KEY PROBLEMS OF CREATING THE AIRFRAME DURABILITY

KLUCZOWE PROBLEMY KSZTAŁTOWANIA TRWAŁOŚCI PŁATOWCA

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Abstract: The paper proposes a selected key issues in the efficient formation of the airframe structure. The issues of concern design lifetime, manufacturing, command of the durability proposed in the accelerated tests and management of sustainability in the operation. A key importance is of the creating a durability of the airframe, which affects to choice materials and construction solutions. A key problem is modeling the system of exploitation and the inclusion of all the factors influencing the persistence in the aspect of aviation regulatory requirements. A key area influencing the prevention after air accidents, causes by loss of structural coherence of the airframe macroscopic structure. A key importance is the use of accelerated durability testing. A key issue is to determine if the concept of durability and viability are separate or similar in characteristics of durability. The key is to determine the diamonds of quality. A key importance is attributed to diagnostics, including integrated to airframe structure, defining a continuous condition of the aircraft through research pre-fault symptoms. These studies provide the knowledge which determines prevention activities.

Keywords: airframe, design of durability, sustaining the durability, durability management

Streszczenie: W referacie postuluje się kluczowe znaczenie wybranych problemów w efektywnym kształtowaniu trwałości struktury konstrukcyjnej płatowca w procesie jego projektowania i wytwarzania, dowodzenia postulowanej w projekcie trwałości metodami badań przyspieszonych i zarządzania trwałością w procesie eksploatacji. Kluczowe znaczenie w kształtowaniu trwałości płatowca ma wpływ wyboru materiałów i rozwiązań konstrukcyjnych. Kluczowym problemem jest sposób modelowania systemu eksploatacji. Kluczowym obszarem, wpływającym na kształtowanie trwałości są przedsięwzięcia profilaktyczne po wypadkach lotniczych zaistniałe z przyczyn utraty spójności makroskopowej struktury konstrukcyjnej płatowca, stanowiące kamienie stumilowe w kształtowaniu procesów projektowania, wytwarzania i eksploatacji. Kluczowe w ocenie trwałości płatowca są badania przyspieszone trwałości. Kluczowym problemem jest określenie relacji pojęć trwałości i żywotności w charakterystyce trwałościowej płatowca. Kluczowe jest wykorzystanie modelu diamentów jakości. Kluczowe znaczenie przypisuje się diagnostyce technicznej, w tym zintegrowanej ze strukturą płatowca, określającej w sposób ciągły stan techniczny samolotu, poprzez badania symptomów przed-uszkodzeniowych. Wyniki badań dostarczają wiedzy determinującej działania prewencyjne.

Słowa kluczowe: statek powietrzny, płatowiec, właściwości eksploatacyjne, trwałość, projektowanie trwałości i zarządzanie trwałościowe

1. Introduction

An airframe is one of the main systems of the aircraft and has a significant impact on flight safety. Due to significant impact on flight safety the airframe is subjected to set high requirements by aviation authority for durability.

Durability characteristics of the airframe express its design property, expressing adaptation to lifetime with set certainty / quality, sustained by the quality of the manufacturing and operated by the quality in the process of exploitation. Durability is one of the dimensions of quality [8,31]. Durability issues included in the terms of pro-quality management in order to achieve the highest quality due to possible technologies, expressing the degree of structural integrity of the airframe structure to ensure high/required flight safety and reliability, while increasing operational flexibility and security structure prior to the damage, particularly catastrophic in the operation. The integrity of the structure creates the structural coherence and provides for its durability and sustainability.

