Some aspects of NDE in Corrosion Control

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ABSTRACT

Aircraft corrosion represents a continuously increasing problem, more when it regards an aging fleet where economic and safety factors are exacerbated.

Because of its spontaneous nature, any electrochemical process producing corrosion can never completely avoided by only means of the enhancement of a preventive strategy. Indeed, corrosion control, that includes prediction and diagnostic, plays actually a prevalent role especially in consideration of the cost benefits; development of innovative non destructive evaluation techniques is therefore essential to promote the early detection requested.

Due to the different nature of the corrosion phenomena occurring on aircrafts, the use of a multitude of NDE techniques can be considered, each one of them being often more indicated to detect a specific corrosion mechanism.

Hidden corrosion generated in overlapped structures, a phenomenon having usually a crevice nature, seems for example effectively monitored by means of thin film galvanic sensors, capable to detect *in-situ* the presence of an aggressive micro-environment. The amount (concentration) of the aggressive species is then proportional to the galvanic current flowing on these sensors and stored on a data logger easy to download usually every 4-6 months. Depending on the expected micro-environment, the galvanic couple can be suitably modified to optimise its duration.

However, to be successful with this technique there must be previously a careful identification of the most critical sites in order to reduce the amount of sensors to be used; in this sense Italian Air Force experienced the need to arrange since 1994 a corrosion collection data bank.

1. INTRODUCTION

For many years “find and fix” has been the corrosion maintenance philosophy all over adopted based on scheduled maintenance and standard non-destructive evaluation, but now that aircraft are being flown beyond their design life, this practice will not allow the requested airworthiness at least not preserving a cost effective management of the fleets.

In this sense, the last decade has been characterized by many significant advances in corrosion control and more are expected in the near future, being early diagnostic procedures and condition based maintenance some of the most interesting of them.

In effect, monitoring in service became the key to obtain an early corrosion detection and to reduce at the same time unnecessary inspections.

Corrosion data collection and analysis 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.

2. CORROSION DATA COLLECTION

Since 1994 Italian Air Force developed the Corrosion Control Register Program (CCR), a flexible and integrated support for making decisions both on corrosion prevention and control and operational measures[1].

The Program was born as a necessary instrument to manage the Tornado's maintenance in agreement with the German and the Royal Air Forces procedures, but was immediately extended to six more aircraft (AM-X, MB.339, C-130, F.104, G.222, and Br.1150) and to two helicopters fleets (HH-3F and AB.212).

The primary aim of this data collection system is to produce a detailed picture of the IAF corrosion situation that once a year is provided to the Logistic Command to enhance the knowledge on the state of the fleet, where special attention is focused on the aging phenomena, and their effective needs.

Nevertheless, because of the high level of interdisciplinary which is characteristic for corrosion science and engineering, the Corrosion Control Register Program overlaps with many different fields first of all with NDE, helping in creating and developing new and more dedicated inspection procedures as far as new inspection techniques.

The CCR Program, that is updated each time corrosion is found at any step of the maintenance inspection carried out by the Air Force but doesn't cover the maintenance performed by any depot outer the Air Force, has been thought to provide many useful data. Among them, the statistical analysis of the acquired maps indicating the corroded areas of the parts, that have been previously detected as prone to suffer corrosion problems. represents a basic source of information to locate the sensors in order to obtain an effective early detecting systems.

An example of this is shown in fig. 1, where the results of 73 corrosion phenomena collected on the cabin compartment floor of the helicopter Agusta AB.212 were reported.

