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Aircraft Maintenance

(AE 401)

Term Project Report

Aircraft Corrosion

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INTRODUCTION.

This report discusses specifically the subject of the aircraft corrosion that is becoming increasingly important in all industrial fields where aircraft are used. Aircraft corrosion is an electrochemical process that results in the destruction of aircraft structural components. Left undetected and /or untreated corrosion can decrease the load carrying capacity of primary structures or act as nucleation sites for fatigue or stress corrosion cracks. Thus corrosion can undetermined the integrity of an aircraft and make it unsafe to fly. The risk and cost of corrosion damage is particularly high. It is a problem that is not always acknowledged or easily solved and constant vigilance is necessary.

The specific purpose of this report is to describe the corrosion agents and effects on aircraft specifically on lap joints and how can be detected and it can be controlled.

The report begins with some background. This is followed by a description of aircraft corrosion factors and effects. And it is followed by a discussion of lap joints corrosion investigation methods. Finally, attention will be paid to how aircraft corrosion can be prevented and controlled.

I. BACKGROUND

What is corrosion, and why should it be prevented. Corrosion is simply the electrochemical deterioration of a metal due to the chemical reaction with its surrounding environment. This reaction occurs because of the tendency of metals to return to their naturally occurring physical states, usually oxides or sulfide ones. For example, iron in the presence of moisture and air will return to its natural state, iron oxide or rust. While new and better materials of aircraft components are continuously being developed, this program is offset, in part, by a more aggressive operational environment. This problem is a compounded by the fact corrosion is a complex phenomenon. It can take many different forms and the resistance of aircraft materials to corrosion can drastically change with only a small environment change. Aircraft corrosion is very costly problem. In United States, sources mentioned that it costs more than $ 2 billions annually.

II. DEVELOPMENT OF CORROSION.

a. All corrosive attack begins on the surface of the metal. The corrosion process involves two chemical changes. The metal that is attacked or oxidized undergoes an anodic change, with the corrosive agent being reduced and undergoing a cathodic change. The tendency of most metals to corrode creates one of the major problems in the maintenance of the aircraft, particularly in areas where adverse environmental or weather conditions exist.

b. Paint coatings can mask the initial stages of corrosion. Since corrosion products occupy more volume than the original metal, paint surfaces should be inspected often for irregularities such as blisters, flakes, chips, and lumps.

III. FACTORS INFLUENCING CORROSION.

a. Some factors which influence metal corrosion and the rate of corrosion are the:

(1) Type of metal;
(2) Heat treatment and grain direction;
(3) Presence of a dissimilar, less corrodible metal (galvanic corrosion);
(4) Anode and cathode surface areas (in galvanic corrosion);
(5) Temperature;
(6) Presence of electrolytes (hard water, salt water, battery fluids, etc.);
(7) Availability of oxygen;
(8) Presence of different concentrations of the same electrolyte;
(9) Presence of biological organisms;
(10) Mechanical stress on the corroding metal; and
(11) Time of exposure to a corrosive environment.

b. Most pure metals are not suitable for aircraft construction and are used only in combination with other metals to form alloys. Most alloys are made up entirely of small crystalline regions, called grains. Corrosion can occur on surfaces of those regions, which are less resistant, and also at boundaries between regions, resulting in the formation of pits and intergranular corrosion. Metals have a wide range of corrosion resistance. The most active metals (those which tend to lose electrons easily), such as magnesium and aluminum, corrode easily. The most noble metals (those which do not lose electrons easily), such as gold and silver, do not corrode easily.

c. Corrosion is accelerated by higher temperature environments, which accelerate chemical reactions and allow greater moisture content at saturation in air.

d. Electrolytes (electrically conducting solutions) form on surfaces when condensation, salt spray, rain, or rinse water accumulate. Dirt, salt, acidic gases, and engine exhaust gases can dissolve on wet surfaces, increasing the electrical conductivity of the electrolyte, thereby increasing the rate of corrosion.

e. When some of the electrolyte on a metal surface is partially confined (such as between faying surfaces or in a deep crevice), metal in this confined area corrodes more rapidly than other metal surfaces of the same part outside this area. This type of corrosion is called an oxygen concentration cell. Corrosion occurs more rapidly than would be expected, because the reduced oxygen content of the confined electrolyte causes the adjacent metal to become anodic to other metal surfaces on the same part immersed in electrolyte exposed to the air.

f. Slimes, molds, fungi, and other living organisms (some microscopic) can grow on damp surfaces. Once they are established, the area tends to remain damp, increasing the possibility of corrosion.

g. Manufacturing processes such as machining, forming, welding, or heat treatment can leave stresses in aircraft parts. This residual stress can cause cracking in a corrosive environment when the threshold for stress corrosion is exceeded.

h. Corrosion, in some cases, progresses at the same rate no matter how long the metal has been exposed to the environment. In other cases, corrosion can decrease with time, due to the barrier formed by corrosion products, or increase with time if a barrier to corrosion is being broken down.

