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RANKING OF THE TECHNICAL CONDITION OF AIRCRAFT ACCORDING TO THE DIAGNOSTIC DATA OF THE GLIDER DESIGN

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Abstract. Analysis of the data obtained through non-destructive testing of the power elements of the airframe structure enables the division of the studied aircraft into separate groups based on operational methods and, accordingly, predicts the probability of trouble-free operation of the airframe structure. Based on a bionic logical analysis of data on the technical condition of the aircraft's airframe design, the article considers methodological approaches to building the author's mathematical model of ranking the aircraft fleet. The ranking of the technical condition of aircraft serves as the basis for solving the problem of preparation, making a decision on extending the service life and taking into account the aging of the airframe design in operating conditions. The application of the proposed set of methods will create and establish a practical and effective system of intelligent support for decision-making on aircraft operations.

Keywords: technical condition of the airframe, strength, operation of aircraft, control systems, decision-making.

INTRODUCTION

Digital systems with classical methods of management, which are mainly focused on practice, except for the frequent productivity of micro-processing systems. A significant increase in the efficiency of such systems can be reached by the implementation of adaptive control algorithms. Adaptation of a living organization, which is designed to change the internal and external minds, is an analogue for the construction of the structures of technical systems with the establishment of the system of control for the change of internal and external parameters up to the criterion of regulation. Based on the classical methods of management, for the implementation of an adaptive control system, the necessary visibility of the great need for the analysis of the preliminary information for the skin-specific regulator, to develop a mathematical model and an adequate algorithm for assessing the parameters of the model, which is to add a folding problem for traditional approaches.

Fuzzy control is based on the rules formed by an expert who has some experience in a particular technical direction, and from the point of view of control system technology, fuzzy control is a regulation with a nonlinear gear response.

Thus, a management system based on fuzzy logic is not blind control using one or another law of regulation, but management with a current analysis of the situation and meaningful decision-making to issue a regulation signal, guided by common sense, that is, the most adequate response to a comprehensively assessed control error. These are minimal transients. This is high flexibility, reliability and efficiency and simplification of control compared to adaptive and self-learning control algorithms [1].

TASK STATEMENT

Management of the aircraft operation process requires the fulfillment of the conditions for ensuring the required level of flight safety and involves the adoption of organizational and technical decisions to maintain aircraft in good condition. The resource and reliability of aircraft is largely determined by the technical condition of the carrier elements (CE) of the airframe design. The results of the CE assessment according to the control data allow distributing aircraft into separate groups (classes), for which there are flight safety solutions obtained by performing strength calculations and based on operational experience. In practice, the known methods and algorithms for making decisions on the further operation of aircraft are reduced to the problem of formal choice of an alternative [2].

When making decisions, three main tasks are solved:

- ordering alternatives;
- distribution of alternatives by classes of solutions;
- highlighting a better alternative.

For example, such classes and, accordingly, solutions can be:

- aircraft meet flight safety requirements and do not require additional restoration work;
- it is necessary to carry out restoration work of various purposes and scope (repair at aircraft repair enterprises, extension of the assigned service life, transfer to operation according to technical condition, etc.);
- further operation of the aircraft is inexpedient due to the loss of the necessary operational characteristics of the CE of the airframe design.

The imperfection of the known methods of decision-making lies in the fact that information about the technical condition of the aircraft is characterized by the peculiarity of incompleteness and limited volumes of operational data, which significantly affects the validity of decisions in the management of the aircraft operation process.

Problematic issues of classification of aircraft into separate groups depending on the results of airframe control carried out in the conditions of operating parts have not been studied in technical diagnostics. Therefore, there is a need to develop methods for classifying aircraft that will increase the reliability of decisions made by an official (decision-maker – hereinafter referred to as DM) for a specific situation based on the results of control inspections of the airframe.

One of the directions for the development of methods for classifying airframe is the development of a mathematical model of bionic processing of experimental data, which simulates the mechanisms of functioning of biological systems and allows DM to understand the validity and expediency of various options for decisions when making decisions.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Decision support systems are a qualitatively new level of automation of management processes in various areas of human activity.

