АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА

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NEW APPROACHES OF FACTORS CLASSIFICATION WHICH AFFECT THE RELIABILITY OF AIRCRAFT

The article examines the methods and approaches to the qualification of factors targeted at their influence on the aircraft reliability. Approaches are evaluated with the view of the possibilities of their practical implementation and the prevention of the appearance of defects on aviation equipment.

All factors that characterize the actual operating conditions and affect the technical condition of the aircraft, can be divided into two groups: objective and subjective. On the other hand, the factors that influence the change in the technical condition of the aircraft can be divided into design-manufacturing, which determine the initial quality of objects, and operational, which reflect the change in the technical condition during operation. Operational factors play a decisive role in changing the technical condition and reliability of aircraft, because the level of reliability of aircraft equipment is determined during the operation. Operational factors can be divided into 3 groups: groups of loading (objective) factors; groups of ambient conditions (factors); human factor groups. Operational factors determine a wide variety of processes that change the technical condition of objects and lead to complete or partial loss of performance. There are three main types which degrade device performance capabilities: fast-flowing processes, medium-speed processes and slow-flowing processes. Fast-flowing processes end within the machine cycle and have a periodicity of change, which is usually measured in fractions of seconds. The medium-speed processes take place during the continuous operation of the machine and their duration is usually measured in minutes or hours. Slow-flowing processes take place throughout the entire period of operation. The variety and stochastic nature of the influence of operational factors on the objects of aviation technique lead to the fact that with the same lifetime or service life the objects have a different actual technical condition, which, naturally, should be taken into account when developing strategies for the maintenance and repair of these objects.

Key words: *aviation technique, reliability, factors, operational factors, loads, processes, flight safety.*

Problem setting. Always in all airlines of the world in the first place is the safety of flights (transportation of goods, passengers, etc.). A very important role is played by the maintenance of aviation equipment; it is a complex dynamic stage of operation that includes a number of interrelated functional processes [1].

During the operation of the aircraft, their units, aggregates and parts are constantly influenced by a number of factors that affect their technical condition in a different way, and therefore their operational reliability and performance.

Analysis of recent research and publications. The most significant results in this direction are reflected in the work on automating the aircraft maintenance system and improving the reliability of aviation equipment (A.A. Komarov, R.M. Salimov, N.N. Smirnov, A.A. Tamargazin), on engineering psychology and the human factor (V.G. Denisov, M.A. Kotik, B.F. Lomov, V.V. Pavlov, A.V. Skripets, G.P. Shibanov).

Maintenance products are not any new products, but completed works provided for by the manufacturing task. The maintenance quality reflects the labor quality of engineering and technical personnel of aircraft maintenance facility [2].

The labor quality is influenced by a significant number of factors. The main groups of factors that have a decisive influence on the labor quality of the maintenance personnel [3].

Nowadays, methods and models describing the maintenance processes, in particular, on the basis of

semi-Markov processes with a finite set of states [4], the generalized structural method [5], the use of game theory [6], the plotting and analysis of causative-consecutive graphs [7], situation evaluation trees [8].

In reference textbook [9], the study of the aircraft reliability is reduced to considering the reliability of the aircraft, taking into account the activities of the maintenance personnel**.**

However, today this task remains unresolved, since the approaches to its analysis are very diverse and depend on a correct, competent analysis of the specific situation and the conclusions of research.

Task setting. Further research requires a return to the classification of operational factors affecting the aircraft reliability. It is the correct prioritizingand its influence, competent research trends and in-depth analysis of the obtained results that can solve a specific problem.

The difficulty is in detailing the conditions for determining the object of research. However, the use of deterministic approaches in combination with the correct modeling techniques can greatly facilitate research.

Statement of basic materials. All factors that characterize the actual operating conditions and influence the technical condition of the aircraft can be divided into two groups: objective and subjective.

The objective are: the influence of the environment, mechanical and other external actions on the structural elements and components of functional systems.

The subjective include those that are to some extent dependent on the person. This could include the construction scheme solutions for the design; selection of materials and design elements; normal operation modes; strategy, methods and maintenance conditions, etc. As a rule, these factors are the causes of sudden failures.

