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CORROSION ON AIRCRAFTS

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ABSTRACT

Corrosion on aircraft is nothing more than rust of the metal parts, an aircraft, like any metal object, is inherently prone to corrosion. Corrosion damage in aircraft structure, if undetected and/or left untreated, can undermine safety. Currently corrosion prevention and management in many civil and military fleet still relies strongly on the use of traditional 'find and fix' maintenance practices, although this has been refined by the increasing use of Corrosion Prevention and Control Plans (CPCP) which provide a framework for targeted inspections and treatment to help with corrosion management. The focus of this paper is to better understand and predict the deterioration and breakdown of protective coatings at aircraft joints, primarily due to the influence of mechanical displacement.

Keywords: Aircraft, Corrosion

I Introduction

Corrosion control can be one of the aircraft industry's most effective weapons in the battle against airplane structural failures. 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 undermine the integrity of an aircraft and make it unsafe to fly. It is a problem that is not always acknowledged or easily solved and constant vigilance is necessary.

Why do aircraft corrode?

Airframe problems associated with corrosion have plagued the aviation industry for decades. The metals that compose aircraft components are subject to several different forms of corrosion, a process accelerated by many factors including prolonged exposure to corrosive agents like industrial fluids, salts, and moisture, or more internal problems such as condensate formation and leaking lavatories and galleys. Some forms of corrosion such as stress corrosion cracking and corrosion fatigue can lead to catastrophic failure if not detected and treated. Compounding the problems associated with corrosion is the age factor. the total number of commercial aircraft in operation, approximately one-fourth are over 20 years old. As a plane ages, it is repeatedly exposed to environments that accelerate the effects of corrosion. Even though some corrosion-control measures have been taken in an effort to enhance the safety of the aging planes now in operation, there is still much to be learned and much to be done.

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Which parts of the plane are most prone to corrosion?

Corrosion is one of an aircraft owner's worst enemies. If left untreated, corrosion can cause unsightly damage to the aircraft and create a serious safety risk, too. That's why it is so important to conduct inspections of your aircraft as much as possible, those who have owned an aircraft for a long time know that the more you inspect an aircraft for corrosion, the better you can detect and remove it before it becomes a serious problem.

II CORROSION MECHANISM

For the purpose of this study, electrochemical corrosion is the most important classification of corrosion. Four conditions must exist before electrochemical corrosion can proceed

(1) There must be something that corrodes or free its electrons (the metal anode)

(2) There must be a cathode to gain electrons

(3) There must be continuous conductive liquid path (electrolyte, usually moisture, condensate and salt or other contaminations) to transfer charged ions.

(4) There must be a conductor to carry the flow of electrons from the anode to the cathode. This conductor is usually in the form of metal-to-metal contact such as bolted or riveted joints between wing skin and stringers and center wing fitting to fuselage, etc.

The elimination of any one of the four conditions will stop corrosion. An unbroken coating on the surface of the metal will prevent the electrolyte from connecting the cathode to anode so that current cannot flow. Therefore, no corrosion will occur as long as the coating is unbroken.