Time limit determines the durability of the aircraft resulting from the presence of degradative processes including aging and wear of materials and connections. Durability of the airframe, in a physical sense, determines the macroscopic structure of coherence design, which is aero-mecha-telematic¹ reliability system in response to the loads in the operation. The loss of coherence is due to the propagation of damage in volume for which the volume of the material of construction, free of damage, it is not able to transfer loads. The structure of the airframe while maintaining global consistency in service is characterized by its local losses. The initiation of damage occurs at different levels of organization of matter as (1) the initiation and propagation of discontinuities caused during the manufacturing processes of materials, components, sub-systems and assembled final product, or (2) propagation of operational damage to local exceedances of the limit loads caused by impacts. Determinant of durability, in the normative sense, is the point on the scale of the life of the aircraft, after which maintain the airworthiness of the a/c would not be possible in terms of quality or non-economic criteria. Persistence in both physical and normative are a global operating characteristics of the aircraft and is determined in the design process of an aircraft for the assumed conditions of its operation. Operating conditions are placed as requirements, assumptions and restrictions on the presence of loads in the system operation (Fig. 1).

The aircraft, including the airframe, it has to start operating life given by the designer/manufacturer using the adopted design techniques that meet the certification requirements, integrated with the techniques of production and prototype testing of requirements in the life of a design stage. The prerequisite for the cohesion of the macroscopic structure of the airframe in the operating

¹The name has derived mechanical system adapted to operate in the Earth's atmosphere through an integrated communication systems and information processing as telematics systems (combining telecommunications and information systems) in the operating system.

conditions is a appropriately selected the strength taking into account of the degradation, destruction (de-cohesion), health and diagnostics of technical condition. Reserve of strength is created by the designer through the choice of materials, connections and shapes for the assumed operating conditions using advisory expert systems as commercial software. In the process of optimizing the structure of the airframe, in addition to the actual experiments the structure and elements of the whole structure, an important role gives a simulations.

Fig. 1 Types of operating restrictions in a subsystem of the aircraft indicating the types of criterion variables

The condition of the airframe during lifetime is changed by the flow of mass, energy and information, as effects of degradation. These flows are the carriers of information for symptom assessment and predicting of the condition for the renewal of the performance, detailing the methods, procedures and tools for diagnosis and recovery capabilities to sustain both operational and technical airworthiness.

The issue of assessment and development of structural airframe durability includes risk assessment for, particularly, catastrophic damage, prevent them and/or mitigate the propagation or the effects of their occurrence. Application of knowledge in this field are solutions for active and passive safety. Active safety is the prevention against the catastrophic damage. The activities of the passive safety must mitigate the effects of catastrophic damage. These measures are derived from the adopted philosophy of design as well as exploitation. A huge impact on durability has quality management throughout the whole life cycle of the aircraft. An achievement the required quality in the design, research, manufacture, operation and sustainment guarantees the determined certainty which gives the confidence of durability modeling. The determined quality produces high operational readiness by minimizing the unplanned maintenance minimize delayed or cancelled flights. These aspects are very important in the air operator's operational policy. Affect the condition of the company in two ways, through the costs and quality of service.

Indirectly translates into reliability, safety and durability. Durability of the airframe has a significant role in shaping the quality of services through the confidence to the structure. The airframe durability includes behavior of macroscopic coherence as well as maintaining the performance characteristics in the specified range. Damages, deformations and repairs could cause the disintegrity or lose cohesion. These have an impact on the deterioration of the aerodynamic properties of the aircraft as a result of generating a significant increase in fuel consumption. Studies have shown that this is a significant problem. The increase in fuel consumption can reach more than 10% of the observed average increase of 1% for every 3000 hours or 1000 cycles with 80% of this increase due to the degradation in powerplant and 20% as a result of decrease in airframe aerodynamics [7]. *Boeing 787-8 Dreamliner*, which is a world leader in the field of aviation application of modern technology and so-called maintenance thinking, characterized by a 20% decrease in fuel consumption compared with the *Boeing 767* [9].

Given above, it is postulated that to effectively manage of the air operator's fleet the best solution is to use the durability characterization of each aircraft according to fleet. This approach is more efficient through optimal resource while minimizing the unplanned maintenance, indirectly raising the level of safety and reliability, and minimizing operating costs.