IV. AIRCRAFT CORROSION FORMS AND EFFECTS.

Corrosion is most often thought as a slow process of material deterioration, taking place over a significant period of time like general corrosion. Other forms of corrosion degradation can occur very quickly, in days or even in hours, with catastrophic results depending on some factors that may accelerate the corrosion process like higher temperature and environments that accelerate chemical reactions and allow greater moisture content at saturation in air.

Corrosion can attack all aircraft components and make a substantial damage for most of them, like exhaust trail areas, battery components and battery vent openings, lavatories, buffets, galleys, bilge areas, wheel wells and landing gears, external skin areas, water entrapment areas, engine frontal areas and cooling air vents, and electronic package components. But for the rest of the report, I will discus specifically different kinds of corrosion that attack the aircraft lap joints and their effects on them. Actually if these lap joints were to corrosion factors and no precaution was not one for that, it would lead to lap joints fracture under stress and fatigue, which lead to a disconnection of the aircraft components and then failure.

A. Uniform Etch Corrosion.

This kind of corrosion results from a direct chemical attack on a metal surface. It is seen at first as a general dulling of the lap joints surface, and if the attack is allowable to continue, the lap joints surface becomes rough and possibly fostered in appearance.

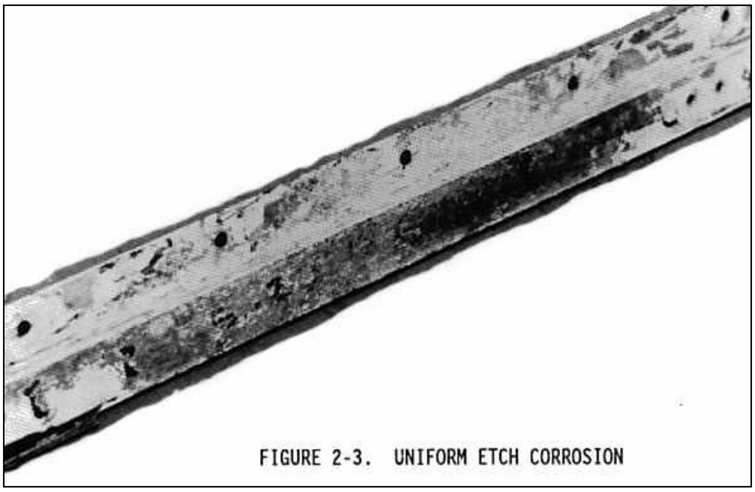
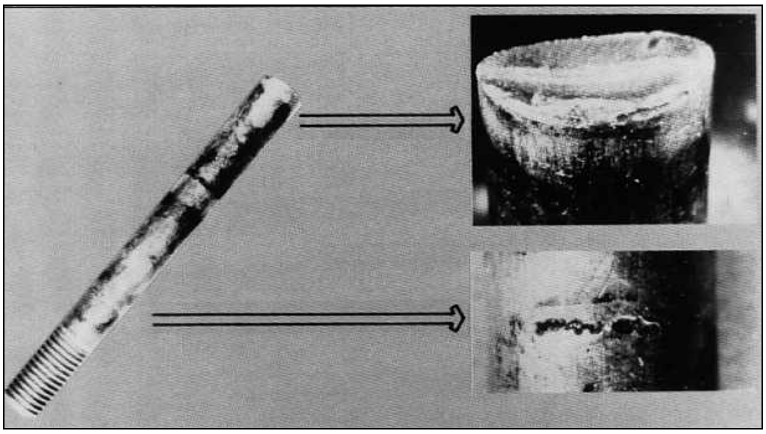


FIGURE 2-3. UNIFORM ETCH CORROSION

B. Pitting Corrosion.

The most common effect of corrosion on aluminum and magnesium alloys is called pitting (see Figure below). It is first noticeable as a white or gray powdery deposit, similar to dust, which blotches the surface. When the deposit is a cleaned away, tiny pit or holes can be seen in the surface. Pitting corrosion may also occur in other types of metal alloys. The combination of small active anodes to large passive cathodes causes severe pitting. The principle also applies to metals, which have been passivated by chemical treatments, as well as for metals, which develop passivation due to environmental condition.



