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MAINTAINING THE AIRWORTHINESS OF AIRCRAFT

THE ROLE OF WORKPLACE ORGANIZATION IN THE AIRCRAFT MAINTENANCE

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The longest stage in an aircraft exploitation cycle is its operation. Features of operation are determined by a number of operational factors, among which an important place is the process of aircraft maintenance. Proper maintenance organization is ensured by a number of conditions, they are the following: completeness and quality of technical documentation; forms of maintenance organization; state of the production and technical base; qualification of specialists; completeness and timely provision of spare parts and materials; appropriate labour working conditions [1].

The manufacturer develops operational documentation for operations during all types of aircraft maintenance. The list of necessary tools, instruments, additional equipment, methods and means of control of operations and minimum time for work completion are regulated. A maintenance program of each aircraft copy is developed and agreed minding the specificity of the flight operation.

In modern conditions aircrafts are intensively operated, and technical service at the lowest labor and material costs is provided by maintenance according to the technical condition. Thus, the prediction and determination of the technical condition of the units, units and systems of the aircraft before failure play an important role. The widespread use of modern production technologies, various control systems, numerous scientific developments in the field of aircraft systems simulation make the work easier, but are not able to fully perform the functions of engineering staff. Depending on the type, maintenance work can be performed in the hangar or directly at the aircraft parking lot, at all seasons and in different time periods of the day. These factors have a significant impact on the work environment and human performance, so minding the working conditions is very important in ensuring maintenance operations directly on site. For example, for activities in the parking lot (open space), weather conditions during the daytime at temperatures plus 30C and wind speeds of 1-3 m / s or at night at temperatures of minus 10C and wind gusts of 15-20m / s cannot be called favorable, so as well as the lack of sufficient light and a limited number of accessories in the hangar [2,3].

In addition to the mandatory use of operational documentation while performing aircraft maintenance, workplace activity is also governed by safety rules, health restrictions, and special types of admissions (for certain types of work). A large number of documents, which guide the work of engineers and technical service sector, is due to the need of minimizing the impact of human factor on the results of operations, and, consequently, to ensure the safety of flights. Due to difficult working conditions, there may be a deterioration in the health of employees, frequent redundancies, or in general, lack of staff, which negatively affects the work process as a whole [2,3]. This raises the question of creating working conditions directly in the workplace of engineering staff that allow them to perform their functional duties effectively, safely and with proper quality.

The workplace is an essential element of the production process where purposeful actions of the personnel are performed, so its rational organization is of the utmost importance. Usually, in addition to the documents mentioned above, workplace attestation is performed in order to assess compliance with the conditions of maintenance operations [4]. This procedure can identify ways to improve working conditions, but does not give an idea of the procedure and does not identify the so-called "weaknesses" of the workflow, where there is an increased likelihood of making mistakes, losing time, getting injured, and so on. Techniques have been developed for certain types of production that allow to optimize workspace, eliminate unnecessary movements, reduce fatigue, and use time more efficiently through local workflow assessment. Unfortunately, insufficient attention is paid to the methods of organizing workplaces during the maintenance of PS and implementation of improvements in working conditions.

The development of methodologies for assessing processes that occur directly in the workplace during aircraft maintenance is complicated by the following factors as: dependence of kinds of work on the technical condition of the unit or aggregate; complex, variable employee moving; individuality of the person's views on the rationality of actions; multiple changes of body position and types of physical activity are possible; significant environmental impact on operations.

It is possible not only to develop measures to optimize work movements and to identify places that need enhanced control, but also to improve working conditions through reasonable ensuring the availability of additional technical devices, protection means, application of possible innovative proposals while evaluating the organization of workplace when performing aircraft maintenance operations using quantitative, qualitative indicators and certain mathematical dependencies.

In addition, the description of the location of work objects and the rational movements in the course of performing maintenance operations for a particular unit or aggregate will improve the training of personnel, which is especially relevant in the process of mastering new types of aircraft serviced.

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USING THE ARTIFICIAL INTELLIGENCE FOR PREDICTIVE MAINTENANCE OF AIRCRAFT

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Annotation — that article deals with the problem of using the artificial intelligence for predictive aircraft maintenance. The application areas of artificial intelligence are analyzed to preserve the airworthiness of aircraft in order.

