On the approach to quality, reliability and safety of aviation engineering systems

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Abstract. The paper considers the possibility of estimating the current stage of operation of aircraft, a problems faced by the air transport industry within the requirements of ensuring the required level of flight safety and aircraft continuing airworthiness. The article deals with the implementation of a safety management system (SMS) in organizations for the maintenance of aviation equipment. Topical issues of ensuring flight safety in civil aviation are considered. Analyzed the methods of risk assessment and hazard factors in the design, production and operation of aircraft. The problems of determining the level of flight safety based on the operational data of the airline were analyzed. This analysis made it possible to take into account the problems listed in this article as a tool for a comprehensive study of SMS parameters and allows an analysis of quantitative indicators of the level of flight safety of an airline. The relationship between the problems of the flight safety management system and the determination of the level of flight safety of an aviation enterprise is investigated. A new promising entropy doctrine is proposed for implementation.

1. Introduction

Assessing the current state of operation of aircraft, to study the problems faced by the air transport industry, the steady increasing in the volume of various types of aviation activities, as well as air transport, both passengers and cargo could be indicated. Due to mentioned before, issues of ensuring the required level of flight safety and operation of engineering systems, as well as aircraft continuing airworthiness remain relevant and need permanent monitoring, analysis and improvement.

The reliability of the aircraft is an indisputable condition for ensuring flight safety. The process of aircraft operation occurs with changes in the reliability characteristics of the airframe and its functional systems, the intensity of which depends on a significant number of different factors. These factors should be investigated and taken into account, starting from the design stage of the development aircraft, then at all stages of the life cycle of the aircraft and ending with the factors of influence of the operating airline.

2. Research of existing problems

The functional systems of the aircraft and their components have partial or complete redundancy, which has a significant impact on flight safety and airworthiness of the aircraft, and thus on the causes of aviation accidents.

Analysis of world experience in the operation of all types of aircraft, as one of the areas of ensuring the necessary characteristics of reliability and level of flight safety shows that the development of this area is carried out in a spiral - periodically mentions the “well-forgotten past” and translated to a new level, as well as new requirements. At the same time, approaches, methodological and mathematical apparatuses, as well as methods and means of studying physicochemical processes of defect formation, degradation and failures are constantly being improved, based on the application of the latest information technologies.

According to data [1], worldwide in 2019 there was a significant increase in the level of flight safety, with almost twice as many deaths (319 people), compared to 2018 (587 people). In particular, in Ukraine in 2019, there were reports of 6 aviation accidents that occurred with civil aircraft of Ukraine and led to the death of 7 and injuries to 3 people [2].

As in the previous 2018, the most common events leading to aviation accidents and serious incidents were rolling out of the runway (RE), collision of a controlled aircraft with the ground (CFIT) and engine failure (SCF-PP) [2].

Analyzing the aviation events that occurred in Ukraine in 2019 with general aviation aircraft, training flights and aircraft used to perform aviation management, the most common factor that led to such events were engine failures and LOC- I - loss of control in the air. According to the results of the analysis, CFIT, RE and SCF-PP events became (and remain, compared to the previous 2018) the categories of increased risk in 2019. According to ICAO Doc 10004, CFIT events account for 2.98% of all world events. At the same time, the number of deaths as a result of such events reaches 24.56% of the total number of deaths. CFIT is a high-risk category [2].

In order to prevent aviation accidents, the existing concept of flight safety management (as per Annex 19 to the Chicago Convention) requires aviation entities to constantly search for, detect and eliminate hazards that can cause an aviation accident [2].

An illustrative example is the two major crashes with Boeing 737 MAX series (2018 release). The first plane crash on October 29, 2018 (flight 610, Jakarta, 189 people died) was the first in the history of the Boeing 737MAX8 and the largest (in terms of deaths) crash in the history of the Boeing 737 in general (before that there was a crash in Mangalura, 158 dead) [3]. Subsequently, after an investigation on November 7, 2018, Boeing reported that the cause was erroneous data in the maneuvering characteristics augmentation system (MCAS) on Boeing 737 MAX modifications, which led to a sharp transition to diving [3].

