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METHODOLOGY OF AIRCRAFT COMPONENTS CONTINUING AIRWORTHINESS CONTROL MODELS DEVELOPMENT

The paper develops a method intended for practical use in conditions of high uncertainty. The basis of the method are special procedures for evaluating the properties of aircraft components that use quantitative values of intuitive – qualitative assessments. Development of the model focused on the use of information technologies to manage maintenance and repair processes. The main idea of such approach is to maintain the inherent reliability of reliability of aircraft functional systems and components, avoid unnecessary maintenance tasks (monitoring generally more effective than hard-time overhaul) and provide increased efficiency. The method of obtaining values for unknown indicators is to use a priori interval estimates of these indicators, followed by the calculation of a posteriori estimates in accordance with the accumulating information is offered in this article.

Such consistent solution of the tasks, depending on the accuracy and reliability of the available information, is the base of the adaptive managing process of the technical condition of the AC components. [dx.doi.org/10.29010/89.12]

Keywords: *airworthiness; aircraft; maintenance.*

1. Introduction

The formation of the reliability of aircraft (AC) components is a complex process that depends on technical and organizational factors that cover the stages of design, production and operation. To ensure the high reliability of the components of the AC, it is necessary to control the process of its formation, influencing its individual stages and controlling the effectiveness of the control effects. The stages of the life cycle of the AC components cannot be considered separately, they are interconnected and are the elements of a single control system [1–3].

Work performance at different stages is accompanied by decision taking that has specific features at each stage, but they are closely interconnected with the totality of decisions made at different stages of the product life cycle. Thus, the issues of the AC components maintenance (M) are already envisaged at the design stage: ensuring full access to the structure for the maintenance, installation of an optimal system for monitoring and diagnosis of the AC components, ensuring compliance with the requirements of economy, usage efficiency, labor costs, etc. For instance, MSG-3 (Maintenance Steering Group) principles are widely used in the AC scheduled maintenance development stages, which are based on various methods of monitoring the technical condition of components [4]. The main idea of such approach is to maintain the inherent reliability of AC functional systems and components, avoid unnecessary maintenance tasks (monitoring generally more effective than hard-time overhaul) and provide increased efficiency. It should also be noted that operational objects at different stages have miscellaneous information support of its properties, which requires the usage of modern methodological approaches in optimizing solutions [5–7].

2. Model formation

The operation of complex technical systems under operational conditions, which provide for the general prevention and preventative replacement of components, maintenance and repairs – MRO (maintenance repair & overhaul), are described by a number of models that have a scholastic nature. Controlled random processes apparatus is widely used to investigate these models. This dynamic task management investigated when decisions are taken, depending on the background or, in markivsky case, depending on the state of the process at this time. In the mathematical study and MRO strategies management, they usually offer a number of possible restorative work in the system and the task of selecting MRO strategies and their implementation terms. All this is solved taking into account the objective characteristics of the reliability of the systems, the nature of the failure indication, the presence of integrated performance monitoring, specific features of operating conditions, etc. [8–10].

Analysis of the most typical mathematical models of prevention shows that they allow to evaluate the influence of system management measures only on the specific characteristics and properties of technical devices, with assumptions that do not fully reflect the operating conditions of the AC components. Thus, in many cases, the fault-free systems characteristics and components are determined in the function of only one maintenance frequency, and the completeness of the maintenance and control are taken as one. In other cases, the fault-free characteristics are determined depending on the completeness and frequency of only one mode of operation, namely, on a very limited part of the technical life cycle of the product. In practice, in most cases, there is a multi-stage maintenance, which has different types (nomenclature) of works, and each type is different in its importance of control and restoration completeness and periodicity [11, 12].

For comprehensive counting of the influence of the control effects on the characteristics and properties of the operation's objects, it is necessary to develop a more modern methodological approach to the AC components condition control, which will allow to determine the optimal control impacts taking into account all operational factors.

The paper develops the method of "prescriptive decisions", which is intended for practical use in conditions of high degree of uncertainty. Specific procedures for evaluating the properties of AC components using quantitative values of intuitive-qualitative estimates are taken as the basis of the method.

The full scope of work with MRO is a set Q, which is divided into a number of subsets Q_i — types of maintenance (line, base, time-consuming, repairs), which differ in the set of controlled parameters — P_i, the nature of maintenance works and the frequency of their execution. Scheduled works are performed repeatedly and consists of:

- continuous monitoring of the components state in the process of use of multiple parameters P_i;
- carrying out works to ensure departure Q_v and the technical condition control from the parameter P_v;
- periodic monitoring of the AC components state from the sets of P_{p1}, P_{p2}, .. P_{pi}; .. P_{pk} and carrying out of preventive-restorative works after working out by products certain operating time Δt_{p1}, Δt_{p2}, ..., Δt_{pi}, ... Δt_{pk}, or duration of operation $\Delta\tau_{pi}$ in volume Q_{pi}.

Full control for the detection of all N states is a set $P_N = \{P_1\ P_2\ ...\ P_N\}$, but global verification is not always possible and not always expedient. In this regard, we use the system of checks K_i according to certain parameters (P_N; P_v; P_{pi}).

To control the process of changes in the properties and characteristics of the operational objects, it is necessary to determine the possible control effects $V_N = \{V_1\ V_2\ ...\ V_N\}$ — the vector of control effects, and to optimize the organization of their carrying out with given constraints to obtain the determined values of the output vector H^T at minimum operational costs [13].

To control the technological processes of the MRO components of AC, it's necessary to specify the duration of any operation and its laborious, which allows to quickly manage the number of staff, taking into account all the variety of products that are in maintenance at the current time.

