practical seminar " Engineering communications and GIS ", Moscow, 14-17.10 1997
3. J.Korolev, I.Kashchinskaja, GIS and telecommunications // ArcREVIEW ¹ 1 (8), DATE +, Moscow, 1999 - pp.7-8
4. A.Glazovsky, the Choice of a route of an oil pipeline of Baku - Dzhejhan // ArcREVIEW N4 (27), DATE +, Moscow, 2003 - p. 15
5. Korsej S.G., Djakova N.B., GIS-TECHNOLOGIES in pipeline transport // ArcREVIEW N1 (24), DATE +, Moscow, 2003 - p. 20-21
6. O.Ishchuk, Conceptual models as the tool of a complex estimation of territories // Scientists of a note of Taurian University it. V.I.Vernadsky, Ô.15 (54), ¹ 1, Geography, 2002 - With. 94-101.
7. O. Ishchuk, M.M.Korzhnev, O.S. Koshljakov, Spatial Analysis and modeling in GIS // Edit. by akad. D.M.Grodzinskogo. - ", 2003. - p 119-123.

O.O. Ischuk

TECHNOLOGY OF CALCULATION OF REGIONAL MAPS OF RISKS FROM DANGEROUS NATURAL HAZARDS BY MEANS OF GIS SPATIAL ANALYSIS

The any natural hazard evaluation always starts from discovering its demonstrations and spatial tarnish within examined territory. The next step is territory zoning by the following indices: zone and climatic, hydrological, geological or other indices that after are become complicated by technogenic, sociological, economical and other factors of anthropogenic origin. By accepted methods [1,3,4], the basic map for risks calculation is obtained normally by the way of consequent application of two, three or more classification systems following by grouping the small results of division into taxons within limits the risks variability can be not considered. Hence, providing geo-informational technologies into risks calculation process it could be logically to expect to automate functions for geometrical application [6] (p.103-108) of objects from different maps, intersected areas calculation, integration and attributes assignment by spatial signs, etc. But, pursuant to the documents of All-Russian conference "Risk-2003" [1], implementation of such powerful tool of spatial analysis as GIS is normally limited by the specialists of mentioned branch by cartographical base creation for presentation and graphical comparison of elements, which specify risk level at the examined territory. In some cases GIS is used exclusively for specification and actualization of spatial position of dangerous areas by the satellite images data [3].

Such limitation in usage of valuable and powerful analytical potential of GIS cannot be considered as effective. The graphical comparison of contours expansion of each indices can present only a picture on their approximate ratio in space. The real effect will appear only after automatic system introduction for complex quantitative evaluation of each element of the territory by many criteria at the same time. In particular, the GIS spatial modelling means [5] are directed to such problems resolution.

Risk evaluation is a very complicated technological process that demands quantitative analysis of mutual spatial relations between many of the indices, which determine the danger level in every area. By calculation of Mr. O.L. Ragosin [3], the formula for determination of danger level or physical risk of territory destruction by natural process of any genesis looks, in general case, as the following:

$$\mathbf{H_s(C) = R_{fs}(C) = R_f(C)/S \approx S_c/S*t,} \qquad \mathbf{(1)}$$

Where, $H_s(C)$ – fixed danger, by area that identical to specific $R_{fs}(C)$ physical risk of territory destruction by definite natural hazards (m^2/year and m^2/km^2year); S – evaluated territory area (km^2), S_c – total area of destructed territory (m^2); t – time interval for destruction developing (years).

So, the natural hazards physical risk evaluation is determined considerably by ratio of destructed territory area to total area of evaluated spatial element.

Technology for risks calculation by GIS tools is based on use on possibilities of GIS spatial analysis in respect of calculation of separate elements of thematic territorial division within evaluated grounds of specified type.

For the purposes to calculate risk by elements of thematic territorial division, the zones of possible flood, under flooding, karst activity, chemical pollution, etc. may be used. By evaluating grounds, the following elements of administrative or departmental division of the territory may be used: region, district, territory of inhabited locality, industrial and municipal agglomerates, mining districts, recreational zones and other objects where risk level is determined.

The mentioned technology for risks evaluation has been introduced during 2003-2004 within project "Creation of informational and analytical subsystem for evaluation and forecasting of risks of vital activity and management at the territories with increased natural and technogenic danger" performed for the Government informational analytical subsystem of Ukraine on emergency situations, the customer is the Cabinet of Ministers of Ukraine and the Ministry of Ukraine on Emergency Situations [7]. The executors of this work are the Institute of problems of national security by RNBO of Ukraine and Centre „GIS Analyst" that have the appropriate experience in the sphere of spatial modelling using GIS tools, and also the appropriate software and equipment. Subsystem realized on the base of platform ArcView 8.3 (Picture 1,2).

Creation of map of specific risk demonstration of dangerous natural hazards

The first stage in risk evaluation from natural hazards demonstration is to prepare original map of natural risk factors distribution. At this stage, introduction of operations of GIS geometrical application gives the possibility to perform more effectively the consecutive application of different classification system of dangerous natural objects and zones with further grouping of small division results into taxons within limits of risk variability may be not considered. In the work on risk maps creation, the following documents of State geological and research institute of Ukraine have been used only for preparation of taxons' original maps that determine the risk of territory flood:

- Taxonomic unit of zoning and its borders;
- Under flooding districts;
- Areas of existing under flooding;
- Reasons of under flooding;
- Areas borders with different depth of groundwater occurence;
- Areas borders that are under influence of water storages of Dniprovskiy cascade to underground waters of Quaternary and Pliocene age;
- Borders of groundwater basin;
- Capacity of superficial deposits;
- Types of superficial deposits sections;
- Bleeds;
- Types of water-resistant complexes;
- Cones of influence.

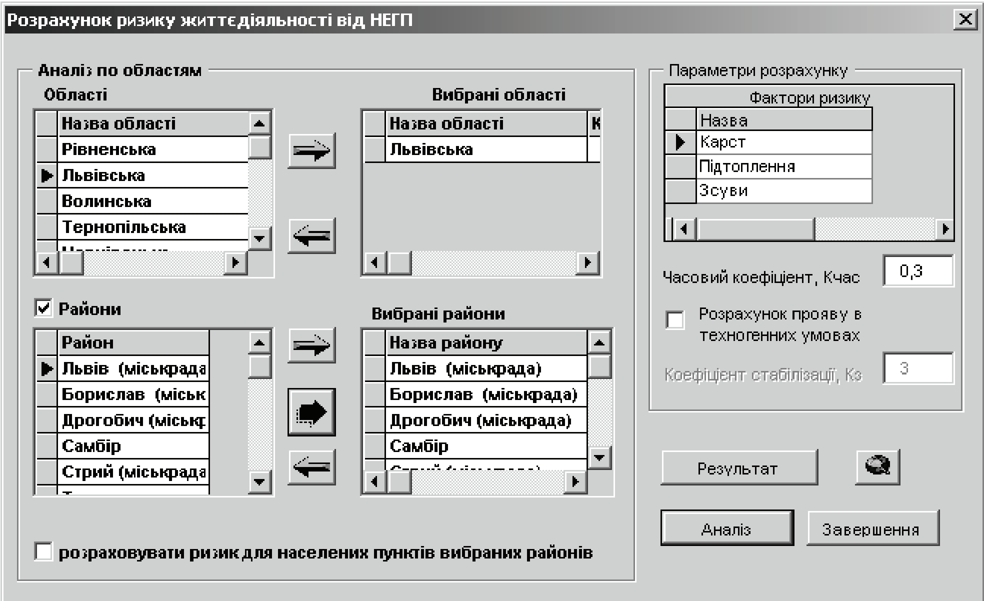


Fig. 1. User's interface for risks calculation of vital activity from dangerous exogenous geological demonstrations (DEGD).

Hence the formula (1), substantial risk of dangerous natural hazards demonstration (fault, karst, under flooding, flood, flash) Hs(C) in natural regime of development depends on interaction of two main components of their development: spatial territory destruction (***Sc/S***) and time dynamics of demonstration development (***t***).

The proposed technology determines the following order for analytical operation execution:

1. Grounds division of destructed zones upon territorial elements upon evaluated limits/borders (Example: under flooding zones by borders of administrative districts) and joining to each ground that has been obtained in a result of territorial element sign under limits it went. The described operation is more convenient to perform by using ***Intersect operation*** in module **Geoprocessing** (ArcGIS) [6] (p. 115-116).
2. Integration of destructed sites areas by sign of their attribute to definite territorial elements (example: using operation on boxes calculation of attributed tables ***Summarize*** (ArcGIS)) and to attach the obtained table to the globe of territorial element by using function ***Join***.
3. To calculate value of specific risk demonstration of natural or technogenic hazards by formula (1).

The following information is given for each administrative element in the resulting table:

- Its name;
- Total area;
- Destructed area;
- Ration of destructed area to total (S_c/S);
- Specific risk of dangerous natural hazards demonstration that valuated ($H_s(C)$)

Creation of thematic map of specific risk of dangerous natural hazards demonstration is performed by the last column of attributive table that contains calculated value $H_s(C)$. All other values are intermediate and required only at the stage of adjustment and checking of calculation programme.

Creation of risk map to vital activity (r) in the zone of dangerous natural hazards influence

Vital activity risk R in zone of dangerous natural hazards influence is calculated based on specific risk of dangerous natural hazards demonstration with consideration of population density.

Formula for its determination:

$$\mathbf{R} = \boldsymbol{H_s(C)} * \mathbf{d}, \quad \text{persons/year*km}^2, \qquad (2)$$

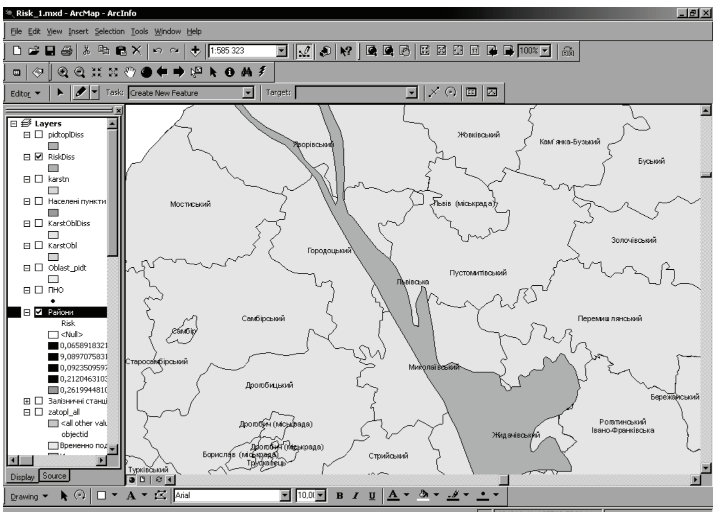
Where, **R** – vital activity risk in zone of dangerous natural hazards influence; **d** – population density in the valuated territorial element.

We found out from the previous section how to calculate $H_s(C)$ but we have still a problem how to calculate population density **d**. State electronic maps of Ukraine in scales of from 1: 200 000 to 1: 1 000 000 have the data about the last census on population number and areas of districts, regions and inhabited locality in the attributive table of objects of administrative division, therefore the users of these maps can find easily the ratio of population number of every object of administrative division to its area.

The principal formula for determination of vital activity risk in zone of dangerous natural hazards influence has to be in structure as to territories conditions.

For example: for agricultural inhabited localities within which the development of dangerous natural hazards is similar to natural regime of development because of lack of the system of engineering protection and substantial influence of technogenic influences, the population density **d** is calculated as ratio of total rural population within territory to total area of rural inhabited localities [7].

Actually, upon risk calculation of natural demonstration processes at the regional level, the potentials of GIS spatial analysis are required only at the stage of basic map creation for risks calculation and determination of spatial destruction of the territory (S_c/S). Calculations of specific risk, vital activity risk, including stabilization influence of systems, engineering protection actions, construction density and changes in geological environment are usually performed at the level of table calculations and elementary measurements of objects' geometry. Thematic map of vital activity risk in zone of dangerous natural hazards influence is based on values in column ***R*** got in calculation results (Fig. 2).



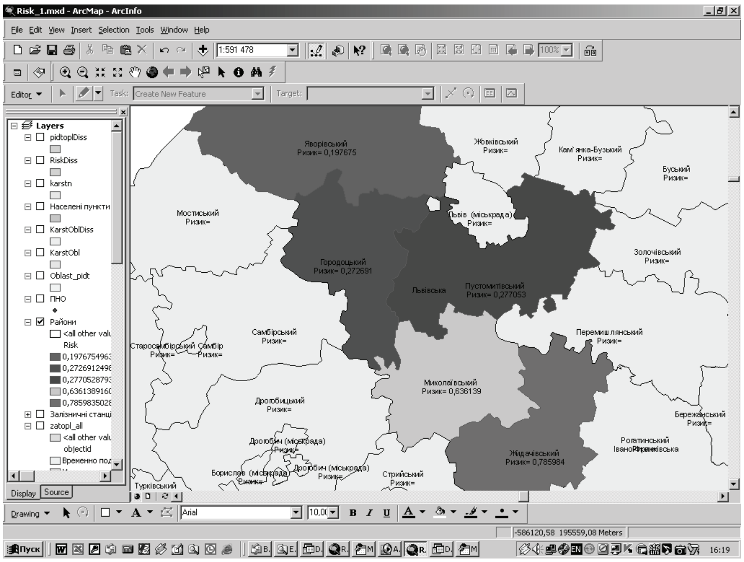


Fig. 2. Example for risk calculation from possible karst demonstration by tools of IAPOR (ІАПОР). Above – a demonstration map of karst activity taxons, below – resulting map of vital activity risk by regions of Ukraine.

References:

1. Estimation and management over natural risks/Documents of All-Russian conference "Risk – 2003". - M.: Publishing House of Russian University of Druzhby Narodov, 2003, volume: 1,2.
2. Doctor of science A.L. Ragozin, V.A. Akimov, M.V. Bolgov, V.N. Burkov, and others. Natural hazards in Russia. Evaluation and management over natural risks. - M.: Publishing House «KRUK», 2003, v.6
3. Doctor of science A.L. Ragozin, V.A. Elkin. Regional valuation of karst and risk dange. Problems of safety and extraordinary situations. – M.: VINITI, issue 4, 2003, p. 33-52.
4. Skuriyat E.I., Sarafanova E.M. Use of GIS for risks estimation at the regional level/ Documents of All-Russian conference "Risk – 2003". - M.: Publishing House of Russian University of Druzhby Narodov, 2003, volume: 1,2.
5. A.A. Ischuk, Conceptual models of region as a tool of complex valuation of the territory // Scientific notices of Tavricheskiy University named by V.I. Vernadskiy, v.15 (54), №1, Geography, 2002 – p. 94-101.
6. O.O. Ischuk, M.M. Korzhnev, O.S. Koshlyakov. Spatial analysis and modelling in GIS. Guide-book //academic D.M. Grodzynskiy – K.: Publication and polygraph centre „Kyivskiy University", 2003. – p. 119-123.
7. Creation of informational and analytical subsystem of evaluation and forecasting of risks of vital activity and management at the territories with increased natural and tecnogenic danger (report with annotations). – Kyiv: Institute of problems of national security by RNBO (РНБО) of Ukraine, 2004.

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THE SAFE AIRPORT BUSINESS CASE

It's quite obvious that by increasing airport capacity, considerable economic advantages will be created for the community. The question is how to achieve the required capacity at the right cost.
The approach that SELEX Sistemi Integrati has developed to identify how to reach safe capacity in a cost effective manner, will shortly be adopted within the Association of Italian Airports, under the patronage of the regulator ENAC and the full commitment of the Service provider ENAV.

The recommended Approach

The approach to enhanced capacity and safety recommended by SELEX Sistemi Integrati is based on a model that can be easily adopted to any airport environment, providing that similar Institutional Arrangement, as in the Italian case can be relied upon for the performance of the study and to ensure its findings are correctly implemented.

In this context we need to recommend that it is of paramount importance not to over specify solutions while ensuring that certification of facilities and working methodologies is achieved at every stage of the developments and implementations.

Airports need to be safe, and today also secure. This is in conflict with capacity growth. Whereby growth could be regulated to fit any given capacity, this is contrary to our Airport Business case that requires growth of demand for landings and takeoffs to yield the very impressive economics addressed later on in this paper.

The concept of Quality of Service is at the basis of the vital Increase of Demand, and this is to be met by the correctly dimensioned increase of capacity, obtainable with enhanced safety through deployment of optimised procedures together with the deployment of the right technologies, at the right time.

Air movements follow a relentless growth trend, due to a number of factors, among which the lowering of air fares, the lowering of political barriers among States, a change in the culture of the citizen, this particularly true in Europe for all ages of the population. Even if we do nothing to enhance demand, saturation of TMA/APP and airports will atke place in the next 5 years.

The rate at which air movements increases is in fact estimated at something around 5% per year. It is clear that by 2020 there is a likelihood of more than twice the air movements experienced today and some say even triple.

By large, a policy based on "wait and see" followed by late capacity enhancement would not be a very good business case, as there would be in the immediate a shortage of capacity, that would rapidly also become insufficient further ahead in time.

In the Ukrainian airspace, there is a potential for an even steeper growth in air movements due to the substantial political, social and economic changes in the area. It is remarkable that this potential may go undetected to the citizen and even to the Authorities because of un-preparedness of all those involved in the process of planning and implementing the required extensive restructuring of the airspace and ground infrastructures in a cohesive manner.

In the Public eye, Air Transport is still perceived as a niche market for few that can afford it. This perception is changing due to the deregulation process in place, but the Media still treat the domain as exclusive.

If we take the main Airports in the Ukrainian State as examples, the following table epitomises the situation in terms of infrastructures available, air movements achieved to date and air movements possible without land side changes to the airports. The increase can be related to slot value and the amount of revenue produced is outstanding.

Grand total

Growth in capacity should match planned growth of demand. If not so, investments would be recovered only in a much longer term than planned for. Demand depends very much on passengers who want to reach a specific destination. Airlines respond to this by intensifying flights to such destination. However neither the passenger nor the Airline wish to incur delays, (although in practice today it is common to accept some degree of "built in" delay because air transport is the only way to reach a valued destination). This leads to the need to implement the concept of "Quality of Service" as the feature through which passenger and airline are pleased to use the airport.

Quality of service (QoS) is a multi-facet argument that is an integral part of the SELEX Sistemi Integrati model for the Safe Business Case development. Lack of QoS results immediately in increases of cost to be faced by airlines and discomfort of the passenger. Also negative effects are reflected in the Press, not to mention negative comments reflected in the Performance Committee of EUROCONTROL

By performing a brief analysis of QoS we appreciate that it is meant to live with the increase of demand and capacity that we plan to implement.

Punctuality of a flight is not the only indicator of QoS, nor is it the best. Commercial practices of the airlines define the optimum "built in" delay on the basis if their own internal resources, flight and airport conditions, and even the incentives Governments may apply to enhance the level of service airlines and airports offer to the passenger.

Such commercially sustainable punctuality value has to then often clash with the real time daily flying practice. A more analytical approach shows that QoS can be better achieved by acting on the following:

- Delays off the block due to a number of very variable reasons
- Cancellation and re-routing due to weather conditions that cannot be mitigated or reduced through ATM or airport operations
- Variability of flight times from entering the TMA till touchdown
- Variability of taxi times
- Reactionary delays affecting arriving aircraft due to airspace management outside the TMA or the takeoff airport

There is a cultural barrier to overcome if we really wish to measure the components of delays. Only if we understand what causes delay may we find solutions in terms of changes to operations or adoption of specific technologies Operators and service providers have a code of practice that can make difficult the attribution of who causes delay.

The cultural change that needs to be introduced to avoid such resistance is that of focussing on what one can do to reduce delays rather than pinpointing who has caused it.

Accurate measurements and their analysis are fundamental to the improvement of scheduled airline plans and for the publication of airport capacity and related QoS for the next season.

SELEX Sistemi Integrati approach to QoS is based on the following:

• Rely on EUROCONTROL data as far as possible as these include the ATM network delays that impact on airport operations. Any measurement performed at an airport cannot take into account the impact on network effects.
• Perform statistically valid measurements of delays utilising direct observation of Aircraft movement from stand to runway
• Utilise a direct link with CFMU
• Relate flight to weather data
• Record Tower operations for post analysis
• Interview all actors involved in the management of the flight: airline, Pilot, Airport Operator, Service Provider along the lines of an hml logical model developed for the Eurocontrol OATA Project

Conclusions

SELEX Sistemi Integrati is ready to provide expertise to conduct the Programme of verification and data analysis of the airports of Ukraine as identified above. Consensus of Airport Operators, the Regulator and the Service Provider are necessary for the positive conduct of the project. The cost of the project would be mutually agreed and should be financed by the Airport Stakeholders of Ukraine. The deliverables will consist of a recommended plan of operational and technical implementations that will prepare airports for safe operation well into 2020.

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SAFETY ASSESSMENT METHODOLOGY FOR SIMULATIONS
- SAFETY INDICATORS -

This paper examines the possibility of identifying some of the most relevant safety indicators and defines a way to measure them. It describes the reasons for using interviews with controllers in order to identify hazardous situations and explains further analysis of the interviews in order to extract indicators.

Introduction

In recent years air travel has increased at unprecedented rates. During the last ten years growth of the air traffic was more than 50% and only in 2004 traffic increased for 4,8% in Europe [1]. Because of this significant increase, it is likely that this trend will remain. Nevertheless, it is necessary to meet the forecast traffic growth while keeping the safety and efficiency at least as it is today, since safety is one of the most important issues in the aviation. If we want to maintain the same absolute level of safety (number of accident per year) with the increase of traffic, the relative level of safety must increase accordingly. Hence, in the CEATS (Central European Air Traffic Services)area where the traffic will increase at a must higher pace, safety will have to be improved same to a much higher degree.

The implementation of ESARRs is a first answer to this requirement. ESARR is the acronym for Eurocontrol Safety Regulatory Requirements. These requirements represent mandatory standards for the European states. The aim of ESARRs is not only to create a properly integrated European airspace with common safety practices, but also to raise standards at least to an agreed minimum.

Another part of the answer to this objective will be given by the CEATS common Upper Area Control centre (CEATS UAC), applying advanced concepts and higher safety standard on a wider airspace. A larger airspace will allow cross border sectors, reduce the number of sector coordination, and implement advanced safety nets and monitoring tools.

The role of the EUROCONTROL CEATS Research, Development and Simulation (CRDS) Centre in Budapest in this context is to test, evaluate and improve the operational and technical concepts and choices to be implemented at the future CEATS UAC. Hence, CRDS aims at defining measurements to evaluate changes in the level of safety introduced by new Air Traffic Control concepts, tools and procedures, during real-time simulations. Evaluation encompasses facets such as feasibility, acceptability, usability, efficiency, etc … but most of all the risk of loss of safety.

Safety Assessment Methodology

Taking into consideration traffic growth in the Central Europe and also safety requirements, the purpose of this study is to investigate safety assessment methodology.

A side objective of this study is to contribute to the compliance of CRDS with ESARR 4, by having adequate safety indicators. ESARR 4 concerns the use of Risk Assessment and Mitigation, including hazard identification, in Air Traffic Management when introducing and/or planning changes to the ATM System [2].

Therefore, main objectives of this study are:

- to identify some of the most relevant safety indicators for simulations
- to define a way to measure them.

This study investigates human factors perspective and the way human reads the ATM system in order to provide (achieve) safety.

Methodology

The aim of the study was to identify subjective but realistic safety indicators based on the air traffic controllers' opinion. The intention was to identify factors that are indicating to the controller events that can develop into unsafe situation. The main idea was to identify situations that are safety critical from the human perspective and then to find out what in those situations pointed out on potential hazard. Therefore, situations that were interesting for this study were not conflict situations, but rather non-routine situations when controllers could anticipate an unsafe situation and take actions in order to avoid potential conflicts. The hypothesis behind was that higher (increased) vigilance should reflect higher workload and occurrence of potential problem.

In order to obtain such situations, one of the adequate techniques is to interview the controllers. At the same time, interviews allow to find out what caused the problem according to them. The required information are related to a problem that occurred and why it happened. Also, the interviews enable the controllers to describe the way they solved the problem (avoided the unsafe or conflict situation) and which factors influenced their decision.

Actually, purpose of the interviews was to facilitate recognizing situations that are safety critical from controller's point of view. Hence, an analysis followed to identify and extract from the interviews the relevant (potential) hazardous situations or unsafe situations.

. The analysis led to setting apart all the events and factors that altogether resulted in an unsafe situation. Those situations were broken apart into smaller events in order to assist understanding the chain of the events that took place in each particular situation so as to lead to an unsafe situation. The assumption was that by finding out what was the exact cause for occurrence of each of these smaller events, actual causes of whole unsafe situation would be found out as well.

However, to consider those indicators of unsafe situations as relevant, it is necessary not just to find out those that are significant for particular identified situations, but those that are significant for all of them. In that way, general relation between identified potential hazardous situations was detected. Once the potential hazardous situations were analysed and broken down into separated events that pursue one after the other, a common pattern where all of these situations could fit was identified. This pattern was deduced in such way to describe all gathered situations.

Additionally, this chain of events was broken down in order to find out the indicators that helped controller anticipating the unsafe or hazardous situation, and what was his/her reaction to avoid conflict situation. . Indeed, the issue was to know what indicator gave enough information to decide what to do in order to avoid these situations. Due to this fact, the situations that controllers described were again analysed in details to distinguish what specific information showed them in advance that there will be unsafe situation and factors that s/he took into consideration while solving the problem.

Once, whole this analysis based on the interviews was conducted, some of the relevant subjective but realistic safety indicators were identified according to the controllers' point of view (Figure 1).

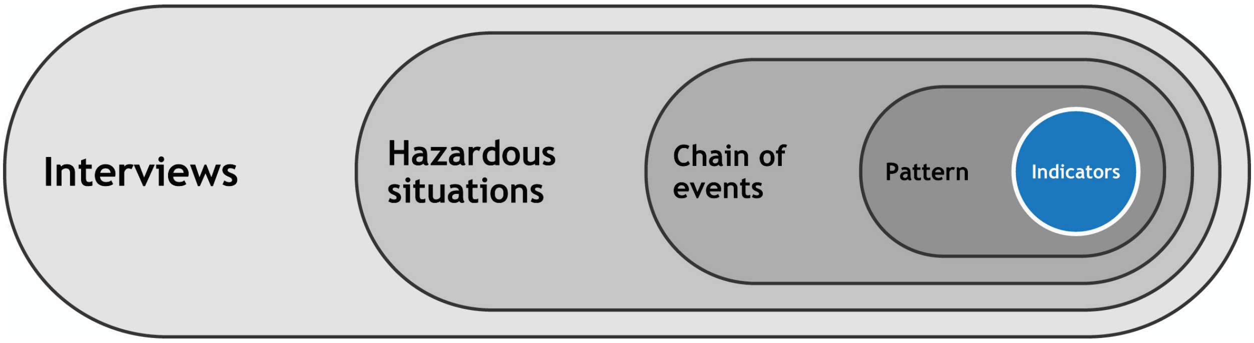

Figure 1. Methodology of identifying subjective but realistic safety indicators based on the interviews

Interviews

The interviews concerned non-routine situations and situations that require more of controllers' attention. The interviews consisted of a series of questions regarding what could help identifying non-routine situations and also analysing those situations in details in order to find out their exact causes.

The interviews were semi-structured. The questions were defined in such way to allow the controllers to describe situations that are safety critical according to their judgement. Also, some of the questions referred to mitigation actions. Mitigation actions were taken based on the controllers' analysis of the events that took place before he could react.

The interviewed controllers were operational controllers coming from different countries, participating in CEATS simulations. All of them had a different nationality and age, working in a different operational environment, with different educational backgrounds and working experience. Before the interview took place, the controller was introduced with main idea of the study. They were aware of the objective of the interviews and of the objective of the study.

The interviews were taken after the exercises of a simulation. These interviews did not take place in the simulation room, but in separate room where were present only the interviewed controller and the interviewer. It is very important to emphasise that controllers were not time limited. They were free to describe required situations as long as they wished and in the way they preferred. In average duration of the interviews was 1 hour. Few of the controllers also used drawings to explain accurate order of events that took place to result in unsafe situation. These drawings facilitated the identification of relevant situations.

Additionally, notes were taken by the interviewer, so information that could not be described by drawings was available for further analysis.

Once the interviews were conducted, the analysis followed.

Analysis and Results

After investigation (research) methodology was defined and interviews were conducted, analysis followed. To begin with, the potential hazardous situations were extracted out of the interviews.

Hazardous situations

Although controllers did not work in the same operational environments, had different backgrounds and years of experience, all situations that they considered as unsafe were very similar. It seemed like all interviewed controllers had same perception about the situations that are safety critical.

The (potential) hazardous situations extracted from the interviews were only few, as some of the controllers described situations that were almost the same (even if some irrelevant details were making differences).

Short description of one of the mentioned situations follows, as well as drawing to assist understanding all circumstances in observed moment; so as to be aware of the nature of situations controllers gave (Figure 2).

Figure 2. Identified potential hazardous situation

In the sector there are two parallel routes with small distance in between, in accordance with in advance designed flight plan.
Aircraft 1 is flying on one of them, and aircraft 2 is supposed to join parallel route in the moment when distance between them is the smallest.
Since both of the aircraft can change heading a bit, without significant change in route, then there can be loss of separation, which means loss of safety.
One possibility to avoid this situation is to give instruction to the pilot of the aircraft 1 to lock the heading and to the pilot of the aircraft 2 to strictly follow instructions while joining the route.
The other possibility is to give to the pilot of the aircraft 2 instruction to join the route before or after designed point, in order to provide bigger distance between aircraft.

Common pattern

Unsafe situations were extracted from the interviews, and analysed in details. The situations were broken down into events that altogether led to this unsafe situation. Very important was to determine exact sequence of those events. The example based on one of the situations described above follows in order to facilitate explanation of this phase of the analysis.

<u>Description of the chain of events:</u>

1. *aircraft flying on a planned route*
2. *other aircraft is supposed to join parallel route (on very small distance)*

3. *based on the other conditions, ATCO analyses situation and decides how to organize them (a/c joining route before or after planned point, or locking heading of the a/c)*
4. *ATCO gives instructions and pilots follow them*
5. *a/c continue flights (flying on parallel routes) with safe separation (Figure 3)*

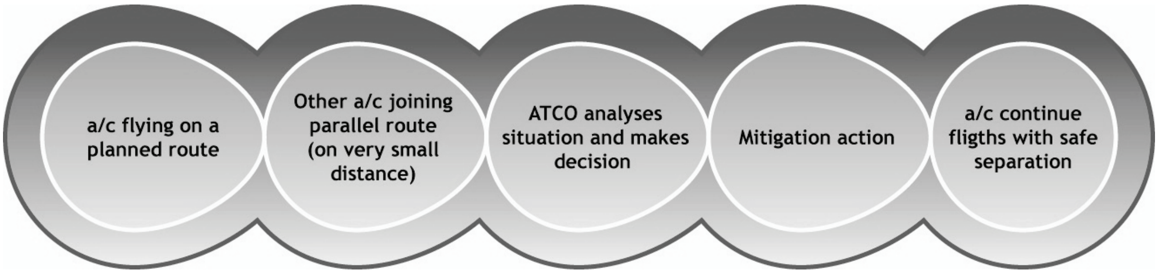

Figure 3. The chain of events of the identified potential hazardous situation

All of the situations extracted from the interviews were analysed in the same way, described with a chain of events that took place so as to result in a situation that requires more of the controller's attention. To consider safety indicators as relevant, they should be contained in attribute that is common for every situation. Therefore, it was very important to identify such connection, and then analyse it further in order to identify indicators that are shared among the controllers.

In fact every situation described by the controllers was based on a consistent order of the events whose description answers one of the following questions:

1. What were the conditions like before disturbance occur?

Description of some normal conditions, something that controller was expecting and that he was prepared for.

2. What happened unexpectedly to take more of the controller's attention (what is the disturbance)?

Suddenly something that requires his attention more than in routine situation would happen – disturbance.

3. What factors the controller took into consideration to decide how to solve the problem and other factors that influenced his decision?

He makes a decision how to solve this situation based on the current conditions in the sector, but also on the other factors as environment, technical limits, and human factors like recent training, refreshment of the knowledge…

4. Which mitigation actions were taken in order to avoid unsafe situation?

Derived from decision, he takes mitigation actions – gives instructions to the pilots in order to keep aircraft safe apart.

5. What were the conditions like after the mitigation actions were taken?

After these actions are taken, there is new condition in the sector. Any new decision would be made based on these new circumstances.

As a result, the pattern common for all potential hazardous situations that has been deduced is presented in following figure (Figure 4):

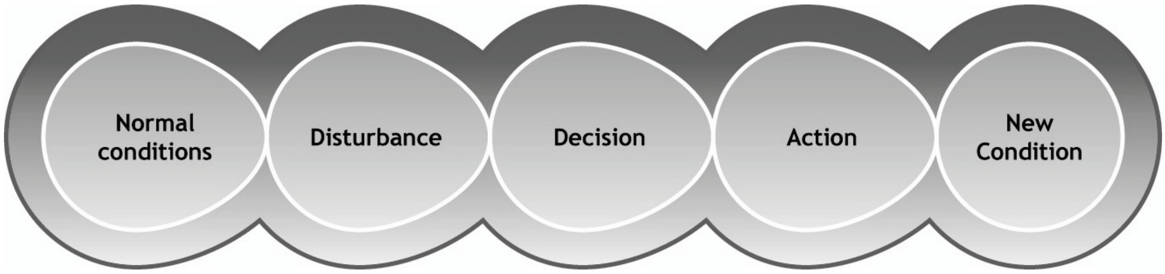

Figure 4. The common pattern

All of the situations gathered from interviews could be described through this common pattern and associated chain of events.

Relevant indicators

The moment when the controller was aware of the problem and the moment when he had enough information to make decision and react to solve the problem, occurred always after the disturbance happened. However, to make decision regarding which mitigation actions should be taken, the controller had to consider as well current circumstances in the sector. Therefore, indicators of an unsafe situation were identified through investigation of circumstances in the sector before disturbance occurred (*normal conditions*), circumstances when disturbance occurred and characteristics of the disturbance itself.

Further, the situations were analysed once more to identify what exact characteristic of conditions in the sector, as well as characteristics of the disturbance, showed to the controller in advance that unsafe situation can occur.

In every situation, being familiar with the sector (size, shape, neighbouring sectors, routes, crossing points, etc.) was very important. Moreover, current situation in the sector was also especially significant (number of aircraft, their movements, distribution of the traffic…).

It is important to emphasise that the controllers considered as a disturbance the holding procedure, a cumulonimbus and other similar occurrences that already have defined procedures for their solving. However, the way they will pursue these procedures to solve the problem, depended on the characteristics of the traffic in that particular moment. Consequently, characteristics of the disturbance itself were not taken into consideration by the controllers, but much more factors that helped controllers to choose the way to apply those defined procedures in order to solve the problem.

Additionally, more important was how the controller was acquainted with the sectors and current characteristics of the traffic. These indicators were recognized in all examined potential hazardous situations.

With further examination, it was possible to categorize identified indicators into 2 different groups:

A. <u>indicators characterizing the airspace (sector itself)</u>
   - Sector shape
   - Sector size
   - Number of neighbouring sectors
   - Number of routes
   - Number of crossing points
   - Distribution of the routes

B. indicators describing the traffic in the moment when situation took place
- Number of routes in use
- Number of crossing points in use
- Number of a/c in the sector
- Distribution of the traffic
- Number of vertical movements
- Number of flight levels in use
- Number of sectors in use

However, when these indicators were considered in the context of the safety, it was realised that they are rather related to the complexity of the traffic in the moment when unsafe situation occurred than to safety itself [3].

Modelling safety/complexity factors

The indicators of unsafe situations from controller's point of view were actually a combination of those factors. The way they were combined helped the controller to anticipate unsafe situation. Additionally, based on those factors, the controllers could decide which mitigation action to take to avoid loss of safety.

But still, these indicators are not reflecting the subjective opinion of the controllers about safety in those situations. Therefore, further investigation follows in order to define connection between these objective measurements and subjective opinion of the controllers [4].

The aim is to define mathematical model that would be able to describe the relation between the controller's subjective but realistic estimation of safety of a situation, and these objective (even partial only) indicators of complexity. Still it is a black box, but one of the possible ways to connect the objective complexity indicators and the subjective opinion of the controllers is regression analysis.

The general purpose of regression is to learn more about the relationship between several independent or predictor variables and a dependent or criterion variable. In the main, the goal of regression analysis is to determine the values of parameters for a function that cause the function to best fit a set of data observations that one provides [5].

In this particular study, a set of data presents objective measurements of complexity indicators. The relationship was sought between objective measurements of complexity indicators (independent variable) and the controllers' subjective assessment of the safety of the situations considered (dependent variable).

As an illustration of such an approach, the (simple) linear relationship between these two is assumed, and, correspondingly, the linear regression analysis used. Simple regression analysis will show how variables are linearly related, and by means of correlation analysis the degree (extent) of this relation will be examined.

The idea is that, during the simulation we could provide measuring of complexity indicators on even time intervals (e.g. 2 minutes) and, at the same moments, subjective controllers' assessment of the overall situation safety (e.g. nominal scale). Let T_j ($j=1,\ldots,n$) stands for the moments when complexity is measured, and X_i ($i=1,\ldots,m$) are the objective measurements of complexity indicators. If Y_j ($j=1,\ldots,n$) is the subjective assessment of the situation safety, made by the controller in moment T_j, then the relationship could be modelled as follows:

$$Y_j = a_1X_1 + a_2X_2 + \ldots + a_mX_m, \qquad (j=1,\ldots,n)$$

where a_i (i=1,…,m) are the parameters to be estimated, which will relate the objective complexity of the situation to the subjective assessment of its safety by the controller. This will point out the controllers' perception of the influence (significance) of any single complexity indicator on the overall situation safety. Besides, it will be shown to which degree the controller's assessment of the situation complexity can be explained by (the set of) complexity indicators taken into account. In addition, it could be determined whether some of complexity indicators are interrelated, and, if so, the nature and degree (extent) of such relationship.

Conclusion

Finding out the nature as well as the extent of such relationship could provide us with a prediction of the controller's subjective assessment of any possible future situation that could be described by the objective measurements (complexity indicators). Furthermore, the controller's subjective safety assessment could be used in order to facilitate the design of safety scenarios for simulations as well as to prevent or alert occurrence of potential unsafe situations (kind of "alert tool").

The indicators, as identified in present study, should be considered together, i.e. combinations of these indicators rather helped the controller to anticipate unsafe situation than any of them separately. Therefore, more work has to be done concerning influence of any single indicator and identifying the most representative combinations that to the greatest extent reflect the controllers' subjective assessment of the safety of the situations. Integration of these issues into the presented work is an interesting problem for further research.

References:

[1] **Performance Review Commission Eighth Performance Review Report (PRR 8)** *(Covering the calendar year 2004), EUROCONTROL*

[2] **EUROCONTROL Safety Regulatory Requirement - ESARR 4 Risk Assessment and Mitigation in ATM**

[3] **Introducing Structural Considerations into Complexity Metrics** *Jonathan M. Histon, Guillaume Aigoin, Daniel Delahaye, R.John. Hansman, Stephane Puechmorel*

[4] **Objective Measures of ATM System Safety: Safety Metrics** *S.R.Kinnersly INTEGRA Project, EUROCONTROL*

[5] **Introductory Statistics for Business and Economics** *Thomas Wonnacott, Ronald Wonnacott*

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ON-LINE ESTIMATION OF THE OBSERVED SAFETY LEVEL

According to ICAO normative documents the assessment of an ATC system is to be based on the estimation of the observed safety level. The presented abstract is devoted to analysis of existing conflict (collision) models and methods of the observed safety level estimation. A new conflict (collision) model and an algorithm for on-line estimation of the safety level that uses the model are proposed.

Normative ICAO and Eurocontrol documents define the safety level of air traffic as,

$$L = \frac{m(T_O)}{T_\Sigma(T_O)}\left[\frac{collision}{flight.hour}\right] \tag{1}$$

where $m(T_O)$ is a number of collisions over the observation time T_O, $T_\Sigma(T_O)$ is a total flight time of all aircraft detected by an ATC system over the observation time. On-line estimation of the safety level relies on the determination of the collision number $m(T_O)$. Estimation of $m(T_O)$ is an extremely complicated problem which successful solution depends on the used conflict (collision) model. At present there are more than 60 methods to estimate the safety level that use different models [1]. All these methods can be divided into two large categories: geometrical and probabilistic.

To determine a collision (conflict) possibility the analysis of air pathways (plan information) is performed in geometrical methods. The geometrical methods are in turn divided into two subcategories: nominal and worst-case methods. In the nominal methods, the current states are projected into the future along a single trajectory, without direct consideration of air position or velocity uncertainties. The worst-case methods determine the worst, i.e. the most dangerous, air trajectories among a set of possible pathways. A virtue of the geometrical methods of the safety level estimation is their simplicity and clarity. However, these methods do not permit to determine the uncertainty of an OLS estimate because they do not consider the probabilistic nature of an air motion along a given route and errors arising in an ATC surveillance system.

Probabilistic methods in this sense substantially differ from geometrical, as they take into account the probabilistic nature of aircraft movement and their position estimation in ATC systems. Analysis of the scientific publications shows that the probabilistic methods are considered now as the most perspective ones.

Among all probabilistic methods the most interesting are the following:

1. Generalized Reich's model, designed in National aerospace laboratory NLR (Netherlands), authors Baker and Bloom [2];
2. Method, designed in National Agency of Space and Aeronautics NASA (USA), authors Paielli and Erzberger [4].

The first method, designed in NLR, is a generalization of the Reich method known since 60s [3]. The authors of a method got rid off some most burdensome axioms of the Reich model. However, principal features of the model have remained. In particular, an aircraft in this model is represented with a 3D box (parallelepipeds) of sizes L_x, L_y, L_z (Fig. 1). All aircraft, located in a coverage zone of the ATC system, are treated by pairs. In a current instant t the distance between each pair of aircrafts $\boldsymbol{r}(t)$ is estimated. This distance is considered as a stochastic process with known (or estimated in real-time) statistics. It is assumed, that collision takes place, if a realization of $\boldsymbol{r}(t)$ falls into a critical region with sizes $2L_x, 2L_y, 2L_z$. Thus, the probability of collision $P_C(T_O)$ is equal to the probability of interception of a stochastic process trajectory $\boldsymbol{r}(t)$ with the boundary surface of the critical region in an observation interval T_O. Accurate mathematical solution of this problem is extremely difficult. As well as the Reich method the NRL method simplifies the solution. The simplification is based on the assumption that the boundary surface of the critical region is not absorptive, as it should be, but transient, i.e. a trajectory of $\boldsymbol{r}(t)$ can repeatedly pass through it. It is clear that this assumption permits "multiple collisions" of an aircraft, but perhaps it is the only way to determine the average frequency of intersections of the process $\boldsymbol{r}(t)$ with the critical region boundaries. This mean frequency of intersections $\Lambda(t)$ is called the intensity of collision flow. Given $\Lambda(t)$ it is possible to find the so-called collision risk

$$R(T_O) = 1 - \exp\left\{ -\int_0^{T_O} \Lambda(t) dt \right\} \quad (2)$$

The collision risk approximately corresponds to the probability of collision, however is not equal to it. This parameter is one of main parameters used for the safety level estimation. A virtue of the method is that it takes into account uncertainties (errors) of aircraft coordinates and velocities. A deficiency of a method is its impossibility to determine accurately the probability of collision $P_C(T_O)$ because the collision risk and the collision probability are approximately equal to each other for seldom events.

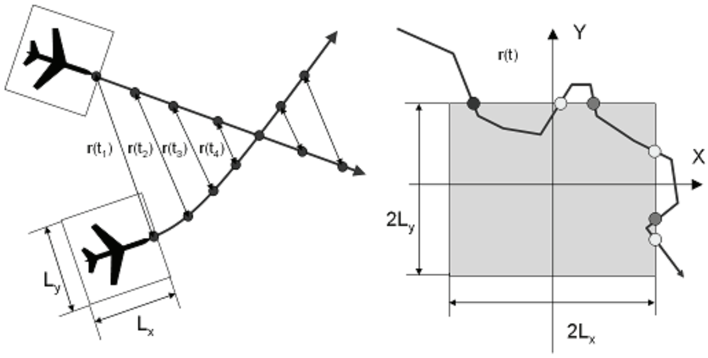

Fig. 1. NLR model

Designed in NASA the second method of the safety level estimation allows to evaluate the probability of collision (conflict). For this purpose one aircraft of a pair is considered to be fixed in its position, and all uncertainties of a relative position of the aircraft pair is assigned to it (Fig. 2). The second aircraft of the pair is considered to be flying along *a priory* known pathway with a velocity of mutual approach of the aircraft. Around the flying aircraft a sphere of some radius $R = D/2$ is drawn (in case of the conflict probability computing $R =$ 5 nm). This sphere is called the conflict zone. Because of the aircraft motion this sphere derivates a cylinder. The probability of conflict (collision) is computed as the probability of the first aircraft to get into this cylindrical area. Geometrically this probability is equal to the probability measure of the intersection volume of the uncertainty zone and the cylinder. A virtue of the given method is its capability to estimate the conflict (collision) probability

$P_C(T_O)$. Its deficiency is the impossibility to take into account the uncertainty of aircraft velocities.

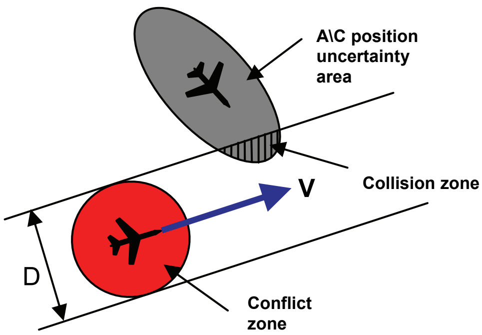

Fig. 2. NASA model

The essence of the designed collision (conflict) model is that after a current instant t the aircraft of a given pair fly uniformly in directions of their instant velocities $V(t)$ (Fig. 3). The analysis is based on determination of the joint probability that a random variable d, minimum distance between the aircraft in a pair, is within a critical region and a random variable τ, time interval to maximum aircraft approach, is within the interval $(0, T_O)$

$$P_C(T_O) = \Pr\{d < D, 0 \le \tau < T_O\} \tag{3}$$

The random variables d and τ are evaluated as,

$$d = |\boldsymbol{r}| \left| 1 - \left(\frac{\boldsymbol{r} \cdot \boldsymbol{v}}{|\boldsymbol{r}||\boldsymbol{v}|} \right)^2 \right|^{1/2}, \quad \tau = -\frac{\boldsymbol{r} \cdot \boldsymbol{v}}{|\boldsymbol{v}|^2}, \tag{4}$$

where $\boldsymbol{r}$ is a current distance between the aircraft, $\boldsymbol{v}$ is a current velocity of their mutual approach.

The sizes of the critical region are selected as in the Reich collision model. The calculation of the collision probability takes into account uncertainties of positions and velocities of aircrafts. The condition on the random variable τ in (3) is of a crucial importance because it permits to control the prediction time interval for the safety level estimation.

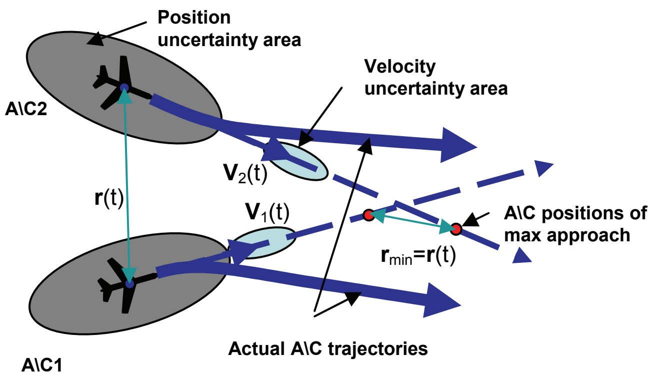

Fig. 3. The proposed model

To verify the proposed model and the safety level estimate two test scenario were considered.

The scenario of the test is the following: two aircraft take off with equal velocities of 720 km/h and fly rectilinearly from sites removed from each other by 30 km (Fig. 4). The pathways of their motion are selected in such a way that in some point their collision takes place for certain. The angle of the aircraft trajectories intersection is equal to 90º. This is achieved through the aircraft azimuth angles chosen equal to +45º and -45º respectively. Distance between the aircrafts varies approximately linearly as it is shown in Fig. 5. The moment of collision corresponds to the 89th second of the flight. During simulation $\Lambda(t)$ and $P_C(T_O)$ are evaluated. The observation time T_O was 1 second.

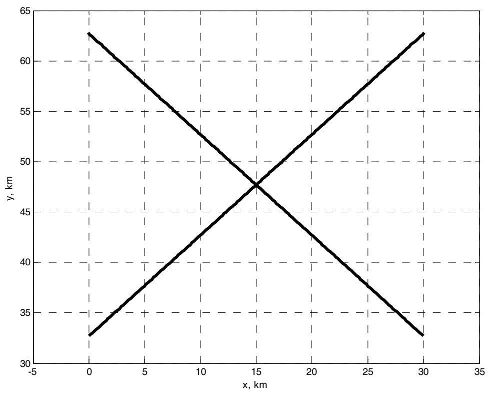

Fig. 4. Trajectories of the aircraft (scenario #1)

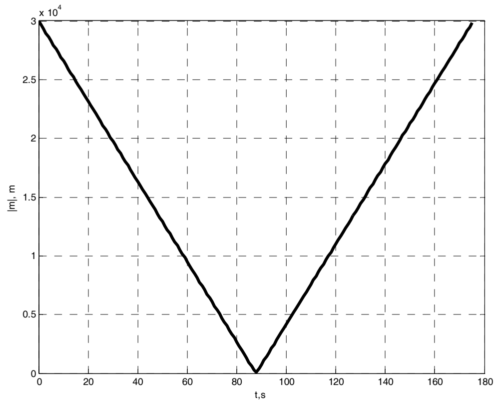

Fig. 5. Distance between the aircraft (scenario #1)

Analysis of the simulation results shows:

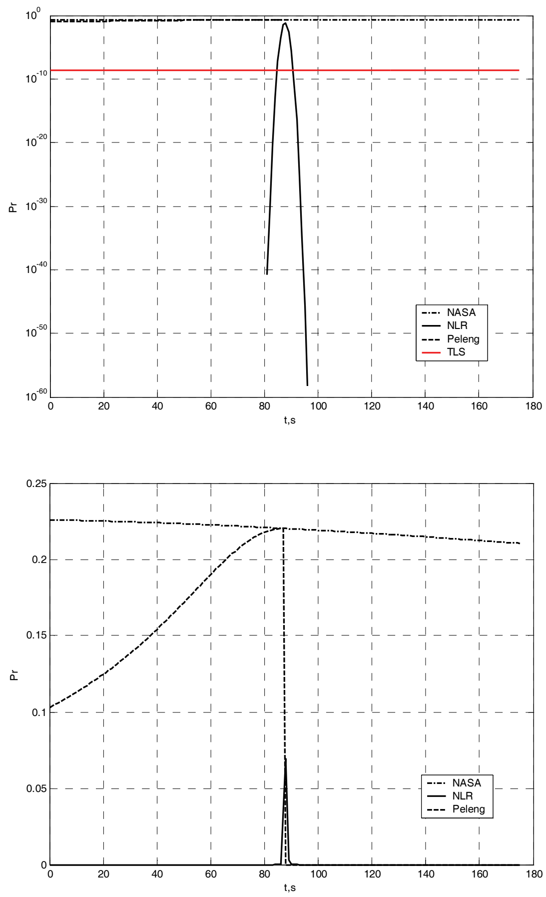

Fig. 6. Collision probability (scenario #1) via time: logarithmic scale – left, linear scale – right.

1. Bearings of the collision flow intensity $\Lambda(t)$ and, therefore, the collision risk for the NLR and the proposed models look like narrow peaks, which maxima correspond to the collision moment. Width of the pick for the NLR model is approximately equal to 8 seconds, for the proposed model its value is 16 seconds. The maxima of two peaks are equal each other.
2. Bearings of the probabilities of collision for the NASA and the models have rather different character. $P_C(T_O)$ for the NASA model practically does not depend on time. This fact testifies that the model poorly depends on aircraft mutual positions. This feature has already been pointed out in scientific publications devoted to the analysis of conflict models. The proposed model has shown an acute response to changing of the aircrafts mutual positions. In case of this model the calculated probability monotonically grows with the aircraft approach each other and reaches its maximum at the collision moment. It is necessary to notice that at the conflict culmination point the values of $P_C(T_O)$ for the both models are equal.
3. The analysis of the proposed model shows that it produces comparable results with the NLR and NASA models. At the same time this model does not have some faults of the NLR and NASA models.

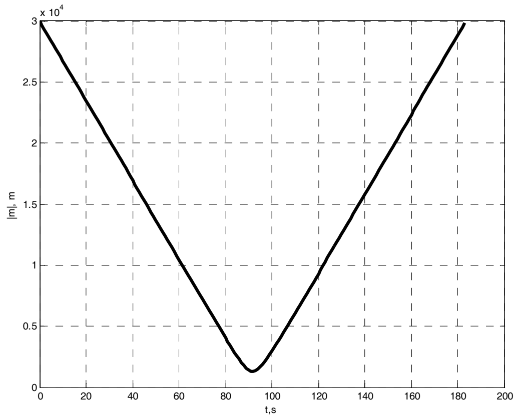

Fig. 7. Distance between the aircraft (scenario #2).

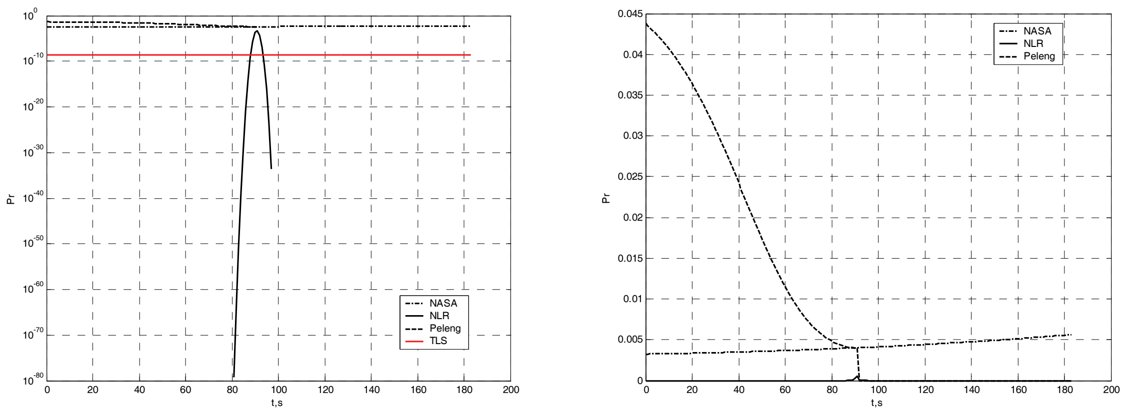

Fig. 8. Collision probability (scenario #2) via time: logarithmic scale – left, linear scale – right.

Scenario of the second test was the same but the azimuth angle of one of the aircraft was equal to -40º. In these circumstances the aircraft do not collide. The distance between them at first decreases approximately up to 1 km in the 89th second and then starts growing. The collision flow intensity $\Lambda(t)$ in this case has approximately the same bearing as before: there are narrow peaks in the vicinity of the maximum approach moment. At the same time the collision probability $P_C(T_O)$ of the proposed model behaves quite differently: with the mutual approach progresses the collision probability decreases and reaches its minimum at the maximum approach moment. Such a conduct confirms the conclusion made earlier: the proposed model has excellent sensitivity to variations of the aircraft positions. The probability $P_C(T_O)$, calculated according to the NASA model, practically does not vary in time and is independent on the distance between the aircraft. It is worth to note that the values of the collision probabilities for the NASA and the proposed models are equal to each other at the moment of the conflict culmination. Thus, the conclusions made from the analysis of simulation results of the first scenario still hold true.

Therefore, the proposed method can be implemented to estimate the observed safety level. The method permits both to estimate the collision probability and to predict the moment of possible collision.

The method was assessed not only via the mathematical simulation but with real air traffic record. The performed tests showed that the proposed method is able to detect the most subtle aircraft separation violations.

References

[1] - Kuchar, J.K. A Review of Conflict Detection and Resolution Modeling Methods / J.K. Kuchar, L. C. Yang.- IEEE Transactions on Intelligent Transportation Systems.- Vol. 1, No. 4, 2000.

[2] - Blom, H. Conflict probability and incrossing probability in air traffic management / H. Blom, G.J. Bakker.- IEEE Conference on Decision and Control, Las Vegas.- NV.- December.- 10-13, 2002.

[3] - Reich, P.G. Analysis of Long Range Air Traffic Systems / P.G. Reich. - Separation Standards – I, II, and III.- Journal of the Institute of Navigation 19.- 1966.- No. 1, pp. 88-96; No. 2, pp. 169-176; No. 3, pp. 331-338.

[4] - Paielli, R.A. Conflict Probability Estimation Generalized to Non-Level Flight / R.A. Paielli, H. Erzberger.- Air Traffic Control Quarterly, vol. 7, no. 3, Oct. 1999.- pp 195-222.

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ANALYSIS AND EXPERIMENTAL MODELLING OF ADO–B PERFORMANCES WITH SECTOR ANTENNAS APPLICATION.

Automatic Dependent Observation and its broadcast ADS-B mode are determined by ICAO as a strategic direction of observation systems' development in prospect for the 2007-2020 years. A number of operations had been conducted by international organizations that are authorized in certification and standardization sphere in civil aviation field. Operations that concern research of performances and the compilation of corresponding system requirements for system parameters (1). A number of national administrations of civil aviation, Russia and Sweden, for instance, have included the development and the inculcation of ADS-B for the application in the air traffic control systems in the near-term outlook. In airspace with radar overlap ADS-B information is an independent source of radar information control and ensures observation in air space without radar control.

ADS-B system possesses considerable advantages as compared with traditional radar control systems. These advantages are observed in two categories as technical – operational and economic and are minutely examined in a number of researches (3). However, a number of scientific researches (4) have disclosed the presence of certain technical problems that create obstacles for the effective ADS-B use, especially under conditions of increased intensity of the air traffic.

The main problem determined by the name of the work is related to the system admission capacity, i.e. how many aircrafts have an opportunity to transmit and receive the necessary coordinate information within the required accuracy performances and in what way the system works under the conditions of increased air traffic intensity.

In ADS-B mode it is possible to calculate the amount of aircrafts that can be simultaneously served by the earth station on condition that each station has a certain speed of information renewal "H" about the amount of transmission per minute (5). One minute is equivalent to certain time slots "C". In this case the admission capacity is equal to "H/S".

The observing system for the ATC cannot have limitations as for the admission capacity. The system is to be able to continue functionating under the conditions of overload, i.e. when the bigger amount of time slots required than it is available, and to adapt in a manageable and and secure way.

In case when the required admission capacity approaches the theoretical maximum, the information that is transmitted from the station outside the certain distance is either discriminated or mutually corrupted.

Supposing that in our case 4500 time slots are used per minute and according to the required standards of the speed of the information renewal in aerodrome zone gives the relation H/C=4500 /12=375, that means 375 aircrafts theoretically can transmit their coordinate information to the ATC earth station with the speed of the information renewal 12 times per minute. However it does not mean that in that case a conflict between any of 375 stations cannot appear in case if they have chosen the same time slot for the sequential information transmission. Theoretically one time slot is sufficient for the principal coordinate information transmission by the mobile station, however, in case of necessity of additional information transmission to the board and to earth, meteorological, for instance, that would mean increase in the necessity of each time case for each station and the relation H/C reduces.

In case of channel overload and as a consequence insufficient amount of time slots, the situation can be improved, as it was mentioned above, by the discrimination of the most distant aircrafts, i.e. by automatic narrowing of the operating range of the earth station or by automatic speed of the information renewal decrease.

None of these methods that are used at the present is not permissible for the ATC purposes and contradicts the established standards for the observing systems on the whole.

In compliance with requirements a certain speed value is to be maintained for the information renewal and a certain level of coordinate information permissible distortions.

For the analysis of the system criteria considered by ICAO AMCP commission in view of appraisal of data links for the observing systems were used (6).

Criteria, determined by ICAO can be divided into two catgories: design and system performances. System design criteria define the degree with which ADS-B can be integrated into general ATM system, for instance, the choice of the frequency and compatibility with the rest of the systems. Criteria of the system characteristic determine the degree of the fulfilment of the basic requirements made of ADS–B.

For the analysis of system performances two scripts are used with high and average air traffic density correspondingly. They are used for the purpose of comparison of the system performances under the conditions of different levels of functioning.

In both cases the analysis of the performances is held by means of appraisal of received transmitter signals within a radius of 250 miles using the receiving apparatus located in the circle centre.

The following factors in the course of analysis are taken into consideration:

- losses concerned with radio-waves diffusion;
- antenna strengthening;
- delay in radio-waves expansion;
- adjoining channel interference;
- interference from closely set radio equipment;
- divisible waves interference;
- alternating transmission from the upper and lower antenna of the aircraft;
- system performances depending on the receiver configuration and its response level;
- transmitted signal fickleness and the configuration;
- repeated receiver launching;
- receiver performances in laboratory testing;
- the consecution of transmitted messages and information substance;
- response level for the noise;
- system accessibility;
- system integrity;
- data acceptance time before the first transmission;
- independent coordinates control;
- functional independence;
- autonomy during the use of air – to – air mode;
- operational air traffic density;
- the scope of the observed airspace;
- period of the receiver information renewal;
- discontinuity of the barometrical altitude;
- discontinuity of the geometrical altitude;

- radio frequency;
- antenna requirements;
- spectrum effectiveness;
- all types of users support;
- support of the corresponding supplements;
- minimal system complication;
- absence of the noise with other aeronautical systems;
- frequency range;
- modulation mode;
- multistation access.

For the purpose of correspondence of the ADS – B system to these requirements under the conditions of increased air traffic, computer modelling were realized as for the system conduct under these conditions with program VM4(7) use, which was rendered by Eurocontrol for the research.

In the introductory parameters of modelling all technical parameters of the ADS – B system that were indicated in the technical specification of the system were brought in, as well as aircrafts and the earth station with certain position data were simulated.

Altogether in the modelling 249 aircrafts and 1 earth station were brought in. The speed of information renewal for each aircraft was taken as 12 times per minute. For the analysis simplification it was taken that all the air objects are static and uniformly allocated in the airspace. The position data that it used during the modelling coincide with those existing for the Azerbaijan airspace. It was made for the purpose of further comparison of theoretical data and computer modelling data with practical results that will be received in future after the practical inculcation of this system in full force and effect.

For the solution of the mathematical statistics task while determining the random distribution law of the data obtained, the totality of initial instrumentation data and observations were summarized in a table of the ordinary statistics totality (5). To make the statistics series more compact and obvious, the additional data handling was conducted. The whole range of observed casual Ψ values was divided into equal intervals – discharges $\Delta\Psi$ and the number of values of casual values n_i that were got in each i-м discharge was calculated. These m_i numbers were divided into total number of observations N and the frequency corresponding each given discharge was calculated:

$$P^*_i=m_i/N, \ (i=1,2,\ldots,k)$$

After that the table was made in which the discharges are given by way of their order and frequencies corresponding them.

The statistical series give the general idea of the random distribution performance. For the better obviousness the statistical series were arranged graphically by way of bar graphs (fig. 1).

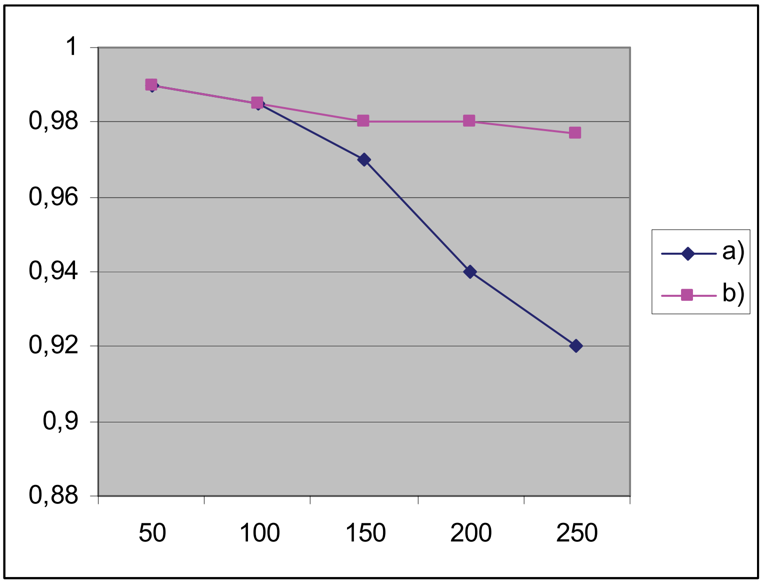


Fig. 1. The change of probability of determination of coordinate information depending on the number of aircrafts on application of a) omnidirectional antenna ADS – B and b) 4 - sector antenna.

With the increase of number of experimental material, decrease of dimensions and increase of discharge number, bar graph approaches the distribution curve, that evaluates distribution density or differential function of distribution of the given casual value. By means of rational selection of parameters of the curve distribution management for the given statistical series the evening-out attains. In this case the analyzed value obeys the normal law, the equation of which is determined by an average of distribution $*_x$ and by a standard deviation σ^2_x. In this work for the processing of statistical material the following body of mathematics is used:

Statistical average of distribution $m=\Sigma_{i=1}^{k} n_i a_i/ N$, (k=1,2,…,n)

Where n_i - frequency of fault hit into i- interval, a_i - the middle of the intervals, n- total quantity of measuring.

The dispersion $D= \Sigma_{i=1}^{n} (a_i-m)^2 n_i/(N-1)$

An average quadratic deviation from an average of distribution

$$\sigma = \sqrt{\Sigma_{i=1}^{n} (a_i-m)^2 n_i/(N-1)}$$

Normalized deviate $x_i= (a_i-m)/\sigma$

According to the calculated values of the normalized deviate xi we can calculate the probability density $\varphi_{(xi)}$ and then we are calculating the theoretical frequency (8, 9, 10)

$$\bar{n} = \varphi_{(xi)} N/ \Sigma_{i=1}^{n} \varphi_{(xi)}$$

By way of discrepancy of the theoretical and statistical series Pirson criterion is used

$$\chi^2= \Sigma_{i=1}^{n} [(ni-ni)2/ni$$

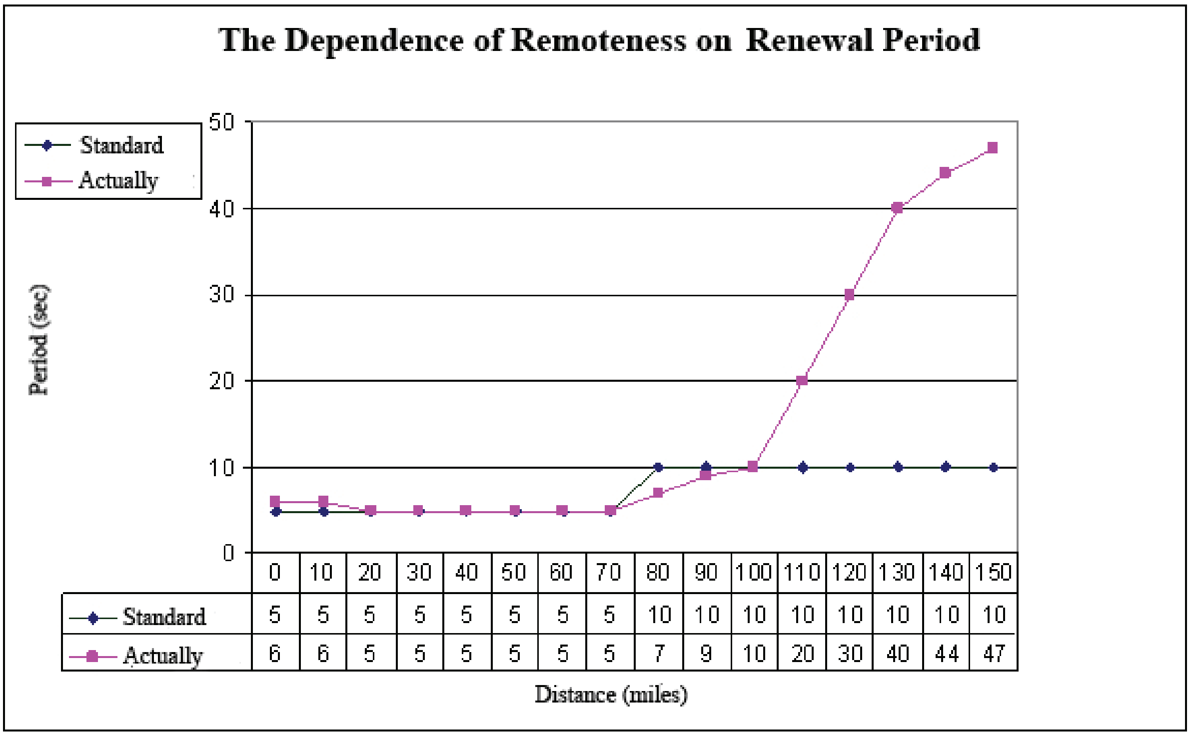
For the appraisal of the precision and reliability of the calculated values of the reliability, dispersion and an average quadratic deviation for the given confidence probability B confidence intervals are used. Since the variate is submitted to the normal distribution law, then the confidence interval for the appraisal of precision of the average of distribution determination

$I_{\beta m} = (m-t_\beta\sqrt{D/n}; m+ t_\beta \sqrt{D/n})$

Where t_β is the value for different confidence probabilities and the dependence on the number n-1. The confidence interval for the dispersion appraisal

$I_{\beta D} = [D(n-1)/\chi^2_1; D(n-1)/\chi^2_1]$

The modelling was realized at first with the standard omnidirectional antenna of the earth station ATC. The results obtained during the modelling indicated that the percentage correlation of the distortions under the conditions of channel fussiness approaches 10% and on average is within the limits of 2-3%, that is completely doesn't correspond to international standards according to the permissible distortions of the coordinate information for the observing systems of ATC. The modelling results are presented on fig. 2 in the form of the ratio of the period of information renewal to the remoteness.



Distance (miles)	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Standard	5	5	5	5	5	5	5	5	10	10	10	10	10	10	10	10
Actually	6	6	5	5	5	5	5	5	7	9	10	20	30	40	44	47

Fig. 2. The Dependence of Remoteness on the Information Renewal Period.

The results can be classified in the following order:

- within the remoteness between 7 – 10 miles the requirements RTCA DO – 242A relative to the information renewal period are completely observed. Within the distance from 1 to 3 miles the dispersal in the process of selection of the slot ADS – B leads out the period of information renewal a bit higher the permissible limits RTCA DO – 242A, that are equate with 5 seconds.

On the remoteness up to 150 miles RTCA DO-242A requirements are not observed.

Thus, the system range amounts 200 miles in the absence thereof noise and n the presence of the minimal and unified for al aircraft stations adiant power. Under the conditions of high volume of traffic as it shown on the picture2 the transmitted information of the system is received with sufficient period of information renewal in a radius from 10 to 70 miles.

Consequently, presence of worsening of ADS – B parameters is determined under the conditions of increase of volume of air traffic in the distant zone (more than 150 miles) and in the near zone (up to 10 miles). The worsening of parameters takes place mainly because of the glut of the frequency channel.

To accomplish this task the use of the earth station with application of sector antennas is recommended.

Sector antennas are in active application in the course of many years, especially military technologies sphere and to find their greater application in mobile wireless systems (11, 12). Sector antennas application has advantages due to increase of spectral effectiveness and channels capacity by means of the range increase and decrease of cochannel interference and decrease of attenuation, connected with the multipath. Apparently, the most important property is the ability for decrease of cochannel interference (13, 14, 15) by means of division of signals accepted in various directions or the possibility to realize selective signal transmission with the exception of objectionable directions. The ability for division of signals depending on the angle of radiation is the profound ability used in sector antennas (9).

The main complexity in sector antennas application in realization of hardware support, as the application of antenna with the N quantity of elements means the increase of hardware support quantity in N times also, that will lead to the necessity of integrated increase, for instance, by means of the application of driver amplifiers, capable to intensify simultaneously several signals of carrier frequency.

Another complexity is the necessity of array antenna calibration in order to maintain high and reliable antenna system performances.

The problem is to substitute as many as possible analogous elements for digital processor signal processing devices. The functions, operated by digital processors are profitable, more stable to the environment changes, such as temperature, for instance, and they add flexibility to the system.

The main complexity of antenna system application is the securing of their mutual concordance with each other. At the conceptual stage it is possible to use 4- directed antennas to check ADS – B system work capacity. In this case in antenna capacity an annular antenna that does not bear any relation to receiving antenna and which does not have orientation. At that the structure chart earth system ADS – B is shown on fig. 3.

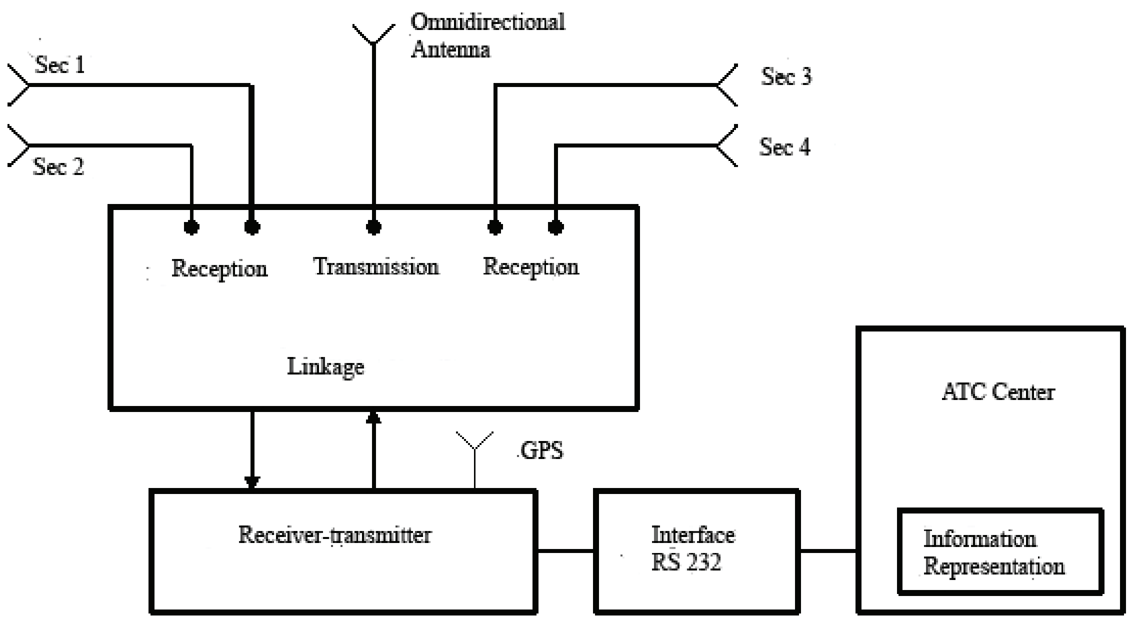


Fig. 3. The Structural Scheme of the Earth System with 4-sector Receiving Antenna Application.

On the base, shown on the picture 3, modellings with application of sector surface antenna and 4 directed receiving antennas were conducted.

The modelling results showed substantial decrease of percentage ratio of distortion during the coordinate information transmission process, it constitutes 2%. The modelling results confirm theoretical suppositions on the positive influence of sector antennas application on the ADS – B system performances in airspace spheres with increased traffic intensity, where correspondingly increased probability of rise of time slots insufficiency for the required information transmission exist, in particular.

The analysis of ADS – B modelling with sector antennas showed that RTCA DO-242 requirements as for the renewal period are realized on conditions that sector antennas are used.

The modelling results were also confirmed experimentally with the application of constructed sector antenna of the system earth station ADS – B.

The results of modelling and experimental tests confirm the theoretical suppositions on the positive influence of sector antennas application on the ADS – B system performances in airspace spheres with increased traffic intensity, where correspondingly increased probability of rise of time slots insufficiency for the required information transmission exist, in particular.

References

1. ICAO SARPS Annex 10 Vol 1.
2. ICAO European air navigation plan. www.icao.int.
3. Southern Ring Phase II, ADS-B Implementationa Feasibility Study for Southern Ring States, Swedavia AB. Final report.
4. Kjellberg, Rikard. "Capacity and Throughput using a Self Organized Time Division Multiple Access VHF Data Link in Surveillance Applications." Thesis. University of Stockholm and The Royal Institute of Technology. April 1998
5. Gadzhiev N. D., Nabiev R. N., Nahmedov E. S. Methods of noise-immunity and transmission path stability, data of mode 4 in ADS – B improvement. / «Mülki Aviasiyanın muasir problemlərinin həllində Elm və Tədrisin rolu» Respublika konfransın materialları, 29-30 Oktyabr, 2002.
6. "VDL MODE 4 Technical Manual"[including changes agreed up to AMCP WG-M/2 meeting] VDL Mode 4 Simulator. Software User manual. Eurocontrol. Paul Ravenhill[Helios Technology] V. N. Anshin, V. A. Rusol, A. V. Lipin. The Application of Mathematical Statistics Methods in Aviation Practice. 1993.
7. Guter R. S., Ovchinskiy B. V. Elements of Numerical Analysis and Mathematical Data Handling of the Test Results. 1970.
8. Kasrasev A. I. The Theory of Probability and Mathematical Statistics. 1970.
9. Smart Antenna implementation issues for wireless communication" – Mattias Wennstrom, October 1999.
10. Rothammel K. Antennas. M.: Energy.
11. Aizenberg G. Z. Ultra-Short Waves' Antennas. Publishing house "Connection and Radio", Moscow, 1957.
12. Aircraft - Type Antennas Parameters and their Measuring. Edited by Gromov G. N., Tsybaev B. G. Moscow – "Mechanical Engineering", 1984.
13. Pashaev A. M., Gasanov A. R., Dzhafarov Dzh. G., Ismailzade G. I. Antenna – Feeder Facility / Manual on the CourseLaboratory Works fulfilment. 1998.

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INTEGRATION OF CIVILIAN AND MILITARY ATM SYSTEMS

One of the principal targets of EUROCONTROL ATM upgrading programmes developed in nineties was harmonization of national ATC (air traffic control) systems with the objective to constitute a virtually single European airspace providing having increased total capacity. This target should be achieved by the harmonization and subsequently integration of civil and military ATC systems at national levels, involved in the programme.

There were programs of air traffic control systems modernization prepared in Czechoslovakia at the end of eighties and beginning of nineties. Several institutions and individuals were involved in theoretical and practical works: Research institute of Air Traffic Services in Brno, and in frame of scientific research activities some of the experienced experts of University of Transport in Žilina and Military Air Academy in Košice. The most significant support to processes of merger of military ATC standards to the civilian ones and integration of military ATC systems with civilian ones has been contributed by the Czechoslovak Air Force general staff by the medium of the Military Air Traffic Services general staff.
The given period and the historical changes in Czechoslovakia in November 1989 brought a convenient social atmosphere for implementation of new state rules, frankness and willingness of responsible state authorities for implementation of new policy and finally, the possibility for every man to undertake responsibility for his own life and to try to put alive own dreams and ideas. This chance was exploited at that time by some military experts of the Military Air Academy, based on their individual scientific research works and Air Force modernization programmes when they have established the ALES® Company as completely new, independent and private entity.
The main ALES® activities are devoted primarily to military ATC upgrading projects since the beginning of its existence. Later on the connected programs of Air Defence command and control systems, programs of radar upgrading and other related programs have extended the Company portfolio. The fact of primary orientation for military projects is justified by the reason that both military ATC and Air Defence (hereinafter "Air Force") systems:

- first - have to be designed from the scratch on the principally more strict requirements for system performance, stability and reliability arisen from principally different character of flights controlled and monitored by the Air Force
- second - are built on civilian ATC systems' core, but are much more complex, which follows from the fact that not only common GAT principals, but as well the national OAT and Air Force rules, which are different and unique in most cases, have to be implemented.
- third - the requirements for radar data processing and multiradar performance are more strict based on the facts that lot of radar sources in the Air Forces of former East block countries are out-of-date (and mostly of the ex-Soviet production), and don't comply with the current performance standards and, moreover, they can not be directly interfaced.

As declared at the beginning of this article, one of the principal steps to the harmonization of national ATC systems was incremental integration of both military and civilian air traffic control systems. The next three levels of integration have been defined:

a) Separate activities: civilian and military ATC systems are separated administratively, physically and technically. Co-ordination between systems is effected by appointed way, usually manually (by phone) or semi-automatically (by receipt of dedicated kind of data). Usually, the flight strips are sent from civilian to military ATC systems concerning the actual GAT flights.

b) Partial integration: civilian and military ATC systems are separated administratively, eventually physically isolated. At least one of the systems enables automatic receipt and processing of the data of the other one.

   In general, the military ATC system processes data of civilian surveillance radars or civilian multiradar data and data of the expected GAT flights.

c) Full integration: both civilian and military ATC systems are practically or virtually coupled into one ATC system which results in fact, that all (both civilian and military) ATC data are processed and shared, and the system provides such a functionality, that both civilian and military ATC controller can use/share the same working position.

In standard practice, there is implemented such integration of both systems, that all the data from the civilian ATC system are primarily presented for the military ATC controllers and civilian ATC controllers are provided with only special information from military ATC system, e.g. complementing radar coverage or with depicted data about the military air traffic.

LETVIS® ATC system developed by ALES® is designed to provide full level of civilian – military integration. However, such a level is not requested yet by the ATC services providers due to not yet existing administrative frame for such operations. At present , various configurations of partial integrations on administrative level and practically full integration on technical level are implemented by the LETVIS® ATC system:

- ACC Bratislava, where civilian GAT and military OAT sectors are located in one operation room, with advanced level of partial integration, where all civilian data are processed by military system and on the other side, civilian system receives data of military primary radars or data of OAT flights
- IATCC Prague, currently installed at the new Integrated Air Traffic Control Centre in Prague-Jeneč, where civilian GAT and military OAT sectors are located in one operation room with advanced level of partial integration, where both systems exchange data about the flight plans under control and airspace in use.
- ACC Kiev-Boryspil, where the already existing system is used by both civilian and military ATC operators since 1996. Currently the upgrade of this system has been designed and is prepared for installation based on the latest technology (LETVIS® – Sun Solaris™ - Sparc Microsystems™) being now installed in IATCC Prague, where, moreover, the data about the real airspace use will be shared.

Generally said, ATC integration based on data exchange, processing complement and back-up data of each system substantially complements content and increases safety of data presented to ATC controllers.

In conclusion of the above stated information about the ATC systems integration it can be stated, that the LETVIS® ATC system has been the first operating ATC system, which provided the ATC integration. And at the same time, it has been the first operating ATC system which enabled connection as well as multiradar processing of data obtained from the out-of-date and ex-Soviet radars.

Later, in the middle of nineties, the ATC terminology has been extended. The Air Traffic Services provided on national level have been extended for Air Space Management - planning and control of the airspace use. The content of ATC has been complemented by ASM, and systems providing this functionality are named as ATM - Air Traffic Management systems. Thus the LETVIS® ATC system has implemented the ASM functionality as well as the perspective of the civil-military integration, and such version is labelled generally as LETVIS® ATM system.

Implementation of the EUROCONTROL Flexible Use of Airspace concept provides possibility of full civil – military integration at the level of ASM services. Depending on the Airspace Management Cell workplace organization, which provides day-to-day allocation and control of airspace use in line with FUA concept, both partial integration and full integration are implemented:

- an example of partial ASM integration is realised in the Slovak Air Force tactical planning system, where military part of AMC functionality is being implemented and the approved airspace requests are sent to the civilian part of AMC for final airspace plan compilation.
- an example of the latest technologies of full ASM integration could be presented by Ukrainian AMC workplace at UKRAEROCENTRE in Kyiv/Boryspil, where both civilian and military operators are involved in planning and control of ASM operations at the same system. LETVIS® UAMC system is unique not only because of the implementation of full integration in real operation, but also by the complexity of functionalities provided.

Field, which can not be forgotten, when the civil – military integration is evaluated, is the Air Defence. Operators of the Air Defence use data processed by both civilian and military ATM systems as the basis for identification and evaluation of airspace targets and operations. Such National Air Defence system has been built by ALES® in the Czech Republic and at the same time, with utilization of acquired experiences, in the Slovak Republic. Both systems have been built in the beginning with respect to the procedures and technologies used at that time in the countries of former Warsaw Pact, and consequently, after joining the NATO , they have been upgraded to the new standards and interoperability. This is the reason, why such solution is currently attractive for some republics of the former Soviet Union.

The last systems implementing features of the civil-military integration are the ATC simulators. They are used for various levels of training depending on customer demands. An example of such simulator is that one installed by ALES® at the Training Centre of the Czech Air Force in Prague. It was designed for both military and civilian ATC training with an objective to also provide training of military ATC controllers for civil ATC standards.

Summarizing experiences from various customers and systems already installed by ALES® from the perspective of civil ATM systems, the most common use of civil-military integration involves partial integration based on the processed data shared by both, civilian and military ATM systems:

- civilian ATM procedures are implemented by military ATM systems
- sharing the surveillance (radar) data sources by both civilian and military ATM systems
- exchange of data about flight plans being actual
- processing data of the air space in use
- processing some of the specific OAT data by civilian ATM systems

Conclusion

Based on the evaluation of the level achieved both by civilian and military LETVIS® ATM systems, as well as by the Air Defence command and control systems, there is common opinion of the ATC experts, that projects of modernization and integration of the above mentioned systems in the Czech Republic and the Slovak Republic got ahead the time. Especially the military systems installed in the above stated countries are highly appreciated by the ATM experts from western Europe.

From the viewpoint of various ALES® customers comparison, we feel, that UkSATSE (as national provider of the air traffic services in Ukraine) is building its own ATM systems purposefully and systematically. ALES® and EXIMAS companies appreciate the fact, that they were allowed to take part in those processes since the beginning and still they have chance to do it for both UkSATSE and military ATM services acting in the frame of UkSATSE.

ALES® and EXIMAS welcomed the establishment of regional RADA group as the great chance to take part in the processes of hand-over of Ukrainian (as well as Czech and Slovak) ATM experiences to the other RADA member countries, under the co-operation with UkSATSE as the leader in the air traffic services development in the region of former Soviet Union. The RADA targets and the ALES® philosophy are the same – to modernize the air traffic services equipment while meeting the current ATM and technology requirements with the objective to provide the most effective solution for harmonization of the RADA airspace.

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REVIEW OF AERONAUTICAL SYSTEMS AND FLIGHT MANAGEMENT SYSTEMS (FMS) CREATED BY SPECIALISTS OF UKRAINIAN COMPANIES

This article summarizes the experience of specialists of the State Enterprise "Orizon-Navigation"(Smela, Cherkassy Region) which in combination with leading organizations of aviation branch of Ukraine (Antonov Aviation Scientific and Technical Complex, National Aviation University, Kharkov Aircraft Plant, Air Companies of Ukraine) is engaged in developing and application of airborne navigation equipment on the basis of satellite navigation

The specialists of State Enterprise "Orizon-Navigation" have 25-year experience in the field of developing, production and application of satellite navigation systems users' equipment such as Transit, Tsikada, GLONASS and GPS. We have developed and put into production more than 30 models of satellite navigation systems users' equipment for different application. Now we have accumulated operational experience of our satellite navigation systems users' equipment in various service conditions.

During work execution on developing, production and application of satellite navigation systems users' equipment we created own design school, definite technical ideology, allowing to solve successfully arising problems and to suggest its products to various users.

All making equipment is certified. The enterprise has certificate of quality management system ISO 9001:2000.

When developing the equipment our enterprise provides the observance of requirements of international organizations, in the first turn, IMO and ICAO, which regulate the use of a single global radio navigation system in terms of GPS, GLONASS systems and various differential supplements, since one by one any system does not provide requirements of traffic safety.

Aviation user equipment is one of the most complicated ones. Such developments of the enterprise as CH-3301 and CH-4311 are systems, which unite functions of position location, navigation planning, hand and automatic control of an aircraft. Equipment units are interfaced with airborne systems, equipment and pilotage indicators.

Strategic purpose of the enterprise is the creation of equipment capable of solving navigation problems and aircraft control in all stages of flight, including flights in area navigation system RNAV, executing all available requirements P-RNAV and B-RNAV with aeronavigation accuracy RNP-5, RNP-1, RNP-03 and higher.

The first product, which got in 2000 Approving letter of AR IAC for use in a new Ukrainian aircraft AN-140, became CH-3301 equipment.

The development of equipment took place using own ideas and scientific developments, thus permanent investigations and improvements of equipment were carrying out according to results of testing in the process of certification. All ideas, embodied in equipment, are defended by patents and appropriate certificates.

The equipment was developed with participation of Antonov ASTC experts: pilots, navigators, airborne radio installation specialists. Antonov ASTC test bed was used for optimizing flight algorithms and forming of signals for automatic aeronavigation in horizontal plane.

Satellite navigation systems users' equipment CH-3301 is intended for:

- navigation parameter determination of aircraft flight according to signals of satellite navigation systems GLONASS and GPS NAVSTAR (open C\A codes);
- generation of navigation parameters (in the form of electric signals) for indication to power supply and integrated systems;
- forming of control signals in Flight Control System (FCS) for execution of aircraft horizontal navigation (separate modification with auxiliary aircraft coupling unit (ACU))

At the same time permanent improvement of CH-3301 takes place in connection with adoption of modern requirements to traffic safety.

The purpose of CH-3301 modernization is the creation of CH-3301 equipment in accordance with ICAO standards, where airborne radio installation must have an independent small-sized navigation aid, designed for flights in the system of precise area navigation P-RNAV in European region according to requirements RNP1.

Now the following modifications of CH-3301 are made:

- modification "01" for aircraft hand control when flying en route using standard Navdatabase enabling to indicate navigation information (to CDU, GPWS, horizontal situation indicator (HIS) and light information board);
- modification "00" for aircraft hand and automatic control having auxiliary functions of data receiving on heading and air speed and generation of control signals to FCS for en route traffic;
- modification "03"and "04" for aircraft hand and automatic control having auxiliary functions of data receiving on altitude, speed, heading and generation of control signals to FCS in digital and analog modes, forming and execution of flight plan when making standard procedures SID and STAR, correction of current flight position coordinates on two beacons DME, use of two equipment sets in the board of aircraft which interact for data and mode of operation transmission;
- modification "02" for aircraft hand and automatic control, having 24-channel receiver GLONASS/GPS/SBAS (EGNOS, WAAS, MSAS), auxiliary functions of flight plan forming and execution when making standard procedures APPROACH.

Modifications of CH-3301 equipment have Certificate of airworthiness and Approving letters for mounting in aircrafts of various types.

Now this equipment is mounted in aircrafts AN-140, AN-3, AN-26, AN-38, AN-74, AN-124, preparatory works are performed for mounting CH-3301 in AN-22, AN-72 and other types of aircrafts and helicopters.

CH-3301 is used in standard mode by air companies of Ukraine, Russia, Iran.