C. Concentration Cell Corrosion.

Concentration cell corrosion is corrosion of metals in a metal to metal joint, corrosion at the edge of a joint even though joined metals are identical, or corrosion of a spot on the metal surface covered by a foreign material (see Figure below). Another term for this type of corrosion is crevice corrosion. Metal ion concentration cells, oxygen concentration cells, and active passive cells are the three general types of concentration cell corrosion.

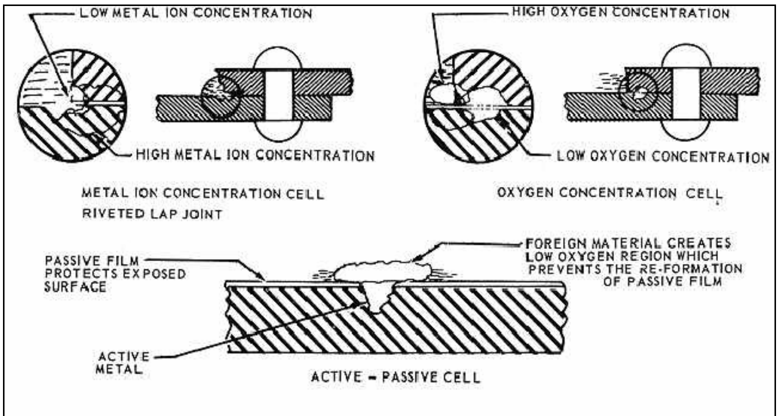


FIGURE 2-6. CONCENTRATION CELL CORROSION

D. Fretting Corrosion.

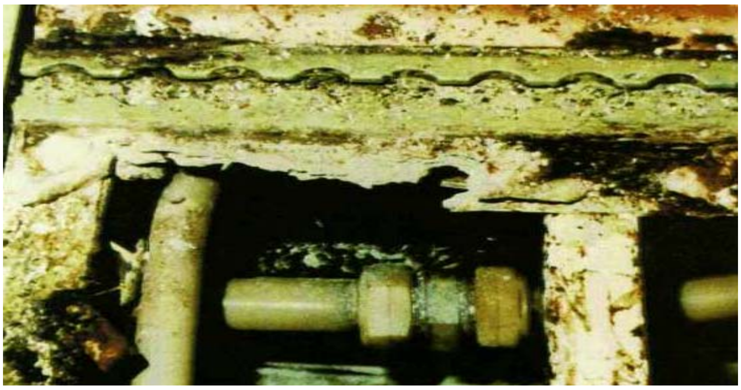
In this kind of corrosion, damage can occur at the interference of tow highly loaded surfaces, which are not supposed to move against each other. However, vibration may cause the surfaces to rub together resulting in damage to the lap joints attaching.

E. Intergranular Corrosion.

Intergranular corrosion is an attack along the grain boundaries of a material. Each grain has a clearly defined boundary, which, from a chemical point of view, differs from the metal within the grain center. The grain boundary and grain center can react with each other as anode and cathode when in contact with an electrolyte. Rapid selective corrosion at the grain boundary can occur with subsequent delaminating (see Figure below). High strength aluminum alloys such as 2014 and 7075 are more susceptible to intergranular corrosion if they have been improperly heat treated and are then exposed to a corrosive environment.

F. Exfoliation Corrosion.

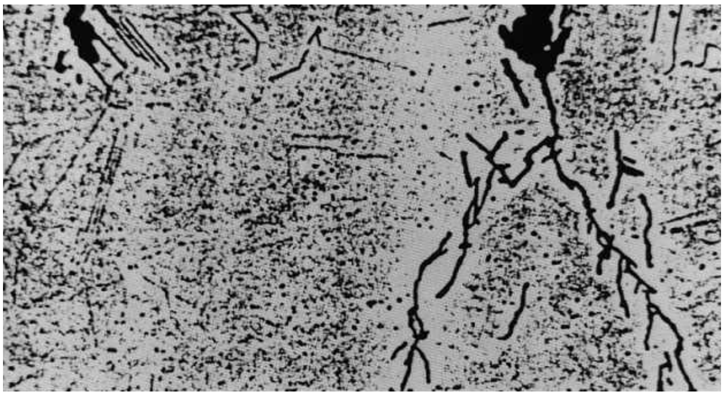
Exfoliation corrosion is an advanced form of intergranular corrosion where the surface grains of a metal are lifted up by the force of expanding corrosion products occurring at the grain boundaries just below the surface. The lifting up or swelling is visible evidence of exfoliation corrosion (see Figure below). Exfoliation is most prone to occur in wrought products such as extrusions, thick sheet, thin plate and certain die-forged shapes, which have a thin, highly elongated platelet type grain structure. This is in contrast with other wrought products and cast products that tend to have an equiaxed grain structure.



