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AIRCRAFT SKIN CORROSION AND STRUCTURAL SAFETY CONSIDERATIONS

ABSTRACT: The aim of this article is to point out some peculiarities of airframe corrosion, the impact of external forces on aircraft skin elements and their impact on structural integrity. The corrosion process is generally associated with fatigue of aircraft structural elements due to the effect of many factors such as the type of loading, the properties of the materials, the corrosive environment, etc. The article is not focused on corrosion processes, but on load factors that are specific to aircraft wing design elements and their influence on corrosion of critical structural elements. Corrosion of the wing is perceived as a consequence of environmental impact on damaged surface protection of the skin and connecting parts (rivets, screws, and welded joints) caused by static and dynamic stress of the wing and also by the interaction of the individual structural elements as a whole. The dynamics of operation of individual structural elements is further enhanced by the fatigue of the material. Early detection of corrosion processes has generally been and is crucial to overall safety of the aircraft. The proposals presented in the article are formulated in order to improve the system of work to ensure the safety of aircraft operation in terms of resistance to corrosion damage.

KEYWORDS: aircraft structure, aircraft safety, non-destructive inspection, corrosion, maintenance, load, fatigue

KOROZJA POKRYCIA SAMOLOTU I WZGLĘDY BEZPIECZEŃSTWA KONSTRUKCYJNEGO

ABSTRAKT: Celem niniejszego artykułu jest wskazanie niektórych osobliwości korozji płatowca, wpływu sił zewnętrznych na elementy pokrycia samolotu oraz ich wpływu na integralność konstrukcji. Proces korozji jest ogólnie związany ze zmęczeniem elementów konstrukcyjnych statku powietrznego pod wpływem wielu czynników, takich jak rodzaj obciążenia, właściwości materiałów, środowisko korozyjne itp. W artykule skupiono się na współczynnikach obciążenia charakterystycznych dla elementów konstrukcyjnych skrzydeł samolotu oraz ich wpływie na korozję krytycznych elementów konstrukcyjnych. Korozja skrzydła jest postrzegana jako konsekwencja oddziaływania środowiska na uszkodzoną ochronę powierzchni pokrycia i elementów łączących wywołaną naprężeniem statycznym i dynamicznym skrzydła. Dynamikę pracy poszczególnych elementów konstrukcyjnych dodatkowo potęguje zmęczenie materiału. Wczesne wykrywanie procesów korozji było generalnie i ma kluczowe znaczenie dla ogólnego bezpieczeństwa statku powietrznego. Przedstawione w artykule propozycje zostały sformułowane w celu udoskonalenia systemu pracy zapewniającego bezpieczeństwo eksploatacji statków powietrznych w zakresie odporności na uszkodzenia korozyjne.

SŁOWA KLUCZOWE: konstrukcja statku powietrznego, bezpieczeństwo statku powietrznego, inspekcja nieniszcząca, korozja, konserwacja, obciążenie, zmęczenie

INTRODUCTION

The main factors potentially reducing structural strength and durability of technical structures during long-term operation are fatigue, corrosion, wear and damage of metals and their alloys resulting in significant economic and technical losses, and worst of all – accidental operational damage. The current system for ensuring and maintaining the airworthiness of airplanes in terms of corrosion safety is to ensure strength during long-term operation. Modern science has a wealth of knowledge about the types and mechanisms of corrosion damage, but does not offer aviation developers acceptable methods to predict the onset of corrosion and its rate of development, which could form the basis for the development of maintenance and inspection regulations. Sufficiently reliable calculation methods can only be used to assess the residual strength.

Corrosion damage to aircraft structures is one of the most frequent and most dangerous forms of aging structural elements of aircrafts during long-term operation. Therefore, special attention is paid to them during routine (preventive and repair) work. In this context, a great deal of material resources is spent on a range of measures to combat corrosion, preventive maintenance, repair, and replacement of individual parts.

Prediction and improvement of the strength characteristics of structures in the event of corrosion damage based on computational and experimental methods, the creation of reference data on the effect of corrosion on the physics and mechanical properties of structural materials, is an essential task in solving this problem. The second serious aspect in terms of tackling corrosion is knowing the load and the forces acting in the structure.

From this point of view, we can hypothesize that the critical elements of the effect of load on the aircraft critical structure elements are one of the factors supporting corrosion. The main purpose of this article is therefore to provide evidence that there is a close relation between load/fatigue and corrosion.

