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Corrosion: A Potential Safety Issue

1. Introduction

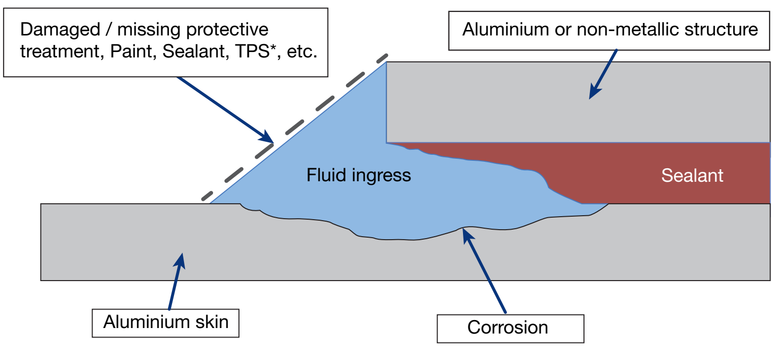
Corrosion, if left to propagate, can significantly reduce the strength of the aircraft structure and compromise safety. Corrosion can also affect the aircraft systems and induce failures in components such as landing gear (corrosion initiated crack propagation) and fuel systems (corroded bonding and electrical connectors, micro-biological contamination) to name a few.

To help and enable operators, Airbus has established a Corrosion Prevention and Control Program (CPCP). The CPCP defines regular inspections on specific parts of the aircraft. The efficiency of the CPCP is dependent on Operators monitoring and reporting findings to ensure the correct type of inspection and interval are selected to prevent propagation of corrosion.

To reduce corrosion, good maintenance practices have to be put in place to keep the aircraft clean (interior and exterior), to ensure the drain paths are clear and to maintain the surface protections (paint, plating, water repellents, etc).

2. What is Corrosion?

Essentially, corrosion is the combination of damaged or missing protective coatings causing exposed metals and fluid ingress or contact between metallic and non metallic structure (e.g. aluminium to carbon fibre). A chemical reaction sets up a positive and negative electrical charge (cathode and anode, like a battery) and the subsequent chemical reaction 'dissolves' and breaks down the metal.



TPS – Temporary Protection System (fluid repellents – Dinitrol, etc)

Figure 1
A simplified illustration of corrosion

3. Types of Corrosion

There are several types of corrosion:

- pitting
- galvanic
- crevice
- exfoliation
- intergranular.

3.1 Pitting Corrosion

Pitting corrosion is a localized form of corrosion by which cavities or "holes" are produced in the material. Pitting corrosion damage is difficult to detect, predict and design against.

Corrosion products often cover the pits. Many small, narrow pits with minimal overall metal loss can lead to degradation of the structural strength and initiate cracking.

Figure 2
Example of pitting corrosion

3.2 Galvanic Corrosion

When a galvanic couple forms between metals, one of the metals in the couple becomes the anode and corrodes faster than it would all by itself, while the other becomes the cathode (the battery effect) and corrodes slower than it would alone.

In the case of a metallic and non-metallic (Carbon or composite material) couple, then the metal part will corrode and potentially cause deformation damage to the non-metallic part, also reducing the strength of the assembly.

For galvanic corrosion to occur, three conditions must be present:

- Electrochemically dissimilar metals must be present
- These metals must be in electrical contact, and
- The metals must be exposed to an electrolyte.

Figure 3
Example of galvanic corrosion of a galley storage container caused by a well known brand of soft drink

3.3 Exfoliation Corrosion

Exfoliation corrosion is corrosion that can occur along aluminum grain boundaries. These grain boundaries in both aluminum sheet and plate are oriented in layers parallel due to the rolling process. The delamination of these thin layers of the aluminum, with white corrosion deposits between the layers, is evident as the surface protections appear distorted, revealing the white deposits.