V. CORROSION AND MECHANICAL FACTORS.

a. Stress Corrosion Cracking.

Stress corrosion cracking is an intergranular cracking of the metal which is caused by a combination of stress and corrosion (see Figures below). Stress may be caused by internal or external loading. Internal stresses are produced by nonuniform deformation during cold working, by unequal cooling from high temperatures, and by internal structural rearrangement involving volume changes. Internal stresses are induced when a piece of structure is deformed during an assembly operation, (i.e., during pressing in bushings, shrinking a part for press fit, installing interference bolts, installing rivets, etc.). Concealed stress is more important than design stress, because stress corrosion is difficult to recognize before it has overcome the design safety factor. The level of stress varies from point to point within the metal. Stresses near the yield strength are generally necessary to promote stress corrosion cracking, but failures may occur at lower stresses. Specific environments have been identified which cause stress corrosion cracking of certain alloys. Salt solutions and seawater may cause stress corrosion cracking of high strength heat treated steel and aluminum alloys. Methyl alcohol hydrochloric acid solutions will cause stress corrosion cracking of some titanium alloys. Magnesium alloys may stress corrode in moist air. Stress corrosion may be reduced by applying protective coatings, stress relief heat treatment, using corrosion inhibitors, or controlling the environment. Shot peening a metal surface increases resistance to stress corrosion cracking by creating compressive stresses on the surface which should be overcome by applied tensile stress before the surface sees any tension load. Therefore, the threshold stress level is increased. {see Figure below}.

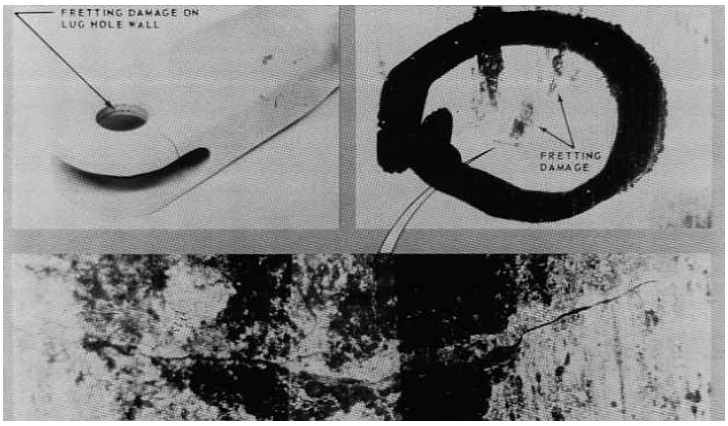


b. Corrosion Fatigue.

Corrosion fatigue is caused by the combined effects of cyclic stress and corrosion. No metal is immune to some reduction in its resistance to cyclic stressing if the metal is in a corrosive environment. Damage from corrosion fatigue is greater than the sum of the damage from both cyclic stresses and corrosion. Corrosion fatigue failure occurs in two stages. During the first stage, the combined action of corrosion and cyclic stress damages the metal by pitting and crack formation to such a degree that fracture by cyclic stressing will ultimately occur, even if the corrosive environment is completely removed. The second stage is essentially a fatigue stage in which failure proceeds by propagation of the crack (often from a corrosion pit or pits) and is controlled primarily by stress concentration effects and the physical properties of the metal. Fracture of a metal part, due to fatigue corrosion, generally occurs at a stress level far below the fatigue limit in laboratory air, even though the amount of corrosion is relatively small. For this reason, protection of all parts subject to alternating stress is particularly important, even in environments that are only mildly corrosive.

c. Fretting Corrosion.

Damage can occur at the interface of two highly loaded surfaces, which are not supposed to move against each other. However, vibration may cause the surfaces to rub together resulting in an abrasive wear known as fretting. The protective film on the metallic surfaces is removed by the rubbing action. The continued rubbing of the two surfaces prevents formation of protective oxide film and exposes fresh active metal to the atmosphere. Fretting can cause severe pitting (see Figure below). Dampening of vibration, tightening of joints, application of a lubricant, or installation of a fretting resistant material between the two surfaces can reduce fretting corrosion.