The load of a structure that is made up of many elements, various materials, under the adverse influence of atmospheric, and climate (e.g. weather) influences is a not negligible factor. Most often, corrosion damage occurs on the skin of aircraft based on airfields located near industrial or coastal areas.

Aluminum alloys remain the main structural material of aerospace engineering. The scope of their application currently makes up approximately 70% of the total number of structural materials in the airframe. The materials used in aircraft structures corrode because the atmosphere of the Earth contains aggressive halogen aerosols, sulfur dioxide, and moisture; and also because of the accumulation of aggressive liquids inside the aircraft airframe.

The main structure of the aircraft consists of all load-carrying members including wings, fuselage, tail unit, engine mountings, landing gear, flight control surfaces and related points of attachment, control rods, propellers and propeller hubs, etc.

For aircraft structures, significant periodic loading occurs during take-off and landing. Other sources of fatigue cycles include cabin pressurization-depressurization (pressure vessel loads), pilot-induced manoeuvres, and encounters with gusts. The fatigue life of an aircraft is based on the number of cycles accumulated during these cyclic loads. While aircraft fatigue damage is based on the number of loading cycles, corrosion damage in aging aircraft depends on the time spent in the corrosive environment[1].

The aircraft wing is one of the most heavily loaded components during the operation of the aircraft on the ground and also in the air. For example, the wingspan of the Airbus 380 is 60m and the wing fuel tank capacity is 291 256 litters of fuel.

The wing of the aircraft is not a perfect rigid body; it is considerably flexible and represents a cantilever beam anchored to the fuselage structure. Bending, or rather swinging the wing during flight, indicates its normal operation. The wings of the aircraft have good flexibility and safety margin. It is the “swinging” that saves the wing from destruction.

The probability of destruction of the wings of the aircraft (as well as the entire aircraft as a whole), even during strong turbulence, is practically zero. The aircraft is designed with a huge margin of safety, and even quite large loads are not able to damage it.

In the history of aviation, unique cases are known when aircrafts were destroyed in the air. But in these cases, the cause of the tragedy was human carelessness and poor-quality maintenance of the aircraft. The consequences of structural failure are often catastrophic.

Aircraft Structure as Elements of Corrosion System

A system is defined as a set of elements that are in relationships with each other, which forms a certain integrity, unity. A corrosion system is a system consisting of one or more metals and all components of a corrosive environment.

The aircraft structure presents an element of the corrosion system, the system consisting of different kinds of metal and those parts of the harsh environment that influence corrosion.

[1] P.W. Whaley, *Corrosion damage tolerance methodology for C/KC-135 fuselage structure*, Oklahoma City, USA, https://dokumen.tips/documents/corrosion-damage-tolerance-methodology-for-corrosion-damage-tolerance-methodology.html (26.02.2020).

Corrosion damage to aircraft structures and equipment is one of the most common failures that can significantly compromise the integrity of structures and systems.

Any detectable result of corrosion in any part of a corrosion system is termed a “corrosion effect” that leads to corrosion damage or corrosion failure. The rate of aircraft corrosion depends on the structural system (corrosion) system and the type of corrosion effect of which these form a part. Since corrosion rates are usually expressed as a penetration rate per time period (year) in inches per year (IPY), or melts per year (MPY), it is very important to detect corrosion at an early stage of its development.

$$IPY = \frac{12W}{TAR} \tag{1}$$

Where:
W = mass loss in time,
T= time, years,
A = surface area,
R = density of material.

For this reason, it is important to provide scheduled maintenance at predetermined intervals to address damage remaining undetected in normal operations. During scheduled maintenance, the aircraft usually stays in a hangar and undergoes intensive inspection and necessary repair work, including corrosion check.

The immediate detection and identification of corrosion is therefore of utmost importance, as is the correct application of procedures to remove and re-protect the area from further attack. Unprocessed corrosion can have serious consequences, including:

– decrease of static strength,
– when stressed by a structure affected by corrosion, cracks develop and spread in the structure,
– conditions to promote stress corrosion cracking,
– reduced fatigue life,
– malfunction of mechanical, electrical, hydraulic, and pneumatic systems,
– uncorrected corrosion can adversely affect flight safety, airworthiness, and structural repair costs.