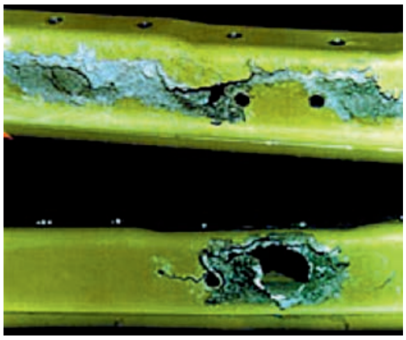


Figure 4
Example of exfoliation corrosion

3.4 Crevice Corrosion

Crevice corrosion is a localized form of corrosion usually associated with a stagnant solution on the micro-environmental level (toilet floor beams, bilges, etc). This occurs in crevices (shielded areas) such as under gaskets, washers, insulation material, fastener heads, surface deposits, disbonded coatings, threads, lap joints and clamps. Crevice corrosion is initiated by changes in local chemistry within the crevice.

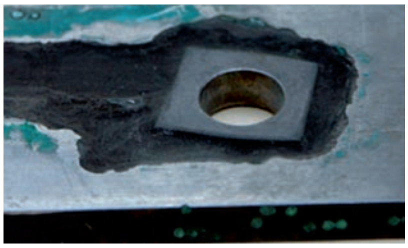


Figure 5
Example of crevice corrosion

3.5 Intergranular Corrosion

This type of corrosion is at the grain boundaries of the metal alloys and can be encountered in alloy castings, stainless steel alloys and 2000, 5000, and 7000 series aluminium alloys. Intergranular or intercrystalline corrosion (IGC) is the preferential attack of the grain boundaries or closely adjacent grains without significant attack of the grains themselves. The material can become susceptible to corrosion attack or crack propagation if under tensile stress. Research and design have reduced this phenomena significantly.

Figure 6
Example of intergranular corrosion

4. Where is Corrosion found?

Corrosion can be found all over the aircraft, however, the evolution in technology, materials, design and manufacturing processes has greatly improved resistance to corrosion. Greater use of titanium, corrosion resistant steels, aluminium-lithium alloys, composite materials, carbon, protective coatings and sealants have all contributed to significantly reduce the level of corrosion experienced a few years ago.

Typically, structure exposed to corrosive products (particularly when the protective coating is damaged or missing) such as water, salty/humid environments, runway de-icer, cargo spillages, food/drinks, human waste, etc are susceptible. So, areas around and underneath galleys and toilets, cargo bay bilges, exterior of the aircraft, fwd/aft wing spars, landing gear bays, flight controls, exterior skins, and fuel tanks are all to be considered.

5. Possible Consequences of Corrosion

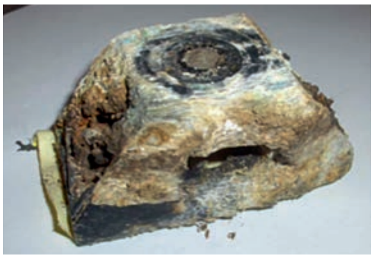


Figure 7
Corrosion of a galley foot fitting may lead to the failure of the security of the galley (or toilet) monument and could cause the monument to detach

Figure 8
Accumulation of corrosive "products" below a leaking toilet could reduce the thickness of the structure (hence the strength). Aside from the potential health concerns, this may lead to structural failure (decompression)

Figure 9
Corrosion through accumulation of dirt, debris and fluids in the bilge area

Figure 10
Micro-biological growth in the fuel tanks may lead to bacterial build up in the boundary between the fuel and accumulated water in the tanks. The micro-biological growth could affect the structure and/or block fuel filters/pumps

Figure 11
Corrosion of electrical bondings, vital for aircraft systems safety (lightening strike, static electricity discharge, etc), could cause them to become ineffective

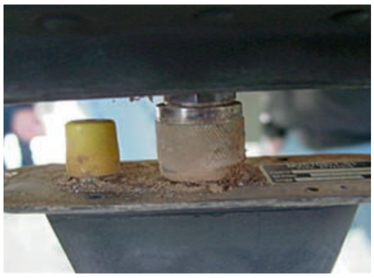


Figure 12
Corrosion between the interlaying surfaces of aerial connections could lead to loss of communication