Thus, in the work [3], a classification model has been developed that is able to accurately identify diseases and provide appropriate recommendations for patients. The proposed system uses a multi-level classification mechanism with appropriate prediction of changes in the patient's vital parameters.

In the process of operation of aviation equipment, as a result of control inspections, many values of parameters are determined that characterize and allow to assess the strength of the aircraft airframe structure.

In geometric interpretation, the technical condition of the airframe can be represented as a point in multidimensional space, the coordinate axes of which correspond to the control parameters.

The mathematical model of such a description of the technical condition of the airframe does not allow to provide the DM with the necessary data on the regularities of the airframe operation process in an accessible visual form, since it does not take into account the peculiarities of the mechanisms of human information processing.

The paper [4] shows that a person perceives the environment with the help of an internal figurative representation, his imaginary model is aimed at analyzing information by generalizing, identifying the dependence between its individual parts, searching for associative connections with previously made decisions.

The internal model of DM is difficult to identify and formally describe the transformations that are carried out when generalizing the acting factors and forming images, transforming multidimensional data and obtaining estimates of objects in a one-dimensional scale of values (from “minimum” to “maximum”, from “bad” to “good”, etc.).

In the same work, it is noted that when processing control data with statistical methods of pattern recognition, intuitive and understandable judgments of people about the trends in changing the parameters of the processes under study are used, that is, there is a transition to one-dimensional scales. In the works on psychology, the position that reveals the features of human processing of information in the form of images is substantiated. This pattern allows you to develop the structure of the bionic model, consisting of an interconnected set of modules that take into account subjective aspects and allow you to simulate the processing of information in the semantic image space of the subject area of the environment.

PRESENTATION OF THE MAIN MATERIAL

When solving the problems of monitoring the technical condition of the CE of the airframe structure, the subject area consists of numerical and linguistic values of the database on crack sizes, depth and area of corrosion, dimensions of deformation of the CE, coordinates of the damage site, normative data on tolerances, service life, etc.

The use of identification procedures in the assessment of technical condition allows you to evaluate parameters when their dimensionality is precisely known. At the same time, the calculation of the difference between the reference and the actual state, i.e. the performance of a comparison, is a necessary operation of the process of localization of the technical state. In addition, the number of parameters that characterize the technical condition is often unknown. Therefore, the disadvantages of existing diagnostic technologies and decision-making systems include the need to form requirements for experimental information about dynamic changes in the system, the use of which will allow classification and comparison of possible technical states.

The structure of the bionic model, consisting of separate modules, shown in Figure 1, uses the principles of vector information processing by a universal mathematical model for biological systems, as well as the principles of logical transformations of information performed by a person during the solution of intellectual problems [5].

To solve the problems of classification of aircraft according to the data of airframe parameter control, three vector spaces F_1, F_2, F_3 are needed, the dimensionality of which is determined by the number of parameters of the subject area of control.

The first space F_1 is created by estimates of the indicators of loss of strength of the CE based on the data of visual and non-destructive testing means of each individual CE, the results of computational and experimental studies of the strength of the CE (Fig. 1).

