ANALATOM
Structural Health Monitoring Solutions

Application Note #001
AN110 – Avionics / Aerospace

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1 Overview

Acquisition programs are becoming increasingly sensitive to cost, schedule and performance risks. Maintenance efforts involved in corrosion inspection are significant across all branches of the armed forces, costing billions of dollars each year in manpower, equipment, and materials. By incorporating a system capable of identifying exposure to corrosive environments and corrosion of aircraft alloys, significant cost savings can be realized, not only in terms of minimized man-hours expended for inspection, but also in reducing aircraft downtime for scheduled maintenance.

1.1 Technology Description

Analatom's corrosion health monitoring system (CHMS), shown in Figure 1, consists of a network of AN110 Data Acquisition (DAQ) nodes. Each node connects to eight micro-linear polarization resistance (μLPR) sensors and one external temperature & relative humidity sensor. Each unit is battery powered, but can also be operated using external aircraft power.

1.2 Benefits

For the first time in 2013, the annual cost of corrosion in the United States exceeded $1 trillion dollars. Approximately 80% of these costs are due to corrective maintenance and the remaining 20% due to preventive maintenance. The single greatest cost to preventive maintenance are visual inspections; the majority of these costs are associated with inspections of inaccessible areas of the aircraft. However, cost is not the only driving factor for preventative maintenance. Federal Aviation Administration (FAA) policies and regulations require routine inspections for corrosion to ensure public safety, driving the need for solutions that are accurate and cost effective.

2 How it Works

2.1 μLPR Sensor

Corrosion is an electro-chemical process that takes place on a metallic surface. The μLPR sensor is comprised of a sample of metal fabricated from the same material as the structure to be monitored. The sensor is placed in areas where corrosion is likely to occur, such as joints and welds. When corrosion occurs on the μLPR sensor metal surface, a current signal is generated. This current signal is generated by a reduction-oxidation (redox) reaction taking place between the metal surface and the environment. The total amount of mass loss is proportional to the total charge generated due to the redox reactions. An absolute measure of total mass loss is derived from integrating the current signal and multiplying by a constant of proportionality dependent on known material properties and physical constants.

2.2 AN110 DAQ Node

LPR data is measured and stored locally on the unit. Data can be retrieved using a wired interface such as RS232 and RS485 or wirelessly using the IEEE 802.15.4 protocol. Post processing is performed on measured LPR data to compute the mass loss per unit area due to corrosion.

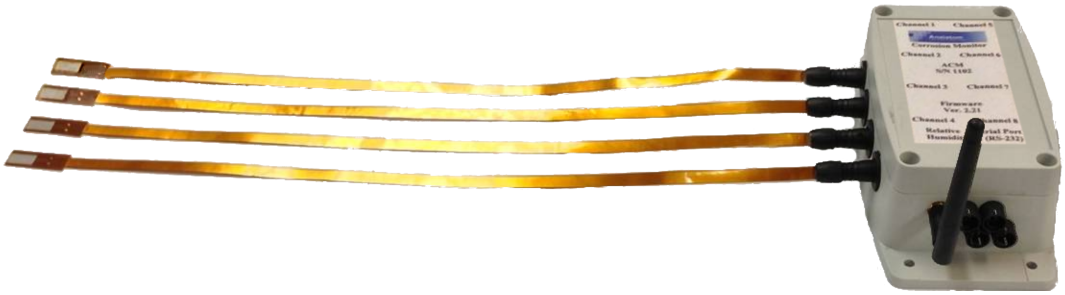

Figure 1: Wireless CHMS consisting of a AN110 DAQ node connected to four μLPR sensors.

3 Advantages

There are several advantages that μLPR has over other corrosion monitoring techniques:

- **Direct Measure** – The μLPR sensor is fabricated from the same material as the structure. This allows for a direct measure of corrosion when compared to other methodologies that infer corrosion from environmental parameters such as time of wetness, relative humidity, and temperature.
- **Measurement Speed** – Changes in the corrosion rate can be detected in minutes, providing a near-instantaneous measuring system. This fast response allows an operator to evaluate process changes and is particularly useful in monitoring the effectiveness of a prevention program.
- **Pitting Classification** – Post processing of LPR data can provide a qualitative pitting tendency measurement, such as whether the tendency for pitting will be shallow and infrequent, or deep and abundant. LPR monitoring can also give an indication of metal behavior, for example when an alloy changes from a passive to an active state, thereby resulting in increased susceptibility to corrosion.

4 Comparison

Direct corrosion monitoring measures a response signal, such as a current or voltage, as a direct result of corrosion. Examples of common direct corrosion monitoring techniques are: corrosion coupons, electrical resistance (ER), electro-impedance spectroscopy (EIS), and LPR techniques. Whereas, indirect corrosion monitoring techniques measure an outcome of corrosion and not the process itself. Two common indirect techniques are ultrasonic/acoustic testing and radiography testing. Each methods has advantages and disadvantages, summarized in Table 1.

5 Example Application

The μLPR has been flight tested on several commercial and military aircraft. An example of a AN110 DAQ node installed on a military transport aircraft is shown in Figure 2. Eight μLPR sensors were routed through the floor just underneath the crew door. Sensors were attached to critical areas of the aircraft structure that are difficult to access. After the installation, the sensors were primed and then painted in accordance with applicable technical orders. Data periodically downloaded wirelessly using a laptop during scheduled maintenance periods provides the up-to-date condition of the structure underneath the crew re-entry door preventing the need to remove floor-boards to conduct a visual inspection. The end-result is a reduction of aircraft downtime and labor-costs without sacrificing safety and reliability.

Table 1: Comparison of different corrosion monitoring techniques.

Parameter	**LPR**	**ER**	**Coupons**	**EIS**	**Ultrasonic**	**Radiography**
Power	Low	Low	None	Med	High	High
Weight	Low	Low	Low	Med	Med	High
Direct Measure	✓	✓	✓	✓	–	–
Non-Intrusive	–	–	–	–	✓	✓
Processing	Low	Low	Low	Med	High	High

Figure 2: AN110 installed on an aircraft equipment rack