Keywords - predictive technical service, artificial intelligence, expert systems.

The problem of solving predicts is changing in the highest number of results that exist in the facility being operated or in the process of being repaired allow for the analytical analysis to be verified and it must use an appropriate solution. Recently, people have used methods that are available in physico-technical and technical-economic approaches. At the same time, it is necessary to investigate factors that are different in nature and using different methods from different specialists to distinguish the valuable information obtained.

Leveraging artificial intelligence (AI) models to identify anomalous behavior turns equipment sensor data into meaningful, actionable insights for proactive asset maintenance – preventing downtime or accidents. Commonly known as predictive maintenance, this intelligence forecasts when or if functional equipment will fail so its maintenance and repair can be scheduled before the failure occurs. Considering the aggressive time-to-market required for aerospace products and services, identifying causes of potential faults allows companies to deploy maintenance services more effectively, improving equipment up-time. Critical features that help predict faults or failures are often buried in structured data, such as year of production, make, model, and warranty details, as well as unstructured data such as maintenance history and repair logs. However, emerging technologies such as the Internet of Things (IoT), Big Data, analytics, and cloud data storage are enabling more equipment to share condition-based data with a centralized server, making fault detection easier, more practical, and more direct.

Predictive maintenance model. The underlying architecture of a preventive maintenance model is fairly uniform irrespective of applications. Analytics usually reside on various IT platforms, with layers systematically described as:

- Data acquisition, storage – Cloud or edge systems
- Data transformation – Conversion of raw data for machine learning models
- Condition monitoring – Alerts based on asset operating limits
- Asset health evaluation – Diagnostic records based on trend analysis if asset health declines

- Prognostics – Failure predictions through machine learning models, estimate remaining life
- Decision support system – Best action recommendations
- Human interface layer – Information accessible in easy-to-understand format

Failure prediction, fault diagnosis, failure-type classification, and recommendation of relevant maintenance actions are all a part of predictive maintenance methodology.

Manufacturing, energy, and utilities verticals are among the biggest demand drivers for predictive maintenance, and the technology is growing in aerospace as manufacturers look to control maintenance and downtime costs. So, it's critical for equipment manufacturers and owners/operators to adopt a predictive maintenance solution to maintain a competitive advantage. The bigger players have been using this methodology for more than a decade. Small- and medium-sized companies in the manufacturing sector also can reap its advantages by keeping repair costs low and meeting initial operational costs for new operations. Offering more business benefits than corrective and preventative maintenance programs, predictive maintenance is a step ahead of preventive maintenance. As maintenance work is scheduled at preset intervals, maintenance technicians are informed of the likelihood of parts and components failing during the next work cycle and can act to minimize downtime. Performance benefits means that predictive maintenance employs non- intrusive testing techniques to evaluate and compute asset performance trends. Additional methods that may be used can include thermodynamics, acoustics, vibration analysis, and infrared analysis.

The continuous developments in Big Data, machine-to-machine communication, and cloud technology have created new possibilities for investigating information derived from industrial assets. Condition monitoring in real-time is viable from sensors, actuators, and other control parameters. What stakeholders need is a bankable analytics and engineering service partner who can help them leverage data science to predict embryonic asset failures, eliminate them, and act in a timely manner.

The article proposes using of AI in the field of predictive aircraft maintenance. The main advantages of AI are the increased speed and accuracy of processing a large amount of data, the ability to prevent flight failure, reducing the impact of human factors on the maintenance of information processing and improving flight safety.

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CHILDREN SAFETY ABOARD AN AIRCRAFT

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Staying children aboard an aircraft requires additional safety precautions undertaken to prevent injuries during transportation.

Doctors recommend refraining from flying with children under the age of three due to the peculiarities of the microclimate aboard the aircraft and the need to adapt the body for staying at different heights.

A restricted space among a large number of people can also unpredictably affect a child's behavior and cause discomfort not only to those who accompany it but also to other passengers.

The travel can be enjoyable and safe only when it is properly prepared, that's why the airlines and numerous specified forums determine the rules and suggest the tips for transporting children under the age of 14.

According to ICAO Doc 10049 [1] and the EASA Guidelines [2] on air travel with children, most airlines provide services to parents with infants over 14 days of age (in special cases, requiring a medical certificate) up to two years without requiring a separate ticket and a seat. Moreover, for the comfort of parents and their babies, leading airlines can offer a cradle or hammock free of charge similar to the ones shown on Figure 1.