On the other hand, the factors that influence the change of the technical condition of the aircraft can be divided into design-manufacturing, which determine the initial qualities of the objects, and operational, which reflect the change in the technical condition during operation.

The design-manufacturing factors include:

– selection of schematic and design solutions, elements and materials;

– manufacturing technology of parts and units, assembly and testing of objects;

– manufacturing quality;

– characteristics of ongoing and output controls.

Operational factors play a decisive role in changing the technical condition **and aircraft reliability. It is during the operation that the level of this reliability is** determined.

Aircraft are operated in specific conditions that are significantly different from the work of overland transport. This specificity is outlined as follows:

– a significant complication of working conditions, that is, an increase in the number of active loads and their absolute values (temperature, pressure, vibration, etc.);

– rapid change in time and space of factors acting on the aircraft (voltage, temperature);

– a wide range of changes in these factors (aerodynamic loads, overloads, temperatures, etc.).

Classification of operational factors that affect the technical condition of the aircraft and engine

Operational factors can be divided into several groups [10].

Groups of loading (objective) factors, h.e. factors associated with the characteristics of the aircraft use and the conditions of its flight operation:

1. *External load*: aerodynamic loads, overloads, pressures, vibrations, acoustic loads, aerodynamic heating, heating from a operating power plant, electrical loads.

2. *Modes of operation* of aircraft engines and functional systems.

Group of ambient conditions (factors):

1. *Environmental withstand*. These include temperature, pressure and humidity of atmospheric air, their daily and annual fluctuations, changes and differences in height and length of the route, precipitation (rain, snow, ice, fog), air saturation with aggressive substances (salt, alkali, etc.).

2. *Conditions that characterize the state of the airfields*: dustiness of the atmosphere, quality of coverage of runways and taxiways, degree of their purity, presence of precipitation on them, etc.

3. *Biological factors*: mold, insects, rodents, birds. Mold causes rotting of materials of organic origin. Rodents and insects litter systems and aggregates, eat insulation, processing details, etc. Birds get into the engine, damage the glazing and coating.

Human factor group:

1. *Flight operation conditions, flight crew performance*: the number of takeoffs and landings, the use of flight modes and engine operating modes, the ability to act correctly in abnormal operations and specific flight conditions, the ability to adequately prepare for flight and correctcomputation of it, etc. These factors depend on the level of training and preparation of flight personnel.

2.*Maintenance quality*: organization of operation, qualification of the engineering and technical personnel,

quality and timeliness of maintenance and repair work, special characteristics of transportation and storage.

During maintenance, on the one hand, the condition of the systems, units and aircraft assemblies are improved and malfunctions are prevented (oil refilling, monitoring of parameters, etc.), while, as a result of poor-quality work, their technical condition may deteriorate and even a malfunction can appear.

Depending on the nature of the impact on the technical condition of the units and systems, two more separate groups of factors can be identified.

1. The initial quality of materials that are used (fuel and lubricants, etc.): the degree of oxidation and aging, contamination by foreign particles, the presence of moisture, etc.

2. Temporary material changes. This is primarily an aging process, that is, a process of slowly changing the physicochemical properties of materials. The speed of the aging process can change under the influence of ambient factors: heat, vibration, oxygen, ozone, moisture, etc.

For many materials, the aging process proceeds without visible signs of deterioration in the properties of materials. These changes accumulate and in some cases can lead to sudden damage. To the greatest extent aging materials are amenable to materials of organic origin.

In each of the three states in which an aircraft can be (in flight, on the ground, during maintenance), a specific group of factors to a given state affect its systems and aggregates, and the degree of influence of these factors is different.

Thus, in flight, operational factors associated with the peculiarities of the application and the conditions of its flight operation, climatic factors and factors connected with the flight crew operation, quality of fuel and lubricants act on the systems, units and parts of the aircraft.

The factors that affect the aircraft on earth include climatic, biological, hourly factors, the state of airfields, etc.