Some modifications CH-3301 are in National Aviation University, where they are utilized in educational process and research activities.

The following stage for specialists of our enterprise in the field of avionics is the creation of airborne multifunction aeronavigation equipment CH-4311 (analog of foreign FMS), having specifications, which provide the performance of modern requirements ICAO accounting prospects of their evolution.

Multifunction aeronavigation equipment CH-4311 enables to control an aircraft at all stages of flight, including non-precision approach.

One of the advantages of CH-4311 is structure perfection and equipment reliability as a complex system, which receives data from airborne navigation sensors, includes a calculator, Navdatabase and specification database of aircraft, and generates data on flight condition onto display and automatic flight control system.

This equipment is designed for navigation task solving at all flight stages from take-off to approach and system centralized control of pilotage and navigation complex, systems of navigation radio equipment, landing and air traffic control (ATC), and radio communication equipment systems.

CH-4311 provides the carrying out of navigation tasks, flight planning, trajectory prediction, aircraft performance control:

- determination of aircraft current position according to information of aircraft systems and from built-in sensor SNS by means of navigation satellites NAVSTAR and GLONASS systems using advanced space supplements WAAS, EGNOS, MSAS and ground supplements LAAS;
- data complex handling, detection and isolation of "erroneous" Navdata;
- aircraft flight automatic, director, hand and combined control (accounting service limitations) in the given service conditions when withstanding requirements RNP 1 and higher, RNP5, RNP12 and RNP20 – depending on availability or absence of necessary ground radio navigation aids, at all flight stages from take-off to approach, along airways and random routes, on equipped and non-equipped airways, at any time of the day and year;
- measurement, forming and generation to interfaced equipment of parameters and signals, necessary for automatic, director, hand and combined flying along the given routes;
- generation of control signals to FCS;
- operation with standard world-wide and user base of aeronavigation data;
- creation and use of before created routes;
- creation of routes with shift;
- execution of computations when flight planning;
- operational change of flight plan;
- recalculation of flight trajectory with flight plan change;
- calculation of technical flight and take-off characteristics of the aircraft, accounting data on aircraft and environmental conditions;
- centralized control by systems of aeronavigation equipment, navigation airborne radio installation, landing and air traffic control, airborne maintenance system and systems of communication equipment in automatic and hand modes;
- centralized automated control of interacting systems, data acquisition and storage on serviceability of interacting systems with localization of failure points for preflight control execution of system readiness to departure, continuous flight control of systems, and also ground processing of flight data;
- continuous automatic (and automated by a command of the crew or operator) control, indication and registration of state variables and modes of operation of airborne installation systems and integrated equipment;

- aeronavigation information and modes of operation indication in alphanumeric and graphic view;
- forming and generation of navigation information for indication in aeronavigation indicators and in electronic system indicators (or multifunction indicators) in alphanumeric and graphic view;
- forming and generation of warning, caution and alarm messages and commands.

The purpose of development consists in the creation of equipment, navigation calculator having multichannel sensor inputs, designed for flight carrying out in the system of precise area navigation according to requirements of RNP with specifications, which provide modern requirements accomplishment of ICAO standards accounting their progress.

The equipment provides continuous solving of navigation problems on the basis of data, received from all accessible sources – GNSS (GPS/GLONASS/SBAS), DME/DME, VOR/DME, INS, ADC (Air Data Computer) etc.

The need in such equipment appears when mounting new aircrafts and also when modernizing aircrafts in the purpose to bring their performances to modern requirements.

For problem solving in providing of correspondent specification requirements it is necessary to use completely the possibilities of available technical aids, and also introduction of new conceptions, such as systems of communication, navigation, CNS/ATM air traffic supervision and organizing, which are created on the basis of digital equipment including satellite systems and automation of different levels.

Navigation element of CNS/ATM system gives the opportunity of world-wide precision reliable and continuous position location at the expense of satellite aeronavigation.

Now the State Enterprise "Orizon Navigation" (Smela, Cherkassy Region) carries on works for creation CNS/ATM system element, multifunction aeronavigation equipment, which solves problems of navigation, flight planning, trajectory prediction and aircraft equipment control.

The enterprise develops and manufactures technologies and equipment of "Safety of Life" class for transport and transportation systems based on the last achievements of computer science, navigation using signals of available satellite navigation systems and the latest system GALILEO. These activities are the priority task of the enterprise.

The use in aeronavigation equipment of modern information technologies, powerful computing systems, high-level software, high-volume database, calculation automation, integration to other airborne equipment, in particular, to communication equipment, flight indication and control will increase considerably operating characteristics of airborne radio installation and will provide higher level of aeronautical safety.

The use of global navigation system GALILEO signals (developed by EC) GPS (USA) and GLONASS (Russia) will provide the carrying out of the last requirements of civil aviation international organizations accounting their development prospects to 2015, that, in its turn, will allow for avionics home operators to carry on its activities all over the world without limitations.

The enterprise invites to collaborate all companies and organizations, which are interested in introduction of satellite navigation technologies in the purpose of technical level increasing of operating installations and executing works.

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DEFINITION OF QUANTITATIVE ESTIMATIONS OF AIR TRAFFIC CONTROLLER PROFESSIONAL LEVEL BY MEANS OF FUZZY SETS THEORY

Principles of air traffic controller professional level quantitative estimations transformation into qualitative form of presentation by means of fuzzy sets theory are developed. The membership functions of linguistic variable "readiness level" are given.

Introduction

Aviation safety among other factors depends on decisions efficiency, which are taken by human-operator (pilot, air traffic controller, maintenance engineer) taking into consideration individual level of their professional knowledge, skills and abilities. According to ICAO and Eurocontrol statistical data sources about 80% of aviation incidents are determined by human factor in aviation [1]. Modernization of aviation personnel professional training ensures operation improvement in normal and emergency situations.

At present time in Ukraine the system of air traffic controllers professional readiness level definition considered not quite effective. To determine professional readiness level only paper-based methods are applied in training centres. It denies arranging full control of air traffic controllers knowledge, skills and abilities. The number of air traffic controller operation estimated parameters and required time to provide tests are to be improved. Traditional methods do not allow to obtain updated description of actual structure of knowledge, skills and abilities. Application of contemporary computer technologies, automated procedures of professional training control provides comprehensive analysis of controllers knowledge, skills and abilities [2-5].

Therefore, one of actual tasks is integration of artificial intellectual modules into complex controller's simulators [6]. It highly extends the abilities to provide control of air traffic controllers professional training. Introduction of special-purpose artificial intellectual modules provides flexible control of professional training processes according to training conditions. The automated training quantitative results gathering, analysis and keeping in database are also available.

1. Air traffic controllers professional readiness level decomposition

Air traffic controllers readiness level is estimated by values of quantitative-qualitative results of professional tasks performance, which describe controller's ability to carry out air traffic control procedures according to procedures, standards and recommended practices in normal and emergency situations:

$$Y_{\Sigma} = arg\ agg\left[\sum_{i=1}^{n} p(S_i) \cup \tilde{p}(S_i)\right] \qquad (1)$$

Y_{Σ} – air traffic controller readiness level (quantitative-qualitative estimation of ability to carry out the most commonly used tasks ($\sum_{i=1}^{n} S_i$) with certain level of professional skills);

$p(S_i)$, $\tilde{p}(S_i)$ – quantitative and qualitative results of air traffic controller readiness level diagnostics.

The quantitative results of training were transformed to qualitative form in order to issue information about air traffic controllers readiness level in understandable and convenient form of presentation. The fussy sets theory principles [7] were applied to obtain qualitative results of air traffic controller readiness level.

The fuzzy subset $\tilde{R}$ of set S is a statistically stable population of pairs [7]:

$$\tilde{R} = \left\{ \left\langle \frac{\mu_R(x)}{x} \right\rangle \right\}, \quad x \in S, \mu_R(x) \in [0,1] \qquad (2)$$

Membership function $\mu_R : S \to [0,1]$ associates with every element of $x \in S$ and describes the membership level of x to fuzzy subset $\tilde{R}$.

To compare quantitative and qualitative estimations of air traffic controller readiness level the generalized linguistic variable "readiness level" is used [7]:

$$\left(X, T^M(X), S, C, M\right) \qquad (3)$$

X – the variable name;

$T^M(X)$ – term-set of variable X, which is statistically stable population of linguistic results of variable with definition domain S;

C – syntactical rule, which determines names of values of variable X;

M – semantic rule, which associates variable X with its content.

2. Linguistic variable "readiness level" composition principles

To construct linguistic variable "readiness level" (Table 1) such classes of fuzzy categories are used [7]:

- qualifiers ($\bar{c}$) – fuzzy categories, which determine dimension scale of estimated parameter ("low", "average" and "high" qualifiers are used);
- modifiers ($\bar{h}$) – fuzzy categories, which specify intensity of estimated parameter ("very" and "moderately" modifiers are used).

Let us assume that $T^M = \{T_i\}$ $\left(i \in L = \{1,2,\ldots,m\}\right)$ is basic term-set of linguistic variable "readiness level" $\left(X, T^M(X), S, C, M\right)$. Designate $\inf X$ as x_1 and $\sup X$ as x_2. Now we use fuzzy variable $\left\langle T_i, X, \tilde{R}_i \right\rangle$, which is connected with term $T_i \in T^M$, where $\tilde{R}_i = \left\{ \left\langle \frac{\mu_{R_i}(x)}{x} \right\rangle \right\}$ $(x \in X)$. R_i is the base of fuzzy set $\tilde{R}_i$, which includes elements from set X with membership function values more than 0. Then, we arrange term-set $T^M(X)$ according to expression [4]:

$$(\forall T_i \in T^M)(\forall T_j \in T^M)(i > j \leftrightarrow (\exists x \in R_i)(\forall y \in R_j)(x > y)) \qquad (4)$$

Table 1

The term-set of linguistic variable 'readiness level"

Term-set $T^M(X)$ ($i=\overline{1,7}$)	Terms rank relationship (T_i)
Very LOW readiness level	T_1
LOW readiness level	T_2
Moderately LOW readiness level	T_3
AVERAGE readiness level	T_4
Moderately HIGH readiness level	T_5
HIGH readiness level	T_6
Very HIGH readiness level	T_7

Consequently, qualitative scale for air traffic controllers readiness level estimation is arranged in the following way:

$$T_{i-1} < T_i, \quad i=\overline{2,7} \tag{5}$$

Membership functions ($\mu_{R_i}(x)$) of linguistic variable "readiness level" are composed taking into account the following conditions [8]:

- membership functions of extreme terms should not be like "bell" curves:

$$\mu_{R_1}(x_1)=1, \mu_{R_m}(x_m)=1 \tag{6}$$

- base set $T^M(X)$ should not contain terms, or intervals $[a,b]$ without any term:

$$(\forall T_i \in T^M \setminus \{T_m\})(0<\sup_{x\in X}\mu_{R_i\cap R_{i+1}}(x)<1) \tag{7}$$

- base set $T^M(X)$ should not contain terms, where $\max \mu_{R_i}(x)$ less then 1:

$$(\forall T_i \in T^M)(\exists x \in X)(\mu_{R_i}(x)=1) \tag{8}$$

In order to use fuzzy set $\tilde{R}_i$ for estimation of set M_i (quantitative results of air traffic controller readiness level estimation) we have to determine relationship between $\tilde{R}_i$ and M_i. We used the generalized Hemming distance to reveal closeness between $\tilde{R}_i$ and M_i [8]:

$$d(A,B)=\sum_{i=1}^{n}\left|\mu_{\tilde{A}}(x_i)-\mu_{\tilde{B}}(x_i)\right|, \quad \mu_{\tilde{A}}(x_i), \mu_{\tilde{B}}(x_i)\in[0,1], i=\overline{1,n} \tag{9}$$

The closest to fuzzy sub-set $\tilde{R}_i$ is set M_i [8]:

$$\mu_{M_i}(x)=\begin{cases} 0, & \forall \mu_{R_i}(x)<0,5 \\ 1, & \forall \mu_{R_i}(x)>0,5 \\ 0 \vee 1, & \forall \mu_{R_i}(x)=0,5 \end{cases} \tag{10}$$

We use linguistic variable "readiness level" in order to ensure quantitative-qualitative transformation of results of air traffic controller professional level estimation. Expert estimation (direct individual anonymous questioning without experts contacts and public discussion) was carried out among well-qualified air traffic controllers in order to compose smooth membership functions of linguistic variable terms [9].

The statistical data method [7] has been applied to compose membership functions of linguistic variable. This method assumes that sub-set element membership degree $\widetilde{\boldsymbol{R}}_i$ is determined by frequency of concept usage by experts.

During the estimation, experts compared quantitative values of air traffic controllers professional level with their qualitative equivalents by means of linguistic variable "readiness level". Experts connected the borders between term names on the upper scale with appropriate quantitative values of readiness level on the lower scale (Fig. 1).

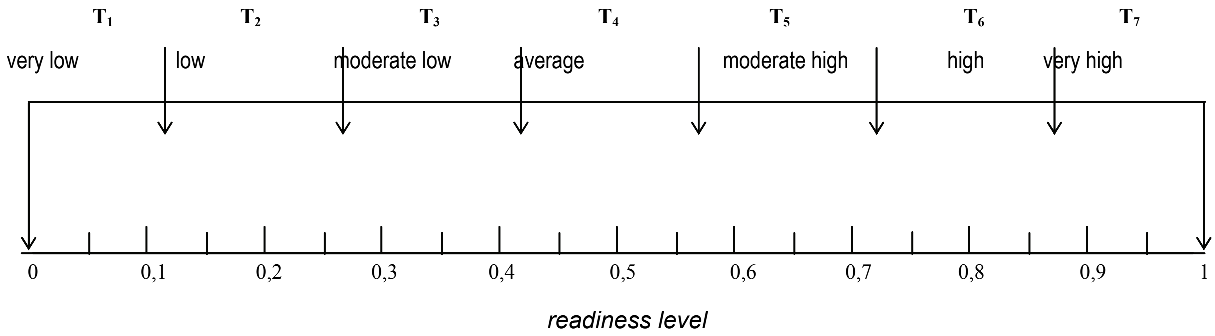

Fig. 1. Relationship of quantitative and qualitative values of air traffic controller readiness

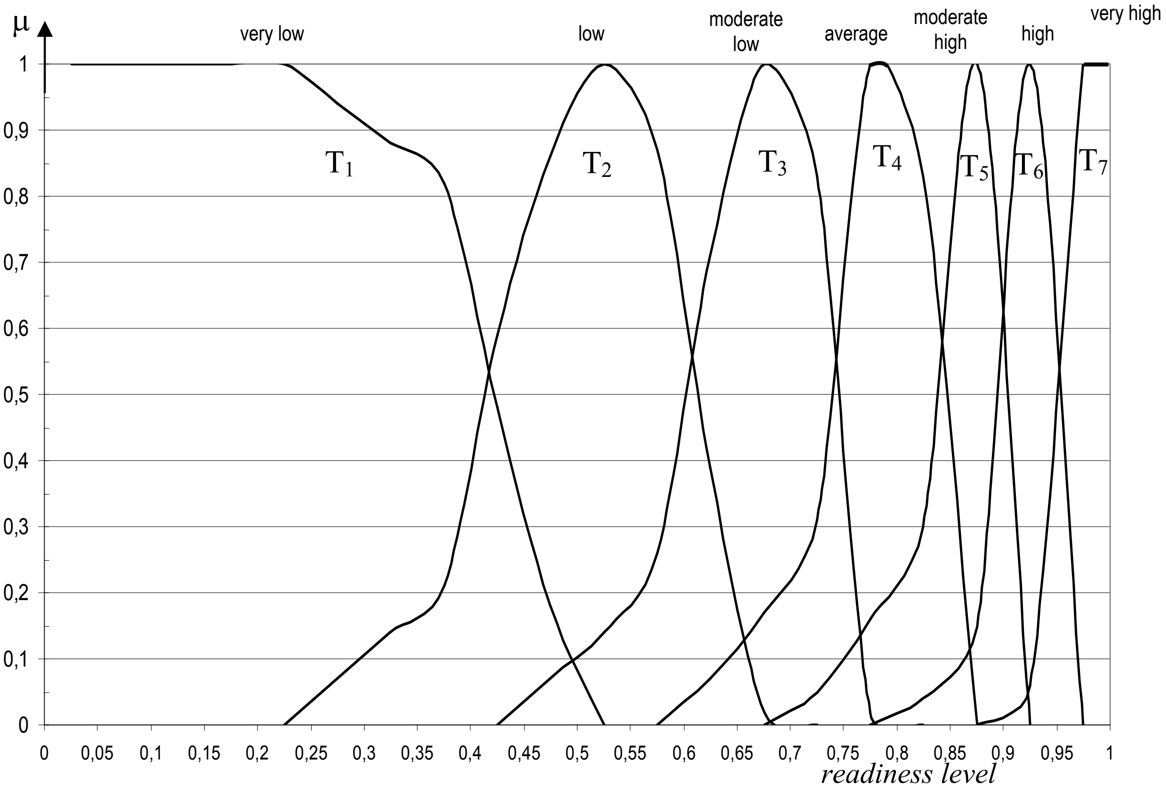

Fig. 2. Membership functions of linguistic variable "readiness level" terms

Conclusions

Consequently, having analyzed results of experts estimation, membership functions of linguistic variable "readiness level" (Fig. 2) were composed. This allows us to ensure transformation of information about readiness level from qualitative into qualitative form of presentation in order to provide users with necessary information.

References

1. *Бабак В.П., Харченко В.П., Максимов В.О.* та ін. Безпека авіації. – К.: Техніка, 2004. – 584 с.
2. *Шибанов Г.П.* Количественная оценка деятельности человека в системах человек-техника. – М.: Машиностроение, 1983. – 263 с.
3. *Макаров Р.Н., Герасименко Л.В.* Теория и практика конструирования целевых моделей операторов особо сложных систем управления. – М.: Код, 1997. – 532 с.
4. *Демин Л.С., Жуковский Ю.Г., Семенин А.П.* и др. Автоматизированные обучающие системы профессиональной подготовки операторов летательных аппаратов /Под ред. *В.Е. Шукшунова*. – М.: Машиностроение, 1986. – 204 с.
5. *Савельев А.Я., Новиков В.А., Лобанов Ю.И.* Подготовка информации для автоматизированных обучающих систем/Под ред. *А.Я. Савельева*. – М.: Высшая школа, 1986. – 176 с.
6. *Чинченко Ю.В.* Концептуальная модель автоматизированной системы профилактики авиационных происшествий // Наукові праці академії. - Кировоград: ГЛАУ, 2000. - Вып. 5, часть 1. - С. 372-379.
7. *Заде Л.* Понятие лингвистической переменой и его применение к принятию приближенных решений. – М.: Мир, 1976. – 165 с.
8. *Мелихов А.Н., Берштейн Л.С., Коровин С.Я.* Ситуационные советующие системы с нечеткой логикой. – М.: Наука, 1990. – 272 с.
9. *Евланов Л.Г., Кутузов В.А.* Экспертные оценки в управлении. – М.: Экономика, 1978. – 133 с.

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RESEARCH OF THE EXPERIMENTAL DATA OF THE SATELLITE NAVIGATION SYSTEMS

In article directions and results of experimental data processing are shown. This data are obtained from the satellite navigation receiver. The statistical estimation with the purpose of further use of the received dependences and the data for researches of accuracy and efficiency of satellite systems are carried out.

The success of landing approach and landing depends on set of separate constants and variable factors: a precision of leading-out of airplane in some area **R** that represents a neighbourhood of some point on a glide path in which the pilot should make a solution about the further process of approach, parameters of airplane motion, dynamic characteristics of airplane, accuracy performances of a control system, atmospheric conditions and their combinations. Therefore the considered problem has probability character. It is impossible to predict beforehand way out of each operation. However, using methods of probability theory, it is possible to predict average outcome of landing approaches and landings.

Given landing system **G** consists from controlling **G1** and controlled **G2** subsystems, that is **G = G1 ∩ G2**. Condition of system **G** is characterized by composite vector **Zi**, inhering **n-dimensional** Euclidean space $\mathbf{R^n}$, that is $\mathbf{Z\ E\ R^n}$.

Components of a vector **Z** are the following magnitudes:

$$\mathbf{Z = \{X, \mu, Y, F, \lambda\}}.$$

X - the vector of a phase condition, characterizes a controlled object (subsystem **G2**) in space (an angle of a heading, a lateral deviation from a prescribed trajectory);

μ - a vector of internal state of object of control **G2**;

Y - a m-dimensional vector of measurements of phase coordinates on an exit of controlling subsystem **G1;**

F - a vector of the controlling system performances (an accuracy, reliability, a service area);

λ - vector - parameter of internal state of a controlling system (a frequency range, polarization, etc.)

During functioning landing system **G** under influence of external events there is a modification of a mechanical trajectory of controlled object **G2**. If the path passes through target area **R** any control is not required.

$$\mathbf{Z\ (t)\ E\ R\ (in)}$$

To keep a controlled object in this status at external actions it is required to control a situation

$$\mathbf{S = S\ (U, t)}$$

Control should be considered, as means of reaching of purposes and as means of compensating of unfavorable influences in an environment, that hinder this.

Control in given system **G** is operations of the pilot of subsystem **G2** on the basis of control commands from subsystem **G1**. And restrictions in control process are performances of controlled object **X.**

Define a set of initial events $\mathbf{\Omega\ (t_0)}$ for a landing system as an admissible set of conditions of subsystems and the groups which are included in them in an initial moment $\mathbf{t_0}$ of a landing system operation. The set of final events $\mathbf{\omega\ (t_k)}$ for a landing system is defined by its operation purpose and the landing system category. The set of final events for landing systems is set by an admissible set of conditions of subsystems in the moment $\mathbf{t_k}$. Reached altitude of decision making $\mathbf{H_{пр}}$ corresponds to this moment (accepted classes: I - $\mathbf{H_{пр}}$ = 60 m, II - $\mathbf{H_{пр}}$ = 30-60 m, III - $\mathbf{H_{пр}}$ <30 м).

Let's choose a set of events $\mathbf{D}_\tau$ to which point - event **{Z, t}** will belong, at normal functioning a landing system.

$$\{\mathbf{Z, t}\}\ \mathbf{E}\ \mathbf{D}_\tau$$

The control object of the landing system is controlled concerning set $\mathbf{D}_\tau$ if for period $\boldsymbol{\tau}$ event **{Z, t}** does not leave the limits area $\mathbf{D}_\tau$**.**

The intersection of minimum area $\mathbf{D}_\tau$ at a set of initial events $\boldsymbol{\Omega}_{(\mathbf{t_0})}$, that defines reaching of purpose, and a scope of a controlling subsystem can be defined by area of tie-up of a landing system under the given conditions of existence and functioning of subsystems.

The permit boundary of a controllability area $\boldsymbol{\Gamma}_{\mathbf{D}\,\tau}$ is one of primal constraints, defining maximum deviations $\boldsymbol{\psi}$ and $\boldsymbol{\varphi}$ during functioning of system. Such boundary can be defined as a set of events each element of which is a limit point event of some sequence of events **{Z, t}, t E** $\mathbf{J}_\tau$.

Necessity of taking into account of dynamic possibilities of controlled objects originates at a problem solving of the analysis of landing systems. First of all it is explained by transience of approach process and boundedness of a resource of control on this stage.

Performances of a controlled object are represented as maneuverable performances of airplane. It is known, that maneuverable properties of the airplane can be described by areas of maximum deviations of phase variables, laws of control and the corresponding trajectories.

For change immediately to calculation of probability performances of success of landing approach we will consider component of landing systems.

The basic phase modifications at landing approach are: a velocity, a linear deviation from a glide path in horizontal and vertical planes, angular coordinates of an airplane.

Generally at the moment of change to contact flight airplane can have both a linear and angular deviation from a landing path. Lateral deviations are a result of trajectory oscillations of the airplane concerning a glide path line. Angular deviations in basic are a result of trajectory oscillations of the airplane and inexact selection of an angle of drift. As trajectory stability and the automatic account of angle of drift are demanded from the modern systems of trajectory controls, practically magnitudes of airplane angular deviations are insignificant.

We will carry out modelling of areas of maximum deviations of airplane taking into account of flight rules of landing approach, runway and airplane singularities, we shall receive area $\mathbf{D}_\tau$**,** for a solution of a problem of optimum control (fig. 1).

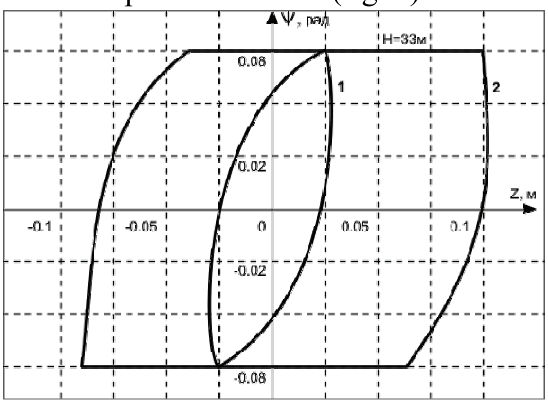


Fig. 1. Area $\mathbf{D}_\tau$ of maximum deviations without taking into account runway singularities (1) and with the account (2).

For the further modelling success of landing approach it is necessary to develop model of errors of a satellite landing system.

In this case as the data about mistakes of landing system we will use the experimental data which have been obtained from the laboratory-scale plant on baseline of satellite receiver **NOVATELL**, hardware and the software.

Obtained by mathematical and statistical processing an error distribution of a landing system are modelled on set of system restrictions which are presented by area $\mathbf{D}_\tau$.

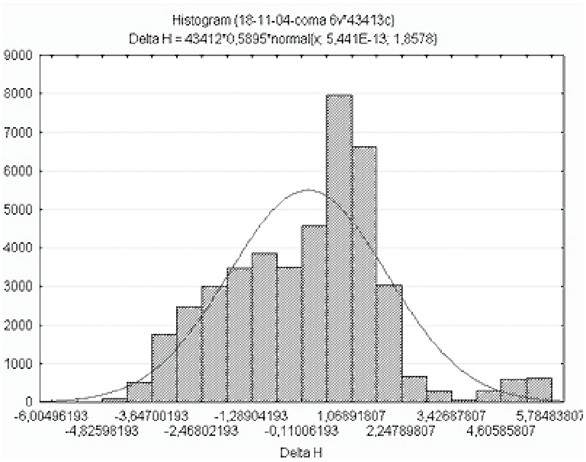
Processing **of experimental data**

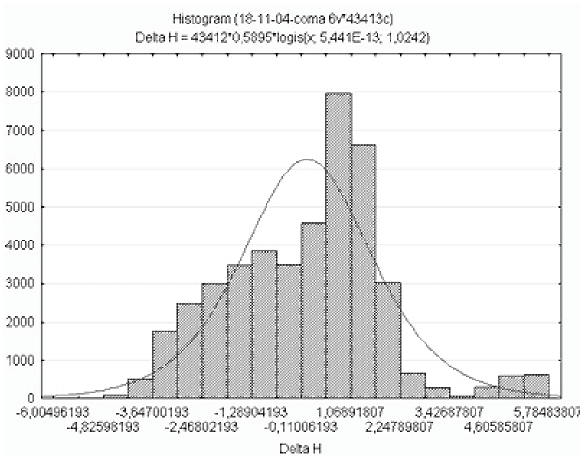
Let's consider experimental data of measurement coordinates **H** (altitude) of airplane location.

The data for April, 18, 2005 contain 43411 measurements during day. The maximum error thus makes:

	Delta H
MAX case 1-43411	6,00496193

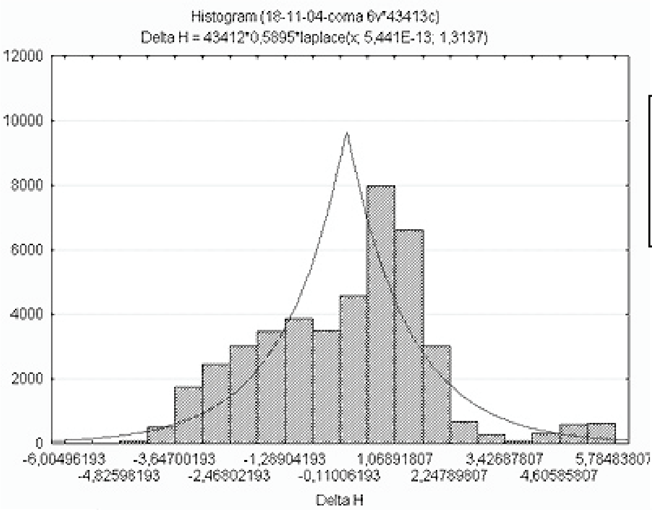
And the obtained data allow to build histograms of errors of position definition of the satellite receiver that allows to approximate histograms by curves and to receive the accordance to the given laws of distribution, and also to estimate accordance to these laws by Kolmogorov - Smirnov criteria and a discrete statistician.



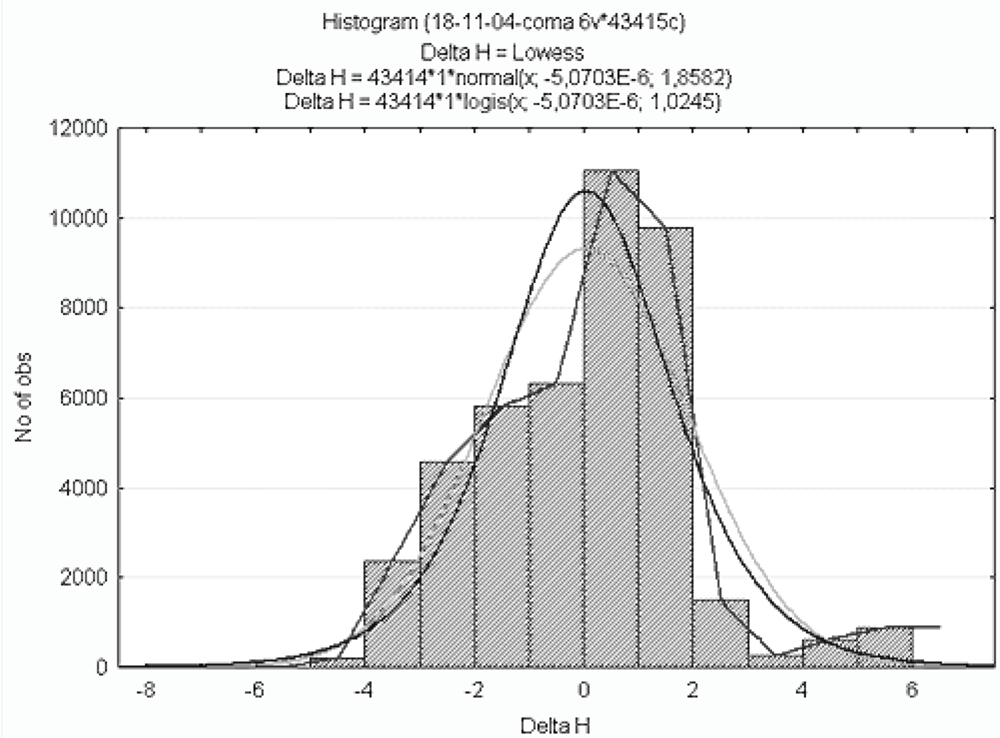


Normal Distribution.
Kolmogorov-Smirnov test
D = 0,0690252308,
p < 0,0100,
Lilliefors-p < 0,00999999978

Logistic Distribution.
Kolmogorov-Smirnov test
D = 1,
p < 0,0100,
Lilliefors-p < n.s.



Laplace Distribution.
Kolmogorov-Smirnov test
D = 3,00000000E+30,
p < 0,0100, Lilliefors-p < n.s.



From the considered experimental data that were approximated by known distribution laws, the greatest coincidence is observed with the logistical distribution law.

Delta H: **N** = 43414, **Mean** = -0,00000507034216, **StdDv** = 1,85817066, **Max** = 6,00496193

Logistic Distribution. The logistic distribution is used to model binary responses and is commonly used in logistic regression. The logistic distribution is defined as:

$$f(x) = (1/b) * e^{[-(x-a)/b]} * \{1+e^{[-(x-a)/b]}\}^{\wedge -2}, \quad \text{for } -Г < x < Г \text{ and } b > 0$$

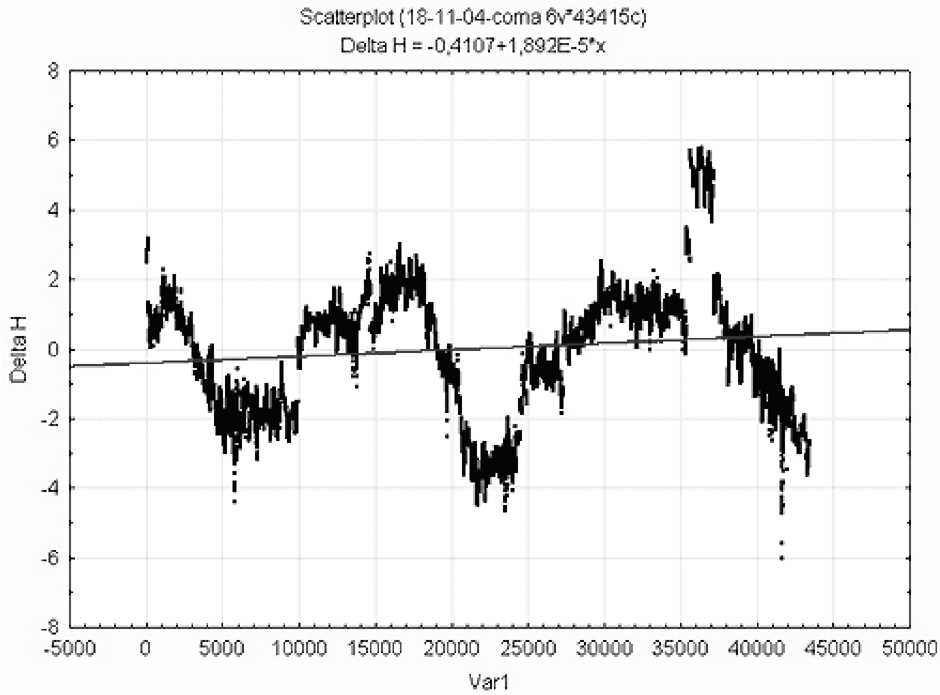
where

a is the location parameter (mean)
b is the scale parameter
e is the base of the natural logarithm, sometimes called Euler's e (2.71...)

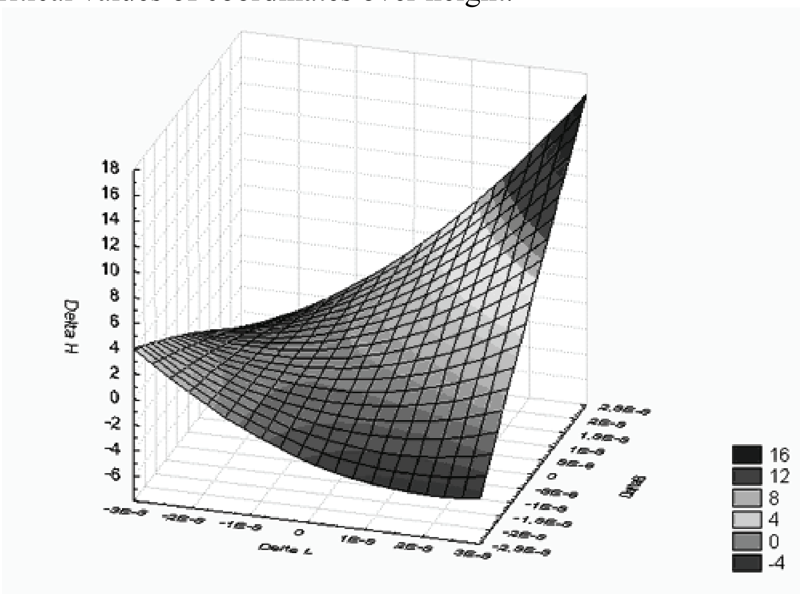
After that it is necessary to integrate within the limits of area $\mathbf{D_\tau}$, that is from **–z** up to **+z.**

$$P(i)=\int_{-z}^{z} f(x)dx$$

Research of dependence of a mistake of coordinates definition from time:



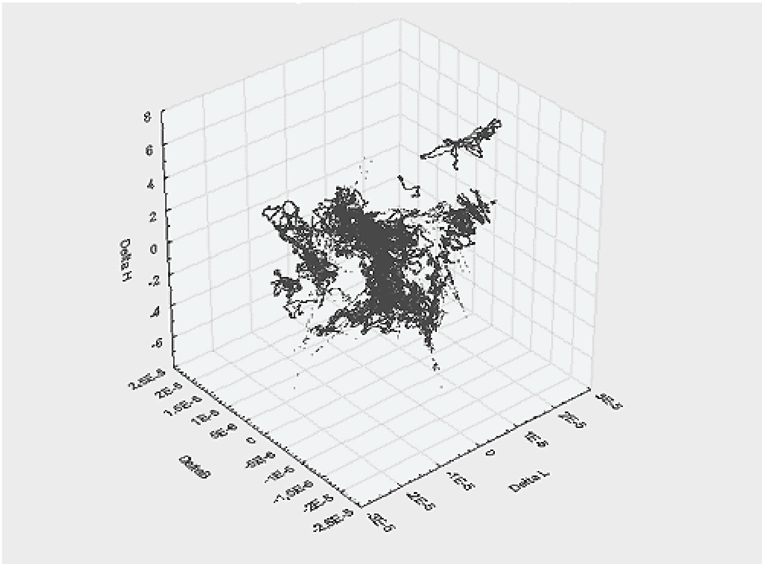
With the purpose of the decision of prediction problem we develop model of dependence of one of coordinates from two others. The decision of such task is the most actual for definition and the control of critical values of coordinates over height.



Let's express dependence of a mistake of measurement on height from two other coordinates:

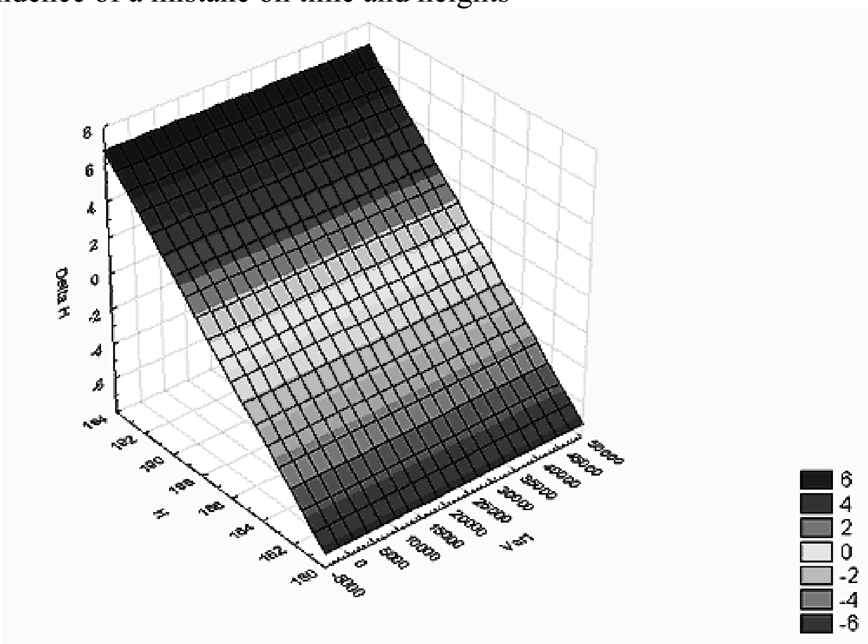
Delta H = 0,0163+1,1168E5*x+1,1564E5*y+3,3114E9*x*x+1,0038E10*x*y-4,7013E8*y*y

x = Delta L, **y** = Delta B



Dependence of a mistake of measurement on height from two other coordinates, expressed by points in space.

Dependence of a mistake on time and heights



Delta H = -187,2333+1,1089E-10*x+1*y-1,0095E-17*x*x-5,9222E-13*x*y+5,1507E-9*y*y

x = time,sec , **y =** H

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SOFTWARE ARCHITECTURE OF MODELING SYSTEM FOR COMPARISON OF AIRCRAFT CONFLICT RESOLUTION ALGORITHMS

In this paper the uniform modelling framework for testing and evaluation of various air traffic Conflict Detection and Resolution (CDR) algorithms is proposed. Motion models, environment models and data banks are described as external components attached to modelling system core. Universality of this approach makes possible system application under different conditions, especially under Free Flight. The paper also presents realization of such software and some preliminary results of the system's use.

Introduction

Variety of CDR methods and algorithms proposed in literature does not assist in searching of proper one for specific task. Frequently efficiency and safety performance comparison of the several algorithms is needed under same conditions. Efficiency can be evaluated in accordance with known criteria. Various situation metrics can be used for safety estimation [1]. In this connection the use of special CDR simulation tool would be advisable. Such research software must allow real-time and fast-time modelling. Moreover it can be used not only for performance comparison but for testing and debugging of new models and algorithms.

In this paper the new approach to developing such task specific systems together with software realization example are considered. There was also an objective to achieve maximum software compatibility and augmentability, namely to provide:

- minimum functional dependencies between program modules;
- ability to attach various CDR algorithms for further performance evaluation;
- use of expandable database with air traffic situation scenarios;
- use of different aircraft motion models and environment models;
- displaying of simulation process and representation of evaluation results in suitable form;
- ability to select evaluation criteria for safety and efficiency estimation.

It is significant that initially the system had been developed for Free Flight conditions, however due to certain restrictions it can be adapted to fixed-route Air Traffic Control (ATC).

General Approach

The architecture of the system is based on multi-agent model of airspace [2]. In accordance with this model each aircraft is represented as a self-independent object (agent) which has its own predetermined flight plan (object intentions), current state parameters and set of constraints (conflict objects and the environment). Each object is capable of executing several basic functions like moving along planned trajectory, conflict detection, communication and negotiation with other objects, providing resolution of conflict and acting as a group leader. This model is quite suitable for software realization since aircraft is expected to be described in terms of object-oriented programming. Using such object-oriented model allows to divide modelling of airborne systems operation into several levels as it is shown in Table 1.

Table 1. System operation levels

Operation level	Available functions	Application range
Cluster (collective)	- Coordination inside object groups and between groups	Long-term, global
Object, with human involved (cooperative)	- Consideration of object intentions (negotiation) - Strategic manoeuvre planning - Airborne separation assurance (ASAS)	Long-term, local
Automatic (noncooperative)	- Danger detection and analysis - Message processing (communication) - Collision alert and avoidance (TCAS, GPWS)	Short-term
Technical (executive)	- Trajectory calculation and flight simulation - State propagation	All over

We emphasize four basic levels of system operation related hierarchically with each other: cluster, object, automatic and technical. Table 1 specifies the available functions and time-space range of application for each level.

To ensure maximum customization of the levels while testing algorithms the uniform software architecture for modelling system is needed. Figure 1 shows the general framework of system including program modules and data bank.

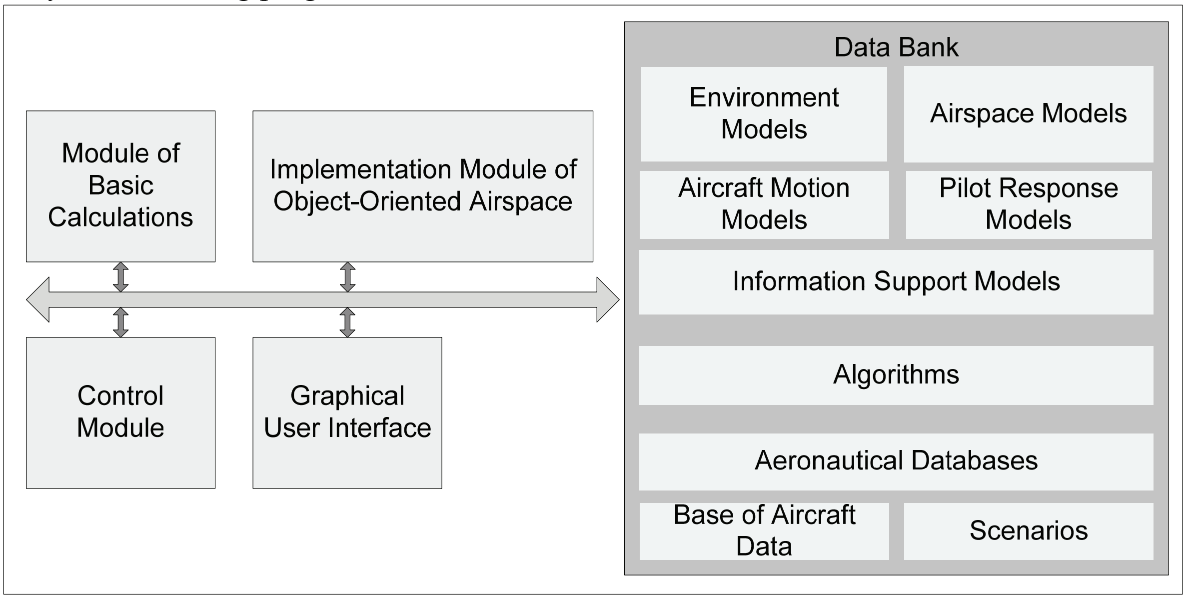

Fig. 1 General Framework of the System.

Implementation Module of Object-Oriented Airspace is the key unit of the system. It simulates behaviour of each aircraft object and its relationship with environment, motion model and pilot response model.

Data Bank contains a set of testable CDR algorithms, motion models, environment models, pilot response models, airspace models, information-support models, base of aircraft data, aeronautical databases and test scenarios. Thanks to the fact that Data Bank allows one to enrich this set permanently, the system becomes customizable and scalable.

Module of Basic Calculations is responsible for implementation of technical-level functions, which are intensively used in all stages of a simulation. It contains trajectory planning and position computation functions.

Control Module coordinates overall system operation, implements simulation process within global timing loop and provides interaction between system modules, including loading and testing of user-preferred models, algorithms and scenarios.

Graphical User Interface includes observation window, performance window and group of simulation control elements. The observation window shows given traffic situation, conflict appearance and evolution, resolution manoeuvres produced by aircraft. Control elements implement the following operations for simulation playback: start, pause, reset, forward and backward rewinding, dynamic events imitation, regulation of simulation speed. Performance window displays current object parameters and final simulation results.

System Architecture

Discrete-time air traffic simulation is realized within system time loop. Figure 2 illustrates the functional diagram of simulation process corresponding to the one time step with application of Data Bank components (models, algorithms, scenarios etc).

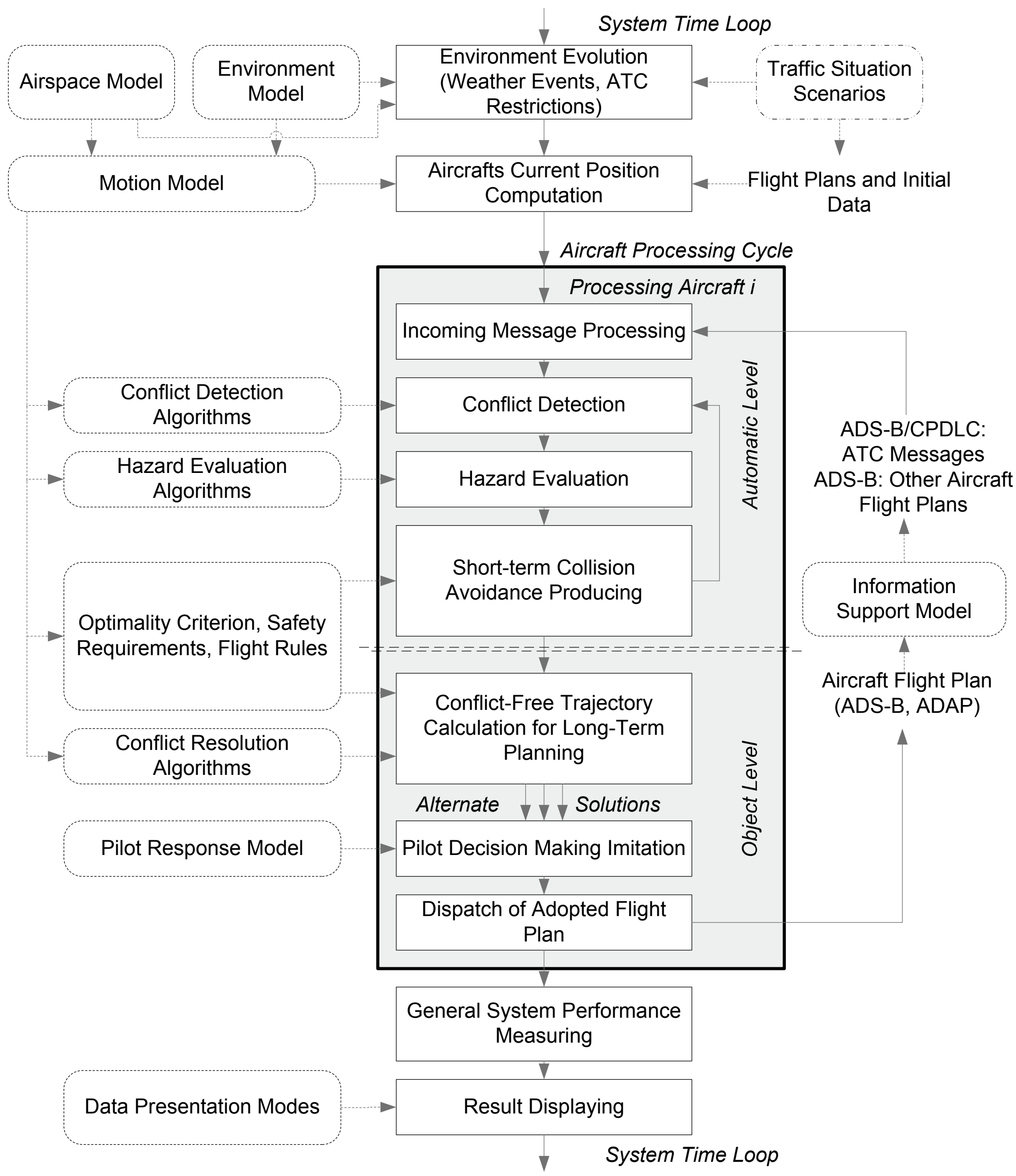

Fig 2. Simulation Process Functional Diagram.

Inside the system time loop simulation process can be conventionally separated into three parts:

- aircraft current position computation and independent environment evolution;

- imitation of airborne systems operation;
- performance measurement and result reporting.

As outlined above system provides user with select option to use various models of environment, aircraft motion, airspace, information support and pilot reaction. For example, environment model describes origination and development of weather events and atmospheric changes.

Aircraft motion model is realized using set of functions designed for position computation and other parameters calculation at any moment in time. The input data for the model are aircraft's current state and characteristics. Environment model properties like wind speed and direction, wind-shear, atmospheric pressure and temperature can be taken into account as well.

The model of airspace implies its type, structure and air traffic services available. The model also enables regulation of pilot responsibility for airborne separation ensuring. Due to this option the modelling of both traditional route-fixed and Free Flight airspace conditions became possible. The input data is information from the aeronautical databases. Thus, controlled and uncontrolled airspace conditions, and presence of restricted areas or special use areas can be modelled. Free Flight simulation is of special interest in this paper, as aircrafts fly by their own preferred routes with possible deviations, and therefore the notion of air corridors and aircraft flow control methods for fixed routes are inapplicable here.

Information support model depicts type and parameters of available airborne communication, navigation and surveillance systems. The receiving of Controller-Pilot Data Link Communication (CPDLC) messages, HF/VHF voice and data messages, TCAS and ADS-B data is simulated within Incoming Message Processing block. All messages are saved to the message-stack and processed in queue discipline. The broadcast distribution of flight plan over surrounding aircrafts through ADAP data-link is a final step in aircraft processing.

Pilot response model is presented by Pilot Decision Making Imitator. The input data for this block is an array of conflict-free trajectories produced by selected conflict resolution algorithm in previous block. Pilot reaction in this case is a set of parameters influencing alternative choice of conflict-free flight plan, its distortion and adoption/rejection. Manoeuvre selection can be both random and specified by priority scheme, e.g. pilot most likely prefers trajectories considering passengers' comfort than effective fuel consumption. Hence, relative safety and efficiency estimation for each alternate solution has to be obtained before pilot reaction will be applied. It is common to use distance separation metrics as a safety criteria. Space and time flight plan deviation, additional fuel costs for manoeuvring, passengers' comfort etc. can serve as an optimality criteria. Moreover, one can present pilot reaction as perturbations of flight parameters like horizontal speed, acceleration, bank angle, attack angle, climb and descend speed. Another adjustable variable is a pilot response time during decision making. The imitation of abnormal pilot actions is provided by the set of dynamic events e.g. refusal to follow airborne systems advisories or contradictory decision making.

Traffic Situation Scenarios

The basic conditions required for testing process are prescribed by executable traffic situation scenarios. The system can operate both in mode of predefined and randomly generated scenarios.

A scenario is proposed to include the following:

- traffic simulation mode: working with individual aircrafts or with traffic flows;
- airspace and environment static restrictions: initial weather conditions, airspace type and structure, ATC services;

- aircraft static information: call sign, aircraft type, airborne equipment installed, crew qualification, flight number, flight priority;
- initial flight plans;
- initial aircraft state: position, speed vector, altitude, fuel, emergency state etc.;
- scheduled events: weather changing, airborne equipment failure, special ATC messages and pilot actions;

The classical scenarios commonly used for studying of enroute conflict resolution are as follows:

- crossing of two or more routes with definite traffic intensity;
- two separate aircrafts are in conflict (the same altitude and opposite/same/crossing flight directions).

Free Flight traffic situation scenarios are the subject of particular interest. As long as Free Flight concept considers user-preferred and optimal trajectories we have to deal with separate aircraft flying by individual plans. In many papers related to Free Flight [3, 4] one can find so-called "wall"- and "star"- configuration of conflicts studied. Such scenarios are especially demonstrative, since they contain super-conflicts with a number of aircrafts involved. But the most interesting are the situations where local groups of aircrafts (clusters) are organized. A cluster includes directly conflicting aircrafts and those aircrafts capable of entering this conflict while resolution between first one will be executing (Fig. 3).

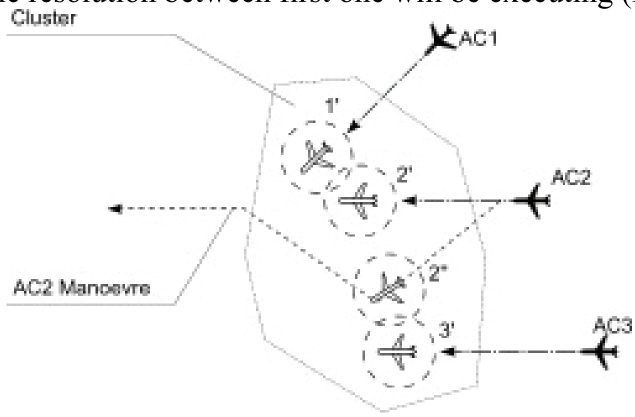

Fig 3. Cluster formation. AC – aircraft.

System Performance Monitoring

Since the main purpose of the system is efficiency evaluation of CDR algorithms there is a need to determine estimation indices. For CDR algorithms these indices can be as follows:

- aircraft's time deviation from initial flight plan;
- manoeuvre duration;
- manoeuvre length;
- maximum deflection from initial trajectory;
- track deviation;
- flight level deviation;
- speed deviation;
- fuel consumption for manoeuvre execution;
- manoeuvre complexity (geometry and number of path sections);
- manoeuvre priority.

Manoeuvre priority is a suitable form for coding different types of escape trajectories, e.g. by height, course, velocity or mixed types, with respect to pilot preferences on manoeuvre realization and passengers' comfort.

One or more criteria specified by user are used to calculate particular and total efficiency indices. The first one is estimated for every aircraft involved in a conflict and the second one – for the whole set of aircrafts.

The computational efficiency can serve as a key factor during selection of a proper algorithm. It can be presented both by amount of computations and by time spent on manoeuvre calculation and its further adjustments. It is evident that time cost index cannot serve as an objective value, since it has to be measured in equal terms for algorithms examined, i.e. on the same computer with identical operation system load, which is difficult to achieve.

It is proposed to deal with single conflict with two or more aircrafts involved when measuring amount of computations. The number of flight plan changes produced by every participating aircraft in order to eliminate a conflict is supposed to be more indicative than counting computational primitives. As soon as many algorithms are expected to produce conflict-avoiding solution in iterative process with step-by-step manoeuvre correction while aircrafts fly, the final amount of computations can be obtained in this case upon completion of the manoeuvre. For algorithms offering immediate conflict resolution within one modelling time step, the amount of computations is determined within this time interval.

Program Realization

The prototype of the simulator was developed using Borland Delphi environment. The program is designed in compliance with outlined scalability concept and allows various CDR algorithm testing. Scenarios are loaded from text files where data is presented in editable form. Thus, user can create new customized scenarios and then load them into the program. New conflict resolution algorithms can be attached to the program through Dynamic Link Libraries (DLL). Aircraft characteristics are loaded from the Base of Aircraft Data [5].

Standard user operation includes the following stages: 1) choosing scenario, models and test algorithm; 2) simulation running, traffic situation observation, performance measuring, event imitation; 3) simulation completing and result analysis.

Graphical User Interface of the program (Fig. 4) contains simulation control panel, options panel for model and algorithm tuning, main simulation window, event panel and performance log window.

Figure 4 shows testing of the "Protocol-Based Conflict Resolution" algorithm [6] which was specially designed for "star-conflict" scenarios. Solid lines indicate initial aircraft flight trajectories and the dotted one designate resolution manoeuvres produced by algorithm.

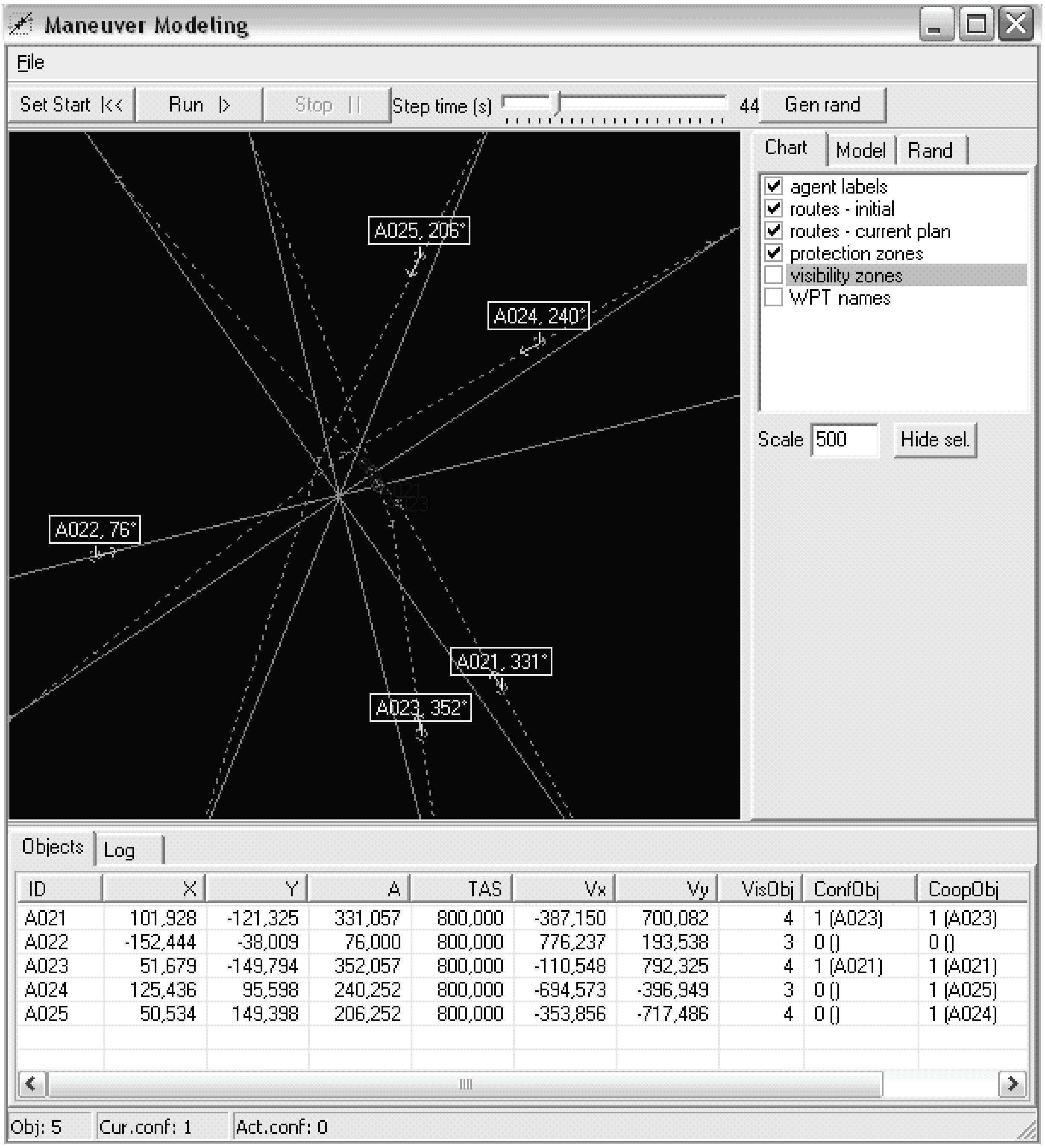

Fig 4. Simulator Main Window.

Summary and Future Work

1. According to the general software framework outlined in this paper the developed system allows for making research on a wide class of ATC problems in special conditions like Free Flight. The main advantage of the system is the possibility to flexibly customize the testing conditions, to choose required models, methods and evaluation criteria. Due to this a comparative performance analysis can be carried out for set of conflict resolution algorithms.

2. The system can be used as auxiliary tool for reproducing of actual accident conditions for further investigation.

References

1. Харченко В.П., Корчунов Д.О. Метричний простір ситуацій повітряного руху літальних апаратів // Вісн. НАУ. – 2002. - №3. – С.63-68.

2. Харченко В.П., Закора С.А. Применение принципов распределенного кооперативного решения конфликтных ситуаций в условиях концепции Free Flight // Журнал „Искусственный интеллект" 3/2004, Донецк, ДонГИИИ. – 2004. – №3. – С.385-391.

3. K.D. Bilmoria. A Geometric Optimization Approach to Aircraft Conflict Resolution. AIAA-2000-4265, AIAA Guidance, Navigation and Control Conference, Denver, Colorado. – 2000.

4. J.M. Hoekstra, R.C.J. Ruigrok, R.N.H.W. van Gent. Free Flight In a Crowded Airspace. 3rd USA/Europe Air Traffic Management R&D Seminar, Napoli. – 2000.

5. Eurocontrol Experimental Centre, "User Manual for the Base of Aircraft Data (BADA) Revision 3.1," EED Note No. 23/97, Eurocontrol. – 1998. – 92p.

6. I. Hwang, C. Tomlin. Protocol-Based Conflict Resolution For Air Traffic Control. Stanford University, Stanford – 2002. – 49p.

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EVALUATION OF PROBABILITY OF AIRCRAFT COLLISION AT COOPERATIVE AIR TRAFFIC CONTROL

The equations for evaluation of potential conflict probability and aircraft collision probability are derived based on stochastic nature and time correlation of deviation from planned flight trajectory under cooperative air traffic control. Stabilization of the intended trajectory parameters by flight management system is taken into account. All equation coefficients necessary for the numerical evaluation are derived.

Introduction

Nowadays in the world aviation community the problem of air traffic safety is widely discussed in connection with a perspective of introduction of the new concepts of air traffic management and transition from centralized air traffic control (ATC) to decentralized one, and with change of traditional ATC to cooperative ATC.

Cooperative ATC is a new concept, aimed to increase productivity and safety of the traffic by optimal interaction of air traffic controller, aircraft crews, and other services at the expense of: a) integration of digital systems of data transmission, b) improving of surveillance methods, and c) automation [1].

The need of transition to new organization of air traffic is caused by the observed and predicted growth of air traffic intensity, and its goal is to increase an air space capacity. It is proposed to solve the problem by introduction of "Free Flight", and by reduction of existing separation standard.

In conditions of operatively changeable air traffic situation, of changeable directions and dynamics of relative aircraft movement, and at reduction of separation standard, the role is growing of system of detection and prevention of dangerous aircraft approach.

The present paper is devoted to the problem of evaluation of the probability of aircraft collision in condition of cooperative ATC, when all the necessary information is available to the subjects involved in decision-making process. In particular ATC system should have an access to navigation data, which are contained in on-board flight management systems.

Motion under control

Consider an aircraft, which moves under air traffic control along a prescribed route. As a result of control, the altitude, flight direction, and velocity along the route are stabilized. Our key idea is to use Ornstein-Uhlenbeck (OU) process to describe the trajectory of the aircraft.

Let xOy be a local horizontal coordinate system, with an axis Ox along a prescribed route. We model the deviation $y(t)$ from the route line as OU process

$$dy(t) = -\alpha_y y(t)dt + \sigma_y dW_y(t)\,, \tag{1}$$

where $y(0)$ is known by the observations, α_y and σ_y are known positive scalars, and $\{W_y(t)\}$ is a standard Wiener process. The longitudinal coordinate $x(t)$ is described by equation

$$dx(t) = (v_0 + u_x(t))dt\,, \quad x(0) = 0\,, \tag{2}$$

where v_0 is a prescribed velocity of the flight, and $u_x(t)$ is deviation from the prescribed velocity. The latter is described by OU process as well,

$$du_x(t) = -\alpha_x u_x(t)dt + \sigma_x dW_x(t)\,, \tag{3}$$

where $u_x(0)$ is known by observation, α_x and σ_x are positive scalars, and $\{W_x(t)\}$ is another standard Wiener process, independent of $\{W_y(t)\}$.

Relative motion of two aircraft

Consider the flight of two aircraft at the same altitude. Each aircraft is characterized by a state vector

$$\vec{z}(t) = [x(t) \quad y(t) \quad u_x(t)]^{\mathrm{T}} \tag{4}$$

in corresponding local coordinates. Based on (1)-(3) we have

$$d\vec{z}(t) = \left[v_0\vec{e} + \Lambda \begin{bmatrix} y(t) \\ u_x(t) \end{bmatrix} \right] dt + Sd\vec{W}(t)\,, \tag{5}$$

where $\vec{e} = [1, 0, 0]^T$, $\Lambda = \begin{bmatrix} 0 & 1 \\ -\alpha_y & 0 \\ 0 & -\alpha_x \end{bmatrix}$, $\vec{W}(t) = \begin{bmatrix} W_x(t) \\ W_y(t) \end{bmatrix}$, $S = \begin{bmatrix} 0 & 0 \\ 0 & \sigma_y \\ \sigma_x & 0 \end{bmatrix}$.

Consider common horizontal coordinate systems xOy, while the motion of *j*-th aircraft is described in the local coordinate system $x_j O_j y_j$, $j = 1,2$. Let $\vec{e}_1$, $\vec{e}_2$ be unit vectors for the first aircraft and $\vec{f}_1, \vec{f}_2$ be unit vectors for the second one, as shown in the picture.

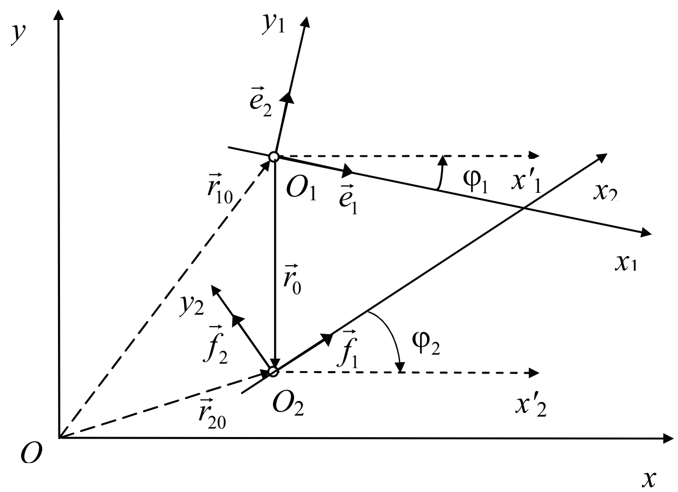

Fig.1 Relative positions of aircraft

Let $\vec{r}_{j0}$ be a vector corresponding to the initial position O_j of j-th aircraft. Then the vector $\vec{r}(t)$ of relative position of the aircraft equals

$$\vec{r}(t) = (\vec{r}_{20} - \vec{r}_{10}) + x_2(t)\vec{f}_1 + \vec{y}_2(t)\vec{f}_2 - x_1(t)\vec{e}_1 - y_1(t)\vec{e}_2, \tag{6}$$

and $\vec{r}(0) = \vec{r}_0 = \vec{r}_{20} - \vec{r}_{10}$. In the common coordinate system we have, see the picture,

$$\vec{e}_1 = \begin{bmatrix} \cos\varphi_1 \\ \sin\varphi_1 \end{bmatrix}, \qquad \vec{e}_2 = \begin{bmatrix} -\sin\varphi_1 \\ \cos\varphi_1 \end{bmatrix}, \qquad \vec{f}_1 = \begin{bmatrix} \cos\varphi_2 \\ \sin\varphi_2 \end{bmatrix},$$

$$\vec{f}_2 = \begin{bmatrix} -\sin\varphi_2 \\ \cos\varphi_2 \end{bmatrix}.$$

Then

$$\vec{r}(t) = \vec{r}_0 + \begin{bmatrix} -U_1 & U_2 \end{bmatrix} \begin{bmatrix} x_1(t) \\ y_1(t) \\ x_2(t) \\ y_2(t) \end{bmatrix},$$

where $U_j = \begin{bmatrix} \cos\varphi_j & -\sin\varphi_j \\ \sin\varphi_j & \cos\varphi_j \end{bmatrix}$, $j = 1,2$. We transform the state vector (4) of each aircraft from local coordinates to common coordinates (below we omit j for brevity)

$$\vec{R}(t) = \begin{bmatrix} U & 0 \\ 0 & 1 \end{bmatrix} \vec{z}(t).$$

Let $P_{23} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$. Equation (5) implies

$$d\vec{R}(t) = (\vec{h} + M\vec{R}(t))dt + \Sigma d\vec{W}(t),$$

where

$$\vec{h} = v_0 \begin{bmatrix} U \begin{bmatrix} 1 \\ 0 \end{bmatrix} \\ 0 \end{bmatrix},$$

$$M = \begin{bmatrix} U & 0 \\ 0 & 1 \end{bmatrix} \Lambda P_{23} \begin{bmatrix} U^{\mathrm{T}} & 0 \\ 0 & 1 \end{bmatrix}, \qquad \Sigma = \begin{bmatrix} U & 0 \\ 0 & U \end{bmatrix} S.$$

For the compound vector $\vec{X}(t) = \begin{bmatrix} \vec{R}_1(t) \\ \vec{R}_2(t) \end{bmatrix}$ **we have**

$$d\vec{X}(t) = \begin{bmatrix} \vec{h}_1 + M_1\vec{R}_1(t) \\ \vec{h}_2 + M_2\vec{R}_2(t) \end{bmatrix} dt + \begin{bmatrix} \Sigma_1 & 0 \\ 0 & \Sigma_2 \end{bmatrix} d \begin{bmatrix} W_{x1}(t) \\ W_{y1}(t) \\ W_{x2}(t) \\ W_{y2}(t) \end{bmatrix}. \tag{7}$$

Here $\{W_{xj}(t), W_{yj}(t), \quad j=1,2\}$, are jointly independent Wiener processes. The initial state $\vec{X}(0)$ is given by the observations. The solution of (7) is four-dimensional diffusion process. Its infinitesimal operator $\mathcal{A}$ acts on a function $g = g(t, r_{11}, r_{21}, r_{31}, r_{12}, r_{22}, r_{32})$, where $\vec{R}_j = [r_{1j} \quad r_{2j} \quad r_{3j}]^{\mathrm{T}}$, as

$$\mathcal{A}g = \sum_{j=1}^{2}\Big[(v_{0j}\cos\varphi_j - \alpha_{yj}\sin^2\varphi_j r_{1j} + \alpha_{yj}\sin\varphi_j\cos\varphi_j r_{2j} + \cos\varphi_j r_{3j})\times$$
$$\times\frac{\partial g}{\partial r_{1j}} + (v_{0j}\sin\varphi_j + \alpha_{yj}\sin\varphi_j\cos\varphi_j r_{1j} - \alpha_{yj}\cos^2\varphi_j r_{2j} + \sin\varphi_j r_{3j})\times$$
$$\times\frac{\partial g}{\partial r_{2j}} - \alpha_{xj} r_{3j}\frac{\partial g}{\partial r_{3j}}\ \Big] + \frac{1}{2}\sum_{j=1}^{2}\Big[\ \sigma_{yj}^2\sin^2\varphi_j\frac{\partial^2 g}{\partial r_{1j}^2} -$$
$$-2\sigma_{yj}^2\sin\varphi_j\cos\varphi_j\frac{\partial^2 g}{\partial r_{1j}\partial r_{2j}} + \sigma_{yj}^2\cos^2\varphi_j\frac{\partial^2 g}{\partial r_{2j}^2} + \sigma_{xj}^2\frac{\partial^2 g}{\partial r_{3j}^2}\ \Big].$$

The evaluation of $\mathcal{A}$ is given in [2].

Evaluation of probability of collision

Suppose that two aircraft collide when their relative distance is less than or equal to d. Denote by q the probability of collision on time interval $[0,T]$,

$$q = P\{\exists\, t \in [0, T] : \|\vec{r}(t)\| \le d\}.$$

Introduce the function of conditional probability of collision

$$f(t,\vec{X}) = P\{\exists\, \tau \in [T-t, T]:\ \|\vec{r}(\tau)\| \le d \mid \vec{X}(T-t) = \vec{X}\}.$$

According to (6), collision occurs when $\vec{X}(t)$ hits the domain

$$K = \{\vec{X} \in \Re^6 : \|\vec{r}_0 + P_{12}(\vec{R}_2 - \vec{R}_1)\| \le d\},$$

where $\vec{X} = \begin{bmatrix}\vec{R}_1 \\ \vec{R}_2\end{bmatrix}$ and $P_{12} = \begin{bmatrix}1 & 0 & 0 \\ 0 & 1 & 0\end{bmatrix}$.

According to L. Pontryagin [3] the function $q(t,\vec{X})$ satisfies the parabolic problem

$$\frac{\partial f(t,\cdot)}{\partial t} = \mathcal{A}\mathbf{f}(t,\cdot), \quad t \in (0,T], \qquad \vec{X} \in \Re^6 \setminus K,$$

$$f(t,\vec{X}) = 1, \qquad \vec{X} \in \partial K, \quad t \in (0,T],$$

$$f(0,\vec{X}) = 0, \qquad \vec{X} \in \Re^6 \setminus K.$$

The function f is defined and continuous on the set

$$D = \{(t,X) : t \in (0,T], X \in (\Re^6 \setminus K) \cup \partial K,\ or\ \ t = 0, X \in \Re^6 \setminus K\}.$$

The probability of collision on [0,*T*] equals

$$q = f(T, \vec{X}(0)), \qquad \vec{X}(0) \in \Re^6 \setminus K.$$

The parabolic problem should be solved by numerical methods.

Remark 1. It is possible to obtain partial differential equations for two other collision risk characteristics, see [4]:

a) mean time till the first collision

$$E \min\left\{ t \geq 0 : \|\vec{r}(t)\| = d \right\}, \qquad \text{and}$$

b) mean duration of collision on the most dangerous time interval $[t_0, T]$

$$\frac{E \text{ mes}\left\{ t \in [t_0, T] : \|\vec{r}(t)\| \leq d \right\}}{T - t_0}.$$

Remark 2. The presented approach can be generalized for the aircraft at different altitudes. The deviation from the prescribed altitude can be described by OU process as well.

References

1. *Hoffman E., Nicolaon J.-P., Zeghal K.* Transfer of Separation Responsibilities to Aircraft: The Freer-Flight Evolutionary Air-ground Co-operative ATM Concepts // EUROCONTROL Skyway, Spring issue. – 1999. – 4(13). – http://www.eurocontrol.fr/projects/cospace/archive/skyway.html.
2. *Kharchenko V.P., Kukush A.G., Vasylyev V.N.* Stochastic evaluation of aircraft collision risk under cooperative air traffic control // Проблемы управления и информатики. – 2005. – №5.
3. *Тихонов В.И., Миронов М.А.* Марковские процессы. – М.: Сов. радио, 1977. – 488 с.
4. *Kharchenko V.P., Kukush A.G., Vasylyev V.N.* Generalized stochastic method of conflict performances evaluation in controlled air traffic // Kibernetica i sistemny analiz. – 2005. – №3.– P. 81-93.

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COMPUTER - AIDED SYSTEM OF NAVIGATION SYSTEMS ACCESSIBILITY FORECASTING

The working out of computer – aided system of navigation systems accessibility forecasting for the purpose of increase of aircrafts' flights safety, which use aids of satellite navigation.

Posing the Problem

Satellite navigation within the next few years is going to transform into the only aids of aeronavigation for the civil and military aviation service in countries-participants of European conference of civil aviation and the USA, hence, nearly in the whole world. Material resources of the transition to the satellite aeronavigation are the global GPS and GLONASS satellite systems, up-to-date created systems of wide area addition WAAS (USA), EGNOS (European Union), MSAS (Japan), GAGAN (India), the system of local addition LAAS (USA), ground regional system of functional addition GRAS, European constellation of navigation satellites GALILEO, local (aerodrome) control-corrective stations made for the ensuring of precise arrangements of the landing up to the third category of meteorological minimum. The most powerful stimulus of this process is the possibility of aircrafts' flights on arbitrary routes, substantial reduction of the ground navigational equipment cost, as well as the opening of satellite navigation aids market, and it is valued at more than 600 milliard dollars within the next few years [1].

Under conditions of intensive satellite navigation aids application into the navigational practice the problem of increase of aircrafts' flights safety gets extraordinarily topical. It refers to the aircrafts which are rigged with satellite radio navigation equipment. One of the effective aids of increase of aircrafts' flights safety and the decrease of aviation occurrences risk is method of computation of satellite navigation systems accessibility by means of forecasting of their precise performances at any leg of the route using information received from navigational satellites exactly before the flight performance, and the information received while modelling scripts of sudden navigation satellites rejection, when the satellites are out of ground services control zone.

Analysis of Last Researches

At present there are no systems of computation of navigation systems accessibility in Ukraine. However, it is necessary to notice that ARINC Company (USA) officially distributes software product WSEM (version 3.6) created for the purpose of accessibility forecasting only GPS satellites. WSEM3.6 programme forecasts navigation satellites accessibility only for one fixed consumer position and does not ensure satellites accessibility forecasting for the objects, coordinates of which are constantly changing in time, for instance such as an aircraft. Thus, at present time there are no systems, which enable to forecast satellites accessibility forecasting in the course of the entire aircraft flight route.

Formulation of Article Aims

In the given article the computer – aided system of navigation systems accessibility forecasting is examined. The main objective of the given complex is increase of aircrafts' flights safety, which are rigged with satellite radio navigation equipment owing to effective forecasting of satellite radio navigation systems accessibility (SRNS) at any moment of time and in any point of the route.

The Main Material Statement

The most optimal way of realization of navigation satellites accessibility forecasting method is computer – aided forecasting system (CFS), which contains multichannel satellite navigational receiver, computational environment in the form of a computer and object-oriented software that works up navigational data received from satellites. The genuine component part of CFS is the software fulfilling data handling using special mechanisms. It handles data obtained by navigation receiver from satellites, and by means of computed geometric factors elaborates satellite navigation systems accessibility criteria in any point of the forecasted route of the aircraft flight [2, 3].

The main principles of CFS construction are modularity and transfer of functions of produce and formation of forecasted information in the computer. The modularity principle has separate, almost free-running constructions for the main functional devices which are connected either with the help of coaxial cable or a great number of wire communication lines which connect the ports of successive interface RS-232 or RS-422. The modularity principle assumes the use of compatible with the computer multichannel satellite navigation receiver in the form of an article, located in a separate unit. The modularity principle applies to the software that gives the possibility to update the software in case of its modernization need.

Multichannel satellite navigational receiver is one of the main functional elements of CFS. For the CFS as a supporting receiver on the first stage it is possible to be guided by more up-to-date GNSS- sensors of the state enterprise "Orizon- -Navigation» or GNSS receiver of the GG24 type produced by Magellan company (USA), which in case of need smoothly by means of module CFS structure can be substituted for more perfected ones.

CFS software is worked out taking into account data received from navigational receiver and transformed into corresponding format. For this purpose corresponding data converters are worked out effectiveness of which is confirmed by the previous modelling.

CFS consists of functional knots and elements given in pic. 1.

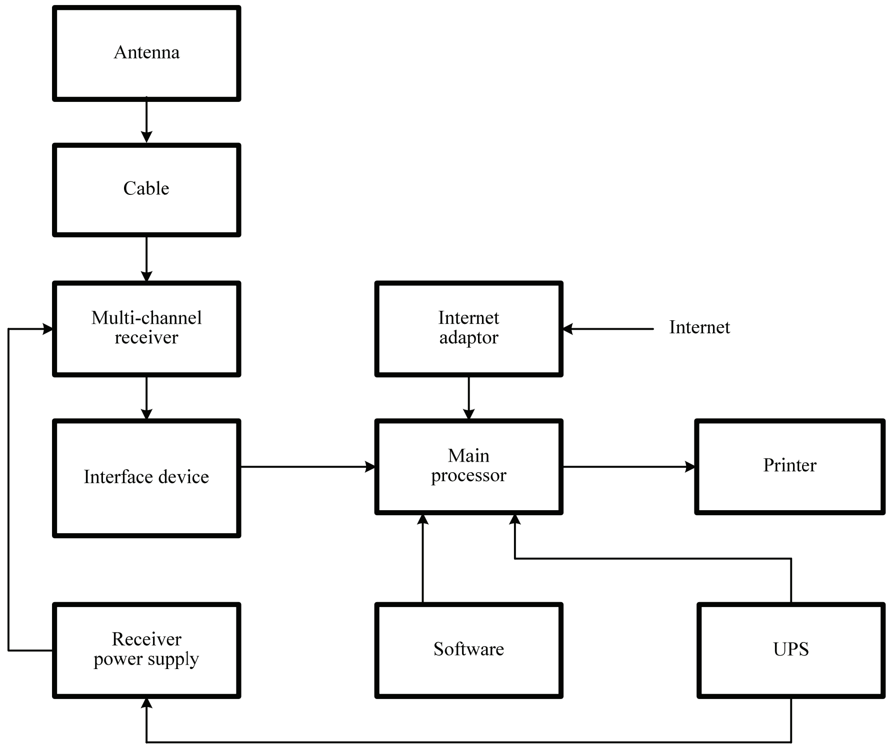

Fig.1. Structural scheme of CFS

To the antenna of antenna-feeder device (AFD) transmit the signals of navigational satellites GPS and GLONASS on frequencies L1. Through the unified cable navigational signals intense by the AFD amplifier, are directed to multichannel navigational receiver. After the processing by navigational receiver signals through the knot of joining with the computer in the form of marked information enter to the data handling device (DHD) and are preserved according to the proceedings in singled out folders of the computer. From Internet by means of joining device into the singled out DHD folders almanac data are registered. The almanacs are published by independent organizations. In DHD with the help of the software navigation data handling is produced. The data is received by multichannel receiver and there produces information on the satellite navigational systems accessibility. The produced information is represented on the paper carrier by a printer, and is recorded on a CD – disk (diskette) and is transmitted to the customer. CFS power supply (computer and navigational receiver) is realized through the uninterruptible power supply and power module of the navigational receiver.

The appearance of CFS model which is assembled from hardware-based means available in National Aviation University is given in pic. 2. The model consists of antenna with multi-radial suppression, basic station ProPak-G2, 12- channel navigational receivers-StarBox (NovaTel company equipment) and computer.

The model is assembled for the purpose of working through of CFS software.

Along with genuine software the model has the following technical performances:

Data receiving form GPS navigational satellites by 12 channels [2].

Data receiving from GLONASS navigational satellites (in the form of logical files by 12 channels) [3].

GPS almanac data receiving from Internet.

Data receiving of the aircraft route, formed with the help of specialized Jeppesen programme.

Data handling in correspondence with interface control GLONASS and GPS documents.

Evaluation of navigational satellites accessibility parameters and the aircraft route accessibility only through navigational of GPS satellite, only through navigational GLONASS satellites and through the common application of GPS and GLONASS satellites.

The time needed to accomplish an accessibility task does not exceed 2 minutes.

The time needed to load the navigational satellites data is within the limits of 1- 2 minutes under the condition of a «hot» start.

The time of solution and documentation of the task of the aircraft route accessibility and documentation of received data takes less than 10 minutes.

The time of sudden messages scripts modelling: one message per minute.

Fig.2. CFS outward

The genuine component of CFS is the software fulfilling data handlingusing special mechanisms. It handles data obtained by navigation receiver from satellites, and by means of computed geometric factors elaborates satellite navigation systems accessibility criteria in any point of the forecasted route of the aircraft flight.

The main CFS modules. The managing CFS programme fulfils the tasks of inquiry and formation of coming and outcoming data, procedures of data streams direct between navigational receiver, databases, specialized Jeppesen programme, Internet, software-based functions that take part in computation conducting and decisions, and the reflection of the decisions on the monitor or/and documentation.

The mathematical CFS server computes geometrical factors, visibility angles, orbit parameters, navigational satellites accessibility and the aircraft route accessibility.

CFS interface console reflects information on satellite navigation systems accessibility and the route of the aircraft flight accessibility in automatic and manual mode. Interface also contains functions of reflection of the satellite visibility angles (azimuth, the place angle), «sorting» of navigation satellites accessibility according to the time and coordinates of the aircraft, filter for the sudden messages scripts modelling.

Jeppesen programme is made for formation of coordinate - temporal information on the aircraft route (where and when the aircraft is).

MySQL database is made for the preservation and organization of convenient access to the following data:

- data on aircraft routes, namely points coordinates and their titles, which are received with the help of Jeppesen programme;
- incoming data from navigational receivers that contain navigational satellites almanacs information;
- outcoming data on the computation of navigational satellites and the aircraft route accessibility.

The receiver gives an opportunity in real time to receive almanacs of navigational satellites of GPS and GLONASS system, to evaluate the current situation of satellite GPS and GLONASS systems.

Internet is an alternative (non-effective) source of receiving almanacs information.

The worked out complex of navigational satellites accessibility forecasting makes it possible owing to effective (2 hours before the flight) radio navigation systems accessibility forecasting to determine at any moment of time and in any point of the aircraft route accessibility.

Conclusions

The use of satellite technology of radio navigation for the purpose of increase and ensuring of aircrafts flights safety can be effective if inculcated equipment facilities will meet the demands as for the sharpness, integrity, persistence and operating preparedness. It is recommended by standards and ICAO practice; by normative documents that regulate the rules and procedures of elaboration and navigation systems exploitation; scientifically grounded methodology of valuation of ground and board navigational facilities parameters.

The CFS application in aviation companies and aviation enterprises will give the possibility to considerably increase flights safety by means of forecasted navigational satellites accessibility on the stage of preparation for the flight, to foresee situations concerning sudden and uncontrolled navigational satellites refusals.

References

1. *Eleventh* air navigation conference (report of the committee in the conference according to the 6th article of the agenda). – Montreal, 2003. – 75 p.
2. *Interface* Control Document Global Positioning System (ICD-GPS-200C), 1997, 160p.
3. *Global* navigational satellite GLONASS system (interface control document). – The Fifth editing. – 2002. – 60 p.

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CAD DATA AND TECHNICAL DOCUMENTATION'S ARCHIVES BASED ON WINDCHILL TECHNOLOGIES

Introduction

PTC's Windchill© is a new generation product lifecycle management (PLM) system intended for: enterprise information space organization, enterprises integration and end-to-end solution of all information exchange questions arising from industrial activity.

One of organizational tasks of modern industrial enterprise information exchange is a task of archive automation.

Enterprise archive's automation may be considered as a set of the following actions:

1. Creation of storages of different type data: 3D CAD data (models), 2D drawings, digital structure of product and other electronic documents.
2. Management of archive's contents with users' different access permissions.
3. Collaborative work with archive objects.
4. Effective search of any archive object.
5. Creation and management of archive object task sequences.
6. Change management of archive objects.

To provide all of the actions above listed in most efficient way; Windchill is equipped with advanced objects, functions and services.

The following features characterize modern enterprise:

1. Variety of information objects.
2. Multiplicity of information sources (enterprise departments and divisions, manufacturers, suppliers, sellers, customers, contractors, etc.)
3. Data information basis is a product structure
4. Document circulation should be automated. Each user should be involved in document circulation. Access to enterprise information resources is allowed to Windchill users only.

"Client - server" architecture does not provide such features effectively because of ever varying project participants and different types of hardware/software used by them. The architecture basic features provide inflexible enterprise information model. Moreover, this model does not allow a connection to centralized data storage (a server of data) presenting centralized databases and special client software. Unique good up-to-date decision for information transfer and collaboration is WEB-based technologies (hardware and software independent system). WEB-based applications allow to organize excellent work environment for archive tasks of complicated enterprises.

Windchill system is based on the following principles:

1. Platform-independent realization.
2. Info*Engine technology-based Distributed Database (using Federative Data Model instead of the Centralized Data Model).
3. Internet features (Intranet, Extranet) compliance.
4. WEB-centric solution (i.e. WEB-technologies are the core of the Windchill system).
5. Flexibility of integration of segments, heterogeneous networks, and separate machines.

It is possible to connect the different type of data sources as well as many consumers of these sources. Administration of Windchill users, data stored by them, processes and access rights of the users is presented in unified information environment, which have WEB/Internet advantages. These advantages allow using Windchill as effective industrial archive.

1. Terms and object definitions in Windchill environment [1].

Cabinet

A type of folder that can contain subfolders, objects that must be stored in a folder, and shortcuts to objects in other folders. In general, cabinets provide an organizational root for information. Because they also represent administrative domains, they provide an association between the objects they contain and administrative policies for access control, indexing, notification, and so on.

Component

A part that cannot be further decomposed in a product structure.

Document

An electronic file or other means to contain information in an application format. A document typically has non-structured content that makes sense only to the external application, but can have a structure hierarchy within Windchill and can reference other Windchill documents. In terms of Windchill applications, a CAD file is considered a document.

Domain

A collection of objects that are subject to the same administrative policies, such as access control, indexing, event notification, and external file vaulting. In the Windchill Explorer, domains are represented as cabinets.

EPM Document

An alias for CAD document used in Windchill object model.

Gate

A transition point for objects exiting one life cycle phase and entering another. Criteria evaluation precedes this transition.

Life Cycle

A process containing an ordered collection of phases and gates.

Part

An instance of a WTPartMaster object.

Phase

A period of time during which an object has a specific state and g specific business rules apply.

Product

An information object that represents an assembly part that satisfies an end-use function and is to be independently configuration controlled. Products provide reference points for unit number effectivity.

Shared Cabinet

A shared cabinet corresponds directly to an administrative domain. It has no single owner and is the cabinet type most similar to a vault.

Workflow

The automation of a business process, in whole or in part, during which documents, information, or tasks are passed from one participant to another for action, according to a set of procedural rules. A workflow instance coordinates user and system participants together with appropriate data resources to achieve defined objectives by set deadlines.