The processes of the design and the exploitation of the aircraft need to optimize operating costs while ensuring the required high level of safety and quality. Aircraft as a structural system designed for use in telematics systems, has the potential for exploitation which is achieved in the pre-operational stage, allowing: (1) prevent the interactions to force, temperature, electrochemical or electromagnetic potential-field for adopted / assumed operating conditions, (2) alert, prevent exceeding the assumptions/constraints in the design and (3) mitigate the negative effects of operational damage. These negative effects are a threat to passenger safety, others and the environment. In this approach, the aircraft must be prepared to meet the tasks: (1) no damage (reliability, diagnostics, prevention, prognostics), (2) particularly catastrophic one (safety, diagnostics, security), (3) at a determined period of operation (durability) and (4) certain operating conditions (requirements, assumptions, restrictions), (5) with respect to renewal of the condition (diagnostics, prevention, renewal operational potential) (6) using the highest/recognized quality standards. The development of the design and the operational characteristics, taking into account the correlation between the durability, reliability, availability, safety and security of the airframe structure, with the greatest possible (recognized technologies) quality for all airframe lifecycle, including pre-exploitation and operation could be described using 'diamonds of the quality' modelling.

Considering above, it is postulated some key issues in the efficient formation of the structural durability of the airframe. The key importance in shaping the lifetime of the airframe has the choice of materials and design solutions, providing consistency and structural integrity of the structure, respectively. The key problem is modeling of the exploitation system and the inclusion of all the factors influencing the

persistence in the face with the requirements of the aviation regulations. The key area is the prevention after air accidents caused by loss of structural coherence of the macroscopic structure of the airframe, which are milestones in shaping the design, manufacture and operation according to the durability. Accelerated durability testing is very important in the assessment of the airframe durability in terms of specifications ways to lose cohesion and determination of structural stability for the assumed operating conditions. The key issue is to determine whether the concept of durability and viability are separated and require separate approaches or are there similar and require standardization one characteristics of durability. The key is to determine the diamonds of quality due to modeling the correlation of property maintenance, assumed and real, in the effective management of the airframe durability. The whole process of design shapes the existence of operating costs to be borne by the air operator to manage the continuing airworthiness of aircraft obliged regulatory requirements. The key is to determine the ability to provide these requirements at minimum costs. The key worthiness has diagnostics, and especially the integrated into airframe structure one, defining a continuous condition of the aircraft through research symptoms of pre-fault or pre-damage aimed at prevention.

2. Effects of the choice of materials and structural solutions for airframe durability

The issue of forming the design life of the airframe is evaluation by use the division airframe to the basic elements of reliability. These elements are characterized by isotropy, orthotropy or anisotropy of mechanical properties, including strength and toughness which are shaping the airframe durability. The most unfavorable risk for loss of cohesion are places of stress concentration occurring in places abrupt changes of material properties on the border of two phases, materials, or as a result of existing defects, cracks, etc. In these places, under fatigue loads an initiation or/and propagation to fatigue damage could occur. This process can be intensified by the degradative environment interact with high chemical activity due to the presence of contaminants in the air, dust or humidity. These factors should be disclosed in the process to be able to apply preventive measures to prevent adverse effects of degradative factors impact on the airframe structure. These sites require protection through the continuous and/or periodic diagnostic testing, non-destructive. Diagnostic protection of the airframe structure affects the growth of flight safety by increasing the level of confidence /certainty to the structure. Security does not go unpunished, in terms of weight and cost to the air operator. Diagnostic system has got the weight to be taken into account for the grid integration of sensors into airframe, suitable cabling and security acquisition system used the waves in the diagnosing. Another problem is the way the collecting and transforming of diagnostic data to useful knowledge. The diagnostic system is the part of the airframe so the reliability of the system must be protected from damages. The number and location of sites threatened damages are a major

challenge for scientists very rapidly developing research in the field of *Structural Health Monitoring*.