The second disaster, near Addis Ababa on March 10, 2019, flight ET302. After takeoff, the pilots reported some difficulties and requested permission to return to the airport of departure, but 6 minutes after takeoff, the plane crashed to the ground, 157 people died [5]. This crash was among the hundreds of major plane crashes in history. Information on the causes of the disaster is currently available, but its investigation is still ongoing.

After the second Boeing 737 MAX 8 crash in less than six months, flights of this type were suspended in all countries until the causes of the crash were determined. Investigators found that the unit, which controls the angle of the horizontal stabilizer of the aircraft, was in the extreme position "on the dive". This means that during the fall of the plane of the wings of the aircraft were switched to a mode of sharp descent, as on flight 610 [6].

All aviation events are the result of the influence of dangerous factors that were not detected and predicted in time, as well as due to the complexity and outstripping growth of various technical means, explosive development of modern telecommunications, which greatly complicates man-made conditions and thus increases the likelihood of accidents and catastrophes.

This brings to the highest level the requirements for the safety of technical systems and stimulates the need for intensive development of a new scientific and technical direction - "safety" and requires revision, improvement and creation of new rules and standards within the safety management system.

The safe operation of equipment cannot be observed without taking into account the impact of the human operator (human factor), the environment, the quality of storage and operation, repair and improvement of equipment. This requires the analysis of the reliability and safety of equipment to take into account the entire system "equipment - human - environment - operation - repair and restoration."

This concept is the basis of standards [7], DSTU 2860 – 94. Nadiinist tekhniky. Terminy ta vyznachennia (Derzhstandart Ukrainy, 1994. https://dnaop.com/html/2273/doc-%D0%94%D0%A1%D0%A2%D0%A3_2860-94), DSTU 3004-95. Nadiinist tekhniky. Metody otsinky pokaznykiv nadiinosti (Derzhstandart Ukrainy, 1995. https://dnaop.com/html/43855/doc-%D0%94%D0%A1%D0%A2%D0%A3_3004-95) and DSTU 3433-96 (HOST 27.005-97) Nadiinist tekhniky. Modeli vidmov. Osnovni polozhennia (Derzhstandart Ukrainy, 1996, http://www.immsp.kiev.ua/activity/Napriam%208_Standarty/Standart_Statystyka_vidmov.pdf).

Moreover, ISO / IEC Guide 51: 2014 offers a quantitative assessment of the criticality of failures in the form of the product of the value of failures on the frequency of their occurrence, i.e. regulates the quantitative assessment of the main safety indicator - risk. And DSTU 2860-94 lays down the basic principles of control of reliability and safety at all stages of a life cycle of products. An example of a modern concept of "preventive" approach to security can be a document of the International Civil Aviation Organization (ICAO) "Guide to the prevention of aviation events" (Dos 9422-AN / 923), which sets out the main issues:

- terms in the field of security;
- safety of flights and prevention of aviation accidents;
- role in preventing aviation events of ICAO, state administrations, aircraft manufacturers, airlines as operators;
- classification of aviation events;
- safety management and risk management;
- basic principles of aviation accident prevention activities: methods of detection and assessment of accident factors, their prevention and elimination, safety assessment, etc.

More detailed information on what methods will be in place until recently, as well as means of ensuring and monitoring reliability, including several regulated standards, have exhausted themselves in practice, which do not require the necessary reliability of aircraft manufacturers in the context of the Union. with this, the world's leading specialists have formed and implemented new approaches to its provision, which are confirmed by the results of research on physical interest and the principles of the new ideology of irresponsibility. A feature is the fundamental changes in the requirements for developers and manufacturers to ensure quality and reliability, which is based on reliability-oriented management of design, production and operation [8, 9]. Table 1 shows some comparisons of old and modern principles of ensuring the reliability of aircraft products.

Table 1. Principles of ensuring the reliability of aviation products.