With the increase in operational information and the increasing complexity of AC components, further improvements are needed in both AC design and MRO organization, as well as the creation of more up-to-date computer and information technologies to solve maintenance control issues.

In addition, the formation of optimal MRO modes (as the task of choosing the optimal alternative to providing a given failure-safe functional systems of aviation engineering (AG)) requires the development of a minimum of two models: models of product functioning (on the basis of which the optimal MRO regulation is formed) and model of their recovery process (based on which is governed by technological processes of maintenance). These models must be interconnected so that the objective function of the recovery process model is an argument of the function that describes the process of of the AG system functioning.

To distinguish a particular structural element of a system from a plurality of other elements, each element is given a formal distinguishing feature — a code. The element code can look like both a numeric and alphanumeric identifier.

The use of code is equivalent to providing a lots of information about the characteristics and properties of system elements, as well as the nomenclature, the structural arrangement of elements that make up a complex system A set of factors is written in a very clearly defined sequence that forms an ordered set — a tuple:

$$Y = \prec x_1\, x_2 \ldots x_n \succ. \qquad (1)$$

The use of a tuple is convenient for recording information about an object in the automated solution of practical problems because each component of the tuple occupies a clearly defined position in it, and allows to record and search information more efficiently and quickly [14].

To form a short complex characteristic of the operational properties of the components of the AC, we select "n" features. It was assigned to each "m" states. Then the complex characteristics of the operational properties of the AC component can be given in the form:

$$V_K = \{X_1^{i_1}, X_2^{i_2}, \ldots X_n^{i_j}\}, \qquad (2)$$

where, $i_j \begin{pmatrix} j = & \overline{1 \div n} \\ i = & \overline{1 \div m} \end{pmatrix}$ — states j signs.

The total number of possible reliability characteristics of the AC components is measured in the range of several thousand, each of which corresponds to one or another operational impact strategy and optimal maintenance mode.

It is quite difficult to determine the optimal MRO mode for each component under the conditions of organization of AC maintenance and economic implementation. It is practically possible to distinguish a small number of maintenance modes and to define for each mode a list of components of the aircraft that require maintenance. There will be losses, which can be determined by the degree of deviation of the optimal modes of maintenance from possible realizations in practice.

If we determine the optimal "basic" properties and characteristics of "perfect" products and their corresponding strategies of previous maintenance

$$V_B = \{B_1^{i_b}, B_2^{i_b}, \dots B_n^{ib}\}, \quad (3)$$

then, based on comparing and evaluating the degree of deviation of the characteristics of the AC components from the base vectors, a number of problems can be solved.

This decision-making approach allows to combine optimization with forecasting, with not directly predict the model parameters, but also input to a mathematical model that serves to determine the optimal combination of properties of the object of operation.

Accepting this hypothesis, the question "what will be the parameters of the object?" is replaced by "what should be the parameters?" and allows considered two separate tasks — forecasting and optimization — to lead to one common task. When combining direct forecasting with optimization, there is an opportunity to actively and effectively manage the quality of AC components in accordance with their accepted target function, instead of passively observing its change in the past when forecasting by the extrapolation method.

In general, the objective function looks like:

$$C = C\{x_1^{i_1}, x_2^{i_2}, \dots x_n^{i_m}, B_1^{i_b}, B_2^{i_b}, \dots B_n^{i_b}\}. \quad (4)$$

During changing the object's settings over time:

$$V_K(t) = \{X_1(t), X_2(t), \dots X_n(t)\}, \quad (5)$$

the objective function is also the time dependent. The effect of the operation of the AC components with possible changes in properties is determined by the expression:

$$\AA = f_e \sum_{j=1}^{n} [x_j^i(t) - B_j^i(t)];\ j = \overline{1 \div n}. \quad (6)$$

One method of obtaining values for unknown indicators is to use a priori interval estimates of these indicators, followed by the calculation of a posteriori estimates in accordance with the accumulating information.

Such consistent solution of the tasks, depending on the accuracy and reliability of the available information, is the base of the adaptive managing process of the technical condition of the AC components.

Methods of theoretical description based on the theory of vague sets, introduced by L. Zade and R. Bellemann, are used to describe the uncertainty and justify the interval boundaries that determine the quality of a component [15–16].

3. Conclusions

Introduction of this approach into practice will ensure the effectiveness and purposefulness of control impacts that contribute to improving the quality of MRO and the efficiency of use of both, aircraft components and aeronautical equipment in general.

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МЕТОДОЛОГІЯ ПОБУДОВИ МОДЕЛЕЙ УПРАВЛІННЯ ПІДТРИМАННЯ ЛЬОТНОЇ ПРИДАТНОСТІ КОМПОНЕНТІВ ПОВІТРЯНОГО СУДНА

В роботі розробляється метод, призначений для практичного використання в умовах високої ступені невизначеності Основою методу являються спеціальні процедури оцінки властивостей компонентів повітряного судна, які використовують кількісні значення інтуїтивно-якісних оцінок. Такий підхід для прийняття відповідальних рішень дозволяє поєднувати оптимізацію з прогнозуванням, при цьому безпосередньо прогнозуються не параметри моделі, а вхідні дані в математичну модель, яка послуговує для визначення оптимального поєднання властивостей об'єкту експлуатації. Побудова моделі, орієнтованої на використання інформаційних технологій керування процесами технічного обслуговування і ремонту. [dx.doi.org/10.29010/89.12]

Ключові слова: *льотна придатність; повітряне судно; технічне обслуговування.*

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