The initiation of damage can occur at different levels of the matter organization, including the development of discontinuities caused during the manufacturing processes of materials, components, sub-systems and assembling the final product as well as the development of local operational failures exceeded the limit loads. The development of structural discontinuities may have a different process depending on the type of materials used in the airframe, the solutions and the impact of the airframe in a makrosystem M-T-E (consist of MAN, Technology, Environment) in the exploitation process. Different effects on degradative processes is noticed to the main groups of materials including metals, ceramics and polymers. Composites exhibit different properties. It is important to determine the effect of various degradative processes for different construction materials including the impact of the environment in the process of the operation. Degradation processes are initiated for the presence of certain structural material physico-chemical potentials, the micro-structural level, resulting from the diversity of chemical bonds or local failures. These sites are infected with the formation of a crack damage for metals and ceramics, and delaminations for composites, etc.

3. The system characterisation in civil aviation in the aspect of the airframe durability development

Civil aviation in its development is subject to globalization and systematization. In the paper systematization has been characterized from the airframe point of view.

The system is viewed by the integration of sub-systems and processes. The sub-systems are modeled methods of trees, graphs and determine the structure of the system in terms of damage prevention. Processes are modeled kinematics and dynamics methods in identifying vulnerabilities and synthesis of operational interactions between system components and interactions in the macro-system M-T-E in response to service loads. System approach is expressed by looking at all of the components and subsystems function as a whole [2] and synergistic interaction between the components and subsystems, including the cause and effect relationship is often classified or non-linear and even distant in time. The system is determined as an ordered according to the laws of physics syntax schemes for the next levels of the organization. This approach allows you to descend to the desired level of organization and design features of it were local to the host system but with the boundary conditions which are characteristic connections of individual elements in the system using logistic tools and systems theory.

In the analysis the airframe durability is modeled as an structural system, material object and subsystem of the aircraft and it is structured in accordance with the laws of physics syntax schemes for further levels of organization of matter which impacts the synthesis of functions including components / subsystems as a whole and the interaction between the components and subsystems, with taking into account the causal relationships of individual processes, including degradative.

System approach to airframe must be included in the processes of design, manufacture and service of aircraft to established / model system of its operation, taking into account all elements of the system: mechanical and logical. When descending to the level of detailed organization of the airframe of the aircraft as a technical object, which is a structural subsystem of aircraft operating in the air operating system determines the risk of adverse events in terms of flight safety.

The airframe, in the pre-exploitation must be adapted to meet the tasks/missions without injury, especially catastrophic, at a specified time and operating conditions, including the renewal of its operating capacity, while ensuring appropriate operational flexibility/availability. The condition of the renewal process involves the use of recognized principles, methods and diagnostic tools to determine the operating conditions for restoration potential. This process is developed during the operation in terms of prevention through the implementation of prevention. The preventions of civil aviation are systematically introduced as airworthiness directives (AD) by the aviation authorities. In the European Union aviation authority exercised by the European Aviation Safety Agency (EASA) and the national aviation authorities (NAA) act as a representative of the EASA for a given country. Prevention project are derived from operating experience, including that based on the results of air incidents and accidents. The fulfillment of the main requirements in the design of the airframe as actions to eliminate design errors/defects, causing damage to supplies and to mitigate the effects of their presence as a result of the destructive impact of the environment with regard to the impact of human factors is done by determining the characteristics of the airframe durability. Analysis taking into account the characteristics of durability and uncertainty translates into a sense of confidence to the structure during operation. This approach is the realization of the requirements for one of the simplest and the first definition of quality, which refers to the degree of customer satisfaction, which is in reverse relationship in the growth of the company's efficiency. Meeting the costs of the company to provide high quality products and/or services takes place through the introduction of recognized principles, methods and tools, for example, included the ISO 90001 series.

Provisions on the construction and operation of civil aircraft, determining how to shape the structural durability of the structure, including the airframe, turn on the stages of design, manufacturing and operation, applications are implemented as a codification standards recognized by the International Civil Aviation Organisation(ICAO) in the standards and recommended practices meet them as SARPs. SARPs, which are 18 Annexes to the Chicago Convention, standardize guidelines for the creation of local rules across the Member States of ICAO. The issue of forming durability of the airframe, are of particular importance Anex 6 and 8 engaging airworthiness requirements for operation and design stages, respectively. In the European Union standards and recommended practices meet their requirements are included in the document (EC) No 216/2008.

