PREDICTING CUMULATIVE GALVANIC CORROSION DAMAGE IN AIRCRAFT STRUCTURES

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OBJECTIVES

- Use a validated computational approach to develop an integrated suite of galvanic corrosion simulation tools to support corrosion risk assessment.
- Extend this methodology to include the longer term, dynamic environmental exposure conditions, common to military aircraft usage.
- Develop a Corrosion Service Life Model (SLM) to predict the cumulative galvanic metal loss and other corrosion related attack (crevice and pitting).

The development and validation of computational corrosion modeling tools has the potential to dramatically improve the durability of an aircraft through better material selection, improved corrosion resistant design, and better predictive maintenance schemes.

WORKPLAN

A computational modeling framework is being developed to support the prediction of cumulative corrosion damage in aircraft structures.

The effects of galvanic, crevice, and pitting corrosion are being incorporated in a corrosion service life model.

The challenges of connecting environmental exposure history and electrochemical data with computational models are being addressed.

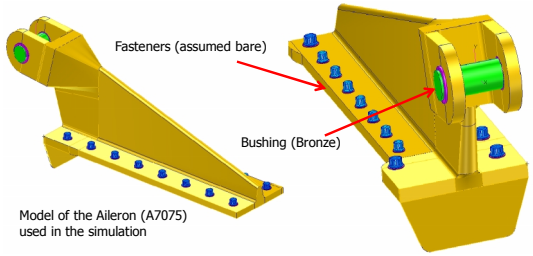
Initial predictions of corrosion damage in an aircraft component, subject to sensor based environmental measurements collected aboard a naval vessel, are demonstrated.

CONCLUSIONS

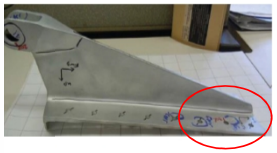
The new SLM methodology has been applied to a multi-material structure (aileron hinge). The results have been compared with observations from a teardown report that marks the corrosion damage and fracture locations. The general spatial distribution of corrosion damage is in agreement with the model predictions.

PREDICTING CUMULATIVE CORROSION DAMAGE

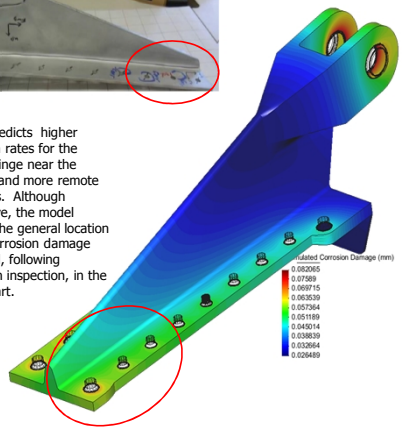
Corrosion damage on an aileron hinge is investigated using the newly created SLM methodology. The aileron hinge mounts to the rear and aft spars, and to a connecting rib in the outer wing section. In this simulation the aileron hinge is subject to an actual Naval operational environment and the accumulated corrosion damage is predicted.

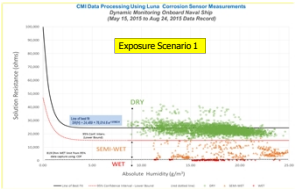


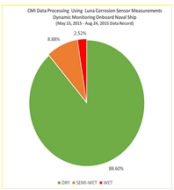
Model of the Aileron (A7075) used in the simulation



Model predicts higher corrosion rates for the aileron hinge near the bushing and more remote fasteners. Although qualitative, the model reflects the general location of the corrosion damage observed, following teardown inspection, in the actual part.