Worklist

A list of work items associated with a given workflow participant (or in some cases, with a group of workflow participants who may share a common worklist). The worklist forms part of the interface between a workflow engine and the worklist handler.

2. CAD data archive's solution

All enterprise CAD data are stored in common virtual Windchill space. This space is accessible for Windchill users only. Such virtual space is referred to as an archive. An arrangement of specific disk or specific machine of archive of any value is not of fundamental importance. Moreover, places of real accommodation of the data can be considerably less. Users have "virtual" access to all these data, without binding to physical storages, i.e. it is not depended from determined hardware and software features of accommodation.

2.1 Archive configuration

Because of an archive is some virtual space; it is required to determine archive structure representation for users. Windchill archive is structured, i.e. it is placed on non-crossed segments. Access permissions to each of the segments are defined independently. The permissions can be determined during each segment organization. This can be done by four ways:

1. During Windchill installation. Some segments are created for purpose of system functionality providing.
2. Automatically, during creation of a new user
3. According to requirements of enterprise's organizational structure.
4. During definition of archive objects access permissions.

In the first case following segments are automatically created: domains and cabinets for Windchill internal administrator.

In the second case a virtual segment is created. Such kind segment is called Personal Cabinet. Personal Cabinet is created for each user. It is accessible for this user only. In Windchill frameworks it can serve as a personal storehouse for this user.

In the third case another virtual segment is created. It is called Shared Cabinet. Shared Cabinets are accessible for group (groups) of users, which have access permissions, defined for group entirely.

In the fourth case created cabinet /folder may have special access permissions.

Each cabinet having been created contains special folder named "Checked-Out". It is meant for user-received document treatment. Subfolders for archive purposes may be created here.

2.2 Document structure and references

In the general case, Windchill-document may have a primary contents (an electronic file), an attachment (electronic files) and Internet-references (URLs). A document, stored in archive, may be structured or non-structured. It means that document may have special type of link, which shows "parent" and "child". Besides structural link a document also may have other type link - "reference link". Reference links allow to organize dependencies between objects, which have been included in different structures. Reference link is not a directional link. Structural and reference links, being established, are automatically traced subsequently by Windchill irrespectively of contents change and logical location (cabinet, folder, subfolder) of document. Thus, flexibility is reached as at organization of document circulation and joint parallel work of users and groups with documents.

According to current set of access permissions, users obtain each document information from an archive. The information has a form of a properties page, which includes document's Number, Name, Title, Type, Authority, and Location in archive, Life cycle and Date of document last change. Besides, a properties page allows users to view (by means of additional menu):

1. Structure of this document.
2. Referenced documents for this document.
3. Version and iteration history of this document.
4. Life cycle and workflow stage details.
5. Document current location's details.

Such organization of document storage in Windchill allows to realize a concept of enterprise distributed archive.

2.3 Access to archive data and their location.

Created document (with or without contents) is transferred to the Windchill, and located into a personal cabinet or into shared one. Further access to the document contents (i.e. to electronic files, Structure, references) is possible for authorized users only. Authorship of determined document is fixed, but it does not mean any privileges at further work with the document. Moreover, when the document is transferred into a shared cabinet where author's access permissions are not determined, the author loses an opportunity to change the document. Properties page presents information about a document only. A work with a document is splitted in two different tasks: editing of document's general properties (attributes) and editing of contents files, which describes document.

To processes document contents' changes (i.e. changes of structure, references or some properties (attributes), etc. it is necessary to check the selected object out and place a working copy in your Checked Out folder placed in the personal cabinet. Users obtain real opportunity to make changes in given document. In shared folder the document typical pictogram is changed onto "blocked" pictogram, for other users at this moment the document becomes accessible for viewing only. After performance of any changes accessible to the user, both in the attributes fields, and in contents of the document, the document can be returned from "CheckedOut" folder to a shared folder (back in common archive). For this purpose it is necessary to execute "CheckIn" function. The document is deblocked at this moment for other users, and becomes completely accessible. The similar organization of work, firstly, allows to get rid of conflicts of multi-user system access. Secondly, it allows constantly seeing changes in a condition of archives of working groups, the enterprises as a whole. Thirdly, it provides tasks' automation of synchronization and integrity of the data.

2.4 Document version and iteration history

Each performance of "CheckedOut" – "CheckIn" calls' sequence automatically derivates a document new iteration. Iteration history of each document is stored in Windchill with binding to date of "CheckIn" operation performance. Document iteration history is accessible for each user who can view document properties page. Each performance of "CheckedOut" - "CheckIn" calls' sequence automatically creates document's new iteration. Iteration history of each document is stored in Windchill bound with date of "CheckIn" operation performance. Document iteration history is accessible for each user who can view document properties page. Iteration history represents processing of one document version.

Document versions required for change activities are stored in the Windchill system also. Every time "Revise" function is used, a new Windchill document version is created. Identification of whole document is provided with "Number"-"Version"."Iteration".

2.5 Comparison of document iterations

User obtaining access to document's iteration history may compare several iterations to get comparison report. Comparison report includes information about various iterations of document contents, structure iterations, iterations of document references, iterations of basic attribute fields. Comparison report is submitted as Web-reference. This reference provides a route to entire additional information.

2.6 Search in archive

"Search" - is a main function of any archive. Any Windchill user from any screen may execute «Search» function any time. "Search" icon and link to the function are accessible always. There are several possible modes of the function. They are: local search, global search depending on data type etc. First of all, the function allows choosing an object of searching. "Search" menu is changed with a choice of "document" object. Chosen document specificity is displayed. Keys of searching, including Name, Number, archive location, last change date, format or any combinations of these keys may be entered into data card fields of searching machine patterns by user. As a result, Windchill system will display a list of references to the document. Search keys appropriate to given combination will be transferred to the user.

External powerful search engine - Convera Retrieval Ware - may be used by the Windchill search mechanism. Convera Retrieval Ware is seamless integrated with the Windchill.

3. Product structure.

Product structure is a basic object for modern expanded enterprise. Product structure describes structure of a product in terms of " Product - assembly unit - subassembly unit - detail " hierarchy of entries. It may contain additional necessary information both with respect to a product entirely, and to each component of the product. Product structure undergoes changes and specifications during performance of all cycle of industrial works. Moreover, product structure submission of hierarchical splitting may be different for various divisions of the same enterprise. Equally, submission of various activities' performance may be different as well.

Everything above mentioned stipulate necessity of processing of product structure no less flexible than document processing. Windchill system is equipped with a broad set of functions to support information of a product, its structure and links.

A node of product structure is called a Part in Windchill system. CAD assembly or CAD detail may describe a Part.

3.1 Product components.

Product components may be obtained either "manually", or automatically from other applications (CAD, CAM, PDM systems, other systems) in Windchill system. CAD data from external PDM system, stored in Windchill, are presented as special type objects - EPM documents. Product structure components may be either assemblies or details. User may obtain product component information from properties page of component. Each CAD data accommodation in Windchill-archive defines component information availability to users. Component's entry in assembly, assembly in product etc. are displayed on properties page of Windchill- component. Properties page of component is equipped with a reference fields, which provide links to other components, displaying quantitative characteristics for this purpose. Thus, irrespectively of components' location in Windchill-archive, links describing a product structure are established. These links will be accessible always

3.2 Product structure components' description.

As previously noted, properties page displays Windchill product component information to users. Properties page information contains data to fill fields Number, Name, Type of detail, Location in archive, Life cycle etc. However, structural information about a component itself only may be insufficient for description of the component. Frequently, it is necessary to have access permissions to a component and obtain additional information concerning this component from archive (i.e. models, drawings, descriptions, technological processes, transitions, operations, photos, sketches etc.) In Windchill all this additional information is stored in most general view - as Windchill documents. "Component - document" links, established in descriptions and references, are kept further and accompanied automatically during as whole component's life cycle and documents connected with the component as well. There are references to call a function of given assembly structure displaying on the properties page.

Thus, there are multidirectional information links, which builds structures and reference links in Windchill-archive. These allow to realize Complete Electronic Product Definition concept practically, not just a simple archival storage of product structure.

3.3 Product structure components location.

Created component is transferred to Windchill. It is located in personal or shared cabinet. Further access to the component contents (i.e. electronic files, Structure, references) is enable for authorized users. Authorship of the component is fixed, but it does not mean any privileges for further processing of the component. Moreover, when the component is moved to the Shared cabinet where author's access rights are not determined, the author loses an opportunity to change the component.

Properties page displays component's information only. To change component's contents (i.e. structure, references, some property's attributes, etc.) it is necessary to execute "Check Out" procedure. In this connection the component is moved from shared cabinet (folder) to personal cabinet. During "Check Out" procedure the component's working copy is placed to "Check Out" folder of user personal cabinet. User obtains a real opportunity to make component changes. Component's typical icon placed in Shared folder is changed by "blocked" icon. At this moment the component becomes accessible for other users for "view only". After any change performance accessible to user, both in attributes fields and in the component contents, the component is returned from "CheckedOut" folder into the shared folder (i.e. back to common archive). For this purpose it is necessary to execute "CheckIn" procedure. At this moment the component is deblocked. It becomes completely accessible for other users.

First of all, such organization of work allows to get rid of access conflicts intrinsic multiuser system. Furthermore, this provides a possibility of observation of continuous changes both of working group archives and whole enterprise archive. And, finally, such organization allows to automate tasks of product structure data synchronization and its integrity.

3.4 Product structure version and iteration history

Each performance of a sequence of calls "CheckedOut" - "CheckIn" automatically creates a new iteration of the product structure. The history of iterations of each product structure is stored in Windchill with binding to "CheckIn" operation's performance date. The product structure iterations history is accessible to each user who can view properties page of this product structure. Iteration history represents processing of one product structure.

Windchill support product structure's versions, which are required for change activities as well. New version of Windchill product structure is created after "Revise" function using . Identification of whole product structure is provided by "Number"-"Version"."Iteration".

Version and iterative history of a product structure differ from the versions and histories of structure's components.

3.5 Product structure's iterations comparison

User, who has access permission to iteration history of the given product structure, can make comparison of several iterations, with the purpose of comparison report's obtaining. In the report are deduced given (references) about various iterations of product structure change, the data on iterations of document references, the data on iterations of the basic attributes values. The report comparison item is submitted as the Web-reference and presents a route for reception of more full additional information.

4. The Windchill Life Cycle Model

A Windchill life cycle[2] is an automated, graphical model, employing phases and gates, used to manage business objects as they progress from conceptualization through obsolescence. While an object is in a specific life cycle phase, certain business rules apply, such as access control rules defined for that phase. When created, an object modeled to be managed by a life cycle enters a life cycle phase, where it is assigned an initial state, and is associated with the initial phase of its life cycle.

The Windchill life cycle implementation also provides interface points for specification of workflow processes at each phase and gate. A default workflow process sends a notification message to the Submitter role player, and is associated with entry into each life cycle phase. Another default workflow initiates Review and Promote activities when an object enters a life cycle gate.

When an object enters a life cycle gate, it is awaiting promotion. When an object is considered ready for promotion to its next life cycle phase, it reaches a decision point (gate) for the phase. If the object is found ready to progress, the Promoter role player moves it to a new phase through an explicit promote action. Promote assigns a new state to the object and associates it with its next phase, where new business rules may apply.

An object's state is a measure of its maturity at any given time. State is an enterprise object, and it's meaning is applied regardless of the life cycle by which a given object was processed. For example, if an access control rule applies to a Requirements object in the Under Review state, the rule is applicable to all

Requirements objects in that state, even if they arrived at the state through different life cycles. However, each phase of a life cycle must be associated with a life cycle state chosen from among all states defined in the system.

Archive life cycle administrator, can create a variety of life cycles dependent on enterprise requirements. These life cycles, which are stored in the System cabinet, define the phases and gates associated with various business objects. For each object's life cycle, life cycle administrator can define the transitions through which an object must move, and the behavior associated with the object while it is in a specific state.

Windchill provides a Default life cycle, with many predefined states, such as In Work, Under Review, and Released.

5. Workflow task in archive

A workflow system[3] gives the ability to automate archive procedures in which information, tasks, and documents are passed among participants. This procedure is based on a process composed of well-defined rules, designed to efficiently accomplish archive and enterprise business goals.

The archive workflow system, implemented by the Windchill Workflow application, consists of four components:

1. The Workflow Process Editor, which allows you to define a workflow process and save your definition as a process template. This graphical editor and its use are the focus of this chapter.

2. The workflow runtime system, which executes a defined workflow process within the context of a specific business object (CAD document, a part or a document). Process execution includes delivering work items to users participating in the process, opening applications (for example, automatically interacting with the Windchill Explorer to check a business object out of the database), initiating subprocesses, and so on.
3. The Workflow Process Manager, a graphical tool for monitoring and reporting on workflow processes.
4. The Workflow History Viewer, which provides a simple ASCII interface used to access recorded workflow events, such as state changes, data transfers, or process start. The information in Workflow History Viewer can assist archive user in optimizing or streamlining a workflow process.

Conclusion

Windchill-based archives for documents and CAD-data allow to realize a concept of Complete Electronic Product Definition concept, not just a simple archival storage of binary files. This solution provides management of modern enterprise complicated objects, not single data files only. Internet-based technologies allow to employ such archives in distributed enterprise.

References

1. Windchill®6.2 Glossary. December 2001
2. Windchill®6.2 User's Guide. April 2001
3. Windchill®6.2 Business Administrator's Guide. September 2002

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PRODUCT STRUCTURE DIGITAL MODEL

Research results of representation of product structure made by means of CADDS5 computer-aided design (CAD) system, Product Data Management Optegra (PDM) system and Product Life Cycle Management Windchill system (PLM), are examined in this work. Analysis of structure component development and its storage in various systems is carried out. Algorithms of structure transformation required for correct representation of the structure are considered. Management analysis of electronic mockup presentation of the product structure is carried out for Windchill system.

Introduction

Requirements of quality improvement, as well as development acceleration of a complex technical product (such as a ship, a plane, an automobile), have resulted in wide use of information technologies. One of the basic criteria of information technologies application usage is a new information object development. Such new information objects may be referred as electronic data objects of any kind. First of all, automation of product designing processes has resulted in usage of CAD systems. CAD systems were the pioneers of the electronic product definition development. Product geometrical mock-up consists of part models and assembly structure models. Each of the models is presented as electronic data. Being used in science-intensive and complicated projects, these models require ordering and control. Data obtained from CAD-systems must be stored and coordinated. To utilize the data, access rules must be determined for the users. Enumerated tasks are carried out by means of the Optegra PDM system and similar systems. Enlargement of an electronic product definition compound demands wider spectrum of EPD-objects modification control and accountability. Information objects require support and control of modification. CAD system data become a segment of the electronic information objects. A decision of an integration task is obtained with the systems like Windchill PLM.

Problem statement

The aim of the research is:

- To determine specificity of assembly structures developed within CADDS5/Optegra/Windchill systems;
- To develop algorithms of structure presentation and transformation providing adequacy of the structures.

Electronic model of a Product

A product's mockup provides a new kind of a product model presentation. New objects are added. Electronic media (EM) are used as information-carrying media. Design work results are presented as electronic design documents. The documents are a structured dataset [1]. This dataset consists of property part, data content and electronic digital signature (signatures).

<HEADER> <Attribute 1>: Value <Attribute 2>: Value … <Attribute 3>: Value <Digital Signature> </HEADER>		*Section: Properties* Identification and authentication attributes
Information Unit 1	<DATA> <HEADER> … </HEADER> <DATA> </DATA> </DATA>	*Section: Content* Information Unit described electronic technical document
Information Unit 2	<DATA> <HEADER> … </HEADER> <DATA> </DATA> </DATA>	
	…	
Information Unit n	<DATA> <HEADER> … </HEADER> <DATA> </DATA> </DATA>	

Tab.1. ETD structure

The documents can be processed, stored, transferred and used both in them hardcopy and digital media.

Electronic technical document structure consists of property part and data content (tab.1). Mandatory attribute of the ETD property part is a digital signature (DS) providing legitimacy of the document.

Assembly structure digital model

Electronic model of a part designed in CAD system is an electronic design document. Data content of the document determines the part geometry as well as production and control requirement.

Two objects of electronic definition determine an assembly. Assembly model is a structured dataset. The assembly is determined completely and unequivocally with the dataset.

"Specification" component of a model is supplemented with an electronic product structure. The later is an electronic design document which data content reflects the product structure in a tree graph form. A top node of the graph corresponds to the product. The intermediate nodes correspond to the product assemblies, their complexes and/or kits. The bottom nodes of the graph correspond to the product parts and, finally, the graph edges determine connections of compound parts hierarchy.

Assembly structure made in CADDS5/Optegra environment

Assembly structure made in CADDS5 [2] environment is presented as a graph (not containing reference assemblies).

Designation of the graph vertex (root component) corresponds to the designation of the assembly. The components corresponding to the assembly parts are placed at the graph nodes. Depending on the simulation requirement development of assembly unit structure of two kinds is possible . These structures may be divided into single-level (Fig.1) and multilevel (Fig.2) according to subordination.

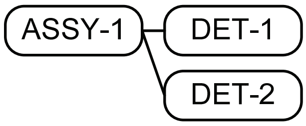

Fig.1. Single-level assembly

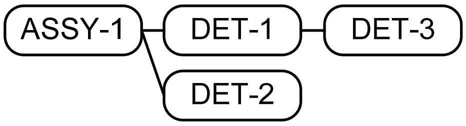

Fig. 2. Multilevel assembly

Multilevel assembly use provides possibility to manipulate mutual allocation of parts in space.

The whole information of part (component) mutual orientation, as well as their interconnection and their quantity is stored in the same information object. This object is an assembly. Aforementioned is independent from the kind of component hierarchy in the assembly. An assembly (CADDS/CAMU data type) is an electronic object describing both electronic mockup and electronic structure. Information storage, as well as its change, is carried out by means of a single file editing. The only part models are external (i.e. these models are independent from the point of view of structure change).

Data management provided with the Optegra system is implemented at information object level (i.e. at file level). Assembly structure is presented as a single information object describing each of incoming components (except reference assemblies). It means that a part is not an object, which affects to the product structure. The assembly determines the last one even if no part is included into the assembly.

Assembly structure made in Windchill environment

Windchill system [3] is based upon management of each object describing a product. Root component of assembly and part components are joined by links (Fig.3).

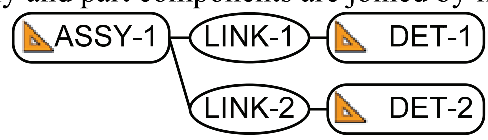

Fig.3. CAD data structure presented in Windchill system

Windchill graph edge is evolved into a single object unlike the Optegra system. From the point of view of the user, the edge, as an object, is invisible. But it is the edge that determines object interconnection.

CAD data are presented as EPMDocument (Fig.4). Variety of CAD data types does not lead to the Windchill data types variety development. CAD data type became one of the EPMDocument attributes. This means

CAMU = EPMDocument (type = assembly)

Part = EPMDocument (type = part)

The structure developed within the Windchill system corresponding to that shown in Fig.3, means availability of EPMDocuments ASSY-1

DET-1

DET-2

And edges as well. The latter ones are described with EPMMemberLink objects:

LINK-1 (ASSY-1 == DET-1)

LINK-2 (ASSY-1 == DET-2)

Neither EPMDocument assignments, nor their names indicate availability of any interconnection between the objects. The interconnection availability may be determined by means of "parent" and "child" attributes of EPMMemberLink-objects describing the edges.

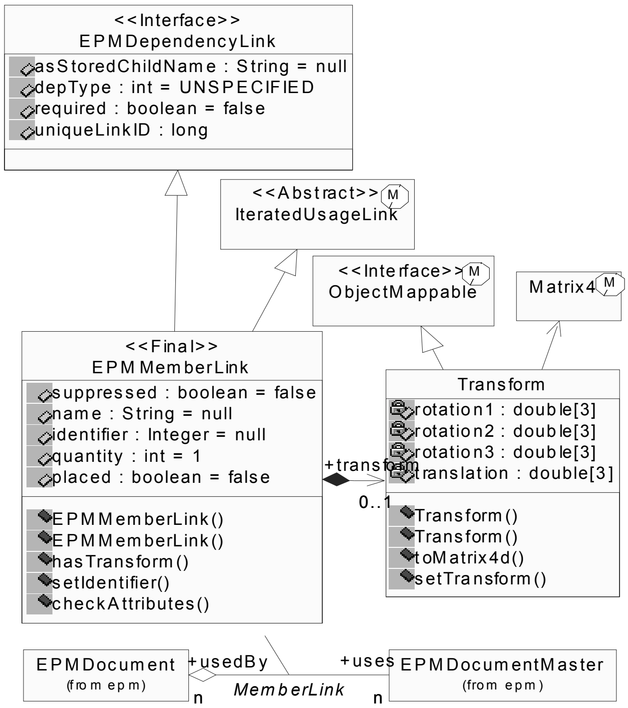

Fig.4. UML-notation of EPMDocument link model

Mapping of various system structures

A part is an indivisible element of a structure. Part's development with CAD-system, as well as its storage within PDM-system, and information transfer to PLM-system, do not require any manipulations from the point of view of the structure developer.

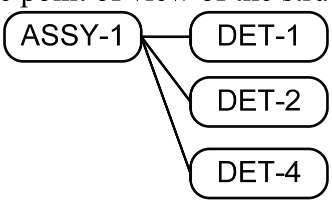

Fig.5. A single-level assembly structure transferred to the Windchill system

A single-level structure (Fig.5) transfer will result in creation of the following objects:

ASSY-1

DET-1

DET-2

DET-4

LINK-1 (ASSY-1 == DET-1)

LINK-2 (ASSY-1 == DET-2)

LINK-3 (ASSY-1 == DET-4)

When the structure graph is displayed, the system indicates a tree, which properties and a view comply with Fig.5. We can see the result for this tree in Fig.6

If we have a source multilevel structure (Fig.7) with addition component, the result of transformation to the Windchill system of this structure will look like Fig.8.

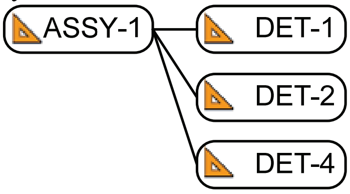

Fig.6. The Windchill system assembly graph according to a single-level assembly structure

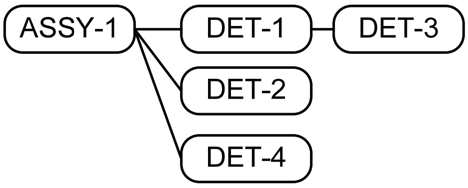

Fig.7. Assembly multilevel structure transferred to the Windchill system

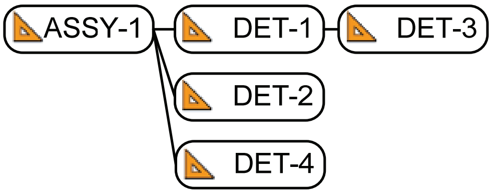

Fig.8. Windchill system assembly graph according to the multilevel assembly structure

There are no differences in the graph structure. And this is quite right. The mistake is in assembly structures, which will be developed in the Windchill system later. The structures will include the objects previously developed. This means that two EPMDocuments («DET-1» and «DET-3») are already interconnected. The interconnection is determined for the project in whole, not for any assembly.

The subsequent publication of the assembly type (Fig.9) into the Windchill system will yield other results.

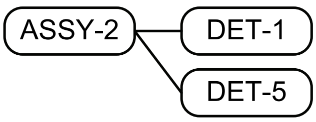

Fig.9. Assembly structure which includes an existing part

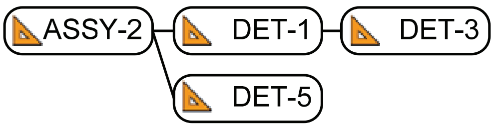

Fig.10. Assembly structure in the Windchill system, containing already existing part

Such representation of the assembly structure (Fig.10) is incorrect. Because in the Windchill environment two object DET-1 and DET3 are linked forever. Development of algorithms of assembly adequate representation is required.

Transformation algorithm

Aforementioned research results have lead to the structure transformation necessity.

The algorithm (Fig.11) given below provides treatment of those assembly structures, which have been developed in CADDS5/Optegra environment [4] previously (i.e. before the structures were placed in Windchill environment).

Series of subroutines have been developed on the basis of the given algorithm. The subroutines allow processing of such kind transformations at publication of CADDS5/Optgera data in the Windchill environment.

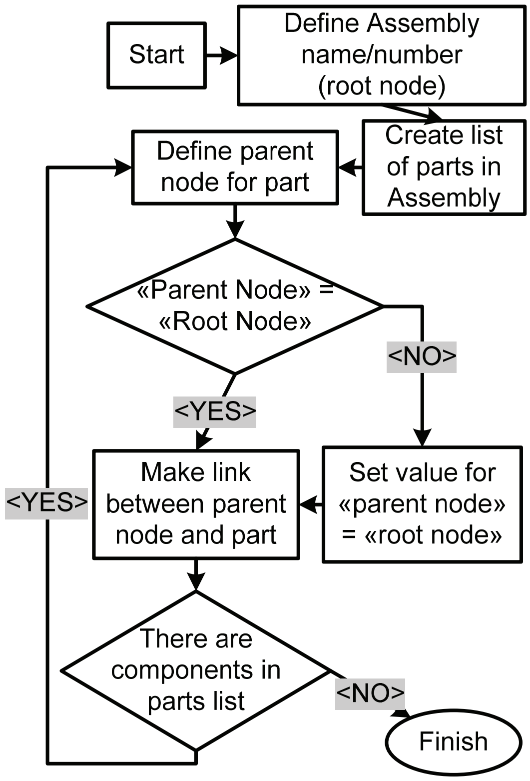

Fig.11 Algorithm of assembly structure treatment

Using this algorithm, the structure shown in Fig.7 will look like the assembly shown in Fig.12.

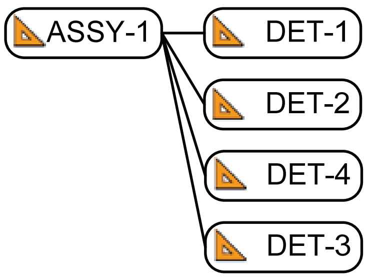

Fig.12. The Windchill system assembly graph produced with the transformation algorithm

The assembly parts membership is preserved by application of the algorithm.

Conclusion

Necessity of state-of-the-art PLM system implementation is a result of enlargement of the EPD information objects' list. Data developed with CAD- and maintained with PDM-systems, are integrated to the PLM - system. Methods of assembly structure representation in the various systems have been obtained during integrating works. Recommendations and algorithms of assembly structure transformation have been developed for data publication. This work has permitted to carry out assembly structure integration in the Windchill system.

References

1. А.Левин, Е.Судов. CALS – сопровождение жизненного цикла. Журнал «Открытые Системы» №3, 2001.
2. CADDS 5 Release 12 Documentation. 13 Apr 2001
3. Windchill®6.2 User's Guide. 2 April 2001
4. Optegra Release 6 Documentation. 11 Apr 2001.

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VISUALIZATION SYSTEM OF ENTERPRISE LEVEL

Today realization of a bright colorful image of high contrast, good saturation, and pretty high clearness on a large flat screen is not a big problem. Certainly, first of all, the multimedia projectors are used to resolve this task. In connection with this, it is necessary to take into account persistent growth of need of simultaneous information review. Qualitative leap of technical characteristics as well as projecting equipment cost, that took place last two-three years, had played sufficient role in this circumstance. Up-to-date display facilities are installed in conference halls, auditoriums, waiting rooms of airports and railroad terminals, movie theatres etc. It is necessary to emphasize a field of application where observer's presence effect should be provided as much as possible, i.e. where an observer should feel himself as a participant of events taking place on screen. To carry out this goal a large screen is required. Large on-screen image coincides with human realistic perception of outward things. To make this effect deeper, an image should be a stereoscopic one. The systems with such information visualization requirements are, first of all, simulators of various kinds. These are naval, aerospace, automobile, tank simulators etc. Moreover, project complexes of such kind are installed in stereoscopic movie theatres, control towers, controller offices, virtual reality rooms. This list is much broader undoubtedly. Developer strives for maximum utilization of CAD facilities during formation of science intensive product, resolving different tasks of complete electronic project.

CAD data visualization on large screen in stereoscopic image mode is a very interesting task. This is a high priority task for automobile and aerospace industry. A process of coordination of system components and assemblies should be done with a high precision. This is especially monumental task because of large amount of objects and space restricted during project elaboration under CAD system job's specificity of each participant should be taken into account during process of designing. Developers of project's different directions have to evaluate together mutual coordination of their components in real scale 3D view on large screen. Use of real scale stereoscopic image on large screen at early stages of project allows getting an idea of design of units and assemblies. Realistic visualization provides simplified designing of interior, cockpit, ergonomics. Production engineers get a possibility of technological processes development and product assembly using software anthropomorphic dummies. Savings on costs (in case of rejection of "hard" anthropomorphic dummy making), reduction of time of product development (because of concurrent job of all project participants) allow getting high economic effect based on embedding of visualization system with a large screen.

Analysis of systems employed at aircraft centers.

World leading automobile and aircraft companies extensively use multi-channel visualization systems. For instance, visualization systems are used by Boeing, Embraer and Beriev TASTC.

Visualization center of Boeing (Figure 1). The center was installed and equipped by Panoram Technologies in partnership with Hewlett-Packard. Boeing staff calls the center

"The theatre of virtual world". This concurrent development center is an environment, where participants of project groups can "to see more, to understand better and to decide quicker".

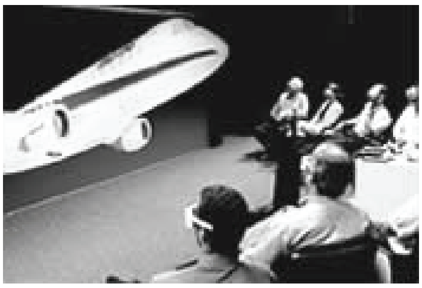
Developers, working on C-130 aircraft in accordance to Aircraft Update Program, as never before have possibility of cooperation in "The theatre of virtual world". This possibility is provided with Panoram's software and powerful Hewlett-Packard sv6 image generator. In addition to real time project consideration and adjustment, designers are able actually to see and compare previous configurations of whole aircraft "without return to the drawing-board". They have possibilities to determine update directions and to reach decisions together as well.

Fig. 1: Visualization center of Boeing.

3,5 million pixels of Panoram's PanoWall™ (3 x 9 meters) are projected from behind the screen. In the middle of the Wall there is a device especially developed for installation in the lecture room. Four workstations adjust screen sides, and projector control unit is placed behind the screen. PanoWall™ and Video Panoram® is a proprietary technology, which provides all staff situated in the auditorium with a possibility to hear each other at the time of their working.

Hewlett-Packard sv6 is a combination of high quality photorealistic image and scalable performance. It provides viewing of complete real time digital mockups by designers and engineers. As a first commercially accessible product, Hewlett-Packard sv6 was presented on the market on August 2001. Scalable architecture of HP sv6 visualization is elaborated to satisfy customer needs of large and complex data interactive visualization.

Visualization center of Embraer (Figure 2). The center supposes utilization of 3D CAD environment, because of Dassault System's CATIA, DMU as well as PTC's Division Reality allow to lighten collaboration of different groups of designers. Such collaboration's aim is to evaluate digital project and virtual prototypes beginning at the early stages of design. Use of WorkWall provides customers with natural understanding of space allocation, design, and configuration variants of both aircraft interior and aircraft entirely. WorkWall is used by Embraer as a part of program intended for acceleration of product release to the market and time reduction of product redesign.



Visualization system is complete RealityCenter™, based on SGI™ Onyx2™ In-finiteReality®. Display system consists of three high-resolution projectors providing color edge dithering. Visualization center is equipped with a headmounted display, movement control system and Fakespace NavPod™ system. Last one is a navigator for combined use with WorkWall.

Fig. 2. Visualization center of Embraer.

WorkWall allows organize specialists' conferences providing stereoscopic large-scale or full view modes of project.

Visualization Center of Beriev's Taganrog Aeronautical Scientific Technical Complex (TASTC, Russian Federation) (Figure 3).

Complex for virtual mockup of Be-200 multistage amphibian jet was developed on demand of TASTC. This complex is intended for breadboard committee activity. Now, the committee is able to use high-precision aircraft mockup instead of expensive "hard" prototype. It is especially important during initial stage of aircraft design.

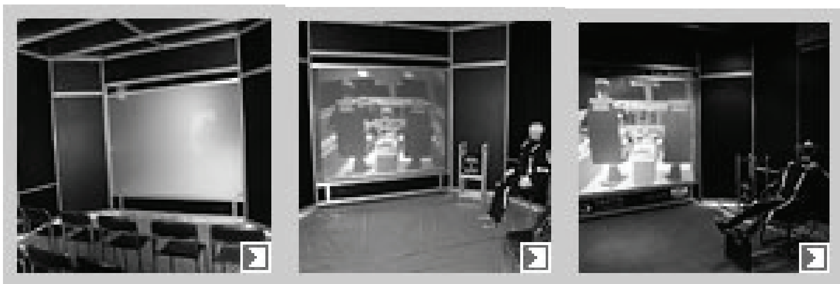


Fig. 3. Visualization center of Beriev TASTC.

The complex is a "dark room" which allows comfortable accommodation up to 10 persons. One wall of this "dark room" is a flat stereo screen of return projection. It has dimensions 2.5 meters width and 1.9 meters height. Two high clearness (1280x1024) projectors generate inactive stereoscopic image on the screen. Four-channel image generator, based on dual processor PC equipped with professional two-channel video adapters, is a core of the complex. Image generator is controlled by WindowsXP OS in Vega Prime software environment.

The virtual mockup is displayed on large shared screen in stereoscopic mode. Members of breadboard committee can observe aircraft cockpit in real scale. They can see avionics, gauge boards, switches, engine controls etc. Software system allows to observe virtual scene from any perspective, to see everything in a "virtual pilot" light.

Special working place of the pilot is stipulated for interactive collaboration of research pilot with equipment of virtual cockpit. Set of special sensors are attached to the pilot's body. Information of allocation of pilot's hands, feet and body is obtained in real time mode.

Gloves are dressed on pilot's hands. The gloves are equipped with sensors which allow visualizing movement of fingers. Vibration sensors, mounted both on each finger and palm, allow appreciating degree of hands approaching to surface of any virtual object, i.e. lever, switch, button etc. To see himself "inside" of a virtual scene, the pilot should to put a high clearness helmet system on his head. This allows seeing Be-200 cockpit interior, pilot's hands, feet, and body in stereoscopic mode. This display system is equipped with pilot head position's sensor of six degrees of freedom. By means of this complex the pilot can make coordinated movements inside of virtual scene right up to equipment control and making of virtual flight above 3D terrain model.

Collection of hardware-software facilities and mockup possibilities make the complex unique and still a single one in Russia. It is a powerful tool of real time complex visualization of engineering data.

Tasks being resolved by visualization system

To examine tasks of visualization system, let us choose typical kinds of works on aircraft design.

Large assembly design.

Use of traditional methods of visualization providing CAD work realization is limited by:

- difficulties of viewing and assembly manipulation; models are not adapted for visualization;
- workstation's hardware restriction of quantity of components;
- CAD-system's restriction of quantity of simultaneously loaded components;
- non-realistic presentation of arrangement.

Multi-channel system of visualization will allow:

- improving of productivity utilization of adapted models for visualization;
- realization of realistic presentation of arrangement (texture, lighting, reflection).

An example of utilization of visualization multi-channel system for review of large volume of data is presented on Figure 4.

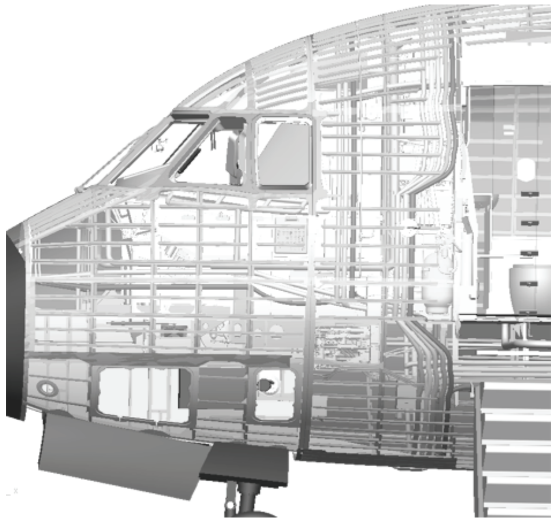


Fig. 4. Aircraft's fore body.

Let us consider, as an example, design of aircraft compartment of restricted volume, saturated with assemblies and aggregates. Using visualization, it provides:

- spatial composition's simplification by means of stereoscopic mode utilization;
- rejection of creation of a "hard" prototype;
- simplification of application of changes.

A typical example of elaborate design in limited space is presented on Figure 5.

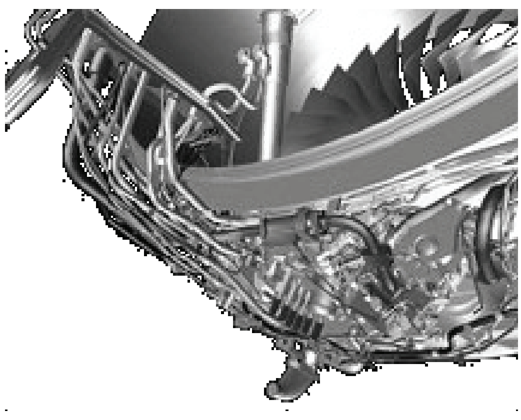


Fig. 5. Aircraft engine.

- Let us consider design of aircraft screw cockpit. Utilization of visualization multi-channel system allows:

- displaying of a realistic image in stereoscopic mode;
- use of textures, facsimiles and inscriptions;
- installing realistic lightning;
- use of special helmet and suit which set up presence effect;
- rejecting of creation of cockpit prototype;
- use of visualization multi-channel system allows to evaluate ergonomics of control arrangement and avionics by means of software dummy;
- easy change making and possibilities of several variants of cockpit building.

Crew cockpit (pilot's view) is presented on Figure 6

Fig. 6. Crew cockpit.

Multi-channel system of visualization allows:

- providing realistic image of a cabin in stereoscopic mode;
- placement of textile textures of upholstery or panels;
- resolving of color solution of a cabin;
- forming several solutions of the cabin and provide their fast visualization for customer's review.

Passenger cabin is presented on Figure 7.

Fig. 7. Interior of aircraft cabin.

To carry out development of aircraft maintenance procedures, multi-channel system of visualization allows:

- task solution of access to attended units;
- evaluating of zones of comfortable work and reach.

Visualization of aircraft maintenance by means of software dummy is presented on Figure 8.

Fig.8. Aircraft maintenance.

Primary intents of 3D object visualization are high quality, reality and velocity. Quality of visualization is determined by several constituent elements. These elements are display resolution, used models of lightning, filling of edges, antialiasing. Image reality is depended on quality of used texture. Moreover, such elements as shadows, reflections and glares of sources of light are important. The shadows provide another object's view (i.e. a view from source of light), so it is possible to obtain better presentation of positional relationship of objects and sources of light on the scene.

References

1. *Clodfelter Robert M., Nir Yoav.* Multi-Channel Display Systems for Data Interpretation and Command and Control. http://www.barco.com/projection_systems/downloads/Multi_Channel_Display_Systems.pdf.
2. *Klimenko S.V., Вигер, Брусенцев* Item Professional systems of a virtual reality on the basis of PC. http://www.nvworld.ru/docs/reality.html.
3. *Михайлюк М.V. C*omputer of the schedule in systems of visualization of training complexes. http://www.imvs.ru/imvs/libel/05/michailyuk_04.pdf.

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NEW TECHNOLOGIES OF VISUALIZATION.

Image generator is a soft hardware complex intended for pretreatment and preparation of an image as continuous videosignal, displaying analyzable data arrays. To resolve such tasks, the main arrays of data are presented as sets of geometrical models. Primary treatment of these models is carried out by software applications based on platform of image generator. Productivity of image generator determines interactivity and response time of system inquiries as well as user actions under processing of various data arrays. This parameter directly concerned with amount of processed data. Image generator productivity is determined by two main characteristics. First characteristic is image resolution. The second one - quantity of frames of defined volume processed by means of specified software application per second. The volume is evaluated by amount of primitive triangulated surfaces describing visualized set of geometric models in applied software format.

The following complexes may be used as image generators:

HP sv7 Visualization Center (Figure 1). sv7 provides functioning of PTC's DVMOCKUP applied software. This software is intended for project data visualization. Data formats required for visualization are obtained under project's data conversion by means of DVMOCKUP-converter and WindChill Graphics Server.

Fig. 1. HP sv7 Visualization Center.

Onix 3 Visualization Center (Figure 2). This visualization center supports PTC's DVMOCKUP and DMU Navigator applied software. For now, it is the only one platform certified for both of these software products. MIPS processors and OS IRIX are used for Onix 3.

Fig. 2. Onix 3 Visualization Center.

Graphic cluster (Figure 3). Soft hardware complex is intended for image generation. It is realized as several personal computers (nodes), which allow scaling productivity by means of add-on nodes connection. Main complex' realization are based on Linux OS.

Fig. 3. Graphic cluster.

Soft hardware complex of image generation based on HEWLETT-PACKARD XW8200 personal computer with XEON dual-processor equipped with a new nVidia FX3400 graphic adapter. For now, this one is the most powerful technique for applications of Catia V5 and DMU Navigator under Windows XP Professional. nVidia graphic adapter allows displaying application graphics by means of multi-channel display subsystem both in the mode of inactive stereo image and in traditional mode.

HP XW8200 provides functioning of Catia V5 and DMU Navigator applied software.

Fig. 4. HP XW8200.

Comparative values of software and approximate cost of different image generators are presented in Table 1.Table 1.

Image generator	HP sv7	SGI Onix 350	High-end PC
Operating System	HP-UX	IRIX	Win XP
Division MockUp	Yes	Yes	Yes
Division MockUp Very Large Data	Yes	Yes	Yes for Win 64bit
DMU Navigator V5	No	Yes	Yes
DMU Navigator Very Large Data	No	No	Yes for Win 64bit
Performance	Very	Midle	Very
Price ($)	> 250 000	> 200 000	> 10 000

Utilization of new (64-bit) processors, RAM-chips (DDR2), fast disk subsystem (SATA) and PCI-Express bus will allow to systems of such kind to compete with much more expensive visualization systems. Let's have a look on new display technologies used for graphic adapters of PCI-Express from nVidia and ATI developers.

Unified PCI-Express (PCI-E) specification assumes several standards of connectors which will substitute both desperately archaic PCI and AGP which has almost reached its technological possibilities limit. Such compatibility has become accessible because of design modularity of slot. Any PCI-E slot includes basic set of service pins and determined quantity of equal bidirectional buses with 256 Mbps baud rate. Amount of the buses is specified by the name of standard and allows defining total connector's capacity. 1x-standard has a single set of pins and corresponding capacity of 256 Mbps. Such baud rate satisfies any expansion card absolutely, except of video adapter. That is why basic connector is positioned as PCI substitution. 2x, 4x, 8x-standards are stipulated for servers, which may require faster interfaces. PCI-E 16x is provided for video adapters. It has 4096 Mbps (256x16) capacity i.e. eight time more than AGP 8x has. PCI-E 16x slot is "back-compatible" with other variants of PCI-E (1x,4x,8x). It allows setting up of any PCI-E cards. Thus, when a motherboard is equipped with integrated video, this slot may be used for setup of any other card. PCI-E slot supports a "hot" connection of devices also.

PCI-E standard is mostly noticed to video cards for today. This is no wonder, AGP-port characteristics are improper for the developers already. For instance, port's capacity is not enough to provide numeralization of HDTV-standard video, which gains users' popularity. That is why developers of graphics chips actively support embedding of PCI-E 16x: Intel, ATI and nVidia had already equipped their products based on PCI-E, when the new platform was announced.

PCI-E will substitute buses of PCI and AGP in desktop systems. Interfaces of memory and disk subsystem will not be changed. This process will be prolonged in mobile systems. Hooks, PC Card adapters and expansion cards as well as different devices integrated on motherboards (i.e. LAN-adapters, wireless adapters etc.) "will speak" new bus language. Being used in server equipment, PCI-E standard intrudes into disk subsystem. It will be able to serve RAID controllers.

In case of need, cards may be equipped with auxiliary pin set to provide such possibilities as either improved synchronization (differential coding of synchronization pulses) or recognition of card installed during "hot" interconnection. Special line is designed to inform about power voltage stability. This line provides correct functioning of the system during transition from "sleeping" to working mode. One more line is used to initiate "sleeping" device. There are pins reserved for SMBus (System Management Bus), i.e. for conventional bus of expansion cards control.

Developers suggest utilization of two technologies - SLI (Scalable Link Interface) from nVidia Co. and CrossFire from AMD to improve image generator capacity. The technologies use PCI-E interface and two graphics adapters. Let's have a look at these technologies.

Each technology is based upon specialized chipset of system logic, providing allocation of two high-rate PCI-E x16 slots. nForce 4 SLI chipset is the one used in nVidia production, and Radeon Xpress 200 CrossFire Edition – in AMD. Each competitors produce logic sets both for Intel and for AMD processors.

Principle of set working is simple: bus' capacity, which is wittingly redundant, is halved between two cards. In other words, each card works according PCI-E x8 protocol. Certainly, chipset can work with a single video adapter also. However, most probably, the adapter will use the same PCI-E x8 bus. The point is that two physical PCI-E x16 slots will be set on the motherboards (as a preliminary announced) but the slots will be connected electrically in accordance of PCI-E scheme. The PCI-E x8 protocol, potentially, may become a bottle-neck, which stipulates for system capacity limitation under high loading of the bus.

Essentially, similarities of SLI and CrossFire are over and the great differences are begun. At that time both of SLI video adapters must be exclusively identical (right up to cards' wire routing as well as BIOS version), CrossFire different adapters may be joined into one team. Evidently, ATI's approach is much more attractive. For instance, a customer may buy one video adapter and, if required later, one more. But for all that he (or she) even does not think: are these adapters identical or not?

Unique requirement for CrossFire adapters is support of this technology by one of the adapters. The second one may be of any kind. The point is that, the adapter with CrossFire Edition mark is equipped with additional chip (so called "mixing engine" which combines video signals from two graphics accelerators).

Finally, a different method of physical combining of two adapters is used in CrossFire system. SLI technology assumes small printed circuit card utilization. The card is mounted on upper edges of two video adapters. CrossFire technology assumes external connection by means of special cable. Such CrossFire method of connection, obviously, provides a possibility to work with adapters none meant of pair connection initially.

One connector of special cable is set to DVI-port of video adapter non-supporting CrossFire, and another – to DMS-59 port of CrossFire Edition adapter. DMS-59 port has the same dimension as DVI-port. However, DMS-59 port has more pins. Up to five monitors may be connected to the bundle: CrossFire platform supports the ATI company SurroundView technology, which provide displaying of a panoramic picture on several screens.

One more principal difference between SLI and CrossFire technologies consists in image rendering mode, which is carried out by two graphics processors.

Three various modes for SLI are presented by nVidia. They are:

1. Compatibility Mode.
2. Alternate Frame Rendering, AFR.
3. Split Frame Rendering.

Just one of two adapters works in Compatibility Mode. There is no additional productivity. In AFR mode one of two adapters carry out all odd frames and the second one – all even (i.e. rendering is splitted between two adapters by frames). In SFR mode a display is halved. First adapter displays upper part of a picture, and the second – a lower one. Because of dynamic balancing of loading, the last one is allocated evenly between two adapters by the driver.

The adapters integrated according to CrossFire technology can work in SFR mode also. However, several more rendering methods are used.

Because of CrossFire possibility to connect various video adapters of different productivity, more powerful video card have to work with a rate not exceeding the rate of less powerful one. Otherwise, image generating would not be realized. ATI's engineers had resolved this problem with a method of dynamic allocation of loading. Here the screen is divided into parts of different size, not equal ones. More powerful adapter processes a bigger part of screen and the less powerful - a lesser one. In such way the ideal synchronization is provided. Each of the adapters carries a load respective to the adapter possibilities. Besides such method (called Scissor), Crossfire supposes three more rendering methods. They are:

- Super Tiling. The method based upon screen division into great number of squares. Here each adapter processes a half of these squares;
- Alternate frame rendering. This time, a first adapter is responsible for rendering of one frame and the second one – for the following;
- So called Super AA ("super smoothing") which provides full-screen smoothing.

In general, Super AA method is enough unusual: it is intended to provide image quality, while the other rendering methods are designed to provide maximum productivity. Sometimes a customer faces a challenge when productivity is not increased in spite of change of a video adapter with more powerful one. Such situation is distinctive feature for computer games because each game has its own absolute limit. In such case, adapter's resources are redistributed. They are used to increase image quality. Naturally, optimum balance between productivity and image quality may be reached using driver's options.

In accordance with ATI's rating, CrossFire technology provides greater productivity than competitive SLI from nVidia. As evidence, results of comparative test of still the same Radeon X850 XT bundle and two GeForce 6800 Ultra video adapters are presented. The same workbench plus Asus A8N-SLI Deluxe motherboard were used for testing. During synthetic test of 3DMark 2005 CrossFire cards have won with ten percent overbalance. Playing Splinter Cell Chaos Theory, ATI bundle had results about 35 percent higher. Playing Need For Speed: Underground 2 – more than 60 percent. Naturally, the most attractive results were presented by ATI. No doubts, playing Doom 3 and other games based upon OpenGL, a benefit would be on the side of nVidia adapters. Nevertheless, the results are quite indicative because adapters of each bundle are, mainly, from a list of up-to-date and most powerful video accelerators.

Support of too little number of games and other applications (including four synthetic tests) is an obvious weakness of SLI. The point is that to increase SLI productivity, the drivers should support corresponding applications. nVidia's programmers just select most profitable modes and optimize their drivers for such modes.

Well thought-out rendering system is the base of CrossFire profit. CrossFire has no problem working with any existing games. If a game has not profile of frame interleaving mode, video adapters are switched to Scissor and SuperTiling modes. This allows accelerate practically any application equipped with DirectX and OpenGL interfaces.

Summarizing it is required to recognize that ATI have presented more flexible and thought-out technology of two game video adapters combining in a single system unit.

Thus, for today, technologies used within PC architecture allow to develop visualization systems either comparable or exceeding UNIX-based system and PC-platform price-quality ratio is preferable.

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STUDY OF THERMAL EFFECTS IN METALLIC RESONATOR CVG

Heat-transfer properties of the metallic resonator CVG are studied in this work. CVG thermal errors effective correction by using resonator natural frequency instead of temperature measurement is shown. Test results are presented.

Introduction

In comparison to micromechanical Coriolis vibratory gyroscopes (CVG) [1], their analogies using metallic resonators, as a rule, are able to provide higher accuracy [2].

Metallic resonators basic disadvantage is low Q-factor, due to gluing piezoelectrods on the vibrating area (rim) of a resonator. The attempts to increase cylindrical resonator Q-factor have led to excitation, control and pick-off resonator modes from the bottom of the cylinder. The latter has resulted in non standard resonator design, that maximizes Q-factor for the account of removing mass surpluses from resonator's working area. In this case, modes controllability is maintained at a good level. As a result resonator Q-factor increases 2-3 times and for resonator diameters 17-22 mm reachs 5000 – 6000 on open air.

Despite the fact that there are reserves to substantially enhance CVG sensitivity and reduce noise by increasing resonator diameter (30 mm, 50 mm and more), by resonator vacuumization and also by switching off the Coriolis mode feedback damping, CVG accuracy is restricted by higher metallic resonator sensitivity to temperature. Therefore, metallic resonator CVG temperature drift correction is the most important problem to reach high accuracy. This is important in gyrocompass application, where low noise and high sensitivity can be reached by CVG.

Theoretical and experimental investigation of different diameter metallic cylindrical resonator heat-transfer properties are presented in this work. Experimentally proved the possibility to use metallic resonator CVG in precise angle measurement systems, provided that temperature correction method is applied. It was showed that as a temperature sensor resonator natural frequency can be used. Test results are given. Possibility to use metallic resonator CVG in self alignment stapdown INS is discussed.

Heat-transfer properties of the metallic resonator

Dependence between relative change of resonator forced oscillation amplitude $\delta U/U_o$, forced and natural ω_o frequencies mismatch $\Delta\omega$, and coefficient of losses ε, due to resonator damping is approximately defined by the expression:

$$\frac{\delta U}{U_o} = \frac{\Delta\omega}{\omega_0}\left(1 + \frac{\Delta\omega}{\omega_0 \varepsilon^2}\right) \tag{1}$$

The frequency mismatch and coefficient of losses changes due to temperature change cause CVG output signal drift. Cylindrical resonator natural frequency is defined by geometrical dimension (radius - R, and wall thickness - h) and elastic material coefficients: Young modulus - E, Poison coefficient - ν, and material density - ρ.

$$\omega_i = l(i)\frac{h}{R^2}\sqrt{\frac{E}{(1+\nu)\rho}} \quad ; \quad l(i) = \frac{i(i^2-1)}{\sqrt{(i^2+1)}} \quad . \tag{2}$$

Here *l(i)* is a coefficient, depending on oscillation mode number *i*.

Proceeding from (2), the following expression for cylindrical resonator frequency temperature coefficient (FTC), can be written:

$$T_\omega = h\frac{\partial h}{\partial T} - 2R\frac{\partial R}{\partial T} + \frac{1}{2E}\frac{\partial E}{\partial T} - \frac{1}{2\rho}\frac{d\rho}{dT} + \frac{1}{2(1+\nu)}\frac{\partial \nu}{\partial T} \quad , \tag{3}$$

where

$T_\omega = \frac{d\omega_i}{\omega_i dT}$ is FTC ; $T_a = h\frac{\partial h}{\partial T} - 2R\frac{\partial R}{\partial T}$ - linear dimension temperature coefficient;

$T_\rho = \frac{1}{2\rho}\frac{\partial \rho}{\partial T}$ - material density temperature coefficient;

$T_e = \frac{1}{2E}\frac{\partial E}{\partial T}$ - material elasticity temperature coefficient.

Material elasticity temperature coefficient T_e is the basic contribution to natural frequency dependence on temperature.

Fig.1 shows typical dependence of anti-nodal signal amplitude and natural frequency

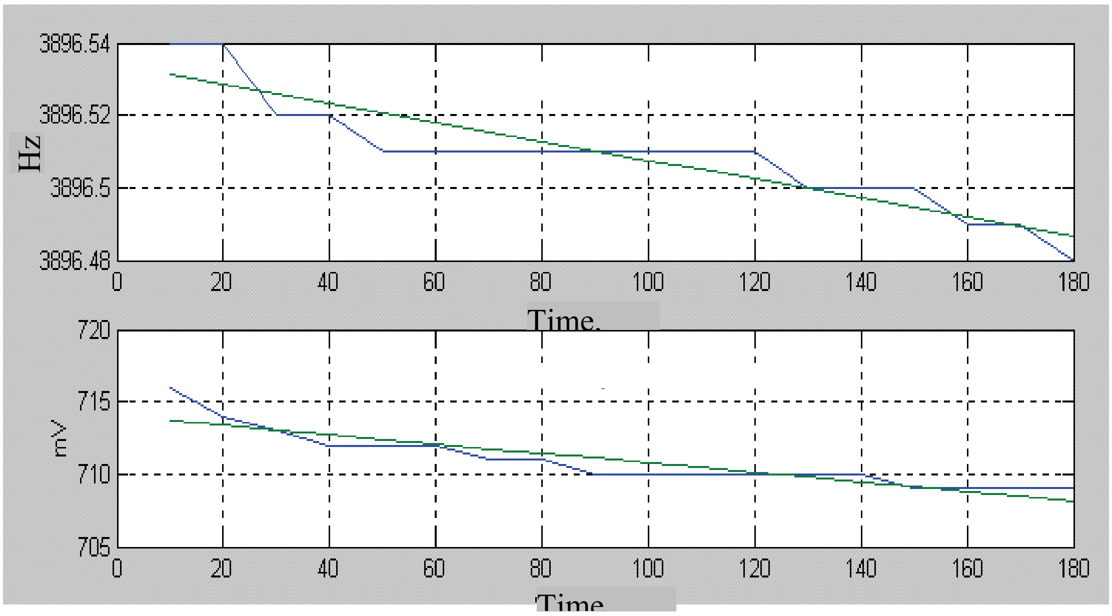

Fig.1. Anti-nodal amplitude and resonator natural frequency

on time.

The basic mechanism to install thermodynamic equilibrium in metallic resonator is design elements thermal conductivity and air for nonevacuated resonator, and for evacuated one – design elements only. The scattered resonator energy is expressed as follows:

$$\Delta E = \frac{2I_0}{k_t}\delta U \tag{4}$$

where I_o - consumption current in resonator excitation circuit, k_t – heat-transfer coefficient, characterizing a part of full power transferred into heat.

Table 1 shows the heat-transfer parameter values for resonator of different diameters obtained by experimental data.

Table 1

Resonator diameter, mm	Frequency, *Hz*	T_ω*10^4 *1/ºC*	K_t, *μW/ºC*	τ, *hour*
50	1188	1.68	11.2	18
25	3906	1.9	9.86	21
21	4535	2.3	8.8	20

In this table τ denotes thermodynamic equilibrium settling time. It is defined as follows:

$$\tau = \frac{mC_p}{k_t} \quad , \tag{5}$$

where C_p – specific heat capacity, m – mass of the resonator.

The resonator temperature is increased by 0.12°C, and natural frequency has drifted by ~ 0.06 Hz, for 3 hours, when CVG electronics were apart from the resonator. However, for the CVG design depicted on fig.2, when electronics are near the resonator, natural frequency, has changed by ~ 3 Hz for the same time interval [3]. Thus the basic thermal source in the CVG is electronic units located around the resonator.

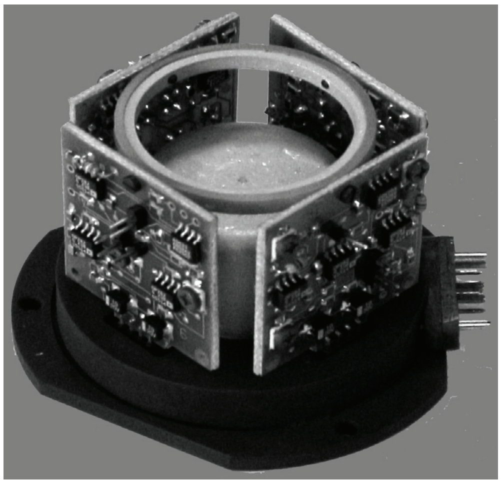

Fig. 2. CVG with electronics.

Temperature drift correction

Metallic resonator CVG can propose high accuracy characteristics under implementation of temperature drift correction. Fig. 3 shows angle measurement errors for 24-faces prism (two faces were shut to indicate full revolution during measurements) with the use of drift correction algorithms developed in laser goniometry [4]. As can be seen from fig.3, measurement error of angles (15o±5'') is sufficiently small for low cost and small-size gyro with resonator diameter 25 mm and CVG total size ∅50 mm, height 50мм. The accuracy can be substantially increased for the account of switching off Coriolis mode feedback damping. Doing so, the CVG bandwidth decreases (this does not influence goniometer accuracy because of constant angle rate), but it will result in noise

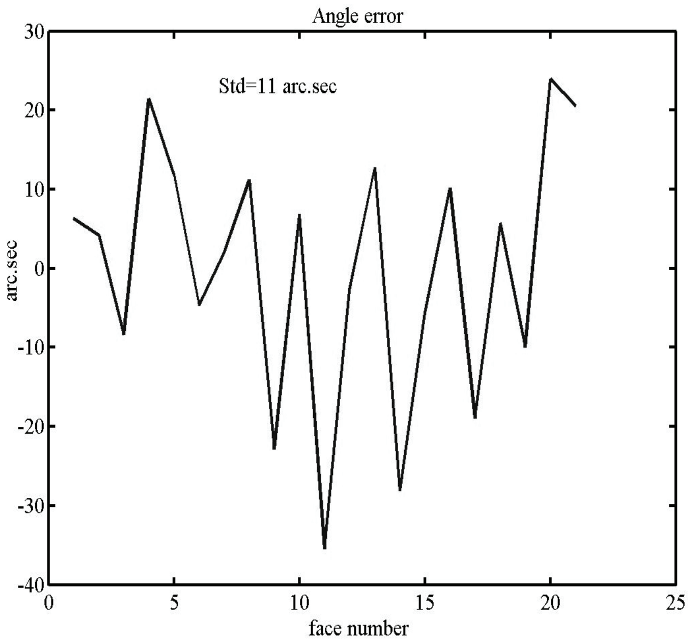

Рис.3.Prism angle measurement errors using goniometer method.

reduction and sensitivity enhancement. This property of CVG can effectively be used in navigation devices, namely, in initial alignment in azimuth of the strapdown INS. In this case, in initial alignment mode Coriolis wave feedback damping is switched off, but it is switched on when motion was started.

Fig..4 shows CVG scale factor temperature correction results using resonator natural frequency measurement instead of temperature. Corection error in the temperature range of T=[-15;+40]^{o}C is 0.2% for non evacuated resonator. Frequency (temperature) correction algorithm is:

$$K_{квг}=25.90 - 0.412(f-3200) + 0.202(f-3200)^2 - 0.00031(f-3200)^3 \text{ mV/(deg/s)} \qquad (6)$$

Thus, metallic resonator CVG parameters temperature correction enables us to use it in precision angle measurement systems.

Conclusion

The basic mechanism of thermodynamic equilibrium in metallic resonator is thermal conductivity of its design elements. Frequency temperature coefficient for the manufactured sensors is changed in the range of T_ω=1.5…2.×10^{-4} 1/^{o}C.. If necessary, it can be reduced some times by choosing special materials. Since heat-transfer coefficient was appeared to be sufficiently small, k_t=8…12 μW/°C, the main heat source in CVG are electronic units. It means that electronic units should be located as far as possible from the resonator. When designing IMU it is necessary to pack orthogonal triad from resonators only, isolated electronic units in another package.

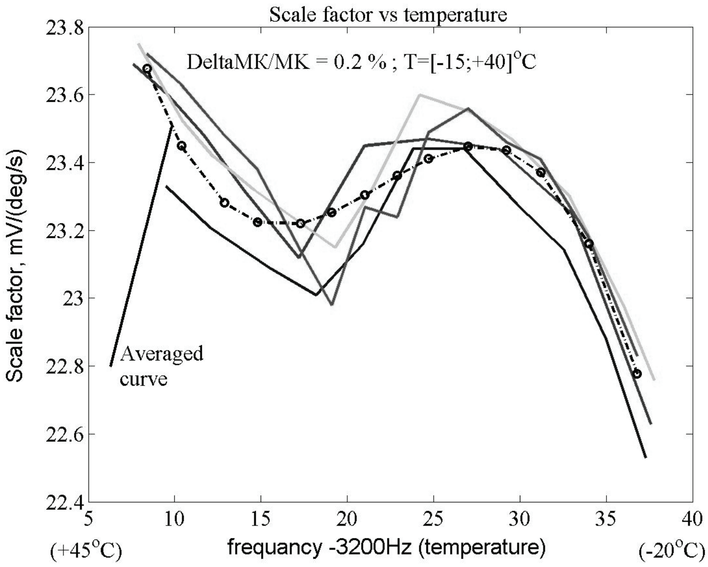

Рис.4.CVG scale factor vs temperature..

Unique CVG properties enable us to use it in precision angle measurement systems provided that temperature error is corrected. In temperature correction it is better to use resonator natural frequency signal instead of temperature sensor one.

References:

1. *Gaiber A., Auber J., Frech J., and others "Evaluation of DAVED – Microgyros Realised with a new 50µm SOI – Based Technology". – Symposium Gyrotechnology, Stuttgart, Germany, 2003, pp.4.0-4.7*
2. *Jeanroy A., Featonby P., Caron J.M. Low-cost Miniature and Accurate IMU with Vibrating Sensor for Tactical Applications.//Symposium Gyro Technology, Stuttgart, 2003.*
3. *Chikovani V.V., Yatsenko Yu. A., Kovalenko V. A. "Test results for the first batch of Coriolis vibratory gyros and analysis of their performance". – Gyroscopy and Navigation. – 2003.#2. pp.32-38.*
4. *Laser measurement systems.- D.P.Lukianov ed., Radio and Sviaz , 1981, (in Russian).*

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MOTION CONTROL APPLIED TO NONMINIMUM PHASE SYSTEMS: A GENERALIZATION

This paper deals with a problem of controlling discrete-time nonminimum phase motion systems in the presence of noises with no parameter uncertainties. The approaches advanced in the previous papers of authors are generalized and extended to the case where these systems contain a pure time delay and may not be controllable whereas the desired motion trajectory is unknown ahead. A controller choice methodology for perfect performance of such system is presented.

Introduction

The problem of controlling a system so that its output follows a given path is referred to as the trajectory tracking problem. This problem is very important for many practical applications of tracking control systems which belong to a class of a motion control system [1]. In tracking control, the object must be moved along the desired trajectory so that transient path error must be minimized. Moreover, the accuracy requirement must be often maintained at high motion speed. Again, this requirement must be satisfied in the presence of external disturbances (noises).

General approaches to achieving accurate high speed tracking capabilities are based on employing feedforward techniques in conjunction with a feedback design. With knowledge of the system dynamics a feedforward scheme can anticipate the effect of the closed-loop dynamics and adjust the reference trajectory accordingly [1, 2]. Such an anticipation amounts to certain dynamics inversion. However, in order to make the best of the feedforward control, the system transfer function needs to be stably invertible. Therefore, these approaches are not suitable directly if the system to be controlled [s nonminimum phase. Nevertheless, most continuous-time transfer functions often tend to exhibit the discrete-time zeros outside the stability domain [3]. In fact, the continuous-time system having relative degree greater than two with the zero-order-holder always yields unstable zeros if sampling rates are fast enough [3, 4]. The inherent difficulties of the precision tracking control of such systems is how to avoid the system's instability and to achieve a small tracking error simultaneously.

To overcome these difficulties, an approach using the so-called two-sided Z-transform technique was proposed in [5]. Similar basic technique has been employed in [1] to design a feedforward controller for controlling nonminimum phase systems. The main feature of an approach [1, 5] is that a future reference signal sequence defined by a desirable motion trajectory of the system must be available to determine the feedforward controller output. Again, the implementation of this approach is possible when the system parameters are exactly known. Although the method given in the paper above is approximate, the approximation error can be made arbitrarily small and this fact is its advantage. Another method to derive the feedforward control law for the motion control of the nonminimum phase systems in the presence of parametric uncertainty has been proposed in [6]. In contrast to [1, 5] dealing with no noise, the paper [2] considers the case where noises are present. Recently, the approach of [2] has been utilized in work [7]. The closed-loop control system consisting of nonminimum phase plants with a time delay but without any feedforward circuit is studied in [8, sect. 6.2.4] for the case where these plants may be uncontrollable.

The aim of this paper is to generalize and extend the approaches of [5, 7, 8] to the case when the desired trajectory of tracking system remain unknown ahead. The main effort is focused on establishing the accuracy index of this system.

Problem Statement

It is assumed that the process to be controlled is a continuous-time, linear, time-invariant plant, whose transfer function is

$$W_0(s) = \frac{k}{sP(s)} e^{-s\tau} \quad (P(0) \neq 0), \tag{1}$$

where k is its gain and $P(s)$ is stable polynomial of some degree $N \geq 2$ with respect to the Laplace operator s and τ represents a pure delay time. Then the transfer function of the discrete-time system having a sampling period T_0 and containing this system together with the so-called zero-order-holder provided that $\tau \geq T_0$ is described by

$$W_0(q^{-1}) = q^{-d} \frac{B(q^{-1})}{(1-q^{-1})A(q^{-1})} \tag{2}$$

with some integer $d \geq 1$ representing the number of pure delay instants and the polynomials

$$A(q^{-1}) = 1 + a_1 q^{-1} + \ldots + a_N q^{-N}, \tag{3}$$

$$B(q^{-1}) = b_1 q^{-1} + \ldots + b_{N-1} q^{-N-1} \quad (b_1 \neq 0) \tag{4}$$

in which q^{-1} denotes the unit delay operator. The coefficients of $A(q^{-1})$ and $B(q^{-1})$ in (3) and (4) and the number d are assumed to be known.

Taking into account (2), let us suppose that the equation of our discrete-time system has the form

$$(1-q^{-1})A(q^{-1})y_t = q^{-d} B(q^{-1})u_t + v_t, \tag{5}$$

where y_t, u_t, v_t are the measurable output, control and the noise, respectively, and t is the time instant $(t = 0, 1, 2, \ldots)$.

Without loss of generality we make the standard assumption that v_t is upper bounded, i.e.,

$$|v_t| \leq \varepsilon < \infty. \tag{6}$$

Since $1 + \deg P(s) > 2$ (due to the fact that $N \geq 2$), the fractional part $k / sP(s)$ of $W_0(s)$ in (1) and the transfer function $W_{\text{h}}(s) = (1 - e^{-sT_0})/s$ of the zero-order-holder yield the unstable zeros of $B(q^{-1})$ in (2) if the sampling period T_0 is sufficiently small. Thereby, $B(q^{-1})$ may be represented by the product

$$B(q^{-1}) = B^{+}(q^{-1}) B^{-}(q^{-1}), \tag{7}$$

defining $B^{+}(q^{-1})$ as the polynomial which has only the roots inside the unit circle (strictly stable polynomial) whereas $B^{-}(q^{-1})$ has the all roots both outside the unit circle and on its bound. (Note that the condition

$$B_1 \neq 0 \tag{8}$$

is always satisfied here.) Thus, further we deal with possibly nonminimum phase $W_0(q^{-1})$ which may also be uncontrollable, in general, provided that $T_0 \to 0$ and assuming that $B^{+}(q^{-1})$ and $A(q^{-1})$ may have, in principle, common roots ($B^{-}(q^{-1})$ and $A(q^{-1})$ are always coprime because of the stability of $A(q^{-1})$ caused by the stable $P(s)$ in (1)).

Denote by y_t^* the set-point, i.e., the desirable value of the output y_t at the time instant t. We suppose that $\{y_t^*\}$ is the sequence generated as

$$\nabla y_t^* = M + s_t^*, \tag{9}$$

where

$$\nabla y_t^* \overset{Д}{=} \nabla y_t^* - y_{t-1}^*, \tag{10}$$

M is an unknown constant and s_t^* satisfies the difference equation

$$C(q^{-1})s_t^* = D(q^{-1})\xi_t, \tag{11}$$

in which

$$C(q^{-1}) = 1 + c_1 q^{-1} + \ldots + c_n q^{-n},$$
$$D(q^{-1}) = 1 + d_1 q^{-1} + \ldots + d_m q^{-m}$$

and ξ_t is an upper bounded variable with zero mean given by

$$|\xi_t| \leq \varepsilon_{\xi}. \tag{12}$$

It is assumed that the polynomial $C(q^{-1})$ is stable to ensure the boundedness of $\{\nabla y_t^*\}$ which is measurable (in contrast to $\{y_t\}$). Again, the coefficients of the polynomials $C(q^{-1})$ and $D(q^{-1})$ are assumed to be known.

The problem is to devise a controller structure so that the closed-loop control system is stable and its output y_t follows the set-point y_t^* as closely as possible in the sense of

$$e_t = \min_{\{u_t\}}, \tag{13}$$

where

$$e_t = y_t^* - y_t \tag{14}$$

defines the tracking error of time instant t.

Motion Control Strategy

The basic idea is to generate the control signal u_t as

$$u_t = u_t^{(\mathrm{fb})} + u_t^{(\mathrm{ff})} \tag{15}$$

summing the signal $u_t^{(\mathrm{fb})}$ caused by a feedback controller and the signal $u_t^{(\mathrm{ff})}$ that is the output of a feedforward controller.

The feedback controller is needed to ensure the stability of closed loop. To minimize the tracking error, the feedforward controller is introduced in control circuit.

In order to implement the control strategy defined in (15), we need to synthesize both the feedback controller and the feedforward controller.

Feedback controller synthesis

Let us write the following Bezout polynomial equation

$$(1-q^{-1})A(q^{-1})F(q^{-1})+q^{-d}B^{-}(q^{-1})G(q^{-1})=1 \tag{16}$$

whose unknown are $F(q^{-1})$ and $G(q^{-1})$. Since $A(q^{-1})$ and $B(q^{-1})$ are relatively prime and (8) holds $(1-q^{-1})A(q)^{-1}$ and $q^{-d}B^{-}(q^{-1})$ have no common roots. This gives that equation (16) has always the unique solution if only $\deg F(q^{-1})=d+\deg B^{-}(q^{-1})-1$ and $\deg G(q^{-1})=\deg F(q^{-1})=$
$=N$. Due to this fact we choose the polynomials $F(q^{-1})$ and $G(q^{-1})$ as follows:

$$F(q^{-1})=q^{-r}+f_1q^{-r+1}+...+f_r,$$
$$G(q^{-1})=g_0q^{-N}+q_1q^{-N+1}+...+g_N,$$

where $r=d+\deg B^{-}(q^{-1})-1$.

The transfer function of the feedback controller incorporated in closed loop is chosen in the form

$$W_1(q^{-1})=\frac{G(q^{-1})}{B^{+}(q^{-1})F(q^{-1})} \tag{17}$$

(see [7]). According to (17) its output $u_t^{(ff)}$ generated at each t is determined as

$$B^{+}(q^{-1})F(q^{-1})u_t^{(ff)}=G(q^{-1})e_t, \tag{18}$$

where e_t is tracking error defined by (14).

Feedforward controller synthesis

To determine the parameters of feedforward controller, define the following Taylor series expansion with positive degrees of q:

$$\frac{1}{B^{-}(q^{-1})}=\mu_0+\mu_1q+...+\mu_kq^k=\sum_{j=0}^{\infty}\mu_jq^j. \tag{19}$$

The useful property of (19) is that μ_k goes to 0 as k tends to infinity, i.e.,

$$\lim_{k\to\infty}\mu_k=0. \tag{20}$$

Let $k\geq d$ be a fixed finite integer specified later. Further, define the variable

$$w_t=\mu_0\nabla y_t^*+\mu_1[\nabla y_{t+1}^*]+...+\mu_k[\nabla y_{t+kt}^*]=\mu^T\nabla\widehat{Y}_t^*, \tag{21}$$

where $\mu^T=[\mu_0,\mu_1,...,\mu_k]$ is the $(k+1)$-dimensional vector of the coefficients of (19) and

$\widehat{Y}_t^* = [\nabla y_t^*, [\nabla y_{t+1}^*], ..., [y_{t+k}^*]]^T$ is the $(k+1)$-dimensional vector of the current value of ∇y_t^* and the k predicted values of $\nabla y_{t+1}^*, ..., \nabla y_{t+k}^*$, respectively, obtained in the time instant t via a predictor. Then, the compensator part of the feedforward controller generating the control signal $u_t^{(ff)}$ is determined from the equation

$$B^+(q^{-1})u_t^{(ff)} = A(q^{-1})w_t, \tag{22}$$

which can be found in [7]. Equation (22) gives the transfer function of this compensator as

$$W_2(q^{-1}) = \frac{A(q^{-1})}{B^+(q^{-1})}.$$

Now, to design the predictor, the term s_t^* needs to be estimated. From (9), it can be written

$$\widehat{s}_t^* = \nabla y_t^* - M_t, \tag{23}$$

where $\widehat{s}_t^*$ is the current estimate of s_t^*, ∇y_t^* is defined by (10) and M_t is the current estimate of unknown M specified as

$$M_t = \frac{y_t^* - y_0^*}{t}. \tag{24}$$

(Note that (24) is obtained by utilizing the property that s_t^* has zero mean.)

As in [9], we find the estimates $[\nabla s_{t+j}^*]$ $(j = 1, ..., k)$ by exploiting the equation

$$[s_{t+i}^*] = -c_1[s_{t+i-1}^*] - ... - c_n[s_{t+i-n}^*] + d_1[\xi_{t+i}] + ... + d_m[\xi_{t+i-m}] \tag{25}$$

derived from (11). In this equation, $[s_{t+j}^*]$ is equal to $\widehat{s}_{t+j}^*$ if $j = 0, -1, -2, ...$ and

$$[\xi_{t+i}] = \begin{cases} 0 \text{ if } i = 1, 2, ... \\ \widetilde{e}_{t+i} \text{ otherwise,} \end{cases} \tag{26}$$

where

$$\widetilde{e}_{t+i} = \widehat{s}_{t+i}^* - [s_{t+i}] \tag{27}$$

is the prediction error. Equation (25) defines the k-step-ahead predictor.

From (23) we get

$$[\nabla y_{t+i}^*] = [s_{t+i}^*] + M_t, \tag{28}$$

where (24) together with (25) to (27) need to be used. Thus, relationship (28) allows to determine the components of $\nabla \widehat{Y}_t^*$.

Performance Analysis

Block diagram of the motion control system synthesized before is depicted in Fig. 1. This system contains the tracking drive, the feedback controller and the feedforward controller consisting of the predictor, product unit and the compensator.

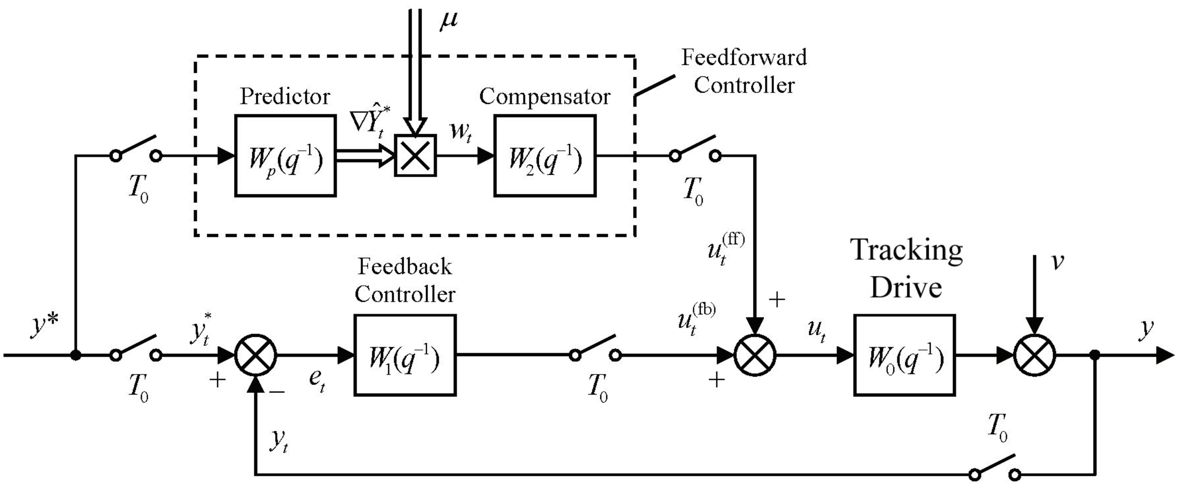

Fig. 1. Configuration of motion control system containing the feedback and the feedforward controllers

It can be established [7] that the tracking error is upper bounded according to the inequality

$$|e_t| \le \| \mu^{(r)}(q^{-1})A(q^{-1})F(q^{-1}) \|_1 \nabla y_t^* + \overline{E}\,, \qquad (29)$$

in which

$$\mu^{(r)}(q^{-1}) = \mu_{k+1}q^{k+1} + \ldots + \mu_{k+N-r-1}q^{k+N-r-1}$$

is the polynomial defined by

$$(\mu_0 + \mu_1 q + \ldots + \mu_k q^k)B^-(q^{-1}) = 1 - \mu^{(r)}(q^{-1})$$

and

$$\overline{E} = \| F(q^{-1}) \|_1 \,\varepsilon + \widetilde{E}\,, \qquad (30)$$

where $\widetilde{E}$ is an upper bound on the component of e_t arising due to prediction errors $\widetilde{e}_{t+i}$ ($\|\cdot\|_1$ denotes the l_1-norm). On the other hand, it can be shown from (11) together with (12) gives

$$|\widetilde{e}_{t+i} \le [1 + |\rho_1| + \ldots + |\rho_i|]\varepsilon_\xi\,, \qquad (31)$$

where $\rho_1,\ldots,\rho_i$ are the values of the impulse response $D(q^{-1})/C(q^{-1})$.

Recalling that $C(q^{-1})$ is stable, we conclude from (31) that $\widetilde{e}_{t+i}$ is always upper bounded by finite number for any i.

Since $\widetilde{E}$ depends on k different prediction errors $\widetilde{e}_{t+1},\ldots,\widetilde{e}_{t+k}$ satisfying (31), it follows from expression (29) together with (30) and property (20) that the upper bound on $|e_t|$ increases for all sufficiently large k. This implies that there exists a k^* defined as

$$k^* = \operatorname*{Arg\,min}_{d \le k < \infty} \| \mu^{(r)}(q^{-1})A(q^{-1})F(q^{-1}) \|_1 \nabla Y_{\max} + \| F_1(q^{-1}) \|_1 \,\varepsilon + \widetilde{E} \qquad (32)$$

with $\nabla Y_{\max}$ determined as follows:

$$\nabla Y_{\max} = M + \sum_{i=0}^{\infty} | \rho_i | \varepsilon_{\xi} < \infty . \tag{33}$$

Thus, (32) together with (33) gives the value $k = k^*$ in expression (21) that must be found to minimize the upper bound of the tracking error given by (29).

Conclusion

Within the feedback/feedforward control concept, it is possible to minimize tracking error in order to achieve the high accuracy index of the tracking control systems containing the pure time delays even if future desired motion trajectories of these systems remain unknown. To realize this concept, we need to incorporate a multi-step-ahead predictor in their open loops. However, such an approach requires the knowledge of system and desired trajectory parameters.

References

1. *Gross E., Tomizuka M.* Experimental flexible beam tip tracking control with a truncated series approximation to uncancelable inverse dynamics //IEEE Trans. on Control Systems Technology.– 1994.–2, N4.– P.382–391.
2. *Zhiteckij L.S.* Robust control strategy design for motion control of non-minimum phase system under parameter uncertainty//Proc. of the IFAC-Workshop "Motion Control", Oct. 8–11 , 1995, Munich .– P.304–311.
3. *Zhiteckij L.S.* On a problem of synthesis of a program control system containing a digital computer//Avtomatika .–1964.– №5.–P.36–42 (in Ukrainian).
4. *Astrom K.J., Hagander P., Sternby J.* Zeros of sampled systems // Automatica.– 1982. – 20, N1. – P. 31–38.
5. *Zhiteckij L.S.* On invariance of combined sampled-data systems with program control//Avtomatika.–1967.– №6.–P.83–85 (in Ukrainian).
6. *Jayasuriya S., Tomizuka M.* Feedforward controllers for perfect tracking that does not invert plant zeros outside the unit disk//Proc. of the 12th IFAC World Congress.–1993.–3.– P.91–94.
7. *Azarskov V.M., Zhiteckij L.S.* On a problem of designing suboptimal program system for motion control in the presence of nonregular disturbances//The Bulletin of Northern centre of science TAU.–2003.– №6.–P.55–57 (in Ukrainian).
8. *Azarskov V.N., Blokhin L.N., Zhiteckij L.S., Kussul N.N.* Robust methods for estimation, identification and adaptive control.–K.: NAU.–500p. (in Russian).
9. *AzarskovV.M., Zhiteckij L.S., Sushchenko O.A.* Adaptive prediction of a class of stochastic processes// Informatization and control problems.–2005.– №12.–P. 12–17.

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THE PROBLEM AND ALGORITHM OF SYNTHESIS OF OPTIMUM STOCHASTIC STABILIZATION SYSTEMS WITH INCREASED ROBASTICITY

New functional qualities and the algorithm of synthesis of optimum robastic stabilization systems which can help to develop sophisticated systems of stabilization with quality levels which are much higher than those obtained with traditional functional.

Introduction

Everegrowing requirements are put forward by the practical level of stabilization systems accuracy due to the rapid progress in engeneering and higher demands on the market to engeneering items and their compatability. First of all, it is necessary to mention moving object stabilisation systems (aircraft, spacecraft, groups of spacecraft, long-range and superlong-range communication systems). At present the highest levels of accuracy of stabilization systems can be practically achieved only in optimum systems, synthesized and realized with the help of complicated scientific and research technologies which are based on ideas of Vinner and Kalman optimum filtration.

In order to reduce negative effects in the process of finding solutions for high level stabilization problems which can appear due to not clear and complete understanding of dynamic object models definite problems and mechanizm of their operation, so called robastic systems are synthesized. It is clear, that the mentioned above traditional optimal systems process high level of "unsensitivity" (low level of pick up) to actions and not accurate enough understanding about models used in synthesis. But the componennt directly responnsible for "unsensitivity" of synthesized system is not present in traditional functional.

Discussion

New problems and spectral algorithm of optimal robastic stabilization structure synthesis which can give accurate analytic solutions and essentially higher in comparison with traditional approaches to synthesis level of stabilization quality have been proposed.

To increase the robasticity of the synthesized system we introduce into the traditional functional an additional component which is responsible for some level of "unsensitivity" (threshold pickup) of the designed system to not clear enough understanding about models used in synthesis. Having no intention to make deep research of some problematic aspects of complicated dynamic systems sensitivity and using ideas expressed in (1), we can determine the threshold pickup or sensitivity level of closed system characteristics to the stabilization object variability by means of comparison with the analogous level obtained for an "equivalent" open system.

Let us clarity the idea. The motion of stabilization object is described by means of the system of usual differential equations, transformed according to Laplace: $Px = Mu + \psi$, where x is n-dimentional vector of object reaction u is m-dimentional vector of control and ψ is n-dimentional vector of disturbances with known dynamic characteristics. P and M are polynomal matrixes of p at n x n and n x m dimention (p is the argument in Laplace transformations).

The mentioned study showes that on the basis of comparison of errors in equivalent open the Sand closed 8 systems, which can appear due to changes in object structure, the equation of mentioned errors connection will be as follows:

$$\varepsilon = F_x P \pounds = \left(E_n - P^{-1} M W_0\right)^{-1} \pounds .$$

The unknown sensivity function ddetermination in closed system will be (2):

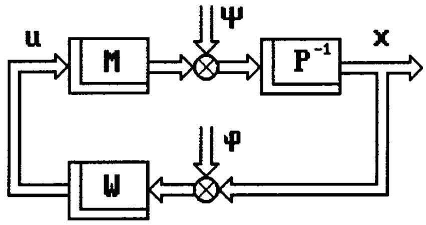
$$\Phi = F_x P ,$$

which is thought to be used in the proposed procedure of optimal robastic systems of stabilization. Here $F_x = (P - MV)^{-1}$.

Let us determine and solve the problem of optimum robastic system synthesis of multidimentional linear dynamic object stabilization at random actions.

In order to fix our attention to the procedure of the provision of system robasticity the object of stabilization in considered to be stable (P matrix determinant is of Gurvitsev type). In case of optimum robastic system synthesis for an object with arbitrary dynamics it is necessary to make the procedure more complicated in accordance with known recommendations [2].

The block diagram of an "equivalent" system of stabilization, which can be common for systems of stabilization and tracing including disturbance control circuit, is presented in Fig.1.



Besides mentioned above symbols the vector of measuring disturbances (p is taken into account. It is very important for the given problem to discuss the following items. Let the motion of the stabilization object be described by the equation (1), where ψ is n-dimensional centring stationary random process with the known matrix of spectral densities is $S_{\psi\psi}$; φ is n-dimensional centring stationary random process with known matrixes of spectral and mutual spectral densities $S_{\varphi\varphi}$, $S_{\varphi\psi}$ and $S_{\varphi\psi}$; detP is of Gurvitsev type.

The unknown matrixes of transformation functions of a closed system are [1]:

$$F_x^{\psi} = (P - MW)^{-1}; \quad F_u^{\psi} = W(P - MW)^{-1};$$

$$F_1 = F_x^{\psi}(E_n, P) - (O_n, E_n); \quad F_2 = F_u^{\psi}(E_n, P).$$

The index above the quantity determines an input to the system we are interested in, while the index under the quantity denotes its output. The equation of connection between matrixes of transformation functions F_x^{ψ} and F_u^{ψ} can be written in the following way

$$PF_x^{\psi} - MF_u^{\psi} = E_n$$

If we introduce the vector of summerized action $\psi_0 = \left(\psi', \varphi'\right)'$ and take into accoon symbols in (3), we can put down signals and reactions of the system as:

$$\zeta = (E_n, P)\psi_0; \quad x = F_1\psi_0; \quad u = F_2\psi_0; \quad \nu = \Phi\varsigma ,$$

where Φ is the matrix of "sensitivity" of the system to the variability of the object presented by equation (2) and rewritten with taking into account some features of "equivalent" system of stabilization and expressed by (4) as: $\Phi = F_x^{\psi} P = P^{-1}\left(E_n + MF_u^{\psi}\right)P$.

If we consider functions (5) and (6), the functional of stabilization quality can be presented in the following way:

$$
\begin{aligned}
& e = < x' R x > + < u' C u > + < \nu' \Lambda \psi_0 > + < \psi_0' \Lambda \nu > = \\
& = \frac{1}{j} \int_{-j\infty}^{j\infty} tr \left\{ \left[\begin{pmatrix} E_n \\ P_* \end{pmatrix} \left(F_{u*}^{\psi} M_* + E_n \right) P_*^{-1} - \begin{pmatrix} O_n \\ E_n \end{pmatrix} \right] R \times \right. \\
& \times \left[P^{-1}\left(MF_u^{\psi} + E_n \right)\left(E_n, P \right) - \left(O_n, E_n \right) \right] S'_{\psi_0\psi_0} + \\
& + F_{u*}^{\psi} C F_u^{\psi} \left(E_n, P \right) S'_{\psi_0\psi_0} \begin{pmatrix} E_n \\ P^* \end{pmatrix} + P^{-1}\left(MF_u^{\psi} + E_n \right) P \left(E_n, P \right) S'_{\psi_0\psi_0} \begin{pmatrix} E_n \\ P_* \end{pmatrix} \Lambda + \\
& \left. + \Lambda \left(E_n, P \right) S'_{\psi_0\psi_0} \begin{pmatrix} E_n \\ P_* \end{pmatrix} P_* \left(F_{u*}^{\psi} M_* + E_n \right) P_*^{-1} \right\} ds.
\end{aligned}
$$

There R, C and A are weighty polynominal characteristics of argument $s = j\omega$ non-negative definite symmetrical matrixes simulteniously not equal to zero; $S_{\psi_0\psi_0}$ is the matrix of spectral densities of summerized action; <> is the symbol of matrix expectations; "'" is the symbol of transposition; "*" is the symbol of Ermitov's type conjugation; tr — matrix trace.

The task of the synthesis is to choose in the class of physically realized functions F_u^{ψ}, which have analytical variation δF_u^{ψ} only in the right semi-plane of the complex variable $s = j\omega$, the one which can supply minimum value to the functional (7) and simulteniously provides stabilizy to the closed system.

The problem can be solved by means of application of Vinner-Kholmogorov method according to which, the first variation of the functional of stabilization quality must be equal to zero under the obligatory condition of physical realization of F_u^{ψ}.