Figure 1 - Means of children transportation under the age of two aboard the aircraft

Equipment, similar to the one shown in Figure 1, is provided free of charge, but is not used during take-off and landing. In case of possible emergency situations in unstated flight phases, there is a risk of injury from a cradle or a seat.

In order to comply with safety rules aboard the aircraft, there have been developed recommendations to provide seats for passengers with children or separate seats for children in airplanes [1, 2]. Thus, it is forbidden for a mother with the baby to sit near the emergency exit. And it is strongly desirable for the elder people to occupy a seat near the aisle. In case of an emergency, special safe postures are recommended for passengers with children sitting on their knees. But it should be noted that in such a case, the adult may himself/herself become a source of additional risk, because during the overloads he/she is physically incapable of holding the baby. While moving the aircraft through the turbulence zone, there is also a risk of injury. In such cases, a special baby vest "Baby B'Air" is offered for passengers with children in their arms [3]. This vest can be worn on a child and can limit its movements aboard the plane by means of putting it through a special loop on a seat belt of an accompanying adult.

For children between 2 and 14 years of age, airlines require a separate ticket. An additional requirement is the use of a special car seat (SCS), which is certified for using in aircrafts. Crew members assist passengers with the placement and attachment of the AK on the seat, and there is a separate sequence of actions for boarding and setting down the passengers with children. There are a number of nuisances during the previous interactions between the passenger and the air carrier: the need for prior approval of the SCS type, restrictions on the use on different types of aircrafts and in the **salons** of different classes. The worst thing is that the access to the aircraft can be denied in a last minute if the crew has doubts about the safety of the SCS, so, the airline envisages the final solution for itself. As a result, we can experience frequent travel cases where the safety requirements are neglected. It refers primarily to charter flights, where the rate of violations is extremely high.

Special tests have shown that a standard safety belt is not capable of restricting the movement of a child in a regular seat because of body size and the sensitivity to belt pressure. The "Cares Harness" seat belt system can be used as an additional safety feature which can be applied to regular seats on the aircrafts [4]. If there is a full and a multi-functional access to the backside of the seat, it is possible to fasten the system "Cares Harness" and use it simultaneously with a standard belt. This system is already certified; it is added to the Quantas child safety list and is successfully implemented.

The development of special stationary seats for the aircraft cabin is seen to be promising from the point of view of a safety. The special design offers are available that take into account the characteristics of children of all ages, but they are inconvenient for adult passengers. The high cost and imperfection of statistics on the required number of such chairs still limit the implementation of such equipment in the cabin interior.

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THE USE OF CLOUD COMPUTING TECHNOLOGIES IN MAINTAINING THE FLYING VALIDITY OF AIRCRAFT

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This article discusses the feasibility, relevance, advantages and disadvantages of using cloud computing technologies in maintaining the flying validity of aircraft. The use of cloud computing technologies in aviation considerably simplifies the data processing and collection. Cloud technologies availability makes the process of documentation exchange easier between departments and crew within an airline. The main advantage of using ’’cloud ’’in the airline's technical department is the speed of information processing. The information about the technical condition of the airplane and its characteristics can be immediately provided to the airline's technical department. Thanks to this technology, the engineers of the department can plan the termination date of aircraft resources, aggregates replacement, and monitor characteristics in real time. Also, the availability of such storage gives an opportunity to move scanned documents quickly to the public and private institutions. To obtain a copy of any document, there is no need to scan it if one already has a database in the cloud. All one has to do is to give it the correct name and find this document using the built-in search.

The disadvantage of cloud computing technologies is the lack of trust in the service provider, which is responsible for both uninterrupted work and important user data storage. In addition, cloud computing puts high demands on the quality of communication channels, which guarantee universal access to the Internet.

It is likely that with the widespread advent of this technology, the problem of creating uncontrolled data will become apparent when the information provided by the user will be stored for years, or without their knowledge, or they will not be able to correct any part of it. An example would be Google services where a user is unable to remove unused services and even delete some of the data groups like in FeedBurner, Google Friend Connect etc.

To make a conclusion, by choosing a quality service provider and ensuring the staff training, it becomes possible to optimize dramatically the airline operation.

