Prevention and Control in Corrosion

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Abstract

Aircraft corrosion is a never-ending challenge where prevention and control play the fundamental role of ensuring the airworthiness requested.
Corrosion prevention moves from design optimization and proper material selection, but it includes much more following phases like a correct finish specification and plans for effective maintenance, inspection and repair.
Corrosion control, in this meaning including prediction and diagnostics, is complementary to prevention and it is actually the field where more efforts are provided, because early corrosion detection is the easiest way to avoid costly aircraft damage or failures.
In effect, considering that corrosion can account for 60% of all maintenance and repair costs, economic factors must be considered as the most important constraint affecting both prevention and control.
In this lecture the attention will be focused on the different corrosion prevention and control strategies adopted and their actual modifications in accordance with the exacerbation of the aging aircraft issues.

1. INTRODUCTION

Control and prevention are both issues used to describe the procedures necessary to provide an effective corrosion maintenance on aircraft.
In effect they must be considered as complementary because corrosion and prevention can have a synergistic effect when each one explicates its specific action. However, it is important to remember that corrosion control includes:

- Corrosion detection
- Corrosion removal
- Renewing the protective systems

On the other side, corrosion prevention is devoted to:

- Material design
- Surface treatments, finishes and coatings
- Corrosion inhibitors compounds and sealants
- Preservation techniques

The entire process including all these phases has been recently called corrosion surveillance[1], indicating the increasing interest from aircraft operators in this matter, largely due to the growing number of aging fleets.
For many years "find and fix" has been the maintenance philosophy all over adopted but now that aircraft are being flown beyond their design life, this practice will not allow a safe and cost effective management of the fleets[2].
So corrosion control and prevention both improved in many aspects in the last decade where environmental constraints also played a very important role.

2. CORROSION CONTROL

Many significant advances have been done in this field and probably more are expected in the near future.
In the past, control procedures were just related to scheduled maintenance, non-destructive evaluation and repair but now early diagnostic, condition based maintenance and paint removal technologies are some of the most interesting areas where impressive improvements are continuously carried out.

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2.1 Corrosion Detection and Monitoring

Several NDT were used since many years to detect corrosion, the most commons of them being:

- Visual inspection
- Magnetic particle flaw detection
- X-ray
- Ultrasonic inspection
- Eddy current
- Dye penetrants

However, the increasing corrosion costs recently introduced the need to obtain an early detection and, at the same time, to reduce the unnecessary inspections.
Monitoring during service became the key of this new approach and as a consequence of that different strategies were investigated.

Corrosion data collection and analysis[3] carried out in order to evaluate the areas most affected, estimate the costs and plan the priority of intervention, should be considered as the first stage, followed by the development of in-situ monitoring systems.
Thin film Au-Cd galvanic sensors[4] were developed and successfully installed on military aircraft for monitoring hidden corrosion or corrosivity in aircraft interiors, sealants and coatings[5]. These bimetallic sensors are kept isolated until moisture from the environment bridges the two electrodes: when it occurs the sensors will develop a galvanic current directly proportional to the corrosivity of the trapped moisture. In harsh environments Ni-Au sensors are recommended to provide a long term life.
Promising investigations are being actually carried out to incorporate fluorescence based sensors into paint coatings to provide an easy and economic means to detect corrosion[6].

At the same time, new technologies are more and more used to reduce the time consuming corrosion control activity, and in this area the Thermal Wave NDI[7] that uses an IR video camera to image the surface of the aircraft after the application of a short pulse oh heat seems very interesting as far as the Double Pass retroreflection Aircraft Inspection System (DAIS)[8].
An user friendly probe with a high degree of accuracy and sensitivity, based on Electrochemical impedance (EI) measurements[9] has also been developed.

2.2 Paint and Corrosion Removal

Corrosion control on aircraft often need paint removal but today chemical stripping is no longer the only way to achieve it: diffusion of composite materials, environmental regulations and health and safety considerations are eroding such a monopoly.
New technologies have been investigated, some of them are widely used, first of all Plastic Media Stripping (Fig. 1), a method that involves subjecting the paint surface to a high pressure stream of acrylic particles, or its closest variation that uses natural products (wheat starch) as the stripping medium.

Fig. 1 – IAF Tornado stripped by means of Plastic Media

However, these techniques need special care and are strongly dependent on the operator ability: wrong swell times or stream pressure could remove the clad on aluminum parts or produce damage on composite materials. Researches are in progress to evaluate safe and cost effective alternative solutions: at the moment the two more attractive options seem :

- Flashjet
(a Xenon flashlamp with carbon dioxide pellet)
- Hand held laser

Though at an early stage of development, interesting, at least for components, seems to be a photochemical process that uses only waterborne stripping media with no organic solvents[10].

Once detected, corrosion must be removed by means a pickling operation also necessary as a surface preparation for the following treatments.
Even in this field, environmental compliance needs to substitute the traditional solpho-chromic pickling with a chromate-free alternative.
In this sense a hot sulfuric-ferric acid mix[11] showed at the moment the best performance.