After some transformations the can write down the first variation of the functional in the following way:

$$
\begin{aligned}
& \delta e = \frac{1}{j} \int_{-j\infty}^{j\infty} tr \left\{ \left[\left(M_* P_*^{-1} R P^{-1} M + C \right) F_u^{\psi} \left(E_n, P \right) S'_{\psi_0\psi_0} \begin{pmatrix} E_n \\ P_* \end{pmatrix} + \right. \right. \\
& + M_* P_*^{-1} R P^{-1} \left(E_n, P \right) S'_{\psi_0\psi_0} \begin{pmatrix} E_n \\ P_* \end{pmatrix} - M_* P_*^{-1} R \left(O_n, E_n \right) S'_{\psi_0\psi_0} \begin{pmatrix} E_n \\ P_* \end{pmatrix} + \\
& \left. + P_* M_* P_*^{-1} \Lambda \left(E_n, P \right) S'_{\psi_0\psi_0} \begin{pmatrix} E_n \\ P_* \end{pmatrix} \right] \delta F_*^{\psi} + \delta F_u^{\psi} \left[\left(E_n, P \right) S'_{\psi_0\psi_0} \begin{pmatrix} E_n \\ P_* \end{pmatrix} F_{u*}^{\psi} \times \right. \\
& \times \left(M_* P_*^{-1} R P^{-1} M + C \right) + \left(E_n, P \right) S'_{\psi_0\psi_0} \begin{pmatrix} E_n \\ P_* \end{pmatrix} P_*^{-1} R P^{-1} M - \\
& \left. \left. - \left(E_n, P \right) S'_{\psi_0\psi_0} \begin{pmatrix} 0 \\ E_n \end{pmatrix} R P^{-1} M + \left(E_n, P \right) S'_{\psi_0\psi_0} \Lambda P^{-1} M P \right] \right\} ds.
\end{aligned}
$$

Let introduse the symbols:

$$DD_* = \left(E_n, P \right) S'_{\psi_0\psi_0} \begin{pmatrix} E_n \\ P_* \end{pmatrix},$$

where matrix Z) is the result of factorization of matrix (9), which has its own features only in the left semi-plane of the complex variable

$$\Gamma_* \Gamma = M_* P_*^{-1} R P^{-1} M + C,$$

where matrix Γ is the result of factorization of equation (10);

$$T = T_0 + T_+ + T_- = \Gamma_*^{-1}\left[M_* P_*^{-1} R P^{-1} (E_n, O) S'_{\psi_0 \psi_0} \begin{pmatrix} E_n \\ P_* \end{pmatrix} D_*^{-1} + P_* M_* P_*^{-1} \Lambda D \right],$$

where "$_0$", "$_+$" and "_" indecies of separation, while matrix elements T_0 are only numbers or polynomes, matrix elements T_+ — are proper fractions, having poles only in the left semi-plane, matrix elements T_- are proper fractions having poles only in the right semi-plane. The unknown algorithm of the synthesis which supplies a minimum value to the functional, can be presented as follows

$$F_u^{\psi} = -\Gamma^{-1}(T_0 + T_+)D^{-1};$$
$$F_x^{\psi} = P^{-1}\left(MF_u^{\psi} + E_n\right);$$
$$W = F_u^{\psi}\left(F_x^{\psi}\right)^{-1}.$$

So, for the practical solution of the synthesis of optimum robastic system stabilization problem it is necessary

• to get initial information about dynamic characteristics of an object and actions on it to substitute specified Matrixes R, C and Λ into equation (9)-(l1) to determine the matrix of optimum transfer function, to make operations of factorization and separation of required matrixes;

• to substitute into equation (12) the received matrixes D, Γ and ($T_0 + T_+$) to determine the matrix of optimum transfer functions of the closed system F_u^{ψ};

• to substitute the required initial information about an object into the synthesized matrix F_u^{ψ} into equation (13) and to determine the second matrix of optimum transfer function of the closed system F_x^{ψ};

• to substitute matrixes F_x^{ψ} and F_u^{ψ} into equation (14) and to determine the matrix of optimum transfer function (optimum structure) of the regulator;

• to substitute the chosen matrixes F_x^{ψ} and F_u^{ψ} into equation (3) and to determine matrixes F_1 and F_2, then to substitute them into the functional (7), to evaluate its minimum value and to study variability of the functional depending on the choice of variable parameters.

The reference [3] gives the comparison of results of optimum systems synthesis of the proposed and traditional functionals. The results are obtained can serve as which the analytical example.

Conclusion

The comparative analysis of synthesis results gives the basis to state that the proposed algorithm of synthesis of optimum robastic systems allows to achieve essentially higher levels of quality of stabilization as those achieved according to traditional approaches.

The payment for increase of accuracy in the given variant is the increase in power consumption for control function. But it is essentially less than the increase of the same power consumption under the condition of invariance to actions, then it is possible in the system synthesize under traditional methods.

Reference

1. *Blokhin L.N.* Optimum Systems of stabilization—E.: Technika, 1982. - 144 p.
2. *Blokhin L.N. .Kadyshev I.E., Trifonov—Bogdanov P.I.* Fundamentals of navigation and

flight-navigation complexes. The text book for civil aviation Institutes, td. by *Blokhin L.N.*— L: Vozdushny Transport, 1993. — 244 p.
3. *Blokhin L.N.* Synthesis of optimum robastic system of stabilization. — E.: Visnik TSNTS TAU. — 1999 » 2 P. 40-43.

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THE PROBLEMS AND METHODOLOGY OF MOVING OBJECTS AIRBORNE METERING AND CONTROL SYSTEMS DYNAMIC CERTIFICATION USING MOTION SIMULATION COMPLEXES

Main aspects of methodology of the process of airborne cybernetic systems dynamic certification have been regarded successful development of compatible airborne complexes of future moving objects is greatly based on it.

Introduction

Dynamic conditions which are getting more complicated and the requirements for automation of great number of modern aircraft and spacecraft different essential modes of flight put evergrowing demands on the accuracy airborne measuring instruments systems and complexes.

Airborne measuring instruments (AMI) must be regarded as complicated multi-dimensional multi-connectional dynamic systems which are under the influence of a number of operational disturbances. The factors of disturbance have a stochastic character; which means that the quality analysis and optimization of such systems and complexes can be done on the basis of statistic dynamics of control systems.

The methods which are proposed by this theory, can serve for the development of technological processes for designing, finishing, adjusting, regulating and certification of airborne measuring instruments.

The dynamic certification of airborne measuring and control (cybernetic) complexes of moving objects means the process and results of experimental determination of transfer functions matrix (frequency characteristics) of the device itself and matrixes of spectrum and mutual spectrum densities of signal vectors which characterizes inputs and outputs of a cybernetic device, actions applied to it and disturbances in measuring of analyzed parameters of the airborne device under dynamic conditions, close to real operational on the basis of data obtained during experimental research of complexes using simulators of motion . It is supposed that with the help of simulators used in researches real movements of these objects are made with enough level of approximation to the real conditions. In other words, the complexes of motion simulation must be multistaged dynamic test benches with sophisticated infrastructure of control.

The dynamic certification of airborne measuring complexes accuracy under conditions which are close to real operation is the basis for the development of new optimum and modernization of existing means of navigation and control of aircraft and spacecraft flight.

The advanced firms of the world spend much money which are comparatively quickly realized in design and development of more sophisticated generations of airborne cybernetic complexes. But only modern, expensive complexes of motion simulation are not sufficient for the development of new devices for navigation and control.

At the same time it is quite necessary to create new science intensive technologies with the help of which it becomes possible to modernize complexes of motion simulation to meet evergrowing requirements of accuracy to the perspective movable objects navigation and control processes as well as to the simulation of motion. It is required to create and to develop new science intensive technologies of the process of dynamic certification of complex dynamic systems.

Among them, for example, there are methods and algorithms of structural identification of a complex object models and uncontrolled disturbances acting on an object under normal mode of motion, methods of optimum evaluation of stochastic conditions of an object under normal mode of motion etc.

It is necessary to have data bases about models of existing objects dynamics of navigation and control systems and their parts, disturbances and actions in navigation and control loops, evaluation of models of real angular and space motion of objects or their prototypes, other information. Finally it is required to evaluate results of different stages of dynamic certification of the given objects.

Discussion

The theoretical basis for dynamic certification can include methods and algorithms of structural identification of models of a device under research and disturbances acting on it under normal or close to normal modes of an object motion. Besides, methods and algorithms of the optimum observation (evaluation) of signals vectors which characterize stochastic conditions of inputs and outputs of a complex dynamic device should be applied. One of the main peculiarities of the identification and evaluation algorithms is their scientific accuracy and simplicity while using them in practical engineering cases.

The definition of dynamics models of multidimensional cybernetic systems is rather complicated process. It is due to the fact that, firstly, it is necessary to have multi-stage test bench generator which can simulate the predetermined space motion of an object with high quality. Secondly, the development of Specialized algorithms and methods of testing is strictly required.

The thing is, that in electro-mechanical multidimensional test benches and devices, the interconnection between their partial movements can be taken into account in the model only in case when specially developed test methodology is applied.

The most complicated are problems for the definition of measuring device disturbances dynamic characteristics in the modes then the movement of the test bench simulator are close to operational movements. It is connected with a number of factors. Firstly, the movement of the test bench must be realized as a multidimensional stochastic process with prescribed dynamic characteristics. Simulation of these movements with the highest accuracy by a test bench-generator is achieved by some stages of development [1,2] of the structure of the bench control System, the main of which must be the dynamic designing of the control system which should be done with taking into account the dynamic characteristics of a test bench as an object of control, signals of programmed motion, test bench internal effects, noise of measuring devices etc.

The research base for this stage should be in the form of practical algorithms of optimum stochastic systems synthesis.

Secondly, it is required to make optimum evaluation of inputs and outputs of a device under research, to make necessary transformations of measured coordinates of the test bench conditions in comparison with the initial system of coordinates, to make necessary analysis of the device in order to find the disturbances vector in the modes of measurements close to real operational conditions.

Statistical processing of received measurement disturbances in some modes of operation and approximation of experimental results by means of mathematical expressions must be done at the final stage of the work for determination of noise models of airborne measuring device under dynamic condition as close to the operational modes as possible. It is necessary to have the algorithms for the optimum evaluation of stochastic condition of complicated dynamic object (for example [1]) as well as the correct problem formulation for every case.

The development of optimum evaluation systems determine stages of their dynamic designing process.

It is necessary to stress that the test bench-simulators can serve for the definition of measuring devices characteristics and noise of measuring process. Optimum control structures must be readjusted depending on the character of the problem and modes of flight simulation.

To visualize the problem of complexes used for dynamic certification of complicated airborne measuring instruments, it is worth to demonstrate a version of a bench-generator block diagram which has predetermined. Random angular movements and can be used for dynamic certification, for example, of gyroscopic systems. (Fig. 1).

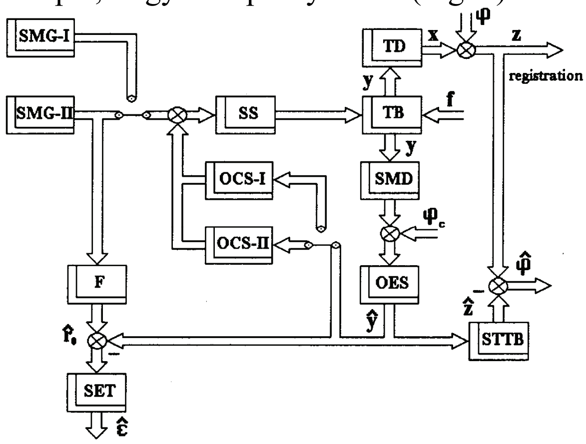

Fig. 1. Block-diagram of a bench generator for dynamic certification of airborne measuring devices

The symbols used on this bloc diagram are as follows: **TD** — tested device; **TB** — test bench; **SS** — system of servomechanisms; **OCS-I** and **OCS-II**— optimum control systems for the modes of determination of dynamic characteristics of generators for modes (I) and (II); **SMG-I** and **CMG-II** — systems of master generator for I and II modes; **SMD** — system of the measuring devices test bench; **F** — filter for estimation of program signals vector r_0; **OES** — optimum estimation system of the test bench y as a result of measurements obtained **SMD** (φ_c — measuring devices test bench noise SMD, y — vector of the "true" condition of the test bench); **SET** — system of closeness evaluation of test bench real movements simulating flight mode; **STTB** — system of transformation of test-bench evaluation to condition of the tested device; z — vector of the device recording Conditions; z — evaluation of are item condition; x — product outputs vector; (p — vector of the measurements noise, which should be taken into account; (p — evaluation of measurements noise vector of the product. The principle of the test bench generator operation is clear from Fig. 1.

Let us consider the optimal observer algorithm of synthesis as an example of science intensive technology. It is necessary to make optimum evaluation of airborne measuring devices test bench generator conditions during stochastic actions practically in all modes of simulated or real flights.

At present these evaluations are very often based on Kalman optimum filtration. In this case disturbances and object conditions are not correlated. But in practice there are many other cases. For evaluation of an object steady conditions and for the simplicity of realization a number of spectral methods of optimum evaluation [1,3] have been proposed. We can explain this by one example.

Let us assume that we know a priori: the dynamics of a steady object **O**, the condition and stationary disturbance i|/, acting on object output, having been measured in an actual test by means of some measuring system UC with matrix, having transfer function K (Fig. 2).

These measurements are accompanied with a disturbance cp which has known dynamic characteristics. It is required to determine a structure (matrix of transfer functions) V and parameters of linear steady system of observation **OH** in such a way that to minimize evaluation dispersion error 8. The proposed algorithm for the case evaluation is the following.

If the movement of an object under the action of disturbances is described by the system of simple differential equations with Laplace's transformations $Px = \psi$,

and a measuring signal is determined by the equation $y = Kx + \varphi$,

then the algorithm [1] for the evaluation of the transfer function matrix V on the basis of initial information will be written as follows

$$V = \Gamma^{-1}\left(N_0 + N_+\right)D^{-1}$$

where D is the result of factorization of the transposed matrix $S'_{\xi\xi}$ of spectrum densities of summarized disturbance $\zeta = KP^{-1}\psi + \varphi$; matrix $N_0 + N_+$ is the result of separation of the matrix

$$N = \Gamma P^{-1} S'_{\zeta\psi} D_*^{-1}, \qquad S'_{\zeta\psi} = S'_{\psi\psi} P_*^{-1} K_* + S'_{\varphi\psi};$$

where $S'_{\varphi\psi}$ is the transposed matrix mutual spectrum densities signals and ψ and φ, "*" is the sign of Ermitov's conjugation,"'" — the symbol of transposition.

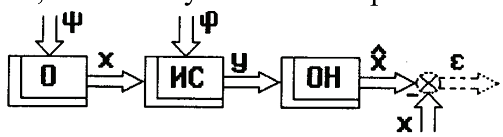

Fig. 2. Block-diagram for optimum estimation

If we substitute initial information (matrixes $S'_{\psi\psi}, S'_{\varphi\psi}$, and P) into the algorithm (1) and make all necessary transformations we can get at once the unknown matrix of transfer functions of optimum observer. Realization of an observer structure by means of modern computers is quite easy.

Optimum observers are necessary for evaluation of stochastic conditions of airborne measuring devices in the process of real-scale and bench tests of aircraft, test-bench generators of space movements As well as for the closed loops of optimum control which are designed on the basis of separation theorem.

Proposed algorithms of optimum synthesis and structural identification of dynamic systems are given in the papers mentioned in the Reference.

Conclusion

The methodology for the dynamic attestation of airborne cybernetic complexes is developed. This methodology is a necessary condition for the creation of optimal control and navigation complexes.

Reference

1. *Blokhin L.N., Kadyshev I.K., Trifonov-Bogdanov P.I.* Fundamentals of navigation and flight-navigation complexes; text-book for Civil Aviation Institutes Ed. by Blokhin L.N. —

Vozdushny Transport publishing house, 1993. — 244 p.
2. *Azarskov V.N.* Methodology of optimum Modification aerospace flight simulators control system. — E. :KIUCA. — 1996. p. 229.
3. *Kwakernaak O., Sivan D.* Linear optimum system. — I.: Mir, 1977, 650 p.

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THE PRINCIPLE OF SYSTEM ACCESS TO A TASK OF FLYING DEVICE OF THE SAME TYPE AUTOMATIC DESIGN

The task of the automated designing of an object as a component of multilevel hierarchical system is considered.

The object being designed represents a flying device, whose main function is to deliver payload to the given area.

The following distinctive features characterize the flying device being designed:

- extreme conditions of functioning (high temperature and strength dynamic loads);
- various configurations and structure of flying device subsystems, meeting the same requirements;
- element of uncertainty of the purposes and conditions flying device and its subsystems, functioning connected with a long interval of time from the moment of the beginning of flying device designing to the moment of starting its application.

The listed features allow to consider a plenty of allowable variants of designs and define a wide field of activity in the process of structuring the system, where the designed flying device belongs.

The uncertainty of choice of the design solutions is explained by disorder of meanings of the design characteristics determined by discrepancy of the initial data in designing. The analysis of the factors of uncertainty and choice of strategy of design search in conditions of uncertainty is an important part of methodology of creation of the automated systems of designing flying device [1].

The designing of flying device shape under the given requirements should be carried out proceeding from the conditions of application, place and importance of flying device in more general system, whose component it is [2].

Proceeding from above-stated we shall define the task of a flying device designing from the condition of peak efficiency of a high level system with flying device, as a lower level system.

In this case the structure of settlement algorithms depends on the structure of multilevel hierarchical system.

The structure of multilevel hierarchical system is showed on fig. 1.

According to the accepted structure it is possible to allocate three levels of hierarchy:

1. Complex of subsystems providing flying device's work (system of hierarchy high level);
2. Flying device, as the subject of system of hierarchy high level;
3. Flying device subsystems.

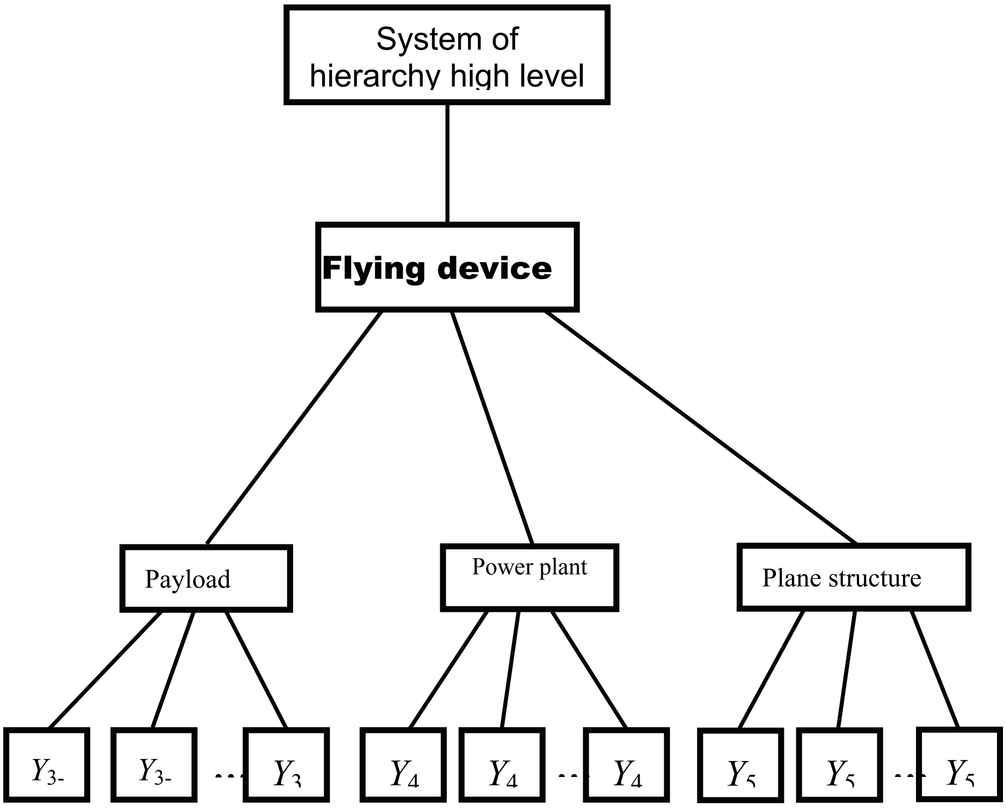

Fig. 1. Structure of multilevel hierarchical system:

$Y_{3\text{-}1}$, $Y_{3\text{-}2}$ … $Y_{3\text{-}i}$ - parameters of payload design elements

$Y_{4\text{-}1}$, $Y_{4\text{-}2}$ … $Y_{4\text{-}i}$ - parameters of power plant design elements

$Y_{5\text{-}1}$, $Y_{5\text{-}2}$ … $Y_{5\text{-}i}$ - parameters of plane structure design elements

Having analyzed the given system structure, we can present a general task of flying device designing, in the structure of this system, as a number of consecutive optimization tasks connected with each other and located on various levels of design search.

Because the task of flying device design is task of multicriterial optimization, therefore for each level it is necessary to choose technical characteristics, which correspond to criteria of estimation of the design solutions.

Let's assume, that at the first level technical characteristics are given and are the initial data for defining of the second level technical characteristics.

The criterion of an estimation of the design solutions of the first level is the number of the executed tasks per unit of given expenses.

Let's designate system effectiveness E, $Y_1 = \{Y_{1\text{-}i}\}$, $i=\overline{1,q}$ - vector of parameters of elements of system design, $T_j(Y_1)$, $j=\overline{1,p}$ - vector of the system characteristics and let's assume, that the external conditions influencing system functioning, are known and fixed, then we have a task of optimization of criterial function $F_1(Y_1)=\sum_{i=1}^{q} c_i f_i(Y_1)$:

$$E = \max_{Y \in H_1} F_1(Y_1) \text{, for } T_j(Y_1) \le T_{\max},$$

where c_i - factors of importance (weight factors) of individual criterial functions, H_1 - area of the allowable decisions for the first level.

Corresponds to the second level there a choice of technical characteristics flying device.

Main criterial technical characteristics are:

- range of flight;
- mode of power plant operations;
- size, weight and aerodynamic configuration.

The criterion for the choice of the specified parameters is probability of payload delivery to required area.

If we designate W probability of payload delivery, and $Y_2 = \{Y_{2\text{-}i}\}$, $i=\overline{1,k}$ - vector of the parameters of flying device design elements and $M_j(Y_2)$, $j=\overline{1,n}$ - vector of the flying device characteristics, we have a task of criterial function optimization $F_2(Y_1)=\sum_{i=1}^{k} c_i f_i(Y_2)$:

$$W = \max_{Y \in H_2} F_2(Y_2) \text{, for } M_j(Y_2) \le M_{\max},$$

where H_2 - area of the allowable decisions for the second level.

Choice of parameters of a payload and power plant to the third level there corresponds , choice of geometry of the case and main planes correspond.

Criterion for the choice of payload and power plant parameters are weight and dimensions.

If $Y_3 = \{Y_{3\text{-}i}\}$, $i=\overline{1,l}$ is vector of parameters of payload design elements and $P_j(Y_3)$, $j=\overline{1,h}$ - vector of payload characteristics, $Y_4 = \{Y_{4\text{-}i}\}$, $i=\overline{1,e}$ - vector of the parameters of power plant design elements and $D_j(Y_4)$, $j=\overline{1,m}$ - vector of the characteristics power plant, and $Y_5 = \{Y_{5\text{-}i}\}$, $i=\overline{1,s}$ - vector of the parameters of plane structure design elements and $G_j(Y_5)$, $j=\overline{1,u}$ - vector of the characteristics plane structure, then by analogy to the first and second levels we have a task of optimization criterial functions $F_3(Y_3)$, $F_4(Y_4)$ and $F_5(Y_5)$:

$$A = \max_{Y \in H_3} F_3(Y_3) \text{, for } P_j(Y_3) \le P_{\max}\text{; } B = \max_{Y \in H_4} F_4(Y_4) \text{, for } D_j(Y_4) \le D_{\max}\text{;}$$

$$C = \max_{Y \in H_5} F_5(Y_5) \text{, for } G_j(Y_5) \le G_{\max}\text{;}$$

where A, B and C – payload, power plant and plane structure design data, accordingly, H_3 H_4 and H_5 - area of the allowable decisions for the appropriate criterion functions.

Criterion for choice of the case geometry and main planes is the minimal value of the drag factor.

Restrictions are a required lateral overload and the degree of static stability.

The task of multicriterial optimization of perspective flying device refers to the most difficult and urgent tasks of the technical systems designing.

The task is multicriterial , if the general criteria (for maximum or minimum) is found by the sum of individual criteria, which can be inconsistent (for example, one criterion is searched for the maximum, another for the minimum) and diverse.

Search of individual optimum criteria with constructing of individual criterion functions and definition of general criterion, as the sums of individual criteria, was considered earlier and does not present any difficulties. The difficulty consists in defining the area of allowable changes in variable parameters and their reduction to normalized (uniform) parameters.

The optimum solutions lay inside area (Pareto area), whose border are lines between points of optimum tasks, received when solving the tasks of optimization separately by each criterion. Outside this area the solution of a task will be obviously worse, than inside it.

The zone of the conciliatory proposals is determined lither in the point of individual criterion functions intersection (the compromise is found) or zone of the compromise, when the general compromise is not found, however the area, in which it is best is found.

An important task in formation of flying device shape, as a component of a sophisticated system, is narrowing the area of allowable parameters up to effective (Pareto optimum), therefore, elimination of design data, that are obviously unsuccessful yielding to other data by all criteria, from the set of possible ones. Thus, the area of decision making may be essentially reduced [3].

Literature list

1. M.I.method's aspens of the automated designing of flying devices. - M.: Mechanical engineering, 1984. 167p.
2. *Golubev I.S., Samarin A.V. D*esigning of designs of flying devices. - M.: Mechanical engineering, 1991. 512p.
3. *Sobol I.M., Statnikov R.B.* Choice of optimum parameters in problems with many criteria. - M.: the Science, 1981. - 110p.

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FUZZY INFERENCES IN THE SYSTEM A TENSOR-VARIABLE

Solving problems of management in conditions of uncertainty at present involves using the theory of fuzzy sets (FS). The authors have offered a new way of presentation of fuzzy variables (numbers) - (FV(FN)) as diadic tensors, that allows greatly extend information base to solve the problems in conditions of uncertainty. In particular, tensor methodology allows to solve problems of fuzzy conclusions quite effectively [1-4].

Let's consider general problem of fuzzy conclusions in the form, as it exists in the system of traditional FS and show that main ideological premises are to be carried to the system of tensor-variables. Fuzzy inference (FI), is well known to be determined as a result of decision making on the basis of fuzzy rules and the values of input variables. The offered general scheme of FI is as follows:

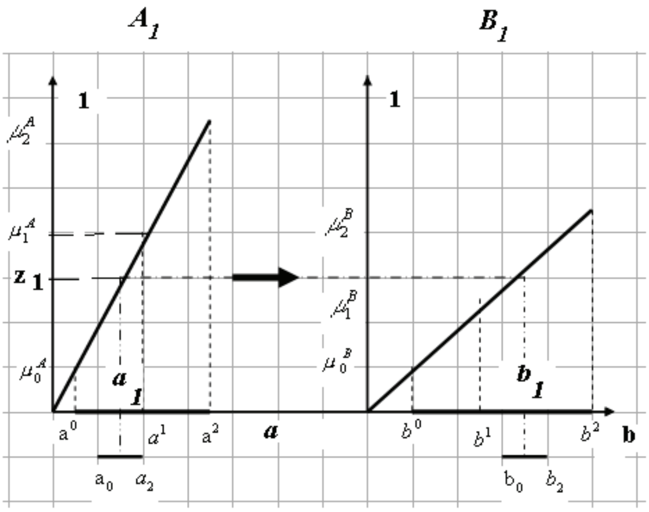
$$\frac{\begin{array}{l}\text{if } (\boldsymbol{X_1} \text{ is } \boldsymbol{A_1}) \text{ and /or } \ldots (\boldsymbol{X_n} \text{ is } \boldsymbol{A_n}), \text{ then } (\boldsymbol{Y} \text{ is } \boldsymbol{B}) \\ (\boldsymbol{X_1} \text{ is } a_1) \text{ and/or } \ldots (\boldsymbol{X_n} \text{ is } a_n)\end{array}}{\boldsymbol{Y} \text{ is } b}$$

where "if-then " - a fuzzy rule or a set of fuzzy rules, $\boldsymbol{X_1},\ldots,\boldsymbol{X_n}$ - input variables of managerial systems; $\boldsymbol{Y}$ - output variable of fuzzy managerial system (FSC); $\boldsymbol{A_1},\ldots,\boldsymbol{A_n}$, $\boldsymbol{B}$ – FS, managerial systems corresponding to fuzzy variables; and/or - a logical operation; $a_{1,\ldots,}$ a_1 - input variables, both crisp and fuzzy; b - output variable, which can also be both crisp and fuzzy. Depending on the problem formulation and the type of input and output variables, methods of FI can change.

In a simple fuzzy inference, is given the base of fuzzy rules $\boldsymbol{A_i} \Rightarrow \boldsymbol{B_i}$, where i=1,…n; FS $\boldsymbol{A_i}$ and $\boldsymbol{B_i}$ are considered as given ones. Also is given the input variable of the managerial system as number $a_1 \in U(A)$, where $U(A)$ - universal multitude of the condition. It is necessary to find value of $b_1 \in U(\boldsymbol{B})$, where $U(\boldsymbol{B})$ – the universal multitude of the result. The problem Scheme is presented in the following manner

$$\text{(Condition)} \Rightarrow \text{(Result)}: \ \boldsymbol{A_i} \Rightarrow \boldsymbol{B_i}$$
$$\text{Premise: } a_1$$
$$\text{Conclusion: } b_1.$$

Let FSC consist of input variable a, output variable b and the base of fuzzy rules R={ R_1: $\boldsymbol{A_1} \Rightarrow \boldsymbol{B_1}$, R_2: $\boldsymbol{A_2} \Rightarrow \boldsymbol{B_2}$ }. In the base of fuzzy rules, $\boldsymbol{A_1}, \boldsymbol{A_2}$ - given FS conditions, describing a - input variable, $\boldsymbol{B_1}, \boldsymbol{B_2}$ - given FS effects, describing b - output variable.



I F	Input variable $\widetilde{a}$ has value a_1	**THEN**	Output variable $\widetilde{b}$ has value b_1

Fig. 1. Simple conclusion Scheme

The value of output variable b_1 is determined with the use of FS $\boldsymbol{B_1}$. Graph FS of $\boldsymbol{B_1}$ is given, and it remains to get the value of output variable b_1. If degree of confidence $\boldsymbol{A_1}$ and $\boldsymbol{B_1}$ is the same, since they form one fuzzy rule, then $\boldsymbol{b_1}$ is calculated from the equation z= $\boldsymbol{B_1}(b_1)$. Simple conclusion at the level of tensor models FV(FN) will be considered for the case, when MF is triangular, $\widetilde{a} = \{a^1/\mu_a^1, a^2/\mu_a^2, a^2/\mu_a^2\}$, $\mu_a = \{0, 1, 0\}$. In this case tensor-variable looks like

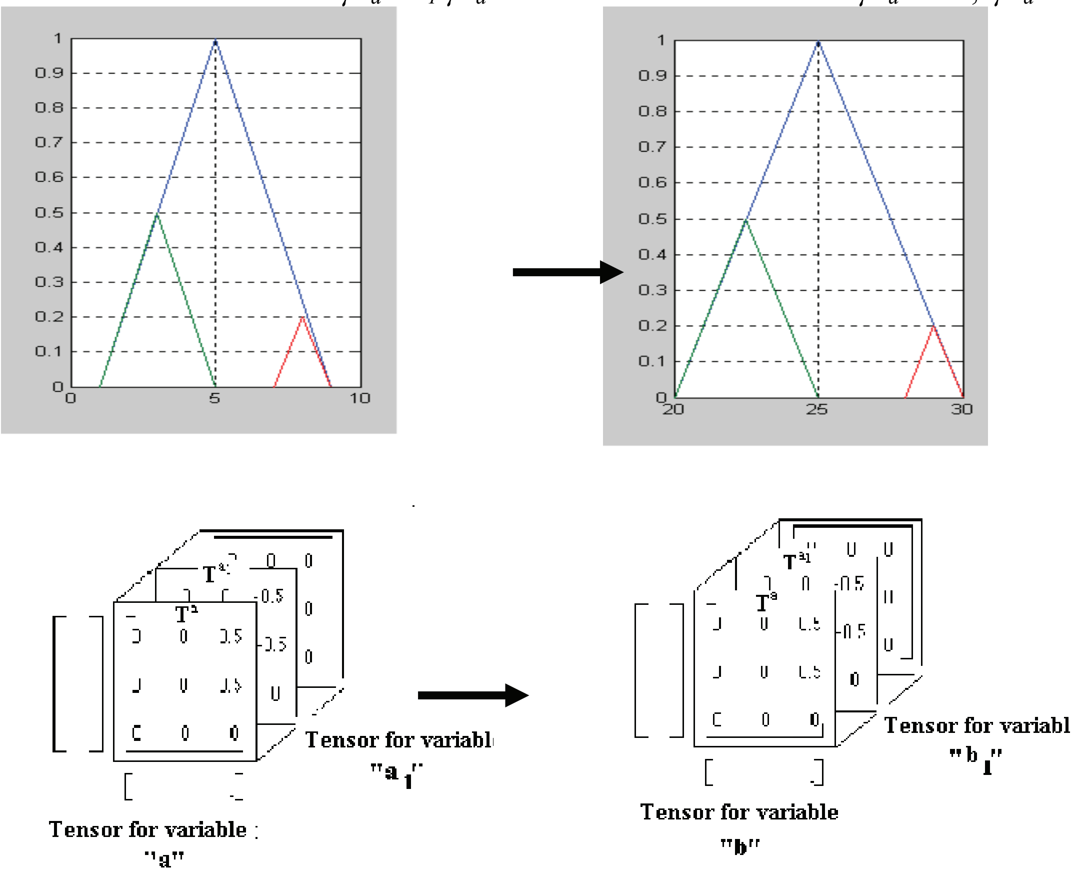
$$
{}^a\boldsymbol{T} = \begin{array}{ccc|l} \boldsymbol{a^1} & \boldsymbol{a^2} & \boldsymbol{a^2} & \\ \hline 0 & 0 & 0 & \boldsymbol{\mu^1{}_a=0} \\ a^1\mu^2{}_a & a^2\mu^2{}_a & a^3\mu^2{}_a & \boldsymbol{\mu^2{}_a=1} \\ 0 & 0 & 0 & \boldsymbol{\mu^3{}_a=0} \end{array}
$$

The distinctive feature of the created tensor-variable is that trace of tensor ${}^a\boldsymbol{T}$ is $I_1 = a_2/3$.

Imagine that entering a system is variable $\boldsymbol{a^1}$ and the condition $\boldsymbol{a^1} \le a_1 \le \boldsymbol{a^2}$ is met. Affine-like FS (having the form of source FS) corresponds to the input variable as well as tensor-variable corresponding to a_1 and has the form of

$$\boldsymbol{T}= \begin{array}{|c|c|c|}\hline 0 & 0 & 0 \\ \hline a^1\mu^2_a & a_1\mu^2_a & a^H{}_1\mu^2_a \\ \hline 0 & 0 & 0 \\ \hline \end{array} \begin{array}{l} \boldsymbol{\mu^1_a=0} \\ \boldsymbol{\mu^2_a} \\ \boldsymbol{\mu^3_a=0} \end{array}$$

On the basis of the theorem on invariant multipliers for affine-similar matrixes (fig. 2), it is possible to write correlation $a^2/\mu^2_a = a_1/\mu^2_a$ and from this it follows that $\mu^2_a = / a^2$, $\mu^2_a = 1$.



I F input variable $\tilde{a} \Rightarrow T^a$
has value $a_1 \rightarrow T_{a_1}$

THEN output variable $\tilde{b} \Rightarrow T^b$
has value $b_1 \rightarrow T_{b_1}$ 1

Fig. 2. Simple fuzzy conclusion in the system of tensor-variables: blue colour – initial FS (tensors T^a, T^b accordingly), green and red colour - concrete values of premises and conclusions, for which bringing out is fulfilled

Example fig. 2 corresponds to such values : source FS : ***A***- x /μ/ = <**approximately 5** >=[1 5 9]/ [0 1 0], ***B*** - *y*= /μ = <**approximately 25** >= [20 25 30]/ [0 1 0]

Parcel $\Rightarrow$ *Conclusions*

a1= 3 (or **approximately 3**) ==> b1 = 22.5 (or **approximately 22.5**)

8 ==> 29

Example fig. 3 corresponds to the following values: initial FS : ***A***- x /μ= < **approximately 5** >=[1 5 9]/ [0 1 0.], ***B*** - *y*= /μ= < **approximately 25** >= [20 25 30]/ [0 1 0.]

Premises ⇒ *Conclusions*

a1= 3 (or **approximately** 3) ⇒ b1 = 22.5 (or **approximately** 22.5)

8 ⇒ 29

Corresponding tensors and graphs, illustrating the process of bringing out are given below. Tensor-variables

Tx =

0 0 0
1 5 9
0 0 0

Ty =

0 0 0
20 25 30
0 0 0

Tx1 =

0 0 0
0.5000 1.5000
2.5000
0 0 0

Ty1 =

0 0 0
20.0000 22.5000
25.0000
0 0 0

Tx2 =

0 0 0
1.4000 1.6000
1.8000
0 0 0

Ty2 =

0 0 0
28 29 30
0 0 0

Note that values b_1, b_2 have been received on the basis of invariant relation - from affine similarity of matrixes. In case when MF of FV(FN) are more complex functions, it is recommend to follow two ways:

- approximate the initial dependency of triangular (fig. 4);
- use a tensor of higher ranks, for instance, tensor, received on the basis of dyadic matrix from 9 x 9 couples "value - MF" and then to roll up to the tensor of the second rank.

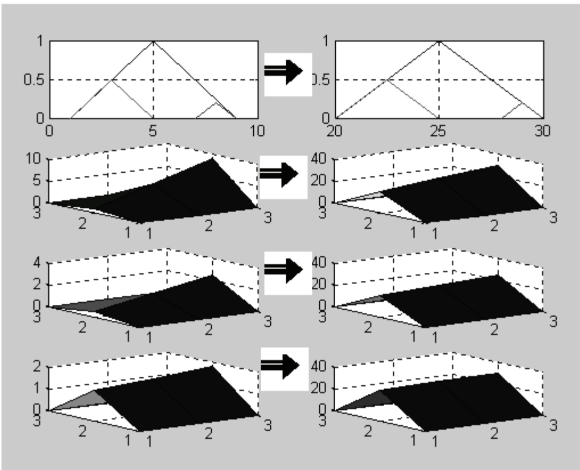


Fig.3. Simple fuzzy conclusion in the system of tensor-variables as an example

Similarly it is possible to define a simple conclusion in case of two fuzzy variables (fig.4).

Considering specifics of dyadic tensor which, with standard triangular MF, has only one line in its composition, as a model FV(FN),

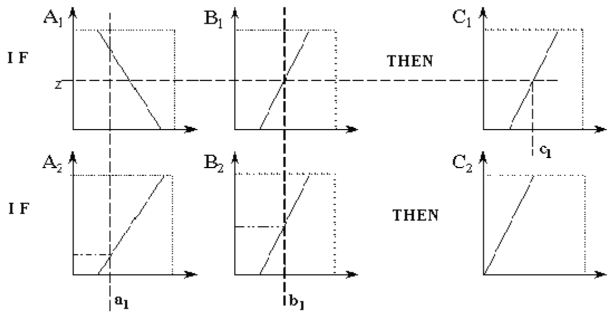


Fig. 4. Simple FI for two variables

It is possible to choose isotropic tensor which, for the tensor-variable $\widetilde{\mathrm{A}}$ and $\widetilde{\mathrm{B}}$, has the following type:

$$\widetilde{\mathrm{A}} \rightarrow {}^{\mathrm{iso}}T^{A}=\begin{bmatrix} a_2\mu_2 & 0 & 0 \\ 0 & a_2\mu_2 & 0 \\ 0 & 0 & a_2\mu_2 \end{bmatrix},\quad \widetilde{\mathrm{B}}\rightarrow {}^{\mathrm{iso}}T^{B}=\begin{bmatrix} b_2\mu_2 & 0 & 0 \\ 0 & b_2\mu_2 & 0 \\ 0 & 0 & b_2\mu_2 \end{bmatrix},$$

and μ_2 =1.

The rule FI can be formulated for isotropic tensors **if** $\widetilde{\mathrm{A}}$, then $\widetilde{\mathrm{B}}$ $\rightarrow$ **if** ${}^{\mathrm{iso}}T^{A}$, **then** ${}^{\mathrm{iso}}T^{B}$.

Using this rule we'll create the tensor equation ${}^{\mathrm{iso}}T^{A} \quad T^{\mathrm{P}} = {}^{\mathrm{iso}}T^{B}$
which is also fair for the first invariant of the initial tensor.

Solution of this equation allows to determine tensor elements of T^{P}. For the input concrete value of a_1, which is modulated by isotropic tensor ${}^{\mathrm{iso}}T^{\mathrm{a}}$, which elements are values of $a_1\mu^a{}_2$, respective isotropic tensor ${}^{\mathrm{iso}}T^{\mathrm{b}}$ is determined, which elements are values $x=b_1\mu^a{}_2$, whence $b_1=x/\mu^a{}_2$.

Conclusion

Tensor Presentation FV(FN) allows in full volume to realize fuzzy inferences, which practically coincide (or are not the worst ones) from conclusions, which can be received by standard presentation of FV(FN) as FS.

References

1. *Жуков І.А., Мінаєв Ю.М., Філімонова О.Ю., Гузій М.М., Давиденко В.В.* Ідентифікація атак на комп' ютерні мережі на підставі тензорного нейромережевого базиса // Проблеми інформатизації та управління. – К.: НАУ, 2004. – Вип.9. – С.3-10.
2. *Жуков И.А., Минаев Ю.Н., Филимонова О.Ю.* Алгоритмы прогнозирования временных рядов на основе тензорніх инвариантов // Матеріали 12-ої міжнародної конференції з автоматичного управління (30.05 – 3.06.2005 р.). – Харків, 2005. – С. 33-35.
3. *Минаев Ю.Н., Филимонова О.Ю.* Тензорный базис в концепции нечеткости и формальных методах // Материалы 10-й международной конференции по автоматическому управлению (15-19 сентября 2003 г.). – Севастополь, 2003. – С. 154-156.
4. *Минаев Ю.Н., Филимонова О.Ю.* Тензорный базис как основа новых алгоритмов решения задач управления в условиях неопределенности // Новые информационные технологии: Сборник трудов VI Всероссийской научно-технической конференции (23-24 апреля 2003 г.). В 2-х кн.. Т.1 / Под общ. ред. А.П.Хныкина. – М.: МГАПИ, 2003. – С. 142-147.

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MODELING AND CONTROL OF NOISE AROUND AIRPORTS

This paper gives an overview of ways to assess the noise situation at EU airports and how action plans may be established, taking into account recent developments in EU legislation.

1. Current situation

Aircraft noise has become a major problem at European airports. Many airports (will) see their capacity affected by constraints imposed by noise issues, before reaching their 'physical' limits due to runway use and/or air traffic control.
In a recent study performed by Anotec for DG-TREN[1] aircraft noise exposure around all (51) major EU airports was determined. The evolution of the noise climate between 2002 and 2015 was assessed for various growth scenarios. One of the main conclusions drawn in this study is that, if no further actions are taken, the total number of people in the EU affected by aircraft noise will increase in the period considered, even in the most conservative growth scenario.

2. Legislative framework

Applicable legislation may be subdivided into that, related to the aircraft (noise certification of aircraft types) and that, related to the noise at airports.
As part of the so-called type certificate, each aircraft type must comply with specific noise limits (Chapters), which have become more stringent over the years. Since April 1, 2002, the noisy Chapter 2 aircraft are banned from all EU airports. Currently all aircraft shall comply with Chapter 3. All aircraft, designed from 2006 onwards, shall comply with the new Chapter 4, which reduces the Chapter 3 limits by 10 dB. Although this seems an important improvement, in reality the majority of currently available aircraft already comply with Chapter 4.
With respect to the airports, in 2002 two important EC Directives came into force:

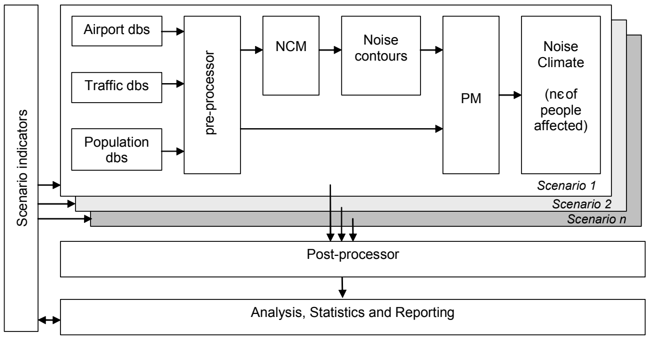
- 2002/49/EC (the Environmental Noise Directive or 'END')
- 2002/30/EC (the Operational Restrictions Directive or 'ORD')
  - The first requires the elaboration of strategic noise maps and action plans for all major airports, whilst the second gives guidelines on what kind of actions may be taken, within the framework of the so-called Balanced Approach (BA). These Directives are to be transposed to national legislation, thus providing a uniform methodology within the EU.

3. Noise mapping

The most appropriate way to assess the noise situation at an airport is by means of noise mapping, in which noise contours are established by a prediction model, which are then combined with population information to establish the number of people affected.
For a noise mapping exercise the following information is required:
- airport data (runways, etc)
- traffic data (number of operations, fleet mix, etc)

[1] "Study on Current and Future Aircraft Noise Exposure at and around Community Airports" – contract nº B2002/B2-7040B

- tracks (SIDs, STARs, distribution of flights among the tracks)
- flight procedures (standard or noise abatement procedures)
- population (census, topography, etc)



The current generation of noise models (INM, ECAC Doc 29(R), SONDEO-see figure) are of the integrated type, in which source and propagation are available as a combination only. These models are therefore quite simple and fast.
A next generation of models is becoming available, in which spectral and directivity information of the noise sources is used in order to be able to simulate more realistic flight procedures and propagation effects (FLULA, SOPRANO, IMAGINE). These models require more detailed information and computer power and their use as general methods for noise mapping is still under discussion.

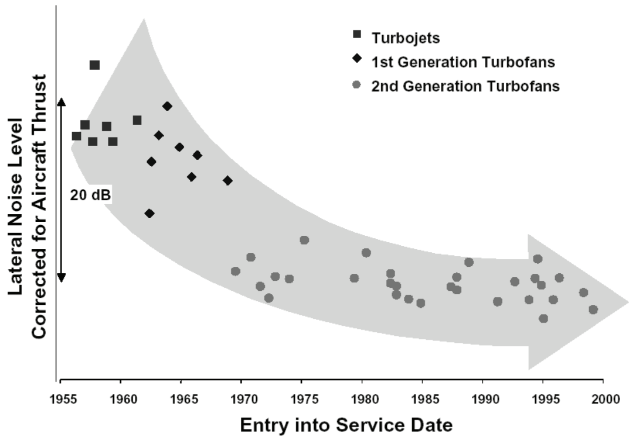
4. Corrective measures

The action plans required to improve the noise situation around airports will have to be elaborated in the framework of the Balanced Approach (BA)

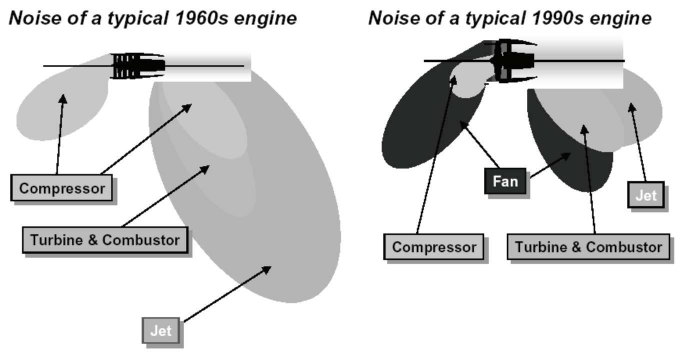
The main elements of the BA are:

- Noise reduction at source
- Noise abatement operational procedures
- Land use planning and –management
- Operating restrictions

<u>Noise reduction at source</u>
Since the introduction of civil jet aircraft some 40 years ago, an important reduction in perceived noise level for each aircraft movement has been achieved. This is mainly the result of the development of low-noise component technology by aircraft- and engine manufacturers. Compared with early turbojets and first generation turbofans, second generation turbofans show a significant reduction in jet noise.



As can be seen from the above figure, the noise reduction is levelling off. In current aircraft and engines, almost all noise sources (fan, jet, airframe) have become equally important. To reduce the overall noise, all sources should be reduced with a similar amount, thus requiring a major technological and economical effort. At present various European research projects are running in which new noise reduction technology is being developed and evaluated by all major players in the field of aircraft noise.



Noise abatement operational procedures

The possibilities for the introduction of noise abatement operational procedures are mainly conditioned by safety issues. These procedures should not be introduced unless it has been confirmed that a noise problem exists. Among these procedures the most important are:

- use of noise preferential runways
- use of noise preferential routes (SIDs and STARs)
- use of low noise flight procedures (e.g. CDA - Continuous Descent Approach)

These procedures are usually 'tailor-made' for an airport and may be used to reduce noise exposure in certain areas, depending on the population distribution around the airport. Care should be taken that procedures designed to reduce noise exposure in certain areas, do not generate more noise in other areas, unless these are noise-insensitive.

In a wider context, the relationship with emissions should be addressed.

Land use planning and –management
Land use planning is used to increase the compatibility of the land use with the airport activity. This can be accomplished by changing the noise sensitivity of the areas around the airport, for instance by replacing noise sensitive use (houses) by less sensitive use (industry).

Various instruments are available within this element:
- Planning instruments (e.g. noise zoning)
- Mitigating instruments (e.g. noise insulation, reallocation, noise barriers)
- Financial instruments (economic incentives, noise charges)

Land use planning is considered a very important instrument to prevent that benefits, obtained with complementary measures (e.g. noise reduction at source), are offset by an increase in noise sensitive areas closer to the airport due to the reduced noise level (encroachment).

Operating restrictions
Under the BA, an operating restriction is defined as "any noise-related action that limits or reduces an aircraft's access to an airport".

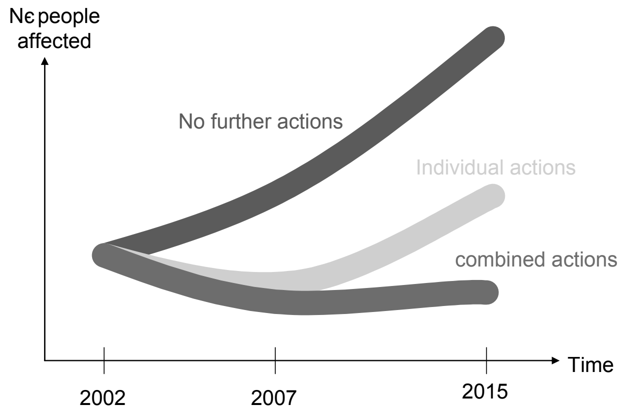
Operating restrictions should only be used after considering the benefits of other measures under the BA. If they are introduced, they should be of a partial nature wherever possible. Economical issues should also be addressed, e.g. by a gradual introduction.

Two main categories of restrictions can be distinguished:
- Noise related restrictions of traffic
  - Limit number of movements or the total noise energy produced
  - Curfews, limiting operations during a certain period of time
  - Noise quota
- Restrictions of use
  - Limit use of specific aircraft, based on their noise and/or flight performance. The indicator(s) to be used for the noise performance shall be the certification levels or derivatives thereof (sum, average, margin)
  - Limit ground operations (engine run-up, APU)

5. Action plans

In the aircraft noise exposure study mentioned above, the SONDEO model was used to simulate the application of the various elements of the BA, so as to assess their effectiveness on improving the noise climate around the airports.

The results of this exercise where similar for all elements: when applying actions individually, the noise climate (at EU level) will be maintained constant or might improve slightly in the short term (2007), whereas deterioration can be expected in the longer term (2015). Any benefit obtained will at the end be fully offset by the traffic growth. Thus, no single (practical) action will be able to guarantee a stable noise climate in the future.



Depending on the local situation and the actions already implemented at an airport the result of action plans may differ for individual airports.

In general, however, it is recommended that any action taken should be accompanied by complementary measures so as to create sufficient margin to accommodate the increased noise exposure due to traffic growth.

6. Conclusion

Significant progress has been made in reducing aircraft noise over the past 40 years. In the future technology will continue to play a significant role in reducing the noise around airports. It is crucial, however, that technology is not considered in isolation, but in the broader context of the balanced approach. All possible cost-effective means to improve the noise climate must be explored. The noise benefits achieved by technology advances must be protected through proper land use management around airports.

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3PRISK – TOOL FOR THIRD PARTY RISK ASSESSMENT AROUND THE AIRPORT

Typical third party risk analysis methods consist of three submodels: an accident probability model, an accident location probability model and an accident consequence model. The results of these submodels are combined to calculate individual risk levels, which are usually presented as risk contours on a topographical map, and societal risk of probable hazards.

1. Introduction

Airports are centres for air traffic in the air transportation system. Consequently, their presence causes a convergence of air traffic over the area surrounding the airport. For the population living in the vicinity of an airport this implies involuntary exposure to the risk of aircraft accidents. It became obvious that only the larger airports carried out any form of airport-specific risk assessment as are carried out for similar installations such as oil refineries [1].

Firstly, the chances of accidents occurring and their effects when they do occur are reduced as much as is reasonably practicable (ALARP principle) through measures taken at the source of risk. Secondly, the number of people exposed to the effects, should an accident occur, is reduced by a zoning policy [2]. Two measures are used in defining these policies: the individual risk as a measure of the level of protection offered to each individual member of the public, and the societal risk as a measure of the disaster potential for the society as a whole. No new dwellings or vulnerable destinations, like hospitals and schools, are allowed within the individual risk contour of 10^{-6}. Less vulnerable destinations, like offices, are allowed in the zone between the individual risk contours of 10^{-5} and 10^{-6}. A policy for Public Safety Zones (PSZ) is under development (in UK, The Netherlands, Germany, USA) to replace land use restrictions that have been in place for a number of years. PSZ are established in the same way as noise zones [3].

Risk assessment produces contour maps defining locations at risk, which can extend over several kilometres from runway thresholds. There are usually three zones, an initial zone closest to the runway identified by a 10^{-4} contour; an inner zone with a 10^{-5} contour; and an outer zone where risk is greater than 10^{-6}. These are the chances of an individual on the ground being killed or injured annually by an aircraft crashing. There is also the additional question of societal risk, a general public aversion to the large numbers of casualties that can arise from transport or industrial accidents.

Third party risk around airports should be carried out and strict land use policies developed to reduce the numbers of people at risk, preferably with independent Health and Safety authorities taking the leading role [1].

2. ICAO requirements to third party risk around airports

Major airport development plans, such as building additional runways, almost invariably involve government decision making and public inquiries. Therefore, public perception of the local consequences of developments is of paramount importance. A method to assess third party risk around airports has been firstly developed in the Netherlands by the National Aerospace Laboratory (NLR) in Amsterdam . This method is in general terms described in Appendix 2 of [3]. Currently the improvements of this methods are under consideration in the Netherlands [4], UK [5,6], Germany, USA [7] and in the National Aviation University [8-10], Ukraine.

3. Definitions of third party risk

Risk is generally defined as a combination of the probability of an event and the severity of that event. For third party risk analysis two dedicated measures of risk are often used: individual risk and societal risk.

Individual risk is defined as the probability (per year) that a person permanently residing at a particular location in the area around the airport is killed as a direct consequence of an aircraft accident. Societal risk is defined as the probability (per year) that more than N people are killed as a direct consequence of a single aircraft accident.

While individual risk is location specific, it is present regardless of whether or not someone is actually residing at that location; societal risk applies to the entire area around the airport and hence is not location specific within that area. Societal risk only exists when people are actually present in the area around the airport. In an unpopulated area, individual risk levels may vary from location to location, but societal third party risk is zero by definition.

In 1992, an El Al Boeing 747-200 cargo aircraft crashed into a residential building in Amsterdam, The Netherlands resulting in 39 fatalities. Since this accident, The Netherlands has had no ground fatalities. Ground fatalities peaked in 1996 when a cargo aircraft crashed into a busy open-air market in Kinshasa, Congo killing 297 people. Terrorist attacks with usage of five aircraft in USA on 11^{th} of September 2001 killed more than 3.5 thousands people on the ground.

4. Third party risk calculation methodology

Usually a method used to calculate third party risk around airports consists of three main elements: 1) accident probability model; 2) accident location model; 3) accident consequences model.

Accident probability model determines the probability of an aircraft accident per movement in the vicinity of the airport. This probability depends on the probability of an accident per aircraft movement (the accident rate) and the number of movements (landings and take-offs) carried out per year. The accident rate is not constant over time. Due to a steady improvement in the level of safety of aviation, coupled with volume growth, the accident rate has decreased at a diminishing rate over the years. The development of the accident rate over time is modelled by a statistical function which can subsequently be used for extrapolations to estimate future accident rates.

Large differences exist in safety levels between different types of operation and different regions of the world, thus a careful data domain definition is required to give airport specific results.

The fatal accident rate is significantly higher for propeller aircraft than it is for jet aircraft, fig. 1. This doesn't mean that propeller aircraft are less safe with respect to design, certification and requirements/legislation.

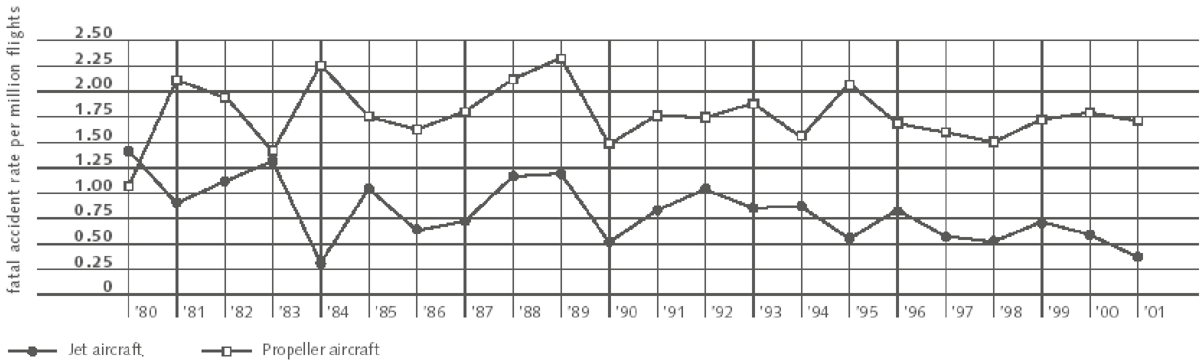

Figure 1 - Fatal accident rate, propeller and jet aircraft

Among other things, the higher rate is due to short flight times, cargo operations, domicile of the operators and probably the increasing age of propeller aircraft. Due to the rise of Generation 3 aircraft with advanced on board technologies, the fatal accident rate has somewhat decreased at the end of the 90's. Aircraft generation - a distinction among aircraft types based on certification year and applied technology: - Generation 1 is defined by aircraft design and technology pre-1965 including the DC-8, Fokker F27, and Boeing 707; - Generation 2 is defined by aircraft design and technology from the late 60's and 70's including Airbus A300, Boeing 737-100/200, DC-9 and DC-10; - Generation 3 is defined by aircraft design and technology from after 1980 including Fokker F100, Airbus A340/330, and Boeing 757/767/777. These aircraft are equipped with modern technology.
Accidents depend highly on phase of aircraft operation, Tab. 1. There are many classification currently exist for describing accident rates, for example Boeing approach is shown in Tab. 2.

Table 1

Accidents by phase of operation

Phase of Operation	Percent of Total	Proportion Fatal/Serious
Standing	1.1	34.6
Taxi	3.5	11.0
Takeoff	18.2	28.9
In Flight:		
Climb	2.8	46.3
Cruise	11.8	41.5
Descent	4.9	58.9
Maneuver	12.6	58.4
Total	32.1	46.3
Landing:		
Approach	10.0	42.5
Landing	33.9	11.3
Go- Around	0.3	27.3
Total	44.2	42.5
Other/Unknown	0.9	83.6
All Accidents	*100.0*	*31.4*

Note: Data includes all (20,399) U.S. general aviation accidents by all aircraft types for the period 1990–2000

Table 2

Summary of Boeing classes and aircraft crash rates

Aircraft class	Crash rate (crashes per million movements)
Class I Jets	1.113
Class II-IV Jets (passenger)	0.148
Class II-IV Jets (non passenger)	0.444
Eastern Jets	0.874
Executive Jets	2.23
Turboprops T1 (passenger)	0.288
Turboprops T2	0.782
Turboprops T1 (non passenger)	0.864
Turboprops unclassified	0.782
Miscellaneous and Piston Engine ('Small')	3.27

Accident location model determines the local probability of an accident that is not equal for all locations around the airport. The probability of an accident in the proximity of the runways is higher than at some distance from the runways. Also, the local probability of an accident is dependent on the proximity of routes followed by arriving and departing air traffic. The probability of an aircraft accident is larger in the proximity of a route and decreases with an increase in distance. Consequently, the local probability of an accident is strongly dependent on the position of the location relative to runways and traffic routes.

The accident location model is based on historical data on accident locations. The distribution of accident locations relative to arrival and departure routes or relative to the runway is modelled through statistical functions – probability density functions (PDF). By combining the accident location model with the accident probability, the local probability of an accident can be calculated for each location in the area around an airport.

The PDFs for a given grid point are functions of the perpendicular distance (x) from the (extended) runway centreline and the longitudinal distance (y) from the appropriate runway end in the form:

$$f(x, y) = f_y(y)\, f_{x/y}(x, y),$$

where $f_y(y)$ a function representing the longitudinal location along the direction of the extended runway centreline, it is derived from y co-ordinate data, $f_{x/y}(x, y)$ - lateral distribution perpendicular to the runway centreline, it is derived from x co-ordinate data, for which the corresponding y co-ordinate is known. The PDFs are better represented by the Gamma and Weibull distributions. The PDFs are calculated at each grid for the to four different accident types: take-off overrun; landing overrun; landing undershoot; take-off overshoot, fig. 2. In UK approah last two cases are named crashes from flight.

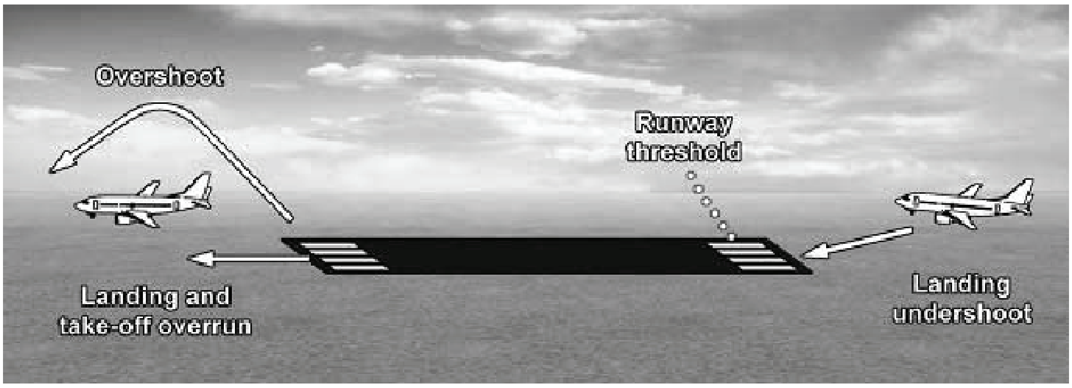

Figure 2 - Four typical accident types, used for risk analysis

Accident consequences model must define probable damages inside accident location. When an aircraft collides with a small building, the results can range from insignificant to catastrophic. A person residing in the vicinity of an airport is not only at risk when a aircraft accident occurs at this person's exact location, but also when an accident occurs in this person's close proximity. Injuries to people on the ground (i.e., people who are not occupants of the aircraft) as a result of general aviation aircraft accidents occur even less frequently than collisions with buildings. The accident consequences may have lethal effects at considerable distances from the impact location. Over the period examined, only 3.1 accidents per year resulted in fatal or serious injuries to people in a building. The dimensions of the accident area are not only a function of the aircraft and impact parameters but also of the local type of terrain and obstacles. Consequently, the size of the accident area is not equal for every location around the airport.

The consequences of an aircraft collision with a target on the ground were found to be affected by many variables. Among the primary ones are: the aircraft weight; the amount of fuel on board; the speed of the aircraft, both horizontally and vertically, at the time of the collision; the angle of contact with the structure (i.e., glancing or head-on); the aircraft attitude when the collision occurs; the extent of aircraft disintegration upon impact; the type of building construction, particularly the composition of the surface struck by the aircraft; and the occurrence and extent of fire after the impact.

The first step in this process is to estimate the frequency of the aircraft crash hitting the building. The standard 4-factor formula is used as shown below for facilities located in the airport flight environment:

$$F = N \; P \; f(x,y) \; Aeff,$$

where F - Aircraft crash hit frequency on to the facility (crash hit/year);

N - Number of relevant flight operations (operations/year);

P - Aircraft crash rate (specific for takeoff and landing, for particular type of the aircraft);

$f(x,y)$ - Aircraft crash location function - probability density function.

A_{eff} – Effective area of the possible target on the ground.

For the risk contour assessment the same formula is used excluding the component - effective target area. To define the contour – the risk values must be calculated in the grid points and the interpolation lines (for predefined values of the risk) are determined for the grid under consideration.

5. Conclusion

Third party risk assessment and its prevention measures become necessary component of Environmental Impact Statement for airports. Necessary calculation and grounding tool are designed in a good compliance with legal requirements.

References

1. Jeffrey Gazzard. Environmental Policies at Europe's Airports. Friends of the Earth Netherlands (Vereniging Milieudefensie) Publication, Amsterdam, The Netherlands & Knutsford, UK, 1999. – 116 p.
2. G.M.H. Laheij, J.G. Post, B.J.M. Ale. Standard methods for land-use planning to determine the effects on societal risk //Journal of Hazardous Materials, v. 71, 2000. – P.p. 269–282.
3. Airport Planning Manual. Part 2. Land Use and Environmental Control. - Montreal, Canada, ICAO Doc. 9184-AN/902/2, 3-rd ed., 2003. – 35p.
4. Piers M.A. et. al., The development of a method for the analysis of societal and individual risk due to aircraft accidents in the vicinity of airports, NLR CR 93382 L, NLR Amsterdam, 1993.
5. Public Safety Zones: A Consultation Document. DETR, UK, 1997.
6. Third Party Risk at Airports and Public Safety Zone Policy: A Review for the Department by Consultants, UK Department of Environment, Transport and the Regions, 1997.
7. Accident analysis for aircraft crash into hazardous facilities // DOE-STD-3014-96U.S. Department of Energy, 1996.
8. Запорожець О.І., Хайдар Х.А. Контуры риска третьей стороны в окрестности аэропортов ГА // Вісник НАУ, Київ, № 4, 2001. - С. 166-171.
9. Запорожець О.І., Хайдар Х.А. Модель визначення місця авіаційної події повітряного корабля // Вісник НАУ, Київ, № 2, 2002. - с. 124-128.
10. Запорожець О.І., Хайдар Х.А. Вероятностная модель оценки последствий авиационного происшествия в районе аэропорта // Матеріали IV Міжнародної науково-технічної конференції "АВІА-2002", Секція 25 - "Безпека транспорту і захист довкілля", НАУ, Київ, 23-25 квітня 2002. - с. 25.25-25.27.

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ISOBELLA – TOOL FOR AIRCRAFT NOISE CONTOUR ASSESSMENT AROUND THE AIRPORT

Aircraft noise levels calculations are performed for several purposes, including the noise zoning around the airports. With reference to this issue, noise contouring is a necessary tool, and its accuracy is a matter of high importance. Some differences in national method for aircraft noise assessment in vicinity of the airport and new ECAC/AIRMOD methodology (Doc 29R, 2004) are analyzed.

1. Introduction

Aircraft noise calculations method in Ukraine has been developed in 1997 in full accordance with the requirements of ICAO Cir. 205. Mostly it was in accordance with the main features of ECAC approach (Doc 29, 1997). Main purpose of the Ukrainian method elaboration (1997) was to support the national regulation on aircraft noise zoning in the vicinity of the airports.

During the last years new results of investigations of the aircraft noise impact were received and used to improve the calculation method. These improvements referred to noise radiation and propagation assessment, and at that their implementation in calculation procedures provided increased accuracy and validity of the calculated levels and contours.

2. Brief Review of the Calculation Method

Current version of the Ukrainian calculation technique entirely complies with ICAO Cir. 205, ECAC Doc 29, and INM 6.0 Technical Guide. This calculation procedure includes the following main stages:

1) Flight path designing along prescribed flight ground tracks;
2) Noise indices calculation within a grid or discrete points;
3) Noise contour definition for specific values of the noise indices.

Concerning noise indices, L_{Amax} and L_{Aeq} are of the main interest because they provide a basis for noise zoning regulations.

At the first stage the Ukrainian method is similar to the current ECAC technique:

- Flight paths must be built along ground tracks around the runways of the airport under consideration like flight profiles;
- Flight profiles are calculated for previously defined flight stages, such as take-off roll, climb (descent) with acceleration (for example, during flap retraction phase) or at the constant speed etc.

Main difference in assessment of the take-off roll and safety distance (till height 10.7 m) between the current national method and ECAC technique consists in direct calculation of roll distance under Miele approach [1] and accelerated climb with gear retraction till height $\boldsymbol{h}$ =10.7 m and safety speed $\boldsymbol{v_2}$ at this height. Other flight stages are calculated in the same manner as it is proposed in

ICAO Cir. 205 and ECAC Doc 29, while not using the averaged coefficients, but real lift and drag coefficients (using of real aircraft polara) and real thrust functional dependence on engine mode, flight altitude and speed. Of course, such approach is possible provided that aircraft/engine parameters are known.
New international Aircraft Noise and Performance (ANP) Database allows to extend applicability of the national method owing to including the aircraft types that were missed in the national database used for current method.

3. Noise Level Calculation

Noise level calculation for discrete or mesh points of the grid are based on usage of NPD-relationships, typical for the aircraft/engine. Corrections to them must be provided with account of ground effect, directivity of noise radiation, sound shielding, installation effects etc.
NPD-curves named in the national method as Noise Radiuses [2] are defined in the same manner for reference conditions, which are mostly required for noise zoning assessment (merely the same as in ICAO Cir. 205). In particular cases, different from the reference flight conditions, Noise Radiuses are to be recalculated.
So, for exposure indices the flight speed influence may be considered using known functional dependence [2] between Noise Radius $\boldsymbol{R_N}$ (i.e. distance for particular mode and index value) and flight speed $\boldsymbol{v}$:

$$\boldsymbol{R_N}\,\boldsymbol{v} = const.$$

Different atmosphere operation factors, such as air temperature, noise radiation and air absorption may contribute essentially to NPD recalculation. Therefore the aircraft/engine reference spectra are used, just as in the new ECAC approach or INM current version. For noise radiation the recalculation is performed with account of dominant noise source for aircraft and the flight mode (stage) under consideration. There are three possible dominant sources considered under the current national technique: jet (usually, by-pass jet), fan (in forward and upward directions of noise propagation) and an airframe. Specific corrections for noise indices are included in the functional dependence on dominant source.
For different air absorption features the correction is performed just as in the new ECAC approach, but according to ISO 9613-1 [4] calculation scheme for coefficients and recalculated spectrum.
Directivity patterns are defined for various aviation engine types (Fig. 1), and at that not only general pattern corresponding to ICAO Cir. 205 [3] model (applicable exclusively for jets) is used, but the specific directivity patterns of particular engine types, as well.

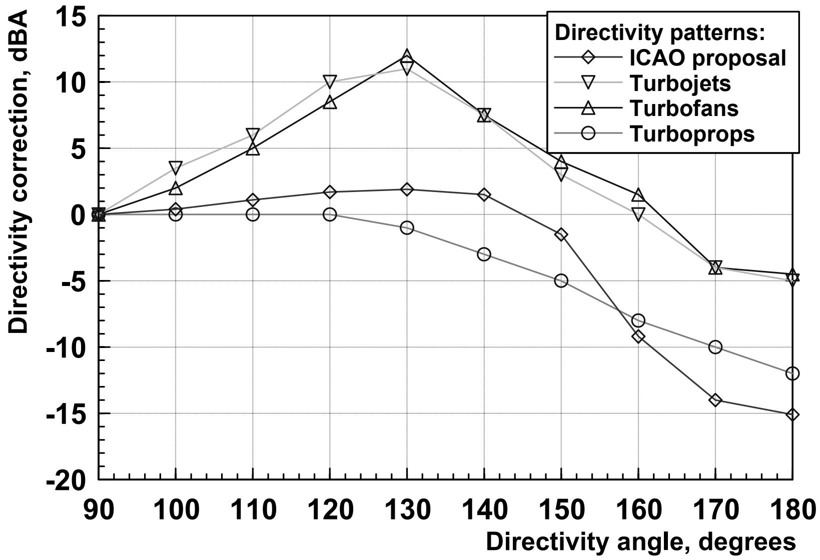

Fig. 1. Generalised directivity patterns for specific engine types

Installation effects are not considered by the current national methodology, but recent investigation concerning few types of the aircraft would produce possible corrections for engine installation, which are representative for flight turns and sideline control points at the noise calculation.

Ground effects are calculated under the routine procedure with account of surface covering effect and use of reference noise spectrum (LATER-generator in IsoBell'a software). SCREEN-generator is used for assessment of shielding effect (Maekawa model, [5,6]).

4. Contour Calculation

Noise contours are defined for pre-calculated levels in the mesh points of the grid using well-known Wasmer Consulting method (*www.wasmerconsulting.com*), which is used in INM and NoiseMap software in a same manner.

5. Results of noise contours calculations by use of INM 7.0 and Isobell'a 2.0

5.1. Choice of airport and scenario

As it was proposed previously the International Airport Borispol' has been chosen for calculation of aircraft noise contours using two soft-wares – USA FAA INM 7.0 [7,8] and Ukrainian IsoBella. Scenario for calculation was defined grounding on 1998 details, because this year most part of flights was performed by aircraft of Russian and Ukrainian production. Thus it was interesting to compare the calculation results for real data for aircraft flight and noise performances, used in IsoBella, and for their substitutions, used in INM. The daily number of flights of FSU aircraft are shown in Tab. 1. Only day and night periods were included, because in 1998 the evening period did not considered at all.

Table 1

Aircraft type	Day	Evening	Night
TU-154	12.0000	0.0000	2.0000
TU-134	9.0000	0.0000	2.0000
YAK-42	3.0000	0.0000	0.0000
AN-124 (Ruslan)	3.0000	0.0000	0.0000
AN- 24	5.0000	0.0000	0.0000
IL-62	3.0000	0.0000	0.0000
IL-76	3.0000	0.0000	0.0000
IL-86	2.0000	0.0000	0.0000

5.2. Noise contours to be calculated

Concerning the indices to be calculated, the meeting recommendation to follow the EC Directive 2002/49 rules was used. Therefore, L_{DEN}, L_{night} were calculated, plus L_{Aeq}, which is used in Ukrainian norms. The values to be calculated are following: 55, 60, 65, 70 and 75 dB.

5.3. Results of calculation

For IsoBella output results NMPlot ver. 4.93 was used, to be sure that contouring is defined in a same manner as in INM [7]. For that Wasmer Consulting Noise Model Grid Format (NMGF) was implemented in IsoBella. The calculated areas of the contours are shown in Tab. 2-4 accordingly.

Table 2

Noise contour area (in sq. miles) for L_{Aeq}

Noise level, dBA	IsoBella	INM	IsoBella/ INM
55.0	91.973	62.270	1,47
60.0	29.705	26.397	1,125
65.0	12.422	11.829	1,05
70.0	5. 543	5.614	0,99
75.0	2.772	2.597	1,07

Table 3

Noise contour area (in sq. miles) for L_{DEN}

Noise level, dBA	IsoBella	INM	IsoBella/ INM
55.0	48.240	37.729	1,28
60.0	18.700	16.593	1,127
65.0	8.340	7.900	1,055
70.0	4.145	3.874	1,07
75.0	1.942	1.346	1,04

Table 4

Noise contour area (in sq. miles) for L_{Night}

Noise level, dBA	IsoBella	INM	IsoBella/ INM
55.0	15.336	15.196	1,01
60.0	6.198	6.894	0,9
65.0	3.002	3.437	0,873
70.0	1.348	1.190	1,133
75.0	0.572	0.502	1,14

5.4. Explanation of the results

For the contours of the main interest the difference between their areas do not exceed 10-15 %, higher results mostly are calculated by IsoBella software. This overestimation is possible because the NPD values, used currently in IsoBella, are the simple statistical values, defined from measurements made USSR-wide without strict solutions for aircraft noise model tasks. This work is doing now, but it may be finished correctly, when the ANP database will be on-line at http://www.aircraftnoisemodel.org with all necessary requirements for such performances.
Besides the theoretical ground of the calculation models are strictly compared too.

5. Conclusion

The differences between the methods are analysed for particular flight events and aircraft types. The findings are applicable for specific cases of the aircraft noise calculation. Thus some features of Ukrainian calculation method may be recommended for implementation in ECAC model.
The results presented here were presented in AIRMOD workshops (November 2004 and April 2005) held in ECAC Office.

References

1. Miele A. Flight mechanics. P. 1. Theory of flight trajectories. - Moscow: Nauka, 1965. - 407 p. (in Russian).
2. Zaporozhets O., Tokarev V. Aircraft noise modelling for environmental assessment around airports // *Applied Acoustics*, vol. 55, No 2, 1998, pp. 99-127.
3. Recommended Method for Computing Noise Contours Around Airports. - Montreal: ICAO, Circular 205 AN/1/25, 1988. - 25p.
4. ISO 9613-1:1996. Acoustics - attenuation of sound during propagation outdoors- Part 1: Calculation of the absorption of sound by the atmosphere
5. Zaporozhets O., Tokarev, V.I., Shylo, V.F. Influence of impedance characteristics of the reflecting surfaces on reduction of aviation noise by screens // *Proceedings of 4-th Int. Congress on Sound and Vibration*, St.Petersburg, vol. 2, 1996, p.1135-1140.
6. Maekawa Z. Noise Reduction by Screens // *Memoirs of the Faculty of Engineering*, Kobe University, Japan, vol. 12, 1966, pp. 472-479.
7. Integrated Noise Model (INM) Version 6.0 Technical Manual FAA-AEE-02-01, January 2002, U.S. Department of Transportation, Federal Aviation Administration, Office of Environment and Energy, Washington, DC
8. AIRMOD – Proposal ECAC.CEAC Doc 29 R – Volume 2, Version 6.0

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NOBEL – TOOL FOR NOISE SPECTRA ASSESSMENT AROUND THE AIRCRAFT WITH ACCOUNT OF GROUND AND SHIELDING EFFECTS ON NOISE PROPAGATION

The models of noise radiation and noise propagation are described as they are realized in software tool for aircraft noise assessment.

1. The complete model for noise assessment around aircraft

Sound pressure levels (SPL) from individual aircraft movement or aircraft on stand at the points (x,z) of a calculation grid are derived from the following formula:

$$SPL(x,z) = SPL_{R0} + \Delta SPL_{\Theta} + \Delta SPL_{AT};$$

$$\text{Д}SPL_{\text{З}} = \text{Д}SPL_{R} + \text{Д}SPL_{ATM} + \text{Д}SPL_{LAT} + \text{Д}SPL_{S}.$$

where SPL_{R0}, is the SPL from the noise source at reference distance R_0, SPL_{Θ} is the correction for the directivity of noise generation and propagation; ΔSPL_{AT} – noise propagation effects, which is consisting of the following: noise divergence ΔSPL_R on distance R between the aircraft and point of a grid; ΔSPL_{LAT} is the lateral (extra) sound attenuation for propagation path lateral to the direction of aircraft movement with distance R and angle of incidence β; ΔSPL_{ATM} is the correction for atmosphere attenuation; and ΔSPL_S is the attenuation by various screens.

2. The typical acoustic model of an aircraft

An aircraft may be represented by a set of noise matrices, each dependent on flight mode and consisting of sound pressure level spectra (*SPL* in a l/3-oclave band form) for a defined number of directions of sound propagation from the acoustic source [1]. In some cases the noise matrices are obtained experimentally, in others they are obtained by means of calculations based on the models for the particular acoustic sources [1-9], of interest for the aircraft under consideration. It is impossible to define the characteristics of all phenomena by means of analytical and semi-empirical models only. The most common phenomena determining or influencing the accuracy of noise matrices are the engine installation effects and noise abatement treatments. Insufficient accuracy of any model for particular noise source can be considered as additional factor but, even so, very accurate models have been used (within 1 dB(A) for a total spectrum assessment). Both experiments and calculations have some disadvantages and the derivation has been formulated to overcome them [1].

The sound pressure level spectrum $\{SPL_{jk})$ of aircraft noise of any type in spectral bands N_j, $j=1,N_j$, and in some k-th direction of sound propagation, where $k = 1, N_k$, with reference to previous considerations, can be defined by:

$$SPL_{jk} = SPL_{jkp} + \Delta SPL_{jk}$$

where SPL_{jkp} is the predicted value of SPL_{jk} resulting from a sum of particular models SPL_{jki} for characteristic noise sources, , $i = 1,..,N_s$; and $\Delta SPLjk$ are spectral corrections for differences between the predicted SPL_{jkp} and measured values SPL_{jk}. For each aircraft of interest, SPL_{jkp} is defined by:

$$SPL_{jkp} = \sum_{i=1}^{N_S} SPL_{jki} \qquad (1)$$

Spectral corrections are defined as the spectral transfer functions for the total acoustic model of the aircraft as follows:

$$\Delta SPL_{jk} = SPL_{jko} - SPL_{jkp} \qquad (2)$$

where SPL_{jko} are the experimentally observed values of SPL_{jk}. The observations must be carried out either during flight testing m accordance with noise certification requirements or during noise engine testing at the outdoor testing facility. In the latter ease, of course, various flight effects and airframe acoustic sources are excluded.

These spectral corrections are defined by solving the identification task for every type of the aircraft under consideration and they have typical values for them, thus they are the important components of the typical acoustic model of an aircraft too. Appropriate calculation algorithm (grounding on formula 1 and2) allows to define *SPL* in a l/3-oclave or octave band forms for every type of the aircraft in any direction for reference distance 1 m (Fig. 1) and then for distance *R* with account of any possible propagation effect (Fig. 2 and 3) along the sound path.

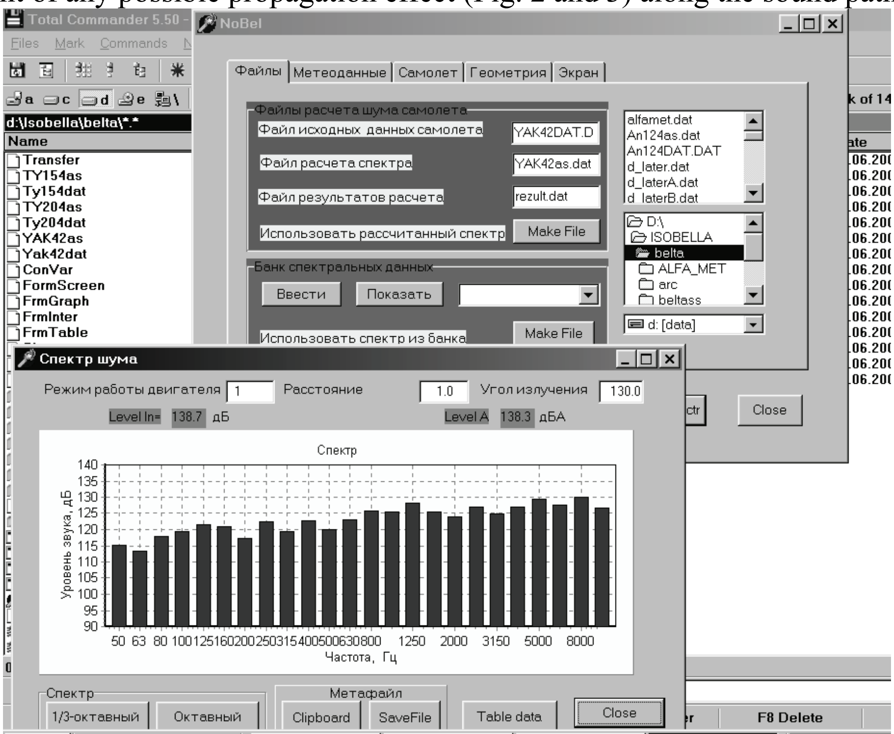

Figure 1 - l/3-oclave *SPL* assessed for the aircraft under consideration by software *NoBel*

3. Sound propagation effects

Sound attenuation in air (Fig. 2) is calculated in accordance with the requirements of the ISO standards [10]. All relationships for the extra ground attenuation of noise ΔSPL_{LAT} are based on approximate solutions of the reflection for spherical sound wave from locally reacting plane surface. The differences between the predicted attenuation effects on overall A-weighted levels for various types of the aircraft (engines) under the same conditions may be till 6 dBA. Differences between the magnitudes of lateral attenuation are considerable for different types of reflecting surfaces also (Fig. 3). Data obtained for grass surfaces have been used as the most appropriate for calculations of noise levels around the airports. All results have been obtained numerically with Soroka and Chien [11] approach to interference effects and with a semi-empirical model for impedance characteristics of reflecting surfaces [12].

Any type of screens may be used for noise abatement for ground stages of aircraft operations and maintenance (engine run-ups) around the airports. The effects of screens are assessed by means of specified model accounting for the effects of sound diffraction at screen edges [13], for interference of direct and every reflected waves from various kinds of impedance surfaces [14], for each type of noise spectra generated by the aircraft, etc. Spectral efficiencies of screens are shown in Fig. 3, they may be calculated for different conditions of noise propagation [14]. Predictions of *OASPL* (ΔL_{in}) and L_{Amax} (ΔL_A) for different types of noise sources under identical conditions are shown in Table 1, where

$$\Delta L = L_{without\ sreen} - L_{with\ screen}.$$

Table 1

Influence of noise source type and character of sound wave reflection on screen's efficiency

Type of noise	$\Delta L_A/\Delta L_{in}$ for character type of sound reflection		
	ground reflection absent	reflection from hard ground	reflection from impedance ground
Turbojet	12,9/ 10,9	8,3 / 6,1	12,0/7,9
Turbofan	15,5/ 8,8	10.8/3,8	13,7 / 5,7
Pink noise	13,8/ 8,5	9,1/ 3,5	12,6/5,9

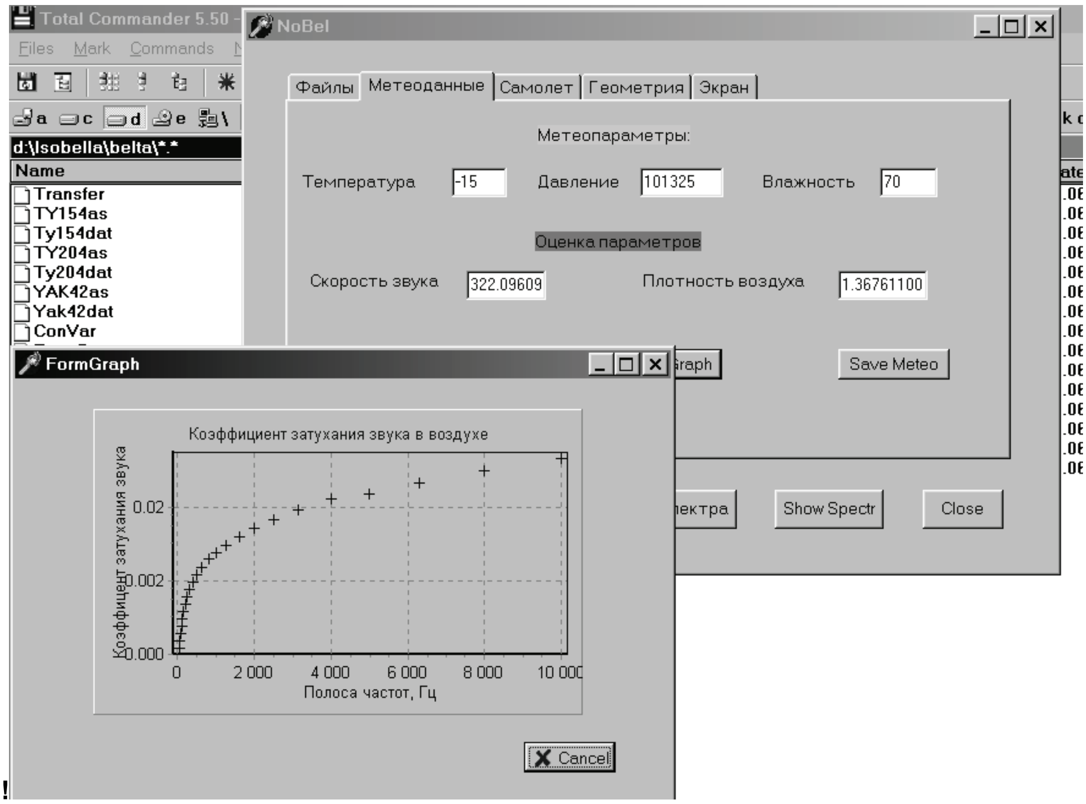

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Figure 2 - Sound attenuation in air module in software *NoBel*

4. Conclusions

Acoustic models and appropriate methods for aircraft noise predictions have been designed. They enable (a) assessment of noise levels around airports, for example to meet the requirements of Environmental Impact Statement procedures (b) investigations of the influence of various operational factors on noise impact and (c) derivation of the optimal solutions for decreasing noise impact in and around airports. The basic principles of the methodology are in good accordance with current national and international requirements for aircraft noise assessment methods.