Provisions on the design and exploitation of aircraft subject to development. This

development is driven by exploitational experience. Directs the exploitational experience determines engineering high performance and efficiency. According to [2] engineering activity includes tasks: modeling (with identification), analysis, measurement and synthesis with the synthesis of the mechanical system is an act which aim is to produce an object or set of objects with data from the top of the dynamic properties. By expanding the definition of - in terms of this paper subjects - a synthesis of the mechanical system is an act whose aim is to produce an object or set of objects with data from the top of the dynamic properties and durability characteristics specified.

4. The experience from the investigation the aviation accidents

The aviation accidents and incidents are and will occur with the different participation of macro-system factors in different intervals. Causes of accidents and incidents are technical, human and/or environmental. The causes of accidents and incidents, if are recognized right, guide the actions to improve weakness in the system and generate research which are preventive in order to improve safety of flights. Exploitational tests show an increase in flight safety for civil aviation with the intensification of the traffic. The safety assessment both calculate hazard and set directly accidents in respect of loss of human life and mileage, as measured in a specific time interval, must be socially acceptable level, giving a sense of safety of flight. Aviation, in this sense, is the safest means of transport. In addition, it should be considered that the people are able to bear the cost of safety and security, but only up to some amount.

Social expectations at the time the cause of the crash make it hot speculation about the cause. It is featured here, with full responsibility, the word speculation as to assign blame at the stage of investigation without the knowledge of all aspects of the ill-fated flight is not an assessment of the facts, and such an evaluation can be conclusively accident investigation committee of the Country in which the event took place (in accordance with Annex 13 to the Chicago Convention). It was not until a judgment about the cause of the crash activates all possible measures to ensure that the global aviation system to fix the weakest link. Prevention in the air transport are the engine of technological progress, giving impetus to the search for (1) new materials with a focus on gradient material and self-repairing, (2) new aircraft manufacturing techniques and combine them into modules, components and finally the overall aircraft, (3) new solutions and methods to manage the system in operation as well as maintenance, (4) development of methods for analyzing the correlation of system's factors (M-T-E), (5) new application of the engineering solutions and its related (6) modeling of exploitation simulation and diagnostic methods for the evaluation of condition. Modern aircraft, as a result of referrals aspects of human consciousness on environmental protection, should be designed on the basis of eco-materials and eco-technologies. The durability is the key to sustainability of fleet in continuing airworthiness from ecological as well as economical point of view.

5. Hazard assessment in aspect of durability

While studying Japanese philosophy kaizen,² one can conclude: "Do not assess a risk is the certain risk" the risk is recognized in terms of absolute coexistence activity risk in any process, spontaneous or forced. Increased safety is therefore determined by the analysis of the hazard of adverse events causing a safety hazard as a result of damage. Measures to prevent damage is done by ensuring high reliability, appropriate diagnostics, prevention and prediction of condition of prevention to detect damage during operation. Measures to prevent catastrophic damage include safety analysis, by identifying and managing the risk of adverse events, which may cause a hazard leading to an incident and, in the worst case, to an accident. Measures to prevent catastrophic damage, as well as mitigating the effects if they occur, are realized through the research, development and implementation of the safety management system. The safety management system in civil aviation - SMS is included in the standards and recommended practices - SARPs. In this system, it is essential to manage the airframe durability, in terms of structural coherence as a criterion for technical suitability, based on a risk analysis of the specific risks damage effects.

6. Accelerated durability testing

Ensuring the structural integrity of the airframe is determined by accelerated durability testing, including simulation and laboratory assessment of the durability of the attached / model system operation, taking into account all the macrosystem M-T-E consist of the man/ human factor (M), technology (T) and environment (E) and for the two sub-processes: operation and maintenance ensuring the continued airworthiness of the fleet. The joint efforts of aviation authorities, research centers and aerospace industries generate reducing accident rates in this disaster (with the progressive intensification of traffic) through the development and application of accelerated stability studies.