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d. Common Corrosive Agents.

There are common agents that can be primary causes of common corrosion.

1. Acids.

In general, moderately strong acids will severely corrode most of the alloys used in airframes, like sulfuric (battery acid).

2. Salts.

Most salt solutions are good in promoting corrosive attack.

3. The Atmosphere.

The major atmospheric corrosive agents are oxygen and airborne moisture, both of which are in abundant supply. Corrosion of aircraft lap joints often results from the direct action of atmospheric oxygen and moisture on the metal, and the presence of additional moisture often accelerates corrosive attack. However, the atmosphere may also contain other corrosive gasses and industrial contaminants such as chlorides and oxidized sulfur compounds.

4. Water.

The most corrosive of natural water are those that contain salts. Water in the open sea is extremely corrosive due to the presence of chloride ions; that explains why those aircraft flying at open sea are more affected by corrosion phenomenon.

VI. Affects of Aircraft Corrosion.

The effects of corrosion agents are simply the damage and changing properties of the materials used in aircraft components. But there is a secondary effect of aircraft corrosion, which is the consumption of money and effort.

VII. AIRCRAFT CORROSION INVESTIGATION.

Inspection of corrosion in aircraft components should be a part of routine maintenance inspection; i.e., daily or preflight. Actually the general inspection should look for obvious defects and suspected areas that are more probably affected and serious like lap joints.

Detailed inspection for lap joints corrosion can be of the following.

A. Visual Inspection.

It is the most widely used technique and is an effective method for the detection and evaluation of corrosion by eyes to look directly to the corrosion effects.

B. Eddy current Inspection.

Eddy current testing can be used to some degree for detecting corrosion on the hidden side of aircraft skins and lap joints, because the eddy current is able to penetrate into materials and show corrosion effects on a screen.

C. X-Ray inspection.

X-ray inspection works by passing high energy generated by X-ray machine through the material being inspected. This exposes the special film placed on the opposite side of the material. Areas of high density are indicated on the film as underexposed areas, while areas of low density are indicated as overexposed areas.

D. Ultra Inspection.

This testing provides a sensitive capability of detecting lap joints corrosion damage. It can investigate even very small damages that cannot be detected by the other inspection methods.

E. Acoustic Emission Testing.

This method using heat generated emissions can be used to detect corrosion and moisture in adhesive bonded metal honeycomb structures. Acoustic emission testing can detect corrosion initiation as well as advanced corrosion.

VIII. AIRCRAFT CORROSION PREVENTION AND CONTROL.

A. Materials.

Corrosion should be prevented even before it happens, which is called controlled corrosion in design.

The nature of the material is a fundamental factor in corrosion. High strength, heat treatable aluminum and magnesium alloys are very susceptible to corrosion, while titanium and some stainless alloys are less susceptible in atmospheric environment the aircraft based on metal strength, weight, and cost, while corrosion resistance is often a secondary consideration. However, corrosion control should be considered as early as possible during the preliminary design phase.

B. Prevention Compounds.

When the aircraft is cleaned, solvent solutions should not be used since they are increasing corrosion capabilities, however, there are some compounds that protect metal aircraft and components from corrosion. Corrosion preventive compounds vary in appearance and consistency from thick black types to light oils. Some are water displacing and others are not. The thicker compounds provide the best corrosion protection, are longer lasting, and are more difficult to remove. The thinner materials provide some lubrication and do not crack, chips, or peel but must be removed and replaced regularly to provide continuing protection.

C. Surface Treatment.

An important step in the corrosion control process is the surface treatment of the metal with a prescribed to form a protective film. Chemical surface treatments properly applied provide corrosion resistance to the metal and impose the adhesion of subsequently applied paints. These surface treatments, also known as chemical conversion coatings. These coatings disconnect the metal of the corrosion environmental factors like moisture and high temperatures. One of the most widely used coating materials today is corrosion-x, which is good in preventing corrosion in aircraft lap joints.

CONCLUSION.

From the previous discussion, it was apparent that corrosion is really the silent enemy of aircraft. If undetected and/or allowed to progress without requisite corrective action, corrosion and its precipitated effects can render the most complex structural problems. Before, the corrosion aspect was not required in the design phase, but now, it could have the first priority because corrosion is very costly problem.

In Saudi Arabia, there is a special organization in Riyadh that concerns about corrosion problems in all industrial fields trying to find the best techniques of preventing corrosion.

Actually, by the time an effective solution to this problem is found, it may easily overcome a big enemy of aviation and save lots of money and effort.

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