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RISK ANALYSIS OF RISKS FOR MAINTENANCE OF AIRCRAFT MAINTENANCE PROCESSES

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Aircraft operation is a complex, multi-tiered process in which all participants are interdependent. Modern economic conditions, congestion of airspace and airports require coordinated operational actions aimed at ensuring flight safety.

Due to the large number of personnel involved in this process, considerable attention is paid to the human factor training. International organizations ICAO, EASA and others have issued a number of documents that describe the safety of flights very carefully and multi-sided for the aviation staff, control services and process controllers. Due to the standards and recommended practices, and the active work of supervisory authorities the number of aviation incidents has been steadily declining.

According to the statistics of aviation incidents in 2018, the main threats to the safety of flights were the violation of the established requirements during the preparation (retraining) of the flight composition and violation of the rules for the use of airspace [1]. They are trying to reduce the risk of flight safety by implementing the latest route control technologies, maintaining communications and automated control of aircraft modes. But disruption of such complex systems can still lead to disaster. That is, the risk does not disappear completely. An example of such a situation is the crash of two Boeing 737 MAX due to a failure in the MCAS system. As a result, there are severe consequences for the relatives of hundreds of victims, also the loss of finances and the trust of Boeing company customers.

Since the part of aviation incidents attributed to maintenance processes is close to 10% [1], not much attention is paid to the operation of the engineering and technical staff. Today, there is a wide divergence in the technologies used for an aging fleet of aircraft and new ones, but all of them are actively exploited now. Each new type of an aircraft that appears on the market has a greater share of the latest developments, the exploitation of which will be carried out in the absence of information and will require a review of the quantitative and qualitative composition of maintenance teams by the operating companies. For example, the transition to a fully electric aircraft concept requires an increase in the number of appropriately qualified personnel. And here we are facing with personnel risks. There is also a need to develop and master appropriate methods of diagnosing and processing information that is captured directly in the flight process [2].

On the one hand, the data exchanged by aircraft operators make it possible to acquire the necessary experience and correct preventive actions more quickly, and on the other hand, the operation of most maintenance crews is reduced to a human operator system. In this system, it is important to evaluate the correctness of information by the employee and securely transmit it to a common server, because with the introduction of computer technologies in aviation activity increases the share of threats in cyberspace. Manufacturers try to keep the main maintenance functions by themselves and the network of partner-organizations to prevent industrial espionage. Thus, they assume technological and operational risks (in the course of operations in the brigade), but future operators are not able to fully assess all aspects of ensuring the airworthiness of such aircraft. Subsequently, aspects that were not foreseen at the stage of the aircraft's commissioning may lead to unpredictable costs, that is, increase the proportion of financial risks [2].

Because the processes that take place in all aviation fields are associated with a tight timeframe and high cost of service, so awareness of threats, timely identification of risks, their assessment, prevention and impact management are very important. The main principles of risk assessment are outlined in ICAO Doc. 9859. AN / 474, but mainly related to flights. In addition, different editions of the document contain risk assessment methods that are not able to cover all aspects of participants' activities according to their specifics. Risk assessment matrices, in some cases, lead to ambiguous interpretations of the degree of risk, which may subsequently lead to incorrect precautionary actions [3]. Thus, there is a need to develop a comprehensive risk management program using ISO 31000 standards.

The operation of aircraft maintenance organizations is focused on a specific type of aircraft (one or more), so the threats, manifestations and consequences of risks will be significantly related to its technical characteristics, as well as the financial capabilities of the company and the coordination of the network of partners and suppliers. The experience demonstrates [2, 4], in modern conditions, the greatest part of risks is related to the processes of interaction of employees of different structural units, technological and operational activities, human resources and cyber security.

The implementation of a risk management program also requires capital investment and prioritization to counteract the risks, but it is entirely justified by the fact that a company will be formed gradually in an environment in which preventive actions will prevail. It is expected that this will significantly reduce the number of accidents that can cause damage and adversely affect the image of the company.

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POWER PLANTS

MODELING OF THE ISODROMIC ROTATION FREQUENCY CONTROLLER

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The rotor rotation frequency controller is one of the main elements of the automatic control system (ACS) of gas turbine engines (GTE). With the advent of electronic control systems on modern engines, a hydromechanical regulator is used as a backup regulator to ensure reliable operation of the fuel supply control system. Therefore, the static and dynamic characteristics of such regulators are subject to string ent requirements. Such characteristics can be obtained using modern modeling methods without conducting experimental studies on test benches.