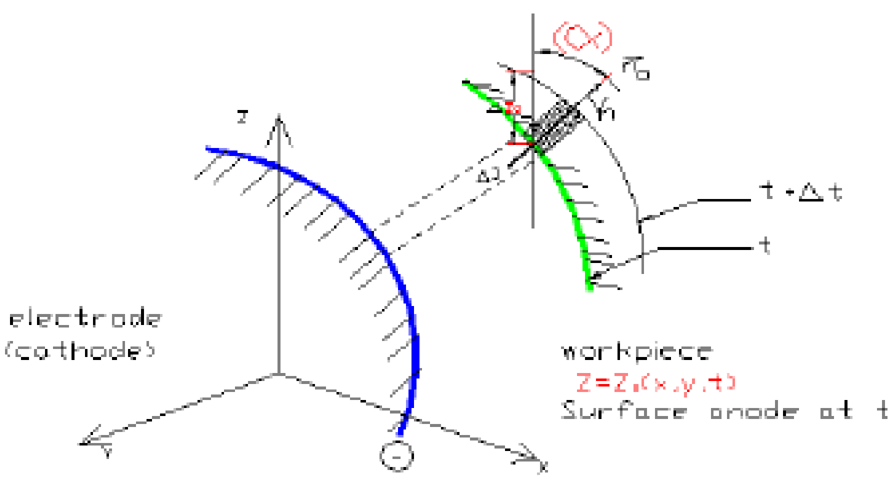

Fig 1 Scheme of Electrochemical Corrosion Model

Protective coatings will be broken if there is continuous contacts of one or more moving parts due to mechanical loads. For deducing expression for corrosion rate in reference system coordinates of the work piece-anode, let us

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consider a small element of anodic surface with area ΔA through which anode current ΔI is flowing as shown in Fig.1. In this process part of the electric charge gets transferred from the anode by metal cations going to conductive moisture; which is important in dissolution, and part of the anions evolves at the anode (e.g. oxide, chloride ions etc.) and is a side effect. The ratio of current ΔI+ applied which is responsible for metal corrosion to current generated by Standard Electro Motive Force (E^o volt), ΔI is named as current efficiency of anodic dissolution, where metal M dissolved to ion M^{n+} according the following electrochemical reaction

$$M \rightarrow M^{n+} + ne$$

where n is the number of electrons transferred from anode to cathode.

$$\eta = \frac{\Delta I +}{\Delta I} \quad \ldots\ldots\ldots\ldots(1)$$

It is often convenient to express the current efficiency in terms of a percentage ratio.

Current efficiency η depends greatly on the material of the work piece, type of corrosive medium (rain water, dissolved chloride, electrolyte, moisture or condensate), and stress load (tension, torsion, shear, flexure, impact and fatigue) to joints. For an efficiency of 100%, the total current generated by electro motive force is carried by ions of dissolved metal to become corrosion product. For zero efficiency, the current passes without metal corrosion. In many of references, the current efficiency is defined as the ratio of the observed mass change to the theoretical one predicted from Faraday's laws, with assumption of 100% current efficiency of the anodic dissolution or corrosion process.

In a case when material removal is purely by electrochemical processes, i.e. there is no mechanical material removal such as hydrodynamic erosion, fretting corrosion or stress corrosion cracking, the corrosion rate can be obtained from Faraday's I Law.

According to I law of Faraday, the mass of metal removed Δm i.e. mass of metal ions) corresponding to current ΔI during time Δt (i.e. to electric charge ΔI+Δt) is given by

$$\Delta m = k\, \Delta I{+}\Delta t \quad \ldots\ldots\ldots\ldots (2)$$

where *k* is the electrochemical equivalent of the work piece material, which is equals mass of ions carrying unit electric charge of 1 coulomb (i.e. 1 Amp sec). On the basis of Faraday's II Law, the electrochemical equivalent for corrosion reaction

$$M \rightarrow Mn^{+} + ne$$

is given by

$$k = \frac{A}{NF} \quad \ldots\ldots\ldots(3)$$

Where A is atomic weight of the metal M, and F is Faraday's constant (96500 C). Combination of atomic weight of reacting ions and valence n, expressed by the quantity A/n being the weight equivalent of an metal atom.

For example, iron has an atomic weight of A=55.85. In its divalent form (n=2) this metal has an electrochemical equivalent $k=29X10^{-5}$g/Amp-sec; trivalent iron (n = 3) has $k=19X10^{-5}$ g/Amp-sec. If an alloy consist of i elements

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such that each element accounts for a fraction Z_i of the total, and it is postulated that each element dissolves independently and simultaneously with the others, the electrochemical equivalent of alloy may be found by the equation

$$k = \frac{1}{F\sum \frac{n_i Z_i}{A_i}} \quad \ldots\ldots\ldots\ldots\ldots(4)$$

Taking the ΔI+ from Eqn.1, and expressing dissolved mass Δm in terms of thickness of material layer Δh removed from surface element ΔA, Eqn.2 is rewritten as

$$\rho \Delta h \Delta A = \eta k \Delta I \Delta t \quad \ldots\ldots\ldots(5)$$

or

$$\Delta h = \eta \frac{k}{\rho_m} \frac{\Delta I}{\Delta A} \Delta t \ldots\ldots\ldots(6)$$

where ρ_m is density of metal part.

