Development of the Atmospheric Corrosion Model of Nickel-Coated Carbon Reinforced Aluminum (Al/C/50f) MMCs

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An atmospheric corrosion model was developed that correlated the corrosion rates of a pure aluminum metal matrix composite (MMC) reinforced with 50 vol.% nickel (Ni)-coated carbon (C) fiber (Al/C/50f) to chloride (Cl^-) deposition rates and time of wetness. The correlation was developed with the utilization of anodic and cathodic polarization diagrams of the aluminum alloy and graphite fibers that were generated under immersion conditions.

Al/C/50f MMC tapes were cut into three inch-long coupons. The test coupons were mounted on Al plates that were later fastened on test racks at seven test sites in Hawai'i. Among the seven test sites, Coconut Island (CI) and Kahuku (KH) are marine, Lyon Arboretum (LA) is rainforest, Kilauea (KIL) is volcanic, Waipahu (W) is arid, Campbell Industrial Park (CIP) is industrial, and Ewa Nui (EN) is agricultural. For corrosion rate measurements, three specimens of each material were exposed for three different exposure periods (i.e., 120 days, 240 days and 360 days) at each test site. The chloride candles were exposed in all the test sites. The chloride candle gauze obtained from the test sites was soaked in a measured volume of ultrapure water from which the pH was measured using a pH electrode, and the Cl^- concentration was determined using ion chromatography. After exposure, the corroded coupons were cleaned in 2% chromium trioxide and 5% phosphoric acid solutions in accordance with ISO standards 8404:1991 (E) C.1.1. Each coupon was weighed individually before and after exposure, and weight loss of each coupon was measured to calculate the corrosion rate. The microstructures of the Al/C/50f MMCs were characterized using scanning electron microscopy (SEM) and energy dispersive x-ray analysis (EDXA).

SEM examination of virgin specimens of the Al/C/50f MMC revealed that the Ni coating on the C fiber diffused into the Al matrix and precipitated as Ni-based intermetallics, which sometimes formed linkages between the C fibers.

The weight loss measurement indicated that maximum corrosion of the Al/C/50f MMCs occurred at the marine sites (CI and KH), followed by the rainforest site (LA), and then by the other the test sites. Corrosion at the volcanic site (KIL) was as low as at the dry sites (W, CIP and EN). This indicated that the Cl^- deposition rate and wetness had a significant influence on the corrosion rates. Despite a moderate amount of Cl^- deposition and acid rain, the corrosion rate at the volcanic site was unexpectedly low. The corrosion morphology of the corroded Al/C/50f MMCs specimen revealed that the Ni based intermetallics, along with C fiber, served as cathodic sites during corrosion. At the volcanic site, however, the acid rain dissolved the Ni-based intermetallics, resulting in a low corrosion rate due to the loss of cathodic sites and possibly the formation of Al-Ni hydrotalcite-like compounds. The corrosion rate was also found to be low at the dry, agricultural and industrial sites, where the time of wetness was low.

The atmospheric corrosion rates of Al/C/50f MMCs were plotted against individual parameters such as Cl^- deposition rate, pH, and the percentage of the time that sites were wet (Q4). The presence of Cl^- had a dominating affect on corrosion of the Al/C/50f MMCs. The galvanic corrosion between C and Al are much more vigorous in presence of Cl^- than in low pH environments, based on the polarization data. The polarization data indicated that the galvanic corrosion rate (i_{gal}) between C and Al was dependent on the Cl^- concentration of the solution. There was a linear relationship between logarithm of i_{gal} and logarithm of Cl^- concentrations of the solutions with an R^2 value close to 0.95. Based on the linear relationships between log (i_{gal}) and log (Cl^-), the atmospheric corrosion models are described as a function of Cl^- deposition rate and Q4. In Figure 2, the atmospheric corrosion rate of the seven test sites are plotted against the model ($Q4*(Cl^-)^{0.538}$). The R^2 value for the curve between established model and the atmospheric corrosion was approximately 0.7.

While establishing atmospheric corrosion model, the data points from the KIL volcanic site were excluded because the selective etching of the Ni-based intermetallics was only asscociated at this site due to the acid rain.

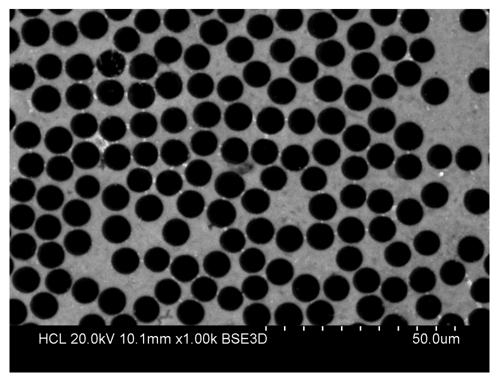

Figure 1: SEM micrograph of virgin Al/C/50f MMCs, showing redistribution of Ni based intermetallics as bright linkages.

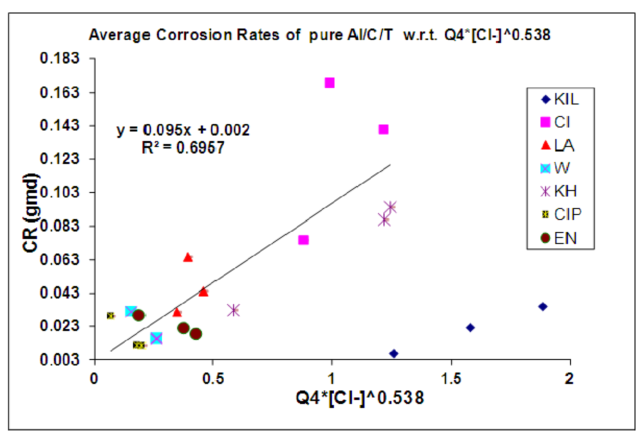

Figure 2: Atmospheric Corrosion rate of Al/C/50f MMCs as a function of Q4x f{[Cl^-]}.

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