7. Divergence or convergence between durability and viability of the airframe

Particularly important is to unify the characteristics of durability issues, expressing adaptability to the operating system. Currently, research are underway to expand the scientific analysis of the durability to adapting the structure to a safe landing in the event of an emergency oversized loads. Studies of this type belong to the viability of the airframe. It seems to be a reasonable extension of the term durability including viability in relation to the structure of the civil airframe design. The modeling of strength must be taken into account the impact of oversized loads in terms of assessing uncertain which begin correlations to availability, reliability, safety and security, and take account of these factors in predicting lifetime. The military technology issues associated with oversized loads are covered in the research aspects of lifetime from hazards to structure by attacking the enemy on the battlefield. The concept of viability is considered as a property of operational aircraft down safely and complete the flight by landing with a significant damage. The civil aviation design standards do not cover this type of research but they are

²Kaizen - Japanese means continuous improvement or change for the better and the better. It refers to philosophy or practices that focus upon continuous improvement of processes

led by research centers in terms of growth initiated by the flight safety service experience. It is to adopt the concept in aviation for structural characterization in case of: (1) the structure of impacts of collisions with other objects derived from the external environment, including ground, (2) damage to the explosive, as a result of following a failure of one of the pressure vessels mounted on the aircraft such as cylinder with oxygen³ (Fig. 2a) and (3) security risk by terroristic attack⁴ (Fig. 2b).

Fot. Edwin Llobrera AP

Fot. Wikimedia Commons – Jim Gordon

Fig. 2 Serious damage to the structure of the airframe in flight: a) the fuselage of Boeing 747-400 Qantas Australian with 3 meters diameter damage after the outbreak of an oxygen cylinder and b) the wing of DHL Airbus A300 with damages when it hit the ground-to-air missiles

8. The diamonds of the quality

The development of technical sciences with a focus on the implementation of a systematic approach is through quality management due to increase efficiency. Scientific methods of quality management based on the Deming cycle, forming cyclic succession: *plan, do, check* and *act* (PDCA). The approach to civil aviation safety PDCA adopt to *prepare, execute, measure, evaluate* in terms of the guidelines in the SARPs are integrated with the developments in science and technology. The developed models of quality management is prepared for all stages of the aircraft durability, including the design, manufacture, testing, operation and

³ November 22, 2003, the DHL aircraft Airbus A300B4-203F crash-landed at the airport in Baghdad after being hit in the left wing of the ground-to-air missile. Terrorist attack was when the plane was in the start-up phase at an altitude of 2450 m Despite severe damage and loss of control of the aircraft landed without casualties and no damage to the machine which was the first case in the history of landing large aircraft (passenger or cargo) on the total loss of steering. The landing maneuver was performed by only the changes thrust engines

⁴ 25 July 2010 Boeing 747-400 Australian Qantas emergency landing in Manila after an oxygen tank explosion. Until the outbreak of the cylinder was the South China Sea at an altitude of 8,840 meters during a flight from London to Melbourne via Hong Kong. The outbreak has caused severe damage to the right side of the fuselage near the wing, with a diameter of about 2.5-3 meters. Damaged systems were used during landing and skid system. The plane landed safely, because its main systems, including engines and hydraulics, functioned properly. None of the 365 passengers and crew members was injured

maintenance. Exploitation experience shows a direct relationship between quality and satisfaction expressed by the concept of scientific certainty. The approach to the development of lifetime is a new/development methodology captivating design and management of airframe durability in terms of pro-quality to ensure the highest, as possible, quality. The author propose as new model engaging performances and processes of identifying correlations between quality coefficients, called *diamonds of quality*. The name 'diamonds of quality' has been inspired by the reading the literature [5, 28]. The term 'diamond' was coined by American and Australian researchers from National Aviation Authorities (FAA and CASA) as a method of quantifying resistance to fatigue airframe and take its adaptation to the problem of corrosion, respectively.