Old principles of reliability	Modern principles of reliability
Reliability forecasting is based on operational data and certain statistical values of failure rate	Reliability prediction is performed on the basis of data on the physics of failures in a particular device and on the basis of checking the actual operating conditions of the components in the object (system) and is adjusted according to the results of diagnostics during operation
In accelerated reliability tests, accelerating factors are used for all components	Accelerated tests use accelerating factors that depend on the type and mechanism of failure of this component (components) and do not reduce (save) the life of the product as a whole
When developing as an indicator of reliability was set the average operating time before failure	During development, the guaranteed service life of the equipment and its technical resource are set as an indicator of reliability

Old principles of reliability	Modern principles of reliability
During the development, a list of permitted or prohibited components was set	During development the list of the forbidden manufacturers (suppliers) and the list of the components allowed to application is set
The components were divided according to their suitability for use in military, industrial or commercial equipment	Components are divided according to suitability for work in certain environmental conditions with an indication of which position and in which equipment
Periodic maintenance is carried out in accordance with the operating documentation	Maintenance is carried out according to the condition of the object as a whole or its components
After storage, the facility is maintained in accordance with the operating documentation	After storage of the object, maintenance is carried out in accordance with the operating documentation, as well as technical diagnostics with replacement of potentially unreliable components
After failure, the facility is repaired and inspected in accordance with the repair documentation	After failure in operation repair and check of work according to repair documentation, and also technical diagnostics of products of aviation with replacement of potentially unreliable components is carried out
The modernization of the facility is carried out mainly to improve tactical and technical characteristics	Modernization of the object concerns, in addition to improving the tactical and technical characteristics, increasing the indicators of reliability and durability
Reliability is provided at satisfaction of requirements of the Customer	Reliability is provided at satisfaction of requirements of the Customer

The concept of "production management" now has a broader meaning than the current concept of "statistically controlled process", in which the statistical control ensures the accuracy and stability of controlled parameters.

The theory of technical safety is developing not only on the basis of the above materials, it is a developed, complex scientific and technical field, which is at the intersection of sciences such as mathematics and chemistry, solid state physics and aerodynamics, information technology and psychology and others.

Since this article is a review, the authors consider it appropriate to show their vision of solving problems in quality, reliability and safety of equipment in general.

The main components of research are proposed to be classified as follows:

I. "Reliability calculation"

- Methods of calculating reliability.
- Evaluation of reliability indicators, including according to actual indicators.
- Statistical analysis [10-13].
- Physical and statistical models of degradation and failure.
- Calculation of sample sizes.
- Markov models of calculation of reservation.
- Model of providing (increasing) reliability.

- Methods and systems of control of reliability indicators.

II. "Reliability Management" (some of these components have been sufficiently studied by the authors)

- A set of methods to ensure reliability.
- Reliability monitoring for all stages of the life cycle of technology [11].
- Prevention of the reasons of failures at a stage of designing of equipment with use of a priori information.
- Formation of requirements to operational influences on equipment, including environmental conditions, service personnel, etc. [12]
- Physical and technical analysis of the causes and mechanisms of degradation and failure of equipment and its components [10, 11].
- Analysis of the criticality of failures, their nature and consequences, the study of the development of dependent failures and the reasons that cause them.
- Analysis of the causes of failures, parametric failures.
- Technical diagnostics, including non-destructive testing, quality and reliability of components and materials [13].
- Modeling of failures, depending on external influences, etc.
- Development and implementation of accelerated tests.
- Development of technical solutions that reduce the impact of defects, degradation and failure of individual components, components on the reliability of the product as a whole.

III. Security Management

- Security calculation methods, security programs, security assessment reports [12, 14].
- Engineering safety tasks: a priori risk analysis, system risk analysis, current risk analysis and decision-making mechanism [15].
- Risk assessments, their classification and ranking - creating a tree of accident risks.
- Reports on events, analysis of their causes, sequence and criticality.
- Development of measures to prevent accidents and reduce risks, etc. [16].

There is an innovative entropy doctrine developed by Professor Goncharenko A. V., Aircraft Airworthiness Retaining Department, National Aviation University, Kyiv, Ukraine, [17-21] that helps assess the available options uncertainty factors in the field of reliability and safety. It is proposed for implementation.

Conclusions

The purpose of this review is to analyze and attempt to lay the groundwork for new approaches to maintaining the airworthiness of aircraft to improve flight safety by investigating the causes of aviation accidents and proposing measures to prevent the recurrence of similar events in the future.

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