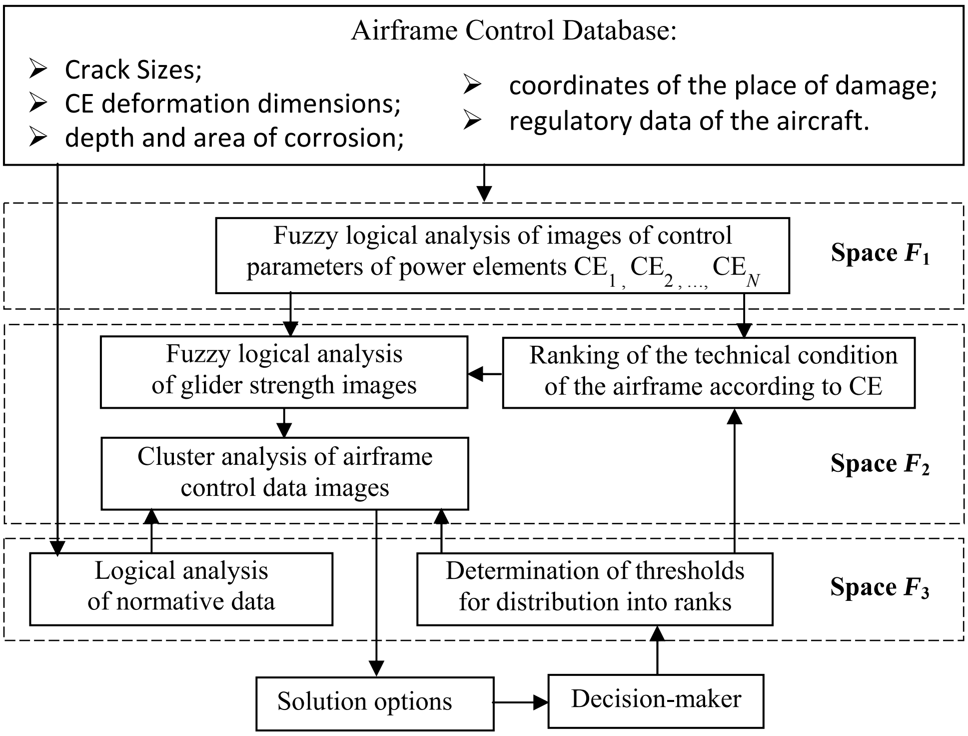

Fig. 1. Structure of the bionic model of data analysis

Due to the incompleteness and limited volume of operational data, the results of assessments of CE strength loss indicators are characterized by the presence of intervals of uncertainty of values. In addition, the assessments contain errors due to the subjective experience of a person working with control materials. Therefore, final decisions on strength loss assessments require amendments and adjustments.

Such clarifications can be carried out taking into account the use of psychological qualities of a person, use the criterion of approximate similarity of objects, i.e. vague logical conclusions when searching for such objects. The work [6] shows that the property of fuzziness of logical thinking helps a person to solve practical problems.

In the modules of the bionic model, which solve the problem of estimating the indicators of loss of strength of CE, operators for processing fuzzy logical dependencies based on the methods of fuzzy set theory are used [7]. Performing a fuzzy analysis of the control results allows you to transform the multidimensional description of the control data and move to a one-dimensional rating scale.

The model provides for the use of the second vector space F_2, where, based on the results of the control of individual CE, a generally fuzzy logical analysis of data images of the technical condition of the entire airframe structure is performed.

Determination of cases in which the values of the strength factors go beyond the tolerances is carried out using the methods of mathematical binary logic, which uses logical operators for calculating predicates.

In the space F_2 the property of a person to group and rank CE according to control data is simulated. The dimension of the space F_2 is determined by the number N – the total number of CE.

The number of CE classes that are formed depends on the values of the thresholds set by the DM. Therefore, the corresponding module of the bionic model also uses the method of fuzzy information processing, which takes into account the subjective representations of the DM.

The CE classification module uses an algorithm based on the principles of taxonomy of objects described in the paper [7] and takes into account that a person perceives the results of classification regardless of the geometric shape of the class in the multidimensional space of features.

Space F_3 takes into account additional information about the airframe operation process, it is here that the ranking of the technical condition and the preparation of draft decisions are carried out. The dimension of the space F_3 is determined by the number of normative numerical data and estimates of linguistic variables obtained by calculation when controlling the loss of strength.

Next, the construction of a mathematical model of the ranking of the technical condition based on a fuzzy logical analysis of the parameters of the glider control is considered.

In the module of fuzzy logical analysis of images of control parameters CE, a linguistic variable is introduced d_f = “difference in strength CE from the norm”. The universal set of d_f is the segment [0 1], and the set of values for d_f is the term set $G = \{G_1, G_2, G_3, G_4, G_5\}$, where G_1 — practically coincide; G_2 — small difference; G_3 — average difference; G_4 — big difference; G_5 — the maximum difference.