Taking the limit as all differential quantities approach zero, by the definition of a derivative, the required relation for velocity of corrosion can be obtained as follows

$$v_n = \eta \frac{k}{\rho_m} i_a \ldots\ldots\ldots(7)$$

or

$$v_n = k_v i_a \ldots\ldots\ldots(8)$$

Where

$$i_a = \lim_{\Delta A \to 0} \frac{\Delta I}{\Delta A} \quad \ldots\ldots\ldots(9)$$

is current density on the anodic part .

The term Kv=ηk/ρ is known as the coefficient of electrochemical corrosion susceptibility, and is equal to the volume of material dissolved from the anodic part per unit electrical charge. The coefficient Kv can only be determined experimentally, by various methods.

III TYPES OF CORROSION FOUND ON AIRCRAFT

- Uniform surface attack

This is the most common type and is caused simply by exposing the metal to oxygen in the air, such as when paint is worn off wing skin or the fuselage. Poor pre paint preparation at the factory, fumes, acid, pollutants or high humidity accelerates the decay.

- Intergranular corrosion

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Normally worst on 7000 –series alloys (those with an appreciable amount of zinc, like wing spars, stringers and other high strength aircrafts parts), this is not frequently found but is a particularly nasty type of corrosion. It is difficult to detect, and once you see it, it's too late that piece of metal is toast.

- Stress corrosion

In highly stressed like landing gear or engine crankshafts, this type may develop from a scratch or surface corrosion. Crankshafts failures are often due to undetected corrosion of this type.

- Crevice or deposit corrosion

This can occur anywhere there is an area where moisture or other pollutants are trapped. Lapped skin joints or rivets on an oil stained belly are examples of prime corrosion spots.

- Filiform corrosion

Particularly on aluminum surfaces poorly prepared for polyurethane paints, this type of corrosion will show up as fine, worm – like lines of corrosion under the paint that will eventually lead to bubbling and flaking.

3.1 How to prevent aircraft rust

- Store your aircraft in a hangar to prevent exposure to the elements.
- Have your aircraft frequently washed to remove debris and corrosive pollutants.
- Have regular, thorough checks of your aircraft, concentrating especially on vulnerable areas like the propeller, cylinder fins, battery box, engine and control hinges and cables.
- Treat your aircraft regularly with a high quality corrosion inhibitor and lubricant. This will stop any rust that is in the process of forming and provide a protective barrier for vulnerable aircraft components.

3.2 How Can We Keep Aircraft Safe?

Implementing corrosion-prevention measures in the design and selection of materials used to repair and upgrade planes, in conjunction with effective maintenance procedures, is the best insurance against corrosion-related failures. When corrosion is discovered, it should be treated immediately. Expanding the amount of time between finding evidence of corrosion and repairing it increases the opportunities for problems to occur. Corrosion control works best when qualified personnel who are trained in corrosion control are used to detect, evaluate, and repair corrosion-related damage. Inspectors must have access to the most current inspection and repair technology and receive training on how to use that technology effectively. By applying up-to-date corrosion control technology, the useful life of aircraft can be prolonged and overall maintenance costs reduced.

IV CONCLUSION

Controlling corrosion in today's air fleet must be an ongoing, dynamic process that starts with design and manufacturing and continues with maintenance and monitoring. It is a problem that is not going to go away. An

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investment in corrosion control is an investment in public safety, and it protects the industry's bottom line. Although significant progress has been made, we must continue to devote time and resources to corrosion control to increase the safety level of all those who fly. To solve the menace of corrosion requires a holistic approach of the complex variables that combine to influence corrosion.

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