Figures 13 & 14
Missing/damaged protective treatments (Paint, primer, sealant, plating's, etc) will all allow ingress of fluids/corrosive products to cause corrosion damage, hence weakening the structure

Figure 15
Water ingress to a landing gear pin led to pitting corrosion, which attacked the chrome plating and blocked the lubrication, could lead to the seizure of the landing gear

Figure 16
Pitting corrosion caused the failure of a landing gear bogie beam

Figure 17
Stress induced corrosion along the fastener holes

Figure 18
Cargo bay spillages damaged a cargo floor beam

6. Corrosion Prevention and Control Program (CPCP)

Cracks and loss of strength initiated by corrosion and pressurization cycles can lead to major structural failure. After a series of incidents involving old, high flight cycle aircraft, new regulations where introduced by Airworthiness Authorities in the early 1990's requiring manufacturers to develop structural inspections to clearly identify and control corrosion.

To enable operators to do this, Airbus has established a Corrosion Prevention and Control Program (CPCP) for all aircraft maintenance programs. These structural inspections are determined by design analyses, in-service experience and regulations. Implementation of these Inspection Programs is mandatory.

6.1 Three Levels of Corrosion

For the purposes of assessment, corrosion is classified into the following three levels:

- **Level 1 Corrosion** - Any corrosion of primary structure that does not require structural reinforcement or replacement (minor surface corrosion requiring minor restauration and reapplication of protective treatments, etc) (fig. 19).
- **Level 2 Corrosion** - Any corrosion of primary structure that requires a structural reinforcement or replacement and which is not considered as level 3 (fig. 20).
- **Level 3 Corrosion** - Corrosion of any primary structure which may be determined to be an urgent fleet airworthiness concern.

Figure 19
Level 1 Corrosion

Figure 20
Level 2 Corrosion

The regulations state that corrosion shall be controlled to level 1 or better and to ensure that corrosion does not exceed the limits of Level 1 between two successive inspections. If level 1 limits are exceeded there are several options:

- Decrease the inspection threshold/interval
- Consider a more detailed inspection level
- Apply Temporary Protection System more frequently
- Embody preventive modifications where appropriate.

CPCP is, therefore, self regulating.

6.2 Role of the operators

The task of the operators is to ensure the aircraft remain at the optimum level of performance and safety by:

- Inspecting the aircraft structure and systems in accordance with Airbus instructions
- Ensuring the bilge drains are clear, the galleys and toilets are clean and leaktight, the cargo bays are free from spillage and the non textile flooring is in good condition
- Maintaining the protective treatments
- Applying temporary protection schemes (TPS), such as Dinitrol, as applicable
- **Reporting findings to Airworthiness Authorities and Airbus.**

6.3 Role of Airbus

The task of Airbus, as manufacturer, is to:

- Lead continuous improvement
- Monitor trends
- Introduce corrective actions
- Adjust the maintenance program accordingly.

7. Conclusion

Corrosion may become a safety issue, as illustrated by past in-service incidents.

The Airbus Corrosion Prevention and Control Program (CPCP) has been established to prevents its propagation. Operators and Airbus have each specific responsibilities to ensure the CPCP is as effective as possible. The capacity of Airbus to meets its obligation is largely dependant upon an efficient reporting of findings by operators.

REMEMBER

Clean it, Inspect it, Drain it, Seal it, Report.

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Safety First, #15 February 2013. Safety First is published by Airbus S.A.S. - 1, rond point Maurice Bellonte - 31707 Blagnac Cedex/ France. Editor: Yannick Malinge, Chief Product Safety Officer, Nils Fayaud, Director Product Safety Information. Concept Design by Airbus Multi Media Support Ref. 20130248. Computer Graphic by Quat'coul. Copyright: GS 420.1329 Issue 15. Photos copyright Airbus. Photos by ExM Company, Baldur Sveinsson. Printed in France by Airbus Print Centre.