The influence of operational factors on the technical condition of objects is in the form of deviations from the nominal of their parameters as a result of wear, aging of parts and misalignmentof aggregates. These factors are the causes of slow failures.

Classification based on the principle of uniformity of the physical essence of damage processes. All the above-mentioned operational factors cause a wide variety of processes that change the technical condition of objects and lead to complete or partial loss of efficiency. There are three main types of deteriorating a device performance: fast-flowing processes, medium-speed processes and slow-flowing processes. Each of them deserves separate attention [11].

Fast-flowing processes have a rate of change reoccurrence, which is usually measured in fractions of seconds. These processes end within the machine cycle and reappear during the next cycle.These include the vibration of units, the change in friction forces in moving joints, fluctuations in workloads, and other processes that affect unit's collocation at any specific time and distort the machine's work cycle.The origination of fast-flowing processes is due to complex physical interactions that occur during the operation of mechanisms, friction in guide elements, etc. On an aircraft, vibrations caused by nonequilibrium of engines masses and units that rotate can be attributed to fast-flowing processes; pipeline vibrations due to both mechanical vibrations and parametric excitation; changes in friction forces in bearings, moving parts of units, for example, pumps; pressure pulsation of the working fluid as a result of its uneven representation by pump; acoustic oscillations that are caused by the exhaust gas stream.

The medium-speed processes take place during the continuous operation of the machine and their duration is usually measured in minutes or hours. They lead to a unvaried change in the initial parameters of the machine. This causes the occurrence of parametric or slow malfunctions and failures.

Examples include changes in ambient temperature and temperature of service fluid in systems during the flight; change in the temperature of the working units of engines and body; change in air pressure inside and outside of pressure cabins. All of these changes are reversible processes.

Among the irreversible processes of this type, we can call the process of changing the physical properties of the working fluid, the progress of which accelerates with increasing temperature; changing the physical properties of organic materials, rubber and other processes.

Slow-flowing processes take place throughout the entire period of operation. Such processes include systematic wear of all working items that experience friction; wear out of bearings; structural elements of the airframe, units, pipelines, joints; corrosion; aging of rubber products, plastics, etc.

These processes have an impact on the tedious strength of materials, the accuracy of the units and mechanisms operation, changes in the engines, pumps and other products efficiency.

It should be emphasized that all these changes occur relatively slow and are characterized by random

functions, which are characterized by spreading of the values of the corresponding parameters. Therefore, for their study and analysis is used the mathematical tool of probability theory, mathematical statistics and the theory of random functions.

Thus, the change in the parameters and characteristics of elements in time is a consequence of the physicochemical processes that occur in them. The process of occurrence of a failure is, as a rule, a certain hour process, the internal mechanism and the speed of which is determined by the properties of the material, stresses, and the influence of climatic and other factors.

The variety and stochastic nature of the influence of operational factors on the objects of aviation technology lead to the fact that with the same operating time or service life, the objects have a different actual technical condition, which, obviously, should be taken into account when developing strategies for the maintenance and repair of these objects.

Depending on the acting loads and the physical nature of the processes that occur, typical failures and damage to aviation equipment products can be classified into such groups:

1. Cracks, deformations and damage caused by the action of repeated loads during operation. These failures and damages are widespread in the form of fatigue cracks. They appear in the skin and elements of the inner structural frame. Especially dangerous are cracks in the wing stiffen panels in localized loads area (for example, landing gear and flap attachment units), as well as in places of stress concentration (for example, changes in longeron thickness).

In general, the development of cracks has a character similar to wear out, with three distinct zones of their development intensity.

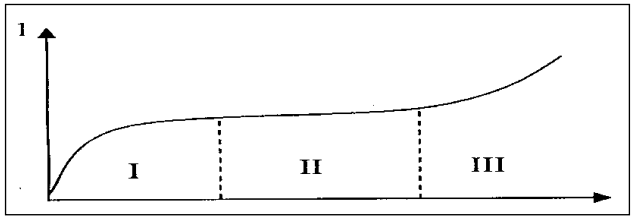

Fig. 1. The typical pattern of development of the size of fatigue cracks in the airframe skin: 1 – crack size; *t* – lifelength

The first zone is characterized first by a high and then gradually decreasing speed; the second zone is the period of sustainable crack development; the third zone is a catastrophic crack growth, which results in the damage of the element.