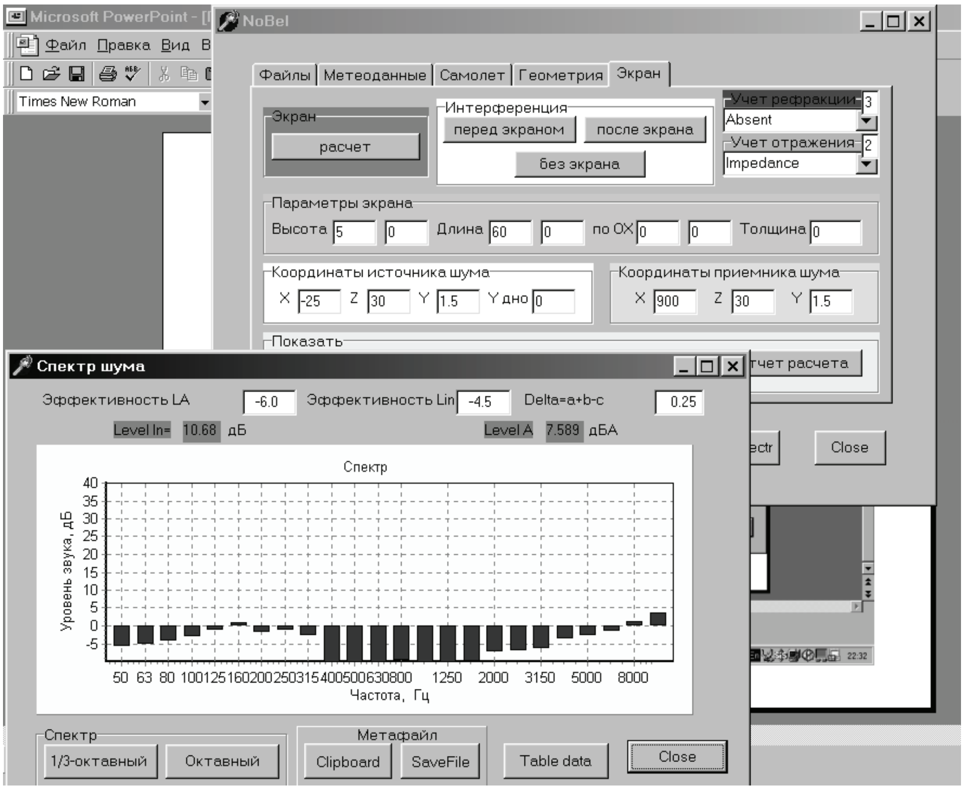

Figure 3 – Extra ground attenuation module in software *NoBel*

References

1. Zaporozhets O., Tokarev V. Aircraft noise modelling for environmental assessment around airports // *Applied Acoustics*, vol. 55, No 2, 1998, pp. 99-127.
2. ICAO Technical Manual for Environment Specified the Usage of Methods for Aircraft Noise Certification, Montreal, Doc. 9501 AN, 2004.
3. Bilwakes K.R. et al. Core engine noise control program. Vol.3 Prediction methods // AEGGEC FAA-RD-74-125.-1974. - 165 p.
4. Fink M.R. Airframe noise prediction method // FAA -RD-71-29. -1977. - 135 p.
5. Heidmann M. F. Interim prediction method for fan and compressor source noise // NASA, TMX-71763, 1975.-- 51 p.
6. Huff R.G., Clark B.I. Interim prediction methods for low frequency core engine noise // NASA, TM-71627, 1974. - 23 p.
7. Gas turbine jet exhaust noise prediction // SAE proposed. ARP-8761975. - 39 p.

8. Stone I.R. et al. An Improved Prediction Method for Noise Generation by Conventional Profile Coaxial Jets. *AIAA Paper-1991*, 1981, - 31 p.
9. Prediction Procedure for Near-field and Far-field Propeller Noise. SAE-AIR-1407, 1977, 22 p.
10. ISO 9613-1:1996. Acoustics - attenuation of sound during propagation outdoors- Part 1: Calculation of the absorption of sound by the atmosphere
11. Chien C.F., Soroka W.W. Sound propagation along an impedance plane // Jour. of Sound and Vibration, vol. 43, No 1, 1975. - p. 9 - 20.
12. Delany M.E., Bazley E.N. Acoustical properties of fibrous absorbaent materials // Applied Acoustics, vol. 3, 1970. - p. 105-116.
13. Maekawa Z. Noise Reduction by Screens // *Memoirs of the Faculty of Engineering*, Kobe University, Japan, vol. 12, 1966, pp. 472-479.
14. Zaporozhets O., Tokarev, V.I., Shylo, V.F. Influence of impedance characteristics of the reflecting surfaces on reduction of aviation noise by screens // *Proceedings of 4-th Int. Congress on Sound and Vibration*, St.Petersburg, vol. 2, 1996, p.1135-1140.

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POLEMICA – TOOL FOR AIR POLLUTION AND AIRCRAFT ENGINE EMISSION ASSESSMENT IN AIRPORTS

A number of models have been developed for the assessment of air pollution produced by aircraft activities inside airport area. It consists of the following basic components: engine emission inventory calculation; transport of the contaminants by engine jets; dispersion of the contaminants in atmosphere due to wind and atmospheric turbulence. The developed models include the influence of the operational factors and allow to determine the adverse conditions of the pollution, which are necessary for Environment Impact Statement calculations. Soft tool PolEmiCa was designed for air pollution and aircraft engine emission calculations.

1. Background

Aircraft (during approach, landing, taxi, take-off and initial climb of the aircraft, engine run-ups, etc.) are the dominant sources of air pollution at airports in most cases under consideration. There is a need to develop and implement models and methods for assessment of air pollution produced by aircraft engine emission [1-8].

Engine emission parameters [9,10] do not display yet total character and level of aircraft impact on environment. The factors, which may provide a difference between emission levels and air pollution concentrations, are following: - type of the engine in aircraft power unit; - configuration of power unit in aircraft design; - parameters of the gases in engine jet, first of all the velocity and temperature of the jet (defined by engine operation mode); - character of an aircraft movement (parking, taxi, movement on runway with creation of wake vortices behind a wing, etc.); - parameters of atmospheric stability and wind, so on. The important feature of the considered emission source is the presence of a jet of the fulfilled gases, which can be transported on a rather long distance, sizes of which are defined by engine type and operation mode, flight mode, meteorological conditions. There were many models developed elsewhere for that [1,11-14], but they are quite different from the approaches realized in national methods, currently in use for Environment Impact Statement of the main stationary sources of the air pollution. It was one of the main reason for developing of the *PolEmiCa* and appropriate models.

Basic components of the assessment are following: engine emission; transporting by jet; transporting by wind and atmosphere dispersion. Models provide the calculation for particular plume event (for considering of single event of contaminant discharge by aircraft or engine oneself) and for the scenario of aircraft movements inside the area of concern. First is important for understanding of monitoring results, second is important for Environment Impact Statement.

2. Engine emission module

Engine emission rate is the main factor of air pollution impact produced by aircraft both in lower atmosphere inside the airport area and/or in higher atmosphere at the aircraft cruise flight. For aircraft engine emission assessment and control during landing-take-off inside the airport area four types of contaminant are under consideration: nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbons (HC), smoke (particles of small fraction). In cruise flight few another contaminants become sufficient: carbon dioxide (CO_2), water (H_2O). The method, described here, concerns the pollution during landing-take-off of the aircraft. Engine emission is defined by the type of engines, their number in aircraft power plant, operation mode.

Under the real operating conditions, comparing with certification ones, emission indices (in g/kg$_{fuel}$) are subject to changes as result of influence of the meteorological factors:

$$EI_{it} = EI_{iISA}\, K_{Eii} \qquad (1)$$

where K_{EIi} are the factors of recalculation of emission indexes from ISA conditions EI_{iISA} into actual meteorological conditions EI_{it}.

For emission values (in g/s or kg/hour) the factors of recalculation K_{Qi} are determined by the formula

$$K_{Qi} = K_{EIi}\ (T_t/T_{ISA})^{1/2}. \qquad (2)$$

3. Modelling of the engine exhaust jets

The extent of jets of the fulfilled gases of aircraft engines can change within the distances of 20...1000 m and sometimes even more. The distance of contaminant transport by jet is defined by power setting, movement/flight mode of the aircraft, meteorological parameters.

There are following types of engines installed in power plants of the current types of the civil aviation aircrafts: turbojet, by-pass jet, turboprop, propfan and piston. The process of contaminant transport by jet is described by the theory of turbulent jets. The restrictions on use of the given theory satisfy to conditions of a considered task: the gas flow in jet is an isobaric process, the Mach number of jet at outlet nozzle of the engine does not exceed 2, Reynolds number for a flow is rather large ($U_0 d_0/\rho > 10^4$), initial turbulence in jet is moderate.

Measurements made everywhere show a buoyancy effect of the jet, which is caused by Arhimedes forces defined by excess of jet gases temperature over the air atmosphere temperature. The vertical co-ordinate Z_E of the jet axis is defined by height of buoyancy effect (Fig. 1)

$$Z_E = h_{EN} + \Delta h_A, \qquad (3)$$

where h_{EN} - height of the engines installation (of their axis above ground surface), Δh_A - height of plume rise. For an estimation of the buoyancy characteristics the Arhimedes number $Ar_0 = gD_0 (Q_T\text{-}1) /U_0$ is used, which can be applied as a function of engine power setting. Parameter $Q_T = T_0/T_H$ for a modern engines changes between 1.15...2, where T_0, T_H are the temperatures of jet gases at engine outlet and of external air, D_0 (R_0) – diameter (radius) of engine outlet. The height of plume rise is defined by empirical formula:

$$\Delta h_A = 0{,}013\ Ar_0\, X_A^3\, R_0, \qquad (4)$$

where X_A- longitudinal co-ordinate of jet axis, which is curved by buoyancy effect (Fig. 1).

The curvature of a jet axis, defined by angle Θ_{CUR}, may be used for the height definition of plume rise also:

$$\Theta_{CUR} = arcsin\left(\frac{exp\,(0{,}00217 Ar_0 Q_T S^3\,) - 1}{exp\,(0{,}00217 Ar_0 Q_T S^3\,) + 1}\right)$$

(4a)

$$\Delta h_K = \frac{2R_0}{Ar_0}\frac{m^2}{(1 - m)} ln\left(1/cos\,\Theta_{CUR}\right)$$

Generalised dependence, (not taking into account of mutual directions of wind and jet outflow) for height jet rise was defined by measurements in airport (Segal H.M., Yamartino R.) area for aeroplanes at ground operation with engines working on idle mode as following:

$$\Delta h_A = 37/ U_W. \qquad (4b)$$

All defined relationships (4), (4a) and (4b) are shown in relation to wind speed U_W in Fig. 3. Existing difference between relationships, especially for (4b), is explained by generalised character of the empirical formula (4b) for different directions of the wind.

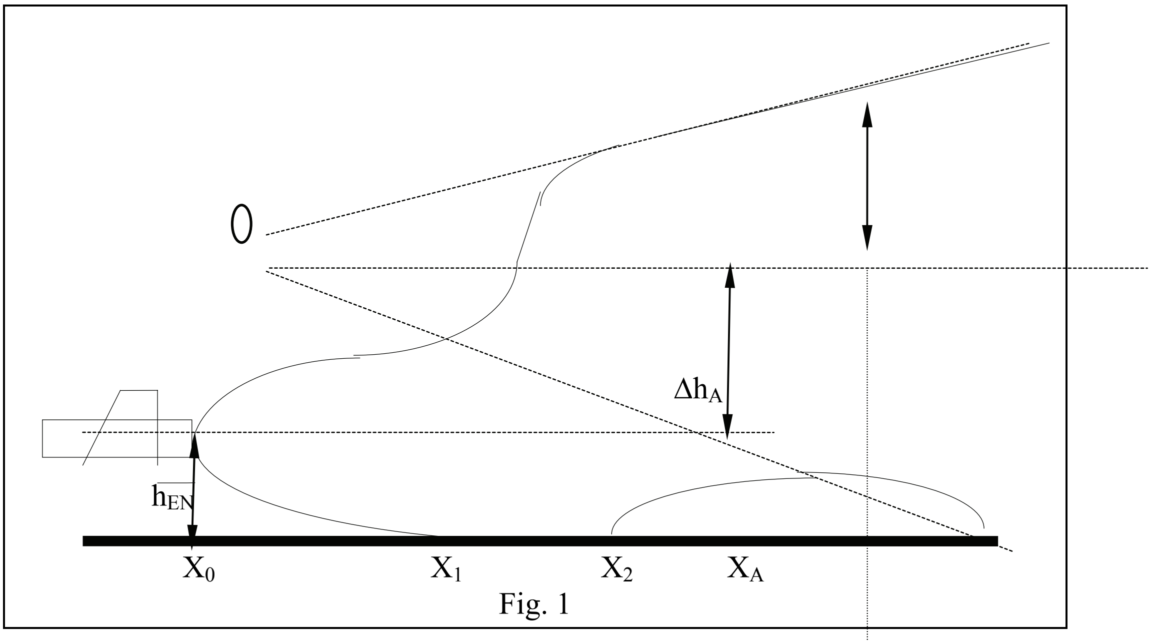

Fig. 1

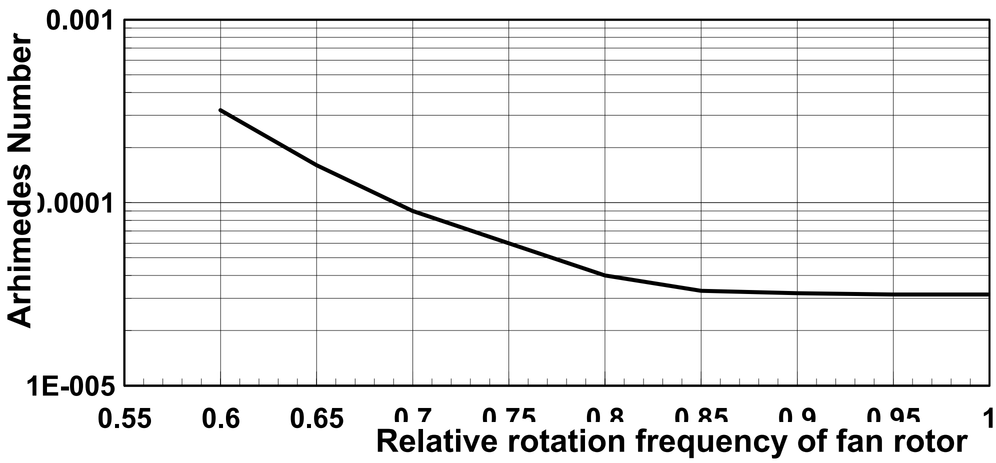

Fig. 2

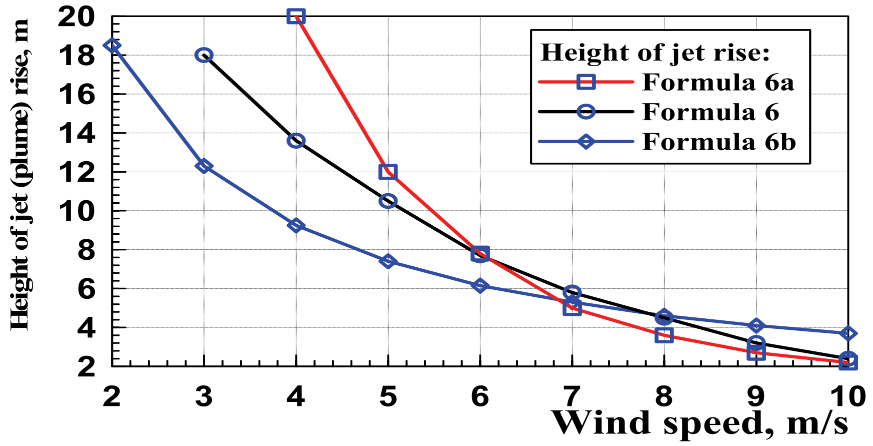

Fig. 3

Other structure of a flow is observed in jets behind the screw. The depth of a jet behind the screw is specified by dependence of relative flow speed along jet axis $\underline{U} = U_m/U_0$, where U_0 is a speed in throat section of a jet behind the screw:

$$U_0 = [2P /F \rho]^{1/2},$$

where P - thrust of the screw, F - area of rotation of the screw, ρ - air density. The dependence is defined by experimental data for air flow behind the prop engines of aeroplanes Antonov-12 and Antonov-24 and shown in Fig. 4.

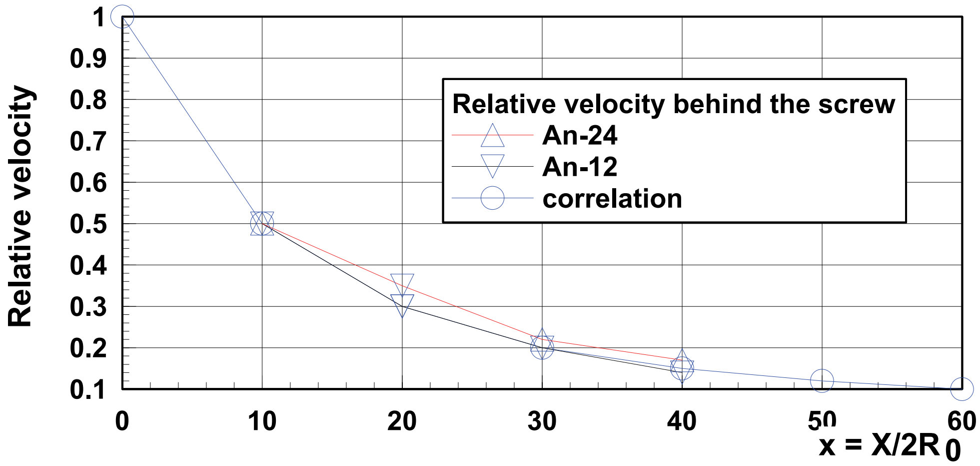

Fig. 4

The results of calculations q_{cal} and measurements q_{ms} of concentrations, meteorological parameters, distances from the aeroplane up to location point of the analyser are given in Tab. 1. There are two cases were considered during the analysis: engines start-up and taxiing of aeroplane out of a parking place before take-off (in the table are designated by the term - "taxiing out") and taxiing in parking place after landing (in the table are designated by the term - "taxiing in").

Table 1 - Calculated and measured concentrations of carbon oxide in jet behind the screw

Measure-ment No	Variant	Wind direction	Emission rate, g/s	Distance to aero-plane, m	Wind velocity m/s	q ms mg/m³	q cal. mg/m³
1	taxiing out	at nose	6,94	60	6	2,2	2,4
2	taxiing in	- " -	5,55	90	4	3,7	3,2
3	- " -	at tail	6,94	130	5	1,64	2,16
4	- " -	- " -	6,94	130	6	2,5	2,1
5	- " -	at nose	4,3	50	6	2,5	2,53
6	taxiing out	- " -	6,94	50	6	5,0	4,1
7	taxiing out	- " -	6,94	50	6	3,7	3,53

4. Aircraft pollution and atmospheric dispersion models

There is a set of methods for the description of processes of transport and diffusion of air pollution. For example, the calculation model of contaminant concentration, based on the decision of the semi-empirical equation of turbulent diffusion (Eulerian approach), is a basis for few regulative techniques in Ukraine used for the control of polluting enterprises. Therefore Eulerian approach is used for the description of diffusion process in a same way for control of air pollution in airport area from moving sources. Lagrangian approach is used for assessment of the results of transport and dispersion by jet. These results are the initial data for atmosphere dispersion calculations.

Flight and track profiles are modelled in a same way as in our aircraft noise model Isobella – similar to INM model or requirements of ECAC Doc 29R vol. 2 – Technical guide. It means that all ground activities are defined by the tracks (for taxiing or rolling) or points (for stands or aircraft in queue) only. For flights – usual aircraft flight equations, strictly simplified for flight stages in consideration. Experience show that the flight paths over the heights equal to100 meters do not contribute sufficiently in concentrations of the matters at ground level, because of influence of distance, height and velocity of the aircraft. Usually they may be excluded from assessment, if the ground concentrations are needed to be calculated.

Second important assumption - airport surrounding is considered as a plane surface. Third - meteorological information into the model is used in a same format as it is necessary for our national calculation method for stationary sources of the pollution. Because this mentioned method does not consider the moving sources at all, and thus can't be used for airports, the current method and software PolEmiCa was developed for the airports' pollution assessment.

In accordance with our national law for habitations around the sources of air pollution we need to consider averaged concentrations for time interval equal to 20...30 min (so called maximum one-time concentrations). So usually the scenarios of aircraft operation in airport must be defined with similar duration (maximum one-time concentrations) and for them the concentration fields are calculated. Usually the situations with inversion in atmosphere are not considered, because the law does not require for such conditions.

The expression for definition of instantaneous concentration from a moving source with preliminary dilution of contaminant by a jet (σ_{x0}, σ_{y0}, σ_{z0}) and with jet rise on altitude H has a form:

$$q(x,y,z,t) = \int_0^{T_S} \frac{Qexp\left[-\dfrac{(x - x^1)^2}{2\sigma_{x0}^2 + 4K_x(t+t^1)} - \dfrac{(y - y^1)^2}{2\sigma_{yx0}^2 + 4K_y(t+t^1)} \right]}{\{8\,[\sigma_{x0}^2 + 2K_x(t+t^1)]\,[\sigma_{x0}^2 + K_y(t+t^1)]\}^{1/2}} \times \quad (5)$$

$$\times \left\{ \frac{exp\left[-\dfrac{(z - z^1 - H)^2}{2\sigma_{z0}^2 + 4K_z(t+t^1)} \right] + exp\left[-\dfrac{(z - z^1 + H)^2}{2\sigma_{z0}^2 + 4K_z(t+t^1)} \right]}{[\sigma_{zx0}^2 + 2K_z(t+t^1)]^{1/2}} \right\}$$

where T_S - source operating time (realisation of emission), x', y', z' - current values of co-ordinates of an emission source:

$$X' = X_0 + U_{PL}t' + 0,5\,a\,t'^2 + U_W(t + t');$$

$$Y' = Y_0 + V_{PL}t' + 0,5\,b\,t'^2; \quad Z' = Z_0 + W_{PL}t' + 0,5\,c\,t'^2,$$

X_0, Y_0, Z_0 - initial co-ordinates; U_{PL}, V_{PL}, W_{PL} - components of source speed vector; a, b, c - components of source acceleration vector; K_X, K_Y, K_Z - diffusion factors and U_W - wind velocity.
The maximum value of instantaneous concentration q_{max} in a point under consideration (X, Y, Z) will be derived at moment t_{max}, which is approximately determined by the formula:

$$t_{max} = \Delta X/U_W + [\Delta X\,K_x/U_W]^{1/2},$$

where ΔX - distance between the researched point and point of the beginning of processes of atmospheric transport and diffusion.
For calculations of concentration fields in airport area it is necessary to take into account intensity of motion of aeroplanes of different types, a loading factor of different taxiways and there are a lot of other operational features. It is possible to simplify basic expression for definition of concentration for particular cases of maintenance and stages of aeroplanes motion. The simplification of the model influences a little on accuracy of calculation results, but calculation procedures become considerably simpler.
For example, at departure cycle there are some pauses possible in motion of an aeroplane, when its speed is equal to zero - start-up and warm-up of engines, queing and waiting for take-off on or behind runway. For such cases it is possible to use the instantaneous model for a fixed point source. Other characteristic version of aeroplane motion is approximately uniform straight-line segment with fixed engine operation mode. If the direction of a wind is not parallel to direction of aeroplane motion, it is possible to use model of linear instantaneous sources.
Domestic normative rules use maximum one-time concentrations with averaging time interval equal to 20...30 min. These averaged concentrations q are calculated by the formula

$$q = q_{max} / K_{30}, \qquad (6)$$

where K_{30} - factor, which determines the attitude of maximum instantaneous concentration q_{max} to maximum averaged q (T_{av} = 30 min).

5. Influence of operational factors on air pollution

By analysis of the developed models of air pollution from aircraft engine emissions main operational parameters were defined that may influence on highest levels of the pollution: meteorological parameters (parameters of an atmosphere condition), aeroplane motion and engine mode parameters.

For example, influence of atmosphere condition on contaminant concentration (maximum instantaneous and maximum one-time) were investigated for various probable cases of a mutual direction of wind and engine jet. It was found that near to aeroplane the maximum concentration will be derived at moderate and weak intensity of an atmospheric turbulence, and on large distances - at very weak intensity (Fig. 5).

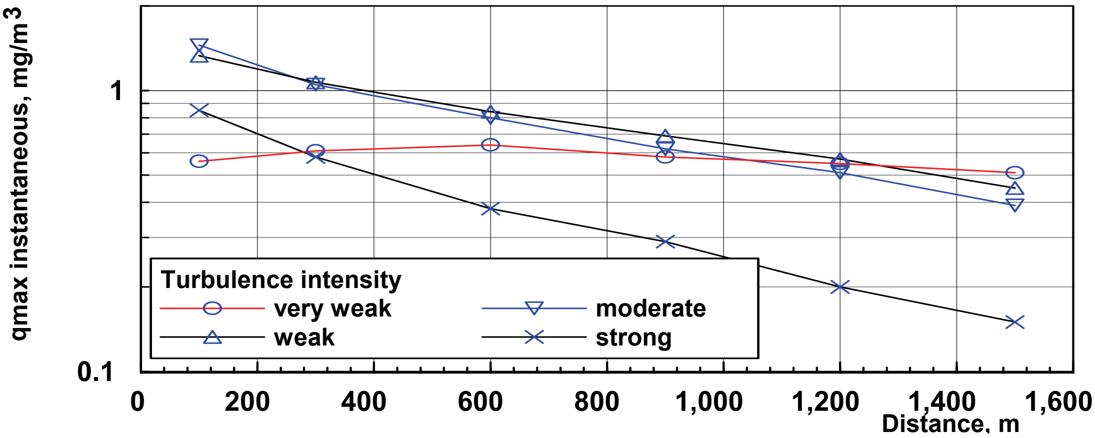

Fig. 5

6. Conclusions

The developed technique of air pollution calculation is realised in computer program ***PolEmiCa*** (version 2). Methods and soft ware are used in procedures of Environment Impact Statement for airports. All the models are improved with time, first of all using theoretical considerations. But the measurements, made in airports worldwide, are used for more strict definitions too.

References

1. Air Quality Procedures For Civilian Airports and Air Force Bases. FAA-AEE-97-03. Final Report September 1995 - April 1997. – 210 p.
2. Segal H.M., Yamartino R. The influence of Aircraft Operations on Air Quality at Airports // JAPCA, v.31, No 8, 1981. - p.846-851.
3. Segal H. Concorde Emissions at Dulles International Airport Results of Measurements // JAPCA, v.28, No 10, 1978. - p.1039- 1042.
4. Perry R., Williams M.L. Air Pollution Associated with Airport // Public Works Congress Papers, 1981. - p.46.
5. Clark A.J., McIntyre A.E., Perry R., Lester J.N. Air Quality Measurements in the Vicinity of Airports // Environmental Pollutions, v.6, No 4, 1983. - p.245-261.
6. Nichols T.P., Leinster P., McIntyre A.E., Lester J.N., Perry R. A survey of Air Pollution in the Vicinity of Heathrow Airport (London) // The Science of the Total Environment, v.19, 1981. - p.285-292.
7. Daley P.S., Naugle D.F. Measurements and Analysis of Airport Emissions. // JAPCA, 1979, v.29, No 2. - P.113-116.
8. Naugle D.F., Grems B.C., Daley P.S. Air Quality Impact of Aircraft at Ten US Air Force Bases // JAPCA, v.28, No 4, 1978. - p.370-373.
9. Environmental protection. Annex 16 to the Convention on International Civil Aviation. Engine Emission. - Montreal: ICAO, Vol.2, 1993.

10. Банк данных ИКАО по эмиссии выхлопных газов двигателей. - Монреаль: ИКАО, Doc 9646-AN/943, изд. 1, 1995. -152с.
11. Smith D.G., Taylor E.A., Doucette S.M., Egan B.A. Validation Studies of Air Quality Models at Dulles Airport // JAPCA, v. 29, N 2, 1979. - p. 110-113.
12. Yamartino R.G., Rote D.M. Updated Model Assessment of Pollution at Major US Airports. JAPCA, 1979, v. 29, N 2, p. 128-132.
13. Nishi A., Cermak J.E. Modelling of Pollutant Dispersion from moving Source. Application to Airport Pollution // Journ. Japan Soc. Air Polluttion, v.15, N 4, 1980. - p. 137-144.
14. Emissions and Dispersion Modeling System (EDMS) Reference Manual. FAA-AEE-01-01. U.S. Department of Transportation Federal Aviation Administration, Washington, D.C. CSSI, Inc., Washington, D.C. September 2002

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CALCULATION TOOLS FOR BALANCED ENVIRONMENT PROTECTION IN AIRPORTS OF CIVIL AVIATION

1. Introduction

Balanced approach to noise management developed by ICAO consists of identifying the noise problem at an airport and then analyzing the various measures available to reduce noise through the exploration of four principal elements, namely reduction at source, land-use planning and management, noise abatement operational procedures and operating restrictions, with the goal of addressing the noise problem in the most cost-effective manner. Operating restrictions must be applied as a first resort but only after consideration of the benefits to be gained from other elements of the balanced approach [1]. It is obvious that such an approach may be spread on other important environmental issues of airport activities, on air pollution and third party risk first of all, because they are main subject of Environmental Impact Assessment of the airports under construction/reconstruction [2].

Before considering the measures to alleviate environmental factors an assessment of these problems at the airport concerned must be based on objective, measurable criteria and other relevant factors. Then the evaluation of the likely costs and benefits of the various measures available must follow and, based on that evaluation, a selection of measures with the goal to achieve maximum environmental benefit most cost-effectively. Dissemination of the evaluation results must be provided for consultation with stakeholders and for dispute resolution [1]. Thus the assessment tools need to be designed for support of proving of all the elements of the balanced approach.

2. Criteria for environmental impact assessment

The process to implement the balanced approach would typically consists of an assessment of the environment situation at an individual airport, definition of the objectives, provision for cnsultation, identification of measures available to reduce the multi-factorial impact, their costs and benefits, selection of measures, adequate public notification of intended measures, their implementation and provision for dispute resolution available to stakeholders. It is important to consider all the elements of the approach and all the issues consistently and operating restrictions must not be applied as a first resort.

Number of factors influencing on environment situation at the airport is quite huge, but generally their list includes types of aircraft used in airport, number of their take-offs and landings, operating conditions, season, weather and time of the day, number and location of runways, flight routes, flight procedures, etc [3]. All of them are accounted in calculation procedures for every specific factor assessment, usually shown as iso-contours for predefined (by normative guides) values – noise indices, concentrations of the matters in the air, risk probabilities, etc.

The contours are not the final values. When they are laid on the map it is possible to define the number of people inside the contours and involved in various kinds of activities (for example working there or living in residential areas inside the particular contour) and in such way to define the possible damage for this population – at the final point in monetary values. For example, the number of people affected by aircraft noise is dependent on the way in which the use of land surrounding an airport is planned and managed, and in particular the extent to which residential development and other noise-sensitive activities are controlled.

Important moment of the assessment is a choice for appropriate type of index used for impact assessment. Currently the day-evening-night level is recommended by EU appropriate directive to assess and control the aircraft noise around the airports. In ICAO guide for airport planning very similar index day-night level is recommended too. Latest investigations made world-wide show that these indices more deeply describe the real impact of noise on population, even in analysis of all kinds of environmental noise – transportation (aircraft noise is a part of which), industrial, social (sport, music, celebrations of all kinds, etc.).

The same is relative to air contamination – what kind of concentration (mostly the duration of the interval of their averaging) is more appropriate to analyse air pollution produced around the airports by all types of the sources, taking in mind that among them moving and stationary (not moving) sources exist and their peculiarities of the pollution are quite different. For third party risk – what kind of probabilities must be used, social or individual risks must be considered, so on.

3. Data bases

Few types of data bases are used now for separate types of Environment Impact Assessment of the airports. Basic among them are the data of aircraft noise and engine emission certification – which are the initial data for many cases of impact assessment. Important moment that the certification conditions may (and usually do) differ very much from conditions in operation – it concerns as environmental conditions, so as operation modes used for flight procedure. For example operation flight mode for certification flight path differ from noise abatement procedure along particular flight route in particular airport and certification levels will be different from real noise levels under the flight path at the same distance as it was defined in certification case. But for making a choice among the aircraft – what type is more correct for situation under consideration such certification data are applicable and even very necessary.

Besides today there are many quantification schemes for noise and pollution charges in airports are grounded on the certification data of the aircraft and engines.

4. Particular flight event

Possibilities to assess particular flight event (particular take-off – landing cycle for engine emission) is necessary for:

assessment of the contribution of particular aircraft, flight route, procedure, etc., in scenario under consideration;

optimization of the parameters of the flight event with purpose to minimize its impact on the environment, beginning from choosing the appropriate type of the aircraft (taking its necessary flight and noise performances from the appropriate data bases) and appropriate flight route, then optimizing the parameters of the procedure for flying.

For example, in NAU program TRANOI was designed for such kind of the researches.

If we need to define noise spectra at some points of the airport territory in NAU the program NoBel was designed and it allows to define the necessary efficiency for shielding the sound waves between the aircraft and point of noise control. Combining with programs for sound isolation assessment, which we need to provide buildings around point of noise control, we may provide the fulfillment of the requirements for noise climate inside the buildings depending on the activities performed inside.

5. Airport scenario

Real impact of the airport on the environment may be assessed with account of all dominant factors, mentioned above. In NAU the following programs were designed for that:

- ***IsoBella*** – tool for aircraft noise contour calculation around the airports;
- ***PolEmiCa*** – tool for air pollution and aircraft engine emission assessment in airports;
- ***3PRisk*** – third party risk assessment around the airports.

Models and initial performance data used in programs IsoBella, NoBel, TRANOI are almost agreed between themselves, thus result received in TRANOI is similar to the same flight event in IsoBella and it is possible provide separate research for optimal flight procedure by usage of NOITRA and transfer its results in IsoBella assessment for airport scenario. In a same way the results for particular event and scenario are almost agreed in usage of PolEmiCa - using its module JET for the event and module CONCEN for total pollution field around the area under consideration.

All the models for three main types of the impact are in a good accordance with EIS and land use requirements.

6. Conclusion

A set of the models and methods currently designed in NAU and used for the proving the particular elements of balanced protection programs in airports. Now they need for more strict agreement with measurement tools like instrument noise and pollution monitoring systems installed in many airport worldwide for improvement of the assessment and its reliability.

There are many activities now fulfilled for implementing noise and pollution charges for airports, the designed tools are appropriate for their proving also. They allows to define the costs of the damage provided by impact of the airport on environment.

References

1. ICAO resolution A33-7: Consolidated statement of continuing ICAO policies and practices related to environmental protection. Adopted by ICAO Assembly 2003.

2. Airport Planning Manual. Part 2. Land Use and Environmental Control. - Montreal, Canada, ICAO Doc. 9184-AN/902/2, 3-rd ed., 2003. – 35p.

3. Guidance on the Balanced Approach to Aircraft Noise Management. ICAO Doc. 9829 AN/451, 2004.

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Incentive Measures on Constant Use of Natural Resources in Ukraine.

Summarizing the situation and the necessity to develop the corresponding promotional actions of stimulating or preventive character, the article quotes the list of measures that comprise the essence of financial mechanism of problem implementation put by Ukraine – ensurance of stable natural resources usage and preservation of biological variety.

All steps on the way to encourage the biological diversity preservation and constant use of natural resources must go out from the pre-conditions listed below:

a) One must base on the analysis of problem's regional and local levels, particular features of concrete situation;

b) It's necessary to consider the co-ordination of existent political instruments and industry priorities;

c) It is necessary to compare the problem scale with the scale of steps, which are being accepted for the introduction, i.e. together with the cost of introduction tools, including the investment programs;

d) There must be a mutual accordance of national instruments with international agreements;

e) It is necessary to find out the proper and mutually increased consequences of hidden factors of pressure on biodiversity;

f) It is necessary to reveal existing negative stimuli of the economic growth towards preservation of a biodiversity, particularly in some special fields of activity.

Among the recommendations offered as „National program of biological variety preservation for 1998 – 2015 years" and as a plan of actions on biodiversity preservation in Ukraine one can distinguish separately:

- financial mechanism;
- economic mechanism;
- organizationally -institutional instruments of introduction;
- educational-informative instruments of providing.

We will stop on the economic-financial mechanisms of providing the realization of incentive measures for permanent usage of natural resources and preservation of biodiversity.

Ecologization of taxation in Ukraine needs to be reformed in the order to increase the part of direct natural-resource taxation, that is taxation of resource stream, passing through the production sphere, instead of modern structure of taxes in which taxation of incomes and wages is emphasized.In connection with the ecologization of taxation for the sake of improvement of biodiversity preservation financial efficiency. It will become finally possible to transit gradually from residual principle of financing to the sufficient principle.

Thus it is possible to use „state budget neutrality" principle, commenced in the end of 90-x years during the ecological tax reforms in countries of the European Union, that means the increase of tax incomes to the budget by means of ecological taxes, must be accompanied by the measured reduction of tax receipts from the taxation of capital, labours or both by introduction of the special correction coefficients to the rates of taxation of capital and labour. By the way, using such means of mutual adaptation it becomes possible to correct balancing the profitable and expenditure parts of the state budget in order to reduce or increase the deficit of the state budget.

However, with in the frame work of existent taxation system of it is necessary to introduce such incentive measure as expansion of benefits for the production of ecological types of products and services with the simultaneous compensation of the proper budgetary receipts losses with the help of acceptance of indirect taxes on the ecologically unfavorable types of production issues. Thus it is necessary to use principle of "fiscal neutrality" in the realization of ecological product taxation and "unecological" product taxation. For this purpose the list of correction coefficients to the existent and future tax rates should be applied. Such list must be based on the product and service ecological certification.

Principle of „fiscal neutrality" in Ukraine may be also introduced in a such way, that in the case of rise of general production taxation on ecological unfavorable products it is temporally accompanied with the correction coefficients. Reduction of taxes on incomes of physical persons and on wage fund will decrease the concealment of incomes from taxation.

The transition to the increase of natural-resource taxation part must be accompanied by rent indexes in payments for the natural resources and in payments for contamination of natural environment – by size of inflict economic harm from the ecological violations, instead of quasiharm.The existence of payments built according to quasiprinciple is caused by the solvency level of nature users and existent system of taxation, when it is impossible to heave up payments because of weak tax discipline of taxes payers. General tax pressure, rise the existence of great part of shadow production and accordingly shadow market all together negativly affect the formal market.

Reformation of the tax system in Ukraine on the way to further ecologization should intend:

1) Substitution of some part of budget incomes of all levels (in particular in part of incomes, that form at the expense of profit taxation, incomes of physical persons, VAT, excises, fund of wages etc.) by incomes from taxation of natural resources, and exactly from taxation of increase of natural resources stream through the production usage;
2) Development of favourable tax credit for some payers of natural-resource tax.
3) Transfer of tax weight from buildings to the land.
4) Creation of the system of accruals in the State budgets for providing local budget for the period of transition to new Tax Code ,taking into account the ecological imperatives.

Socio-economic consequences of taxation reformation in Ukraine on the basis of permanent development and integration of ecological ones will lead to:

1) better resource preservations and protection of natural environment;
2) better tax gathering, due to impossibility of natural resource to be hidden;
3) appearance of financial sufficient funds of biodiversity preservation support ;
4) not only greater ecological efficiency, but also greater economic efficiency because of economy of resources and their better technological usage stimulation;
5) introduction into practice existent abroad methods of ecology oriented national accounts, that it will be able to pass to the inclusion in Ukrainian CHP so called „green" accounts.

Nature protective activity in Ukraine should be financed from:

a) tax system;
b) receipt by the state rent incomes where it is proprietor of natural resources;
c) protected positions of budget expenses in articles.

Target budgetary facilities on the nature protective activity, rational use of resources in Ukraine, taking into account the heavy consequences of the Chernobyl accident must be not less, than 4% from GDP of Ukraine.

Important financial instrument to provide the biodiversity preservations is a mortgage of natural resources, that will attract domestic and foreign investments to the development of the Ukrainian economy. For this purpose it is necessary to develop and confirm the Law of Ukraine „About mortgage of natural resources" obligatory part of which must be investment expenses on biodiversity preservation. The public property would be fixed on the strategic types of natural resources , that would eliminate possibilities of their mortgage. It is necessary to consider that previous stage for acceptance of that Law was the work on rent estimation of natural resources for determination of their real cost in all cases using them as mortgages.

One of important directions of biodiversity preservations, that is confirmed in documents of almost all countries, is a reorganization of book-keepers control with the purpose of internalization of international expenses. Obligatory reflected balance of full inflict ecological harm and rent payments in the book-keeping in Ukraine will stimulate resource preservations and introduction of resource preservation, environmentally clean and nature protective technologies, that will stimulate selfinvesting of domestic enterprises into nature protective activity.

Formation of funds which support biodiversity preservations will assist to preserve biodiversity, due to rent payments, that must be reflected in the item e) of the article 48 of the Law of Ukraine „About protection of natural environment". Accumulated in these funds, amount of rent payments will be directed not only to restore that resource from which the state appropriates rent, but will be distributed primarily coming from necessities of biodiversity preservations, thus priority distribution of money direction will take place.

Pretty interesting for Ukraine is usage of experience of others countries, for example Poland and Colombia, on realization of mechanism of „exchange of debts on nature". For example, Poland made, by means of investment of money in nature protection, 10% of its debts to Finland and 1% of its debts to France. Money according to this mechanism are transported to those industries and regions, from where the unfavorable ecological influences on neighbours can appear. Realization of this mechanism by negotiations of the Ukrainian party with the countries-creditors, though it is rather complicated, would be especially desired for Ukraine from the point of view of the ecological problems related to the Chornobyl accident.

The insurance financing of activity on biodiversity preservation must foresee deduction of part of insurance bonus by underwriters on the prejudicing actions, for example, from the fund of the insurant preventive actions; financing at the expense of profit from operations on insurance of ecological risks; investment of costs into development of waste-free and recycling technologies and equipment, primarily, on insuring enterprise, and on other enterprises.

Risks of environment contamination and influence on preservation of a biodiversity must be insured by insurance on responsibility of nature users for infliction of losses to the natural objects.

It is possible to subordinate the privatization mechanism which should assist to the formation of budgetary privatization ecological fund to the aims of biodiversity preservation. Rules and principles of primary and the secondary privatization, that were changed, and which properly designed from point of view of legislation are to be directed on the obligatory consideration of ecological imperatives. In the privatisation competition the advantage should be given to those investors that can secure ecological situation of privatised enterprise in sufficient volume and time. It is needed to lay this requirement also into the mechanism of auction on holding selling, taking into account necessary sums of ecological expenses. The part of costs spent by the privatizing investor is brought to budget and forms a budgetary privatization ecological fund, where the money are being accumulated.

At the expense of these accumulated money it is possible to recover part of money expended for providing preservation of a biodiversity soon.

A privatization ecological fund has to appear at the expense of redemption money of the privatizing invest; parts of deductions on amortization of nature-protective objects; profit reinvested by the privatized enterprise into the nature-protective actions.

The sources of financing the measures to save the biological variety in Ukraine are subdivided into budgetary and non-budgetary ones.

Budgetary sources of financing contain state funds, funds of Autonomous Republic Crimea, local funds of direct and related action, including subfunds (without specific incomes received by budgets), specific sources of assets which in their turn include:

- incomes from deposits of natural resources;
- incomes from sale of licenses on nature management;
- incomes from privatization taking into account geological factor as well as economical estimation of natural factors; economical estimation of natural resources as a part of aggregate property of economic object being under privatization;
- incomes from export sales of goods from the funds of resources of biological variety;
- assets from potential implementation of principle "debts versus nature";
- incomes from biogenetical resources trade;
- assets of state institutions for scientific researches and manpower training on the basis of especially secured natural territories, reserves, etc.

Non-budgetary assets include enterprise's own assets; territorial ecological funds as juridical persons; local environmental protection funds; incomes from allowed economical activity on the territory of national parks, etc; assets from foreign ecological funds; credits of domestic and foreign funds; assets of insurance companies; assets of investment projects based on pure disked income taking into account ecological estimation of natural resources.

Summarizing the situation and the necessity to develop the corresponding promotional actions of stimulating or preventive character, we'll quote the list of measures that comprise the essence of financial mechanism directed to resolve the problem put to Ukraine – ensurance of stable natural resources usage and preservation of biological variety.

1.The measure of the first priority is the ecologization of taxation system in Ukraine that will allow the state to receive maximum rent incomes and accumulate financial costs for budget.

2.Complete financial estimation of enterprises external costs, their inclusion in the price on production and introduction of funding or taxing (dues, fees and penalties) according to the positive or negative external influence of separate enterprise activity.

3.Multifunctional distribution of costs from ecological funds basing on priorities of ecological and economical estimation of the state biological variety, residual quantity of natural resource and its discounted cost.

4.Mechanism of usage of special-purpose budget costs for payment of credit interests the investment projects to preserve the biological variety in the natural reserve zones according to special state and local programs.

5.Assistance to the foreign companies investments (especially after 2008) in reforestation under the carbon credit when direct decrease of CO^2 emissions will cost more then equivalent expenditure on ecological effect reforestation.

6.Establishment of monopolistic prices on genetic resources sale on world market with the purpose of getting by state the adequate incomes. Establishment of state monopoly on genetic resources is also possible.

7. Changes in taxation system that will result in benefits from ecological products and services and, from utilization of harmful wastes with getting useful production. It concerns in:

- distribution of grants among farmers (private sector) if the manufacture is handled in a non-poluting way and the ecologically pure products are produced as a result;
- stimulating payments or bonus purchases for conducting of organic agriculture without using insecticides and pesticides
- stimulating of agricultural manufacture that works on a natural basis without chemical fertilizers and special additives, especially in cattle breeding and poultry farming reducing half the income tax or purchasing these goods under higher prices.

8.Grants for reduction of areas under agricultural cultures, if a plowing degree exceeds norms accepted in a certain region.

9.Preferential tax crediting of ecologically safe technologies created in Ukraine by reduction to 50 % of taxation rates of a capital gain as well as introduction of increased norms of the accelerated, ecologically safe equipment amortization with the purpose of encouragement of it's installation.

Reformation of subsidizing: reduction of subsidies costs to that kinds of manufacture and economic activity that harms nature and environment. The question is about subsidies that have the stimulating influence on manufacture and cause the excessive intensification of agriculture, excessive fish catch and usage of polluting kinds of fuel (for example, the necessity to decrease subsidizing of excessive fertilizing of soil under crops). Some governmental subsidies in Ukraine support resource wasting kinds of activity (black and nonferrous metallurgy) or non-profitable kinds of activity that exhaust natural resources (most of coal mines), and the enhancing export manufactures that impoverish domestic raw materials possibilities of country, especially from the point of view of future remains. Providing of "budget neutrality" principle under introduction of taxation privileges on the ecological kinds of production and ecologically safe technologies, as well as under introduction of new ecological taxes and indexation of existing tax rates on resource usage neutralizes the budget consequences of capital and labour taxation. Ecologization in Ukraine shouldn't become one more way of taxation press on producer and consumer with the aim of obtaining more incomes to the profitable part of budget.

10. Strict control over adherence to ecological standards of manufacturing process on the environmental costs of the producer.

The economic-organizational means of financing mechanism introduction of the sustainable resources use are the following:

1.The introduction of the defining the economic estimation of natural resources is based on rental estimations, total economic cost and method of discounted cost, as well as on the method of economical losses estimation from ecological harm and at the same time on the methods of calculation to prevent ecological harm as the means for actual restructuring and ecologization of taxation in Ukraine.

2.Increase of compensation guarantees of special purpose credits of domestic and foreign banks for environmental protection projects.

3.Improvement of registration and legislative control in the field of genetic resources trade.

4.Accepting in Ukraine the law "About ecological ensurance" that reflect the normative part of insurance benefits, directed on financing of preventive actions to preserve the biological variety.

5.Insurance of the most valuable biological objects, providing preventive action to reduce the probability of causing them harm in the case if incidents (at neighbour enterprises), and indemnification of damage in the cases of causing damage to these objects or other resources.

6.Changes in the mechanism of privatisation taking into consideration the ecological factor and creating the corresponding privatization ecological fund.

7. Assistance in implementation of foreign experience to exchange the part the foreign debt on the implementation of environmental protection measures.

8. Certification of production and services on ecological criteria when giving taxation benefits on ecological kinds of products and services.

9.Introduction of accelerated amortization of domestic ecologically safe technologies to prevent pollution instead of expensive control over pollution. Because of this it's recommended to change the edition of law of Ukraine "About environmental protection" in point в) of 48'th article, where phrase "amortization of basic manufacturing environmental protection funds" should be replaced by "amortization of domestic ecologically safe equipment".

10. Introduction of compulsory cost appreciation of expected losses at the stage of preliminary ecological audit.

11. Carrying out the competitive selection of investement project basing on ecological-economical criteria taking into account social and economical consequences of it's long-term life cycle, is based on index of pure discounted income that would reflect rent estimations of natural resources and economical losses from ecological damages. The reformation of tax rates should be based on the calculation of pure discounted income.Economic and legislative components of the mechanism of effective supporting of the stable usage of natural resources and biodiversity preservation include the following incentive measures:

I. Measures, connected with microeconomic calculations and macroeconomic level of economic and ecologic policy, should be first of all reflected in the system of national calculations as well as in completing it with special macroeconomic aggregates. Now the methodology of calculation of "green" natural accounts in the system of national accounts is almost absent while other countries have promoted far forward in this direction from year 1996.

That's why the proposition the system of "green accounts" should be considered by Government and introduced on the macroeconomic level. The gross national ecological product should be calculated as one of main macroeconomic indicators (Daily, 1996) and the index of pure ecologic wealth or the index of quality of life (Modilieni, Fridman, 1972) should be introduced in the system of Ukrainian economical monitoring with the help of methodology used in normative documents of OECD.

As the quantity of preserved biological diversity is the part of calculated index of the quality of life via, certain coefficient of closeness of connection should be included. And in future it's necessary to carry out the division into districts of living territories according to the value of life quality index. And in those districts, where it's higher it's necessary to increase rent and income taxes. The prices for real estate will become automatically higher in comparison with other regions. Ecological division into districts should be carried out throughout all the country with assigning marks according to a special 100-point scale.

It's necessary to provide state statistical calculations of state financial debt according to government obligations, after also the calculation of state ecological-resource debt on financing manufacture by intensive mining of natural resources and related decrease of biological variety. That is the data about the size and dynamics of state "ecological" debt before nature and population of Ukraine, that is the collective owner of natural resources and social goods that have ecological value, according to this methodology should be included.

The definition of discounted cost of ecological CNP should be introduced as the economical action basing on bank's interest rate and average term of amortization of certain resource.

National macroeconomic indicators should be accomplished with the social index of ecological justice via estimation of disproportional division of ecological loads (such as industrial air and water pollution, toxic wastes and so on) that are brought by different economical and social groups per unit of time.

The indexes that characterize the increase of natural resources usage efficiency should be included in the system of macroeconomic monitoring, particularly material capacity of natural resources per unit of production, kinds of materials in the branch contents and average consumption of natural materials per unit of population. Dynamics of regeneration index of this natural resource (level of regeneration of fish, wood, soil and water resource) within the same unit of time allow to visualize the process of transition for the stable usage of natural resources.

On the base of financial estimation it's necessary to calculate the value of biological kinds and include it to the common sum of national wealth. Then catching of wild animal or destruction of world plants will be considered as doing harm to the society by decreasing national wealth. That should be adequately compensated and regenerated to the wild nature.

In statistical calculations it's necessary to take into account the quantity of natural resource and it's quality from the biological point of view. For example, certain resource should receive the mark on correspondence to the standard of maintenance of biological variety. Basing on this data it will be possible to divide conventionally the territory of the country into zones of priority usage of natural resources and zones of primary preservation of biological variety. In general it's necessary to introduce the account of dynamics of negative factors influencing the state of biological variety. For example, the list of lakes that exceed the limit acceptable pollution indicator over the summary list of chemical pollutants.

It's necessary to have the statistical data about the quantity and quality of the rest of natural resources: on how many years within the current rate of supply they'll suffice, what possibilities of their regeneration exist, in what way they regenerate or don't regenerate and what possibilities of their substitution by other equivalents exist. And on the base of calculations of present volumes of natural assets and cost indicators it'll be possible to develop the adjusted ecological and economical policy taking into account total alternative cost of natural resources.

The multilevel system of statistical account and monitoring should exist in Ukraine according to: separate components of biological variety; general state of biological variety in the whole; regional aspects of the state of biological variety; factors that have positive influence on biological variety; factors that have negative influence on biological variety; influence of the most significant non-manufacturing social factors for preservation of dynamic biological variety; correlation between current biological variety and residual potential;

observed ecological effect from separate kinds and means of economical policy from the point of view of necessity of preservation of biological variety.

At the same time the system of economic efficiency indicators of environmental protection actions and programs should be introduced, i.e. the monitoring of results with the aim of timely correction of accepted means in the indicators that yield to quantitative estimation (the last meets the requirements of GEF). Choosing a certain investment project for financing, it's necessary to use special ecological scale with the marks system that foresees checking the correspondence of investment measures to the existing criteria:

1) Maximum improvement of indicators characterizing health state of population;
2) Minimisation of economic losses from pollution of environment and reduction of expenditure costs on pollution elimination;
3) Maximization of effect of actions to preserve the biological variety or minimization of negative influence on the biological diversity.

The Ministry of ecological resources should develop the methodology of state monitoring of biological diversity and factors influencing upon it.

II. Actions, directed at preservation of biological variety and constant use of natural resources by enabling the market mechanisms and means of economical policy, foresee use of such methods as licensing, investment stimulating, entrepreneurship and rent relations regulation, implementation of property rights, technological possibilities, production certification e.t.c. At the same time we base designing the recommendations and incentive measures on preservation of biological variety in Ukraine, on the analysis of economical preconditions: objective economic factors (per capita GNP, level of unemployment, poverty and inflation, provision with own natural resources, shadowization of economy and off-bank money circulation, property structure and brunch industrial structure, level of technology and informatization, economical influence of neighbour countries) and subjective causes (special economic factors, corruption, legal possibilities, rest financing and debt obligations).

Among the means of biological variety we should distinguish: direct market incentives and non-direct market incentives. They include: licenses sale on the collection of quoted quantity to wild plants and animal world objects that are used in economic activity; licenses sale on shooting wild animals in the case of temporary exceeding of constant level of population in given region; prohibition of private collection of biological kinds, especially at schools; introduction of virtual modelling on computers of real biological investigations of animals and birds; cloning of biological kinds that are currently on the border of complete extinction; prohibition of any ways of extraction of objects of The Red Book.

Conclusions

As a previously mentioned, all recommended organizational - economic measures from world experience for Ukraine, and also necessary unstructional measures, bills, programs, techniques of monitoring etc., should be based on an economic estimation of elements of biological variety in the monetary form. For example, in view of scientific - methodological development in Russia, and in documents of the Sixth meeting of Conference of the sides and the Convention on biological variety, in documents SBSTTA (UNEEP/CBD/COP/6/1) and in documents OECD (Handbook of Biodiversity Valuation: A guide for Policy Makers, OECD, 2001), and also in documents IUCN Gland, Switzerland, the 22-26 April 1996 (T.Swanson: The Underling Causes of Biodiversity Decline: An Economic Analysis). In documents of the international organizations the economic estimation of biological variety a sufficient stimulating measure (Handbook for Measures for Biodiversity. Design and Implementation. OECD 1999).

Besides, an economic estimation in money terms has to be provided in order to achive the purposes of ecological policy which we aspire to reach in Ukraine by practical introduction of the chosen or some new measures on stimulation of biodiversity preservation and constant use of natural resources.

The economic axiom is, that a measure on preservation of a biovariety, practical actions on its realization, can not cost more expensively, than the cost of those objects of a biovariety which will be kept due to this measure. Therefore a prime measure can be a monetary estimation and the account of biovariety objects of regions and territories and of the country as a whole for the purpose of the organization of monitoring of a biovariety. So, the general problem of effective introduction of the proper incentive measure divides into three problems:

1. Calculation of the received benefits from preservation of biovariety thanking to certain offered action. For this purpose monitoring of conditions changes can conduct a biovariety in the monetary form, but also significant benefit from introduction of a measure on all possible(probable) can be calculated. Directions of influence are social, economic, cultural;
2. Counting of the measure's realization cost ;
3. Comparison of the first with the second and calculation of effectiveness ratio of the project on an embodiment of the certain measure.

Concerning measures on preservation of a biovariety we shall notice, that it is necessary to use methods of the adaptive coordination for monitoring consequences and entering of corrective amendments into the current work which will allow to achieve in common a definite purpose and to avoid mistakes which cost much. Necessity of such coordination answers a principle of the ekosystematic approach.

References

1. Handbook of Biodiversity Valuation: A Guide for Policy Makers, OECD, 2001.
2. Handbook for measures for Biodiversity. Design and Implementation. OECD 1999
3. Environmental Tax Reform: The European Experience. By *J. A. Hoerner and B. Bosquet.* Center for a Sustainable Economy. Washington D.C. 2001.

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STATE ROLE IN REALIZATION OF FOREIGN TRADE ACTIVITIES

In all states without exception, and in particular in the states which are in transition period, where the economic relations are unstable, the state regulation of foreign trade activities is an objective necessity. Thus reform of a general economic mechanism in these countries and reform of the mechanism of management of foreign economic relations are closely interconnected.

General.

The objective of this article is to make in definition of a role of the state in realization of foreign trade activities, i.e. how the state can and should assist development of foreign economic relations. Development of foreign trade activities in the countries with transitive economy was connected with the study of market experience at the advanced countries, coming to new markets, necessity of development of a competition, increase of a level of production, implementation of foreign investments and new technologies, financial support for market transformation of their economic system. It would have been impossible under old system of organization of foreign economic relations, when these relations were carried out only by specialized foreign trade organizations.

Problem setting.

For the decision of a problem of foreign economic relations development it was necessary to expand the rights of enterprises, i.e. to give them the rights of a direct output on the external economic market. Besides, it was necessary to realise the county's foreign economic policy, which provides basic purposes of the state in the external economic relations' as a whole, country or its groups, and also definicion methods and means, which provide the achievent of the objectives.

Actuality of studies.

The external economic policy regulates all kinds of foreign trade activities: international trade by goods and services, and also international moving of material, money, labor and intellectual resources. With the help of tools of the external economic politics the state can actively influence formation of structure and directions of development of own foreign economic relations, and in some cases foreign economic relations of other countries.

The modern state regulation of foreign economic relations is carried out with the help of different mechanisms, and its number constantly grows. It is explained by the fact that the expansion of foreign economic relations of the countries demands new tools for regulation of their participation in the international specialization, protection of national economy against fluctuations of currency rates, cyclic falls, unfair competition, assistance in positioning of the national manufacturers on the global market.

The state opportunities and tools of participation in foreign trade activities. In a most general way they can be divided into direct and indirect. The direct participation in the international economic relations provides attraction of this or that state bodies to reproducing processes. Such attraction can be shown directly as the centralized state export deliveries and import purchases, participation in the international economic cooperation of state enterprises, but it is limited to influence principles of settlement of payment.

The indirect participation of the state in foreign economic relations demands legal regulatory base, organizational framework, which are established by competent state institutions according to their understanding of national reason of this or that kinds of international cooperation, and also economic and specialized institutions of, currency-financial regulation: taxation, tariff parameters, amortization politics, state orders, grants, loans, subsidies.

The legal basis for practical realization of the external economic policy is created on the base of the laws of Ukraine "On foreign trade activities" (April 1991), "On free economic zones" (October 1992), "On foreign investments" (March 1993). The concept of the Law "On foreign trade activities" is based on the application of opportunities of market economy, which gradually affirms in the state. In the Law the mechanism of regulation of foreign trade activities is given in details which should ensure progressive structural shifts in economy and favorable conditions of its attraction to a global division of labor together with the maintaining balance in economy and balance of a home market of Ukraine.

The Cabinet of the Ministers carries out the external economic policy according to the laws of Ukraine, concludes and provides realization of the intergovernmental agreements, carries out measures on rational use of state currency fund and stabilization of payment balance of the country etc.

International relations of Ukraine are carried out both in foreign trade, and in economic, scientific, technical and cultural cooperation, in the international tourism and other forms.

Most natural for the market and widespread tool of support of foreign trade activities, the stimulation of economy and rationalization of import are numerous privileges and exeptions from the taxation, system of the customs duties. The thing is that opportunities of clearing from this or that kind of the direct or indirect, central or local taxes or reduction of the appropriate rates for industries (for example, clearing of payment of the duty on import of the highly technological equipment, which is used on main directions of science work), (a favorable tax, investment climate for small business). The important element of state financial support in foreign economic business is the contractual relations with other countries for prevention of the double taxation and with the purpose of the greatest assistance to foreign trade.

The features of the present stage of development is real demand for capital resources which dictate the necessity of active assistance to the inflow of the foreign capitals to the, national economy. A consequence of such policy should be me creation in Ukraine of an organic sell-regulated subsystem of market economy. It will assist general stabilization of on economic and financial condition both in national scale, and at a level of the enterprises to stimulate scientific and technical progress, introduction of resource technologies, additional cooperation contacts, filling of the market by rare and essentially new products, reconstruction of capacities.

Under present conditions the economy of Ukraine finds itself in a long economic crisis, which negatively influences conditions of foreign trade. Volume of export does not meet requirements of our manufactures of goods and does not satisfy needs of the state in hard currency necessary for stabilization of economy, reduction of a rate of inflation and budget charges.

New aspects of research.

The foreign trade activities of Ukraine requires radical reorganization - especially change of raw material export, an increase in the export part of production of industries, improvement of a import structure. It is known, that Ukraine produced and can produce the whole spectrum of; planes, buses, cars, tractors, combines, vessels of different functions, rocket complexes, machine tools, turbines, communication, electronics, radio and TV equipment etc. It can be real that basic exporters competitive in the global market of production are enterprises of a military-industrial complex, at which high-quality equipment, modern technologies, highly skilled experts are concentrated.

The attraction of the foreign investments will assist also general activation of business, development of new economic relations, which to a certain extent can compensate instability of the economic relations with the partners in the countries of CIS. An essential role can be played experience, advanced methods of organization of manufacturing, technologies, and also granting of the scientific - advisory help when foreign investors will be interested (interested in giving it to) Ukrainian partners.

The Ukrainian state should ensure protection to export organizations to give them a chance a survival and grow at economy, especially of its export sectors.

At the same time it is necessary to create the wide system of foreign trade organizations, representative, offices which will understanding business and would push Complicated and sophisticated modern products progress: Ukrainian goods it the world (global) market. It is expedient to arrange grants to Ukraine of the target credits by foreign countries, manufacturers.

Renovation of economic relations, imposing by the metropoly, especially such, as excessive specialization of the national economy, high level of militarization of economy etc., contrasted national interests of Ukraine.

So, it is necessary not only to restore former relations, with Russia and other countries of CIS but to start new, convenient for Ukraine. Unification of the legislation, uniform tariff procedures, transfusion of labor and capitals within the of CIS are not benefitial a Ukraine. The export-import interests of Ukraine should meet strategic interests of our state.

Can be mettle the young independent state of Ukraine. A number of difficulties the on ways development of own it economy. For this purpose it is necessary to provide privatization and transfer to the market oriented system, to liquidate categorically ideological approach to the economic and old means of management. All these steps will help to establish new forms at economic system structure. Clearly, it will result in significant reforming, specializations of different areas of economy, occurrence of economic areas, economic regions, and centers. The economic cooperation with foreign partners will assist growth of prestige of Ukraine.

Statement of basic material.

The formation of modern external economic policy of Ukraine requires such methods of state influence, which would carry out stimulating and regulating functions and assist introduction of effective mechanisms of foreign trade activities. In spite of the fact that in modern conditions the national economy becomes more and more open, the state should take into account in the foreign economic policy interrelation of processes, which occur inside economy and in the sphere of foreign economic relations. Therefore liberalization of conditions of foreign trade activities should be carried out in connection with system of implementation of nation-wide interests in this area. With this purpose in the international practice, laws, economic tools and regulatory base are supplemented by measures of operative state regulation of the external economic operations, which include: registration of contracts, quotation, licensing, rules of the termination of foreign trade activities, regulation of operations with foreign currency and realization of the investments abroad, movement of goods and property through customs and other measures. The external economic policy Ukraine is directed to: transition to active export focused strategy of economic development on the basis of target formation and effective realization of export potential of Ukraine in priority areas of economy; liberalization of sphere of foreign economic relations; implementation of the requirements of the General Agreement on the Tariffs for these of international trade organization; priorities in sphere of the economic relations which countries of CIS. The main attention will be given to industrial and scientific, technical cooperation, creation of joint ventures, financial industrial structures, development of joint objects of infrastructure, cooperation on the markets of the developing countries; development of the concept of the external economic policy of Ukraine, and also state program of development of the export potential of Ukraine.

The foreign trade is most advanced form of the international economic relations, and the foreign trade policy is one of the basic directions of state regulation of economy. It represents system of measures directed to protection of the external market, to stimulation of growth of volume of foreign trade, change of its structure and direction of commodity flows.

In this area the important tasks for Ukraine is harmonization of its foreign trade policy with the requirements and norms of (General Assembly on tariffs and trade / World Trade Organization), the status of the observer in which Ukraine has received in 1992. The membership in World Trade Organization requires from Ukraine the completion of the external economic legislation and its conformity with the international. Is means that the worked out legislation norms and standards will regulate trade, tariffs, taxation, finances, investment and other spheres of the nation all economy of Ukraine

In order to be accepted by the world economy. The state should provide goods exporters with a high level of legal assistance, create favorable conditions for the Ukrainian exporters at interstate negotiations; in the international organizations, etc.) and advertising-propaganda protection. It is necessary to organize also crediting and support of exporters of the competitive goods in the world market. At the same time it is necessary to protect our economy, manufactures from bad quality goods which come from other countries. For this purpose certificates are created but not tariff barriers. The system of the foreign trade organizations, representations, Chambers of Commerce and other structures which at a high organizational level will deal with problems of promotion of goods on the world markets, is created for advertising and realization of products of the Ukrainian enterprises. So, reorganization of foreign trade activities of Ukraine will assist appreciably to its promotion on the world market and to integration in the international economy. In general, the program-target scientific and technical policy is an obligatory element of the centralized regulation of foreign trade activities. Its real methods and forms defines state priorities for research and development with acceptance of necessary organizational-economic actions in relation to the economic-enterprise organizations, coordination of scientific and technical development, mobilization of resources, partial identification of expenses at realization of long-term work cycles, patent-license regulation, provision of favorable conditions for the international cooperation. Foreign trade activities can positively influence development of a national facilities under condition of creation of opportunities for its functioning as certain system formation. Efficiency of external sector of economy appreciably depends on a degree of development of an infrastructure, therefore the external economic sector should be considered as the integrated system which will consist of two interconnected blocks: subsystems of actually foreign trade activities and a subsystem of an infrastructure serving it. Presence significant subjects of foreign trade activities and a variety of necessities of classification of a market infrastructure of foreign trade activities behind different criteria lead to: in general, to determine a level of functioning and a direction of specialization. As foreign trade activities in Ukraine gets wide development only from the beginning of 90th years for our country at the present stage are important both qualitative, and quantitative increase in infrastructural elements of foreign trade activities.

Prime development those elements of an infrastructure which have for the purpose of service of the individual subject of foreign trade activities, and also, in our opinion, demand granting of financial and insurance services.

Conclusions.

It is necessary to stress that the urgent task, from our point of view, is the development of the national infrastructure and services for foreign trade activities. We mean the formation of official bodies for sanitary, patent-licensing control, financial, statistic, information provision of international economic contact of participant of economic activities. The development of transportation, construction of airports, modernization and construction of oil terminals are quite necessary elements for the international economic contacts.

References

1. *Коломойцев В.Е.* Аналітична оцінка та розвиток зовнішньоекономічних зв'язків в Україні, К. – 97 р., 245 с.
2. *Кузнецова Н.В.* Регулирование ВЭД в Украине, К. – 97 г., 135 с.
3. *Новицкий В.Е.* ВЭД и международный маркетинг, К. – 94 г., 210 с.

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GLOBALIZATION AS THE ESSENTIAL FACTOR OF INFLUENCE ON ECONOMIC SAFETY IN AIRCRAFT

Modern lines of globalization are examined, its influence on economic safety, the basic concept of safety of the aviation enterprise is offered.

The subject of research. In connection with numerous cases of illegal intervention in activity of aviation sphere the world community constantly strengthens measures concerning maintenance of economic safety in aircraft. Today transport safety should be considered as an economic category. The increased level of safety of an air transport is its high appeal and, as consequence - high economic efficiency.

The typical tendency of development of the international economic relations in the beginning of the XXI century is internationalization which important factors is regionalism and globalization. Influence of globalization has not bypassed aviation. The essence, the mechanism and consequences of this process is not investigated up to the end and also cause opposite sights. Some consider, that globalization is dynamic process of formation economic and political neoliberal market law and order. Others, on the contrary, consider that it has chaos and may turn back as global chaos, the third design intermediate hypothetical concepts. Undoubtedly, at present "globalization is the highest phase of internationalization (integration) of economy and politics and culture in its elementary state". Today the world has turned into global economic system in which practically do not remain opportunities for the spontaneous market relations between the countries. Appeared globally functioning international industrial and economic mechanism, which consist of separate national economies. One generation is the eye-witness of the fact that there is a condensation of space and time in global scales, mutual rapproachement of the countries, people, regions. Under influence of globalization liberalization of sociopolitical sphere extends, market relations in economy are improved, manufacture and the market of a labour is transformed, mass media is technologicaly updating. Such phenomena do not bypass Ukraine. The main task is to find out changes and to develop decisions in time which will allow to use advantages of world economic globalization. But it is necessary to make the weighed steps in direction of globalization of economic relations.

The analysis of last researches and publications. Globalization is one of the sharpest topics which are discussed both in political circles, and among scientific experts and the public. Processes of globalization significally influence the contents and paces of formation of new types of relations in a modern society and experts of new generation. Global changes, together with other objective factors, assist search of effective ways of reduction of adverse consequences, reliable methods of forecasting of possible changes with the purpose of a survival and the further development of the enterprises of civil aviation.

This issue is an object of research of many scientists [1-4]. Various conferences are regularly carried out. So, for example, March, 13-14, 2003 on the basis of Donetsk institute of management Ukrainian scientific and practical conference "Social, economic, political and psychological consequences of globalization in a modern society" was held. More than 50 scientific experts, scientific and pedagogical workers, 10 national, state and private higher educational institutions, 6 regions of Ukraine, including Donetsk, Dnepropetrovsk, Lugansk, Kirovograd, Kharkov and Kiev took part in its work. In general more than 35 different works were presented, the third of them is prepared by prestigious national high institutions of Ukraine (Kiev T.Shevchenko national university, Kiev national trade and economic university, Donetsk national university, Donetsk national technical university, the Kharkov V.N.Karazina national university, Y.The Wise National legal academy of Ukraine, National metallurgical academy of Ukraine).

The part of the issue that was not considered earlier. This question was studied from the end of 80th years of the last century. However, in conditions of a strongly pronounced protectionist policy influence of globalization was levelled. The fact of globalization as one of the most outstanding factors of environment will allow to construct an effective control system of economic safety of the aviation enterprise.

Objectives of the article. Lately, transport globalization is more clear. There is a question - the advanced insurance markets of aviation services approach or keep away one from another.

In this context, definition of influence which causes globalization on economic safety of aviation [5] has not only theoretical, but also the important applied value for the countries which are at a stage of market transformation.

The basic material. Without development and consecutive realization of national strategy, which is oriented on global challenges, advantages and threats, such answer is impossible.

On the basis of long-term researches of global transformations in political, economic and social spheres such conclusion draws famous economist, diplomat and politician, member correspondent of the National Academy of sciences of Ukraine Oleg Grigor'evich Belorus in his work " Globalization and national strategy of Ukraine". For the first time in the world and national scientific and scientific - methodical literature the unique concept of national strategy of development of the definite country (Ukraine) is developed by the author in conditions of transition to the new era - era of a global civilization.

Outstanding feature of globalization during last decade became huge influence of the new information and technologies of communication on reduction of expenses. Such reduction of expenses has caused new investments, creation of a plenty of new workplaces, increase of productivity of work, and increase of well-being, but has resulted as well in aggravation of competition. Financial innovations gave a push to sharp increase of the international streams of the capital that has resulted in occurrence of new opportunities and risks. In theory, free trade enables the countries to concentrate on those kinds of activity in which they have comparative overweight, and subordinates firms to the sound discipline caused by a competition with the foreign companies. It means the maximum productivity and increase of a standard of living while consumers have an opportunity to have wider choice of the goods and services for lower prices.

Fall of incomes and slump in production in Ukraine during independence was sharper, than in other countries with economy of transitive type. This sharp recession of incomes is frequently explained by initially adverse historical situation or a geographical arrangement. However, in our opinion the basic reason is, that Ukraine has failed to go through all transformations, necessary to react to the initial shock connected with fall of incomes, increase of productivity due to increase of efficiency which is provided with innovations and restructuring of the enterprises. Absence of real transformations revealed in inability to serve physical actives of the country under condition of gradual infrastructure decline. One of the reasons of this is the fear of mass dismissals. However, experience of other countries proves that many new workplaces are created at appropriate circumstances if the correct economic policy is applied.

The aviation enterprises in questions of a safety of manufacture act not only within the framework of legislative requirements. Full scale strategy of management of the aviation enterprise should cover the greater circle of issues, than simple observance of the norms and rules. Existing risks should be examined not only from technical, but also from the economic, political, legal and ecological points of view. Accordingly, should be expanded the list of possible methods of influence on risk, including financial mechanisms, such, as insurance and creation of reserve funds.

The general concept of safety of the aviation enterprise should cover the following questions:

1. Development of a general technique of gathering and granting of the information on industrial activity for all branches and divisions.
2. Identification of possible dangers and incidents which result in them, an estimation of frequency of incidents.
3. Gathering and data processing concerning the past losses. Development of a general technique of an estimation of the loss from adverse events which should take into account both dirct and indirect losses.
4. An integrated estimation of risk, reception of average indices by kinds of risk and separate objects and divisions, revealing of statistical regularities.
5. An estimation of opportunities of the enterprise for management of risk and presence of resources for deletion of consequences of adverse situations.
6. Formation of the general concept of aviation safety, management of different groups of risk in view of their specificity, features of functioning of separate objects, their territorial arrangement etc. The account of legislative requirements to industrial safety.
7. Creation of complex system for control of quality production.
8. Fixation of the developed concept in normative and methodical materials, registration of the declaration of industrial safety. Development of a long-term plan of actions for the period from three to five years.

One of the main features of globalization is, that this phenomenon is accompanied by "uncontroled" expansion of the world markets for the certain kinds of production, goods or services. For example, planes of "Boeing" corporation, program production of "Microsoft" company, Internet technologies and services have filled in the world markets which became global for these kinds of goods and services. Thus, there is an acute problem: how to keep advantages of the global markets with the purpose of maintenance of sufficient spaces for development human, public and natural resources, that is that globalization works not only on profit of separate corporations or people.

When the global market, being not balanced, "undividedly" begins to dominate above social and even above political spheres of a society is an attribute of "other side of a medal" of globalization phenomenon, the evidence of insufficient development of democratic institutes of this society.

Since 80's of XX century in many countries of the world the phenomena of a social inequality begins. As a consequence of an excessive social inequality in the world there are new threats for safety of people, in particular:

· financial and economic instability;

· threat of mass loss of work as a result of merge of the different companies in process of globalization;

· threat of political, public and personal safety in connection with global business criminalization, politics, law enforcement bodies, increase of illegal trade;

· threat to environment which is connected with uncontrollable development of powerful engineering, an intensification of industrial, transport and military activity of people.

To receive positive results from globalization is possible only under condition of realization dynamic and efficient control using all spheres of public work.

It means that this management may establish system of rules and methods which, on the one hand, stimulate development of public institutes and persons, and on the other hand, enter the necessary socially recognized restrictions.

In this respect globalization "pushes" to viewing principles of management as on national and supranational levels. For the sake of preservation of advantage of the competitive markets at presence of precise rules and political and geographical borders, and an orientation of these transformations on satisfaction of needs of the person, management at the specified levels may become more effective and coordinated. Ideological bases should at least dominate over principles of tolerance and pragmatism on the big economic spaces. That is that fact should be admitted, that benefits for one of participants of the global market (the countries or the transnational company) not necessarily may suit other participants and it is necessary to concede for the sake of the common strategic development.

Conclusions and prospects of the further development. In modern conditions globalization as the important feature of development of world economic system is one of the major factors of environment that, certainly, influences activity of the subject of managing. The effective decision of a problem of construction of system of economic safety will allow management of the aviation enterprise to increase parameters of activity and efficiency of strategic decisions which are accepted.

The list of the literature:

1. *Андронова Ю.М.* Реформування податкової системи України в умовах інтеграції до Європейського Союзу: прибутковий податок з громадян // Збірник наукових праць Української Академії державного управління при Президентові України. - 2004. - №1. - С.143-151.

2. *Барановський О.* Проблеми фінансової безпеки в умовах інтеграції України у світовий фінансовий простір // Вісник Національного банку України. - 2004. - №10. - С.18-19.

3. *Барінгольц О.* Інтеграція України до європейського економічного простору // Вісник Київського національного торговельно-економічного університету. - 2004. - №3. - С.27-38.

4. *Баронін А.С.* Інтеграційні перспективи України очима керівництва Європейського Союзу // Трибуна. - 2003. - №11-12.- С.32.

5. *Андрійчук В.* Глобалізація, інтеграція та економічна безпека України // Політика і час. - 2004. - №9. - С.61-70.

6. *Дергаусов М.* Проблемы интеграции украинской и европейской транспортных систем в контексте экономической интеграции Украины в ЕС // Вісник ТАНГ. - 2003. - №18.Ч.1. - С.131-135.

7. *Бесараб Є.О.* Фінансово-промислова інтеграція: зарубіжний досвід та уроки для України // Фінанси України. - 2004. - №2. - С.133-144.

8. *Губський Б.* Євроатлантична інтеграція України. - К.: ЛОГОС, 2004. – 328 с.- (НАН України).

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THE ECONOMIC SAFETY OF THE UKRAINE ENTERPRISES

The questions of estimation of structure and criteria of enterprise economic safety, the directions of maintenance the state economic safety of , as determining factor of the enterprises safety are considered

Statement of a problem

Ukraine as the independent state exists in interconnected and interdepended world. One of the basic problems of the state development is on the one hand overcoming the contradiction between necessity to be integrated in world economy, and to ensure the extended reproduction, protection of the home market, own commodity producer and national interests, with another. To overcome these contradictions it is possible only on the basis of protection of national interests, control of the state of an effective utilization of own resources, achievement of a high level of manufacture and quality of production. It provides competitiveness of production of the enterprises and allows on equal terms to participate in world trade, cooperation spheres and exchange of scientific and technical achievement.

The economic safety of the state, real support of domestic manufacture can be ensured with development and realization of the concept of national strategy of economic safety, which will have short-term, intermediate term both long-term objectives and concrete mechanisms of their achievement. Besides it is necessary to ensure constant monitoring on the part of the appropriate state structures behind realization of this strategy. Development of strategy should become creation of the appropriate normative-legal base, which will determine the basic criteria of economic safety and will adjust activity of the economic subjects.

Taking into account above told, the urgency of maintenance, development and estimation of the adequate mechanism of economic safety of the enterprise is explained in view of conditions, restrictions and criteria of all basic participants of its productive and economic activity: the states, enterprises - competitors, consumers.

The analysis of last researches and publications

The significant attention politics, practical worker and scientists is given to development of theoretical bases, and also techniques of account and analysis of economic safety. In 1998 the Concept of economic safety of Ukraine was developed, in which the essence of economic safety of the country is determined as « … ability of national economy to ensure the free, independent development and to keep stability of a civil society and its institutes, and also sufficient defensive potential of the country under all adverse conditions and variants of development of events, readiness of the Ukrainian state for protection of national economic interests against external and internal threats ». The concrete definitions of situations of economic safety with reference to the enterprise are devoted works V.Tamdovzev, V.Shlikov, E.Olejnikov, A.Kozachenko, V.Zabrodski, N. Kapustin. V.Tamdovzev such condition determines economic safety of the enterprise as which means, that the probability of undesirable change of any qualities, parameters of property, belonging to it, and touching its external environment, is insignificant. Depending on what combination of parameters of ability to live of the enterprise is for it desirable, the concrete filling of concept «undesirable changes» will vary also [6].

The representatives of a resource-functional campaign as basic making economic safety allocate intelligence - personnel, financial, techniques-technological, policy-legal, economic, information and power. E.Olejnikov analyzes all characteristics and interrelations of set of processes, which, from his point of view, make uniform related group on a functional role in maintenance of economic safety of the enterprise [5].

V.Zabrodski, N.Kapustin considers economic safety as «the quantitative and qualitative characteristic of properties of firm reflecting ability «self-survivals» and development in conditions of occurrence of external and internal economic threat» [3]. In opinion of the author, the economic safety of firm is determined by set of the factors reflecting independence, stability, opportunity of growth, maintenance of economic interests etc. В.Шлыков considers economic safety of the enterprise as « … a condition of security of the vital interests of the enterprise from real and potential sources of danger or economic threats » [7].

Unsolved earlier part of a general problem

The analysis of existing sights on essence and the definition of a level of economic safety of the enterprise shows presence of two basic approaches. The first approach is characterized by the certain limitation in treatment of concept « economic safety of the enterprise », that narrows opportunities of observation of influence of all set of internal and external threats, quantitative definition of a level of economic safety in view of financial and economic, social, political quantitative and qualitative parameters of internal and external environment. On the contrary, breadth of the second approach results in an identification of concept of economic safety of the enterprise with efficiency of this enterprise activity.

Statement of a task

In this connection, there is a necessity for completion of the concept of economic safety of the enterprise, creation of the tool of an estimation of a level of economic safety on the basis of the comparative analysis of the enterprises, account of the quantitative and qualitative characteristics of economic properties of system, revealing destabilization of influence of the internal and external factors.

The purpose of clause is the further research of economic safety of the enterprise, estimation of structure and criteria of maintenance of economic safety of the enterprise, directions of maintenance of economic safety of Ukraine as determining factor of economic safety of the national enterprises.

Statement of the basic material

Characterizing economic safety of the enterprise, it is necessary to consider in complex, in interrelation not only with internal environment, but mainly in interaction with the factors of external environment. The coordination of interests of the enterprise and subjects of an external environment, them harmonization in time and space is a measure of realization of economic safety of the enterprise. Among the subjects of external environment it is necessary to allocate, first of all, state rendering most significant influence on activity of the enterprise, in the different forms adjusting practically all aspects of its activity. What tasks face to the state, which decision would allow to ensure economic safety of the enterprise? First, this strengthening of the proved protectionism directed on maintenance to a diligent competition in the Ukrainian market. On a home market it is necessary to carry out resolute measures on restriction of realization of the counterfeit goods and production, which are delivered on dumping to the prices.

The trade in the import goods in Ukraine should get civilized character, that is provided with observance of the procedures, established by the legislation, of certification, increase of an overall performance of customs and tax bodies, practical approbation of the mechanism of application anti-dumping of procedures. Secondly, it is necessary to ensure stimulation of import in Ukraine of critical raw material, technologies "«know-how", highly effective equipment certain restriction with tariff and not tariff ways of import of ready production, which can be made in Ukraine. On the basis of this principle the list of production, so-called « of critical import » should be formulated, be established the rates of the customs tariff. For maintenance of stability of process of delivery of raw material on the domestic enterprises the creation of joint ventures and industrial - financial groups with the foreign partners - suppliers of raw material is expedient.

It is necessary to create conditions for availability of the bank credits, especially long-term, for the manufacturers. It is reached first of all at the expense of integration and increase of reliability of commercial banks, restriction of their opportunity to speculate on operations with currency and state valuable papers, decrease of the rate refinancing, introduction differentiation norm of bank reservation depending on structure of a credit portfolio. Attraction of the bank credits in priority sectors and the branches of economy should be provided with state guarantees.

It is necessary to carry out radical reforming of tax system. Indemnification of decrease of a level of the taxation is possible by attraction of means « of shadow economy »; the basic directions of tax reform should be reduction of the list of the taxes, privileges and maintenance of the maximal transparency of base of the taxation.

To number of prime tasks on maintenance of economic safety of the enterprises it is necessary to relate actions of the states promoting preservation of scientific and technical and technological potential and orientation to manufacturing of a competitive final product; introduction of new technologies, activization innovation of activity with the purpose of updating manufacture and increase of its technical and economic parameters; decrease resource-capacity of manufacture by introduction resource- and power-safe technologies, reforming power-and resource-capacity of manufactures; activization of functioning of a home market by maintenance of equation of manufacture and consumer demand, reorientation of branches of mechanical engineering, metallurgical and chemical industry on more complete satisfaction of needs of interbranch cooperation. The efficiency of activity and economic safety of the enterprises of Ukraine will depend substantially on development of optimum economic model, which would take into account national interests, geopolitical and geoeconomic factors, culture of a nation.

Major element in definition of economic safety the enterprise is the choice of criterion. According to the display approach the level of economic safety is established by results of comparison of actual parameters of activity of the enterprise with indicators, as which the threshold meanings of parameters of activity of the enterprise in various functional areas act.

Problem of application of the given method consists in absence of methodical base of definition of indicators, which provides the account of specificity of activity of the enterprise, and also opportunity of application of indicators depending on changes of internal and external environment of the enterprise. The resource-functional approach assumes an estimation of a level of economic safety on the basis of an estimation of a condition of use of corporate resources by special criteria. According to the resource-functional approach most effective utilization of corporate resources is reached by prevention of threats of negative influences and achievement of the following basic functional purposes of economic safety of work of the enterprise: maintenance of a high financial overall performance of the enterprise, its financial stability and independence; achievement of technological independence of the enterprise and achievement of high competitiveness of its technological potential; High efficiency of management of the enterprise, optimality and efficiency of its organizational structure; a high level of qualification of the personnel and its intellectual potential; a high level ecology of work of the enterprise; qualitative legal security of all aspects of detail of the enterprise; maintenance of protection of information environment of the enterprise; trade secrets, safety of the personnel of the enterprise, its capital, property and commercial interests.

The unsufficient efficiency of application of the resource-functional approach is connected to complexity of an estimation of functional spheres of activity of the enterprise and by enough high reserve of an estimation of a level of economic safety on the basis of cumulative criterion determined by an expert estimation by individual functional criteria.

Rather difficult in application the approach to an estimation of economic safety of the enterprise is on the basis of principles both conditions of a program-goals management and development with use of several levels of integration of parameters and such methods of their analysis, as cluster and multidimensional analysis.

In opinion of many scientists, major making economic safety of the enterprise is its financial condition, which can be estimated on the basis of a general synthetic parameter estimated on the basic factors, describing financial-economic activity of the enterprise. Application in domestic conditions of such known complex parameters as an index Altman, model Springejt, model Lis there is enough problems. The Ukrainian scientists develop such models as discriminant model of an integrated estimation of a financial condition of the enterprise (O.Tereshehko), which is based on use of methodology discriminant analysis of financial parameters of a sample of the domestic enterprises, complex estimation of a financial condition of the enterprise on the basis of use of matrix models (O.Hotomlianski, T.Pernata, G.Severinja). As shows experience of application of an integrated parameter, the account of specificity of manufacture and estimation of the factors is required, a degree of influence and which priority for various branches and different enterprises essentially differ.

From our point of view, for an estimation of a level of economic safety it is expedient to use the approach, bases on comparison of size of the investments of the enterprise, and mainly for the account reinvestment of the profit, with volume of means necessary for maintenance for economic safety of the enterprise.

The individual character of the given approach is connected to definition of size of the profit necessary for extended reproduction of the capital, as it depends on concrete dynamics of process of manufacture inherent to each concrete enterprise.

On the basis of the executed analysis, it is possible to make the following conclusions:

1. Economic safety of the enterprises — a basis of national safety of the state.

2. Transition to market economy, occurrence of significant number of the managing subjects with various patterns of ownership, strengthening of a competition, imperfection of legislative base, weakness of state structures called to create of a normal condition for business, put is especially sharp before the enterprises a problem of maintenance of the economic safety.

3. The decision of a problem of structure and parameters of an estimation of economic safety of the enterprise with reference to features of national economy is required.

References

1. Грунин О.А., Грунина С.О. Экономическая безопасность организации — С-Пб.: Питер, 2002. — 160 с.
2. Безпека економічних трансформацій: Зб. матеріалів "круглого столу"/ Під ред. Я.А.Жаліна. — К.: НУСД: "Альтерпрес", 2000. — 386 с.
3. Забродский В., Капустин Н. Теоретические основы оценки экономической безопасности отрасли и фирмы / Бизнес-информ. — 1999. — № 15-16.
4. Козаченко А.В., Пономарев В.П., Ляшенко А.Н. Экономическая безопасность предприятия: сущность и механизм обеспечения.— К.: Либра, 2003. –280 с.
5. Основы экономической безопасности. Под ред. Е.А. Олейникова. — М., 1997. — 288 с.
6. Тамбовцев В.Л. Экономическая безопасность хозяйственных систем: структура проблемы / Вестник Московского гос. ун-та. Сер. 6 Экономика. — 1995 — № 3.
7. Шлыков В.В. Безопасность предприятия в условиях рынка. — Рязань, 1997. — 134 с.

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FORECASTING AS AN INTEGRAL PART OF BUSINESS PLANNING IN AVIATION

The article is dedicated to development of forecasting in business planning for aviation. Possibilities of adaptation of foreign experience to Ukrainian economical conditions. Main methods qualitative forecasting, quantitative forecasting models that could be implicated to management system of our domestic enterprise.

Actuality:

Today's Ukrainian aviation companies faced a necessity to compare with foreign producers in their market segment. That makes them to introduce the contemporary standards of production and operation management, widely used in many international companies. In conditions of transforming economy it is imperative the importance of having effective approaches to forecasting adapted to Ukrainian specific. Forecasting is an integral part of business planning in process of producing. The question of forecasting in business was researched by Ukrainian scientists in field of management M.Vynogradsky, V. Skibitsky and others. But the most complex researches in field of business forecasting were made by foreign scientists N.Gaither, R.G. Murdick, D.M. Georgoff and others. The adoption of these complex researches to Ukrainian conditions has ultimate importance for development of domestic enterprises. The comprehension of this article is to research existing possibilities for such adaptation.

Problem's analyzes:

When managers plan, they determine in the present what courses of action they will take in the future. The first step in planning is therefore forecasting, or estimating the future demand for products and services and the resources necessary to produce these outputs. Estimates of the future demand are the starting point for all the other forecasts in producing organization.

Managers in aviation companies need long-range forecasts to make strategic decisions about products, processes, and facilities. They also need short-range forecasts to assist them in making decisions about production issues that span only the next few weeks. The forecasting methods or models may be either qualitative or quantitative in nature. Qualitative forecasting methods are used to develop sales forecasts. These methods are usually based on judgments about the causal factors that underlie the sales of particular products or services and on opinions about the relative likelihood of those causal factors being present in the future. These methods may involve several levels of sophistication, from scientifically conducted opinion surveys to intuitive hunches about future events. In table below cited some examples of possible subjects for forecasting.

Table 1

Some examples of recommended forecasting for aviation

Forecast horizon	**Time period**	**Examples of things that must be forecasted**	**Units of forecasting**
Long-range	Years	New product lines Old product lines Factory capacities Capital funds Facility needs	Hryvnas, euro, dollars Hryvnas, euro, dollars Units, hours Hryvnas, euro, dollars Space, volume
Medium-range	Months	Product groups Department capacities Work force Purchased materials Inventories	Units Units, hours Workers,hours, Hrivnas,euro, dollars Hrivnas, euro, dollars, units
Short-range	Weeks	Specific products Labor-skill classes Machine capacities inventories	Units Workers, hours Units, hours Hryvnas, euro, dollars, units

There are some of the benefits below offered by qualitative forecasts.