9. Cost issues in the aspect of airframe durability

The durability and sustainability management by providing appropriate/required level of flight safety generates costs. Operating costs incurred by the air operator to manage the safety are generated, mainly, in the pre-exploitation process. In this process durability is shaped as design lifetime of the aircraft, especially airframe. The airframe durability, given by the designer/manufacturer, is characterized by a specific quality. The measure of the quality of the design is be sure to adapt to the exploitation in the certainty of the methodologies in all stages of aircraft. It is measure of prevention damages and determine the degree of structural integrity of the airframe for the assumed operational system. Determines the quality of the production of certain aspects of manufacturing processes meet design requirements for compliance deviations of the expected size. Operational (exploitation) quality determines the degree of suitability to fulfill the requirements of flight safety including identification of factors affecting the durability characteristics of endurance during the operation and use of appropriate preventive and corrective methods reconstruction of health potential. Operational quality is derived from the design quality as well as manufacturing quality.

Air operators need rational decision support tools to minimize operational costs. Reducing operating costs, as one of the major challenges for designed new aircraft for the commercial aviation, can be achieved by the application of methods of durability analysis presented in the paper. While operating costs resulting from the underestimation of durability design, in terms of reliability, safety, security and operational compliance within the meaning of 100% can be reduced by 10 to 20% by upgrading the structure. The more effective reduction costs at the design stage, through the application of reliability assessment gives 80 to 90%. reduction Structural errors are the most expensive, in the worst case can lead to accident, hence the efforts of research centers in order to improve design techniques in the search for risk analysis in terms of damage to the cause - effect degradation.

In aerospace engineering the highest quality, possible to achieve recognized technologies, is require. The percentage of material costs for passenger aircraft represents approximately 4.5% of total costs so that the airframe is built using the best known materials and manufacturing technologies. Used modern technologies do not make significant cost, in relative terms of quality. The economic calculation shows that the most expensive are operating costs. In recent years, it is the lower operating costs of aircraft, which replaced an aging fleet is the main argument of marketing. The mentioned Boeing 787-8 *Dreamliner* is characterized by a significant reduction in operating costs (projected) relative to comparable, currently operated (long-range) aircraft, with a reduction of 30% of the costs

associated with maintaining the airworthiness status and 20% of fuel consumption comparing with B767, with the highest readiness compared to other operated aircraft [9].

An important component, in the overall costs, are the cost of changes in the pre-exploitation stage of the aircraft life (Figure 3). The cost analysis of the changes shows the highest efficiency of the detailed design stage. At subsequent stages of the diagram there is the increase of costs by a logarithmic scale.

Fig. 3 Qualitative presentation of the cost size versus changes at each stage of the pre-exploitation process of the aircraft, X - mean value of changes

Fig. 4 The area of costs for the life cycle of the aircraft (LCC), indicating high efficiency by using efficient systems consulting and uncertainty analysis data obtained from real experiments and simulations. Diagnostic methods using Structural Health Monitoring integrated with the airframe structure and based on multi-level modeling could give the yellow point, the most needed

It is postulated that the possibility of reducing the costs of providing high-quality methods is the uncertainty analysis. The costs should be formed by using efficient expert systems. The basis of this approach is to analyze the uncertainty in estimating durability and monitoring of sustainability, highlighting the qualities from excellent, A to the smallest, E (Fig 3).