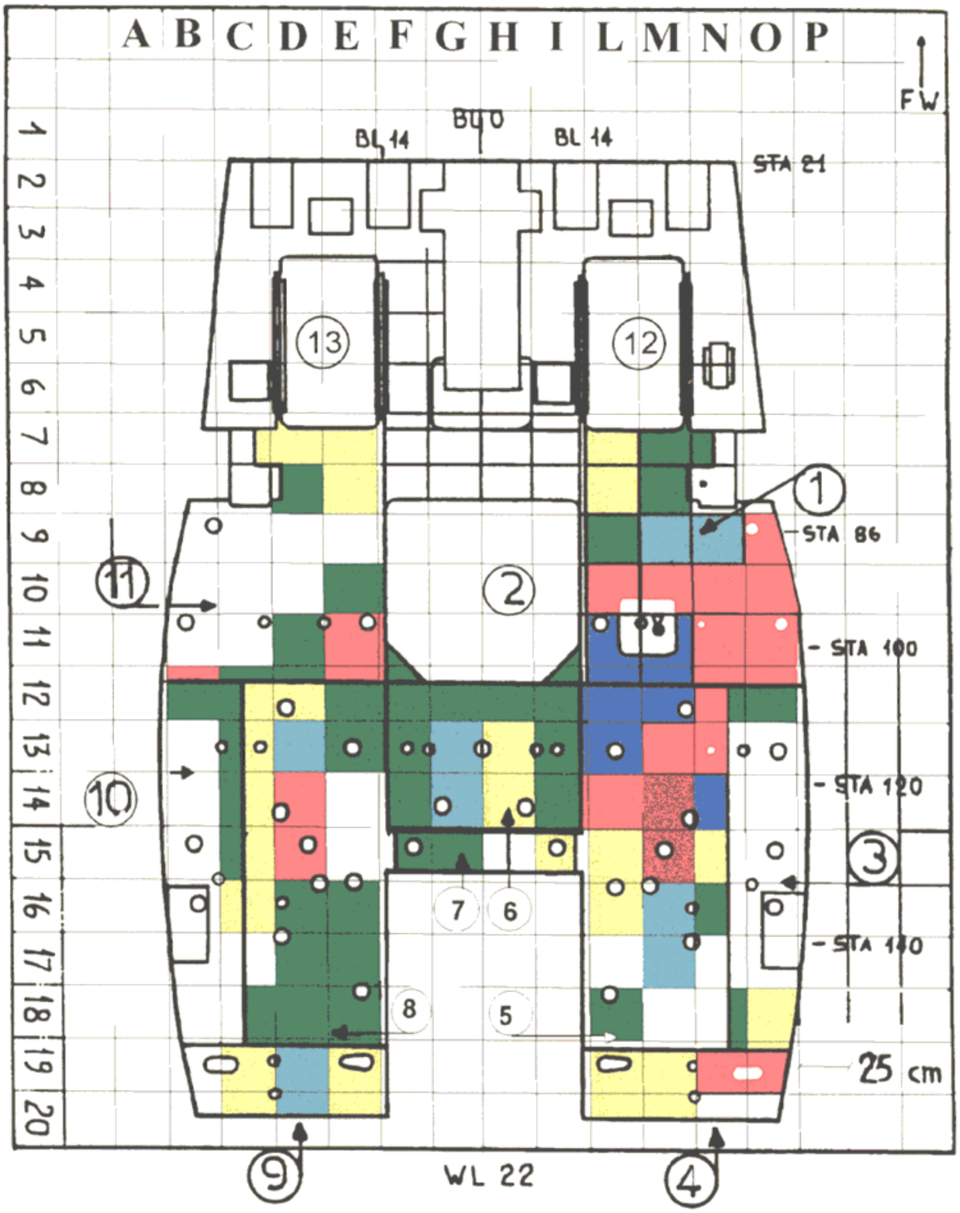

Figure 1

This is a case of the hidden corrosion phenomena very frequently observed on aircraft structures, which develop in overlapped structures or under an aluminum cover sheet. Moisture trapped inside the natural crevices produces corrosion in agreement with an aeration deficiency mechanism that makes anodic the crevice with regards to the external area because of the difficulty in supplying oxygen (fig. 2).

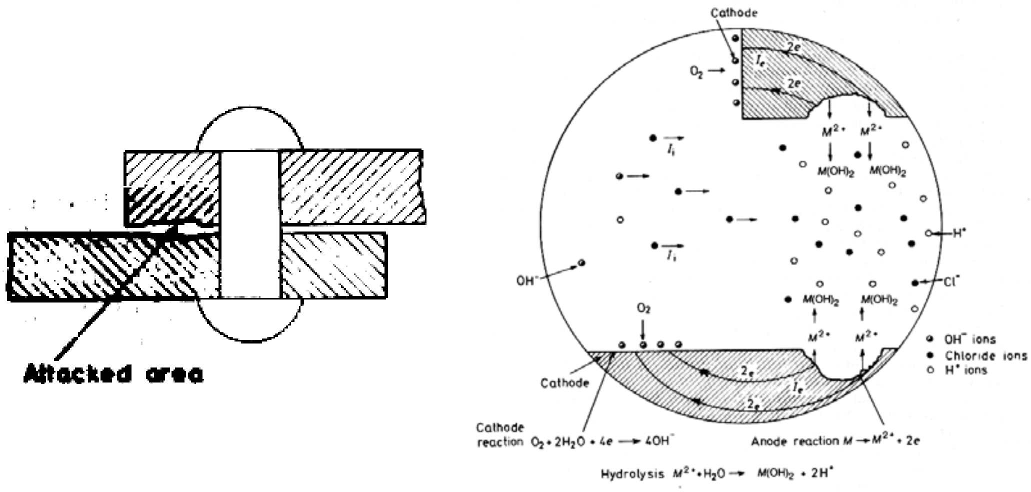

Figure 2

Therefore, with reference to this type of corrosion, sealants play the most relevant role in terms of corrosion prevention.

