2017 Department of Defense – Allied Nations Technical Corrosion Conference

Student Research in Progress Symposium

DAMAGE EVOLUTION IN COATINGS AT LAP JOINTS

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Keywords: aluminum alloys, coating, lap joint

ABSTRACT

The work described in this paper focuses on mitigating the effects of the corrosion of Aluminum alloys 2024-T6 and 7075-T3 with cadmium-coated steel fasteners at aircraft lap joints. The objective of this work was to develop an electrochemical method to detect the onset of coating failure and extent of corrosion damage. To accomplish this a non-destructive electrochemical methodology for each exposure stage using real-time electrochemical impedance spectroscopy (EIS) was designed. In these tests coated samples containing MIL-spec fasteners were exposed to mechanical fatigue cycles, UV exposure, freeze/thaw cycles, and ASTM B117 salt fog exposure to study their effects on coating failure and corrosion of the samples. The samples were coated with MIL-PRF-23377 epoxy primer followed by a MIL-PRF-85285 polyurethane coating. Electrochemical impedance spectroscopy was used to evaluate the time of coating failure on the sample in real time during fatigue testing. Studies were done with and without the UV exposure and/or the freeze/thaw cycles as a control to study their effects on coating failure, and the corrosion of the samples.

2024-T3 and 7075-T6 aluminum sheets were machined into dogbone samples similar to “Specimen 6” in ASTM E8/E8M -15a with holes and countersinks added for rivets, as shown in Figure 1 (a sample as received from the machine shop). Some samples were machined with an intentional defect in the countersink where the countersink was drilled 10 degrees off from the normal angle. The samples were polished with 600 grit SiC and degreased by cleaning with DI water, acetone, ethanol, and DI water (in that order). The rivets were tightened to a constant torque (the collars were designed to have a part break off at the desired torque), and the samples were cleaned again in the same manner as they were cleaned after polishing. Two inches on both ends of the samples (in the grip section of the dogbone) were taped off to prevent them from being coated. On the day of the coating application, the PreKote was applied first. Then the MIL-PRF-23377K epoxy primer was applied, followed by the MIL-PRF-85285E polyurethane topcoat. A spray gun was used to apply the coatings. After the coating dried, silicone was applied to the collars on the backside of the sample to prevent coating failure/ corrosion from initiating there.

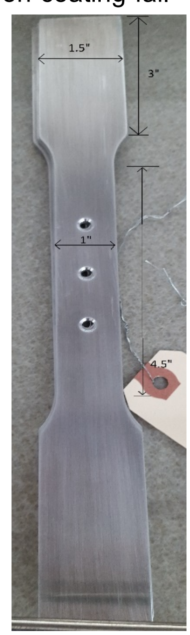

Figure 1 as received sample

Figure 2
small paint test cell

Figure 3
in situ EIS test cell

Electrochemical Impedance Spectroscopy (EIS) tests were performed on each rivet individually. A small O-ring cell was used to isolate each rivet for a separate EIS scan, using a Silver/Silver Chloride (Ag/AgCl) reference electrode and a stainless-steel rod counter electrode, as shown in Figure 2. This paint test cell had a diameter of only 1.5 cm, allowing for EIS tests that isolated each rivet. The EIS scans were performed at the open circuit potential, and scanned from 100,000 Hz to 0.01Hz with an AC voltage of 10 mV ms, collecting 10 data points per decade. Then the sample was fatigued while exposed to a 5% NaCl solution. The fatigue cycle used had a peak stress of 11.7ksi, R ratio of 0.05, and a frequency of 5 Hz for a total of 10,000 cycles. EIS was also recorded during the fatigue cycle, using a cell that fits over the entire gauge section of the dogbone sample, and contains the 5% NaCl solution, as shown in Figure 3. After collecting EIS data post fatigue testing, the samples were put into a Cincinnati Sub Zero freeze/thaw chamber cycling between -65°F and 85°F for 2 full temperature blocks over a 4 day time period. The cycle started with ramping down to -53.9°C (-65°F) over the course of 1 hour, then (step 2) the sample was held at that constant temperature for 23 hours. Then (step 3) the temperature in the chamber was ramped up to 29.4°C (85°F) over the course of 1 hour, and (step 4) was held at that temperature for 23 hours. Next, the samples were moved to a Q-UV chamber for a week of UV exposure at a temperature of 60°C and an irradiance of 0.89 W/m^2. They were placed in the chamber oriented so that the "top" side of the samples, with the head of the rivet countersunk into the sample, was facing the UV lamps, and the entire gauge section was exposed. From there, the samples were placed into an ASTM B117 salt fog chamber for 2 weeks. After the samples finish the 2 week salt fog exposure, one full cycle is completed, and the cycle returns to the inspection step with EIS.

EIS results for a coated 7075-T3 sample can be seen in Figure 4. This figure shows the EIS results on the same rivet before and after the fatigue step. The phase data shows that there are two time constants in the initial data, which is likely due to pore resistance. The data shows a consistent reduction in the resistance ("Zmod") after the sample was fatigued for all three rivets (only data from one shown here as the data from all three rivets looked very similar to each other).

CONCLUSIONS

This electrochemical method is shown to be useful for determination of coating failure of MIL-PRF-23377 epoxy primer with a MIL-PRF-85285 polyurethane topcoat coating on cadmium coated steel rivets in 2024 and 7075 aluminum plates.

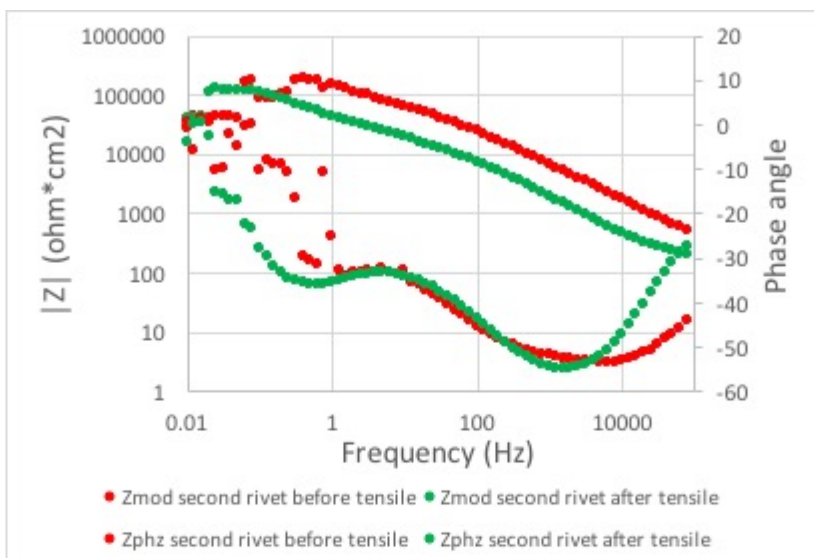

Figure 4. Bode plot of second rivetl

Acknowledgements

This work was sponsored by the US DoD Technical Corrosion Collaboration (TCC) supported by the U.S. Department of Defense Office of Corrosion Policy and Oversight through the US Air Force Academy Grant FA7000-14-2-20016. The authors thank Daniel J. Dunmire and Richard Hays for their continued support.