- **New facility planning.** It can take as long as five years to design and build a new factory or design and implement a new production process. Such strategic activities in producing economy require long-range forecasts of demand for existing and new products so that operations managers can have the necessary lead time to build factories and install processes to produce the products and services when needed
- **Production planning.** Demands for products and services vary from month to month. Production rates must be scaled up or down to meet these demands. It can take several months to change the capacities of production processes managers need medium-range forecasts so that they can have the lead time necessary to provide the production capacity to produce these variable monthly demands
- **Work force scheduling.** Demands for products and services vary from week to week. The work force must be scaled up or down to meet these demands by using reassignment, overtime, layoffs, or hiring. Operations managers in aviation need short-range forecasts so that they can have the lead time necessary to provide work force changes to produce the weekly demands

Methods of solving problems:

The inputs are processed through forecasting models or methods to develop demand estimates. These demand estimates are not the sales forecasts; rather, they are the starting point for management teams to develop sales forecasts. The sales forecasts become inputs to both business strategy and production resource forecasts. There are six basic methods for qualitative forecasting:

1 Executive committee consensus. Knowledgeable executives from various departments within the organization form a committee charged with the responsibility of developing a sales forecast. The committee may use many inputs from all parts of the organization and may have staff analysts provide analyses as needed. Such forecasts tend to be compromise forecasts, not reflecting the extremes that could be present had they been prepared by individuals. This method is the most common forecasting method

2 Delphi method. This method is used to achieve consensus within a committee In this method, executives anonymously answer a series of questions on successive rounds Each response is fed back to all participants on each round and the process is then repeated As many as six rounds may be required before consensus is reached on the forecast This method can result in forecasts that most participants have ultimately agreed to in spite of their initial disagreement

3 Survey of sales force. Estimates of future regional sales are obtained from individual members of the sales force. These estimates are combined to form an estimate of sales for all regions. Managers must then transform this estimate into a sales forecast to ensure realistic estimates. This is a popular forecasting method for companies that have a good communication system in place and that have salespersons who sell directly to customers.

4 Survey of customers. Estimates of future sales are obtained directly from customers Individual customers are surveyed to determine what quantities of the firm's products they intend to purchase in each future time period. A sales forecast is determined by combining individual customers' responses. This method may be preferred by companies that have relatively few customers

5 Historical analogy. This method ties the estimate of future sales of a product to knowledge of a similar product's sales. Knowledge of one product's sales during various stages of its product life cycle is applied to the estimate of sales for a similar product. This method may be particularly useful in forecasting sales of new products

6 Market research. In market surveys, mail questionnaires, telephone interviews, or held interviews form the basis for testing hypotheses about real markets. In **market tests,** products marketed in target regions or outlets are statistically extrapolated to total markets. These methods are ordinarily preferred for new products or for existing products to be introduced into new market segments.

Quantitative forecasting models are mathematical models based on historical data. Such models assume that past data are relevant to the future. Some relevant data can almost always be found. Here, we shall research several quantitative models, forecast accuracy, long-range forecasts, and short-range forecasts. All of these models can be used with times series.

1 Linear regression. A model that uses what is called the least squares method to identify the relationship between a dependent variable and one or more independent variables that are present in a set of historical observations. In simple regression there is only one independent variable In multiple regression there is more than one independent variable. If the historical data set is a time series the independent variable is the time period and the dependent variable m sales forecasting is sales. A regression model does not have to be based on a time series, m such cases the knowledge of future values of the independent variable (which may also be referred to as the **causal variable)** is used to predict future values of the dependent variable. Linear regression is ordinarily used in long-range forecasting, but if care is used m selecting the number of periods included in the historical data and that data set is projected only a few periods into the future, regression may also be appropriately used in short range forecasting. Regression assumes equi-normality, which means that observed values of the dependent variable (y) are assumed to be normally distributed about their mean (y) and the standard error of the forecast (s_{yx}) is constant as we move along the trend line.

2 Moving average. A short range time series type of forecasting model that forecasts sales for the next time period. In this model the arithmetic average of the actual sales for a specific number of most recent past time periods is the forecast for the next time period

3 Weighted moving averages. This model is like the moving average model described above except that instead of an arithmetic average of past sales, a weighted average of past sales is the forecast for the next time period.

4 Exponential smoothing. Also a short-range time series forecasting model that forecasts sales for the next time period In this method the forecasted sales for the last period is modified by information about the forecast error of the last period. This modification of the last period s forecast is the forecast for the next time period.

5 Exponential smoothing with trend. The exponential smoothing model described above but modified to accommodate data with a trend pattern. Such patterns can be present in medium range data. Also called **double exponential smoothing,** both the estimate for the average and the estimate for the trend are smoothed two smoothing constants being used.

Long-range forecasting means estimating future conditions over time spans that are usually greater than one year. Long-range forecasts are necessary in aviation to support strategic decisions about planning products, processes, technologies, and facilities. Such decisions are so important to the long-term success of any company that intense organizational effort is applied to developing these forecasts for designing a new product, determining production capacity for a new product, planning for the long-range supply of materials.

To purchase and build new airplanes and buildings and to develop new sources materials takes time, and long-range forecasts give managers the time to develop plan for these activities.

Although long-range data may look erratic, if we look beyond this surface appearance we usually can identify rather simple underlying data patterns. The historical sales data tend to be made up of several components. Among these components are trends, cycles, seasonality, and random fluctuation or noise.

In Ukrainian aviation widely used three different approaches to forecasting. The first is expensive and complex forecasting system, the second is inexpensive and simple forecasting system, and the third is a dynamic system for selecting forecasting models. That all three organizations appear to be pleased with the accuracy and cost of their forecasting system demonstrates that there is no single forecasting approach that is appropriate for all situations. In many situations, simple and low-cost forecasting methods tend to provide forecasts that are as accurate as more complex and high-cost forecasting methods.

The data that are available and relevant for forecasts is an important factor in choosing a forecasting method. For example, if the attitudes and intentions of customers are a relevant factor in forecasts and if the data can be economically obtained from customers about their attitudes and intentions, then a survey of customers may be an appropriate method for developing demand estimates.

On the other hand, if the requirement is to forecast sales of a new product, then a survey of customers may not be a practical way to develop historical analogy, market research, executive-committee consensus, or some other method may have to be used.

Several factors should be considered in the selection of a forecasting method (2) accuracy, (3) data available, (4) time span, (5) nature of products and ser (6) impulse response and noise dampening [3]

In choosing a forecasting method, there may be a trade-off between costs and in other words, more forecast accuracy can be obtained at a cost high-accuracy to use more data, the data are ordinarily more difficult to obtain, and the models costly to design, implement, and operate. Such methods as statistical models, analogies, and executive-committee consensus tend to be of low or moderate cost complex econometric models, Delphi, and market research tend to be high (organization must make the cost and accuracy trade-off that is appropriate situation).

The choice of an appropriate forecasting method is affected by the nature of the production resource that has to be forecasted.

Once managers have selected the forecasting model to use, the performance of the model must be tracked. It is important that the performance of forecasting models be monitored and controlled.

References

1.David M Georgoff and Robert G Murdick "Manager's Guide to Forecasting ' *Harvard Busme* (January-February 1986) 112-119

2. "Production and operations management" orman Gaither, 1995

3."Which Indicators Are Truly Indicative f Economy's Health?" Houston Chronicle*,* August 8, 1993, 10E.

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SOME ASPECTS OF MANAGEMENT OF INFORMATIONAL PROCESSES OF ECONOMIC SAFETY OF ENTERPRISES

In the article some aspects of management of informational processes of economic safety of enterprises are analyzed, associated with structuring of information sphere on the basis of balanced system of indices and the usage of this methodology in building of comprehensive system of economic safety.

General problem.

In modern circumstances of running business in Ukraine the needs of economic safety of enterprises make a number of new demands for information quality, which can not be ignored, which can and have to be met using modern information technologies, that is why the problem of economic safety of any enterprise becomes the informational problem, which lies in providing relevant, qualitative information for the processes of management of both an enterprise as a whole and its individual subdivisions.

Analysis of recent studies and publications.

Quite a number of studies are devoted to informational problems associated with economic safety of enterprises; these studies focus on finding exponents of economic stability of enterprises and allow for first of all defining the level of financial stability and its extreme values [3]. The level of financial stability is concerned with predicting losses in economy risks, risks management, and antirecessionary management [2].

A part of general problem unresolved before.

Traditional approaches of economic safety of enterprises studies based on individual calculations of financial stability indicators. They are not concerned with general informational sphere of internal and external sphere of this enterprise, despite the fact that most of enterprises implemented informational systems on the basis of modern informational technologies. On the other hand, the existing approaches to the evaluation of efficiency and information technologies importance are first of all concerned with characteristics of specific functional components: productivity of network equipment, development process and systems implementation efficiency etc. P. Drucker states that big and prosperous enterprise is far from business yet, business is marketing and innovations [2]. Innovations represent some features of the product of a specific enterprise which can be more interesting for a customer than the product of its competitors. If there is no clear information about customers at the enterprise, if it is unknown who it works for, what goods/services are necessary for customers, which price customers are ready to pay and what they will need tomorrow, it means that there is no marketing at the enterprise, there is no business accordingly, that is economic safety of the enterprise can not be guaranteed.

Problem raising (number of articles).

In this scientific work we study the problem of management of informational processes of economic safety of enterprises, the informational sphere of which needs a corresponding structuring.

Actuality of studies.

The implementation of informational system in the activity of enterprises is concerned with receiving of large volumes of information, which can be effectively used only under the condition of corresponding structuring and coordination. Modern informational systems require significant expenses from the enterprise, which in case of unreasoned, economically groundless approach will not make additional value, will not be covered, and may become an additional factor of affecting economic safety of the enterprise. Thus, the problem of management of informational processes of economic safety of enterprises is doubly actual.

Novelty of studies.

In this work we suggest to consider the problem of economic safety of enterprises in terms of general informational sphere of this enterprise. For the first time, we suggest to use the idea of balanced system of indicators in order to systematize and to structure the informational sphere of economic safety of enterprises.

Statement of basic material.

Modern business is characterized by high level of competition and the circumstances of management, which are constantly in change. The competition in all markets so much increased that extensive factors of business development in most of the companies were fully realized. That is why the factors that allow for making business develop at intensive pace have been of great interest for middle and even small business. Among the factors of intensive business development information and informational technologies take a particular place. Modern worldwide trends in the development of informational technologies cardinally change their role in the development of companies' business.

The processes of informational providing of any activity or solving any problem at the enterprise can not occur spontaneously and without any control. The main problem is the absence of mutual understanding between business and informational technologies, when there are no clear criteria of contribution evaluation of informational technologies implemented at the enterprise. Enterprise economic safety is, by its essence, in authors' opinion, is the basic goal of every enterprise, which aims to provide effective operation under any circumstances. That is why the forming of its informational surroundings should correspond to this goal. Creation, development and management of usage of informational surroundings of the enterprise on the basis of modern informational systems and technologies is one of the main tasks of management of any enterprise in the sphere of its economic safety.

In this work we suggest to provide the management of informational processes of enterprise economic safety in the following directions:

- planning of processes of informational providing in the sphere of enterprise economic safety;
- organization of informational surroundings of the enterprise: structuring of informational base, the division of informational tasks, which are solved in separate subdivisions and their coordination;
- motivation of staff in the sphere of information search and protection;
- quality control of informational surroundings of the enterprise.

As the basis of the management of informational processes of enterprise economic safety the conception of comprehensive system of providing economic safety is taken. The goal of this conception is creation and providing of comprehensive system of enterprise economic safety, the performance of its tasks, activity principles, strategy and tactics providing.

The goal of comprehensive system of enterprise economic safety – minimization of external and internal threats for economic condition of the enterprise, including its financial, material, informational, staff resources, on the basis of developed and realized complex of undertakings of economic and legal and organizational nature. It is worth bearing in mind that the biggest importance in providing enterprise economic safety belongs to primary economic and legal and organizational undertakings, which serve the foundation, basis of safety system, unlike the secondary – technical, physical etc. In the process of achieving the goal set a few problems are being solved, that unite all trends of economic safety.

The subject of informational processes of enterprise economic safety is the management of this enterprise.

In authors' opinion, the object of the management of informational processes in comprehensive system of enterprise economic safety as a whole is a stable economic condition of the subject of business undertakings in current and perspective period. Specific objects of protection are the following resources: financial, material, informational, staff.

In this work we suggest to manage the processes of informational providing in the sphere of enterprise economic safety on the basis of the methodology of balanced system of indices (BSI), suggested by D. Norton and R. Kaplan [4]. The methodology of balanced system of indices represents the rules of balancing the goals and enterprise development indices. The main idea of this conception: to provide the management of the organization with the most important information for performing effective processes of administration in a brief, structured manner, as a clear system of indices. In classic version of this conception all the information necessary for the director to take decisions is divided into four interacted blocks of indices, as it is illustrated on a fig. 1.

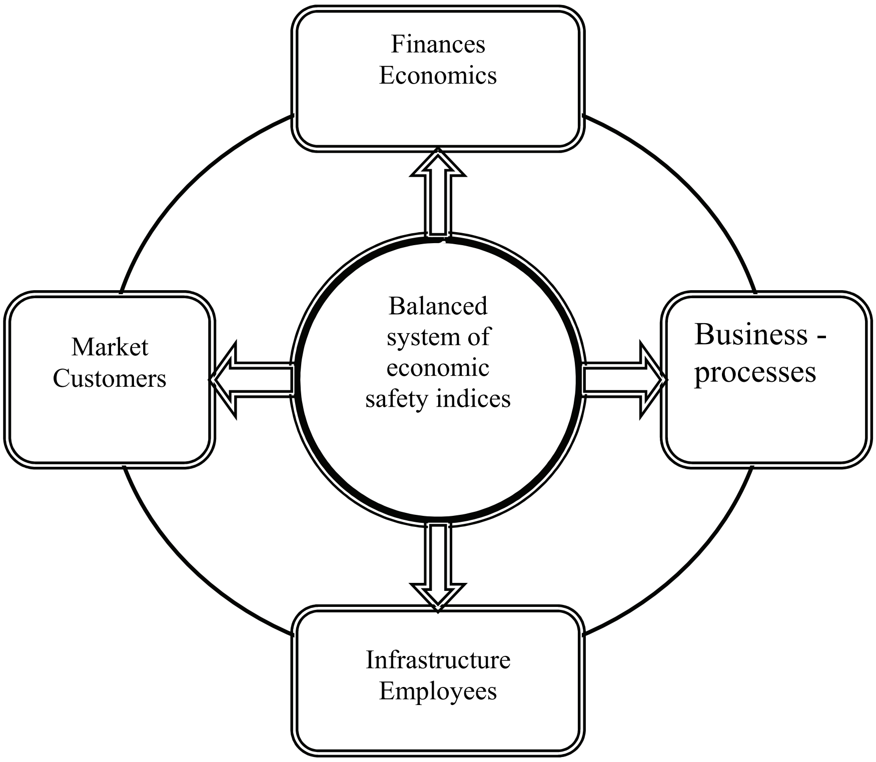

Fig. 1. Balanced system of indices in the system of the management of informational processes of enterprise economic safety

Balanced system of indices of enterprise economic safety is patient of forming strategic cards, which represent the grouping of goals and indices by four categories (perspectives):

- finances: financial goals of development and the results of enterprise work -: turnover, income, profitability, assessment and prediction of financial risks, financial stability etc.;

- clients and markets: the goals of presence in the market and quality indices of servicing customers – developing of the market and sales territory, the length of order performance, "perfect order", assessment and prediction of risks of customers' loss or markets' loss, or the risks of developing new products, sale markets, assessment and prediction of competitive risks etc.;

- business-processes: demands for processes efficiency – cost, time, errors quantity, riskiness etc.;

- employees: the goals of development and raising the level of staff qualification, risks, associated with the staff.

Thus, balanced system of indices in the system of the management of informational processes of enterprise economic safety gives an opportunity to the director, as to the plane pilot, to see "the system of tools" in front of him and perform the management, guided by the values if indicators, grouped by four interacted blocks.

The direction of financial indicators is BSI, without any doubt, is the main one, because it is in monetary units that sold goods and services are evaluated, money is considered as a universal mean in acquiring resources necessary for the enterprise, raw materials, workbenches, human resources, information etc. That is why planning and predicting, control and optimization of financial flows are vitally important tasks for enterprise economic safety.

It is worth mentioning that the quantity of traditional indicators of financial stability used at defining the level of enterprise economic safety is not already enough. With that end in view western companies use a whole complex of means, based on information technologies. Namely:

- budgeting systems include forming and controlling of enterprise budget according to activities type, goods and services and its groups, the centers of financial responsibility, revenues and expenses;

- mutual payments˜ making and controlling of performing schedule of appearance and payment of accounts receivable and payable, defining of payments priority, fulfillment of payments;

- attracting and allocating of funds˜ short-term crediting of current activity, investing of spare financial resources;

- financial accounting – making and consolidating of financial accounting of enterprises of holding company, striking balance, including the one by international standards;

- control of financial and economic activity – calculation of different coefficients which describe the structure and dynamics of assets and capital;

- optimization of financial flows, tax planning;

- financial document circulation – organization of drawing up documents on financial activity of the enterprise;

- analysis and prediction of financial condition of enterprise – multi-parameter analysis and prediction of financial condition of enterprise, according to rate of exchange, raw materials and final products prices, production volume etc.;

- business cost – the management of business cost, impact analysis of different parameters on shares cost, attractiveness for investors, adoption of the decision on managing of the parameters;

- investment projection with using of business-planning systems.

Effective comprehensive analysis of all above mentioned trends of financial stability studies envisages the usage of modern information technologies.

There are mutual causal effects of balance systems indices. It should be noted that in general this logic lies in the following. The higher the qualification of the staff and the more modern the equipment, the simpler to support efficiency of business-processes, which in its turn contributes to qualitative customer service and realization of competitive advantages, ant the latter leads to planned financial indices, and this all is a guarantee of enterprise economic safety.

Thus, for an enterprise as a whole, financial indices are the final goal of functioning and are basic indicators of its economic safety, while other perspectives determine the potential of the company for future periods and enable the forming of enterprise economic safety in future.

In authors' opinion, in similar way one may define key factors of the management of information processes of enterprise economic safety that is to set the perspectives of information technologies development in the sphere of economic safety. It should be understood that it is quite difficult to define the basic result as financial metrics on account that information technologies impact on financial indices of the company is at best indirect. Expenses on information technologies should be regarded in the view of payment for information technologies contribution in business development.

The solution of the problem of the management of information providing processes in the sphere of enterprise economic safety, in authors' opinion, requires the following specifications: the sphere of information technologies of the enterprise transforms from information servicing agent into a partner capable of providing qualitatively new opportunities for running business and realization of competitive advantages in the market, meaning that:

- first of all, planning of the development of information technologies at an enterprise has to be closely connected with enterprise development plans;
- secondly, the implementation of approaches, which enables to have an agreement as to the role of information technologies in business development, to plan its development and to provide control of fulfillment of goals set;
- thirdly, the approaches to the evaluation of information technologies usage efficiency are cardinally changed.

These assumptions are based on increasing of strategic role of information technologies and on the fact that information infrastructure and its context have to constantly proceed from the structure of enterprise business-processes and their cost filling and controlling.

Thus, there is a demand for a balanced system of metrics, which can evaluate a qualitative level of enterprise economic safety taking into account efficiency of information technologies functioning. AT that there should be provided the basic requirements:

- connection with company development strategy;
- availability of effective "leading" indices to provide current monitoring and control;
- a necessary accent on the importance of innovations process and development of technologies and staff.

Such approach, in opinion of this article authors, enables to transform the development of information technologies into a more deliberate process, directly connected with basic business needs, namely, with monitoring of economic safety level. The role of information technologies in improving company positions in the market and in creasing of its financial results becomes more comprehensible.

Conclusions and perspectives of further studies.

Total of information necessary for making a conclusion on a specific process, effect, fact or situation, associated with enterprise economic safety, is characterized by balanced system of indices, which indicate the main directions of effective implementation of modern information technologies into activity of modern enterprises. Information surroundings of balanced system can significantly change the approaches to determining and predicting enterprise economic safety.

Literature

1. Антикризисный менеджмент // Под ред. проф. *А.Г.Грязновой.* — М.: Ассоциация «Тандем», Экмос, 2003. — 386 с.

2. *Друкер П.Ф.* Задачи менеджмента в XXI веке: Пер. с англ. — М.: Издательский дом «Вильямс» — 2000. — 272 с.

3. *Сенчагов В.К.* Экономическая безопасность: геополитика, глобализация, самосохранение и развитие. Кн. 4. ИЭРАН. — М.: Финстатинформ, 2002. — 478 с.

4. *Kaplan R.S.*, Norton D.P. Linking the balanced scorecard to strategy // California Management Review. - 1996. - Vol. 4, Fall. - P. 53-79.

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PRIORITY DIRECTIONS OF USE FSA IN CA

In comparison with other types of transport air transport has higher cost price, therefore application FSA (is functional the cost analysis) air transport production is economically expedient.

The objective of application FSA - completely eliminates or reduce to a minimum change of costs on air transport production.

The civil aviation is a component of the uniform transport system of the country, which has a number of the specific features and differences. To them it is possible to attribute:

- High speed of delivery of the passengers and cargo;
- High passable ness and smaller, than on other types of transport, dependence on physics-geographical conditions of district;
- Possibility to organize combined transportations with a condition to support a high level of comfort for the passengers and services for consignor;
- Large mobility and flexibility in application of air transport, it ability to execute mass expendable and special transportations.

However, air transport has higher cost price of air transportations in comparison with other types of transport, what sometimes forced limits sphere of application of air transport. For the last years a structure of direct technical expenditures – air combustive-lubricating materials (petroleum PRODUCTS), amortization and operating repair of air engineering essentially varied. Under the cost price of transportations the costs of air PETROLEUM PRODUCTS have decreased for this time, and the costs of operating repair of air engineering, amortization of air engineering were increased. It speaks about increase of a share of costs materialized labour, nested in vehicles (airplanes and helicopters), on which share 60 % of all funds, that speaks about the higher cost in comparison with other types of transport.

The lowering material capacity and improvement of quality of airtransport production demands the system comprehensive approach to the analysis, assessment and optimization of use material resources in civil aviation.

The effective tool for solution of problem detection of these reserves is the functional - cost analysis (FSA), directed on optimization of ratio between quality and costs - minimization of costs on useful effect unit.

This method is widely applied in a number of industries at designing and modernizing of product constructions, perfecting of production technology, standardization and production unification, organization of main and auxiliary production.

The application of FSA will allow to reduce the cost price of air transport production at the expense of saving material and labor costs, more effectively use fixed capital, improve technical and economic metrics of their production-economic activity.

In conditions of transition to the market the role of economical managing, careful ratio to all sorts of available resources.

In these conditions in full measure the high efficiency FSA - method of a system research of the object can be shown.

FSA is based on principles of the system and functional approach, principle of correspondence significance degree of functions to costs and quality degree of their implementation, economic approach, principle of collective creativity.

The main tasks of the functional - cost analysis:

- Lowering the cost price of air transport production and rises it quality;
- Economical use of material, labor and financial resources;

- Improvement of use material, labor and financial resources;
- Cutting and liquidation of spoilage.

The efficiency of this method is explained that it allows execute a control behind a level of the greatest number of material production units costs, considering any process as the complex system stipulated by a number of interdependent internal and external factors.

The efficiency of FSA air transport production is based on non-standard sort of the analysis reveals concrete interrelation between consumers cost of air transport production and material costs of production. The cost analysis on the basis of use value cost implements. For what use value of air transport production is represented as a collection of consumer properties, i.e. collection of useful properties making production suitable for satisfaction of necessities.

Use value of air transport production characterizes it public utility, represented qualitatively by various conditions, at which there is a change of location (moving) of the object transportation:

- Speed of delivery;
- The warranty of passengers and cargo safety;
- The warranty of in time delivery;
- Cultural service at moving.

Estimating these conditions, the client compares all pluss and minuses of transportation variants and select most convenient for him. The various degree of different variants utility of airtransport services means their various use value cost represented by a collection of consumer properties.

The consumer property is qualitative characterized with the help of the function. The function is a sold ability of a product.

Quantitatively consumer property is determined with the help of function parameters (technical, economic and technical metrics).

Using a system approach, the experts of FSA consider the consumer cost of production as functions collection. All costs of airtransport production can be divided on " functional - necessary costs " and "functional - excessive".

In fixed ratio costs of functions implementation of airtransport production with its importance for the consumer the cost approach consists.

FSA has universal character, i.e. is applicable everywhere, where it is necessary to optimize a ratio between costs and utility of operation.

FSA of airtransport production is directed on detection and search of paths for lowering costs in.

- Designer researches;
- Engineering-economic researches;
- Technological researches;
- Organizational researches.

References

1. Основы ФСА. Под ред. М.Г. Карпунина, Б.И. Майданчика. М., Энергия, 1980, 1983.
2. Практика проведения функционально-стоимостного анализа в электротехнической промышленности. Под ред. М.Г. Карпунина, 1987.
3. Справочник по функционально-стоимостному анализу. Под ред. М.Г. Карпунина, Б.И. Майданчика, 1988.
4. Е.И. Голибардов, А.В. Кудрявцев, М.И. Синенко. Техника ФСА. К., Техника,1989.

С.Ф. Худасова, Т.О. Гаврилко. Функціонально-вартісний аналіз. Конспект лекций. К., видавництво НАУ, 2001.

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STATE REGULATION OF CIVIL AVIATION IN UKRAINE

Approach to clarify the ways of improvement of state regulation of civil aviation is offered in this article. It is shown that state regulation of civil aviation in Ukraine is an essential element of state policy.

The problem itself

State regulation of civil aviation in Ukraine plays an important role in any country's life today. It is impossible to imagine a country in the world without regulation in the field of civil aviation.

Analysis of research and publications

Analyzing the latest research and publications it is important to mention that this topic is rather essential and is needed a detailed research.

Unsolved part of a common problem

We can stress that Ukraine has already done two major conditions for functioning a civil aviation of the state – a legislation on civil aviation has been created and a state body which regulates this activity has been formed. But it is necessary to point out that the legislation base is not excellent.

Goals of the article

To clarify the ways of improvement of state regulation of civil aviation and to show that state regulation of civil aviation in Ukraine is an essential element of state policy.

The main material

Civil aviation in Ukraine has big historic traditions. In 1992 Ukraine became a member of International Civil Aviation Organization – ICAO and signed The International Convention on civil aviation (Chicago Convention in 1944). Since then Ukraine has some duties which should be fulfilled.

On June 11th, 1997 according to the Constitution of Ukraine a decree of the President of Ukraine was signed "On activities connected with civil aviation in Ukraine" and in the Ministry of transport a new administration was formed – Ukrainian aviation. It was formed on the basis of the state department of Ukrainian air transport.

Ukrainian aviation also has some duties. Among them:
to provide a state's policy on civil aviation;
to provide legislation which regulates an activity of civil aviation in Ukraine;
to organize and provide a service of air transport;
to provide certification and licensing of civil aviation in Ukraine:
to provide a control connected with a safety of flights.

State aviation administration of Ukraine is composed of fifteen major departments, Major inspection on safety of flights and other groups. These structural departments have one or some state functions. All of them are subordinated to The President of Ukrainian aviation or his deputies [2].

All technical experts have a high qualification and they have had a special training. But the department needs special equipment and administrative support. For example, there are not enough PCs and there is no e-mail. The creation of Information network on the basis of PC could make better its performance. Time for searching information could be decreased.

Only in a year on June 8, 1998 The Provisions on State aviation administration of Ukraine were approved. But these provisions were approved in a month by the President of Ukraine.

The following things are stated in the decree of Ukrainian President:
to implement a state policy on civil aviation;
to implement a centralized state regulation in the field of civil aviation of Ukraine;
to organize and provide air transportation;
to use effectively Ukrainian airspace;
to implement certification of objects;
to license their activities [3].

We suppose that the major ways of state regulation improvement in the field of civil aviation could be as follows:
improvement of the state's regulation system on certification and its separate elements;
improvement of certification's legislation;
ways connected with overcoming of confidential information on certification.

The last point plays an important role but all the documents pay not very much attention to it.

The major aviation legislation is very important and an effectiveness of any department in civil aviation depends on it very much. It should contain the following elements:
provisions on delegations of responsibilities;
responsibility for research and adaptation of rules which regulate civil aviation;
requests that all international private air transportation is done on behalf of the state;
requests that all companies which fulfil international private air transportation must have a certificate for doing it;
provisions which provide necessary implementation of rules connected with the regulation of civil aviation and all directives;
provisions on the access of all activities connected with the implementation of private air transportation.

For the sake of state regulation of Ukrainian civil aviation bodies of executive branch are also in charge of:
development of civil aviation;
implementation of control and exploitation of airplanes;
certification, registration and issue of certificates;
regulation of airspace;
control over implementation of standards on the safety of flights;
protection of airplanes.

In general, it is necessary to make a procedure of issuing normative acts on civil aviation a bit easier or listen to specialists' thoughts. When these documents go through the Ministry of Justice they change their own content [4].

For example, a thesis in the Rules of certification was changed: "a company should have not less than three air vessels". But the rules which have been approved by the Ministry of Justice contain the following words: "it is possible to have at least one air vessel". As a result, we have a big amount of companies which lease even one-two helicopters.

Regarding the amount of flights a state body which is responsible for all types of activities in Ukrainian civil aviation should be organized in the way it could provide an effective control over the flights of air vessels in the country. It does not mean that a country can delegate its functions to any company or organization on its territory.

But we should not forget about the final responsibility for providing such request which suffers a government of Ukraine. That is why a country should create all necessary structures and organizations which are up-to-date.

Ukrainian aviation field is developing and modernized. Foreign manufactured planes are appeared in Ukraine. Ukrainian aviation has a task to adopt Ukrainian aviation legislation to European in the near future.

It is time to look through the Air code of Ukraine. We think that the name of the clause #3 of the Code "State regulation of civil aviation in Ukraine" should be added with the words "and airspace" to use this clause and determine its action.

General provisions of the Air code of Ukraine are necessary to be added with the clause "Ways of state regulation of civil aviation by the body of executive branch on civil aviation and Ukrainian airspace".

This clause should contain a centralized body of executive branch on civil aviation and Ukrainian airspace according to requests of the Air code of Ukraine and other legislation on civil aviation.

That is why this article will have the following view: "The right to implement entrepreneurship in the filed of civil aviation may have any company or individual that deals with exploitation, technical assistance, repairing, production, development and other activities in the field of civil aviation, having obtained a certificate or license according to Ukrainian legislation".

The implementation of normative acts which regulate activities connected with civil aviation and airspace of Ukraine should be done by an executive body of the state. This body should also control requests on normative base of Ukrainian aviation.

We think that a new variant of the Air code of Ukraine should contain detailed provisions connected with maintaining laws and rules on transgressors.

It is also important to point out there the body which is responsible for national and international aviation laws and rules [1].

Conclusion

Except legislative acts which should be approved on the state's level there is a need to accept some documents.

It is necessary to adopt a decree of Ukrainian aviation President which could have a list of individuals for structural departments of Ukrainian aviation. These individuals have to be involved in the implementation of certification according to the Rules of certification.

Hence, we can say that Ukraine has already done two major conditions for functioning a civil aviation of the state – a legislation on civil aviation has been created and a state body which regulates this activity has been formed.

But it is necessary to mention that the legislation base is not great. Therefore, both elements of the system need some improvement.

Literature

1. *Повітряний* Кодекс України // Закони України. Київ. 1996. Т.5.
2. *Указ* Президента України "Про заходи щодо впорядкування державного регулювання діяльності цивільної авіації в Україні" від 11 червня 1997р. № 531/97.
3. *Постанова* Кабінету Міністрів України "Питання Державної авіаційної адміністрації" від 8 червня 1998 р. № 815.
4. *Руководство* по процедурам эксплуатационной инспекции, сертификации и постоянного надзора. ICAO БОС 8335-AH/879. 1995.

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CARGO AIR TRANSPORT

Today it is my intention to present the concept of " cargo air transport" not only as a way of doing in itself but also as a developmental strategy for all Nation.

At the moment the worldwide economy, after overtaking the historic moment of the autarchia, mainly based on the extraction and manufacturing of the rough materials of each State, it turned to commercializing the products according to the location of the rough materials. In other words, he real wealth and prosperity of a Nation does not depend anymore of the primary rough materials it possesses bur rather on the skills of workmanship and most importantly, on the ability to sell the products, which means the goods handling.

The main categories which govern this Handling activity are space and time, however time has no more absolute value since there is a variable which depends not only on the space but also on the concept of real time and just-in-time.

To the three classic modalities of transportation - road, rail and sea - in a decisive way , a fourth has been added "air way" which for its capability to carry from 5000kgs to 250.000kgs and for the flexibility regarding cargo, destination and use -all cargo o combi- increasingly controls the world traffic, mainly in as far as the value of the carried goods and for the increased value the this fact adds to it.

In fact, even if a quite small part of the entire carried enter in the worldwide trading – from 4% to 6% - its value is about 62-64% of the entire interchanges value.

This increase is constant also in the event of a crisis since commerce never stops.

Consequently , in the last years a strong increase in air transportation has been registered which was caused by the intensified exchanges at an intercontinental level which fostered a radical change in the philosophy of transportation.

The expansion of the production techniques "just in time" has discovered a very relevant component in the cost of transportation which is represented by the cost of the immobility of the transported goods. As matter of fact, always more expanded are the productive processes which are organized by techniques which require a continuous and dependable flow of rough material and components, in this way reducing as much as possible and at times eliminating the intermediate storage and also intervening in the various and appropriate phases and organization of the work.

At this point another observation must be done: the majority of the air cargo traffic is moved on a very few number of great airport; as matter of fact the air cargo is more focused than passenger traffic and it needs particular support structures, such as specialized warehouses and efficient customs organization. The capability to attract activity related to logistic and transport in the airport area depends fundamentally on three principal component:

a. High air cargo traffic volume rise from the closer airport
b. Geographic closeness regarding to the final destination
c. Availability of equipped area surrounding zone

The combination of these three variables shows that the importance of the airport like connector of logistic activities is real only if all these three factors exist. In fact, more than passengers traffic market, in air cargo transport the economic systems and the synergies with other activities (specialized warehouse and advanced technology user operator) are more important in order to start up an increasing mechanism for direct and indirect economic activities of the entire airport area.

As clear example of wealth brought by an airport with an high specialization in goods handling we can make mention the case of Barcelona where, after two years of airport cargo activity, about 1600 foreign industries were established in a range of 50 Km. Another example is Düsseldorf that, in the same time and in a range of 30 Km has attracted capital investment of 500 industries.

Looking over European situation, analyzing the four most important airport – Frankfurt, Paris, Amsterdam and London – trough these pass the majority of the intercontinental traffic with Europe like initial and final destination; all together these airports moved in 2003 more than 6 millions tons of goods, with a mean increase of 5% in comparison to the previous year.

City (Airport)	Total Cargo 2003
Paris(CDG)	1 723 700
Frankfurt (FRA)	1 650 476
Amsterdam (AMS)	1 353 760
London (LHR)	1 300 420
Luxembourg (LUX)	657 254
Brussels (BRU)	586 313

Source: ACI – Airports Council International

Anyway cargo air transport in Europe is a very small part of the transport market in terms of tons: from Eurostat source it can be understood the reason why the 4% of goods traffic moves by air, but it must be considered that, in the same way, move the 23,3% (import + export) of the entire value of extra UE goods; in fact high value and obsolescence goods needs a safe and fast means of carrying to reach the final consumer, especially if he stands on the other side of the world. So this data isn't encouraging and it shows a certain late about the comprehension and the management of this new typology of transport; however it also offer us new interesting and challenging possibility of development and sure potentiality, as well for the reason that we can avoid all the conceptual and program mistake committed in the past.

IATA (International Air Transport Association) has point in its last prevision about air transport development for the period 2005-2008 an increase of 6,0% both for passenger and for tons carried.

The increase of cargo traffic will be most important in the Asiatic and Pacific area, with particular reference to the connection with Chinese and Indian market, that will have an high growth rate (above 7% yearly for the traffic with Europe). Nevertheless the north-eastern Europe is growing with the almost same velocity, so that the first final statement of 2004 figure an increase of the traffic equal to 10,1%.

As I've said before the possibility, the potentiality and the opportunity are great, It's our duty to take them.

Finally the air transport is proving to be, every day more, a decisive factor for all sorts of economy, both as cargo carrier, and as attraction for any financial and industrial capital investment.

I don't want to express any sort of judgement neither about Italy, my Country, nor about Ukraine, the Country that offers me hospitality, but, considering Europe in its entirety, I'm forced to admit that, in this area, It is a little bit late. However this must not stop us, instead it must encourage us to take advantage from this gap in order to create new opportunities and to contribute to the development of our Country.

As I've no intended to give judgement about our two Countries, I also haven't the intention to promote the company in which I am Managing Director, Malpensa Logistica Europa (MLE). However I feel the duty to spend a few words not for MLE, but for Nations, cooperation in which MLE would be the power factor. demand and wish a powerful and proactive partnership between our two

Accessibility Indicators aircargo (June 2004)

Aeroporto	2000	2001	2002	2003	2004
Frankfurt	100,00	100,00	100,00	100,00	100,00
Paris	90,73	87,90	77,46	73,73	69,96
London	85,11	81,32	75,32	72,52	67,38
Amsterdam	73,68	65,80	64,06	62,30	66,59
Milan	38,28	32,05	37,16	31,85	34,54
Zurich	49,61	44,57	34,63	31,83	25,46
Brussels	44,08	38,77	31,97	27,78	24,67
Rome	30,23	24,20	26,36	21,48	20,21
Madrid	27,47	25,16	27,20	21,66	18,78
Stockholm	6,35	7,56	5,53	5,92	6,36

Source: Certet Bocconi – Unioncamere Lombardia

The great majority of the national air cargo traffic is moved by the two airport of Malpensa and Fiumicino. In fact, as I said before, the air cargo is more focused than the passenger traffic and it needs the support of particular structures, like specialized warehouses and efficient customs organization and, above all, it needs an handler with high qualifications.

In order to make an examination about the national air cargo scheduling not only in absolute terms but also in relative terms, it's possible to utilize a six-monthly calculated indicator about the intercontinental air cargo transport accessibility for the principal European airports, in which figure Malpensa and Fiumicino.

This indicator considers a series of variables as the importance of final reached destination, the frequency and the quality of the service and the prices, analyzing the elements in an equilibrated way.

Numbers of the extra-continental destinations served by Malpensa airport and by main European Hubs. Summer weekly schedules.

Examining the results about the analysis of the summer timetables in the years 2000-2004, the data consents us to declare that Lombard area, the Malpensa Hub and MLE are the ideal partner for the development and the increase of an interchange between our two Countries in a prospective of common interest, I hope not only in the air cargo branch, but in the greatest sense of the term "partnership".

Hubs	1998	1999	2000	2001	2002	2003	2004
Frankfurt	125	118	124	125	119	126	122
London	135	124	132	127	121	113	117
Paris	122	126	125	125	111	106	113
Amsterdam	102	95	104	90	86	86	100
Milan	24	49	51	45	54	48	52
Rome	66	52	63	51	48	46	48
Brussels	60	54	55	56	46	39	37
Zurich	63	58	54	55	48	46	36
Madrid	39	33	38	38	41	33	32
Totale	213	205	220	217	214	207	214

It is my principal wish and desire: I hope that this convention represents the point of departure.

Nekrasov A.G. MADY (GTU)
Chairman of subcommittee of
standardization GOST P/TK355/PK

APPLICATION OF STANDARDS SPEC 2000 IN LOGISTIC OF AIR RESOURCES DELIVERIES

One of the main directions in logistical processes in the air industry is delivery of resources from manufactories of the aviation industry in sphere of operation - civil aviation.

Now the wide computerization of all kinds of activity in sphere of air transport proceeds. Wide application of personal computers, telecommunications development, technologies of automatic identification are promoting to this tendency . These technologies generated on the logistically based principles, gives great cost efficiency as a result of integration of participants, increasing of visibility and reliability of the receiving information, refusal of significant volume of the paper documentation.

Universal principles of interaction in the integrated chains of deliveries are:

- Standardization of logistical systems and data-processing technologies;
- Creation (integration) of unified information space for participants of logistical chains (networks);
- Cost reduction for cooperation between participants of electronic data exchange.

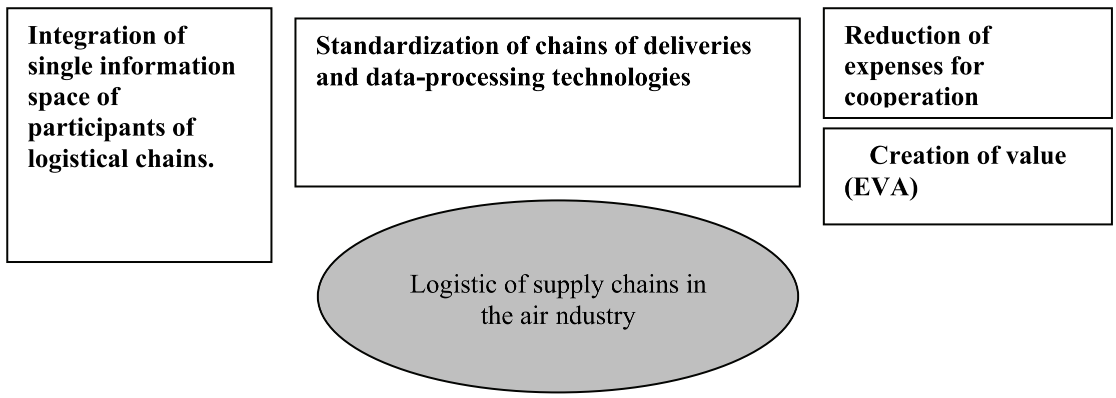

Fig. 1 Principles of logistical cooperation in the air industry

Subcommittee on standardization of GOST P/TK 355/PK6 with participation of leaders of scientific research institute of an aircraft industry and civil aviation, airlines and manufactories, organize joint work on development and introduction of harmonized national standards and other normative and technical documents (rules, requirements, norms) for territories of Russia and the interested countries members of the CIS. Now by subcommittee and intersectorial laboratory «Analyze and diagnostics of supply chains », created by MADY (GTU), GOSNYY aviation systems, institute Fraungofera (Germany), developing and realizing the concept of intersectorial cooperation of the enterprises in aircraft industry and air transport in sphere of delivery of aero technical property (DAP) basing on the application of logistical methods of technologies. Today's conditions of development of economy of Russia urgently demands creation of conditions for integration of enterprises - manufacturers of the defense-industrial complex, independent resources sale and delivery dealers, the enterprises of maintenance service and airlines, in the integrated chains of deliveries. They are capable quickly, in due time and with the minimal expenses to carry out deliveries of production to the consumer, to carry out radical transition from economy of "technique" to economy «system logistical competence and self-organization ».

Committees of standardization, Interstate aviation committee, Government research institute of civil aviation, Government research institute of aviation systems and large suppliers of technical aviation property ("Aviatekchsnab") are considering aviation standards system SPEC 2000 as practical steps in development and introduction of harmonized international standards in Russian Federation and the CIS. During transition to a new control system for airlines the stage-by-stage problem-solving suggested, first of all, in sphere of material and technical maintenance is offered. SPEC 2000 has been accepted by the international community of air carriers under aegis of Association of air transport of America and admits as the branch standard in many countries of the world.

Purpose SPEC 2000 is to provide decrease of expenses and improvement of quality and safety of deliveries using modern effective methods. SPEC 2000 provides an opportunity of an exchange both business, and technical information between customers, manufacturers and suppliers by use of the electronic form of messages and magnetic storage. The system is developed in view of requirements of the aviation industry and directed on the conclusion of transactions on maintenance service of aircrafts.

Structure SPEC 2000

SPEC 2000 it is organized with the help of independent modules (the chapter of standards), intended for the following spheres of managements:

- Supply;
- Planning purchases;
- Administration about interaction;
- An extract of accounts to the customer;
- The information and data exchange;
- Commands of connection;
- Administration of repair service;
- Planning of service / restoration;
- Shaped coding;
- Management on performance SPEC 2000/ASC X12;
- Reliability of gathering / data exchange;
- Redistributed system of registers of airlines;
- Guarantees of performance;
- The given configurations of deliveries.

Pic. 2 are shown the basic interrelation of processes of automatic identification SPEC 2000 for providing characteristics of quality of airspace parts that is the major element for creation of system of logistical service.

Expected results

Introduction of system of standards SPEC 2000 allows:

• to carry out more effective regulation of market ;

• to supersede from the corporate market the unregistered and not certificated production;

• increase safety of flights and to improve quality of services in system of deliveries ATI;

• to reduce cost of the order of spare parts due to unification and uniform codification of subjects of supply, and also due to introduction of paperless technology;

• to reduce volume of unused stocks of spare parts of units and subjects of supply wit the help of control system « on a condition » and autoimmunization of a warehouse facilities, and also delivery of spare parts and units « just in time »;

• to reduce amount of mistakes of operators and to reduce a degree of risk of " the human factor" due to introduction paperless technologies and machine-readable documents (decrease in loss of time to 30 %).

Full-scale introduction of standards SPEC 2000 will allow the industrial enterprises, to suppliers of accessories and airlines to increase competitiveness of quality and safety of deliveries of spare parts, material service and repair of air courts as on national, and international the markets of an airline traffic, to lower cumulative expenses for 20-30 %.

Final results of realization of the program of standardization of intersectorial interaction should become creation of a modern infrastructure of deliveries of resources and transportations, and also development of logistical service on the basis of modern technologies of electronic supply.

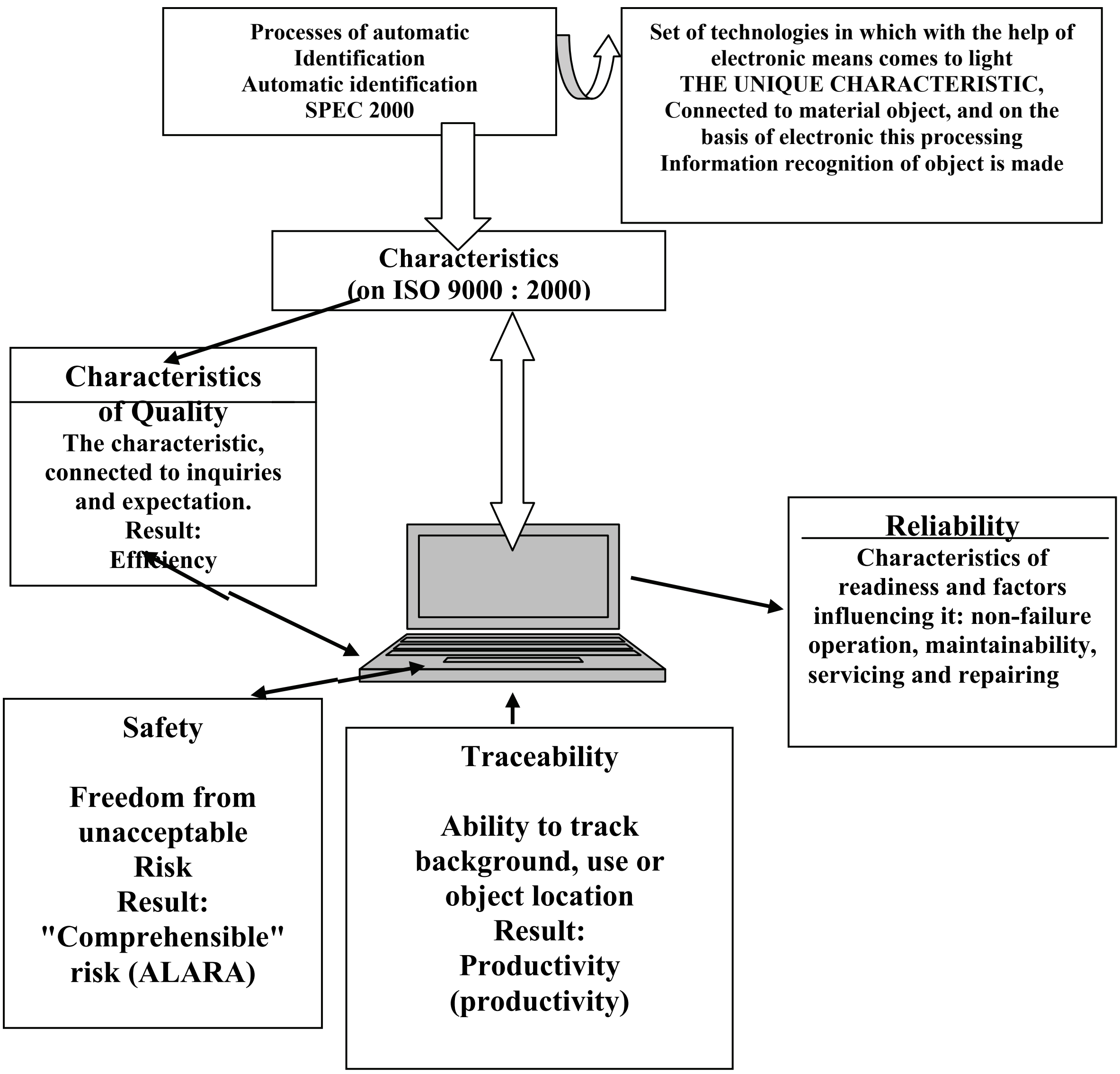

Fig. 2. Interrelation of processes Automatic identification with quality of airspace parts

The program provides:

- Re-structuring an existing infrastructure of the market of deliveries of resources on the basis of methodology of the integrated logistic, base mechanisms of self-organizing and technical regulation;
- Increase of economic potential of the enterprises of a defense-industrial, transport and warehouse complex, maintenance of their high competitiveness and safety;
- Development and application of the standard harmonized international standards in sphere of logistic of deliveries, creation of system of certification of electronic logistical services,

Increase of productive use of cumulative logistical resources of suppliers for achievement of the maximal advantages from joint activity, decrease{reduction} in cumulative expenses and system risks, improvement of quality of service of consumer

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TEAM PERFORMANCE FACTORS

Keyword ; *Team, TRM, Technical innovation, Aggravating fatigue factors, Personality Compatibility, National culture, Leaderships*

Introduction

Globally, airlines are dedicated to achieving higher standards of Flight Safety. They have therefore developed and applied programs such as CRM, LOFT, Risk Management and Threat and Error Management. Despite these efforts, Commercial aircraft accidents continue to occur. Accident statistics over the last 40 years show that mechanical or maintenance related accidents comprise only 15% of the total, and have been decreasing. Accidents attributable to flight crew, however, are about 65% of the total, and show little trend towards reduction (Boeing, 2003). So there is much continuing effort to reduce these kinds of accidents. Additionally, many researchers world-wide are developing and applying programs which are focused on Human Factors. This study analyzes both the factors affecting flight crew and the results obtained from research conducted in Korea.

Background

Modern aircrafts have been changed in order to pursue efficiency. According to above reason, the role of flight crew has been changed, too. The influenced factors on flight crew in team work are changes of technical environment, physical cockpit environment, cockpit culture, personality between crew members and leadership. The influence of these factors in flight operation are as follows.

1. Key factors in flight operations:

(1) Changes in the Technical Environment

Cockpit design and crew complement have altered with the passage of time. In the early stages of the Airline Industry, the cockpit crew comprised Captain, First Officer, Flight Engineer and Navigator. With technical development, Navigators were the first to disappear, followed more recently by Flight Engineers in most modern aircraft. High tech aircraft have been developed primarily to increase flight path accuracy and flight efficiency. Efficiency increases have been driven by economic factors affecting the whole industry. Cockpit automation has grown as a part of this drive, and has had a large effect on the flight environment. Increased automation had the following benefits (C.Y.Kim, 2002) :

1. Reduction in errors caused by human error
2. Improved flight accuracy and stability
3. High speed information control
4. Reduction in crew workload
5. Increased efficiency in the use of cockpit space

(2) The Physical Cockpit Environment

Changes in the cockpit environment are a key element, and those which have an impact on crew duty should be analyzed to provide key data for Human Factors research. Pilot efficiency and fatigue are much affected by the physical environment in the advanced cockpits of high tech. long range jets. There are many studies indicating that crews operating in such environments are much affected by factors such as noise, humidity, and the electromagnetic fields generated by avionic and other equipment on the flight deck.

(3) Culture

There are great differences between the culture present on the flight deck and elsewhere in industry and commerce. One such difference is that the Captain acts as both leader and operator. In most organizations a leader instructs and supervises, but the Captain is the final decision maker and the prime operator in the cockpit. This can lead to structural weakness because error detection is reduced when the leader and operator are one and the same. Future research must focus on solving this weakness. For example, a dual pilot crew concept might assign the operating job to the F/O, leaving the captain to manage and make final decisions. Research on this subject must continue, because views on this problem vary from country to country.

(4) Matching personality between crew members

Personality has a great effect on teamwork, but existing CRM programs have not given serious consideration to this. So the synergy effects that flow from matching personalities have not been adequately researched. Several researchers have shown that team performance is affected by the relationship of team members (C.Y.Kim, 1996), and for this reason flight scheduling can have a bearing on Flight Safety.

(5) Leadership

Theories concerning the role of leadership vary considerably amongst different researchers. Leadership is also connected with power. Korean captains in particular are apt to control the cockpit in an authoritative manner (B.S.Moon, 2001). However, coordination is more important than control in the cockpit, so the leader's role should concentrate on coordinating the different team members' abilities. Today, the captain should manage the flight rather than being fixated on aircraft control. So, leadership in the cockpit is vital to Flight Safety.

Discussion

1. Factors effecting on the team performance

I mentioned 5 main factors which have an effect on flight safety and show through research how the factors have effect on team performance.

(1) Changes in the Technical Environment

Automatic flight is more common than manual flight today, through the use of systems such as FMS (Flight Management System), so system monitoring becomes more important than manual flight. However, new errors can be introduced through the use of high technology if crews neglect to monitor system performance. For example, typing errors on the CDU (control display unit) can result in flight path errors if not detected. Johnston cites automation errors as (Johnston, 1995) :

1. Time delay or failure of situational awareness.
2. A blind belief in automation.
3. High technology stress due to lack of knowledge and low trust in automated system.
4. Overdependence on automation in an emergency.
5. Difference of situation awareness between flight crew and automation system.

It is difficult to solve problems in a two pilot system when the captain and F/O have different situational awareness. Also, difference of situational awareness between flight crew and automation system obscures decision making in the cockpit. If these kind of things happen in an emergency, the pilot's ability and reaction time would be affected. For these reasons, we need to study the pilot's role and relationships between crew (Tony, 1998).

(2) Physical environment in cockpit

We studied noise, temperature, humidity and electromagnetic waves in the cockpit. This research was conducted in a B737-400/500 & a B747-400 from March to May.1997 in Korea. Measurements were taken at the F/O's head position when seated. Noise, temperature, humidity and electromagnetic waves were measured more than 40 times in each flight phases.

<Table 1> Phase of Flight

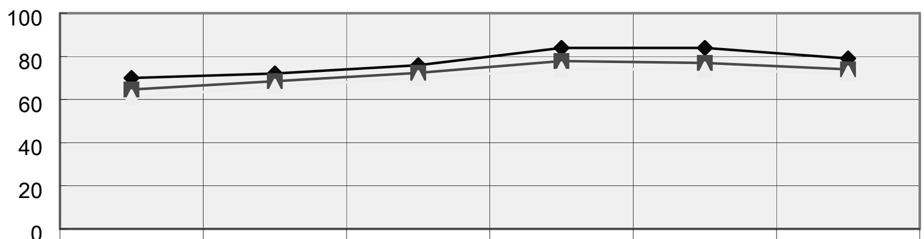
Before Engine Start	After Engine Start	Take-Off
Ready to engine start after preflight is completed.	Engine is stabilized with idle thrust after engine start.	Take-off thrust is established and aircraft is accelerating.
Climb	Cruise	Descent
Climb thrust is established and aircraft is climb passing FL 140.	Level flight with cruise thrust at cruise altitude.	Approach idle thrust is established and aircraft is descending passing FL 140.

1) Noise

Noise can cause physical and psychological problems so it is an impediment to flight safety. Noise affects the body by producing unpleasant feelings and sleeping disorders. There are differences in the effects of noise according to its intensity over time, and environmental and individual differences. Generally, people feel an unpleasant feeling above 45~ 49bB in hospitals and recuperation facilities, 50dB in a residential area, 55~ 59dB in industrial district and noise above 35dB induces sleeping disorder in the night. Before hearing damage occurs, the time of noise exposure below 80dB is a maximum 16 hours per day but it is decreased 50% for every additional 4dB. For example, The time of noise exposure at 84dB is 8 hours per day, but no matter how short a time we are exposed above 115dB, hearing can be damaged.

CUSTOM sound level meter SL- 1250 was used for the noise measurement and the result is <Fig. 1> as below.

< Figure 1> The noise distribution at each flight stage (B737-400/500) Uint: dB



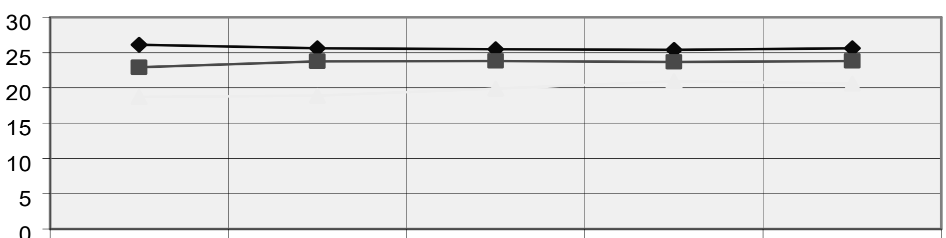
	Before enging start	After engine start	Take- Off	Climb	Cruise	Descent
Max	70	72	76	84	84	79
Average	64.6	68.44	72.33	77.79	77.04	74.07
Min	61	66	70	74	74	72

Crew members have to speak louder in the cockpit because of the masking effect, and this causes a breakdown in crew communication.

2) Temperature

Human beings maintain a constant temperature without reference to outside temperature. People have adaptability to maintain a constant body temperature but feel uncomfortable below 15.6℃ and above 29.4℃. Each country has a comfort range in temperature (℃) and relative humidity(%). In England it is 18.3℃ to 21.14℃ and 40% to 65%, in the USA it is 20.0℃ to 22.24 ℃ and 40% to 60%, in Korea it is 18.4℃ and 40%. The measuring of temperature and humidity was conducted by TETRON Corporation Thermo Hygro.

< Figure 2> The distribution of cockpit temperature Unit:°C

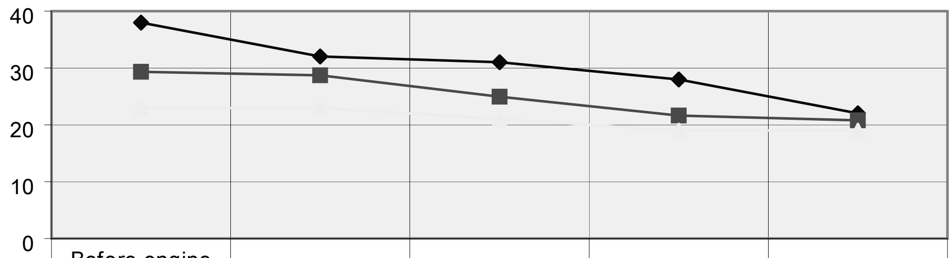


	Before engine start	After engine start	Climb	Cruise	Descent
Max	26.1	25.6	25.5	25.4	25.6
Average	22.92	23.76	23.83	23.67	23.79
Min	18.7	18.9	19.9	20.9	20.6

3) Humidity

Relative humidity is a very important factor because it decides how much water evaporates from a body. Humans feel uncomfortable when the relative humidity is below 30% or above 80%. The pleasant relative humidity range is 40% to 60% in summer and 40% to 45% in winter (in normal temperature conditions).

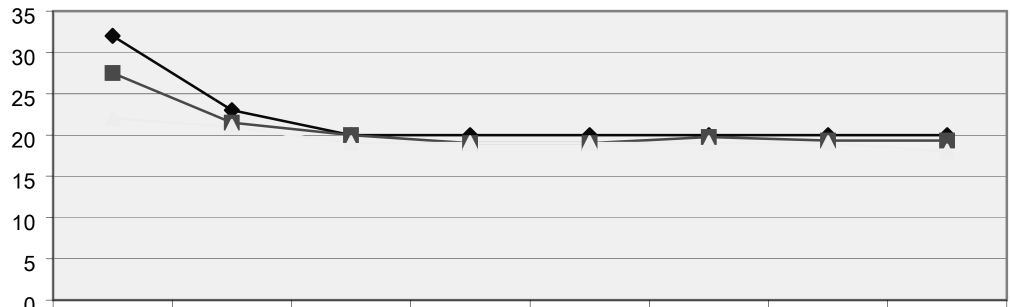
< Figure 3> The distribution of cockpit humidity (B737-400/500) Unit: %



	Before engine start	After engine start	Climb	Cruise	Descent
Max	38	32	31	28	22
Average	29.31	28.69	24.93	21.62	20.76
Min	23	23	21	19	19

The air become drier with altitude but the relative humidity is maintained at 22~23% by the rate of ventilation, the passenger load factor, the temperature and the outside air pressure affecting the aircraft. The relative humidity in a jet airliner is very low due to the economic altitude being high altitude. <fig. 4> show that the relative humidity is 19~20% from one hour after take-off.

<Figure 4> The distribution of cockpit humidity with flying time (B747-400) Unit: %



	Before T/O	30 mim after T/O	1 hr after T/O	2 hr after T/O	3 hr after T/O	5 hr after T/O	7 hr after T/O	9 hr after T/O
Max	32	23	20	20	20	20	20	20
Ave	27.5	21.5	20	19	19	19.75	19.33	19.33
Min	22	21	19	19	19	19	19	18

According to this study, the average relative humidity is 23.7% before take-off and 19% as flight-time increases. So relative humidity is lower than normal in flight.

4) Electromagnetic waves

The United States Environmental Protection Agency (EPA) made public that electro-magnetic waves can be one of the causes of cancer, even though only a small effect was evident up to 1990. The Korean government announced in 1996 provisional result that overexposure of electromagnetic wave should be avoided as much as possible. It is accepted in most countries that electromagnetic waves are bad for the human body. Especially, there are three kinds of electromagnetic waves which have an effect on humans :

1. Extremely Low Frequency wave (ELF, 0-1㎑),
2. Very Low Frequency wave (VLF, 1-500㎑)
3. Microwave(300㎒-300㎓)

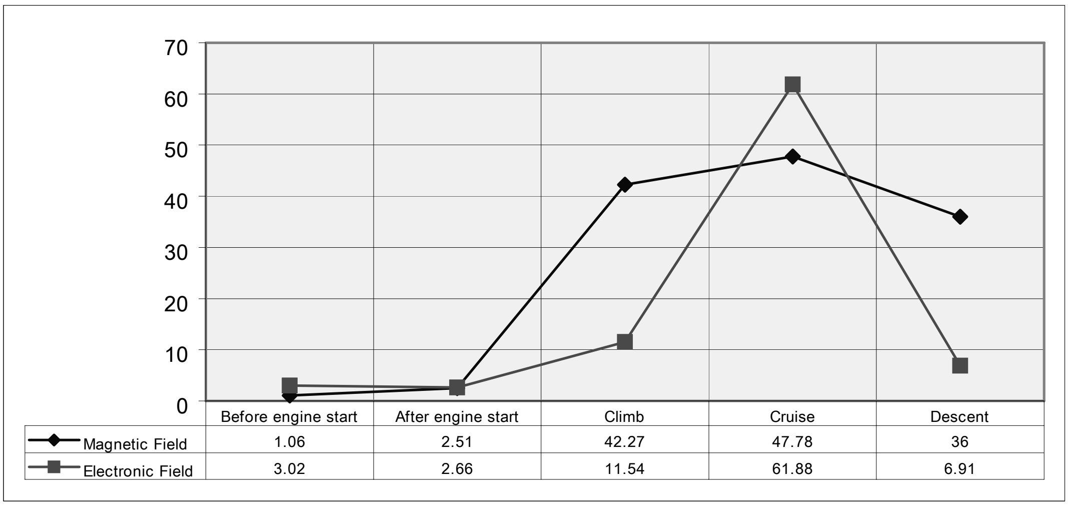
<Table 2> Safety, Caution & Warning range of Microwaves

	safety range	caution range	warning range
Magnetic Field (mG)	0~1	1~3	more than 3
Electronic Field (kV/m)	0~1	1~3	more than 3
Microwave (mW/㎤)	0~0.02	0.02~0.1	more than 0.1

We measured the magnetic field (mG), the electric field (kV/m) and micro waves (mW/㎤) in the cockpit by using a Trifield TM Meter (ALPHALAB, INC). Measuring range the magnetic field and the electric field were 0-100milligauss(mG), 0-100Kilovolts/meter (kV/m) and microwave reading was 0.01-1Milliwatts/㎤(mW/㎤).

The microwave measurement was below 0.1mW/㎤ in all flight phases, and it is satisfactory with the safe and alert ranges as <fig 5>.

<Figure 5>Distribution of Microwave at each flight stage Unit: mG, kV/m



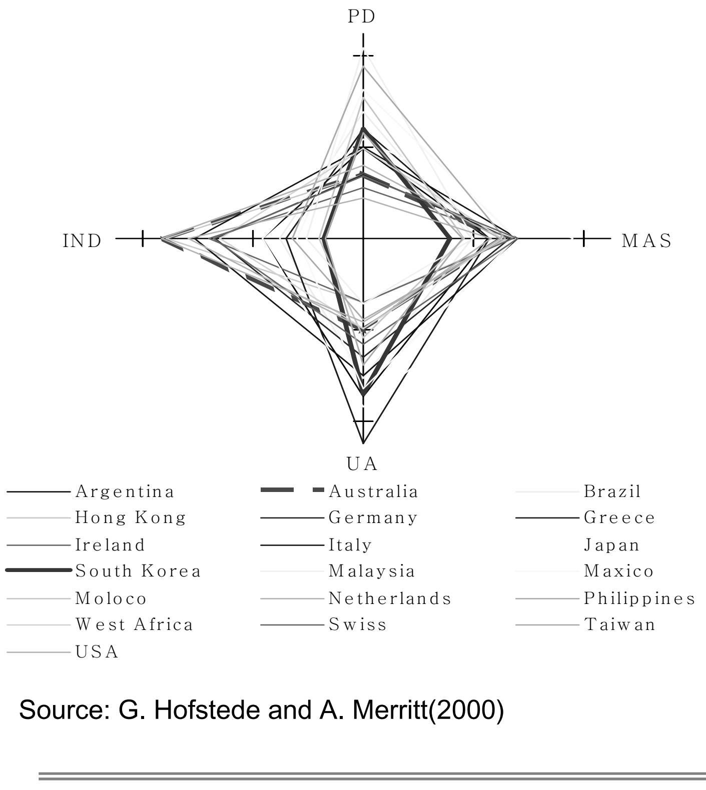
There was a large difference between in the magnetic and electronic fields before and after engine starting because of the activation of avionic equipment after engine starting. The magnetic and electronic field were at the edge of alter range (1 and 3) just after engine starting, but over alter range (above 3) during most of the flight phases (climb, cruise and descent). We found that the electronic field was 61.88kV/m, and the magnetic field was 47.78mG in the cruise phase. This could be a latent danger factor for safe flight. The most powerful electronic waves were radiated from the circuit breaker panel (overhead panel). The EFIS (electrical flight information system) was the next because of the concentration of electronic equipment in it (H.D.Kang,2003)

(3) Culture

Professor C. Perrow (1982) said Human Factors originate from the constitution of an organization. Lauber(1989) mentioned that personal ability did not affect failure to perform a task, but that such failures which lead to trouble always stem from team work or cultural background. In his theory, aircraft accidents can be related to team work related problems, not to individual problems.

J. Richard Hackman(1986) said regarding team work, that all the pilot's tasks in the cockpit are related through team work to flight safety. Also, H. W. Orandy and L. M. Orandy emphasized that pilots always execute their jobs systematically.

"Individuals don't crash, flight crews do" was the way that it was put by A. McArtor(1987). In his words, flight crews mean pilots for flying and pilots as team members (H. W. Orandy and L. M. Orandy). In their team's view, aircraft accidents due to human factors have originated from absence of team work, and this always begins from the team work or cultural background. Therefore, we can say that there is a close relationship between team work and cultural background. Merritt (2000) conducted research concerning the national culture of pilots in 19 countries, the results are shown in the redial shape graph as below <fig 6>.

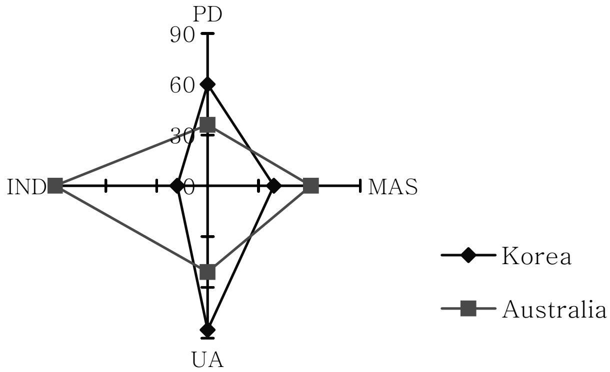


Source: G. Hofstede and A. Merritt(2000)

<Figure 6> national culture of pilots in 19 countries

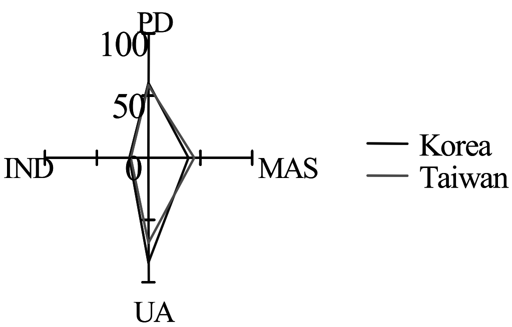
As we compare Austrian data (zero accident rate) with Korean data based on <fig 8>, we can make the graph shown in <fig 7>, and this shows that Austria has a horizontal diamond shape but Korea is a vertical diamond shape.

<Figure 7> national culture of pilots in Austria vs Korea



We found some similarities between Korea and Taiwan in <fig 8>. The two countries have a difference in their aviation market scale but they share the same Confucian cultures. Their points of similarity are that there are traditional values and cultural differences between their old-fashioned captains and young first officers (Chinese cadet pilots) who were educated in the America style (ab-initio).

<Figure 8> national culture of pilots in Taiwan vs Korea



According to the studies of Korean pilot culture, Korean pilots showed horizontal collectivism. Captains predominated in collectivism, and first officers had a propensity to individualism. This tendency stems from where the pilot underwent his education before becoming a pilot. In other words, pilots from a military background have a strong vertical collectivism whereas those from a civil aviation background show horizontal individualism

(B. S. Moon, 2001).

There is a difference between Korean cockpit culture and Western style cockpit culture and this can hinder crew coordination. Therefore, we suggest the dual pilot concept to solve this problem. The dual pilot concept is that the captain performs the final decision making job and the F/O does the operating job. Several researches related to cockpit efficiency show that pilots who have individualism with a high power distance can have trouble with crew coordination. If these kinds of pilots are scheduled in the same cockpit, we should not expect good coordination in the cockpit operation because the operation might be affected by power and individualism. Finally, there is too little chance or not enough time to correct errors because the final decision maker and operator are the same.

The cockpit system is that the captain acts as both leader and operator, and the first officer just follows the captain's order until now. Therefore, the Captain is the final decision maker and the prime operator in flight. It may cause diminishing in cockpit efficiency. We studied some cases in order to improve the problem as below < Table 3>.

<Table 3> Distribution of cockpit system operation

구분	captain	1st officer	Flight engineer
case 1	Decision Marker, Processor	Assistance 1	Assistance 2
case 2	Decision Marker, Assistance 1	Processor	Assistance 2
case 3	Decision Marker, Assistance 1	Processor	.

Case1 shows a traditional cockpit system in < Table 3>, the captain has flight control and a first officer/flight engineer has the job of supporter. Cases 2 and 3 show the workload management when the first officer has flight control and the supporter is a captain or flight engineer. So the first officer has flight control under the captain's supervision in flight, and the captain plays the role as final decision maker and supporter. It is the same concept as when an instructor takes the right seat as supervisor for cadet pilot training.

(4) Matching personalities between crew members

The personality of team members has great effect on team work (Giuon, 1987). This can apply to cockpit operations for a crew. According to our research for matching personality between crewmembers, we found several factors such as:

1. Team satisfaction of flight crews in the cockpit can be increased or decreased by matching personalities between crewmembers. This suggests that a good match of personality is one method for increasing the satisfaction of flight crew by pilot scheduling.
2. Pilot's performances are directly proportional to team satisfaction.
3. Errors from flight crew are inversely proportional to team satisfaction.
4. The quality of decision making is directly proportional to team satisfaction.
5. Crew performance is first considered in matching personality between crew members, as team satisfaction is a key factor for maximizing performance. That is to say, a well-matched flight crew does not mean better relationships between crew members but means better team satisfaction.

Finally, we can say that team satisfaction plays a role as a parameter between performance and matching of personality. If flight crew management would consider crew personality when planning and scheduling crews, we could expect to improve team satisfaction, crew performance, and flight safety, due to the reasons given above. (C. Y. Kim, 1996).

(5) Leadership

There are many types of leader, such as military commanders, CEOs, head coaches or leaders of sport teams, and conductors of orchestra etc.. In the case of flight crew, helper type crews perform better according to our study (C.Y. Kim, 1996). In order to achieve efficiency and flight safety, we need to look carefully at the concept of team management for flight crews, whose work is affected by space limitation and time pressure. There are several factors which should be considered for the team concept:

1. The team pursues the same goal.
2. The team is composed the smallest number to achieve the goal.
3. The team members have been trained and qualified to do the task.
4. Workload management is clearly established in the team.

In the case of flight crew, we suggest changes to leadership theory should be adopted to replace ordinary leadership theory, based on the reasons given above. The new system will be able to modify the role of the leader. From this point of view, the "servant leader" type is the best for flight, because they prepare their tasks in advance.

(6) Other factors

One of the other factors affecting team performance is communication skills. It is under continuous study by Embry-Riddle Aeronautical University.

Also CRM/TEM has been developed as the 6^{th} generation CRM program. IATA and many airlines take these programs for CRM training and they are succeeding in aviation safety with these programs.

2. Managing the factors which affect team performance

We suggest several ways to manage unsafe factors in aviation as follows:

Firstly, the most important aspect regarding factors in the physical environment in the cockpit is that the crew manage these factors. We need to reinforce CRM/TRM training to become aware quickly of a bad situation in an emergency. In addition, the cockpit system must be changed to promote good situational awareness and control in bad situations.

Second, these factors are related to fatigue.

1. The ideal ways to diminish noise effects are removal of the noise source, reducing its intensity and time exposure to the noise.
2. Temperature and humidity are not expected to be improved, because such improvements are related to weight and operational cost. The next best solution is that the cockpit temperature should be maintained lower so as to feel comfortable. Also it is recommended enough water be taken to prevent dehydration, and to abstain from drinking coffee to prevent urination.
3. The walls and instrument panel in the cockpit should be treated electromagnetic wave interception material to reduce electromagnetic wave effects Also, the main cause of exposure to electromagnetic waves, the duty time in the cockpit should be reduced. It may be recommended that wearing electromagnetic wave interception treated uniform

or apron type protector be considered. Crews should try to prevent electromagnetic wave effects in off duty time. We have to do our best to maintain good cockpit conditions because

this will reduce pilot fatigue and increasing pilot performance.
Third, We would like to speak about improvements of cockpit culture.
Several studies on cockpit efficiency show pilots who have vertical individualism have poor performance in the cockpit. These kinds of pilots control the airplane by power and personal propensity. To manage these problems, we must realize that an aircraft should be controlled by crew coordination, not authority. A synergic effect system is required for flight safety.
Fourth, We need to match personality between team members. The team can be called a "cell" which is the minimum unit to perform the necessary duties. First job analysis must be accomplished in order to constitute the team. Jobs can be specified and workload management accomplished through job analysis. In other words, we must clarify the minimum number of members and personal abilities to make a team.

The principle of working together should be kept when making a team because the team is minimized and members are assigned their own tasks. Also, personality matching should be considered to maximize the team's performance. Generally speaking, a team should be constituted with similar personality between members to get the highest team performance.

In additional, we need to change recognition of team for TRM. Especially, a leader should discard his/her authoritative attitude and understand the role of the other members in the team.

Team members should recognize that their duties should be coordinated and the members have their own roles in the performing team's work. The members have to have good abilities to carry out the team duties. We think that training, qualification management and good workload management systems should be supported to improve performance.

Results

Even though much CRM research has been conducted into cockpit operations, many problems derive from CRM programs. This study is focused on TRM to improve the efficiency of cockpit operation with fundamental CRM concepts, including Korean research. Finally, we continuously try to do our best to find solutions for automation problems and the best cockpit environment. Also, TRM which considers new leadership concepts and personality matching should be pursued for better efficiency and safety in aviation.

References

C. Y. Kim(1996), "A Study on the Type and Compatibility of Flight Crew Personalities", *Journal of the Korean Society for Aeronautical and Flight Operation*, 4(December), 39-62.

H. D. Kang(2003), "A Study on the Physical Environment in the Cockpit of Air-Transportation Airplane", *The Korean Journal of Aerospace and Environmental Medicine*, 13(April).

B. S. Moon(2001), "A Study on the Cultural of Korean Pilots", *Journal of the Korean Society for Aeronautical and Flight Operation*, 9(August), 15-30.

Y. C .Choi(2002), "A Study on Partner's Relationships for the Air Traffic Management Effectiveness", *Journal of Korean Society of Transportation,* 20(April), 39-46.

Tony Kern(1998), Mc Graw-Hill, Flight Dishpline.

Johston, Neil(1995), Avebury Aviation, Aviation Psychology: Training and Selection.

R. M. Giuon, "Changin(1987), Views for Personnel Selection Research," Personnel Psychology, 40, 199□213.

O'Leary, Beesing & Nogosek,(1983), The Enneagram.

Boeing(2003), Statistical Summary Of Jet Airplane Accidents Worldwide Operations 1959-2002.

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A STUDY ON THE EFFECT OF AVIATION SAFETY OVER THE AIR PASSENGER'S BEHAVIOUR FOR ENHANCEMENT OF AVIATION SAFETY MANAGEMENT

The research purpose for A Study on the Effect of Aviation Safety over the Air Passenger's Behavior for enhancement of aviation safety management lies at the judgement that passenger's airlines selection criteria has much changed after several serious aviation accidents as before when we used to overlook "aviation safety" variable through surveying to Korean aviation passengers and foreigners visit or travel Korea on various purposes. Therefore, for this research, practical analysis methods are employed after surveying to actual passengers who use Kimpo International Airport's international and domestic terminals. This study will be regarded significant in terms that empirical analysis was used to prove "Aviation Safety", a variable which had not been regarded as a airline choice factor within Korea air transport market so far, and has an effect on the air passengers' airline preference change and choice after recent frequent aviation accidents. Presenting this dissertation, I wish, it can be another opportunity for Korean two national flag airlines to reappraise and reinforce the significance of "aviation safety" and set forth immediate vigorous efforts to support the government's aviation safety improvement countermeasures.

Ⅰ. Introduction

1. The Purpose of the Study

A few years ago the air transport sector is facing rapidly changing world air transport market and the role of airlines become more important in international competition power to aviation safety in korea. The Mokpo accident, however, by Asiana Airlines on July 1993 and Guam accident by Korean Air on August 1998 followed by serial accidents, Pohang accident on February 1999, Sanghai of China accident on April, and directly after Stansted airport accidents of England on December by Korean Air result in a situation that the discomfort factors are increasing when air consumers use air transport mode as well as lowered international credit level and some foreign airlines decided to stop codesharing flights with accident airlines. So it is time to improve airlines' image.

Therefore, focusing airlines making an effort to compete in world air transport market, it is studied the influence on domestic/international air consumers' air selection according to recent frequent air accidents' level of involvement on aviation safety . Also it is studied how "aviation safety", the variable recognized to not affect in selecting airline within Korean air transport market so far, much affected to air consumers purchase behavior in selecting airlines after accidents.

1. The Scope and Methodology of the Study

1) Scope of the Study

The target group was established as domestic and foreign air passenger who uses Kimpo International Airport of Korea. Target group was classified in terms of great categories as Korean, American & European, Japanese, Chinese air passengers. In here domestic air consumers specify the respondent nationality is Korean and foreigners are English language speaking people from aviation advanced countries whose GNP score are higher than other countries and they can be classified U.S.A, England, Germany, France, Canada, Austrailias, and Japanese speaking Japanese and Chinese speaking Chinese, HongKong.

2) Methods of the Study

This 1st survey was cited as restrictions that it is limited to Korean, had deficiency in systematic sampling. Processing some implementation, after one year, from may 25 to June 7 After one year, for 14 days, the 2nd survey was performed to compare and analyse the change in Korean air safety recognition and between domestic and foreign air passengers. As survey target group. to survey further, distinct from 1st survey, the questionnairs were prepared by each 180 pieces of Korean, Japanese, Chinese, English Language. And the survey was performed in arrival lounges, departure gates, check-in counters of Domestic, International 1st Terminal, International the 2nd Terminal of Kimpo Airport. The survey time has followed systematic sampling, selecting 1 among 5, by airlines time table which korean and foreigners most frequently depart and arrive.

Also domestic/foreign group travellers are excluded in this study, because the airline choices were on trevel agency's own preference, and the individual passengers are limited to whose air travelling experiences is more than one time in a year. To boarding passenger using domestic/international airlines of Kimpo International Airport including 173 Korean(96% were available from 180), 169 American and European(94%), 116 Japanese(61%), 128 Chinese(70%) were surveyed. The total number of collected by each countries was 720 and among them 120 questionnaire, the unfaithfully answered or personal information were omitted , thus had no standards for analysis, as well as Russian, Iran, African, Vietnamese, Pakistan, Indian, Carmeroon, Philippine air user were excluded. Thus the certified questionnaires as final analysis target was 586, in the 2nd survey, to get more available questionnaire and faithful answers from foreigners, though it took long time for the survey. the researcher directly participated in implementing survey.

① Hypothesis

The focus of this study's hypothesis lies in practical analysis on consciousness of domestic/international air consumers who use domestic airport on national carriers accident happened frequently more than two times in a year. The hypothesis were established as below, after air accidents, air consumers' airline selection, behavioral change to air travel experience, consciousness difference on aviation safety by each countries, the importance of aviation safety by age.

[Hypothesis 1] After the frequent air accidents, more than 2 times within a year, domestic air consumer would prefer another transportation modes.

[Hypothesis 2] After recent air accidents happened more than 2 times within one year, the international air consumers show lower preference with the airlines had accidents.

[Hypothesis 3] After aviation accidents, the aviation safety has been much reflected in airline selection by aviation consumers.

[Hypothesis 4] air travel experience will have correlation with air consumers' attitude or behaviors to aviation safety.

[Hypothesis 5] The confidence on air travel safety would show lower level of effect to countries experienced frequent air accidents.

[Hypothesis 6] The air consumers from advanced countries are much conscious of safety emphasis considered in air travel.

[Hypothesis 7] The older the respondent, the higher do the emphasis on the confidence of air travel safety

Ⅱ. Review for previous studies

As for the foreign literature, Mesatusetts Institute of Technology(MIT) in U.S.A, Professor Arnold Barnett from 1957-1976(20 years), 1977-1986(10 years) performed relationship between air consumers death risk and non-fatal safety accident. And Barnett, Abraham, and Schimmel[1979], Barnett and Higgins [1989]) were announces. Recently in FAA Safety Report 1987-1996(10 years), the whole world's air consumer's fatal risk analysis by Arnold Barnett and Alexander Wang[1998].

Also there is study about the statistical difference on aviation safety by each airline group by Higgins (1987), GAO [1988], GRA [1988], Barnett-Higgins [1989], Oster et al. [1992], Stouffer [1992], FAA [1996], GAO [1996] In U.S.A or aviation advanced countries, the air accident rate are lower than undeveloped countries, particularly in U.S.A the accident rate of which airline operate jet aircraft are lower than commuter or regional airlines. In U.S.A established airline's accident rate are lower than newly entry airlines. FAA, GAO [1996]

As for on domestic literature, aviation safety, Choi[1995] told in "The Public Perception and Airline Safety : Case of Korea Airline Industry" that after the airlines competition system, air consumer's consciousness change for aviation safety and airlines have important duties to provide reasonable aviation safety information to air consumers and the problems are to be resolved from wrong consciousness. In "The impact of aviation safety on the consumer's choice of airline in the air transport market of korea" by Lee, KangSeok · Lee SeungChang(2000) there implemented a research about consumer's behavior before and after air accident to limited numbers of Korean.

Ⅲ. Empirical Analysis for how aviation safety affect air consumer's behaviors

1. Technical statistics

After air accident, the adding value(30%) for aircraft safety in using domestic airlines, matters as well as air fare(30%). in using international airlines, the airfare(36%) and safety(31%) as important selection factors

<Table 1> Technical statistics for air service variables

Observed variables		Average	Standard Deviation
consideration importance for domestic flight selection(X2-1)*	air fare(X2-1-1)	30.24	22.90
	schedule(X2-1-2)	24.36	21.64
	safety(X2-1-3)	30.42	20.77
	service(X2-1-4)	15.54	12.47
consideration importance for international flights selection(X2-2)*	air fare(X2-2-1)	36.00	22.67
	schedule(X2-2-2)	18.04	14.70
	safety(X2-2-3)	31.32	21.63
	service(X2-2-4)	15.27	12.11
Aviation safety confidence(X3)**		76.26	19.17
New aircraft importance(X4-1)***		3.93	.85
Pilot performance importance(X4-2)***		4.62	.55
Airport facilities importance(X4-3)***		4.10	.80
Airline safety policy importance(X4-4)***		4.50	.69
Domestic air travel experience(X10-4-1)***		4.35	7.28
International air travel experience (X10-4-2)***		3.07	6.86

note) * total sum is 100 as standards ** 100 points full as standards. *** 5 points scale standards

2. Analysis for Reliability and Validity

1) **Reliability and Correlationship Analysis**

According to Nunnally(1978), Cronbach α , if usually above 0.7 in the fundamental study is admitted to be significant in terms of statistics. safety factor 0.7055, image factor 0.675, and convenience factor 0.827, they are relatively higher than economic factor 0.565, service factor 0.574.

Nextly, with the final selection variable which were excluded Cronbach α , we tested how exactly measured the concepts to try to measure. To certify the correct factors as established in advance, we used VARIMAX, A Rotation Method through principal component factor analysis

<Table 2>shows the result loaded factors after air service variable's rotating in the 1st survey on June 1999, <Table 3> shows the result loaded factors after air service variable's rotating in the 2nd survey on June 2000, after one year from the 1st survey.

To certify the correct factors as established in advance, we used initial Factor method as principal component analysis, selected eigenvalue more than 1.00 and decided 5 factor values, factor 1(safety), factor 2(image), factor 3(convenience), factor 4(economy), factor 5(service); which has 62.3% of explanation power, and judged considerably significant.

On the other hand, after analysing using VARIMAX, a kind of Rotation Method, the most big difference is lied in several factors are reconstructed compared to the 1st survey. Namely, in the 1st survey, it is analysed with image and services are distinguished, otherwise in the 2nd survey image and service are composed as same item. The air fare is composed with willingness to pay for service and it has positive appreciation for air consumers willing to pay air fare according to air service improvement.

<Table 2> Factor load after rotating (in the 1st survey)

	Factor1 (safety)	Factor2 (image)	Factor3 (convenience	Factor4 (economy)	Factor (service)
X1- 5 Select safe airlines	**.862**	002E-02	432E-02	4.192E-02	933E-02
X1- 6 Not prefer to accident airlines	**.598**	.182	5.681E-02	-1.921E-02	7.729E-02
X1- 4 Discomfort for accident	**.494**	.198	7.909E-02	2.855E-02	.278
X1- 8 Prefer good image	.348	**.761**	5.966E-02	5.248E-02	.246
X1- 7 Company morality	.319	**.548**	.173	-.162	8.229E-02
X1- 9 Image/service relationship	-2.732E-02	**.527**	9.366E-02	.177	.308
X1-14 Convenient telephone	431E-02	.328	**.797**	2.503E-02	.185
booking	.224	.201	**.742**	3.804E-02	.208
X1- 2 Selection for bonus system	.138	-1.505E-02	1.521E-02	**.800**	-4.971E-02
X1- 3 Selection for alliance card	-3.357E-02	-1.555E-02	-4.303E-02	**.739**	2.210E-02
X1-10 Difference crew service *	.276	.295	.128	2.537E-02	**.632**
X1-11 Service importance*	-6.547E-02	-.198	3.487E-03	.138	**-.487**
X1-12 Willing to pay for service	5.732E-02	3.943E-02	9.874E-02	-5.193E-02	**.452**

<Table 3> Factor load after rotating(in the 2nd survey)

	Factor1 (safety)	Factor2 (image)	Factor3 (convenience	Factor4 (economy)	Factor (service)
X1- 5 Select safe airlines	**.830**	.160	.051	.098	.093
X1- 6 Not prefer to accident	**.750**	-.049	.113	-.065	-.126
airlines	**.671**	.251	.145	.097	.132
X1-11 Service importance*	-.081	**.712**	-.102	-.123	-.079
X1- 9 Image/service relationship	.072	**.678**	.213	.013	.203
X1-10 Difference crew service *	.302	**.664**	.135	.023	-.075
X1- 8 Prefer good image	.474	**.564**	.134	.157	-.123
X1- 7 Company morality	.380	**.492**	.109	.043	-.203
X1-14 Convenient telephone	.273	.145	**.801**	.171	-.160
booking	.262	.197	**.732**	.196	-.213
X1-13 Convenient boarding	-.213	.056	**.687**	-.253	.235
X1- 2 Selection for bonus system	-.012	0	.034	**.881**	0
X1- 3 Selection for alliance card	-.032	.113	.065	**.876**	13
X1- 1 Low air fare *	.176	.145	.024	.167	**.743**
X1-12 Willing to pay for service	.276	.128	.127	.034	**-642**

Note) * means reconstructed items different from 1st survey. The bold are the groups of above 0.4 judged to be significant

3. Hypothesis Verification

1) Verification for [hypothesis 1]

"**After the frequent air accidents, more than 2 times within a year, domestic air consumer would prefer another transportation modes" .** Though recent frequent happened air accident, there is more passengers who responded would change another airline than change another transportation mode, representing 42.1%, 41.6%, in the 1st and 2nd survey, and the respondent who would change transportation mode to 7.81%, 8.33%. This survey result show, different from other hypothesis, after air accidents, there is more air consumers who would move to another airlines than to another transportation mode in <Table 4>.

Above analysis was made through frequency of airline selection change in domestic route after air accidents, however <Table 4-1>shows Chi-Square test between the 1st survey and the 2nd survey's responses which would change airlines or transportation mode, the result was concluded it was not significant as shown <Table 4-1>. This is analysed that there is no difference between who respond would change domestic airline selection and would change transportation mode.

