Corrosion Protection of Interfaces between Aluminum and Mechanically-Coupled Polymer Matrix Composites (PMCs)

Raghu Srinivasan and L.H. Hihara
Department of Mechanical Engineering
University of Hawaii at Manoa
2540 Dole St., Honolulu, HI 96822

OBJECTIVE

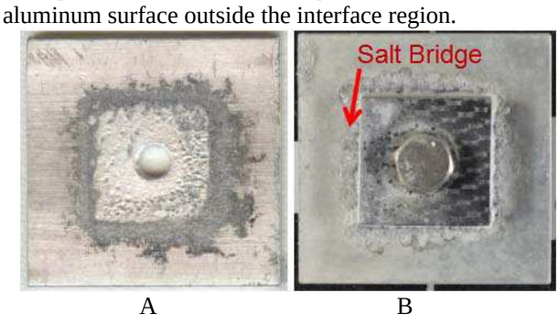
Connections between monolithic aluminum (Al) and conductive polymer-matrix composites (PMCs) are susceptible to galvanic corrosion. The mechanisms of decoupling the Al-PMC galvanic couple using an insulating layer of various lengths, salt loading, and humidity was investigated.

BACKGROUND

Today, many components and equipment are comprised of a material system rather than a single type of material. PMCs, for example, are being used with greater frequency in defense, aerospace, automotive and civil-infrastructure industries. Modern automobiles use 100 kg of polymers compared to only 3 kg in the 1980s. In the quest to reduce weight and increase performance, more and more advanced structures, systems and machines are being developed using a combination of alloys, composites, polymers, and ceramics. A system of dissimilar materials, however, may induce significant corrosion problems. Metal alloys coupled to composites may lead to crevice and galvanic corrosion problems**.** Hence, in order to take advantage of material systems, compatibility issues must be thoroughly understood in order to devise corrosion control strategies.

CORROSION PROBLEMS

Electrically conductive PMCs such as carbon fiber reinforced (CFR) PMC can accelerate the corrosion at PMC-Al interfaces by galvanic action and crevice corrosion. On a 6061-T6 Al coupon coupled to a conductive CFR PMC significant corrosion was observed outside the interface area when exposed at a marine test site (Figure 1A). The chlorides deposited on the couples formed a salt layer beyond the interface region of the 6061-T6 Al and CFR PMC (Figure 1B). This continuous ionic path resulted in excessive galvanic corrosion on the aluminum surface outside the interface region.



A B

Figure 1: Galvanic corrosion (A) beyond the interface region of a 6061-T6 Al/ CFR PMC couple resulting from the formation of a salt layer (B).

APPROACH

A typical method used to mitigate galvanic corrosion when bolting aluminum to CFR PMCs is to insert an insulating layer of E-glass–reinforced PMC between the members (Figure 2). In doing so, however, direct contact between the aluminum and CFR PMC is eliminated, but the aluminum and the CFR PMC could still be galvanically coupled through the fastener. An insulating layer of G-10 fiber glass was introduced in the interface to separate the conductive CFR PMC from the 6061-T6 Al so that the direct contact between the Al and CFR PMC was eliminated. The Al and the CFR PMC, however, were still galvanically coupled through the Ti-6Al-4V fastener; hence, galvanic corrosion can occur if the electrolyte bridges over the G-10 fiber glass barrier. To minimize the galvanic effect, the insulating skirt was extended beyond the CFR PMC coupon (Figure 2).

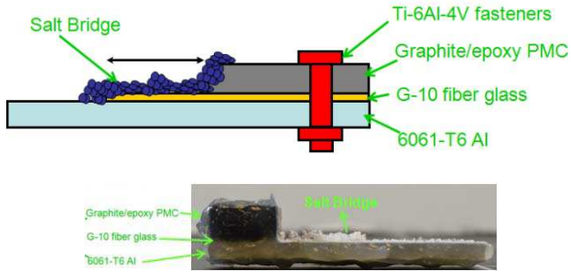


Figure 2: CFR PMC/Al couple with insulating skirt.

The galvanic corrosion rate of 6061-T6 Al alloy coupled to CFR PMC were monitored over a 5-day period inside of a humidity chamber at 90% relative humidity (RH) and 30^{o}C using the zero resistance ammeter (ZRA) technique with different skirt lengths of the insulating layer. The samples were sprayed initially with 3.15 wt% sodium chloride solution for a salt loading of approximately 0.75 mg/cm^{2}. For each length of skirt, three sets of experiments were conducted and the average galvanic currents were reported. Figure 3 shows the average galvanic current between 6061-T6 Al and CFR PMC with three different G10 fiber glass skirt lengths for 5 days.

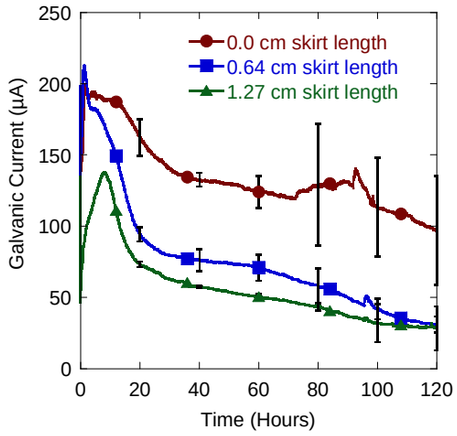


Figure 3: Galvanic current between 6061-T6 Al and CFR PMC with three different G10 fiber glass skirt lengths (3.15 wt% NaCl spray at 90% RH and 30°C)

The galvanic corrosion rates will also be monitored as a function of electrolyte loading, electrolyte type, humidity, and longer skirt lengths. Measurements will also be taken in the field.

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