Aircraft Structural Safety and Corrosion

Safety of the structure in terms of strength is a property (quality) of the structure and a way of maintaining its strength in service, which allows to keep the strength of the structure at the least of acceptable level, even in case of possible unintentional and not too long degradation processes and/or combinations of (fatigue, corrosion, etc.) as well as accidental or discrete source of damage.

The structure of the wings can be considered as a safety-critical system, consisting of structural components with high safety priorities such as the skin or spars. The safety-critical system in certification is the fail-safe design concept, which considers the effects of failures and combinations of failures in defining a safe design. Fail-safe for structures is concerned with residual strength after sustaining damage.

The main factors that can potentially reduce structural strength during long-term operation are fatigue, corrosion, wear, and accidental operational damage.

Modern science has a lot of knowledge about the types and mechanisms of corrosion damage, but does not offer aviation developers acceptable methods to predict the onset of corrosion and its rate of development, which could form the basis for developing maintenance and inspection regulations. Sufficiently reliable calculation methods can only be used to assess residual strength.

An evaluation of strength, detail design, and fabrication must show that catastrophic failure due to fatigue, corrosion, manufacturing defects, or accidental damage will be avoided throughout the operational life of the airplane. This evaluation must be conducted for each part of the structure that could contribute to a catastrophic failure (such as wing, empennage, control surfaces and their systems, the fuselage, engine mounting, landing gear, and their related primary attachments)[2].

Flight safety is directly related to the structural strength and durability of aircraft structures. Design is called safe in operation if minimal inspection and repair are required with satisfactory performance of basic functions. Satisfactory performance means a low probability of structural failure for civilian aircraft or an acceptable low probability of structural failure for military aircraft. The safety of passengers and crew of civil aircraft is of paramount importance.

A modern aircraft has a semi-monocoque type construction, consisting of thin-walled sheets supported by beams (spars) and stringers to prevent buckling. The outer skin or wall forms the aerodynamic shape of the structural unit – the fuselage, wing, horizontal/vertical stabilizer. Stiffeners are attached to the inner surface of the skin and absorb concentrated loads. For many years, this design served as the main object of aerodynamic research and significantly distinguished devices from conventional building structures.

Degradation by mechanisms such as corrosion and fatigue can become important later in-service life, particularly in joints, and managing potential degradation, by repair or replacement of parts, can have a significant effect on the overall maintenance cost of the aircraft[3].

Structural corrosion damage of aircrafts is observed in inner and outer different places, especially from extruded panels. The upper surfaces of the skin of aircraft are in better conditions than the lower ones. This is because the dew settled on them, moisture after rain, or condensed after planting, evaporates relatively quickly. This is facilitated by the temperature of the air and the flow of air. The lower ones, due to the insignificant distance from the earth, are moistened almost constantly due to the evaporation of moisture from the soil.

[2] Federal Aviation Regulations: Airworthiness standards, transport ..., Part 25, § 25.571 Damage - tolerance and fatigue evaluation of structure. https://www.law.cornell.edu/cfr/text/14/25.571 (26.02.2020).
[3] A. Jaya, U. H. Tiong, R. Mohammed, C. Bil, G. Clark, *Corrosion treatments and the fatigue of aerospace structural joints*, Australia 2010, https://core.ac.uk/download/pdf/82351243.pdf (26.02.2020).

Corrosion of the internal surfaces of airplanes and parts inside structures works under conditions more difficult than those of the external ones, which is explained by the long moisture retention inside the structure. Moisture enters the inner surfaces in rainy weather or when washing through leaks in the joints of the skin; it also condenses from the air after landing due to a sharp temperature drop.

In especially unfavorable conditions are the inner surfaces of the lining and the details of the internal set under the floor of passenger cabins. Here, the condensed moisture is retained for a long time, becomes contaminated, and becomes corrosive. Water pollution under the floor of the passenger cabin is most often due to insufficient tightness of the floors of the toilets and malfunctioning communication of the bathrooms. These fluids are very aggressive, especially with regard to aluminum alloys. Moisture is also retained for a long time on the lower inner surfaces in case of poor location or clogging of the drainage holes for water drainage, as well as in the absence of periodic ventilation and blowing of the underfloor space with warm air[4].