In operation, these processes are well studied and on the basis of a thorough analysis of the reliability and survivability of the structure, the maximum allowable crack sizes are established.

2. Damages represented by cracks, deformations and demolitions caused by cases of excessive loads are not local, but are common remaining damage of the construction main parts. Such overloads can occur as a result of rough landings, getting into a zone of thunderstorm activity and a turbulent atmosphere, unacceptable maneuvers, etc.

3. Corrosive damage as a result of the destruction of lacquer coating and other types of protective coatings.

4. Different types of mechanical wear out that occur during long-term influence of variable working loads (for example, backlashes of sliding and rivet joints, scuffing of constructional elements, etc.).

5. Malfunctions that occur as a result of aging of parts made of organic materials (glass, rubber, plastics, etc.). The aging process is stimulated by climatic factors (precipitation, temperature and its changes, solar radiation, humidity, etc.), environmental factors (saturation of the atmosphere with salts, dust, dirt, etc.). Usually this process is unseen and most often turns out to be in the form of sudden damage.

6. Various mechanical damage of the skin, floors and other elements caused by negligence during maintenance, commercial activities, repair, etc.

Conclusions. Thus, from the representedconsiderations, the interaction and interweaving of known causes and operational factors can be seen.

To build a reasonable structural model of their mutual influence, more in-depth researches are needed.

Moreover, their direction should be based on a determining influence with limited TBO (time between overhaul) and SLL (service life limit).

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Рагулін С.В., Сироїжка І.О. НОВІ ПІДХОДИ ДО КЛАСИФІКАЦІЇ ФАКТОРІВ, ЩО ВПЛИВАЮТЬ НА НАДІЙНІСТЬ АВІАЦІЙНОЇ ТЕХНІКИ

У статті досліджуються методи та підходи до кваліфікації факторів, орієнтованих на їх вплив на надійність повітряних суден. Підходи оцінюються на вигляд можливостей їх практичної реалізації і запобігання появи дефектів в авіаційній техніці. Всі фактори, які характеризують реальні умови експлуатації і впливають на технічний стан повітряного судна, поділяємо на дві групи: об'єктивні і суб'єктивні. З іншого боку, фактори, які впливають на зміну технічного стану повітряного судна, можна розділити на конструктивно-виробничі, які визначають початкові якості об'єктів, та експлуатаційні, що відображають зміну технічного стану у процесі експлуатації. Вирішальну роль у зміні технічного стану та надійності повітряних суден надають експлуатаційні фактори, тому що у процесі експлуатації і визначається рівень надійності авіаційної техніки. Експлуатаційні фактори можна поділити на 3 групи: група навантажувальних (об'єктивних) факторів; група зовнішніх умов (факторів); група людського фактора. Експлуатаційні чинники зумовлюють широке розмаїття процесів, які змінюють технічний стан об'єктів і призводять до повної або часткової втрати працездатності. Виділяють три основних види погіршують працездатність пристроїв: швидкоплинні процеси, процеси середньої швидкості та повільно поточні процеси. Швидкоплинні процеси закінчуються в межах циклу машини і мають періодичність зміни, що вимірюється зазвичай частками секунд. Процеси середньої швидкості проходять за час безперервної роботи машини і їх тривалість вимірюється зазвичай у хвилинах або годинах. Повільні процеси проходять протягом усього періоду експлуатації. Різноманіття і стохастичний характер впливу експлуатаційних факторів на об'єкти авіаційної техніки призводять до того, що за одного і того самого напрацювання або тривалості експлуатації об'єкти мають різний фактичний технічний стан, що, природно, має враховуватися у розробці стратегій технічного обслуговування і ремонті цих об'єктів.

Ключові слова: *авіаційна техніка, надійність, фактори, навантаження, експлуатаційні фактори, процеси, безпека польоту.*