Fig. 1 shows a scheme of a hydromechanical controller of the rotor rotation frequency (RRF) of an engine, or rather, its hydraulic drive of an inclined washer (IW) of a fuel pump. The main feature, which is the presence of two pistons in a single hydraulic cylinder: a piston directly acting on an inclined washer (IW piston) 10 and a piston covered by rigid feedback (FB piston) 8. In this case, the displacement of the IW piston and the change, as a result, of the fuel consumption in the combustion chamber can occur:

– when FB piston 8 is fixed (when it is on mechanical stops 7) due to a change in the volume between the pistons cavity (BPC), in suchc ases the regulator works as an isodromic “I” regulator;

– when FB piston 8 is moving to get her with the IW piston 10 when BPC is locked, in such cases the RRF controller works as a proportional “P” controller.

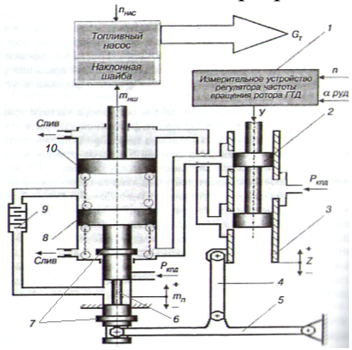

Fig. 1. Scheme of a hydromechanical RRF controller of GTE

A model of GTE with an ACS including an isodromic RRF controller, made in Mathlab, is shown in Figure 2. The main processes that occur in the controller and the main elements are presented in the form of “Simulink” blocks with corresponding input and output signals.

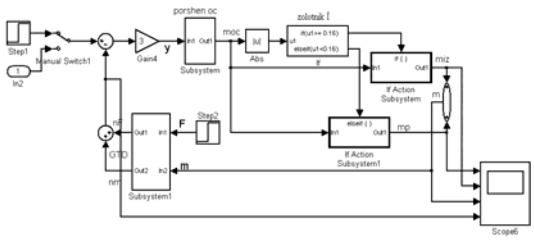

Fig. 2. A model of GTE with an ACS including an isodromic RRF controller

The results of the simulation of the transient process in the ACS of GTE with an isodromic RRF controller caused by a change of the disturbance F are shown in Fig. 3.

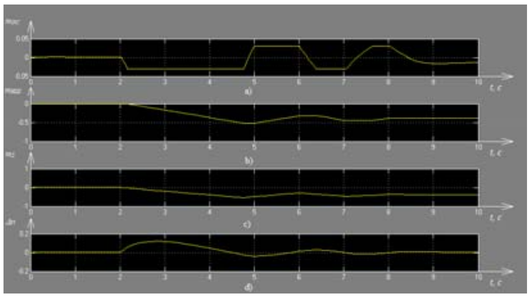

Fig. 3. Transient process in the ACS of GTE with an isodromic RRF controller

As a result of the transient process study that is caused by an intermittent controlling action change relatively to the GTE, using the simulation model, the next is obtained:

– dependences of changing of the isodromic and proportional components of the control action over time;

– dependence of the change in the engine RRF during the transition process;

– the ability to obtain the optimal nature of the change in the RRF without unacceptable temperature overshoots and the necessary acceleration characteristics due to changes in the throttle package performance and the position of the mechanical stops.

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SOME ASPECTS OF ENSURING THE PURITY OF TURBINE OILS DURING OPERATION

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Turbine oils ensure the availability of turbines of electric power stations, gas-compressor units of gas supply systems. Pollution of oils with mechanical particles and water courses disturbance of turbine unit operation and leads to significant economic damage.

Operation of contaminated working fluids leads to a violation of lubrication conditions, to failure and damage of control systems, to a violation of the operating conditions of generator shaft seal systems. The consequence of such failures are, as a rule, long-time repairs of components and units. In parallel, it is necessary to carry out work on cleaning the systems and replacing the oil in the oil tank.

Solid contaminations particles lead to active wear of the mating elements, the working surfaces of the control equipment, the failure of control valves and regulators, with the development of emergency situations.