The corrosion problem is a question of scientific and technical assessment of the airframe airworthiness in case of corrosion damage. A prerequisite for ensuring the airworthiness of an aircraft is to comply with the airworthiness requirements under the conditions of static and fatigue strength of the airframe in the event of accidental damage,, fatigue damage and corrosion damage.

In the event of corrosion damage, calculation methods are also necessary to justify the maximum permissible corrosion rates of the structural components of the airframe to take into account the effect of corrosion damage on fatigue and structural survival. Fatigue damage, corrosion damage, and a combination of these are the main factors that undermine the integrity of the aircraft structure.

Damage tolerance is a property of a structure and a way to ensure its safety under strength conditions by establishing conditions for the first and subsequent inspection of the structure in service to detect possible damage and subsequent repair of the structure or replacement of the damaged element prior to onset when a strength decline is unacceptable.

MATERIALS AND METHODS

MROs predominantly rely on visual inspection and non-destructive operational testing (NDT), methods by which we detect defects on the surface and in subsurface (volumetric) tests of the material without breaking it.

More than 80% of the inspections on large transport category aircraft are visual inspections. Visual inspector's tools are his eyes, a high-quality flashlight, and a 10x magnifier.

Visual inspection is usually the most economical and fastest way to obtain an early assessment of the condition of an aircraft and its components. Most of the defects found in aircrafts are found by visual inspections, and airframe manufacturers and users depend on regular

[4] *Ibidem*.

visual inspections to ensure the continued airworthiness of their aircraft. Consequently, it is important that visual inspection methods are understood and properly applied by those responsible for the continued airworthiness of the aircraft. The proficiency in visual inspection is crucial to the safe operation of the aircraft.

Typical airframe defects that can be detected by visual inspection can be divided into three types: cracks, corrosion, and disbanding[5].

Visual corrosion inspection was applied to wing rivet joins. For this type of corrosion are typical operational factors, combined with structural components made of various metal materials, which greatly contribute to the rapid development of corrosion processes (See Figure1,2). These processes are most strongly reflected in the fatigue characteristics of structural materials.

The endurance limit of parts affected by corrosion, as a rule, sharply decreases. Corrosion damage with a depth of 50 μm leads to a decrease in endurance by 40 ... 30%, and a depth of 100 μm - by 50% or more. With a damage depth of 250 μm, the material endurance limit is 25% of the initial value[6].

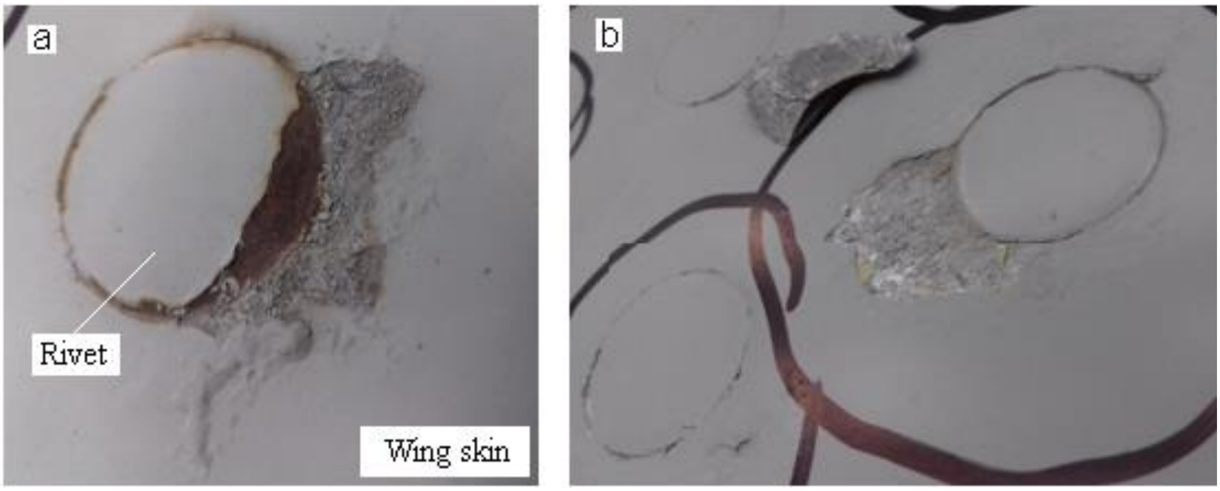

Fig. 1. Electrochemical and exfoliation corrosion
Source: Authors.
(a) electrochemical corrosion, (b) exfoliation corrosion