The number of discrete states of the term set G is chosen in accordance with the ability of the human operator to simultaneously perform operations with 5... 7 objects that belong to different images.

As a function of belonging $\mu(d_f)$, the formula (1) of a trapezoidal fuzzy number $d_f = (a_1, a_2, a_3, a_4)$:

$$\mu(d_f) = \begin{cases} 0, & \text{if} \quad d_f < a_1; \\ \mu(d_f) = \exp(-\exp(-(d_f - C_1))), & \text{if} \quad a_1 \le d_f < a_2; \\ 1, & \text{if} \quad a_2 \le d_f \le a_3; \\ \mu(d_f) = \exp(-\exp(-(d_f - C_2))), & \text{if} \quad a_3 < d_f \le a_4; \\ 0, & \text{if} \quad d_f > a_4; \end{cases} \qquad (1)$$

where C_1, C_2 — the displacement coefficients of the function (1) along the axis d_f.

The sides of the trapezoid are formed on the basis of the functional dependence

$$\mu(d_f) = \exp(-\exp(-d_f)). \qquad (2)$$

The dependence (2) approximates the assessment of observations in various subject areas of the experimenters' real decisions on the admissibility of research results. Dependence (2) has the beneficial properties of continuity, monotony, and smoothness.

The value of the belonging function $\mu(d_f)$ is perceived as a measure of the truth of the term G_i, which is established by experts in the subject area of aircraft operation. Fig. 2 shows the distribution of belonging functions to the linguistic variable d_f.

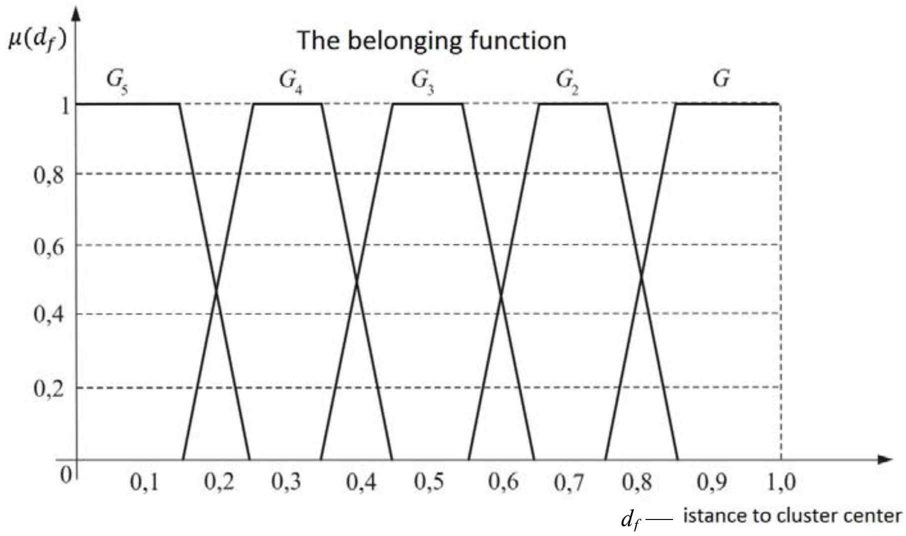

Fig. 2. Membership functions of subsets of the term set *G*

To analyze the dependence of the distance d_f on the parameters of the v_i of the first vector space F_1, a linguistic variable B_i is introduced, which, by analogy with the term set G, consists of the following terms:

B_{i1} — very small difference between the parameters of v_i;

B_{i2} — a slight difference between the parameters of v_i;

B_{i3} — average level of difference in v_i parameters;

B_{i4} — a significant difference between v_i parameters;

B_{i5} — a very significant difference between v_i parameters.

The volume of the database used during processing is determined by the elements of the set $V = \{v_1, v_2, ..., v_l\}$, where the list of parameters v_i $(i = 1,...,l)$. The number of parameters *l* is set by experts taking into account informal methods of describing the subject area.