The presence of water leads to a deterioration in the operating abilities of oils, as additives are washed out of them. Water in oil initiates and accelerates the corrosion processes of contact surfaces, which in turn increases the pollution of the oil. Water promotes foaming in the oil, which impairs lubrication conditions.
All types of contaminants entering the liquid cause increased slime formation.

As a result of the appearance of contaminants in oils, a number of indicators of their quality deteriorate: acid number, oxidative stability, viscosity [1].

Loss of operating abilities of turbine oils, on the one hand, is difficult to detect during operation, and, on the other hand, is a danger to the operation of turbine units.

Based on the foregoing, it can be asserted that contamination in oil systems is extremely undesirable and the urgent task of ensuring the required level of purity of lubricating oils.

Decision-making on the use of certain purifying equipment should begin by determining the potential possibility of their use, after which the economic efficiency of their use is analyzed.

Currently, two main purification methods of working liquids are used in industry: filtering through porous partitions and removing contaminations particles in force fields of various nature.

Porous filters are fundamentally capable of providing any level of purity. But to achieve a high class of purity, multi-stage filtration is required. So, the company HYDAC recommends installing at least two filter elements in the lubrication systems of turbine units to achieve class 13 according to GOST 17216. But, it is known, that porous fine filters are the high cost and the inability to regenerate them.

In circulating fluid systems, changing of particle-size distribution are continuously going on [2]. Particles of small contaminants in systems, as a rule, coagulate and are quite large structures. However, having hit the surface of the filter elements, being under the influence of a dynamic fluid flow, they are destroyed and can pass through the pores of the filter. Researches show that behind 5-micron filters a large number of particles with a size of 10-25 microns pass into the system and even particles up to 50 microns in size are found. In addition, the required level of purity is not always achieved due to vibration, local water hammer, inhomogeneity of the filter material[3].Thus, during operation there is only a deterrence of the oils pollution.

Power purifiers are deprived of porous filters disadvantages.

So, centrifugal separators are widely used in various technological processes. They well remove solid metal or sand particles larger than 10-15 microns. However, when particle sizes are reduced, a phenomenon occurs that prevents the separation of liquid and dirt. As the contamination size decreases, the relative thickness of the boundary layer attached to the particle increases. This boundary layer is formed by surface active substances (tars, water, etc.). In this case, the specific gravity of the particle decreases, and the mid-section increases. When centrifugal forces act on a particle, it courses a large hydraulic resistance when moving[3]. Therefore, centrifugal separators could not provide the task of oils purification in the systems.

Electric purifiers are highly effective when working in dynamic systems, have a number of distinctive features. Electric purifiers do not have moving elements, create low hydraulic resistance (one or two orders of magnitude lower than porous filters), have good dirt capacity and the possibility of regeneration. The most important characteristic of an electric purifiers is a significant service life. Electric purifiers provide fine purification of liquids. Electric purifiers in combination with inexpensive coarse porous filters can be used for purification of heavily impure liquids.

It should be noted that ensuring the purity of turbine oils during operation can be achieved by solving several problems. First of all, it is oil quality control using various methods and means of control, including express methods, continuously and one-time checks. Oils purification from water and solids can be performed using modern equipment by integrated methods, which is due to the disadvantages of individual purification methods. The condition of oil in a dynamic system is related to the cleanness of the system itself. The cleanness of the system during operation can be also ensured by special measures.

Thus, the integrated methods of attackin ensuring the purity of turbine oils during operation are in interest.

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MODELLING OF STRENGTH CHARACTERISTICS OF FAN BLADE

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One of the important requirements for the engine is a high level of reliability. One of the reasons for premature damages and malfunctions of compressor elements is an insufficient safety factor margin [1]. The constant development of aircraft engine manufacturing, namely in the field of numerical methods, is directly related to the use of different calculation systems. They help to save time on calculations and more accurately evaluate the characteristics of the studied elements.

The aim of the work is to assess the strength characteristics of a fan for a medium-bypass turbofan engines.

A numerical experiment was used to study the strength characteristics of a fan.

The studied fan had a peripheral diameter 1.185 m and hub 0.326 m in the inlet section. Number of fan blades - 33, material – Ti6Al4V. On the fig.1 solid model is presented. Studies were conducted for a rotor speed of 2202 rpm, the inlet speed was 100m/s.