[5] *Advisory Circular*, AC No: 43-204, FAA, U.S. Department of Transportation, 1997, https://www.faa.gov/document-Library/media/Advisory_Circular/43-204.pdf, (26.2.2020); M. Siegel, P. Gunatilake, *Remote Inspection Technologies for Aircraft Skin Inspection*, Ontario, Canada 1997,https://www.researchgate.net/publication/2314728_Remote_Inspection_Technologies_of_Aircraft_Skin_Inspection (26.2.2020).

[6] Особенности коррозионной повреждаемости авиационных конструкций, https://helpiks.org/6-19149.html (29.11.2021)

Fig. 2. Aircraft wing panel
Source: Authors.

The application of cyclic load, coupled with the pressure in the through-thickness direction exerted by the rivets, caused microscopic displacements at the contact surface and degraded the metallic surface. The degradation on the surface then developed to form micro-cracks, propagated, and linked up with other micro-cracks to form larger cracks, which eventually caused the sheet to fail. This degradation process is also known as fretting[7].

As the aircraft is operated, rivet joints relax, surface and subsurface cracks form around rivets, atmospheric water begins to penetrate deep into the joint, causing corrosion around rivets in both the first and second aluminum sheet.

Corrosion products are concentrated in the cavities of the metal. This type of corrosion causes swelling and delamination of metal products.

When discovered, this type of corrosion is removed by grinding away the corroded material until the pristine material is exposed. The area is then treated using standard surface treatments (CPC, prime, paint, etc.). In severe cases, the grind-out method may not be feasible, as the remaining pristine material may not support the required fatigue life or residual strength. In such cases, a more elaborate repair or replacement of the part may be the only option.

[7] A. Jaya et al., *op.cit*.

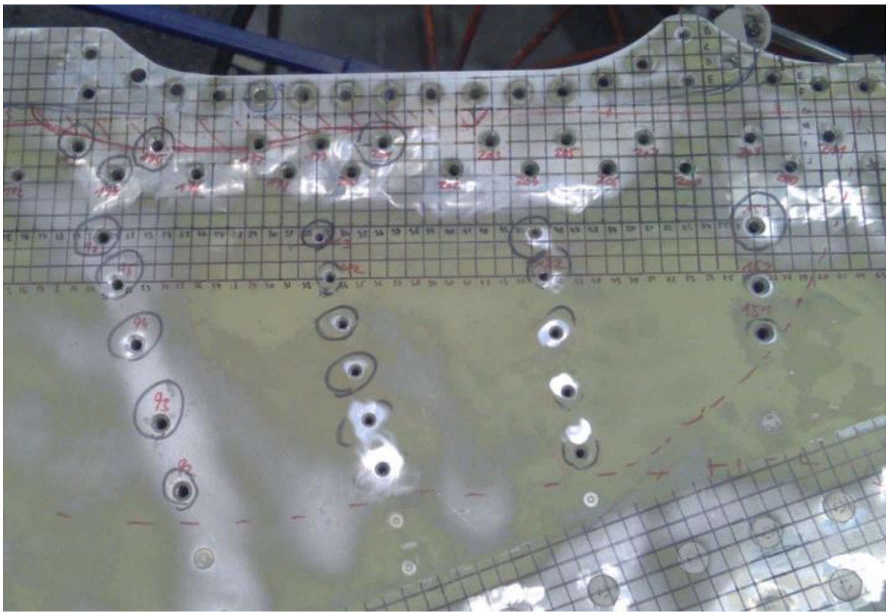

Fig. 3. Wing skin cleaned from corrosion
Source: Authors.

Exfoliation corrosion is considered a form of intergranular corrosion that attacks metals that have been mechanically deformed, primarily by extrusion or rolling, producing elongated grains that are aligned directionally. Most often, the attack is initiated at exposed endgrains, as has been the case with aircraft skins around fasteners and rivets. This form of corrosion is most evident in some of the aluminum alloys and is shown in Figure 4. Metals susceptible to exfoliation corrosion are aggressively attacked in environments corrosive to that particular metal. As an example, many aircraft are known to perform well in urban type environments but are severely attacked in marine environments[8].