It is also assumed that each linguistic variable is described by a trapezoidal fuzzy number $v_i = (a_1, a_2, a_3, a_4)$. Thus, a two-dimensional array of fuzzy linguistic variables $B_{i\kappa}$ $(i = 1,...,l;\ \kappa = 1,...,5)$ is created.

To form the rules for the transition from the values of the parameters to the values of the variable itself d_f in accordance with [7], an approximation of fuzzy logical inference rules is carried out using the formula

$$d_f = \sum_{k=1}^{5} h_k \overline{d_{f_\kappa}},$$

where $h_k = \sum_{i=1}^{l} (1/l)\mu_{lk}$ characterizes the influence of each term of the linguistic variable G_k; $\overline{d_{f\,k}}$ — is the middle of the interval on the d_f axis, at which the values of the term $G_k \in (a_{k1}, a_{k4})$ are non-zero.

The module of fuzzy logical analysis of glider strength images is built by the method of designing and debugging fuzzy knowledge bases, which are sets of linguistic or logical operators.

The logical formula for determining the value of the loss of strength σ the airflame is built on the basis of the logical operator "TA" $(\wedge)$ and thevalues of the term set G of individual CE_i ($i = 1,...,N$):

$$\sigma = \min \mathop{\wedge}_{i=1}^{N} d_{fi}.$$

The module for ranking the technical condition of gliders by CE selects such homogeneous subsets in the initial multidimensional data so that the objects within the groups are similar in known content to each other and have the same dimension, and the objects from different groups are not similar.

The module uses an algorithm that provides for the construction of the shortest open path between the vertices of the graph in the space F_2. The distance between the vertices of the graph is calculated by the method of potential functions [8].

Mathematical models of F_3 space modules are developed using methods that are used in F_2 space modules.

Effective application of the proposed mathematical model in the existing operation system can be, for example, when determining the timing of periodic maintenance. Thus, depending on the actual technical condition and the results of ranking by power elements, the deadline for work may be postponed. For example, for a specific aircraft, the technical condition of which is characterized by such variables as G_1, B_{i1}, i.e. loss of CE strength, there is no deterioration of the condition, the design is ranked as serviceable, the airframe meets the requirements of flight safety and does not require additional restoration work, the DM in the technical condition management system decided to increase the terms of performance of the relevant periodic work from 3 months to 6. This made it possible to save and efficiently allocate the resources necessary for the technical support of the operation process.

CONCLUSION

The application of the developed mathematical model for classifying the ranking of the technical condition on the basis of bionic logical analysis of airframe control data as part of the mathematical support information systems for managing the technical condition of aircraft will improve the quality of organizational and technical decisions made.

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РАНЖУВАННЯ ТЕХНІЧНОГО СТАНУ ПОВІТРЯНИХ СУДЕН ЗА ДАНИМИ ДІАГНОСТУВАННЯ КОНСТРУКЦІЇ ПЛАНЕРА / А.С. Бологін, Ю.О. Бологіна, Ю.М. Тимчук

Анотація. Аналіз даних, які отримують за допомогою засобів неруйнівного контролю силових елементів конструкції планера, дозволяє розподілити досліджені повітряні судна на окремі групи залежно від методів експлуатації і, відповідно, прогнозувати ймовірність безвідмовної роботи подальшої експлуатації конструкції планера. На основі біонічного логічного аналізу даних про технічний стан конструкції планера літака розглянуто методичні підходи побудови авторської математичної моделі ранжування парку повітряних суден. Ранжування технічного стану повітряних суден покладено в основу вирішення завдання підготовки прийняття рішення про продовження терміну служби з урахуванням старіння конструкції планера в умовах експлуатації. Застосування запропонованого комплексу методів дозволить створити і налагодити дієву та ефективну систему інтелектуального підтримання прийняття рішень про експлуатацію повітряних суден.

Ключові слова: технічний стан планера, міцність, експлуатація літальних апаратів, системи керування, прийняття рішень.