An adaptive grid is builded on the model, the number of elements is 65883, the number of nodes is 120389. Fig. 2 presents a visualization of the constructed computational grid.

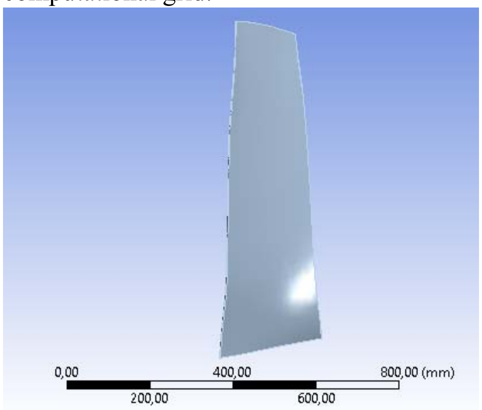


Fig. 1. Solid fan model

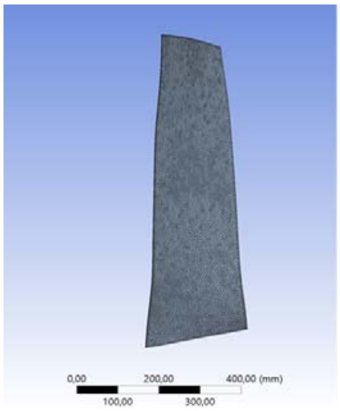


Fig. 2. Visualization of the calculation grid

The first stage of the study was to obtain the aerodynamic characteristics of the fan. The results of the aerodynamic calculation were carried forward for further strength calculations.

Fig. 3-5 represent the results of the study.

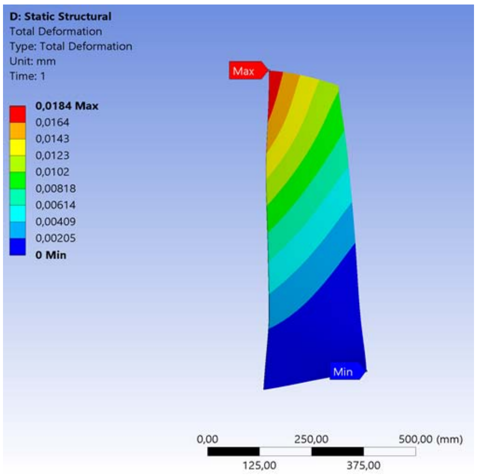
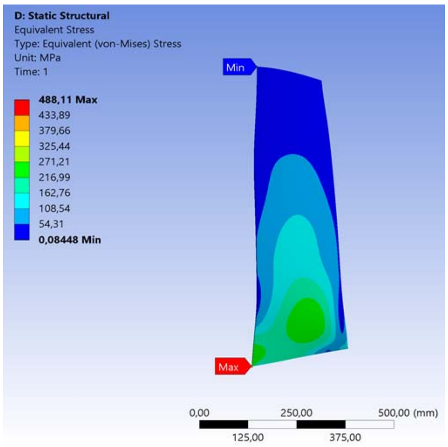


Fig. 3. Visualization of total deformation of fan blade



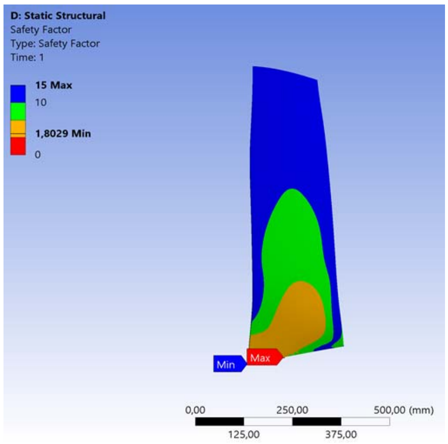


Fig. 4. Visualization of equivalent stress of fan blade

Fig. 5. Visualization of safety factor of fan blade

The article presents an assessment of the strength characteristics of a fan blade. The calculation results showed that the minimum value of the safety factor is 1.803, which meets the read standards that are presented to the fan blades of aircraft engines.

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THERMOCYCLE FATIGUE AND DESTRUCTION OF HIGH-PRESSURE TURBINE BLADES IN CRITICAL CROSS-SECTIONS

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Abstract. The report identifies critical cross sections and points at the edges of high-pressure turbine blades (HPT) for the experimental study of the thermocycle durability of alloys by the limit parameters of cyclic changes in extreme temperatures and thermomechanical stresses acting at the start and stop of aviation gas turbines engines (AGTE).