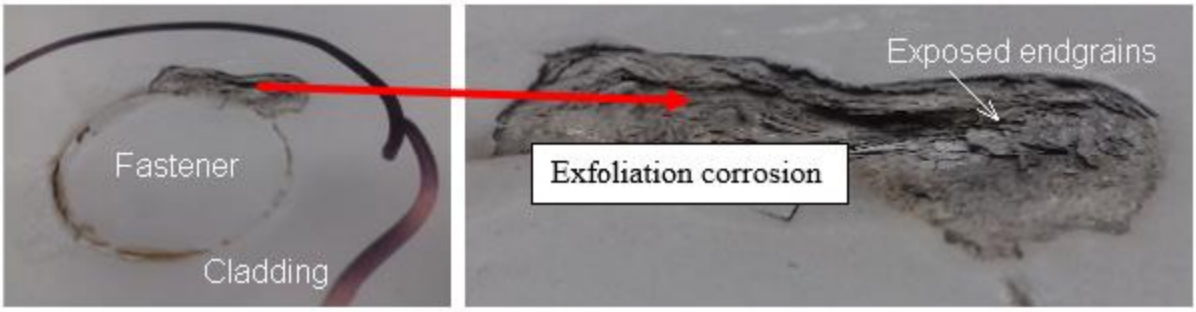

Fig. 4. Corrosion of the wing skin exfoliation
Source: Authors.

[8] R.B.D. Craig, D.A. Lane, H. Rose, *Corrosion Prevention and Control, A Program Management Guide for Selecting Materials*, 2006, http://www.acqnotes.com/Attachments/Corrosion%20Prevention%20and%20Control%20A%20Program%20Management%20Guide%20for%20Selecting%20Materials.pdf, (26.2.2020); J.M. Greer Jr. and others, *Fatigue and residual strength effects of exfoliation corrosion damage*, https://saf-engineering.com/wp-content/uploads/2020/05/Aging2005-FATIGUE-AND-RESIDUAL-STRENGTH-EFFECTS-OF-EXFOLIATION-CORROSION-DAMAGE.pdf (26.02.2020).

Ultrasonic techniques are widely used and well-developed methods. The application of ultrasonic to the study of hidden corrosion has been limited, due to some of the physical characteristics of the corrosion problem. The two techniques usually applied to these problems are pulse-echo and guided wave ultrasonic.

Guided waves ultrasonic are mechanical stress waves that propagate contained within the structural boundaries of plates with wavelengths that are comparable to the thickness dimensions of the plate. Guided waves are used in rapid testing or screening tools to detect, locate, and classify corrosion defects.

Pulse-echo ultrasonics is conceptually simple and is used in many applications. It can make highly accurate thickness measurements. Its ability to measure below the first layer in multilayer structures, which may have sealant, adhesive bonding, or corrosion product between layers; is severely limited. Simple thickness measurements are also not necessarily indicative of corrosion loss: sheet tolerances in thin sheets range from 5 to 8%. This technique is also quite slow, requiring raster scanning of the entire area to be inspected[9].

Visual and Pulse-Echo Ultrasonic OmniScan MX2 NDT Instruments has been used for wing top skin panel corrosion detection. Probe modifications are performed by introducing time shifts in the signals sent to (pulse) and received from (echo) individual elements of an array probe. Any ultrasonic testing technique for flaw detection and sizing can be applied using phased-array probes.

Area description: wing top skin panel around the rear spar bolting, which penetrates the lower surface corrosion detection.

Preparation for Inspection:

No paint layer on the scan surfaces needs to be removed, as long as it is in good condition with no bubbles or flakes. If there is any doubt about the condition of a paint layer in the scan areas, the paint layer (excluding primer) must be removed using an approved method.

The paint was removed from the rear false spar (See Figure 3) trailing edge overhang area and the ultrasonic phase array inspection was performed (See Figure 6).

The correct use of the classification of defects allows you to pre-identify the nature and location of the defects, the method and the possibility of elimination, the number of required labors, materials, spare parts and time, as well as the estimated cost of eliminating the defects.

In order to choose a method and means of control, taking into account the features of objects, their purpose, conditions of use, defects are divided into explicit and hidden. A defect is considered explicit, for which control methods and means are provided in the regulatory documentation. Hidden - a defect for the detection of which the rules, methods, and means of control are not provided in the regulatory documentation.