Nevertheless, taking into account that Condition Based Maintenance (CBM) is not yet employed as a widespread maintenance technique, sealants are expected to fail in some cases, usually under the effect of the vibrations associated with normal or abnormal operational use of the fleet. Furthermore, aging problems due to the kept in service of the aircrafts beyond their original operational life promote always new failures, often caused by hidden corrosion on unexpected parts or components; in those cases, where old materials are still in exercise, recent events demonstrate both an inadequate revision of the Non Destructive procedures and the ineffectiveness of the only protective strategies.

3. EARLY DIAGNOSTIC METHODS

In order to contain the increasing costs in maintenance and repair generated by the budgetary contractions in investments, the development of early diagnostic systems seems to be one of the most promising tools.

Reduction in maintenance expenditures can be achieved reducing the frequency of major overhauls, corrosion inspections and unanticipated structural rework/repairs.

There are many techniques that are applicable to monitor corrosion in aircraft structures, nevertheless they can divided in two basic categories: techniques that provide a direct measure of corrosion and techniques that utilize a related parameter to provide an indication of the presence of corrosion.

Some of the most widely used techniques are Electrical Resistance, Linear Polarization Resistance, Electrochemical Impedance Spectroscopy, Electrochemical Noise, Harmonic Impedance Spectroscopy and Galvanic Currents.

Although many of them are very sensitive and in some case represent a considerable promise[2-3], their application is often discouraged by the need for sophisticated analysis and relative expensive equipment.

Because of their easy-to-use nature and their particular ability in terms of hidden corrosion phenomena detection, thin film galvanic sensors[4], developed in the recent past at the U.S. Naval Air Warfare Centre, were chosen by the IAF to comply with the Corrosion Control Register Program objectives.

These devices are miniature wireless corrosivity sensors that make use of a bimetallic coupling, usually Au-Cd, capable to detect *in-situ* the presence of an aggressive micro-environment (fig. 3).

GALVANIC SENSOR

Figure 3

They 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 (fig. 4).

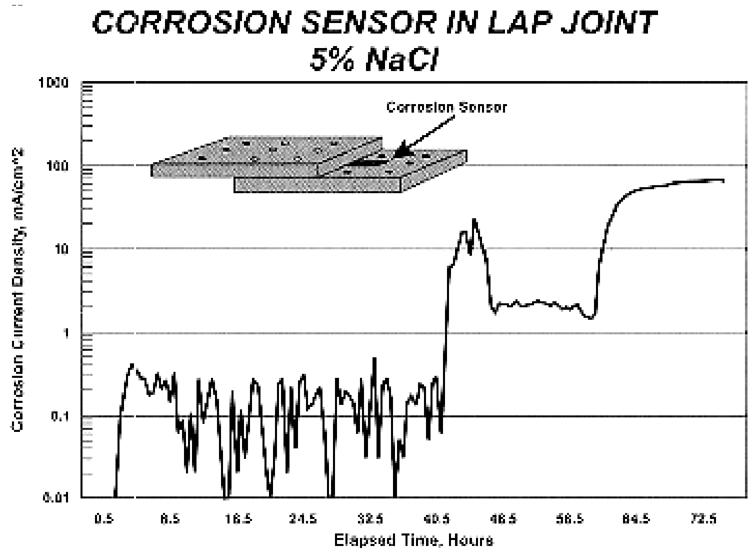

Figure 4

In terms of sensitivity, the gap between the electrodes of the sensor were made very close to each other (< 25 µm), so that a condensed thin film of moisture formed even at 60% relative humidity could easily bridge it[5].

The current flown will be then stored on a data logger easy to download usually every 4-6 months.

Depending on the expected micro-environment, the galvanic couple can be suitably modified to provide a long term life; therefore, in case of harsh conditions, Au-Ni sensors were developed.

A different approach has been investigated to incorporate fluorescence based sensors into paint coatings to provide an easy and economic means to detect corrosion[6-7].

Here, fluorescent compounds have been incorporated into primer paint coatings for aluminum alloys and they were found to fluoresce if the coating was scratched and the exposed to air and moisture. This smart coating utilizes its electrochemical property to change from a non-fluorescence to fluorescence in an oxidized state.

To verify directly the presence of a corrosion phenomenon, it can be detected when morin is added to the primer coating because of its ability to form fluorescent complexes with aluminum ions.

Both of these methods appear to have potential application in aircraft where large surface areas could be scanned with UV light to detect the fluorescence of these materials indicating possible corrosion sites.

4. CONCLUSIONS

The ability to detect and monitor the presence of corrosion on structural aircraft components located in difficult-to-access areas must be considered as one of the most significant fields to explore in order to reduce maintenance costs and to ensure the requested airworthiness.

A number of corrosion monitoring techniques have become more and more reliable in the last decade and are already available to be used in order to enhance the level of maintenance.

Among them, the Italian Air Force considered the use of thin film galvanic sensors as the most reliable technique, able to fit the needs to detect hidden corrosion and at the same time to catch the opportunity given by the Corrosion Control Register Program activated in 1994.

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