EXPERIMENTAL AND COMPUTATIONAL EVALUATION OF THE CORROSION OF ALCLAD AA2024-T3 EXPOSED AT A SEACOAST ENVIRONMENT

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The throwing power of a common metallic cladding was investigated by analyses of samples of scribed Alclad™ AA2024-T3 were exposed outdoors at Daytona Beach, FL for between two and eighteen months. The site was 75 m from the position of mean high tide. Controlled "defects" were made in through the clad by using an end mill to machine away the cladding across the width of the coupons and to make rectangular-shaped defects of varying widths at the center of the sample. Scribe widths between 1 and 10 mm were studied on samples of 7.6 cm long. The results of metallographic examinations of the samples are complemented by computational modeling of the thin film exposure conditions.

Both optical microscopy of the plan surfaces and cross-sectional metallography were performed in order to assess the width of scratch that could be protected. The specimens were first inspected visually, then cut and mounted for metallographic analysis. The samples were cut at their centerline perpendicular to the machine defect. To avoid any edge effects, cross-sections close to the center were exposed and examined with optical microscope. For scratches 5 mm or smaller, the entire exposed AA2024-T3 substrate was well protected by the AA1230 clad. The 10-mm wide scratches were only partially protected by the clad, with the exposed AA2024-T3 suffering severe corrosion near the centerline of the scratch, with the severity of the attack increasing with exposure time. Figure 1 shows a metallographic cross-section for a sample with scribed width of 10 mm after 18 months of exposure. From the higher magnification pictures, it is possible to see that clad was not able to provide protection to the entire exposed substrate. Only the ~20% of the substrate nearest the Alclad was protected. Samples of bare (i.e., unclad AA2024-T3 after various times of exposure were also available and were compared with the corresponding samples with 10 mm scribed width. Considerable more attack was observed on the AA2024-T3 with no clad.

The clad exhibited significant pitting corrosion over its entire surface independent of the size of the scratch. Within the smaller scratches, limited (both in diameter and depth) corrosion was observed. The presence this limited corrosion even within the smaller scratches was most likely the result of wet-dry cycling linked to the diurnal cycles. As the surface dried, regions of electrolyte formed on the AA2024-T3 scratch, but were isolated from the clad.

A computational mass transport framework [1], which has previously been extended to study alloys exposed to the thin electrolytes characteristic of atmospheric corrosion was adapted to model the interactions of an aluminum-clad layer with its Al-alloy substrate in the vicinity of a scratch as in the samples described above. The model focuses on open circuit conditions and local galvanic couples. Accurate electrochemical kinetics for metallic clad and bare AA2024-T3 exposed to chloride solutions were used based on experimental measurements [2]. For exposure to atmospheric conditions, there is a direct relationship between the water layer thickness and diffusion limited current density for the oxygen reduction reaction, as the water layer represents the diffusional boundary layer. A quantitative computation of the throwing power of metallic cladding on AA2024-T3 in thin electrolytes was implemented.

Several sets of parameters were computed, Figure 2 compares experimental and model results with different input parameters that follow the trend observed experimentally. The only case with a high [Cl⁻] that followed the observed trend was that set with a water layer of 25 μm, which might suggest that the average water layer present in the field is of that order. It is important to note that the model assumes the same water layer since considers an instantaneous coupling, whereas the field tests as indicated above surely were subject to oscillations on the water layer.
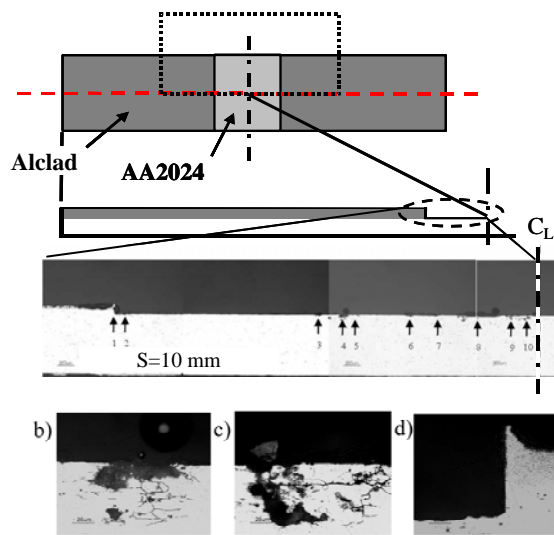

Figure 1. Sample diagram, and metallographic view of scribed Alclad 2024 sample with S=10 mm after 18 months of exposure. b) #3, c)#9, and d) opposite end
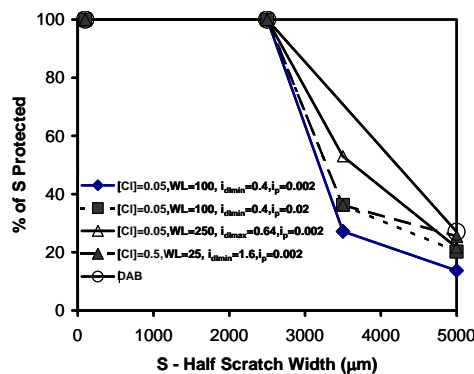

Figure 2. Comparison experimental and model results

References:
1. H. Wang, F.Presuel, R.G. Kelly, Electrochimica Acta 49 (2004) 239-255.
2. F. Presuel, F. Cui, R.G. Kelly, "Modeling of Corrosion Protection Provided by an Aluminun-Based Clad: Water Layer Effect", The 204 Electrochemical Society Meeting, Orlando, Florida, October, 2003ECS Fall/03