[9] J.P. Komorowski et al. *Probability of detection of corrosion in aircraft structures*, Ottawa 1998, https://www.researchgate.net/publication/44076249_Probability_of_Detection_of_Corrosion_in_Aircraft_Structures (26.2.2020).

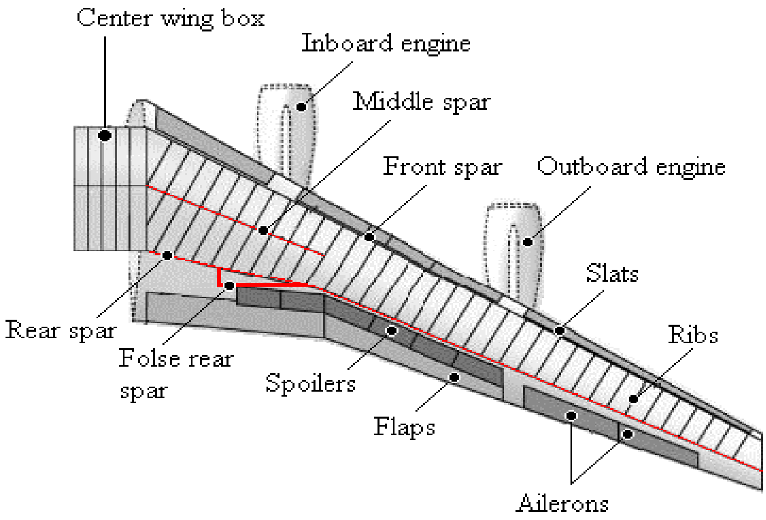

Fig. 5. Components of the wings structure
Source: Authors.

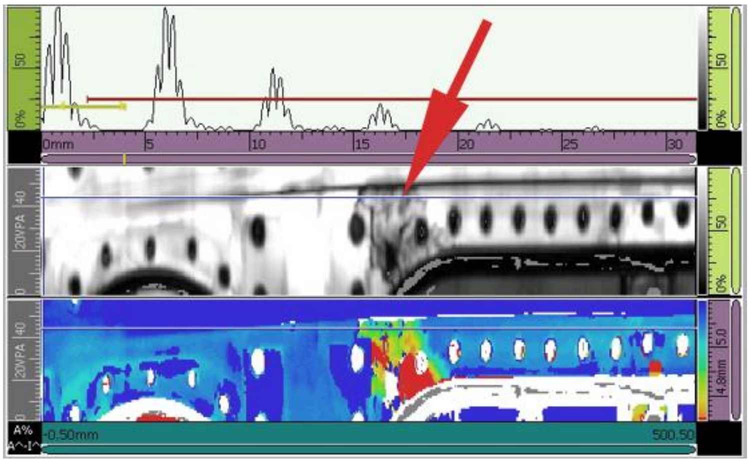

Fig. 6. Wing corrosion mapping by the OmniScan Ultrasonic Phased Array Flow Detector
Source: Authors.

RESULTS AND DISCUSSION

A modern aircraft during flight experiences tremendous mechanical stress, especially during take-off and landing. The wing skin transfers shear stresses between the stringers or longerons that run lengthwise along the wing and transmit tensile or compressive stress.

The wing skin is the main element for the transmission of torsional loads. In today's airliners, the spar is a part of the skin, but the wing skin ahead and aft of it is also a part of the primary structure.

In general, the external load is counteracted by the stiffness of the structure. Advanced corrosion can cause a reduction in stiffness, with additional consequences in the area of aeroelasticity.

In high-speed aircraft, structural stiffness requirements are important to provide adequate strength to prevent some high-speed phenomena such as:

– flutter,
– control surface reversal, whereby the control surface has lost its effectiveness due to weak torsional stiffness of the wing box,
– static divergence - whereby the wing structure becomes torsionally unstable as the angle of attack increases due to the applied loads[10].

When the structure is loaded, the parts that are the most resistant to deformation are deformed, i.e. carry most of the load. Other parts with similar stiffness will also be loaded proportionally to their cross section. Since most aircraft designs are made of aluminum, they have the same rigidity.