3. CORROSION PROTECTION

Many factors have to be taken into account in order to carry out an effective corrosion prevention, most of them are being strongly correlated.
Of course, the starting point must be the materials design that will depend not just on its corrosion behavior but, often more than this, on its mechanical properties.
Once chosen the material, its corrosion behavior will not be fixed unless surface treatments, finishes, coatings and operating environment are not clearly identified.
Aging aircraft and environmentally acceptability have deeply modified old concepts and rules, making of all this matter a big deal of research and development of technologies[12].

3.1 Materials

With regard to the materials, if it is true that in the design of new aircraft there exists a trend towards plastics, nevertheless, aging fleet requires in many cases the substitution of alloys with equivalent strength but with higher corrosion resistance in order to extend maintenance schedules and decrease down time.
Particular attention is given to some of the most dangerous forms of corrosion as Stress Corrosion Cracking (SCC) and Exfoliation.
On aluminum alloys, the most interesting performances have been achieved by means of the new tempers (in particular the T77) that allows to have a better control of the size, the spatial distribution and the copper content of the strengthening precipitates[13][14].
The 7055-T77, provides an high resistance to intergranular corrosion, exfoliation and SCC, attributed to its high ratio of Zn:Mg and Cu:Mg and, as a consequence of that, an optimum microstructure at and near grain boundaries[15].
Chemical composition improvements, finalized at a lower Fe and Si content, have brought reduction to pitting initiation on aluminum alloys series 2xxx. 2024-T3 suffers in effect pitting corrosion attack, and this phenomenon is strongly dependent on the Fe and Si bearing second-phase constituent particles[16]: the reduction of their density and size achieved on the derivative alloy 2524-T3, resulted in a reduction of the pits nucleation that can act as potential initiation of fatigue cracks.

3.2 Surface Treatments, Finishes and Coatings

Chromate based pre-treatments and chromate pigmented primers are extensively used in the corrosion protection of aluminum alloys because of their excellent performance.
However, many investigations about chromate-free protection schemes have been undertaken since about ten years and some of them (cerium salts, nickel metavanadate[17], Phosphoric Sulfuric Acid anodizing[18], etc.) have already given promising results.
A non-toxic trivalent chromium conversion coating formed applying dilute solutions of basic chromic sulfate plus hexafluorozirconate has been already successfully proposed[19]; it appears at the same time also promising for applications to cadmium and zinc-nickel coated steels.

Anyway, just cadmium plating process, able to provide an effective corrosion sacrifical protection and high lubricity on high strength steels, will be no longer allowed even in military and aerospace applications; its main disadvantages is the toxicity of the cyanide baths.
Many studies have been started and investigations are still in progress to evaluate the best alternative process (zinc-nickel or zinc-cobalt-iron electrodeposition, metallic-ceramic consisting of aluminum particles in an organic matrix spray, etc.)[20]

3.3 Corrosion Preventive Compounds and Sealants

Corrosion preventive compounds (CPC) are able to explicate a really effective corrosion protection, and their use is considered essential to procrastinate the corrosion initiation, extend the scheduled maintenance and reduce costs.
They explicate a combined effect: isolating the metal surface from the environment (barrier effect) by means of a water displacing action carried out by the wax base, and modifying the local environment to make it less aggressive (active effect) by means of the inhibitors included in their formulation.
CPC will be consumed and as a consequence of that they must be renewed with a frequency dependent on the environmental aggressiveness they will be exposed, usually every two years.
Here the environmental compliance forces the R&D to look at new products reducing the VOC content.

Sealants and jointing compounds on the other hand are necessary to avoid both galvanic coupling between dissimilar metals and crevice corrosion that could act as nucleation points for fatigue crack propagation.

It's important to remember that effectiveness of the protective measures both by sealants and CPC depends on a good preparation and proper application; it means that specialists training is a decisive step in corrosion prevention.

3.4 Preservation techniques

Preservation is a really wide area that includes many different actions. The most common preservation technique is washing and rinsing the aircraft after each mission, mostly when it was a low-high mission on the sea: to eliminate chloride and salts from the metal surface in this case is considered a must.
Usually preservation is conceived in agreement with three different strategies, depending on the preservation time:

- short term (0-90 days) preservation
- medium term (up to 1 year) preservation
- long term (beyond 1 year) preservation

When long term preservation is required, dehumidification is necessary.
In any case, more is the preservation time and less will be the manhours spent on maintenance.
Sometimes can be necessary to protect the aircraft or part of it for a long time from contamination and the effects of high relative humidity by means of a barrier material. This is the case of the Nitrogen Purging Packaging (NPP) System[21], that uses a flexible barrier to form a cocoon around the object to be protected and the inner atmosphere is modified to achieve the desired level of relative humidity.

4. SUMMARY

Corrosion prevention and control have been separately described in this presentation in order to deal with the most interesting concerns in their respective matters, although they represent a continuous that can be summarized as corrosion surveillance.

They cover many different areas and represent a really multidisciplinary subject strongly related to airworthiness.

This paper contains a selection of the numerous studies and investigations that have been undertaken in the recent past, many of them being still in progress, to ensure an effective corrosion protection and control under the aging aircraft and the environmental constraints.

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