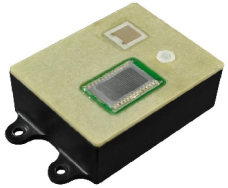




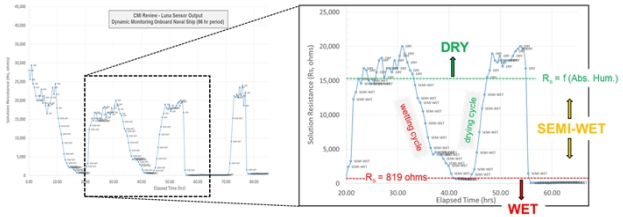
The aileron hinge was subjected to Exposure Scenarios 1 (duration 1.5 yr) & 2 (duration 0.5 yr), sequentially cycled, over a ten year period.

NAVAL OPERATIONAL ENVIRONMENT

In order to predict the accumulated corrosion damage, the environmental exposure of the structure over its service life, must be quantifiable. To address this requirement CMI is investigating the practicality and feasibility of using corrosion sensor measurements to inform computational models. This appears to be a more attractive option, compared to using historical environmental records, because the sensor is located directly on the structure and provides an accurate, time-based, measure of the environmental exposure (e.g. T, RH, R_s, R_p). Data sets describing the measurements obtained aboard a Naval vessel using a corrosion sensor manufactured by Luna Innovations have been used in the SLM predictions.



Environmental sensor Luna Innovations Inc

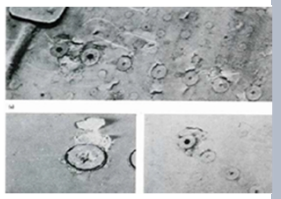


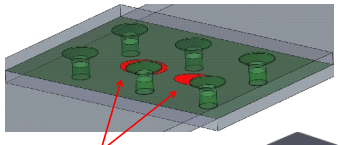
Sensor measurements and electrochemical laboratory data have been used in developing the corrosion Service Life Model (SLM). An approach previously developed by NAVAIR is currently being implemented to classify the changing moisture conditions on the component surface. (C. Boswell-Koller & V. Rodriguez-Santiago. "Corrosion Risk Assessment through Dynamic Environmental Monitoring On Board a Naval Ship", NACE Corrosion Conference 2017). After processing the corrosion sensor measurements the surface moisture film can be classified as either WET, SEMI-WET, or DRY. In addition to this time of wetness determination other necessary input parameters for computational corrosion models include electrolyte properties (conductivity, film thickness) and material specific polarization curves. Currently CMI has implemented a method whereby the polarization curves and conductivity measurements that represent the WET and SEMI-WET conditions can be used in the SLM model. Corrosion is assumed not to occur during the DRY condition.

ASSESSING THE IMPACT OF DIFFERENT CORROSION DAMAGE SCENARIOS

The loss of protective coatings due to mechanical damage or age related degradation can exacerbate corrosion damage including metal loss and pitting.

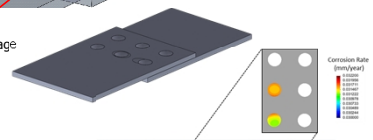
The new SLM software framework provides the capability to create and store a library of typical corrosion damage scenarios. This feature is useful in exploring corrosion risk and can be used to assist with maintenance planning.



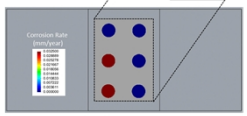


Damage Scenarios Sequential loss of topcoat/primer and Cd plating on rivet heads near discrete damage areas

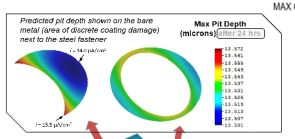
Discrete coating damage assumed on the Al-2024-T6 plate (red shaded areas)



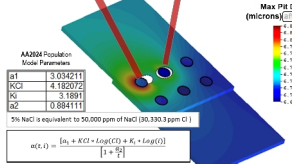
Damage Scenario #1b
Complete loss of topcoat/primer on two rivets near discrete damage areas



Damage Scenario 1b
MAX Corrosion Rate = 0.025 mm/yr



Damage scenario #2
Further loss of Cd plating on two rivets near discrete damage areas. In this case the exposed Al-2024-T6 now behaves anodic



Pitting model predictions in the Al-2024-T6 discrete damage areas

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