Riveting the wing elements is the only reliable way to join them without damaging their internal structure. Rivets can greatly increase the reliability of the structure, providing high vibration and impact resistance. The tightness of the threaded joint is achieved by the use of sealing materials and various damping materials. However, under static and dynamic stress of the wing, the surface protection between the threaded joints is impaired, and this is the gateway for aggressive environment entry causing various forms of corrosion. Wear and backlash of movable joints, loosening of bolted joints, rivet joints, abrasion of structural elements and other types of mechanical wear are typical symptoms triggering conditions for corrosion. Other factors are:
– aging of parts made from organic materials (sealant, etc.),
– mechanical damage caused by negligence during technical services, repairs, and other cases,
– cracks, deformations, and fractures caused by the action of constantly repeated loads in operation and cases of excessive loading of the aircraft in operation.

This group of failures is a combination of structural damage caused by overload in flight and during preloading, thus exceeding the maximum permissible value, and numerous structural fatigue failures due to repeated loading.

Fig. 7. Wing skin delamination
Source: Authors.

[10] C.Y. Niu, *Airframe stress analysis and sizing*, Hong Kong 1999.

Delaminating corrosion is one of the types of subsurface, selective corrosion that develops mainly in the direction of rolling through less corrosion-resistant phases and is accompanied by the appearance of cracks and delamination of the metal (See Figure 7). This type of corrosion is characteristic of certain types of semi-finished products from aluminum alloys and composite materials.

Damage and deformation of the wing structure due to excessive overload in service are rare (rough landing, penetration into storm areas, creating unacceptable maneuvering overload, etc.). The mass defects of the wings are cracks in the riveted part of the wing on the skin and auxiliary structural elements.

The most difficult to determine and dangerous is corrosion in the connection stringer - skin of the lower part of the fuselage. In this case, crevice corrosion most often develops in the absence of sealant between the stringer and the casing due to the ingress of condensate or aggressive liquids from the toilets and cabinets, and during repair work, a flushing inside the joints.

To solve the problem of increasing the corrosion resistance of aluminum alloy structures, it is necessary to design a comprehensive program that includes the following:

- studies of the rate of corrosion development in various materials and development of methods for monitoring and predicting the corrosion status of materials and structures;
- development of high-performance coating and varnish materials for painting the exterior surfaces of aircraft, which provide reliable anti-corrosion protection of aluminum parts in the harshest atmospheric conditions for at least 6 years.

CONCLUSION

A number of corrosion problems encountered during maintenance checks show that corrosion is indeed a serious problem in aircraft. Impact of climatic conditions; humid environment, industrial, marine atmosphere, ultraviolet radiation, damaging paints and varnishes (special acrylic materials) are typical corrosion factors.

Galvanic corrosion, exfoliation, and atmospheric corrosion are very common types of corrosion encountered in controls. However, these can be eliminated to some extent by a better choice of materials than currently accepted by aircraft manufacturers. Regular aircraft cleaning can also reduce atmospheric corrosion.

According to existing operational standards, each aircraft is regularly inspected according to the number of flight hours to detect possible errors or fractures and the organization of repairs and prophylactic work.

The existing system for ensuring the safe operation of transport aircraft structures contains several measures, one of which is the establishment of a maintenance and repair program (MRO).

In this situation, the necessary level of flight safety under the strength conditions of the power structure can be fully ensured only by an effective airworthiness maintenance system that provides close monitoring of the structure in operation in order to timely identify and eliminate corrosion damage and factors contributing to the active formation of corrosion (violation of protective coatings, increased humidity, etc.)

The safety of aircraft operation in terms of corrosion resistance during long service time operation is largely determined by the level of monitoring the technical condition of the structure in operation and the quality of preventive measures.

Related problems connected with the corrosion prevention[11]:

- insufficient use of modern diagnostic equipment does not make it possible to ensure the necessary information, its completeness and accessibility for the analysis of the technical condition of the structure;
- limited ability to adapt the specific operating conditions and maintenance level of a particular operator;
- the subjectivity of the assessment of the technical condition.
- lack of qualified staff;

It seems that the main directions to reduce the corrosion problem and improve safety are the following:

- development of the experimental base and expansion of research into the laws of origin and development of corrosion;
- improving materials, structures and increasing their testability;
- development and implementation of more advanced methods of non-destructive objective control;
- development of a network of independent maintenance and repair centers and their equipping with equipment and qualified staff;
- development of information technologies to monitor the technical condition of structures.

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