<Table 4> The rate of change to domestic airline selection

Classifications		1st Survey	2nd Survey	Total
change to another airline	frequency	**81**	**80**	**161**
	change rate(%)	**42.19**	**41.67**	**83.85**
	Row Pct	50.31	49.69	
	Col Pct	84.38	83.33	
change to another transpotation mode	frequency	**15**	**16**	**31**
	change rate(%)	**7.81**	**8.33**	**16.15**
	Row Pct	48.39	51.61	
	Col Pct	15.63	16.67	
Total	change frequency	**96**	**96**	**192**
	change rate(%)	50	50	100

<Table 4-1> Chi-Square Test according to domestic airline selection direction

Test method	Chi-Square value	Degree of freedom	Prob
Chi-Square	**0.038**	1	**0.845**
Likelihood Ratio Chi-Square	0.038	1	0.844
Continuity Adj. Chi-Square	0.000	1	1.000
Mantel-Haenszel Chi-Square	0.038	1	0.845
Fisher's Exact Test(Left)			0.652
(Right)			0.500
(2-tail)			1.000
Phi Coefficient	0.014		
Contingency Coefficient	0.014		
Cramer's	0.014		

To the question why do not change the international airline selection after a series of air accident, the survey result for air consumers are in <Table 5>. In the first survey who didn't change international airlines were 78 among 140(55.7%), In the 2nd Survey, 116 among 171(60.2%).

In total survey including the 1st and 2nd. among air consumers who did not change the international airlines were 40.2%, 59.7% each. and there showed meaning difference between 1st and 2nd survey in terms of selection change rate. The reason why did not change the international airlines were convenient schedule(29.90%), mileage(26.80%), fare(13.92%), and good service(13.40%), otherwise in the first survey the priority was schedule(30%), mileage(25.7%), fare(17.1%), service(4.3%).

In the 2nd survey, schedule and mileage has no change compared to previous year, however, fare(14%), service(13.4%) variables showed great change. Therefore, in case of domestic air consumers, there is no great change between who replied would change airline selection and would use another transportation mode. It can be said that air consumers are will to pay air fare as far as the airlines' service is good. Thus the hypothesis 1 "**After the frequent air accidents, more than 2 times within a year, domestic air consumer would prefer another transportation modes"** " was rejected and there is significant to change selection to another airlines.

<Table 5> The reason why change international airlines

Classifications		1st Survey	2nd Survey	Total
mileage	frequency	**22**	**30**	**52**
	percentage of change (%)	**11.34**	**15.46**	**26.80**
	Row Pct	42.31	57.69	
	Col Pct	28.21	25.86	
convenient schedule	frequency	**21**	**37**	**58**
	percentage of change (%)	**10.82**	**19.07**	**29.90**
	Row Pct	36.21	63.79	
	Col Pct	26.92	31.90	
fare	frequency	**12**	**15**	**27**
	percentage of change (%)	**6.19**	**7.73**	**13.92**
	Row Pct	44.44	55.56	
	Col Pct	15.38	12.93	
good service	frequency	**4**	**22**	**26**
	percentage of change (%)	**2.06**	**11.34**	**13.40**
	Row Pct	15.38	84.62	
	Col Pct	5.13	18.97	
others	frequency	**19**	**12**	**31**
	percennage of change (%)	**9.79**	**6.19**	**15.98**
	Row Pct	61.29	38.71	
	Col Pct	24.36	10.34	
Total	not changed frequency	**78**	**116**	**194**
	selection rate(%)	40.21	59.79	100

<Table 5-1> Chi-Square Test for international airline selection change by cause

Test method	Chi-Square value	Degree of freedom	Prob
Chi-Square	**13.079**	**4**	**0.011**
Likelihood Ratio Chi-Square	0.038	4	0.008
Continuity Adj. Chi-Square	0.000	1	0.485
Mantel-Haenszel Chi-Square	0.038	1	
Fisher's Exact Test(Left)			
(Right)			
(2-tail)			

2) Verification for [hypothesis 2]

The hypothesis 2 "after recent aviation accidents happened more than 2 times within one year, the international air consumers show lower preference with the airlines had accidents. "

has similar results with the 1st survey and the 2nd survey in those who respond he would change airlines in international air travel". At the 1st survey, as shown <Table 6>, the change rate of domestic airline selection is 45.5% which is lower than 15% by before accident. in the 2nd survey, the change rate was 45% which is appeared to be no big change. This means there is no larger than in domestic than international and there is more strong motivation to lead using previous airlines continuously.

<Table 6> Whether change international airline selection or not(In the 1st Survey)

Whether international airline selection or not (N=145)	Number of samples	rate
Changed	66	45.5%
Not changed	79	54.5%
Total	145	100%

<Table 6-1> Whether change international airline selection or not (In 2nd Survey)

Whether international airline selection or	Number of samples	rate
Changed	140	45.0%
Not changed	171	55.0%
Total	311	100.0%

There for, the hypothesis 2, "after recent aviation accidents happened more than 2 times within one year, the international air consumers show lower preference with the airlines had accidents." is accepted, though in 2nd survey, the domestic airline change rate is 59%, which is lower than in the 1st survey 58%. But the respondents' preference on airline selection about accident airlines as shown in the 1st survey 45.5%, in the 2nd survey 45%.

3) Verification for [hypothesis 3]

The hypothesis "After aviation accidents, the aviation safety has been much reflected in airline selection by aviation consumers." is a questionnaire(V) how recent frequent air accidents within 2 years was reflected as a aviation safety variables in selecting airlines. Shown in <Table 7>, the average has scored to 3.88 from 3.40 when setting standards at 5.00

<Table 7> The average reflection level of aviation safety variable to airline selection variables

Classfication	Air safety reflection level before	Air safety reflection level after
Average	3.40	3.88

<Table 8> Analysis between the level of aviation safety reflection and airline selection change

8a	Changed domestic airline selection (N= 92)	Accident	Before accident	After accident
		average value for refleciton degree	3.5652	4.1413
		correlated value	0.424***	
		t-value of reflection degree before and after accident	-5.604***	
8b	Unchanged domestic airline selection (N = 64)	accident point	average reflection degree before accident	average reflection degree after accident
		average reflection value	3.1563	3.5625
		correlated value	0.497***	
		t-value of reflection degree before and after accident	-4.108***	
8c	Changed international airline selection (N = 66)	accident point	average reflection degree before accident	average reflection degree after accident
		average reflection degree value	3.6364	4.1818
		correlated value	0.433***	
		t-value of reflection degree before and after accident	-5.034***	
8d	Unchanged international airline selection (N = 79)	accident point	average reflection degree before accident	average reflection degree after accident
		average reflection value	3.1772	3.6329
		correlated value	0.425***	
		t-value of reflection degree before and after accident	-4.170***	

1) t-value stands for average difference between the reflection level before/after accident and changing domestic/international airline selection

note) : *** 1% significant

<Table 9> Logistics regression analysis to effect on aviation safety

Variables	Domestics	International
Average safety-related factors	0.7382***	1.0254***
Degree of consideration safety-related factors in domestic/international airline selection	0.00975	0.0302**
Safety confidence	-0.00969	-0.0143
Avition safety component	-1.0821***	-1.6794***
Degree of reflection after accident	0.6223**	0.7627**
-2Log(L)	33.815***	54.889***

Note) N=146 ** 5% significant *** 1% significant

After analysing safety-related factors at the first survey, in domestic routes, the safety-related factors, namely aviation safety elements and the level of reflection after air accidents appeared to be significant effect to air consumers domestic purchase behaviors while in international routes, safety-related factors, namely, the level of consideration for safety in domestic/international routes, aviation safety elements and the level of reflection after accidents proved to be significant effect to air consumers international purchase behaviors.

As shown <Table 10>, the significant variables to air consumers' purchase behavior after air accidents are analyzed as safety, services, and airport facilities. On the other hands, <Table 10-1> shows, in case of international routes, the significant variable to air consumers' purchase behavior after air accidents is analyzed as safety,

<Table 10> significant Variables to purchase behaviors after air accident

Variables	Level of flexibility	Parameter estimate	Standard error	Wald chi-square	Pr〉chi-square
INTERCEPT 1	1	-8.0641	1.6817	22.9951	0.0001
Safety	1	0.7330	0.2392	9.3866	0.0022
Airfare, Service	1	0.4051	0.1904	4.5286	0.0333
Airport Facilities	1	0.5421	0.2209	6.0252	0.0141
Criterion	Intercept only	Intercept & Covariates		chi-square for Covariates	
AIC	191.947	187.187			
SC	194.888	237.195			
-2 LOG L	189.947	153.187		36.759 with 16 DF(p=0.0023)	
Score	-			32.854with 16 DF(p=0.0077)	

Note) purchase behavior=-8.0641+0.7330(safety)+0.4051(airfare · service)+0.5421(airport facilities)

<Table 10-1> significant Variables to purchase behaviors after air accident (international)

Variables	Level of flexibility	Parameter estimate	Standard error	Wald chi-square	Pr〉chi-square
INTERCEPT 1	1	-5.4680	1.2311	19.8582	0.0001
Safety	1	0.5526	0.2255	6.0040	0.0143
Criterion	Intercept only	Intercept & Covariates		chi-square for Covariates	
AIC	186.467	176.779			
SC	189.372	223.263			
-2 LOG L	184.467	144.779		39.688 with 16 DF(p=0.0005)	
Score	-			32.643with 16 DF(p=0.0053)	

Note) purchase behavior = -5.4680 + 0.5526(safety)

Namely, the hypothesis 3 "After aviation accidents, the aviation safety has been much reflected in airline selection by aviation consumers was accepted.

4) verification for [hypothesis 4]

The hypothesis " **air travel experience" will have correlation with air consumers' attitude or behaviors to aviation safety" ,** proved in the first survey that the number of domestic or int'l air travel have no special relations with aviation safety variables. In the Correlation Analysis with the first survey and the second survey, in domestic routes, they analyzed the number of air travel experience affected no significant effect to aviation safety or attitude. In case of international, however, the correlation analysis with the first survey and second survey of a year after, there seemed that the number of international air travel experience have no little significant correlation to safety and it is interpreted it has no relations with the level of confidence to aviation safety.

But it also could be doubted in terms of the level of confidence air users of many experiences have tendency to have lower confidence in air travel safety than air users of little experience, which the former can consider various air fares, services and safety in constrast with that domestic air users have limited selections. In this study, they judged the more experiences have the air travellers, the lower confidence to air safety. Therefore <hypothesis

4> **air travel experience" will have correlation with air consumers' attitude or behaviors to air safety"**was accepted international air transport.

<Table 11> The relationship between air travel experiences and other air safety variables

Classification	The number of domestic air travel experience	The number of international air travel experience
Aviation safey confidence	-.88	-.008
New aircraft	-.31	-.123
Pilot performance	-.99	.094
Airport facilities	.68	.154
Airline safety policy	-.011	.084
Degree of aviation safety reflection after accident	-.106	.091
Safety	-.055	-.025
Image	-.010	.085
Convenience	.38	.207*
Economical Efficiency	.009	.095
Service	.034	.167*

Note) * 5% significant(2-tailed)

5) Verification for [hypothesis 5]

At the hypothesis that **"The confidence on air travel safety would show lower level of effect to countries experienced frequent air accidents",** after reviewing the confidence on air travel safety by each group of countries, it showed at <Table 12> after accidents Japanese, America-Europe, Chinese people shaped a group, and the Korean people shaped another group of considerably low level of confidence in air travel safety after accidents, according to Duncan Grouping analysis from Among ANOVA test. This difference is analyzed that a series of air accident by Korea national flag carriers frequently happened in recent made Korean people distrust in aviation safety and this trend is partly because newspapers and mass communications raised the aviation safety issues and the consciousness that air travel is safe is relatively low than other target countries people.

<Table 12> The confidence on air travel safety

Duncan Grouping	Average	Number of Samples	Group of Countries
A	81.133	105	Japan
A			
A	80.232	166	America, Europe
A			
A	78.792	120	China
B	73.373	166	Korea

Therefore, <hypothesis 5> **The confidence on air travel safety would show lower level of effect to countries experienced frequent air accidents"** was accepted**.**

6) Verification for [hypothesis 6]

At the hypothesis that **" The air consumers from advanced countries are much**

conscious of safety emphasis considered in air travel", there appeared Chinese group is distinct from the other similar group consist of Japanese, America and European, Korean group. The reason why Chinese group show difference than other groups is analysed it is because people does not much consideration on air fare from socialism system as well as from GNP effect and it naturally brought higher importance for aviation safety while air travellers from advanced countries has tendency to put less importance on aviation safety in air travel. Therefore , the hypothesis 6, **"The air consumers from advanced countries are much conscious of safety emphasis considered in air travel"** was rejected.

<Table 13> Relative importance of safety in air travel

Duncan Grouping	Average	Number of Samples	Group of Countries
A	50.374	107	China
B	38.379	87	Japan
B			
B	37.171	155	America-Europe
B			
B	32.516	153	Korea

7) Verification for [hypothesis 7]

To verify hypothesis 7 "The older the respondent, the higher do the emphasis on the confidence of air travel safety", a SNK(Student Newman Keuls) through ANOVA test method is applied. Among <Table 14a, b, c, d, e>, <Table 14a>, the table analyzed by age for confidence for air travel safety, shows there is no difference by age between air travel safety confidence. Furthermore in <Table 14b>'s analysis by age for aircraft age among aviation safety elements, there shows no difference by age from who replied it is important to aviation safety variables

The air consumers who responded pilot performance is important among aviation safety variables show no differences by age at <Table 14c>. On the other hand <Table 14d> show some difference by age between who responded the airport facilities are important as aviation safety variables; the air consumers under 20 were distinct from other age groups, this can be judged they are not highly of air facilities. <Table 14e>show no difference by age between who responded the airline safety policies are important as aviation safety variables; Therefore <hypothesis 7> **"The older the respondent, the higher do the emphasis on the confidence of air travel safety."** was rejected, because there appeared some significant differerence by age only for airport facilities, however not for any other variables.

<Table 14 a, b, c, d, e> Analysis to air travel safety by Age

Aviation safety confidence for air travel analysis by age ANOVA TEST						
[Table 14a]	Source	DF	Sum of Square	Mean Square	F value	pr) F
	Model	4	1575.0778079	393.7694520	0.96	0.4301
	Error	312	128076.94381	410.5029961	-	-
	Corrected	316	129652.01261	-	-	-
	Classification	R^2	C.V.	Root MSE	Mean	
		0.012149	27.11600	0.4736726	1.3455882	

Aircraft age among aviation safety imporatnxw by age ANOVA TEST						
<Table 14b>	Model	4	24.54893316	6.13723329	2.78	0.0404
	Error	322	6776.6804246	21.04559138	-	-
	Corrected	326	6801.2293578	-	-	-
	Classification	R^2	C.V.	Root MSE	Mean	
		0.003609	107.3053	4.58754738	4.27522936	

Pilot performance among aviation safety importance by age ANOVA TEST						
<Table 14c>	Model	4	8.61790205	2.15447551	0.41	0.7987
	Error	323	1681.8577077	5.20698981	-	-
	Corrected	327	1690.4756097	-	-	-
	Classification	R^2	C.V.	Root MSE	Mean	
		0.005098	49.56673	2.28188295	4.60365854	

Airport facility among aviation safety importance by age ANOVA TEST						
<Table 14d>	Model	4	4.78346956	1.19586739	1.56	0.1857
	Error	323	248.14031093	0.76823626	-	-
	Corrected	327	252.92378049	-	-	-
	Classification	R^2	C.V.	Root MSE	Mean	
		0.018913	21.82908	0.87649088	4.01524390	

Ariline safety policy among aviation safety importance by age ANOVA TEST						
<Table 14e>	Model	4	2.11004514	0.52751128	0.87	0.4812
	Error	323	195.49971096	0.60526226	-	-
	Corrected	327	197.60975610	-	-	-
	Classification	R^2	C.V.	Root MSE	Mean	
		0.010678	17.62289	0.77798603	4.41463415	

Ⅳ. Conclusion

The result of this study can be summarized as below; firstly, it is fact that the air frequent air accidents by national flag carriers during recent 3 years affected greatly the level of perceptions of air consumers and it brought a big change in airline selection, quite different as before air accident which happen by chance. **[hypothese 1], <After the frequent air accidents, more than 2 times within a year, domestic air consumer would prefer another transportation modes>** was rejected, this shows the preference for another airlines moved than for another transporation modes.

According to survey result, the international air consumers require high involvement purchase than domestic air consumers and except for 'aviation safety" variable, such variables as airlines mileage, schedule, price(air fare), and service constantly worked as factors to strongly maintain air consumers in international air travel than domestic one.

Thirdly, after recent air accidents happened more than 2 times within one year, the aviation safety has been much reflected in airline selection by aviation consumers. Whether aviation consumers change airline selection in domestic / international according to the amount of "aviation safety" variable being aware of, there is significant difference between air consumers who has changed airline selection and who hasn't reflected level for selection after accident is higher than before accidents.

Fourthly, as "aviation safety" variable are not obviously demonstrated different consumers behavior pattern derived from air travel experience difference in Korea air transport market, "aviation safety" variable is so much regarded the object of enduring involvement as one of situational involvement. Therefore it is difficult to find out obvious consumers behaviors by each social layers.

It is expected the air travel frequencies has close and significant relations with aviation safety confidence because the consumers of many experiences show coherent consumers behavior in product selection than of little experience. In the 1st survey with the 2nd survey. In case of international air travel, however, air travel frequencies make an significant minus effect on safety. It is judged domestic airlines selection can be taken within only limited consideration otherwise international airline selection, various air fare, service and safety factors because the more experienced of air travel, the lower of confidence in aviation safety.

Fifthly, as for aircraft age, pilot's performance maneuver, and airlines safety policy are how much significantly affect to aviation safety; aircraft age has no relations with aviation safety otherwise pilot's performance maneuver and airlines safety policy has significantly relations. This means air consumers are conscious that aircraft age are not related to aviation safety

At the 1st survey, there is no difference in air consumers responses on the importance of aircraft age and airport facilities to aviation safety. Otherwise after 1 year there happened changes in air consumers consciousness in terms of responses on pilot's performance maneuver and airlines safety policy has significant relations with aviation safety. It also can be said that from the pilot's performance maneuver factor suggest human factors are important in aviation accident and airlines aviation safety policy affect air consumer's consciousness of aviation safety.

Sixthly, among the factors which considered in air travel, the relative importance of aviation safety are highly differed only in Chinese otherwise Japanese, North American and European, and Korean can be grouped as one. This can be analysed that the higher GNP and the more advanced countries, the lower of safety's relative importance.

Seventhly, the confidence of air travel safety, Japanese, North American and European, and Chinese are classified into one group otherwise Korean into another. Between Korean people, the level of air travel safety confidence are considerably low. This phenomena is due to the recent air accident more than 2 times within one year and the problems on newspapers and mass communication, which gave distrust to Korean consciousness for aviation safety. Therefore as far as confidence in air travel safety, the confidence level of Korean are relatively low than other countries.

Eighthly, the reflection level of aviation safety as airline selection factor after aviation accident has most significant effect in North America, Europe and Japan; particularly in North America and Europe are shown to be highest level in term of aviation safety reflection otherwise in Japan the significance are relatively low than North America or Europe.

Ninthly, as for the domestic airline section change Japanese, North American and Korean can be classified into one group otherwise Chinese into another group. It can be said that Japanese, North American and Korean are to be significant to air accident in national airline selection and Chinese are not to change international airline selection irrespective of accident.

Also, as for change of international airlines selection, Japanese North American and Korean can be classified into one group otherwise Chinese into another group. It can be said that Japanese, North American and Korean are to be significant to aviation accident international airline selection and Chinese are not to change international airline selection irrespective of accident.

Tenthly, as for the common sense increasement on aviation safety, its level difference between groups are large; the analytic data show its increasing trend of North-America and Europe is higher than those of China.

As a conclusion, this research has significance in the fact it analyse air consumer's preferential change by demonstrating "aviation safety" variable which has not been regarded as airlines selection factor in korean air transport market because airlines selection factor rose up after the recent air accident. Therefore this research result is expected to make some contribution to the effort for elevating aviation safety level and enhancing air transport competition power by preparing the government's fundamental policies to aviation safety and airlines systematic devices for aviation safety based on those policies.

Reference

1. Assael Henry(1998), *Consumer Behavior and Marketing Action,* ITP, 6th,
2. Abeyratne R.I.R.(1998), "The regulatory management of safety in airtransport", *Journal of Air Transport Management*., 25-37.
3. Ashford, R.(1994), Safety in the 21st century - the need for focused regulatory targets and maximized safety benefits. Paper presented at the 47th International Air Safety Seminar, Flight Safety Foundation, Lisbon, Portugal, Oct. 31st-Nov. 3rd
4. Barnett Arnold and Higgins K.Mary(1989), "Airline Safety : The Last Decade", *management science*, vol 35, No 1.
5. Barnett A. Abraham, M., schimmel, V.(1979), Airline Safety: some empirical findings. *Management Science* 25(11), 1045-1056.
6. Barnett Arnold and Wang Alexander(1998), "AIRLINE SAFETY : Recent Record", *NEXTOR Research Report RR-98-7. MIT.*
7. Choi, Sejong(1985), "The Public Perception and Airline Safety : Case of Korea Airline Industry", Unpublished Master Thesis *Embry Riddle Aeronautical University*.
8. FAA(1996), *90 Day Safety Review,* 4.
9. Federal Aviation Administration(1996), *FAA 90 Day Safety Review.*
10. ----(1999), Safety Reports - Aviation Safety Data Accessibility Study Index: Availibility and Accessibility of Safety Information.
11. GAO(1997), "AVIATION SAFETY - FAA Has Begun Efforts to Make Data More Publicly Available", *GAO/RCED-97-137*.
12. Geoffrey D. Gosling(1998), Development of System Safety Performance Measures in Support of the Global Analysis and Information Network, *NEXTOR WORKINGPAPER UCB-ITS-WP-98-3.*
13. Hong, Soonkil·Lee, Kangseok(1997), "The impact of cultural factors on the aviation safety", *the third Aviation Safety & Human Factors Seminar*, Organized by Korea Civil Aviation Bureau in Ministry of Construction & Transportation, 51-74.
14. Laurie Taylor(1994), "*Air Travel, How Safe is it*?", London, England : BSP Professional books.
15. Lee, Kangseok(1999), " The enhancement on aviation safety through the cultural factors harmonization in air system.", *the fifth Aviation Safety and Human Factors Seminar*,

Organized by Korea Civil Aviation Bureau in Ministry of Construction & Transportation, , 333-389.

16. Lee, Kangseok·Lee, seungchang(2000), "The impact of aviation safety on the consumer's choice of airline in the air transport market of korea", *The Journal of Korea Navigation Institute*, Hankuk Aviation University in Korea, Vol 4, Number 1., 78-92.
17. Lee, sungwoong(1999), "A study on the air safety regulation in Korea", Unpublished Master Thesis, *Seoul National University.*
18. Lim J.W·Kim J.I·Hong S.T·Lee Y.J(1998). *"Consumer Behavior*". Seoul : Kyungmoon ltd.
19. Oster, C.V. Jr., Strong, J.s., Kurt Zorn, C.(1992), *Why Airplanes Crash - Aviation Safety in a Changing World.* Oxford University Press, NewYork.
20. Rice Chris, *ConsumerB ehaviour -Behavioural aspect of marketing-* , Butterworth Heinemann Ltd.
21. Semmens, J., & Kresich, D.(1989),*Deregulation, Privatization, and Air Travel Safety"*, Chicago, IL *: The Heartland Institute*.
22. Yoo K. E. (1995), A Study Korean Air Passenger's Choice Behaviour ; Utilising Stated Preference and Revealed Preference Method, *Unpublished Doctoral Dissertation, Loughborough University of Technology.*

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PSYCHO-DIAGNOSTIC AND PSYCHO-THERAPEUTIC ASPECTS OF THE HUMAN FACTOR OPTIMIZATION IN AVIATION

Urgency of questions of psychodiagnostics and psychotherapy in conditions of military-medical establishment has increased for last years, this is connected with the increase among a contingent of military pilots of amount of persons, who are possible to relating to a group of patients with functional and psychosomatically frustration. For this reason the attention increases of participation of not only aviation psychophysiology's as expert of vocational guidance or the expert in emergencies, but of the clinical psychologist and psychotherapeutic in the system of psychological support of military pilots, as well. Modern expansion of a circle of professional work has caused changes of understanding of orthodox approaches. Our subsection provides the clinic-psychological activity in the Military-medical Center. First of all, it is the work with air crew which passes medical expertise, carrying out of clinic-psychological inspection which essentially differs from similar procedures in the majority of others establishments (with its tasks and methodological approaches). Our is not purpose to carry out vocational guidance, which professionally occurs during training of the future pilots, and revealing of psychological properties of the person and psychopathological syndromes. Our task during medical expertise support is a definitions of a level and features of display of mental processes, functions, actual psychological conditions and properties of the person which enables to estimate the general common psychological condition at present and to show on the clinical level some somatic infringements, with the purpose of their further preventive maintenance and preservation of professional health air crew. Thus, we consider the person with holistically positions in mentality of the clinical psychologist.

The aggravation of the certain personal features and formation of specific psychological stereotypes, which caused by features air works beat off on both mental and physical conditions of the pilot. During the performance of professional tasks the pilot can (not always) react completely all emotions which arise at him. However, these emotions exist and do not disappear anywhere, whatever the level of their comprehension. These emotions without reaction are shown by somatic frustration, or so-called „body language", symptoms of infringements of nervous, cardiovascular, respiratory system, nervously-muscular device. At psycho emotional overstrain, on conditions of presence emotions without reaction rather frequently there is an internal psychological conflict or specific mechanisms of psychological protection which is shown by an aggravation of already existing chronic diseases or occurrence of new illnesses are formed, which in fact are psychosomatic. Therefore it becomes clear how important a duly carrying out of clinic-psychological inspection is. Its purpose is the revealing of changes of mental processes, functions and conditions which specify on preclinic changes of a condition of an organism.

Clinic-psychological diagnostic inspection will consist of the research of cognitive processes, psychomotor properties, intellectual work capacity, affective sphere and definition of personal qualities. Psychodiagnostic inspection with the help of a complex clinic-pathopsychological and experimental-psychological techniques-tests makes possible an estimation of functioning as separate spheres of mental activity, and integrative formations: types of temperament, features of character, personal qualities which can act determine as the factor of occurrence psychosomatically frustration.

The revealed tendency, which testifies to the expressed personal changes in psychosomatic patients. The analysis of results of personal researches can testify about certain psychosomatic precondition, and clinical-psychological inspection can be used for revealing on preclinic level of propensity to occurrence psyhosomatic diseases.

Most participation of mentality affects in a display of such diseases, which develop on the basis of functional infringements, vegetative dissonances, and also at a lot of illnesses from "the unknown reasons", where there is no precisely certain caused reason. In genesis of these psychosomatic diseases the significant role is allocated to personal qualities of the patient. These qualities of the person inherent in each individual also create base for occurrence psychosomatic dissonance on which background stressful factors get pathogenic character and destroy mechanisms of psychological protection. In somatic patients personal qualities rather frequently display and predecease properties and elements of deformation of the person under influence of illness. In psychosomatic patients is often difficult to divide in the general problematic a situation of disease, psychodynamics and the person. As psychosomatic diseases are the display of connection biological–psychological-social, or propensities (genetically caused congenital precondition) - persons (the realized and not realized conflicts, mechanisms of protection, personal features and forms of reaction) - situations (vital, professional, in микро-and macro society). Thus, somatic and mental, influence of propensities and environment, an actual condition of an environment and its subjective processing, physiological, mental and social influences in the set and addition each other - all this matters as various influences on an organism which are factors which cooperate among themselves. The somatic pathology can arise and be display of not realized conflicts during pathological neurotic development which results to that actions directed on external object are not carried out. If the person does not manage to meet the desires of security and dependence (which occur from the basic base conflicts), the emotional pressure any more does not manage to be appeased, vegetative changes accompanying it which further demonstrate in the deformed kind are kept and can lead to organic changes at a fabric level which already and is disease. So, if it is blocked by the external or internal reasons of enmity aggressive displays (struggle or flight) or search of dependence and the help, is shown replaceable behavior and corresponding unhealthy conditions.

Recently within the limits of a functional direction the tendency to a multivariate estimation of the general condition of patients that is shown by multiaxial systematization diseases actively develop. This multiaxial diagnostic approach allows to estimate not only expressiveness of the basic clinical syndrome, but also type of adaptive behavior, a level of social functioning of the individual. The greatest expressiveness of biopsychosocial connections is shown within a contingent, which is in difficult, and sometimes and extreme conditions. One of such groups is pilots in who to extreme operating conditions the difficult social moments are added. We had lead studying distribution diseases between groups of military men according to features of functional duties and service ranks. Thus precise enough correlations have been revealed.

During the clinical inspection of the group of highly skilled pilots of different groups of specialization it has been revealed, that in the general picture of disease prevailed forms with expressed psychosomatic influence. Therefore we had lead clinic-psychological inspection of this contingent. The purpose of research was to reveal the correlation between a disease, a traumatism and personal characteristics. During the research methods of interrogation, purposeful conversation, test - questionnaire MMPI and the block personal-focused techniques were used.

While the processing of the results we paid attention that about 25 % interrogated high parameters on 2 and 8 scale MMP I had, and this increase correlated with the data of questionnaires where pilots marked the certain rejections in a state of health during the different periods of time (on the part of cardiovascular system of change of frequency of intimate reductions and differences of arterial pressure, episodically loss of consciousness at carrying out of high-altitude researches in a pressure chamber, osteochondrosis of different departments of a backbone). The same as research at questioning mentioned different emotionally-meaning vital situations, both on work, and in family which preceded diseases or deterioration in a state of health is more often. Also for this group surveyed high parameters on 9 scales which specified the weak tendency at pilots to a reflection, i.e. to introspection and comprehension of inwardness were characteristic. The results, received during the using research behind different techniques, coincide behind the orientation.

Also we had lead a comparative research of parameters of alarm-conditions and alarms-features to patients with the expressed tendencies to increase of arterial pressure (or with already the diagnosis of hypertension illness) and a gastroenteric pathology. For the first group of patients, with displays of increase of arterial pressure, there was a characteristic increase of the level of situational uneasiness, at low parameters of personal, that correlates with desire to hold a situation under the control and in due time to react increase of internal pressure upon pressure of external circumstances. In the second group there was a revealed general tendency for all patients: at all diseases the low level of situational uneasiness and increase of a parameter of personal uneasiness to abstemious to a level which specifies constant sensation diffuse dangers, uncertain anxiety and even fear has been diagnosed. Such диссоциация between levels of personal and situational uneasiness in these groups of patients can be caused by differences of protective psychological mechanisms which already are characteristic for psychosomatic aspect.

So, we once again prove, that practically behind each symptom or a trauma there is an intrapsychical problem which at present can not be realized by the pilot, but represents the display of the internal conflict personal determined. The changes of psychosomatic frustration depend not only on a course of disease, but also from features of inwardness, and also its external displays. A disease or unhealthy conditions, behind our supervision, appear at pilots or at the initial stages of employment, or at the end of career is more often. In both cases it in a smaller measure is connected to professional work, and in the majority with questions of social adaptation: the pilot during these periods is more disturbed with daily vital circumstances which provoke its consciousness and, that is more important, subconsciousness to actualization emotional without reactions. And from here, certainly, that correction of a psychological condition of pilots can influence their physical condition and a state of health as a whole.

The urgency of the received data is connected to an opportunity preclinic revealing specified diseases, duly orientation in a choice of the necessary further profound inspection and corresponding preventive or in case of need medical actions. Under conditions of revealing at air crew psychosomatic diseases expedient there is a psychotherapy, which directed on change of comprehension by the pilot of illness and its possible consequences.

At carrying out of individual psychotherapeutic work as psychological consultation or psychocorrection the expert should adhere to corresponding rules with the purpose of creation of a therapeutic climate and a guarantee of psychological safety of the client. In work with air crew it is important to remember, that correction should be very cautious that psychodynamics as a result of work has not put the even greater harm. For this reason the focal approach in work with a problem or a symptom more often is used.

Group of psychocorrection is not an independent direction of psychotherapy, and represents only specific form at which use by the basic tool of action the group of participant's acts, as against individual psychocorrection where such tool is the psychologist. The group is a real world in a miniature. In it there are the same, as during lives of a problem of interpersonal attitudes, behavior, decision-making, etc. Here are possible decision of tasks, which unsoluble in a real life, and their decision during employment in group guarantees psychological safety. The basic attention in these groups is focused to individual development and uniqueness of each person. In psychotherapeutic group it is considered, that expressions of one participant, its behavior, displayed in a group mirror, are divided by other participants, and the group behaves as the interconnected system in which the whole appears something big, than the sum of its parts. To the head in such group the passive role is allocated, whereas members of group investigate features of own behavior - the head of the group remains in a shadow. In psychocorrectional plan such group has two basic purposes: self-improvement of the person, training to skills interpersonal dialogue. Except for function of teaching, the psychotherapeutic group carries out also function of mental improvement. It means, that occupations in the group make its participants sensitive to another's sensations and needs, allow to realize more deeply itself and own behavior, adequate interpersonal relations, help to adjust, to raise the skill to communicate, frankness, to strengthen honor to associates and sensation of own advantage, not only better understand itself, but raise the adaptability.

One of approaches to realization of personal growth during the group work is carrying out of thematic training, focusing of attention of the group on any theme which for all cycle of occupations is through. The technique of carrying out such version of cognitive training of personal growth reminds a variant of thematic discussions. Themes can mention vocational guidance, professional features, emotional experiences, interest of value of a life, etc.

One more method of group work is discussion which in translation from Latin means consideration, research. In a context of the group work it is considered as a way of the organization of the general activity with the purpose of an intensification of process of decision-making in the group; a method of training which raises intensity and efficiency of process of perception due to active inclusion learned in collective search of true. Group discussion concerns to methods group of psychocorrection. Together with term « group discussion » such concepts, as « free discussion », « not structured discussion » are used, etc. Traditionally the group discussion carry to verbal methods, as the basic means of interaction here is the verbal communications, and in the center of the analysis there is mainly verbal material. Similar distribution is a little bit conditional, as the analysis of nonverbal behavior, coordination's or disagreements of the verbal and nonverbal communications makes a prominent aspect of the group discussion. Usually the discussion proceeds hour for one and a half. This method is applied in the psychotherapeutic purposes, and also with a view of training, development, an establishment of mutual relations in group.

Thus, psychodiagnostic inspection essentially improves preventive work, extends professional suitability air crew, allows to define in due time a physical and mental condition of the pilot and to prevent disease and emergency adventures which brings appreciable economic benefit. Also expedient there are introductions in to before flight preparation psychocorrectional the actions directed on increase of psychological readiness of the pilot to flight and adequate perception by him existing validity. Under conditions of revealing at air crew psychosomatic diseases expedient there is a psychotherapy, which directed on change of comprehension by the pilot of illness and its possible consequences.

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TRANSFORMATION OF PSYCHOLOGICAL CRITERIA OF PROFESSIONAL FITNESS OF CIVIL AVIATION PILOTS IN THE PROCESS OF AIRCRAFT GENERATION REPLACEMENT

Pilot compliance with the professional psychological fitness requirements is the most important flight safety factor provided by the whole complex of measures among which in addition to the appropriate flight training and necessary psychological qualities formation system the professional psychological selection also takes its important place.

The individual and psychological characteristics variability of different people by far not always can be compensated by this or that individual style of activities in any profession, especially in flying activity with its clear regulation and specificities of work conditions. Thus, the initial professional psychological selection of the candidates for the flight training is the important element of provision of a particular person real characteristics compliance with the pilot profession requirements.

There exists a certain psychophysiological characteristics dynamics connected with human age and some characteristic features of the human ontogenesis. So, the conducting of the psychological selection by way of the psychological screening during the operating personnel continuous certifying process is made relevant by this fact.

For the solving of the problems mentioned above the well-founded psychological fitness indicators and criteria set is needed. Both the flight activities matter analysis and successful professionals psychological characteristics studying can serve as the basis for their development.

The pilot activities multiaspect form when analysing gives grounds to use various present typologizations of the operator activity matter. Then, for example, depending on the current problems solved during flight the pilot can be determined as primarily manipulator, observer, researcher, technologist or the team leader. And here both the nature of operations performed by the pilot and also the factors influencing the pilot's psyche depend on the design of the aircraft, level of its on-board systems automation, the ergonomic conception presented and, respectively, on the characteristic features of the on-board human operator functional status.

Thus, the increasing of the automation level cause the various pilot functions correlation redistribution towards the rise of the scope of the passive observing function and understanding of different systems automatic operations logic. Another automation process consequence is the rapid reduction of the pilot's share in the permanent operations which required the aircraft controls effect dosed by the effort and coordinated by the different channels, the fact that long ago was taken as the piloting. In this case, what is acquired by aviation and lost by pilot?

The whole range of the aircraft automation operational consequences is given in detail in ICAO Circular №234-AN/142 and we won't spend our time for their consideration.

Not all changes in the specific features of the pilot activities with the aviation engineering new samples can be absolutely obvious. In a number of cases, having the formal similarity of some operations or other, the pilot's perception of significance of the things taking place, own role and responsibility, risk level, etc. can be changed.

Characterizing the situation as a whole, it's worth stating that the pilot of the modern aircraft has more and more psychological grounds to percept himself in the role of the specialized control computer operator, and only repeating vestibular sensations and visual impressions reminds him of the sky being still the field of his activity. Meanwhile, a person having all necessary characteristics for being a perfect operator for the sophisticated computer system can have no prospects as the candidate pilot in general and as a candidate pilot for the highly- automated modern aircraft in particular.

Thus, the modern aircraft pilot should comply with the requirements of at least two professions:

1) the pilot profession proper with its traditional meaning (the pilot "manually" keeps the given flight parameters and stabilize the aircraft position in the airspace, giving necessary controlling efforts to the steering wheel and other controls, solve navigational problems independently, etc.);
2) the profession of the sophisticated polyfunctional automated equipment operator.

Each of these two aspects of the modern aircraft pilot activities puts forward its own specific requirements to the professional psychological fitness.

The change of the aviation engineering generations requires the serious revision of the pilot psychological fitness criteria and the simultaneous operation of the aircraft of different generations and classes being inevitably found in the future requires a well-grounded differentiation of these criteria.

Traditionally, the professional psychological selection activities in aviation provided for the examining of the following points:

- the indicators of the perception and thinking psychic processes;
- the speed of the simple and complex sensory and motor reactions to the various signals;
- the peculiarities of the complex sensory and motor abilities forming.

For the initial conclusions on the professional fitness the above mentioned points are of fundamental importance for they outline the stable individual characteristics which, to considerable or even primary extent, are determined by the steady physiological factors.

However, during the aviators' professional psychological selection, not only the cognitive psychic processes indicators, but the personal features as well are carefully examined. But the conclusions on the professional success anticipation based on the analysis of a person character features diagnosed with the appropriate methods of examining, as a rule, are much less harsh being drawn more cautiously.

It's worth mentioning that the personal characteristics information having its own independent value for the professional selection problem, also provides for more adequate analysis of the cognitive psychic processes indicators and evaluation of the human cognitive abilities, for these processes are widely connected with other personal factors. In particular, for example, the well-known fact of the cognitive psychic processes proceeding being influenced by the characteristic features of the personal emotion sphere is connected with the important place taken by the emotional activation in the mental tasks solution structure. Emotional states represent certain regulative and heuristic functions in thinking. Emotional surpass is the necessary tool for the action to be accepted as the right one by the subject. There also exists the connection between motivations and purpose determining specificities on the one hand, and thinking process, on the other hand. In this case motivations represent stimulating, sense making and structuring functions in thinking process providing.

And finally, there is a very important bond between peculiarities of the thinking processes and those of the personality "I-concept", the perception of self.

We consider that the important conceptual principle for scientifically grounded identification of significant indicators of psychological fitness of pilots who operate the aircraft of different generations that is based on the analysis of individual psychological characteristics of the successful professionals should be:

1) Expectation that age changes of indicators of some mental processes in representatives of different professional groups of pilots will be characterized by different dynamics.
2) Expectation that statistical interlinks between indicators of different mental processes will gain some specific configurations in pilots who operate the aircraft of a certain generation.

The arguments that support these assumptions are based on the mechanisms of ontogenetic evolution of human psychophysiological functions. The conditions for psychological functions evolution, that consists in achieving new, higher indicators at a mature age, are (Anan'ev, 1969):

- optimal load;
- sensitization;
- motivation;
- operational changes of functions.

The main condition for functions sensitization in the process of professional activity is the systematic load under pressure that is optimal for such activity. As an example one can give the results of the research of correlation between eyesight and the age of pilots, the aim of this research was to study sensory sensitivity of 185 commanders and other pilots in the age rage of 25-54 years according to different parameters of sight analyzer (Ustinova, 1966). The research found gradual age related decrease in eyesight acutance due to abnormal refraction and weakening of visual accommodation at the older age. On the whole, this research showed the sufficient stability of functional condition of the sight analyzer cortex section.

The accumulation of psychophysiological functions realization experience by an individual in his profession triggers a specific mechanism of influence that cortex produces on its own tonus (Anan'ev, 1969). This mechanism of development of certain psychophysiological functions is known as bilateral regulation mechanism because it is concerned with influence on tonus by means of interhemesphere regulation "cornerwise". Lets consider this mechanism. The cortex doesn't age as quickly as its reticular system that generates activating processes. That is why as the organism becomes older cortex potentials start to exceed the capabilities of reticular activations. Because of the extremely complex organization and great variety of vertical and horizontal bonds the cortex, keeping its potential, is able to compensate the age related deficit of the activating influences of the reticular formation and to some extent to define its own tonus.

The action of the mechanism results in the fact that psychophysiological functions that find systematic application in the professional activity escape age involution. The formation of the appropriate compensatory bilateral regulation contour is the effect that resist the involution processes.

So, if we observe that some psychophysiological indicators experience less age involution in one professional group than in the others, it indicates the action of the bilateral regulation contour that in its turn confirms the active participation of the appropriate psychophysiological functions in the structure of the activity. The extent of participation should be reflected by the extent of immunity against involutory changes. Thus, being guided by theoretical provisions mentioned above and by implementing an appropriately organized empirical research one can precisely define psycho physiological functions for definite specialties, as well as compare the importance of these functions for different professional groups. As the professional activity of the operator is based on the complex of different mental processes it is possible that it can stimulate the formation of statistic bonds among some of their indicators. The presence of such bonds can be studied empirically. The argument for the assumption that the bonds can appear among indicators of different mental processes due to the content of the human activity is that any mental process is formed as constellation of mental functions, actions (operations) and motives. Both operations, performed by the specialists of certain professional groups and, to large extent, their motivation (connected with satisfaction from the content and results of the activity) are common, thus, it can lead to formation of the appropriate bonds in professional groups that have considerable professional experience. It is worth noting that some typical operations that form the activity of the engineering system operators are provided by several functionally connected mental processes at a time.

All above stated creates a methodological and theoretical basis for carrying out the appropriate empirical research.

At the same time one should be guided by the idea that in accordance with the stated paradigm the empirical study should encompass selected groups of pilots who for a long time up to the day of the research operated the aircraft of a particular generation. Only under this condition there appears the best chance to detect respective correlation bonds and to highlight the list of the leading psychological functions in each selected group.

To illustrate the suggested approach we propose a correlation scheme of some indicators of cognitive processes in groups of pilots who operate Antonov-24, Yakovlev-40, Tupolev-154 (Fig. 1). These airplanes belong to the generation of aircraft with low level of cockpit automation. Correlation bonds, which were obtained, highlighted a range of indicators that are relatively independent from the age of the pilots as well as the range of indicators with significant interdependent correlation bonds.

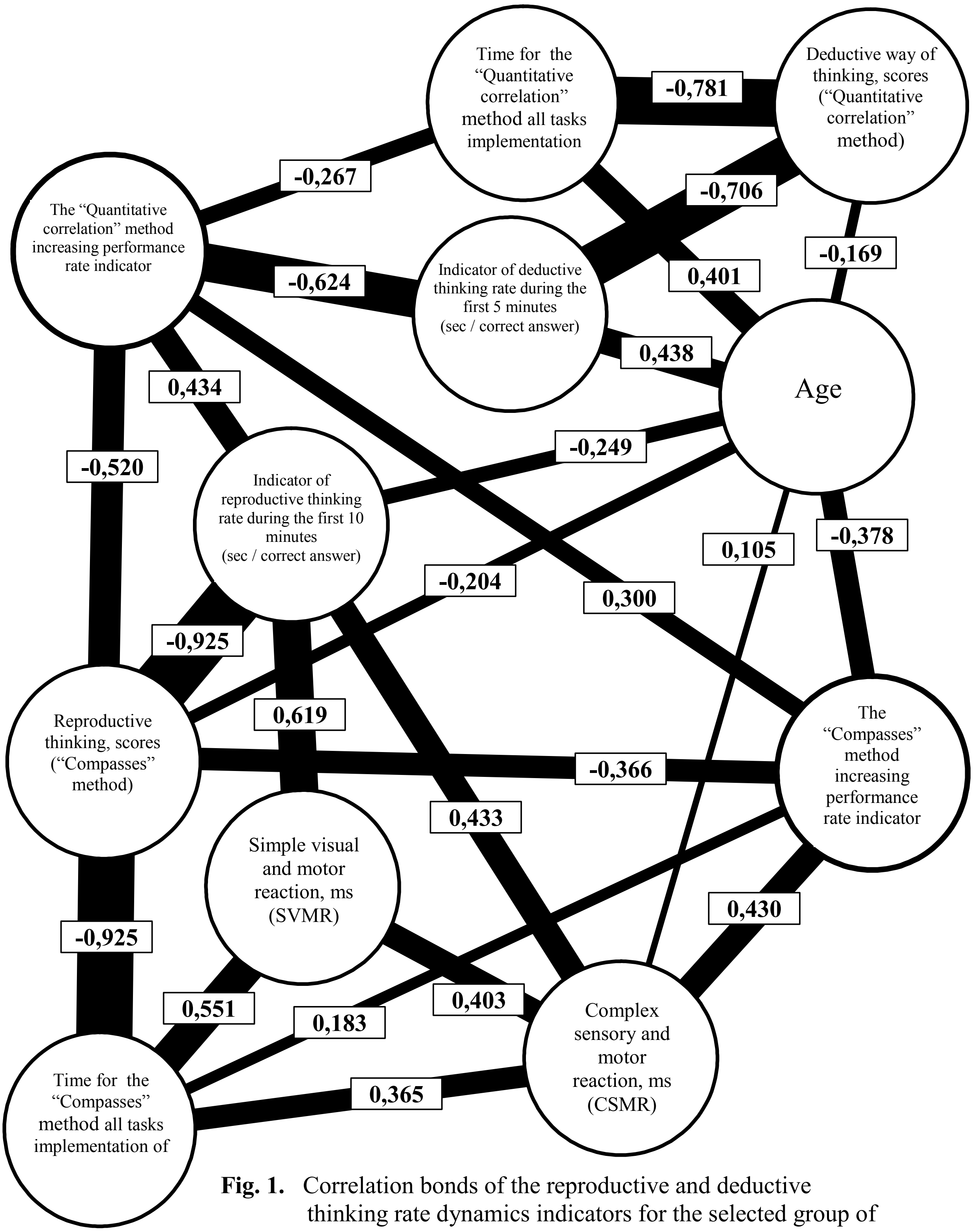

Fig. 1. Correlation bonds of the reproductive and deductive thinking rate dynamics indicators for the selected group of Antonov-24, Yakovlev-40, Tupolev-154 airplanes pilots.

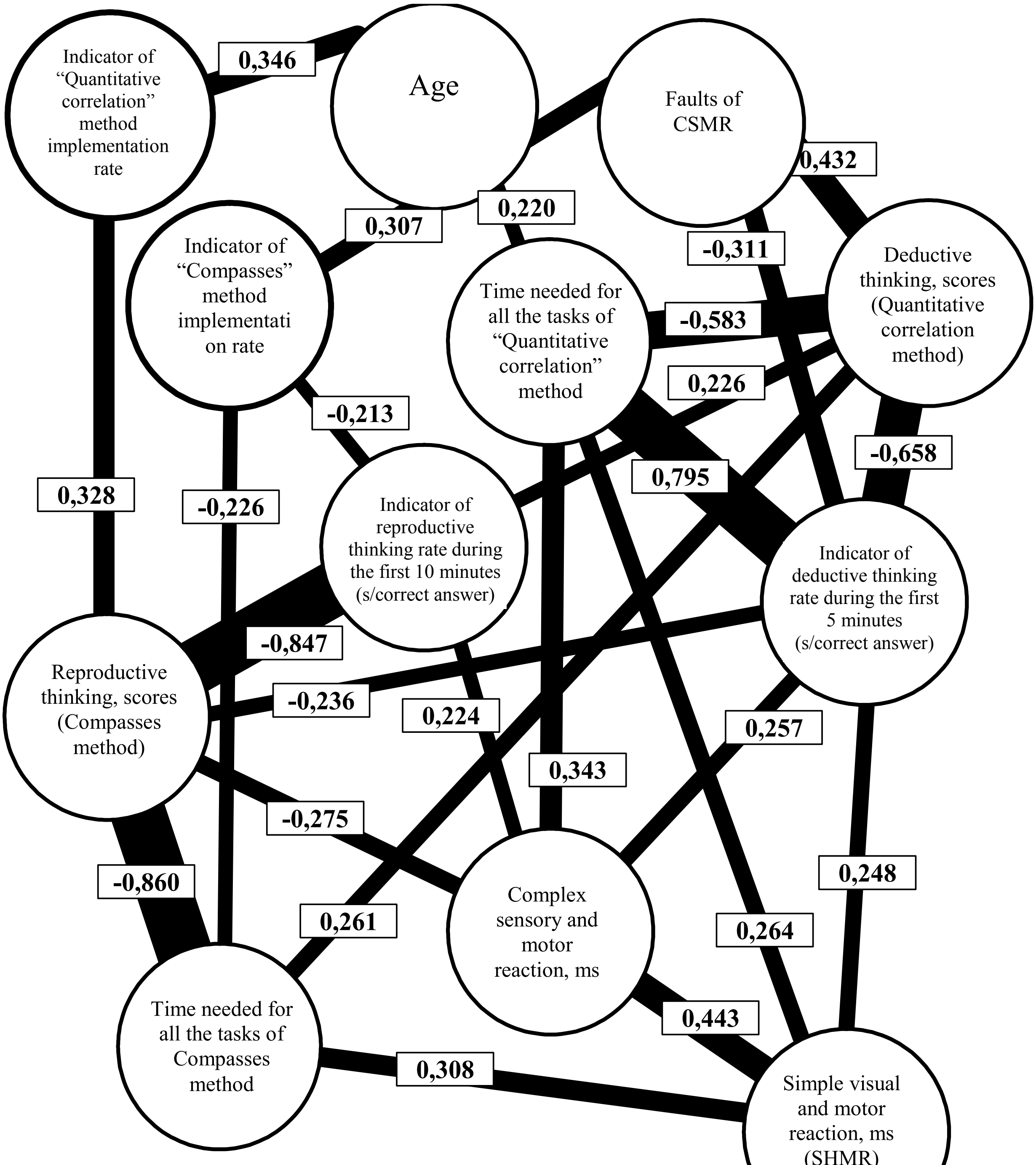

Fig. 2. Correlation bonds of reproductive and deductive thinking rate dynamics indicators for selected groups of air traffic controllers (for comparison).

One can see that this selection depends on the age of the pilot the least and, thus, the time of the simple visual reaction as well as the number of faulty sensory and motor reactions were defined as the most important psychophysiological indicators for professional selection.

For the comparison one can look at the results of the correlation analysis according to the same range of indicators in selected groups if air traffic controllers (Fig. 2). And here one can see significant differences: the least dependent on age here are not the sensory and motor indicators but the indicators of deductive thinking ("quantitative correlation" method) and reproductive thinking ("compasses" method).

According to the theoretical provisions that were discussed here, the obtained data leads to the conclusion that in selected groups of the pilots who operate aircraft with low level of automaton the bilateral regulation contour better resists the age involution tendencies as to sensor and motor reactions, and in selected groups of air traffic controllers it better resists the age involution tendencies as to reproductive and deductive thinking.

The calculation of data of correlation schemes aims to approbate the research method that is why the presented results serve only as an illustration of the capabilities of the suggested approach until the range of priority indicators of professional fitness is specified.

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QUANTITATIVE MODELS OF INFLUENCE OF SUBJECTIVE FACTORS ON FLIGHT SAFETY

The right method of approach to the matter of estimation transitive probabilities at the set of flight situations is based upon using canon preferences at the set of alternative controlling strategies. It is shown how to get the canon preferences distributions and how they are used in computation schemes for probabilistic indices of flight safety. Calculations of quantitative examples are adduced.

The system "aircraft-pilot", in a wider sense – an air-transportation system performing its service, is an active system which includes not only "machine" components but also "active" ones – staff-people who fulfill both strictly ordered actions and making decisions in circumstances and situations different from standard schemes described in normalizing documents (flight operation guides, instructions etc.). It is accepted that those systems belong to the category of active systems. A discussion of active systems peculiarities can be found at monographs [1, 2].

Active systems are highly-organized and with complex structures. Subjective entropy as a measure of uncertainty plays an important role in analysis and characterization of those systems. It is shown that in active systems, the sum of entropies, both produced within the system and exported, can decrease if the export exceeds the production.

The analysis of active systems safety on the base of entropy approach is an actual and considerably new problem. We can expect the appearance of new methods and results on the way. There is a certain variance principle in the basis of the approach suggested. The principle is pertaining to the psychology of a subject – a person making decision.

Canonical distributions of subjective preferences $\pi(\sigma_k)$ at an "individual" set of alternatives are used for active systems functioning description in paper [2]. The distributions are got as the result of a variation problem solution. The problem deals with a functional Φ containing the subjective entropy being computed at a discrete, finite set S_a of the alternatives σ_k. It can be shown that in the case if a problem of a danger minimization is being solved by the way of choosing an alternative from the S_a, then it comes that the subjective entropy is maximal. The mentioned variation problem is analogous to a similar problem formulized for probability distributions p_k in [3].

The statement that the human psychics functions, in a certain sense in an optimal way, is just a hypothesis but a trustworthy hypothesis. Anyway, conclusions got at the first stages of using this principle happen to be pretty trustworthy, according to "common sense" and empiric data.

A flight is considered a consequence of changing each other flight situations [4, 5, 6]. A situation c_t is defined as the next set of "variables".

$$c_t = \left\{z,\ t,\ \omega,\ \tau,\ S_z^{(1)},\ S_z^{(2)}\right\}$$

Where z – a vector of structural parameters, parameters of a state and controlling parameters at the moment t; τ – disposable time; ω – a "terminal" set for z (for z getting into ω within the time available meets the situation c_t ended safely); $S_z^{(1)}, S_z^{(2)}$ – limitations of two types, set upon z in the process of sorting out the situation c_t; $S_z^{(1)}$ – limitations set by restriction documents; $S_z^{(2)}$ – "physical" limitations realized in design, environment etc. The set of flight situations C is divided into several subsets. In accordance with the generally accepted practice there distinguish the set E_1 of normal situations and four sets of special situations; one of which is the set of catastrophic situations E_5.

We suppose that when any special situation arrives (excluding the catastrophic), there exist a few strategies which can be used by the crew in order to decrease the level of danger – to transfer the situation from a more dangerous into a less dangerous one or decrease the probability of a transition into a more dangerous situation. Corresponding required R^r and R^d disposable resources are connected to each alternative strategy (disposable and required time; displacement of elevators; fuel reserve etc.).

Let $E \subset C$ – is a subset of flight situations and an event E means that $c_t \in E$. A probabilistic measure is given at the set C.

Let

$$P(E(t);\ \xi(t_1)) = P(c_t \in E(\xi(t_1)))$$

is a probability that a system, which at the moment t is in a situation $\xi(t_1)$, at the moment $t > t_1$ changes its state for another one $c_t \in E$ (transitive probability).

One of probabilistic models of flight situations dynamics or "situational dynamics" is based upon integral-differential equations for discrete stochastic processes by Feller [7]. If sets $\omega, S_z^{(1)}, S_z^{(2)}$ can be parameterized in some way (the visibility distance when approaching or landing; the accepted diapason of centering; the accepted diapason of lateral wind velocity etc.) and a set of situations is getting countable or finite, then the equations by Feller can be replaced with the equations by Kolmogorov:

$$\frac{\partial P_{i,j}(t_1,\ t)}{\partial t} = -q_j(t)P_{i,j}(t_1,\ t) + \sum_{k=1}^{N(\infty)} q_k(t)Q_{k,j}(t)P_{j,k}(t_1,\ t)$$

$$\frac{\partial P_{i,j}(t_1,\ t)}{\partial t_1} = q_i(t_1)\left[P_{i,j}(t_1,\ t) - \sum_{k=1}^{N(\infty)} Q_{i,k}(t_1)P_{k,j}(t_1,\ t)\right]$$

where $P_{i,j}(t_1,\ t)$ – a probability of a transition of a system from a situation i at the moment t into a situation j at the moment t_1 satisfies conditions $0 \le P_{i,j}(t_1,\ t) \le 1$; and $\sum_{j=1}^{N(\infty)} P_{i,j}(t_1,\ t) \le 1$ for $\forall\ i,\ j,\ t_1,\ t$; as well as the equation by Kolmogorov-Chapman. Initial conditions: $P_{i,j}(t_1,\ t) = \delta_{i,j}$; $\delta_{i,j}$ – symbol by Khronecker. The value $q_i(t)\Delta t$ is a probability of the event that causes the change of the situation. The elements of the matrix $Q : Q_{i,j}(t_1)$ – conditional probabilities that the system being in the situation i at the moment t gets into the situation j as the result of the transition. In aviation normalizing documents related to flight safety, five types of flight situations are distinguished – from normal to catastrophic one (E_1, E_2, E_3, E_4, E_5).

Conditional probabilities $Q_{i,j}$ of transition from a given situation into a more dangerous one are particular criteria of a "danger". If we talk about a transition from a more dangerous situation into a less dangerous one, then the corresponding probability characterizes the level of a "stableness" of the system. The transitive probabilities $P_{i,j}$ are "integral" characteristics of safety and danger since they take into account a set of stimulating events, arising with probabilities $q_i(t)\Delta t$ at a set of conduct strategies of a system in special situations, through probabilities $Q_{i,j}$. The more the considerations of possible particular situations the more reliably the probabilities $P_{i,j}$ represent the system. If these probabilities are known, then generally accepted criteria of safety could be expressed through them as mathematical expectations:

$$K = \sum_i \sum_j C_{i,j} P_{i,j} \, ,$$

where $C_{i,j}$ – prices of losses.

Lets consider, for example, a case when $q_1(t)=q_1=\text{const}$; $q_i=0$ for $i \in [2, 3, 4, 5]$, $\sum_{j=1}^{5} Q_{i,j} = 1$; for $\forall\ i \in \overline{1, 4}$; $Q_{5,5}=1$ (catastrophic situation is the situation without a "way out").

The solution of equations by Kolomogorov has the view:

$P_{11}(t, t_1) = e^{-q_1(t-t_1)}$; $P_{15}(t, t_1) = 1 - e^{-q_1(t-t_1)}$; $Q_{11}=0$; $Q_{15}=1$; $P_{1j}=0$; for $j=2, 3, 4$; $P_{ii}=1$; for $i=2, 3, 4, 5$.

All other elements of the matrix P equal zero. The example has an illustration meaning as well as other examples.

If we suppose that $Q_{11} \neq 0$ and $Q_{15} \neq 1$ and if all probabilities Q_{1j} of the first line of the matrix Q do not equal zero, the solution has the view:

$$P_{1j}(t, t_1) = \frac{Q_{1j}}{1 - Q_{11}} \left(1 - e^{-q_1(1-Q_{11})(t-t_1)}\right)$$

We suggest taking into account the subjective factors in the next way. It is supposed that in each of the flight situations, there are a few alternative strategies $\sigma_{m,i}(t) \in S_{\sigma,i}(t)$ of a "conduct" of the system. Every time the event happens with the probability $q_i \Delta t$, the pilot analyses several possible variants (go around, continue landing, continue take off – stop, choose an emergency airport from a few available etc.) in accordance with disposable and required resources and other circumstances influencing making his decision.

$$\begin{array}{ccc} & q_i(t) & \\ \swarrow & \downarrow & \searrow \\ \sigma_{1i}(t) & \sigma_{2i}(t) & \sigma_{Li}(t) \end{array}$$

The transitive probability $Q_{i,j}(t)$ can be written as:

$$Q_{i,j}(t) = \sum_{m=1}^{L} P(\sigma_{m,i}(t) | i) Q_{i,j}(t | \sigma_{m,i}(t))$$

with the help of the formula of the total probability, where $P(\sigma_{m,i}(t)|i)$ – the probability that the pilot chooses the strategy $\sigma_{m,i}(t) \in S_{\sigma,i}(t)$, and $Q_{i,j}(t|\sigma_{m,i}(t))$ – the probability of the transition from the situation i into the situation j at the condition that the strategy $\sigma_{m,i}(t)$ has been chosen. The subjective factor can be taken into account by the way of replacing the probability $P(\sigma_{m,i}(t)|i)$ with functions of preferences $\pi(\sigma_{m,i}(t))$, normalized with a condition

$\sum_{m=1}^{L}\pi\left(\sigma_{m,i}(t)\right)=1$.

Then

$$Q_{i,j}(t)=\sum_{m=1}^{L}\pi\left(\sigma_{m,i}(t)\right)Q_{i,j}\left(t_1\middle|\sigma_{m,i}(t)\right).$$

A criterion for getting a model of $\pi\left(\sigma_{m,i}(t)\right)$ has the view:

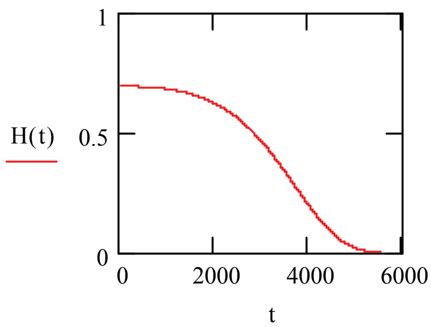
$$\Phi_{\pi_i}=-\sum_{m=1}^{L}\pi\left(\sigma_{m,i}(t)\right)\ln\pi\left(\sigma_{m,i}(t)\right)-\alpha_i R_{\sigma_i}+\beta\sum_{m=1}^{L}\pi\left(\sigma_{m,i}(t)\right),$$

where $R_{\sigma_i}=\sum_{m=1}^{L}\pi\left(\sigma_{m,i}(t)\right)C\left(\sigma_{m,i}(t)\right)$, and $C\left(\sigma_{m,i}(t)\right)$ – the "price" of losses, related to the choosing the strategy $\sigma_{m,i}(t)$, including evaluation the resource situation (feasibility study or extent of the strategy ability of being realized). The solution of the variation problem drives to the next formula:

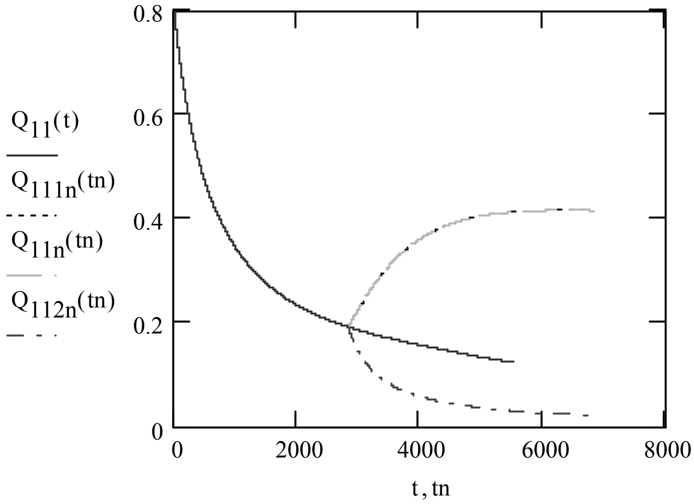
$$\pi\left(\sigma_{m,i}(t)\right)=\frac{e^{-\alpha C\left(\sigma_{m,i}(t)\right)}}{\sum_{j=1}^{N}e^{-\alpha C\left(\sigma_{m,j}(t)\right)}}.$$

The practical calculation for conditional values and two strategies preferred yields the entropy got by the formula:

$$H_\pi=-\sum_{m=1}^{L}\pi\left(\sigma_{m,i}(t)\right)\ln\pi\left(\sigma_{m,i}(t)\right).$$



Supposedly the pilot makes a decision to choose one of the strategies, more preferred, at the moment the entropy becomes less than H^* (for example, H^*=0.3), and he does choose it. It means the distribution of his preferences becomes a singular. Corresponding time is the next initial time. It has the corresponding values of the new set of initial conditions. Moreover the preference of the strategy chosen is $\pi_1(t)=1$ and the other is zero. Iterating the calculation process we get conditional and transitive probabilities changed due to one of the strategies chosen.



References

1. ***Эбелинг В., Энгель А., Файстель Р.*** **Физика процессов эволюции** (Синергетический подход). УРСС. М.: 2001. – 326 с.
2. ***Касьянов В.*** **Элементы субъективного анализа.** НАУ, Киев: 2003. – 224 с.
3. ***Стратонович Р.Л.*** **Теория информации.** М.: Сов. Радио, 1975. – 423 с.
4. ***V. Kasjanov, A. Goncharenko.*** **Modeling of technical and economical aspects of flight safety** // The World Congress "Aviation in the XXI-st Century" press-release. K, Ukraine: NAU, 2003. – P. 2.63-2.66.
5. ***Касьянов В.*** **Моделирование полета.** НАУ, Киев: 2004. – 397 с.
6. ***Безопасность*** **авиации.** Под ред Бабака В.П. К.: Техника, 2004. – 583 с.
7. ***Баруча-Рид А.Т.*** **Элементы Теории марковских процессов и их приложения.** М.: Наука, 1969. – 511 с. Bharucha-Reid A.T. Elements of the Theory of Markov Processes and their Application. New-York, 1960. McGraw-hill Book Comp., INC.

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THE REALIZATION SPECIALTIES OF COMPUTER TECHNOLOGIES IN PSYCHOPHYSIOLOGICAL RESEARCHES IN AVIATION

The main idea of the project consists in combination in one computer diagnostics complex of respondent's neuro-dynamic and personal characteristics with synchronic registration of emotional stress indexes for significant individual's stimulus material, with data processing with the help of authorial programs and mathematical statistics methods. There are no counterparts of such system in the world practice.

The suggested computer complex is foreseen to be used both for instant diagnosis and profound diagnosis and also for experts' teaching of special psychophysiological researches conducting in the vocational selection system. Data base accumulation with the help of worked out computer complex allows to update and substantially complement operators' job analyses and psychograms in general and the operators of aviation ergatic systems in particular. Test batteries standardization allows to boost the quality of special psychophisiological researches conducting, creates the conditions for complex estimating of psychological and psychophisiological operator's rates, enhance reliability, validity and informational content of vocational selection. In its turn, it will give the possibility to construct the typical psychological and psychophisiological operators' portraits according to the age, article and qualification. It is also foreseen that worked out three-stage system implementation using computer complex will facilitate reformation of vocational selection systems and boosting its effectiveness and reliability, will significantly decrease operators mistake risk in freelance situations and increase reliability of "human factor".

Structural scheme of computer complex for special psycophisiological researches conduction is given below. (fig. 1).

Methods and methodic, standardized by the author, that are used in computer complex for the conduction of special psycho-physiological investigations.

Table 1

#	Methods and methodic titles	Applicability levels (in accordance with T scale)										
		Low (0-39)				Medium (40-60)				High (61-90)		
		L	M	H		L	M	H		L	M	H
Indices of sensor motor coordination development												
1	Petrov's ruler –is the medium coefficient of difference threshold of visual perception		*			*				*		
2	Dynamometry – is the index of maximum effort	*					*				*	
3	Dynamometry – is the coefficient of perception of reflection precision of given efforts	*					*					*
4	Chronoreflexometry – is the coefficient of 10-sec. interval of perception precision	*					*					*
5	Chronoreflexometry – is the precision coefficient on the moving object reaction (3 modes)		*					*				*
6	Latent time of visual and motion reaction of tension		*				*			*		
7	Latent time of visual and motion reaction of relaxation		*				*			*		
8	Latent time of complex visual and motion reaction of choice		*				*			*		
9	Latent time of complex visual and motion reaction of sign transformation		*				*			*		
10	The number of mistakes while fulfilling complex visual and motion reaction of sign transformation		*			*				*		
11	The medium time of central delay in complex reaction of choice		*				*			*		
12	The medium time of central delay in complex reaction of sign transformation		*				*			*		

Indices of cognitive processes development												
Attention												
13	Attention volume (Gorbov's tables)		*				*					*
14	Attention switch rate (black and red Gorobov – Shulte table	*					*			*		
15	Coefficient of attention precision		*					*				*
Analysis and synthesis of mental activity parameters (3x5 V. Pushkin modification change)												
16	Medium time, spent on test 3x5conduction		*				*			*		
17	Medium quantity of steps while conducting 3x5 test		*			*				*		
Memory analysis parameters based on three lines of simple numbers by V. Rozhdestvenska												
18	Number of sums in the 1st series		*				*					
19	Time spent on summation in the 1st series		*				*					
20	Average time spent on one summation in the 1st series		*				*				*	
21	Average time of one digit uttering		*				*				*	
22	Time spent on one simple summation		*				*			*		
23	Number of sums in the 2nd series		*					*				
24	Time spent on summation in the 2nd series		*				*					
25	Average time spent on one summation in the 2nd series		*				*					
26	Coefficient of initial relative efficiency		*				*					
27	Coefficient of final relative efficiency		*				*					
28	Coefficient of average relative efficiency		*				*				*	
29	Comparative efficiency index		*				*				*	
30	Weighted proportional coefficient		*				*					
31	Relative number of sums executed in the 1st series		*				*					
32	Relative number of sums executed in the 2nd series		*					*				
33	Average ratio of the number of sums executed in the 1st series through the 2nd series.		*				*					

Table 1 continued

	Individual, typological and personal characteristics											
	Quiz by Isank											
34	Extraversion-intraversion	*					*				*	
35	Neurotica		*			*				*		
36	Lie corrections scale		*			*				*		
	Quiz for temperament research by Strelau											
37	Force of excitation processes		*				*				*	
38	Force of inhibition processes		*				*				*	
39	Motility of nervous processes		*				*				*	
40	Balance of nervous processes by the force of excitation		*			*				*		
	Tapping-test (modified by O. Rodionov)											
41	Index of the nervous system tolerance (force quality)		*				*					
42	Index of the nervous system lability		*					*				
43	Nervous system motility		*					*				
44	Equilibrium		*					*				
	Quiz by Leongard-Shmishek											
45	Hyperthymia		*				*				*	
46	Sticking		*			*				*		
47	Emotivity		*				*				*	
48	Pedantry	*					*					
49	Anxiety		*				*			*		
50	Cyclothymia		*				*				*	
51	Emphatity		*				*				*	
52	Excitability		*				*				*	
53	Dysthymia	*				*				*		
54	Exaltation		*				*				*	
	Quiz by Terstone (temperaments' scale)											
55	Activity		*				*					
56	Physical activity		*				*					
57	Impetuosity		*			*				*		
58	Leadership	*					*				*	
59	Equilibrium		*				*					
60	Sociability	*					*				*	
61	Reflexivity		*				*					
	Motivation characteristics											
	Quiz of the educational activity motives by M. Alexeyeva											
62	Ideological and political	*					*				*	
63	Cognitive		*					*				
64	Practical and profession-oriented		*				*					
65	Social prestige		*				*					
66	Sociable	*					*				*	
67	Self-education	*						*				
68	Intensification (secondary in respect of education)		*				*				*	
69	Utilitarian		*				*				*	

Table 1 continued

Quiz for estimation of the cognitive motives maturity by I.Zhadan and O. Malkhazov												
70	Being oriented at the process of education, its content and result		*					*				
71	Being oriented at acquirement of the methods of educational operations		*				*					
72	Being oriented at acquirement of the generalized operational methods	*					*					

Note: * – we specified the index level when characterizing person's ability to act as an ATC controller. Ability level to function as a controller and indexes which are used to characterize them are discovered by the author by means of the expert quiz of 30 professional ATC controllers. Concordation coefficient is equal to 0.75. Methods included into the test battery and their keys may be obtained from the author at the specialized seminar, which program stipulates for training on their use and interpretation. We also developed computer-based standardized methods (MMPI, male and female options with 123 additional scales). To increase the reliability, validity and self-descriptiveness of proposed psychometric methods (quizzes) synchronously with the quizzee's response the quizzee is taken his galvanic skin response and voice modulations. All showings are computed by the authors statistics program in automatic mode and displayed as tables and diagrams according to experimenter's desire. We offer computer-based complex for carrying-out special psychophysical research enables the researcher or customer to download new tests and standardize them. Unit of multi-channel logger of emotional tension enables to carry out screening tests in polygraph quiz mode.

The test battery we offer is a basic one. Number of tests and parameters examined can be changed in accordance with customer's request, though in the test battery there must be 2-3 instrumental tests, 2-3 quizzes with corrections scale or internal reliability scale, and 2-3 projective methods. In the case of adding a new test to the offered battery, it should be standardized regarding the battery; that test should be checked for reliability, validity, self-descriptiveness using dispersing, regression, correlation, cluster, and factor analysis of the whole data array.

We believe that selection of this kind of test battery enables researcher to determine the psychological and psychophysical profile of the personality, to develop more correct personal and professional psychogram. This also increases quality of correction work and psychological support i.e. improves efficiency of psychologist's work in the field of psychological support of professional selection, training and professional activities of air crews and air traffic controllers of civil aviation by all directions of their work. The complex we offer may be of interest of scientists, professors of psychology, teaching staff of the continuing education institutes, all establishments dealing with professional selection in any field of economical or administrative activity in Ukraine.

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DEVELOPMENT OF AVIATION ENGLISH TEST FOR AIR TRAFFIC CONTROLLERS

Development of Aviation English test for Air Traffic Controllers is a crucial issue. A key point of the quality test provision is to meet multifaceted and strict requirements to its design and implementation. They are identified by the profession specificity and the international standards approved for the English language level of Air Traffic Controller, as well as by the qualities demanded for the high stake tests.

Aviation English test (AET) development should be considered as a comprehensive procedure based on a relevant approach to evaluation. It is of great importance that this approach should reflect approaches to ESP teaching and learning, namely communicative approach and learner-centered approach. Therefore, tests should be recognized for the important role they play in the teaching-learning process.

The communicative approach to testing allows to simulate real life situations within the test environment. Communicative language tests are tests of communicative skills, typically used in contradistinction to tests of grammatical knowledge. Such tests often claim to operationalize theories of communicative competence, also the form they take will depend on which dimensions they choose to emphasize, be it specificity of context (AE for Air Traffic Controllers), authenticity of materials or the simulation of real-life performance.

The reflection of a learner-centered approach AE test development would provide better measurement of a learner EL competence. Competency-based assessment in AE teaching means an approach to assessment which places primary emphasis on the competencies needed by an Air Traffic Controller to perform a particular job adequately. In the teaching and assessment of language, the focus is on the intended outcomes of language training, that is, the sorts of tasks an Air Traffic Controller is expected to deal with in the target (non-standard) situation.

Thus, the AET should take into account specific learning needs (in our case those of Air Traffic Controllers). These specific needs are identified by the ICAO levels of EL competence required for Air Traffic Controllers licensing.

Such assessment is necessarily criterion-referenced. The main difficulty in assessing language within such a framework is in defining what the necessary skills or competencies are and in establishing mastery levels, particularly where language skills are not only one contributing factor in success (occupational knowledge and personal qualities being other relevant skills). This fact could be one of the reasons why ICAO scale offer requirements in general English. Then there is a question: how much the AE test based on this scale will be a reliable tool to measure an Air Traffic Controller's EL competence to fulfill specific job tasks in target situations? The latter will require knowledge of the subject. Therefore the test will measure integrated language and professional skills. This may lead to reducing both test validity and test reliability. To keep them at the proper level one should care of the relevant balance between a/ complexity of subject knowledge and b/ language skills required to go through the test tasks.

Any language teaching course has certain evaluation requirements, but in EA course these requirements are brought sharply into focus by the fact that this course has specified objectives identified by ICAO descriptors. EL for Air Traffic Controllers, as any other ESP, is accountable teaching. Air Traffic Controllers and sponsors are investors in the AE course and they want to see a return of their investment of time and/or money. This accountability has produced a demand for more and better evaluation procedures.

In spite of the importance, noted above, which AE course should logically give to assessment of student performance, there is a lack of discussion or guidance AE (or any other ESP) testing. The authors as a rule lay down highly detailed procedures for the specification of learning objectives, and make no mention of HOW these objectives might be tested.

In the EL course for Air Traffic Controllers, provided by AEROLINGUA, there are three basic types of assessment:

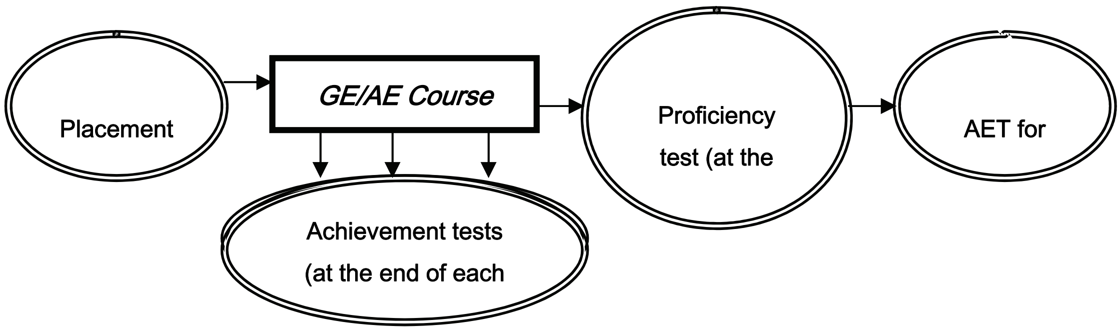
1/ *Placement tests*. These are used to place learners in the course most suited to their needs. The placement test comes before the course begins.

2/ *Achievement tests*. These test how well the learner is keeping up with the syllabus and can be administered any time through the course.

3/ *Proficiency tests*. These assess whether or not the student (Air Traffic Controllers) can cope with the demands of a particular non-standard situation, which may require appropriate level of skills to use general English within the ground-to-air communication.

In addition, all three types of tests can be used as diagnostic tests to determine the areas of weakness a particular learner may have. This diagnostic evidence can then be used as a means of determining what and how much tuition the learner needs.

All the above mentioned types of tests are used within the EL/AE course provided by the AEROLINGUA Training Center. Each of the tests is placed at the definite intervals which are the best to serve the testees needs (see the Scheme below).



Scheme 1. Place of testing within the EL course.

<u>Note:</u> GE – General English; AE – Aviation English; AET –Aviation English Test; ATCO – Air Traffic Controllers.

All the tests fulfill the peculiar function relevant to the objectives of both teaching and evaluation.

PLACEMENT TEST

The aim of the placement test (see a sample format in the table 1 below) is to determine the learner's state of knowledge before the EL course starts. The test results should indicate what form of course the learner should take. In the first instance, therefore, the placement test is a proficiency test. In its second function, the placement test is diagnostic, indicating how far and in what ways the learner falls short of the proficiency level. In this respect the test has a formative value – the test results can be used in forming the nature and content of AE course that the Air Traffic Controllers will take.

What should be borne in mind is that any placement test can only be approximate guide and should be treated with due caution. The good placement test should also reveal positive factors. It should show not just what the learner lacks, but also what potential for learning can be exploited in the AE course.

Table 1.
SAMPLE format of the placement test developed by AEROLINGUA

A.
The placement test consists of three sections:
Section 1 - Listening Comprehension /20 items/ - 20 min.
Section 2 - Vocabulary and Grammar /100 items/ - 60 min.
Section 3 - Reading /10 items/ - 20 min.
The third section is an option. It can be used to get more details at the start point
in order to obtain more homogeneity in groups.[1]
B.
This is a pencil-end-paper test.
The total number of items – 130
The total sitting time – 1 hour 40 min.
C.
The weighting of the test items:
Listening Comprehension – 2 scores per item;
Vocabulary and Grammar – 0.5 score per item;
Reading – 1 score per item.
D.
The scoring scheme:
Listening Comprehension maximum score – 40;[2]
Vocabulary and Grammar maximum score – 50;
Reading maximum score – 10;
Total SCORE – 100.
E.
The distribution of the scores in relation to the standard levels of EL knowledge:
Score 0-40; group: (zero) beginners
Score 41-60; group: elementary
Score 61-80; group: pre-intermediate
Score 81-90; group: intermediate
Score 91 -100; group: upper intermediate

The academic groups are formed according to the scale on the base of the scores obtained (see the part E in the sample format above).

ACHIEVEMENT TESTS

This kind of test is the least problematic, since it is usually internal to the course. The achievement test is, however, the kind of test the AE teacher is most likely to have to construct. In constructing a good AE achievement test one should follow the same basic principles as for constructing any test, namely:

[1] While composing groups of the UKSATSE personnel, UKSATSE internal test results were used in addition to the results of the AEROLINGUA placement test in order to obtain as much homogeneous student contingent as possible.
[2] If Reading Section is not included, Listening Comprehension Section is enlarged up to 25 items with a maximum score of 50.

1/ Test what is reasonably assumed the learners have learnt. This is not necessary the same what the have been taught.[3]

2/ Test should test what is actually wanted to be tested (high validity). For example, testing of comprehension ability should not be dependent on the ability to interact. A learner may well be able to comprehend, but unable to response properly to a stimulus heard.

3/ Bias in the test should be avoided. For example, the test items should not demand specialist subject knowledge or cultural knowledge. This is a problem with any kind of language test, but it is more apparent in AE tests, which may often involve the use of specialist content the important point is that getting a correct answer should not depend on specialist subject knowledge outside the material used in the text. [4]

For the Air Traffic Controllers it is also important to take into account ability of the personnel to stand stressful situations which can occur as non-standard ones. The stress caused by peculiar non-standard situations in real life, will definitely have an impact on the ability of Air Traffic Controllers to use EL properly. The stressful factor of non-standard situations should be considered while measuring the Air Traffic Controller level of EL knowledge in order to predict the degree of skills deterioration.

PROFICIENCY TESTS

Proficiency testing is identified as testing designed to assess whether candidates will be able to perform the language tasks required of them. Therefore, such tests are primarily criterion-referenced. In other words, the candidate's ability is assessed according to how far it matches the certain criteria judged to be essential for proficiency in a particular task. With criterion-referencing, there is no pass/fail distinction, but rather a scale of degrees of proficiency in the task. An example of such a scale is that used for ICAO levels of EL proficiency. The scale is used to assess the Air Traffic Controllers ability to use general English in non standard job situation.

The move towards proficiency testing fits very neatly with the concept of ESP, which crucially concerned with enabling learners to perform certain language tasks. Proficiency tests for specific purposes should be able to give reliable indication of whether a candidate is proficient enough to carry out the tasks that will be required at the work place. Such tests also have high face validity in that they look as if they are reliable indicators. An air traffic controller might well question the results of a test which, for example, assessed their proficiency in responding to a pilot's request on the basis of their ability to comprehend properly short dialogues. But a test which asked to respond directly to a pilot's replica would seem to be a valid indicator of the required proficiency.

Yet although specific language tests seem to be a logical extension of the ESP principle, they still remain problematic:

A. Proficiency tests are criterion-referenced. And therein lies a problem: what should the criteria be? Should they vary within different subject areas? What skills and knowledge enable someone to perform particular task? How specific are those skills

[3] In case with Air Traffic Controllers it is a different story. There is a tendency to standardize the content and methodology of teaching. But it is doubtful whether it is possible to standardize the learner's acquisition process, which is individual. In other words, what is taught may not be learnt.

[4] For example, in PELA test a testee should have strong subject knowledge in order to demonstrate good test results.

and that knowledge to any particular task? In spite of all the recent developments in our knowledge of language use, we still have to admit that we do not really know what makes communicative performance possible. This argument might be countered by having real-life tasks as tests. However, this is rarely possible to set up in practice and so still leaves us with the problem of determining what features are crucial to the real-life performance.

B. How specific is specific? Can PELA test adapted for ATCO (initially designed for future pilots) be, for example, a valid indicator for all branches of air traffic control? Until we know more about what enables a language user to perform particular communicative tasks at the work place, we must view proficiency tests as only approximate guides.

As it was already noted before evaluation can fulfill two functions – assessment and feedback. Assessment is a matter of measuring what the learners already know. But any assessment should also provide positive feedback to inform teachers and learners about what is still not known, thus providing important input to the content and methods of future work. Although used in the first instance to assess learner performance, the key to the development of a positive attitude to tests lies in recognizing and capitalizing on their feedback function, and playing down the obsessive or fearful attitudes engendered by reviewing tests exclusively as determiners of grades.

Given also the fact that AE learners are adults, there is no reason why the educational use of tests should not be taken a stage further, with learners becoming increasingly involved in providing feedback to themselves and their peers, and sharing in decisions about the most appropriate procedures for evaluating their progress. Such work can involve both useful realistic communication practice and deepen the learners' awareness of the learning process.

The AET development is related to proper understanding and applying the ICAO English language descriptors. There are other issues involved in establishing a testing solution in terms of 1/ security issues, 2/ administration, 3/ double-marking schemes, 4/ issue of certificates, 5/ dealing with appeals.

The AET is a high stake test since its results have an impact on Air Traffic Controllers' job licensing. Therefore it is obvious that the AET design should be based on the ICAO descriptors and in accordance to the test standardization requirements. For example, the ICAO descriptors will identify the test specifications, namely the test format, construct specificity, expected responses, scheme of scoring and criterion-referenced rating scale, pass rates, etc. The AET standardization will enable to get a quality product. To meet the requirements of test standardization the AET should be evaluated at least in respect of its validity reliability and practicality. For example, in order to have proper AET validity, the test should include at least three parts aimed at measuring ability of a testee to interact successfully coping with the tasks in target professional situations. These parts should be Comprehension of short dialogues, Interaction in the format of radiotelephony and face-to-face interaction.

Conclusion:

AET development for the Air Traffic Controllers is a complicated as well as a complex task. To solve the task effectively the following main points should be targeted: a/specific air traffic control situations which may cause stress and confusion of the personnel; b/precise understanding of ICAO requirements as well as ICAO descriptors as a base for assessment;

c/standardization of the AET and the procedure of scoring; d/training and certification of test designers, administrators, interlocutors, invigilators and raters; e/place of the AET in the testing system as an integrate part of the teaching-learning process.

References:

1. Studies in language Testing. Dictionary of language testing / by Alan Devies, Annie Brown, Cathie Elder, et al. – UCLES, Cambridge University Press, 1999. – 270 p.
2. English for Specific Purposes / by Tom Hutchinson & Alan waters. – Cambridge University Press, 1987. – P.p. 144 – 157.
3. Петращук О.П. Тестовий контроль у навчанні іноземної мови в середній загальноосвітній школі. – Київ, 1999. – 260 с.

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ICAO STANDARDS AND RECOMMENDED PRACTICES CONCERNING LANGUAGE PROFICIENCY REQUIREMENTS.

The paper is devoted to some aspects of the implementation of ICAO English Language Proficiency requirements for aviation specialists

Background to strengthened ICAO language proficiency requirements

In three accidents (one collision on the ground, one accident involving fuel exhaustion and one controlled flight into terrain), over 800 people lost their lives. What these seemingly different types of accidents had in common was that, in each one, accident investigators found that insufficient English language proficiency on the part of the flight crew or a controller had played a contributing role in the chain of events leading to the accident. In addition to these high-profile accidents, multiple incidents and near misses as a result of language problems are reported annually, instigating a review of communication procedures and standards worldwide.

Concern over the role of language in these and other aviation accidents and incidents has been expressed from several quarters. Data obtained from the ICAO Accident/Incident Data Reporting System (ADREP) database, the United States' National Transportation and Safety Board reports, and the United Kingdom's Mandatory Occurrence Reporting Systems corroborate that the role of language in accidents and incidents is significant. A number of other fatal and non-fatal accidents appear in the ICAO ADREP which cite "language barrier" as a factor. Additionally, the United Kingdom's Mandatory Occurrence Reporting Systems cite 134 language-related problems in fewer than six years.

Such concern heightened after a 1996 mid-air collision in which 312 passengers and crew members were killed in yet another accident in which insufficient English language proficiency played a role.

In 1998, the ICAO Assembly, taking note of several accidents and incidents where the language proficiency of pilot and air traffic controller were causal or contributory factors, formulated Assembly Resolution A32-16 in which the ICAO Council was urged to direct the Air Navigation Commission to consider, with a high level of priority, the matter of English language proficiency and to complete the task of strengthening the relevant provisions of Annex 1 — Personnel Licensing and Annex 10 — Aeronautical Telecommunications, with a view to obligating Contracting States to take steps to ensure that air traffic control personnel and flight crews involved in flight operations in airspace where the use of the English language is required are proficient in conducting and comprehending radiotelephony communications in the English language.

Assembly Resolution A32-16

Concern over the role of language in airline accidents led to the 1998 ICAO Assembly Resolution A32-16, in which the ICAO Council was urged to direct the Air Navigation Commission to consider this matter with a high degree of priority, and complete the task of strengthening relevant ICAO provisions concerning language requirements, with a view to obligating Contracting States to take steps to ensure that air traffic control personnel and flight crews involved in flight operations in airspace where the use of the English language is required are proficient in conducting and comprehending radiotelephony communications in the English language.

Amendments to Annex 10 — *Aeronautical Telecommunications,* Volume II — *Communication Procedure's including those with PANS status* and the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444) regarding the harmonization of radiotelephony speech and improvement in the use of standard phraseology, in partial response to the task assigned, became applicable on 1 November 2001. The 33rd Session of the ICAO Assembly (Montreal, September/October 2001) noted that provisions related to language proficiency were being developed and considered that the objective should not be limited to the English language. To complete the assigned task, the Secretariat proposed amendments to the following Annexes and documents:

a) Annex 1 — Personnel Licensing;
b) Annex 6 — Operation of Aircraft;
c) Annex 10 — Aeronautical Telecommunications, Volume II — Communication Procedures including those with PANS status;
d) Annex 11 — *Air Traffic Services;* and;
e) Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc 4444).

The proposed amendments to Annexes 1, 6, 10 and 11 and to the PANS-ATM were adopted by the ICAO Council in March 2003.

ICAO Standards and Recommended Practices (SARPs) concerning Language Proficiency Requirements

2. The ICAO language proficiency requirements:
   a) strengthen the provisions related to language use in radiotelephony communications, both for the language of the station on the ground and, in airspace where it is required, for English, from the level of Recommendations to Standards;
   b) establish minimum skill level requirements for language proficiency for flight crews and air traffic controllers;
   c) introduce an ICAO language proficiency rating scale applicable to both native and non-native speakers;
   d) clarify the requirement for the use of both plain language and phraseologies;
   e) standardize on the use of ICAO phraseologies;
   f) recommend a testing schedule to demonstrate language proficiency; and
   g) provide for service provider oversight of personnel compliance.