Keywords - empirical model of boundary thermomechanical stresses.

Introduction. Creating reliable large-scale aviation GTEs requires more accurate methods of estimating the thermocycle durability of their hot parts, especially at the critical points of the high-pressure turbine blades that limit the GTE's life. Methods for estimating thermocycle longevity can be based on empirical models of boundary thermomechanical stresses at extreme cycle temperatures [1].

Determination of the critical areas, sections and points of the HPT blades. In modern high-pressure turbines, the extreme temperatures of the T_b blades are much higher than 1200 K, and the temperature gradients ΔT of the cross sections and the length of the blades reach up to 650 K. Extreme thermal stresses in absolute values exceed ±450-650 MPa, exceed the conditional limits of elasticity, partially compensate, and lead to the accumulation of uniquely structural yielding, to the exhaustion of a complex yield resource, to the destruction of blades alloys in the maximum temperatures range $T_{b\max}$, which is clearly visible in photo 1. This zone is localized in point size 1 - 2 mm.

Photo 1

In experimental studies at NAU on the alloys samples (2-3 cm long), the area of damage localization in the size of 1-2 mm was also revealed, in the hysteresis zone

T_{max} at changing $T_{min} \leftrightarrow T_{max}$ with a difference in ΔT = 650 K. Such thermophysical analogy justifies experiment.

Due to the existing rule of the gases maximum temperature directing T_{gmax} to the peripheral third length of the blades, in continuous and modern cooling nozzle blades HPT (photo 1) mainly operate T_{bmax} and alternating extreme thermal stresses along the front and back edges of the blades. Gas forces are relatively insignificant, and mechanical ones are almost absent.

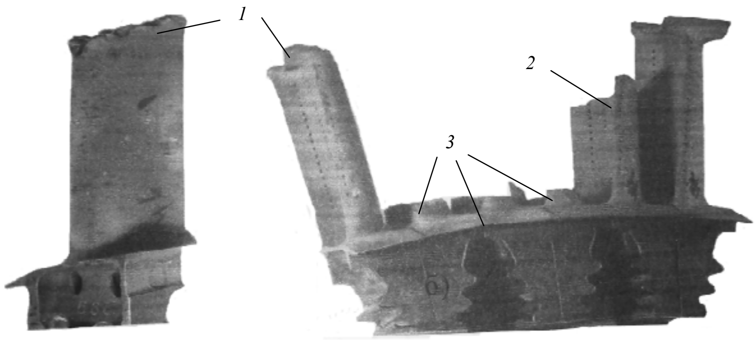

Photo 2

In the HPT blades (photo 2), the spectrum of operating temperatures and thermomechanical stresses $\sigma_{\Sigma тм}$ is much more complex and includes all the main acting components: $\sigma_{\Sigma тм} = \sigma_р \pm \Delta\sigma_т + \sigma_{-1} + \sigma_{иг}$ and other less significant where σp is the tensile stress of the centrifugal forces in the mode $\sigma_р = \sigma_{ст}$; alternating thermal $\pm\Delta\sigma_т$; vibration – σ_{-1}; gas bending – $\sigma_{иг}$. From the standpoint of three- and multicomponent approaches, one can explain the destruction of the HPT working blades in its three sections (photo 2, points 1, 2, 3): on the shelf (point 1); in the maximum temperatures range (point 2); and in root sections (points 3). At point 1 due to thermocyclic creep and unbundling by vibration of the shelf. At point 2, due to the extreme temperatures action and complex thermomechanical stresses (T_{bmax}, ΔT, $\Delta\sigma_{тм} + \sigma_р$). At point 3, due to the high temperatures action T_b, thermomechanical stresses $\sigma_р + \sigma_{ги} \pm \Delta\sigma_т$ and vibration σ_{-1} after weakening of the blades bandages connection.

Conclusion. For the design of large-scale aviation GTEs, experimental studies of thermocyclic durability of heat-resistant alloys under extreme conditions of limiting temperatures, their variations and thermomechanical stresses corresponding to the operating conditions and modes of operation of GTE are required. Creating mathematical models for calculating the resource of parts.

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