The civil aviation due to the most important aspect of flight safety is required the highest - possible to achieve recognized methods - quality. Quality can be ensured through appropriate financial outlay. Lower limit of the gray area (Fig. 4) is the minimum cost line, total. Yellow point on the line shows a possible (the most needed) state to be achieved through the use of expert systems consulting (DSE) based on the latest achievements of science and technology in modeling the characteristics of durability in terms of pro-quality, integrated with exploitation knowledge, determining the quality of the design. The useful, proper aided analysis techniques for determining the design quality, due to the incompleteness of the data used in the analyzes of strength, there are methods of artificial intelligence (AI). Operating costs, resulting from the underestimation of persistence, can be generated by the assumed lifetime distribution, modeled as a random variable, which can be an indirect cause of financial losses due to oversized prevention or even catastrophic damage as a result of wrong assessment of prevention. It is important to aplicate the durability management into the exploitation proces by verifying the distributions based on the exploitation data and/or by modernization of the diagnostic system. This modernization could consist of structural heathh mositoring system which is intergrated to the airframe.

Considering above, the forming of operating costs connecting with sustain the airframe in a continuous airworthiness throughout the life cycle of the aircraft, it must be supported by effective expert systems, including uncertainty analysis of data obtained from real experiments and simulations, based on multilevel modeling in the analysis of cause and effect of structural degradation of the airframe. The highest operating efficiency can be achieved by pro-quality approach in shaping the lifetime in the pre-exploitation stage (in the detailed design development stage at the figure 3) and durability management in exploitation (operation & sustaining the airworthiness) stage.

10. The effect of diagnosis in airframe dyrability

The role of technical diagnostics in the management of the airframe durability is key, as mentioned in Section 2 of this paper. The integrated diagnostics increases the confidence to the airframe (certainty), with the actual assessment of the condition, and the number of milions elements for passenger aircraft, the complicated reliability structure - requires the use of expert systems in the analysis of durability. The role of the airframe durability has a key position next to the powerplant and flight control systems.

Operational problems of an aging fleet of aircraft, subject to scientific analysis, improving the initiate procedures: (1) the design of future construction, eliminating the causes of defects and (2) techniques for monitoring the safe development. That is why it is very important flow of information about injuries with the use of scientific tools and methods in the analysis of computer-aided diagnostic information. This is a useful process affecting the increased security as a result of the assessment and leveling threats damages, as an indirect action to prevent the occurrence of incidents and accident, in reducing operating costs. The study used operational problems are many scientific disciplines and interdisciplinary orientation is important in evaluating and shaping the life of the airframe structure

design of the aircraft as a safe life. Benefits in terms of prolongation of safe use are achieved through the use of integrated assessment of technical condition (Fig. 5), including methods for monitoring the technical condition, in a continuous manner, using methods belonging to the SHM, NDT non-destructive testing methods and monitoring capabilities wear and tear.

Fig. 5 Integrated diagnostic system for the assessment of airframe condition based on the wear out the exploitation potential and the methods of the damage detection

11. Summary

The key importance in shaping the lifetime of the airframe has the choice of materials and design solutions, providing consistency and structural integrity of the structure. The key problem is the modeling of a exploitation system. The keys importance has the prevention after air accidents caused by loss of structural coherence of the macroscopic structure of the airframe, which are milestones in shaping the design, manufacture and operation & sustain airworthiness. Key is the use of accelerated durability testing in the assessment of the airframe durability against the degradation and destruction of the airframe. A key problem is the unification of research in terms of durability and viability designating the airframe durability. The key is to determine the diamonds of quality in the effective management of the airframe durability at minimal cost. The key importance is attributed to technical diagnostics, in particular *Structural Health Monitoring* applications, determining the current condition of the airframe, allowing the effectiveness of preventive measures. A key challenge is to create a system of management airframe durability, as an integral part of the aircraft coming into operation stage. The system is designed on the assumption of the highest quality level, ensures the safety of flight in terms of resistance to the degradation and destruction. The system should be based on a comparison the exploitation systems: modeled and real.

Developing the durability requires an approach which is compilation of (1) a strategy of *top-down* and *button-up* representing the transition from the general to

the details and from details of the whole, (2) using methods of artificial intelligence: (a) the artificial neural network, (b) rough sets, (c) fuzzy sets, and (d) genetic algorithms for optimization tasks. Analytic-logical approach, includes given above methods, is the development strategy for the recently applied to the airframe, considered as a complex system: aero-mechanical telematics.

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