3. Annex 10 SARPs clarify that ICAO phraseologies shall be used whenever possible.
4. Annex 1 SARPs describe how language should be used for radiotelephony communication.
5. The language proficiency requirements in Annex 1 apply equally to native and non-native speakers.
6. Pilots and controllers are required to demonstrate Operational Level 4 language proficiency in the use of both ICAO phraseology and plain language by 2008.
7. A Standard in Annex 1 stipulates recurrent testing for pilots and controllers who demonstrate language proficiency below Expert Level 6.
8. Annexes 6 and 11 stipulate service provider or airline oversight of personnel language proficiency.

Linguistic Awareness

1. The ICAO language proficiency requirements apply to native and non-native speakers alike.
2. The burden of improving radiotelephony communications should be shared by native and non-native speakers.

   a) States should ensure that their use of phraseologies aligns as closely as possible with ICAO standardized phraseologies.
   b) Pilots and controllers should be aware of the natural hazards of cross-cultural communication.
   c) Native and other expert users of English should refrain from the use of idioms, colloquialisms, and other jargon in radiotelephony communications and should modulate their rate of delivery.
   d) Native speakers must ensure that their variety of English is comprehensible to the international aeronautical community.
   e) Plain language should be specific, explicit, and direct.
   f) English-speaking organizations, airlines or training centres may wish to explore how they might provide cost-efficient English language learning opportunities to code share partners and other airlines at minimal cost.

Language Training and Radiotelephony Communications

1. An important first step in the establishment of efficient and cost-effective language learning programmes is the selection of appropriately and adequately qualified teachers.

a) Learning a language is a great deal more complex than the familiar use of our own native language in our daily lives often leads us to believe.
b) Language teaching is a professional activity that requires specialized training and is further distinguished from other teaching activities because of the unique nature of language learning: a complex blend of skill, knowledge and cultural awareness, combining physical components with mental and communicative processes.
c) A chart outlining appropriate qualifications for a language training and testing specialist is provided in this chapter.

2. Aeronautical subject matter experts (SME) should collaborate with language teachers to develop accurate and effective programmes.

a) The SME can ensure accurate and appropriate training content, and the language teacher can ensure that delivery focusses on language learning.

b) The task of *teaching* language classes or developing appropriate language learning materials should be guided by language teaching experts and material developers.

3. Flight crews and air traffic controllers need to acquire phraseologies, but aviation English training should not be limited to phraseologies.
4. Language proficiency is an intricate interplay of knowledge, skills, and competence, requiring much more than memorization of vocabulary items.
5. Many factors influence the language learning process. It is difficult to predict how long any particular individual will require to reach the ICAO Operational Level 4 proficiency; as a general rule 200 hours of language learning contact hours are required for *measurable* improvement. This number can be reduced by involvement in specific-purpose classes which focus solely on speaking and listening.

Linguistic research now makes it clear that there is no "form of speech" more suitable for human communication than natural language. Artificial languages — and there are many — have had little impact in any sphere even decades after their introduction. Computer-aided voice recognition and translation technologies remain unproven, especially in the context of the demand for reliability in aviation. As all other options fall short, natural language continues to be the most reliable and efficient form of human communication.

Although standardized ICAO phraseologies have been developed to cover many circumstances (essentially routine events, but also including some predictable emergencies or non-routine events), no set of phraseologies can fully describe all possible circumstances and responses. Aircraft are flown and controlled by humans, and human behaviour is infinitely variable; the need to communicate an infinite variety of circumstances or nuances will continue. Pilots and air traffic controllers need sufficient language proficiency to manage all of the potential requirements of communications, which can range from routine situations to circumstances not addressed by the limited phraseologies, as well as non-routine situations and outright emergencies. Human language is characterized, in part, by the ability to create new meanings and to use words in novel contexts, a creative and complex function of language which accommodates the complex and unpredictable nature of human interaction, even within the relatively constrained context of aviation communications. There is simply no more suitable form of speech than natural languages for human interactions. Attempts to delimit the scope of a language will always fail at some point, when the need to communicate a new and unexpected situation exceeds the resources of the artificially constrained language.

The ICAO language proficiency requirements cannot completely eliminate all sources of miscommunication in radiotelephony communications. Rather, the goal is to ensure, as far as possible, that all speakers have sufficient proficiency in the language used to negotiate for meaning, in order to handle non-routine situations. Communication errors will probably never be completely eliminated; however, compliance with the ICAO language proficiency requirements will enable speakers to more readily recognize errors and work towards the successful and safe resolution of misunderstandings.

The ICAO language proficiency requirements are:

- **strengthen** the requirement for English to be provided by air navigation service providers for international flights by upgrading it from the level of a Recommendation to that of a Standard (Annex 10);
- **establish** minimum skill level requirements for language proficiency for flight crews and air traffic controllers (Annex 1);

- **introduce** an ICAO language proficiency rating scale applicable to both native and non-native speakers (Annex 1);
- **clarify** the requirement for the use of both plain language and phraseologies (Annexes 1 and 10);
- **standardize** on the use of ICAO phraseologies (Annex 10);
- **recommend** a testing schedule to demonstrate language proficiency (Annex 1); and
- **provide** for service provider and operator oversight of personnel compliance (Annexes 6 and 11).

The language-related SARPs can be broadly categorized into three types: Annex 10 SARPs clarify which languages can be used for radiotelephony communications; Annex 1 SARPs establish proficiency skill level requirements as a licensing prerequisite; and Annexes 6 and 11 provide for service provider and operator responsibility.

The language requirements and scale were developed for use in assessing speaking and listening proficiency in the particular context of aviation communications. Specifically developed for aeronautical radiotelephony communications, they may find applicability in a wider context within aviation. The requirements were also developed for use in assessing language proficiency in a variety of languages, not just in the English language.

Proficient speakers shall communicate on common, concrete, and work-related topics with accuracy and clarity. Context is an important consideration in communications, and an individual's language proficiency may vary in different contexts. This holistic descriptor attempts to limit the domain of the communicative requirements to work-elated topics; that is, air traffic controllers and flight crew personnel are expected to be able to communicate about issues common to their field of workplace knowledge. At the same time, proficiency should not be limited to memorized phraseologies but should range across a relatively broad area of work-related communicative domains. Chapter 7 introduces *many* topics and domains appropriate to the work-related requirements of pilot and air traffic controller communications. It is not a complete and exhaustive list, however, but merely a guide to curriculum development, and the assessment of radiotelephony communications should *not* be limited solely to those topics.

Proficient speakers shall use appropriate communicative strategies to exchange messages and to recognize and resolve misunderstandings (e.g. to check, confirm, or clarify information) in a general or work-related context. Strategic competence has been identified by a number of linguists as an important part of what defines language proficiency or competency. One aspect of strategic competence important to air traffic controllers and flight crews is the ability to recognize and resolve potential misunderstandings, e.g. having strategies to check for comprehension in a meaningful way, such as asking for a read back. Equally important is the ability to rephrase or paraphrase a message when it is apparent that a message was not understood. Sometimes the phraseology "Say again" should be understood as a request for clarification rather than repetition. Air traffic controllers and flight crews should understand that silence does not always indicate comprehension. On the part of native-speaking air traffic controllers and flight crews, strategic awareness can include an appreciation of the threats presented by cross-cultural communications and a sensitivity to strategies to confirm comprehension.

ICAO RATING SCALE

The ICAO Rating Scale contained in the Attachment to Annex 1 delineates six levels of language proficiency ranging from Pre-elementary (Level 1) to Expert (Level 6) across six areas of linguistic description: pronunciation, structure, vocabulary, fluency, comprehension, and interactions. The number of levels was determined as sufficient to show adequate progression in developing language proficiency without exceeding the number of levels between which people are capable of making meaningful distinctions. It is not an "equal interval" scale; the amount of time required to progress between levels will vary, i.e. moving from Elementary Level 2 to Pre-operational Level 3 may take longer or more training than moving from Operational Level 4 to Extended Level 5.

There are essentially two types of language proficiency rating scales: those which use a "can do" approach and those which describe specific features of language use. The ICAO Rating Scale uses the latter approach and is in a form familiar to any professional language teaching or testing specialist (see Chapter 4, Language Training and Radiotelephony Communications, for a description of appropriate qualifications). Nonetheless, a list of language functions and communicative tasks common to controller and pilot communications is also provided as training support in other sections of this manual.

It is important to note that the Rating Scale does not refer to "native" or "native-like" proficiency, a philosophical decision that "native" speech should not be privileged in a global context. All participants in aeronautical radiotelephone communications must conform to the ICAO proficiency requirements, and there is no presupposition that first-language speakers necessarily conform. An additional reason for avoiding the use of the term "native" language or referring to a "native" speaker is because of the proven difficulty in defining just precisely what a native speaker is, a topic well covered in Jenkin's work. The term "native speaker" is essentially only useful when we are referring to monolingual speakers, that is, to those individuals who speak only one language. However, monolingualism is no longer the norm in the world at large. Bilingualism and multilingualism are conventional in many, if not most, nations and cultures. In a multilingual context, it can become difficult to clarify with precision what is or is not any one individual's native language because there may legitimately be more than one.

Raters can assume that the descriptors at one level presuppose any skill or feature described in the preceding level. That is, it is assumed that anyone awarded a particular rating level demonstrates proficiency better than the descriptors contained in each level below. Failure to comply with descriptors in one category in one level indicates that the next lower proficiency level should be awarded; i.e. a person's proficiency rating level is determined by the lowest rating level assigned in any particular category. This is essential because the Operational Level 4 descriptors are developed as the safest *minimum* proficiency skill level determined necessary for aeronautical radiotelephony communications. A lower score on any one feature indicates inadequate proficiency; for example, pilots with Operational Level 4 ratings in all areas except, say, pronunciation may not be understood by the air traffic controllers with whom they must communicate.

An individual must demonstrate proficiency at Level 4 in all categories in order to receive a Level 4 rating.

LINGUISTIC AWARENESS

This problem outlines some key features of language use and communication, highlighting some trigger points for miscommunication, and provides both techniques for improved cross-cultural communication in English between speakers of different native languages and a review of good radio techniques. An awareness of the dangers inherent in voice communications, particularly in cross-cultural communications, will assist native English-speaking air traffic controllers and pilots to more fully appreciate the challenges faced by speakers of English as a second language.

Most humans use language readily and usually successfully without much cognitive knowledge about the nature of language. Because language is mostly unselfconsciously used to accomplish daily tasks, not much thought is given to the actual complexity of language. David McMillan, in his graduate thesis "Miscommunications in Air Traffic Control", points out that the ease with which we use language(s) to communicate in our daily lives and the usual lack of serious consequences for miscommunication mask the fragility of human language as a vehicle for clear communications. The apparently simple use of language actually requires a sophisticated interaction of complex processes, and our usually successful daily experience with language belies its complexity. Breakdowns occur for any number of reasons, for example:

- two words may sound the same;
- there may be dramatic pronunciation differences, even among native speakers, which cause miscommunication;
- a speaker's message may be too indirect so that the intent is missed; or
- a speaker may have inadequate familiarity with the language and so is unable to communicate effectively.

In daily life, miscommunication occurs but rarely results in anything other than minor inconvenience, minor embarrassment, or lost time. In air traffic control communications, however, the stakes are dramatically higher and communication errors have the potential for far more serious consequences. Subsequent to an accident in 1977 where miscommunication was identified as a contributing factor, ICAO published changes to phraseologies and procedures based on lessons learned from an analysis of the communications prior to the accident. Nonetheless, miscommunication continues to occur decades later, as numerous incidents and a number of other high-profile accidents in the intervening years attest.

CONCURRENT NEED FOR CAREFUL USE OF PLAIN LANGUAGE

Although the careful use of ICAO phraseologies is one means to increased communication safety, no set of phraseologies, however extensive, can account for the breadth of human communicative need, even within the relatively constrained environment of air traffic control communications. In all those situations for which phraseologies cannot suffice, of urgency, emergency, or other non-routine but normal circumstances, controllers and pilots will use plain language. An example of a normal, non-urgent communication which would require plain language is given in this excerpt from an actual transcript, as two aircraft are descending towards the airfield: "Who's ahead? Us or the Air Europe?" In this case, there appear to be no ICAO phraseologies to cover this request for information. While ICAO phraseologies should always be used in the first instance, there will always be situations, some routine, for which phraseologies do not exist.

Clarity, conciseness, and correctness are goals of air traffic control communications. The purpose of phraseologies is to reduce the possibility for ambiguity and to facilitate efficiency. For all the many circumstances where phraseologies do not apply, the use of plain language should achieve the same goals as phraseology. Avoiding idioms whenever possible and being aware of the difficulty they may present help make plain language clearer. Overall, an awareness of the differences between jargon and idioms and of their sometimes useful but possibly complicating role in communications will help pilots and controllers communicate more safely across linguistic and cultural barriers.

CROSS-CULTURAL COMMUNICATION

There are a number of features of radiotelephony communication that make it particularly challenging to speakers of English as a foreign language. Firstly, many people consider communicating in another language quite stressful. Speaking a foreign language with a highly proficient or native speaker of the language can be an intimidating experience. Secondly, radiotelephony communication is absent of any visual clues, making communication even more difficult, since, in face-to-face communications, much is communicated through non-verbal channels, including body language and facial expression. Finally, some studies indicate that stress negatively affects language performance. Flying and controlling aeroplanes are, to some degree, inherently stressful activities. Consequently, flying or controlling an aeroplane while communicating across linguistic barriers on a radiotelephone, devoid of visual clues, brings a number of stress-inducing factors to the communication process.

In this context, if native speakers are simply aware of the challenges faced by speakers of English as a foreign language (EFL), they can take greater care in their speech. Native and highly proficient speakers can, for example, focus on keeping their intonation neutral and calm, admittedly difficult at busy control areas but a good strategy to calm the language anxiety of an EFL speaker. They can take particular care to be explicit, rather than indirect, in their communications and train themselves away from the use of jargon, slang, and idiomatic expressions. They can ask for readbacks and confirmation that their messages have been understood, and they can attend more carefully to readbacks in cross-cultural communication situations, taking greater care to avoid the pitfalls of "expectancy", a topic well covered in Human Factors literature. Additionally, a slower rate of delivery seems to make speech more comprehensible; therefore, taking care to moderate speech rate is a common sense approach to improving communications.

SUMMARY

Implementation of the ICAO language proficiency requirements cannot realistically completely eliminate all sources of miscommunication in radiotelephony communications. Rather, the goal is to ensure, as far as possible, that all speakers have sufficient proficiency in the language used to negotiate for meaning. While communication errors will probably never completely go away, disciplined use of ICAO phraseology, compliance with the ICAO language proficiency requirements, alert awareness of the potential pitfalls of language, and an understanding of the difficulties faced by non-native English speakers will enable pilots and controllers to more readily recognize communication errors and work around such errors.

References

1. ICAO Assembly resolution, A-3216, 1998
2. Personnel Licensing, Annex 1
3. Aeronautical telecommunication, Annex 10
4. Operation of Aircraft, Annex 6
5. Procedures for Air Navigation Services, Air Traffic Management, PANS-ATM, Doc 4444
6. IATA assessment methodology, 2005

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QUALITY MANAGEMENT IN THE CHEBOKSARY COOPERATIVE INSTITUTE

The paper uses a quality management framework to analyze quality management approaches that have been implemented in Cheboksary Cooperative Institute. The framework is comprised of three parameters, which are quality of design, quality of conformance and quality of performance. It turned out that only one of the nine articles that were examined dealt explicitly with quality of performance issues.

Most institutions have established systems of quality assurance and control, but of different degrees of complexity and effectiveness. In many countries, governments have felt the need to assure the quality of the awards granted by their institutions of higher education. The application of quality management principles, tools and techniques to solve industryrelated problems has been used very successfully. Quality management is widespread and heavily institutionalized in many companies; it is part of the organizational culture and dominates all aspects of the daily organizational activities of management and workers. In the technology and the automotive industries, quality is one of the primary drivers of competition. Higher education institutions in many countries began to adopt and apply quality management to academic problems and opportunities because of the success that was attributed to quality management in industry. Several universities in such countries like USA, UK, and Japan have developed unique quality management approaches for improving the quality of teaching, student life, academic programs, research and university operations. The problem stemmed from the lack of appropriate and existing comprehensive quality management models in higher education. The problem was so pervasive that it motivated the development of a comprehensive Total Quality Management (TQM) framework shown in Fig. 1.

The framework was used with some success at Cheboksary Cooperative Institute. The Cheboksary Cooperative Institute represents one of leading higher education establishments in Chuvashia. It is an educational and scientific centre for training experts in the field of economy and law.

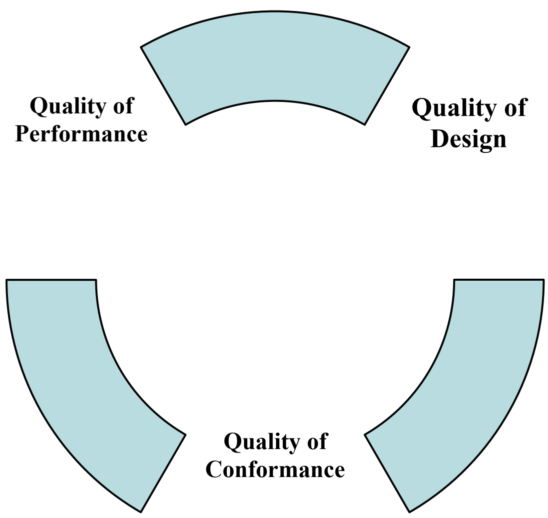

Figure 1. *Relationship between components of the model.*

Students receive training in nine fields to obtain higher education and seven for obtaining a postgraduate degree. Advanced training and preparatory courses are also available. The Institute is introducing a quality management system in accordance with The International Standards Organisation (ISO 9000). The Institute has developed a policy of quality in education and a Program of Development for the Institute. The system of continuous education is being improved. The staff of the Institute participates in various competitions held both by the State and Chuvash Republic authorities.

Institute Awards:

- Winner of the Chuvash Republic President Prize in the field of quality of education (2001)
- Winner of the competition "Systems and Ways for Providing Quality of Education" held by the Department of Education of Russia (2002)
- Winner of the international award "Crystal Knight" in the Branch Leader category (2003)
- The Institute also possesses the international gold certificate of quality.

The arrows in Fig. 1 indicate feedback mechanisms and continuous improvement. The model may be useful in helping colleges integrate quality into their daily operations, curriculum (both design and classroom teaching) and research. If we can illustrate how a relatively good TQM implementation may be improved then it will be obvious how to improve inferior plans. *Quality Management* is that aspect of the overall management function that determines and implements the quality policy.

Total Quality Management (*TQM*) is defined as the management philosophy and the organizational practices that aim to harness the human and material resources of an organization in the most effective way to achieve the objectives of the organization.

There are many management theories and postulations. Management as a continuous process through which members of an organization seek to coordinate their activities and utilize their resources in order to fulfill the various tasks of the organization as efficiently as possible. The function of management is the process of achieving organization goals. There are generally four areas managers need to consider, these are: planning, organizing, leading and controlling. It is essential that any system of quality assurance and control consider these functions to ensure procedures take into consideration the role of managers and employees in all aspects of the four functions summarized above.

There is a great deal of research that advocates the role of leadership in successful management of change. The management of change is to some extent a misleading phrase in that it has been used in a number of different contexts and with a variety of different emphases. Success of any change program depends on leadership quality. Leadership is the most important function of management in instigating and implementing change. We believe that the problem is not the programs for change, but that evidence suggests that the burden of change usually rests on so few people. We believe in the involvement of everybody in the organization.

The basic parameters of quality management can be grouped into three areas: quality of design (QD); quality of conformance (QC) and quality of performance (QP).

QD deals with determining the characteristics of a good education in a given market segment at a given cost. For example, we can compare the quality of education among higher schools.

QC deals with how well the design requirements (i.e. the education ideals of a university) are satisfied, including the cost requirement (uniformity and dependability). For example, it is well known that Moscow University prepares its students to become political and business leaders. QP deals with how well the education serves the student in his/her environment. It is a measure of the value that students derive from their education. QP measures include the level of endowment, tuition revenues, student enrollment, salaries of new students and career advancement.

The three parameters of the model are interrelated. For example, low QP may lead to changes in the QD or QC. Similarly, low QC may require better quality control techniques or changes in the design stage. The parameters of the model were chosen because they are often used in quality practices and the model itself has been used in several industries.

In addition, the three components collectively represent a comprehensive approach to quality management. Quality management implementation should always address design, conformance and performance. The building blocks of our model have their roots in two well-known quality management models. The first is "Juran's Triology", developed by Juran, and the other is plan-do-check-act (PDCA), by Deming. Our model was also used to implement TQM at Cheboksary Cooperative Institute.

Juran's model has three components:

· *Quality planning*, which corresponds to "quality of design".
· *Quality control*, which is "quality of conformance".
· *Quality improvement* refers to "quality of performance".

For Deming' s four-stage PDCA model, plan and do correspond to "quality of design", check corresponds to "quality of conformance" and act corresponds to "quality of performance".

Table 1 shows the connection between Juran's model, Deming's PDCA model and our model.

Quality improvement is directly related to quality of performance. By valuating the quality of performance we determine how well the product performs in the marketplace. Poor quality of performance suggests that quality of design or quality of conformance or both were not satisfied.

Table 1

Connection between Juran, Deming and proposed model

Juran	Deming	Our model
Quality planning	Plan, do	Design
Quality control	Check	Conformance
Quality improvement	Act	Performance

The importance of our quality model should be interested because it helps higher institutes to focus on the three important parameters of quality, including the most challenging part that is the QP. Despite the challenge, external data are required to determine the ultimate test of the QD and QC of products and services. All three components of quality should be considered equally important because the success of products is dependent on the QD, QC and QP. Therefore, it is strongly advised that future implementations of quality management in higher education should consider gathering external QP data. The planning for the data gathering should be done *a priori* and the appropriate measuring instruments and systems should be developed. Data gathering problems identified in the planning stage may force changes in the design and conformance stages. It is ill-advised to design a product whose success cannot be measured effectively.

To help with future implementations of QP in education we identify several examples of external data. They include the following: performance on standardized tests; employer assessment of graduate performance; entry-level salary of graduates; employment rate of graduates; ranking and reputation of the school by external sources; increase of the student population; and the quality of incoming students. This list is not intended to be comprehensive but to identify some possible examples.

The university could have addressed QP by undertaking a follow-up study to measure the effect of the changes. This could have been accomplished by sending a survey to alumni and current students. This would have provided valuable feedback to the university on the effectiveness of the improvement measures that were undertaken.

Since it was also mentioned that the university was in financial crisis, looking at the financial measures after the changes were implemented could have been another approach for implementing QP.

The importance of performance data gathering must be stressed because it is a critical dimension of quality management that indicates how well a product is performing relative to the competition. It determines how well the designers have achieved their design and conformance objectives. Feedback gathered from customers may be used to identify problems of design and conformance.

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CONTINUING EDUCATION IN RUSSIA AND THE USA

The article says about the organization of continuing education in Russia and the USA and the role of the government in this part of education. There is a proposal that the state recognition of educational institutions of continuing education should be introduced.

Russia

Continuing education in Russia is officially called Additional Professional Education. At present the government is going to liberalize this part of education. According to the Bill "About introduction of alterations to Russian Federation Law "On Education" in the part of additional professional education that was prepared by the government, it is supposed that the state, practically, will fully leave this sector of education. It is impossible at the present stage of economical development of Russia, in particular. The government must establish control over educational trends, related to security of people, society and state. It should also encourage continuing education, in particular, the part of the working population, employees, funding to training their personnel, and educational institutions, working in this sector.

Positive about the proposed Bill is the enlargement of the list of organizations realizing the programmes of additional professional education. But we should go further. It is necessary to allow everybody who wants and can teach something, to be on this market. Licenses should be cancelled for educational institutions of additional professional education. It is necessary to license programmes, not educational institutions, and what is more only the programmes, requiring the government control. They are further training programmes as well as programmes related to security of people, society and state (for example, medicine, accident prevention, labour protection etc.). These programmes must be licensed regardless of their volume. The government must grant licenses on these programmes to run classes.

Instruction without a license must be prosecuted. At the moment instruction is allowed on the programmes with the volume under 72 hours.

Educational management bodies must license only the programmes on further training, other programmes must be licensed by the government body of related type.

To increase the access to additional professional education for employees and employers, no taxes must be charged for tuition fees and must be related to production costs and services regardless the place it is carried out. Employers and employees must determine themselves where and what to study regardless the pressure from the government.

Educational institutions need tax and other privileges to provide educational services and be profitable, so that the business is invested and besides there won't be decrease of access to additional professional education. But not all of them are necessarily to be given these privileges, but only those related to some criteria.

The main criterion now is the correspondence between the programmes and fixed standards, that is determined by the state certification and is fixed by the government accreditation. Most programmes don't need standards and they are even harmful to additional professional education. The programmes are very dynamic and very often they are designed for a concrete customer. Standards must be fixed therefore only for further training programmes and for some programmes on the trends, stipulating license.

In the overwhelming majority of educational institutions the programmes, having standards will be lacking or make a small part of their job. These educational institutions won't be able to get the state accreditation according to the proposed Bill. And it is correct. It is necessary then to introduce a concept and a procedure of the two level recognition (Federal and Federal subject). Those who have got the state recognition, get federal or/and regional privileges correspondingly. Regarding privileges the state recognition must be equivalent to the state accreditation.

A recognition procedure may be similar to the degree awarding procedure. Special committees are formed in the provinces, their complements being confirmed by the Central body that confirms as well recognition, examining selectively the work of the committees. The committees examine educational institutions and give recommendations to the Central body.

Though there should be some criteria of recognition such as during the defence of a dissertation, the decision will be formed out under the impression made by the educational institutions on the members of the committee. Professional and public accreditation of the programmes will be taken into consideration while making a decision and if an educational institution has accredited the majority of the programmes, it may become decisive.

The same procedure may take place while recognized by the Federal subject.

The USA

The major kinds of continuing education in the United States are:

1. Professional development. This is work related continuing education for workers in a wide variety of occupation, from lawyers to factory workers. There are about 30 professions where continuing education is required by law, for example, medical professions, law and real estate.

2. Personal development. This is leisure or hobby continuing education for people of all ages. The subjects range from learning how to play sports, to learning how to knit, to learning the history of Greece.

3. Business training. This is training related where the company owner or business brings an educational programme to the business and workers take the class. The content is almost always related to the business and training of the workers.

Who offers continuing education?

A wide variety of institutions offer continuing education. They include:

- Colleges and universities
- Public schools
- Associations
- Recreation departments
- Museums
- Private for-profit companies
- Hospitals, governments, churches, consultants, shops and many more.

Funding

Almost all continuing education is paid for by individual learner taking the class. Business and corporations also spend training their workers, but may do not. There is almost no funding from the government. Most government funds are for teaching adults literacy (how to read) and graduate from high school. There are limited government funds to train workers.

Formats for learning

Here are some formats for continuing education.

1. Certificate programmes.
   This is a popular and growing format. This is a professional development where there are 3-5 courses each students takes. After completing all the courses, the individual gets a certificate (a piece of paper) saying the student has certain skills. It is voluntary and it is not regulated by the government. It has nothing to do with the state or government.

2. Certification programmes.
   This is like the certificate programme, only the student takes a test at the end providing she or he has the knowledge skills. These programmes are offered by associations for their own occupation or profession. After passing the exam, the person gets initials after their name. For example, I am a Certified Association Executive (CAE) meaning I have passed the exam for managing an association. Any organization can offer such initials. Permission or recognition of the government is not required. Recognition comes from the respect of the students or customers, not from the government.
   For the provider, usually an association, these programmes are very profitable, making about a 50% profit.

3. Summer camps.
   Summer camps are week long programs for children, usually aged 10-16. Sometimes they are for two weeks. Some camps are at actual camps. Other camps are located at a college or a local building. Sometimes children stay overnight. Sometimes children go home every day.
   Summer camps have a theme. Art camps are popular. There are theatre camps, writing camps and more.
   Providers of summer camps include recreation departments, schools and colleges. Summer camps are very profitable and popular. They are making about 40% profit.

4. One night classes.
   One night classes last from two to three (2-3) hours. They are given only once, usually in the evening. Most of the subjects are personal development, hobbies and other non-job related topics.
   The classes are usually fun and people take them for their own interest.

5. Evening courses.
   Evening courses are offered once a week for 4-16 weeks. Some subjects are professional development or work related. Other courses are for personal development.

6. <u>Online courses.</u>
   Online courses are courses taught over Internet. This format is growing in popularity. Many of the subjects are work related. There are also personal interest courses offered over the Internet.
   Usually one company produces all the courses, and local organizations promote the online courses in their community.
7. <u>Contract training.</u>
   A provider brings the instructor to the business or company. The company sends as many employees to the training as the company wants. The company may pay just one fee and can send as many employees as it wants. Or the company may pay a fee for each person.

8. <u>Credit courses.</u>
   Colleges and universities offer credit courses for college credit. Some courses are offered on weekends.
   The course fees are usually high, and students get credit towards a Masters degree.

Most continuing education classes are profitable. Some are very profitable. Most organizations are nonprofit tax exempt and do not have to pay corporate income taxes to the government.

Who teaches the courses

Most of the instructors are professionals who are not professors. The instructors have jobs in other occupations and teach part time. They do not need credentials or a license to teach continuing education courses. Most students prefer instructors who are not professors, as these instructors have more practical experience and expertise in the work world.

Any organization can run continuing education classes. No licenses are required. Sometimes an organization has to get approval from a voluntary association to have their education accepted by that professional body.

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IATA - TRAINING TRENDS FOR AVIATION SPECIALISTS

The article deals with the history and structure of the IATA Training and development Institute in Canada. The author describes all the methods and aids used in the Institute as well as new trends and prospects.

Investing in human capital can reap benefits not only for employees, but also for the organisations that employ them. In today's rapidly changing air transport environment, companies with the best opportunity to succeed and prosper are those that nurture training.

Considering the industry's high turnover rate, professional training can help your staff cope with a host of complex and unrelenting challenges such as privatisation, restructuring, cost reductions, new technologies and customer expectations.

IATA Training & Development Institute

IATA has been delivering aviation training to aviation managers and staff for more than 20 years.

The IATA Training & Development Institute (ITDI) was formed in 1999 by combining the IATA Learning Centre, which started delivering aviation training services on behalf of IATA in the early 1980s, with the International Aviation Management Training Institute, active in the same field since 1987.

The mission of ITDI is to develop and deliver a wide range of progressive training solutions that promote leadership, commercial success and good governance in the aviation and transportation industry. The Institute is the world's only international aviation training centre, covering the training and development needs of five of the major industry segments: airlines, airports, civil aviation, cargo and travel and tourism.

Developing practical skills aviation professionals can apply to complex situations is a unique focus that sets ITDI apart from other training institutions. It focuses on developing learning methods that are best suited to the needs of its clients such as:

- **Classroom training**
  Delivered by highly qualified international experts from carriers, shippers, airports, infrastructure suppliers and civil aviation authorities.
- **Customised (in-company) training**
  Unbiased and fully confidential training that is adapted to meet customers' specific needs and challenges. All IATA courses in the fields of strategic management, marketing, finance, law, operations, technical services, safety and security are tailored to the customer's business strategy and culture and delivered in the company's own work environment.
- **Distance learning and e-Learning**
  IATA has developed a series of courses that allow individuals to study when and where it is most convenient for them. Students can complete training programmes independently or join classes offered in their area by independent IATA-authorised schools.

In 2004, more than 5,500 participants attended more than 200 classroom courses at IATA's training centres in Beijing, Geneva, Miami, Montreal and Singapore, plus affiliated training centers in Amman, Johannesburg and Moscow, as well as regional and in-company training programmes delivered worldwide.

This year, ITDI conducted courses in the Ukraine on Airline Commercial Challenges and Regulatory Issues, hosted by Ukraine International Airlines, and a Senior Civil Aviation seminar, hosted by Aerosvit and the State Aviation Administration of Ukraine. The training was sponsored by the International Airline Training Fund (IATF), an independent not-for-profit foundation, established by IATA in 1984 to enhance the knowledge and skills of employees of IATA Member airlines in developing countries.

Training Trends

Distance learning

Distance learning is quickly "becoming an accepted and indispensable part of the mainstream of educational systems in both developed and developing countries, with particular emphasis for the latter," said a 2002 report issued by the United Nations Educational, Scientific and Cultural Organization (UNESCO). This type of learning has existed for about 100 years in the world's developed countries but only for one or two generations in the developing regions.

Substantial prospects exist for distance learning to educate and train the highly populated developing countries due to barriers like lack of infrastructure and professional proficiency determined the report entitled, "Open and Distance Learning: Trends, Policy and Considerations." The costs are also lower for this type of instruction compared to the capital investments required by conventional institutions where economies of scale are a critical factor.

This year, ITDI conducted a survey to determine what topics of interest would enhance the Institute's distance learning curriculum. Respondents indicated that the most preferred course for distance learning in the Airline sector was Quality Management in Airline operations. The highest ranked course in the Airport segment was Commercial Management, while Safety Management Systems was the top ranked Civil Aviation course.

In 2004, over 21,000 students enrolled in IATA Distance Learning programmes in airlines, cargo and travel and tourism. The total number of IATA/UFTAA Authorised Training Schools now number 240 with 41 IATA/FIATA Schools.

E-learning

According to the 2004 report issued by the American Society for Training & Development (ASTI), the world's largest association dedicated to workplace learning, the use of technology is on the rise. Training delivery via learning technologies increased 23.6% in 2003, up from 15.4% in 2002.

More than half of technology-based delivery was on-line in 2003 and 2004, the report said, and at least 75 percent of on-line learning was self-paced.

The greatest growth is in rapid e-learning, according to a report issued in May by Bersin & Associates, a U.S. research and advisory firm. This type of web training is created in a matter of weeks by subject matter experts based on PowerPoint presentations and other internal documentation.

Driving this growth, the report said, is the demand for faster deployment of tactical training and the need to use subject matter experts more efficiently in training initiatives.

Rapid e-learning, which accounts for more than one-third of all current training projects, is expected to be deployed for nearly half of all e-learning initiatives within the next three years.

Best suited for e-learning is the broadcast of information or the transfer of critical knowledge, the report indicated.

A 2003 study commissioned by the IATA Training & Development Institute supports this finding. The main objective of the study was to identify and rank the training priorities of various organisations within the industry by first identifying overall training priorities then determining which of these priorities were best suited to an e-learning context.

Respondents indicated Security Awareness, Airline Passenger Services and Dangerous Goods regulations and awareness were better suited to the Internet, with Travel and Tourism and Airline Operations the segments with the highest potential for e-learning.
Topics less suited for e-learning involved human relations and interaction.

ITDI currently offers the following e-learning courses:

- Basic Airside Safety
- Dangerous Good Awareness
- Aviation Security Awareness

Though e-learning and distance learning are now mainstream, most executives still provide 30–60% of their learning in a classroom setting, according to *Chief Learning Officer* magazine, due to cultural requirements, the preference of the student and the need for training at an advanced level.

However, without a doubt, e-learning and distance learning cut costs like travel and hotel expenses in an air transport industry that is subject to ever escalating fuel charges and eroding profit margins. These types of learning also impart time management skills to employees and the flexibility to enable them to spend fewer hours away from their families and job responsibilities.

Outsourcing

Though the marketplace is still evolving, outsourcing is a prime growth area according to a joint report issued in 2004 by ASTI and IBM. The main reason companies are looking to third-party suppliers are potential cost reductions, said 67% of the learning and human resources executives surveyed.

ASTD and IBM conducted the survey as both companies noticed an increased interest in organisations considering outsourcing for learning processes.

When choosing an outsource provider, 71% based their choice on the supplier's reputation and knowledge about the organisation's industry and their company and its internal challenges as well as the quality of the training.

The lack of internal resources and access to best practices and subject matter experts were cited as two other reasons companies outsourced their training. In future, companies will look to outsource to help accelerate the transformation of their learning environments, the report said.

Trends may come and go but what remains a constant is the importance of investing in your staff so they can develop their technical and management skills to their full potential. Skilled personnel are major assets in an international air transport environment that is one of the most dynamic and fastest changing industries in the world. In the field of training, the IATA Training & Development Institute is committed to developing and delivering a wide range of progressive training solutions that promote professionalism, leadership and commercial success in the aviation industry.

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PECULIARITIES OF AVIATION PERSONNEL UPGRADING SYSTEM ON THE BASIS OF EDUCATIONAL ESTABLISHMENTS COOPERATION

The article deals with the history of training specialists from the Soviet times up to now. It describes training institutions available at present in Russia..

Under the Soviet Union, the training of specialists was carried out in specialized schools of higher and secondary learning. Besides, airports and the Airflot employed specialists from other non specialised schools. Therefore, they paid special attention to the personnel upgrading.

The upgrading system had several levels (picture 1).

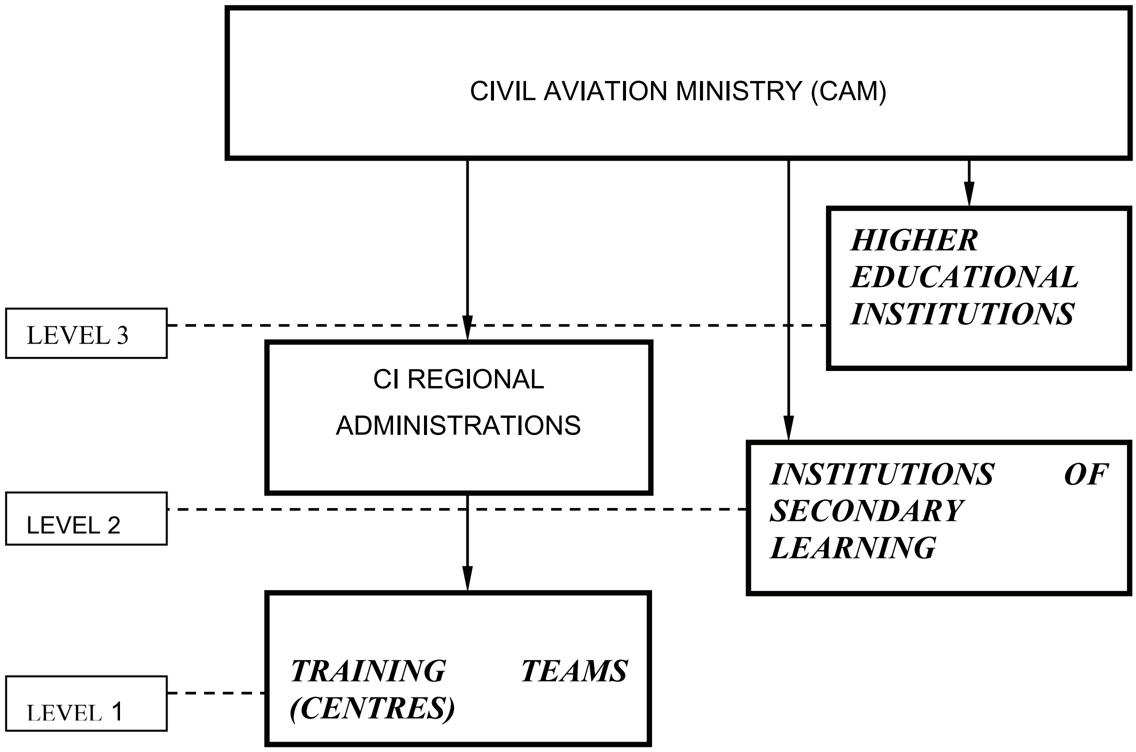

Fig. 1. Diagram of the upgrading of aviation specialists.

Training centres used to be established in regional centres within large airports (level 1). The centres provided refresher courses for the air crew, technicians, air traffic control officers, and air stewards once in two years. There were method guides approved by the Ministry according to which the centres developed syllables and curricula.

The ground personnel were not trained on a regular basis. The services for passenger carriages had upgrading programmes approved by the Ministry, whereas airport services had no such programmes.

The specialized schools of secondary learning (level 2) trained technicians that included the following specialities: fuel and oil, special transport. These specialists used to take refresher courses once in five years.

The higher educational institutions (level 3) retrained and upgraded engineers and managers. The upgrading term was once in five years too. To progress the career ladder a specialist who left a non-specialized school had to get a second degree in aviation. The Leningrad Civil Aviation Academy had faculty providing one-three years refresher courses for the officers.

The collapse of the USSR and the introduction of the market economy considerably changed the former system of upgrading aviation specialists in Russia. Since Russia lost a number of aviation institutions, airports and airlines started employing specialists from different branches and graduates of non-aviation institutions. These specialists had to be retrained.

Present training centres are owned by various structures: state, private, airlines, airports. There are no single training programmes. They are elaborated by the centres themselves. These programmes are approved either by regional administrations of air transport or by the Transport Ministry. But there are no single standards and some services (air traffic control service) train their specialists on their own.

We can see positive trends in training the airborne personnel. Since most Russian airline companies are trying to enter the foreign market of carriages, syllables must be brought into accordance with the ICAO standards. To meet the ICAO requirements Utair has extended the training term for the airborne personnel up to once a year.

In the 1990s the ground personnel were not provided refresher courses. As late as since the beginning of the 21st century a number of regional centres in Russia have been elaborating training programmes and since 2002 they have providing refresher courses engaging the teachers of the National Aviation University. These courses are highly estimated by students.

There are also training programmes for upgrading engineers, passenger carriage services, electricity and light supply services.

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ACTUAL PROBLEMS AND TRENDS IN THE DEVELOPMENT OF ADDITIONAL PROFESSIONAL TRAINING

The article looks into ways to narrow the gap between demand for workforce in the labour markets and supply in the educational services market. The author analyses proposals to streamline the legislature of the Russian Federation aimed at improving the quality of adult vocational training and enhancing participation of employers' associations in shaping and implementing educational policies.

The existing imbalance between the demand of work force in the labour market and supply of educational services is growing year after year. Employers are experiencing problems recruiting people with required skills, the population is complaining about poor job opportunities while recruitment agencies are lamenting that clients are becoming excessively demanding. Problems of the Russian labour market today are obtaining an increasingly structural character.

At the same time the economy is suffering from two maladies, which seem to be incompatible i.e. unemployment and shortage of workforce with required skills. The system of vocational education and training should help do away with this imbalance or at least reduce it. There are two ways to do so. The first one implies adjustment of learning syllabus and standards of higher and secondary vocational education in compliance with models of employees and the needs of the real sector of the economy. However, training in required skills with academic education will require at least 5-7 years. The other option is to upgrade skills and provide opportunities of vocational retraining to meet the needs of the real economy, which will allow people with basic vocational qualifications to soon gain their footing in life.

The official statistics shows that Russia now has more than two thousand training institutions delivering programmes of adult vocational training (AVT), where annually about 1,5 million people pursue skills upgrading courses and more that 100 thousand attend vocational retraining programmes. Such statistics does not cover millions of trainees pursuing short-term courses (with duration of training being less than 72 hours) and on-the-job training.

AVT system is flexibly and adequately responding to changes in the labour market, simultaneously addressing the issues related to labour market analysis and projections based on quantitative and qualitative indicators, which makes it more than just an educational tool. Unlike academic educational programmes, programmes of skills upgrading are short-terms courses, which do not have and can not have standards since they cater for a specific customer. Vocational retraining programmes, even those regulated by standards or national requirements for the learning content, are also flexible and swift to respond to market changes.

In the Soviet times, the system of skills upgrading and retraining was operated by sector, and funded and strictly monitored by the state. In the market economy, AVT system became self-sustained and demand-driven.

Unlike Russia, governments in the developed countries (i.e. USA, Germany, Italy, France, etc.) provide efficient support to the system of adult vocational training. The regulatory and legal basis in force in these countries encourages employers to invest in skills upgrading of their workers. The Governments allocate funds to AVT training institutions, and there is a system of benefits and social guarantees for teachers, as well as tax breaks for companies if they invest in training. Public funding channeled into adult learning system in these countries exceeds funds allocated to higher vocational education.

In the Russian budget for the year 2005, the AVT system will only get one and a half percent of the total expenditures planned for vocational education. The legal and regulatory basis of the AVT system in Russia is not perfect and in some instances even contradictory. Many issues are not defined at all, leading to their arbitrary interpretation not only by AVT workers, but also by auditing and monitoring organizations, resulting in the negative effects impairing the performance of training institutions.

The impact of AVT system on the country's welfare is recognized both by the academic community and by professional associations of employers. To consolidate efforts, different unions and associations have been established to unite training institutions and their top management to promote interests of the AVT system. Adult training issues are discussed by the Russian Union of industrialists and entrepreneurs (employers), Chamber of Commerce and Trade committees, and also during conferences of Mercury Club involving State Duma deputies (parliament members), high-ranking government officials and top executives of industrial enterprises and companies.

However, the need to develop AVT system in a new environment is geared not only by the market drivers but also by national priorities of the economic development and developments in science and technology, which implies a constant process of knowledge upgrading. Due to its nature, the system of adult vocational training is capable of and actually does influence supply and demand of workforce in the labour markets and acts as a backbone element in relations between skilled labour and employers.

The present situation constrains further development of AVT system and fails to address the problem of providing the national economy with professionals and managers with required qualifications. Amendments to the Federal Law "On Education" related to the operation of AVT system as well as some other bills are currently under consideration. However, this fails to address all the problems accumulated over the years.

It is necessary to improve legal and regulatory basis of AVT system related to defining its status, ensuring statutory measures to encourage employers to invest funds into personnel training (skills upgrading and retraining of their workers).

Current legislation in the Russian Federation contains specific provisions that might be interpreted as ensuring the right of employers associations to participate in designing legal acts regulating training of skilled labour. However, such legal acts are rather vague and are not supported by implementation mechanisms. In reality, legislation in force provides neither for employers' participation in labour market forecasting and monitoring at the national level, nor in identifying the list of training profiles (list of training occupations), nor their involvement in procedures to monitor the quality of vocational training.

Currently, discussion is underway on the bill that would ensure participation of the national associations of employers and national sectoral (intersectoral) associations of employers in the process of forecasting and monitoring skill needs in the labour market at the national level, identifying the list of training profiles (list of training occupations) and monitoring the quality of vocational training. This should facilitate linkage between education and labour market; improve involvement of stakeholders among community groups in identifying prospects for streamlining provision and delivery of vocational training.

To ensure the above mentioned provisions, it is necessary to provide institutional arrangements, which would give national associations of employers a legislatively guarantee of the right to participate in:

drafting federal bills, or other regulatory documents related to vocational training and affecting interests of employers;

developing medium-term projections and monitoring the needs of the economy for skills, as well as designing federal components of the national educational standards for vocational education and training;

certifying training institutions delivering vocational education curricula of any level, as well as identifying the list of training profiles (training occupations) in VET sector.

All this could contribute to narrowing the gap between supply and demand in the labour market, positively influence the quality of vocational education and training and facilitate enhanced social participation of employers' associations that could have a vital role in creating a targeted system of vocational education and training.

Not only it is necessary to make provisions for employers to train workers by offering them a system of incentives, but it is also necessary to hold them legally responsible for not complying with requirements to provide training for their workers on a regular basis.

On the whole, the concept of this draft bill has been positively evaluated by experts, but, unfortunately, this bill does not define the role of adult vocational training system as a key link between the system of vocational education and training and employers' associations, which is what it actually is, despite all the efforts to ignore this fact. The draft bill does not envisage creation of incentives system for employers encouraging them to invest in training and education. Should this bill be passed into law as it is, this will significantly diminish its effectiveness.

The idea of validation (certification) of AVT programmes by the public and professional community is now generally accepted and reflected in another draft bill aiming at establishing a new procedure to regulate operations of organizations delivering vocational training programmes, with regard to expanding the list of organizations delivering AVT programmes, changing procedures to validate adult vocational training programmes, creating conditions to provide for validation of mainstream vocational training curricula by the public and professional community and altering the respective procedure of the national accreditation of organizations delivering adult vocational training programmes.

The draft bill envisages that only vocational training programmes should be validated (certified) by public and professional bodies and such validation should be performed on a voluntary basis. It is also proposed that validation (certification) of adult training programmes should be assigned only to public and professional bodies (except AVT programmes, which according to the Law are regulated by the national standard). During the transition period, the draft bill provides a statutory provision that allows educational and other organizations delivering adult vocational training programmes to have the right to award national certificates to the graduates of such programmes. It is assumed that in the future accreditation certificate will be given to educational and other institutions on the condition that educational curricula delivered by such institutions have been positively assessed and validated by the public and professional bodies.

Alongside with this, the question arises about employers' recognition of certificates issued by training providers delivering adult training programmes, in case they are not granted the right to issue national qualifications. The draft bill does not cover this problem.

Also, the issue concerning the creation of an efficient system of quality assurance and monitoring the quality of training with the participation of employers has never lost its relevance.

Adjustment of the vocational education and training system to the market environment will inevitably require introduction of a set of new statutory provisions missing in the current legislature. One of the these provisions should ensure creation and support for fair competition in the educational services market, which would improve the quality of AVT programmes, reduce training costs and, consequently, would encourage development of new learning techniques, introduction of innovations, and better use of scarce resources.

The first step should imply creation of regional systems of monitoring the labour market and educational services market, providing efficient supply of information and data about staff potential in training institutions, training programmes and employment prospects of graduates. Such information should be available to ensure real and not declarative character of vocational guidance and would ensure a direct link between the wellbeing of training institutions and their ability to flexibly meet the labour market needs.

Training institutions delivering AVT programmes should anticipate changes in the learning process in line with competitiveness, global development trends and employment options and opportunities in the labour market.

All draft bills regulating AVT system should be considered in package, since issues related to public and professional accreditation of educational institutions and definition of rights and obligations of employers are closely linked to each other.

The issues of enhancing the quality of education in a new economic environment, improving its legal and regulatory basis, assuring the required quality of education, including adult vocational training are common to the majority of CIS countries. Consolidating efforts to address these problems will contribute to the task of training and retraining of skilled labour for the national economy, preserving and developing the intellectual capacity of the country.

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UPGRADING OF TOP-MANAGERS QUALIFICATION AS A FACTOR OF SAFETY PROVISION

The article deals with problems the Institute of training specialists faces nowadays in upgrading top-managers. It describes the system of education the Institute offers its students.

The Institute of training specialists in the field of industry is a state higher educational institution for post-graduate education as well as the chief organization for training, retraining and upgrading specialists of the Ukrainian Ministry of Industrial Policy.

The Institute was founded in 1949.

For over fifty years, the Institute has upgraded several generations of top-managers.

Since 1990 the Institute has trained more than 40,000 students. Every year it graduates over 3,500 people.

Nowadays the Institute is a multiprofile educational institution upgrading office employees, top-managers as well as personnel reserves for the management, economy, ecology, law, science and technology and labour protection area.

The Institute has the 3rd grade accreditation, the license to retrain specialists in "Accounts & Audit", "Finances". State accreditation and licence guarantee the quality of training.

The Institute is also licensed to upgrade specialists in "State management".

The training of office employees and top-managers is an important part of the Ukrainian personnel policy, that is the reason the Institute puts special emphasis on it.

Reforms in our country made it necessary to train highly skilled managers, to improve co-operation with top-managers and to create personnel reserves.

The Ukrainian Cabinet of Ministers adopted a number of regulations on the procedure of upgrading specialists. According to the regulations, the upgrading of top-managers is a training to improve knowledge and skills needed to run a business and improve its activity.

The rapid development of modern technologies makes specialists to improve their skills. In present-day society, top-managers tend to obtain two-three degrees. The state needs skilled personnel. Thus, the Ukrainian Ministry of Industrial Policy take care of the industrial personnel.

The main policies of an upgrading institution are:

- improving basic training of specialists in the field of new economy;
- training reserves for managing posts;
- improving professional skills by means of teaching modern achievements in science and technology using special purpose programmes.

All the policies have one objective. It is to make a manager more effective which will have a positive effect on the activity of a business and economic development of Ukraine.

This objective has a number of the main tasks which involve study process, curriculum and methods:

- to train students in theory and practice of management, new methods and techniques of work;
- to form or improve professional skills;
- to make managers exchange experience;
- to make students continuously perfect themselves.

The team of the Institute has developed a model of upgrading top-managers and personnel reserves.

Our Institute can conclude agreements and provide both methodical and practical assistance and offer training to promote continuous education.

In training we use modern foreign experience and methods forming professional business skills.

The training programme includes three components: general, functional and special.

The general component of the programme provides for improving existing skills and obtaining new ones in law, economy, politology, management, sociology and humanities.

The functional component of the programme provides for improving existing knowledge and obtaining new one in psychology, management organization, marketing, finance management, fund market regulation, modern communication techniques and documentation- keeping.

The general component of the programme provides for obtaining new knowledge in developing state industrial policy, energy supply, labour protection, industrial sanitation and ecology.

The upgrading programme has been made up according to the legal rules, guidelines of the Chief Administration of Ukrainian State Service as well as special administrative documents.

The Institute trains specialists in accordance with the syllable and curriculum developed by the appropriate departments of the Institute and approved by the Academic Council and the customer. The curricula are continually being reviewed following the the Chief Administration of Ukrainian State Service and the decrees of the Cabinet of Ministers.

To make it more convenient for the managers, the programme is divided into periods which enables the manager to be absent from his business for some time.

The Institute also runs short-term seminars on the following subjects: "Corruption. Methods of Fighting it", System of Social Guarantees", "Behaviour of Office Employees", "Language Culture", "Personnel Management".

The short-term training uses up-to-date equipment (computers, printers, scaners, photo-copiers, etc.) which meets all the requirements of modern training.

The students can use Internet to be in touch with Ukraine's present-day basis of legal rules as well as foreign materials on the subject.

According to the curriculum, the students should participate in scientific and practical conferences, seminars, round tables, business role-plays, outside classes.

Active forms of training let managers know about problems arising in business. In co-operation they try to solve them, and it leads to mutual contracts between them during training.

The concluding session with special subjects is conducted in form of the round table

Preparing reports, the students use:

- information, analysis and statistics of their own enterprise with suggestions as to the ways of solving a problem;

- experience of a similar enterprise;
- regulations and instructions on the issue;
- literature;
- method and scientific and research guides of top-specialists;
- professional consultations;
- foreign experience;
- personal opinion.

The Institute has a consultation and information centre providing legal and personnel instructions and offering personnel audit service.

After graduating from the Institute the managers can apply to the centre.

The Institute employs highly skilled professors and researchers from various educational establishments of Kiev.

The students can take a course of lectures, obtain a set of documents and consulting assistance of top-specialists of the Ukrainian Industrial Ministry, the Ukrainian Chief Administration of State Service, the President's National Academy of State Administration, the Ministry of Labour and Social Policy, the Customs Committee, the Court of Arbitration etc.

The Institute has a library with a reading hall for 80 seats. Here you can find scientific literature, textbooks and training aids used in the study process.

The library has 15,000 copies in stock, last year saw another 1775 copies. Each year the Institute subscribes to 48 periodicals. Assistance is rendered by the "Vidrodzhennya" Fund and S.Pavlychko's Publication House "Osnovy".

The students are accommodated in comfortable hotel rooms situated in the study building.

The students can have proper leisure-time activities.

The crucial changes that take place in social and political and economical life of Ukraine, including the reforming of production relationships, make it necessary to know a new system of industrial production management.

To meet the requirements, top-management should be able to anticipate and face the changes in politics and economics.

The state personnel policy has for its objective to train a new generation of industrial directors at upgrading institutions.

Thus, we face the problem of improving the study process and raising the new requirements of organising academic activity using interactive methods.

In this connection, the Institute will focus on self-education of managers, individual classes, consultations using computer technology, and distant learning.

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UPGRADING AND CONTINUOUS EDUCATION AND THE AIR TRANSPORT SAFETY

The article deals with the necessity of creating special programmes and techniques for upgrading specialists in aviation safety. The author names and describes components of the post-graduate education system in the field of aviation safety and elaborates on existing training programmes developed and introduced in the study process by Ukrainian and Russian experts.

Retraining and upgrading specialists has always been important for safety of the transport branch. The aviation, where the human factor is of special importance, has state systems of retraining, upgrading and certificating specialists.

This system existed in the USSR, but has survived in none of the Independent States with air traffic. It increased the aviation safety in these countries first of all on account of the human factor. For example, in Ukraine 95 % of the air accidents involve the human factor, with 60-70 % in more developed countries.

This fact makes it necessary to create a system of post-graduate education in aviation safety. This system should use the experience and requirements of the international organisations for aviation safety, take into account interests of national companies at the air traffic market, and conform the price and the quality of the training.

To elaborate on the system of the post-graduate education in the field of aviation safety and the principles of its functioning we shall consider the notion of aviation safety using the approaches adopted in civil aviation today. The safety of aviation is a complex feature of air traffic system which functions without causing damage (or causing minimum damage) to the system itself and the population [1]. The system's main components are flight safety, aviation and ecological safety. The aviation safety also includes economic safety of the aviation plants, which is a topical problem for airline companies of developing countries facing tough competition from the world leading air traffic actors.

Aviation is the most innovative among not only transport branches. Every years sees increase in requirements to reliability of equipment, aviation systems and units, introduction of modern materials and technology, improvement in communication techniques. But there is no decrease in aviation accidents, the faults of the human factor as the reason rising (by 10 % in last 10 years according to ICAO). That is why the aviation traffic activity pays more and more attention to the human factor, under which they mean the integral feature of a specialist's personal qualities dealing with his affecting sociatechnical system. The human factor comprises 4 main components: organisational, technical and technological, professional and ethical [1].

We shall elaborate on the technical and technological and professional components of the human factor as they are directly connected with the post-graduate education of aviation specialists. The technical and technological component is the maximum account of specialists' capability in designing the aviation equipment, units and devices, developing techniques for maintenance of the aviation equipment. As early as at the first stage of designing a new sort of equipment it is necessary to find the best solutions with respect to the human factor, which reduces the time of designing and the prime cost of developments that are becoming science capacious and demand pretty investments.

The professional component includes aspects of a specialist's professionalism as to air traffic. At present, the post-Soviet countries have many virtually uncontrolled small ventures, which make it a pressing problem to upgrade aviation specialists. To achieve this purpose it is necessary to control the quality of training, introduce promising communication, computer and psychophysiology technologies while selecting, training and upgrading aviation specialists.

Thus, the system of the post-graduate education in the field of aviation safety has two principal components: technical and technological and professional (picture 1).

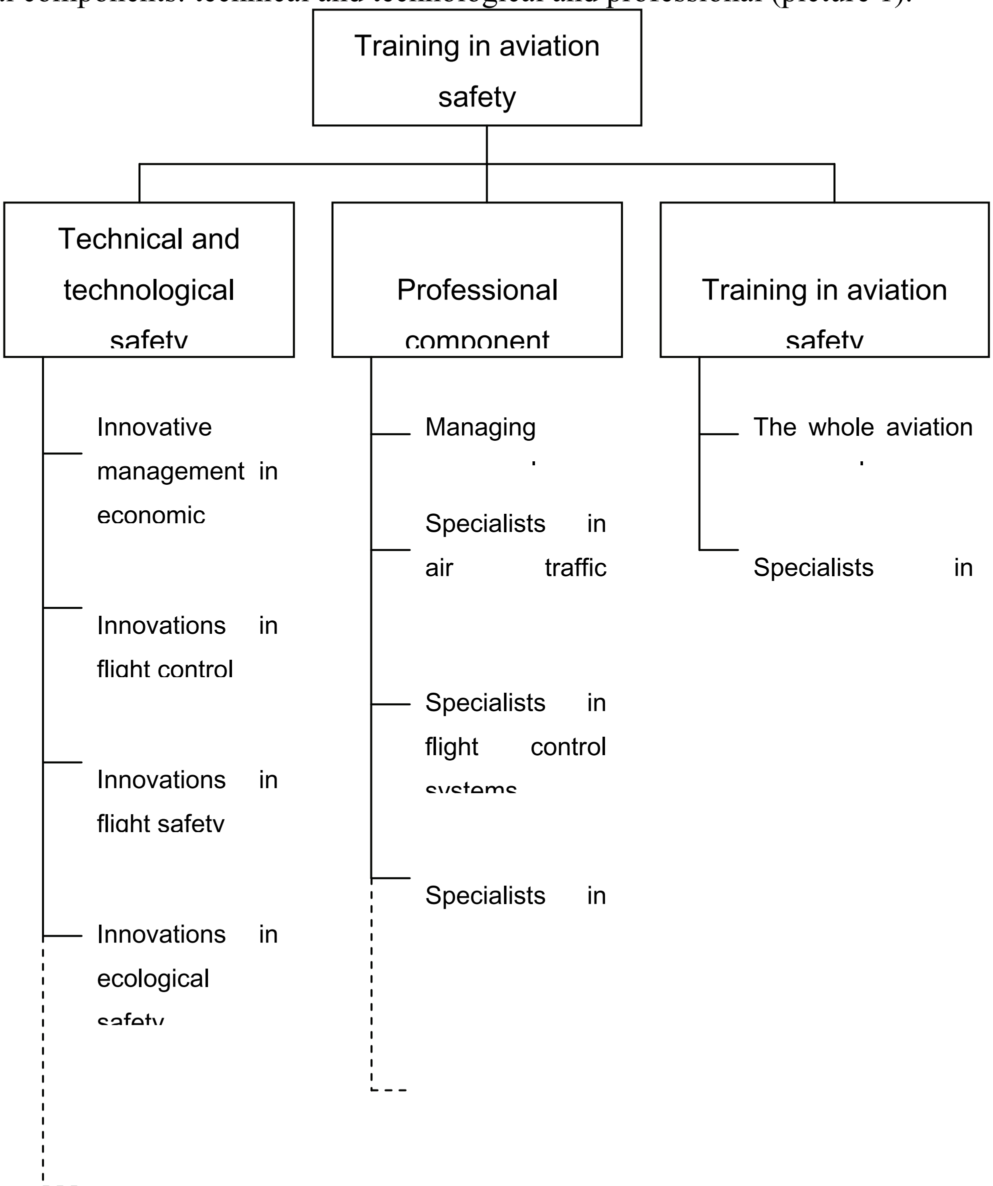

Fig.1. System of the post-graduate education in the field of aviation safety

The technical and technological component includes the following principal components:

- Innovative management in economic activity;
- Innovations in flight control;
- Innovations in flight safety;
- Innovations in ecological safety.

Introduction of modern technology has a positive effect on all the aspects of aviation safety in question. Scientific and technical innovations are important for economic survival and growth of transport companies; they have to be properly planned and controlled. In spite of economic problems, some aviation innovations succeed. The post-graduate education is to compose training programmes to teach the modern technologies using the latest methods.

As an example of training aviation specialists in innovations we can cite programme of teaching in the An-148 avionics developed by a team of 200 Ukrainian, Russian and other companies. The Antonov Academy acted as a system integrator of the on-board equipment, the flight and technical performance systems and units developed by the Russians and the Ukrainians.

The method complex designed to study the on-board equipment comprises programmes on: 1) the computer system of aircraft piloting VSS-100 controlling horizontal and vertical navigation, optimising flight data, and expanding the use of navigation bases internationally; 2) the four channel electrical and distant control system of improved reliability providing safe control of air traffic operational bodies; 3) the system of computer aided control SAU-148 allowing landings in the II and III ICAO categories. The equipment to be studied meets all the latest world technical and safety standards.

The professional component is the most extensive and composed of refresher courses in maintenance of aviation systems and flight facilities. The courses are chosen according to the qualification and post of the personnel. The managing personnel are offered short-term amd long-term courses (over 72 hours) in personnel management techniques, conflictology, management psychology. The professional component of training specialists in flight safety (without respect to specialisation) includes the following sections (picture 1):

- Upgrading of managers
- Upgrading of aircraft maintenance specialists
- Upgrading of flight control
- Upgrading of airport personnel.

The third component (picture 1) includes special training of aviation specialists in safety, i.e. studying normative documents, foreign organisations activity regulating safety. Training must be given to as more personnel as possible, be regular and periodic (once a year) and carried out by aviation experts in aviation organisations. Another form of special training is training provided to safety consultants using definite programmes, e.g. training safety inspectors according to the "Investigation of accidents and preventive measures", registration personnel according to the "Deciphering and analysis of flight data". Consultants should be trained in educational institution equipped with laboratories. After attestation graduates are qualified and certificated.

Consider methodical principles of the post-graduate education in the field of aviation safety (picture 2).

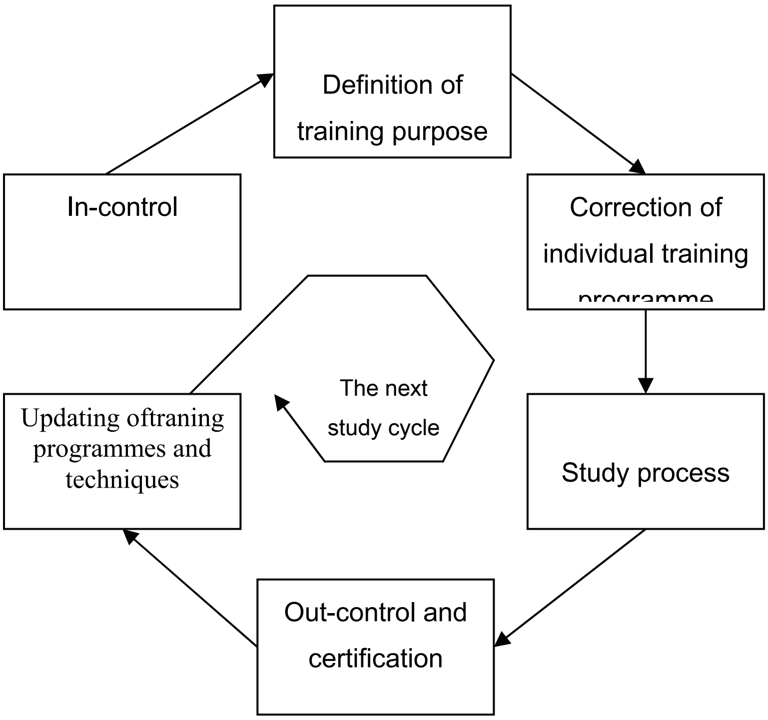

Fig.2. Diagram of functioning of the post-graduate education

Principle 1 – continuity. Training in safety is carried out during all the period of professional activity in cycles, programmes and techniques improving with every new cycle. Principle 2 – obligatory. The state bodies of safety regulation establishing periods and duration of training. Principle 3 – in-control of knowledge. Before training, students undergo individual control of their knowledge and get a corrected programme. Principle 4 – following the certification procedure. Aviation personnel is allowed to perform their duties only if they have a Certificate issued by authorised bodies. Principle 5 – use of innovative training techniques (active training methods, communication techniques).

References

1. Безпека авіації / За ред. В.П. Бабака. – К.: Техніка, 2004. – 584 с.

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PROBLEMS OF PERSONNEL TRAINING FOR AVIATION

The article deals with problems Tajikistan faces in training and upgrading aviation specialists from ground personnel to airborne crew. The author stresses the need to review and up-date the study process, to raise the requirements to meet European standards. Special attention is focused on the phenomenon of continuous education and self-education.

The standard of knowledge of graduating students depends on how high is the standard of training of teachers. In any educational establishment the most important component is a teacher conserving and passing old knowledge as well as reproducing new one. To achieve this purpose the civil aviation is waiting for a new generation of specialists educated and trained according to the world standards.

The civil aviation is one of the first branches on the way to the World Union integration. It has to meet the world demands made to the managing staff of airline companies first of all which are involved in administrative and business activity.

According to researches, under present-day market conditions successful activity of any production area can be by 80-85% accounted for by good personnel organisation and management. It means that a modern manager have to comply with higher demands than 15-20 years ago.

The civil aviation has an urgent need in personnel managers trained in business activity.

Transport is an important part of Tajikistan's economy. Its development and efficiency is necessary for a rapid economical growth, national integrity and safety, rise of living standard, Tajikistan's admission into the world economy.

Last five years saw consecutive modifications that brought about new methods of forming the state economic policy. It gave the transport section a number of documents regulating its development strategy.

Nowadays we face tough competition. And we have to be well informed about new technologies arising abroad.

With airline companies, producers, colleges, scientific centres disintegrated we had to create a single information area. We consider that the modern aviation psychology must continuously educate a person capable to handle non-typical situations.

Of great importance is the continuous education of an airman, which includes professional self-improvement.

The continuous education is regarded a particular eco-socio-cultural and creative space ensuring the harmonious spiritual and professional growth of a personality. Object of the continuous education is the man capable to organize his spiritual and practical existence in harmony with the Universe. An airman is much closer to the new cosmic and biosocial development of the civilization.

As is generally known, the post-industrial economy is an economy of knowledge. The essential condition for its functioning is application of scientific knowledge, use of resources for scientific and technical development. It is becoming a firm foundation for increasing the well-being of the people.

The transformation of the social economy into the capitalistic one needed to be managed. The first stage of the reforms did not include this point.

At present the aircraft building uses the old scientific and technical, design and technological reserves. The insufficient financing confined to state orders and federal purpose programmes puts off or stops promising researches and developments, makes them more expensive. With no investments into innovations it is still harder to compete with western corporations.

In 2004 the head of the State issued a decree to found the Institute of Transport turning out specialists in various transport fields including the aviation faculty having three departments.

Till now we have our airmen trained in Kazakhstan and Kirgistan, though the training leaves to be desired. But these are not the teachers who are to blame. Pilots, navigators, engineers, air stewards and operators do not get sufficient training.

Airlines tend not to employ pilots-graduates, as they have flight practice of not more than 50-70 hours or do not have it at all. Therefore, about 25% of graduates can find a job. In this case we have to cope with another problem and train fewer specialists, but highly skilled not to waste money on flight practice of potential non-employees.

Another problem of the modern aviation is the aircraft. On the one hand, the State wants to support the aviation industry, for it is an important part of the national safety. On the other hand, the Russian companies do not want to buy home aircraft on account of their low economy. Home aircraft are much cheaper than Boeings, but they cost more if we consider their repair and maintenance.

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HUMAN FACTOR AS ONE OF THE MOST IMPORTANT CRITERIA FOR EMPLOYMENT SERVICE STRATEGY DEVELOPMENT

The article deals with the necessity to use human resources instead of computer ones to develop the employment service strategy. It analyses two major approaches of strategic management – technocratic and humanitarian.

If the operative task of management includes the optimising of the algorithm of problem-solving within the existing administrative system, the strategic task is to optimise the system itself. Considering the limited size of the article, we shall analyse but two major approaches of strategic management – technocratic and humanitarian.

Since the second half of the last century, both operative and strategic management have preferred the technocratic approach as more efficient. Efficient equipment in enterprises, general computerisation of state organisations, ministries and departments should have drastically raised labour productivity and the quality of services offered. But there was no wonder as expected. Quantity was not transformed into quality. On the contrary, we saw all showings generally falling, missing percentage of fulfilled plans being just added and efficiency showings of state institutions misrepresented. Unfortunately, administrative or rather political faults were not considered to please the dominating doctrine. Huge sums of money were wasted.

Times change as well as leaders do. Leaders choose different approaches. Following western experts we became aware of the fact that technical re-equipment and general computerisation would be no solution for the problem. Now we understand that the machine should be just auxiliary in solving human problems.

But we cannot think the technocratic approach to be fully faulty. To raise our productivity we need up-to-date equipment, computer technologies, modern information systems and database.

As we mentioned above, the second approach in the strategic management is called humanitarian placing the man at the first place in the managerial system. This approach considers the man both a producer and consumer. In the last decade it has become prevailing. The humanitarian approach at its best applies to the social area, which includes the State Employment Service.

The State Employment Service was set up fourteen years ago to solve the main strategic or rather political problem of social tension at the labour market. Though it is hard to talk about any market at those times of economic depression in our country: general closing-down of industrial enterprises, mass dismissals of employees, collapse of the money system, etc.

The State Employment Service is made up of three levels:

1. The State Employment Centre is responsible for strategy of the Service according to government tasks, distributing and controlling finances in regions, reporting on the plan.
2. The Regional Employment Centres (Kiev, Sevastopil, the Crimea). They are to

execute regionally planned tasks, organise the work of district employment centres and distribute finances given by the State Employment Centre.

3. The District Employment Centres are in charge of services offered to the customers of the employment service.

In Ukraine there is the Fund of obligatory unemployment insurance, the main component of social insurance. The Fund is managed according to the European three-part model. The board of the Fund consists of representatives of the associations of employers, trade unions and the government. All the parts have the equal number of participants. Representatives of each part of the social partnership take it in turns to head the board. The State Employment Service is subordinate to the Fund, its executive management. Besides, under the Ukrainian obligatory state unemployment insurance law the employment service is subordinate to local self-governing bodies. This complicated system generates numerous formal and informal functional links in which an important role is given to the human factor. It is accounted for by the fact that interests of businessmen are different from those of trade unions representing wage workers, local administrations disagreeing with the point of view of the employment service on the local labour market. So the human factor is important for establishing positive relations both between the three parts and the employment Service and local administrations.

The State Employment Service is a social service and it primarily deals with the man though it co-operates with enterprises and organisations as payers of the Fund as well as controls the observance of the labour legislation. To understand how the human factor influences the work of the State employment Service, it is necessary to give a general idea of an average client.

So, the client of the employment service is a middle- or older-aged person who got his degree ten or more years ago but for some reasons lost his skills to meet the requirements of a modern employer. After failing to find a job on his own, the person begins to feel inferior, which aggravates the situation. Unemployment involves problems with the social environment, family, children, etc. This makes it necessary to take professional advice. In this connection we want to stress the word professional. Though there are many commercial employment organisations that proved themselves to be good experts in this field for a long time. Till now employment organisations are not to be stately licensed, which has a negative effect on the professionalism of the service.

Solving the client's problems requires a complex approach which can be a success if applied by a interdisciplinary team. The team of specialists must be highly skilled. Such people must be well paid. This is where it is hard to keep a good specialist for a long time. Last year the Kiev Employment Centre saw a bad labour fluidity of over 50%. The Centre fulfilled its plan due to a small number of highly skilled employees working there for a long time. This year we have seen the situation stable owing to the pay rise. In the Kiev employment Centre more than 92% of employees have a higher education and some of them are post-graduately educated.

Specialists of an employment service must be good at communication methods. So, the employees are trained in fundamentals of corporate culture. To be aware of the responsibility and commitment is one of the main pre-conditions for a successful work.

In this connection, the management of the Kiev Employment Centre organised a number of seminars called "Corporate culture as an important component for raising service standards" designed for directors. During the seminars the students had to fill in a questionnaire dealing with organisation, relationships between workers and management, conditions of work, etc. The survey showed unequal contribution, high working load, lack of privileges, low pay.

The Ukrainian President and his government set new tasks for state services. The main accent is put on the efficiency of social services. The State Employment Service is not only to place people in jobs and find personnel for organisations, but also promote to create new working places. According to the President's decree, one million new working places must be created each year. And it is quite real. To face the challenge we should use all the range of managerial tools pushing the human factor into the foreground.

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UPGRADING OF AIRPORT GROUND SERVICES SPECIALISTS AS ONE OF THE IMPORTANT COMPONENTS IN FLIGHT SAFETY PROVISION

The article deals with flight safety control by ground personnel as well as factors affecting the flight control. the authors analyse the actual problem of upgrading ground personnel.

Flight safety has always been the principal performance of the civil aviation.

Every passenger wants to be certain that the airline, on the one hand, and the airport service, on the other hand, will make his or her flight secure.

How must the ground personnel ensure flight security?

First of all using an airfield with a runway, taxiways, apron and parking places, all in good condition to ensure a safe start and landing. Besides, flight safety depends on proper actions of ground personnel.

Investigations of the reasons of accidents show that more than 50 % of them are accounted for by a bad qualification of personnel, lack of control.

According to ICAO documents, users of an airfield hire qualified and experienced personnel and upgrades them.

Expensive and sophisticated materials and equipment cannot ensure good maintenance of airfields if used by a low-qualified personnel. The human factor plays the principal role in the ergonomic system "man – aircraft – airfield – environment" that makes airfield equipment reliable and durable and flights safe and regular. The "Man" has to be properly qualified and experienced. It is recommended for managers and engineers (airfield, special vehicles, fuel and oil materials, electrical engineering and light) to have basic education (correspondingly: master (specialist) in automobile roads and airfields, master (specialist) in airfield techniques and equipment, master (specialist) in light engineering, etc).

Unfortunately, statistics points to the fact that the above mentioned offices in CIS countries are held by people without basic education. According to 320 questionnaires of the students who took refresher courses in 2002-2005 in Kiev (Ukraine), Tashkent (Uzbekistan), Vilnius (Lithuania), Saint-Petersburg, Tyumen, Ekaterindurg (Russia), Astan (Kazakhstan), have:

-higher basic education – 31 (9,7 %);
-higher technical non basic education – 182 (56,90%);
-secondary technical basic education – 26 (8,1 %);
-secondary technical non basic education – 38 (11,9 %);
-no secondary technical education – 43 (13,4 %).

It is necessary to point to the firm tendency that the rate of ground personnel with higher basic education is declining. The similar situation is faced in Mongolia.

In the 1970s-80s, this situation was considered a loss of connection between life (production) and higher school. It can be accounted for to some extent. Since aviation colleges went to be controlled by the Ministry of Education, they were alienated from aviation bodies that could no longer control curricula and enrolments. On the other hand, due to a drastic reduction in air carriages and passage of ownership of aviation subjects aviation managers did not hold it for a priority to finance personnel upgrading. It is worth mentioning that 2002-2005 saw 20% refresher course students who were trained in the early 1990s.

General positive tendencies affected both economy and civil aviation. There is a gradual increase in air carriages. At the same time, Ukrainian airports like airports of other CIS countries face a great deal of problems including artificial runway surfacing.

As was said at the 25th Moscow International Conference "Civil Aviation Safety", flight safety begins on the runway, most accidents happening at the moment of start or landing and having to do with the condition the runway is in.

Insufficient financing disabled aifield services to overhaul and repair and caused a sharp reduction in reconstruction works. According to experts, over half of all runways, taxiways and other constructions need repairing.

A wide range of domestic and foreign materials and techniques available at the market, on the one hand, and scanty investments, on the other hand, make the problem of keeping airfield in good condition quite different.

In this connection, it is important to solve the urgent problem choosing suitable material and technique. The airport need specialists capable to help find a proper solution.

To achieve the purpose, we should attach much importance to the upgrading of personnel responsible for flights. This personnel needs to be certificated as insurance of passengers is very expensive enough.

As long as 30 years the teachers of the National Aviation University provide refresher courses for airfield specialists (engineers and managers). The teachers are publishers of a wide range of training aids and scientific books (textbook "Airfield of Civil Aviation" / V.Blokhin, I.Belinskiy, I.Ciprianivich, A.Bileush – M.: "Air transport", 1996; monography "Winter Maintenance of Airfields" / I.Belinskiy, U.Samorodov, V.Sokolov – M.: Transport, 1982; guidebook "Maintenance of Airfields" / L.Goreckiy, M.Pecherskiy, Belinskiy and others. – M.: Transport, 1990; training aids Construction and Maintenance of Airports abroad" / I.Belinskiy, V.Zolotoperiy, N.Shinkarchuk and others. – K.: KNIGA, 1993; "Technical Maintenance of Airfields" I.Belinskiy, V.Zolotoperiy, N.Shinkarchuk and others. – K.KMUGA, 1996; a number of normative documents, incliding SniP 2.05.08-85 "Airfields").

In 1989, ICAO ordered a courses 109 "Technical Maintenance of Airfield Surfaces and Runways" written in the English language. The teachers prepared aids and lecture texts for the course students. Two groups of specialists were trained. Another number of ICAO specialists worked on probation. Probation period of an ICAO regional representative in South Africa (2000) was 10 months. Quite regular was training of Uzbekistanese (1995, 1996, 1998, 2000, 2002, 2003) and Mongolian (1994, 1998, 2000, 2003) specialists in course "Airfield". In 2001 training was offered to two groups of Borispil airfield employees. In 2002-2005, the Ural and Tyumen centres UTC GA offered training to airfield engineers of Russian Federation (Ural and Siberia regions); in 2002, the Vilnius airport provided training for specialists from the Baltic countries (Lithuania and Latvia); in 2005, the Astan airport trained its specialists. More intense is the upgrading of engineers in Ukraine.

The refresher course "Airfields" is designed to train students doing the maintenance of civil airfields: chiefs, engineers, mechanics. The course includes the following modules:

- "Airfield planning".
- "Limiting and account of altitude obstacles".
- "Airfield surfacing".
- Vertical airfield planning".
- "Technical maintenance of airfields".

The courses meet the latest civil aviation requirements specified in the Standards of Civil Airfield Planning, the Norms of Civil Airfields Usability and the International Standards and ICAO guidelines considering their application according to the region and national norms.

Nowadays international airports face a problem of accordance of their airfields with the ICAO requirements. Unfortunately, not all documents are available and specialists find it sometimes difficult to understand and interpret the text of the Standards. The teachers make the requirements clear without elaborating on fine methods of planning and calculation. Though it is possible to get more detailed information on the subject. The "Technical maintenance of airfields" deals with overhauling and repairing, especially application of some sorts of surfacing to different airfields.

"Airfield provision of flights" uses handouts with pictures, diagrams, charts that can be used in study and professional activity.

The Syllable is certified by the State Observance Service of the corresponding countries. It is co-ordinated with the each customer and amended if necessary.

The term of study is from two weeks to three months. If the customer wishes, he can work on probation for up to one year. The students are certified to be upgraded.

Till the 1990s, all specialists as a rule took an upgrading course once in five years. This procedure must be restored and improved using the best scientific staff and high educational institutions.

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DISTANT FORM OF EDUACATION FOR AVIATION SPECIALISTS IN THE FIELD OF AVIATION SAFETY

The article deals with communication systems evaluating the control of training process. The author elaborates on the notion "system", representing its diagram and emphasising that every organisation should be systematic.

The development of communication technologies made it necessary to create a communication system (CS) of any comapany, especially in organisational management. The CS provides information in integrated form and facilitates decision-taking.

The system is an object that is considered both a unity and a unity of different elements to achive a purpose. Composition and purposes make systems different. A modern educational institution can be regarded as a complex social and training system consisting of, on the one hand, professorial staff training specialists and students, on the other hand, who wish to be eduacated. According professional skills, physical ability, psychological compatibility, all the people included in the organisation are quite different. Every component is unique and needs a special approach to be managed. Therefore, there a need in co-ordinating their activity, exercising organisational control.

In communication technologies, the notion of system is widely used and differently understood.

The use of the word "communication" with "system" makes clear the purpose and application of a system. CSs collect, store, process, search and output information needed to take decisions in any field. They help analise problems and create new products.

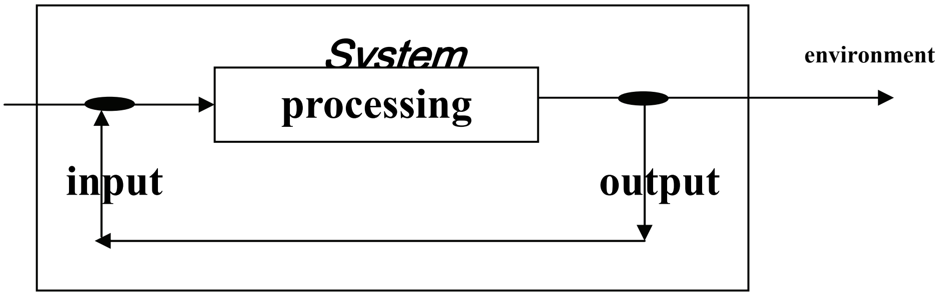
Thus, the communication system is a unity of means, methods and personnel used to store, process and output information to achieve a purpose.

The organisation is a community of people with commom purposes and material and financial means for manufacturing material and communication products and services.

The properties of systems are:

- keeping its structure (according to the law of conservation);
- needing to be managed;
- depending on its components and sub-systems (a system can have a property absent in its components and on the contrary).

Each system is characterised by input, processing, final results and feedback.



It is clear that each organisation must have all the characteristics of a system. Once one of them is lost, an organisation ceases existing. Thus, an organisation exists till it is a system. On the other hand, all existing systems take into accurate consideration all criteria as to be managed both partially and as a whole. In social system there are a number of mutual relationships and connections (line pattern, ring (functional) pattern, "wheel" pattern, hierarchical pattern, matrix pattern). One organisation can have different types of relationships. It can be illustrated by the way classes are carried out.

Using the line pattern, the teacher has no knowledge of the contribution each student makes into the final result. The ring pattern uses feedback and the teacher is enabled to control results. This method is used in full-time tuition.

The "wheel" pattern is a typical one. The teacher conducts lessons and corrects students.

The "star" pattern approaches each student individually. Students get individual assignments.

According to abilities of students and the form of studies (full-time, by correspondence, distant), the teacher is allowed to choose any pattern he/she considers the most effective.

By selecting and developing various forms and methods of studies, the teacher confirms his/her professional pedagogical level. So, determinig these criteria is a scientific task demanding management skills. These criteria are a basis of communication systems used for managing organisational systems. After selecting among these criteria, it is possible to put the knowledge students have into an algorithm. It points to how high the actual standard of a student's knowledge is and how correct the selected method was.

The training process characterised by exchange of information can be called an influencing communication. To carry out the influencing communication effectively, we should put into an algorithm social and economical and psychological data describing the relationships between a worker and his organisation. These descriptive traits include such social and psychological data as S - resistance, A - activity, I - selectiveness N – uncertainty with respect to the influence. By defining changes and interdependency of the data, we can find the most effective patterns for organising and conducting lessons.

References

1. Преображенский Б.Г. Оперативное управление в производственных системах: проблемы и ресурсы интенсификации. Воронеж: Издательство ВГУ, 1988. – 200 с.
2. Автоматизированные информационные технологии в экономике: Учебник / М.И.Семенов и др. М.: Финансы и статистика, 2000. – 416 с.
3. Автоматизированные технологии в экономике: Учебник / М.: Компьютер, Юнити, 1999. – 400 с.
4. Устинова Г.М. Информационные стстемы менеджмента. К.: Диасофт, 200. – 386 с.

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SYSTEMS OF SPECIALISTS CONTINUING TRAINING AS ONE OF THE MOST IMPORTANT FACTORS OF AVIATION SAFETY

The article deals with the continuing training offered by theInstitute of post-graduate education at the National Aviation Universuty. The author analizes purposes and the structure of upgrading and retraining courses,contents of the second higher education.

Actuality of the topic is accounted for by the fact that the market of the second higher education has an annual increase by 20-30 %.

The second economical education courses are taken by people with technical (54 %) and humanitarian degree (29 %).

According to surveys, 90 % of the population find an additional education necessary as it improves prospects.

As a rule, second educational courses are paid by employers.

The philosophy of the National Aviation University includes educational programmes of the multi-stage university education according to the principle "Life-long education".

An important factor for the system of life-long post-graduate education is the Institute of post-graduate training (IPT), its separate structure.

The objective of the post-graduate education is to be a leader in the field of post-graduate education of the country (number of students, specialities, standard of training, meeting customers' demands), brining good income.

The system of post-graduate education pays special attention to the quality of the education by managing it. It will make the system competitive. Another priority of the system is improving relationships with customers (inside and outside) by meeting their demands and treating them as both customer, supplier and partner. Of great importance is indtroduction of innovative techniques into training adults using both domestic and foreign experience of researches.

Tactics of the system of post-graduate education includes:

- investigations of the labour market and continual monitoring of the demand for promising specializations in the field of post-graduate education;
- data bank of supply of retraining and upgrading courses;
- presence at regional and foreign post-graduate education markets;
- common responsibility in all levels of the system;
- optimisation of the structure;
- financial management of any initiative.

There are two kinds of the second higher education:

1) second higher educatio;
2) additional special education.

For a second time can be educated people with the higher education degree of a specialist, bachelor, master as well as senior students of day-time study and study by correspondence. Students are admitted being interviewed without entrance examinations. Subjects that had been learned by the students are considered passed. Students who are successful with all subjects in the syllable and pass the attestation examinations get the second education certificate of adopted pattern according to qualification level: junior specialist, bachelor, specialist, master.

The additional special education includes:

1) retraining in a differemt speciality;
2) upgrading courses (100-50 hours);
3) short-term upgrading courses (18-100 hours);
4) specialisation and probation period.

Retrained can be people who are specialists or senior students of full-day study or study by correspondence. The retraining term is fixed according to the curriculum and amounts to 2-3 years. Students who are successful with all subjects in the syllable and pass the attestation examinations get the retrained specialist certificate of adopted pattern confirmed in the Ukrainian Cabinet of Ministers.

Upgrading courses (including the short-term ones) are taken by employees according to upgrrading curricula co-ordinated with them. Those who are successful with all subjects in the syllable the upgrading certificate of the state pattern.

Participants in the programmes on specialisation, probation period, workshops, roun tabled, trainings, get an IPT certificate.

Principles of the post-graduate education are specified in the statute of the IPT.

Contents of the education are established in:

1. The second higher education – training syllables, curricula, subject working syllables, individual plans, methodical aids.
2. Retraining – retraining syllables, curricula, subject working syllables, individual plans, methodical aids.

Training terms are fixed by:

1. The second higher education – the normative training period according to the professional grade and the curriculum.
2. Retraining – the normative retraining period according to the professional grade and the curriculum.
3. Upgrading courses, probation periods, workshops, round tables, trainings – appropriate syllables..

Forms of studies: day-time studies, evening-time studies, studies by corresponence, mixed studies (day-time and by correspondence), external studies.

Kinds of classes: lectures, laboratory and practical classes, consultations, workshops. An obligation is to use innovative methods for training adult people: round table, brain storm, group discussion, business group, problem diagnostics.

Principle of organising the structure:

1) vertical strategies for organising departments (second higher education, upgrading courses, employment centres etc.);
2) horizontal strategies of organisation according to the field of knowledge (economics and management, law, communication and computer technologies, aviation and astranautics, energetics, radio engineering, electrical engineering, transport technologies etc.);

3) Relationship of vertical and horizontal structures and permanent control of income.
4) Single system of planning and organising – "management of projects".

In 2000 the National Aviation University and its upgrading faculty in operation since 1938 founded the Institute of post-graduate education retraining and upgrading specialists.

The second education includes such licensed specialisation of the university as economics, transport technologies, communication and computer technologies, power engineering, radio engineering, electronics, aviation and astranautics, law, culture. Students can select among different forms of studies: day-time studies, mixed studies, studies by correspondence, individual studies, corporate studies. The Institute has adopted the credit and module system studies. The principal curriculum has additional modules: eurolanguages, eurointegration, logistics, international quality system etc. Students are enrolled throughout the year, classes begin as soon as groups are formed.

The Institute offers over 200 upgrading courses and workshops. Courses are planned according to modern methods including object-setting, initial audit, developing of modules, evaluating of results, object-monitoring. Courses are offered both at the University and at the customer's territory.

The customers are aviation officials, industrial business, financial organisations, banks, insurance companies, oil companies, educational establishments.

The Institute comprises centres: labour safety, applied ecology, training of property valuers, yachtsmen, auto school.

The Institute collaborates with employment centres retraining and upgrading unemployed people.

The Institute operates in other countries upgrading specialists in Russia, the Middle Asia, the Baltic countries, Transcaucasia, Asia, and Africa.

The faculty of the Institute is made up of leading specialists of the University and other educational establishments.

The Institute uses up-to-date multimedia lecture-halls, computer classes, lingaphone rooms meeting the ICAO requirements. The students are offered technical library, the world largest training hangar, hotel, dining-hall, medical centre, sports facilities.

The Institute is a member of the intergovernmental association of post-graduate education.

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