LAMBDA Technologies Group

Diffraction Notes

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AN INVESTIGATION OF THE FORMATION OF CRACK-LIKE INTERGRANULAR FISSURES IN 7000 SERIES ALUMINUM BY GRAIN BOUNDARY GALVANIC CORROSION

INTRODUCTION

It is well known that residual stresses have a significant effect on the overall strength and longevity of critical metallic components. Stress corrosion cracking (SCC) is a prime example of a failure mechanism where residual stresses can significantly alter the likelihood of component failure. When choosing to apply a surface treatment to impart compressive residual stress for SCC mitigation it is imperative that the diagnosis of the failure mechanism be correct. If the failure mechanism is improperly diagnosed compressive residual stress may result in little to no improvement.

In their 1981 paper titled “Mechanism of Localized Corrosion in 7075 Alloy Plate,” Maitra and English suggest that anodic polarization of a galvanic couple falling between two breakdown potentials could cause significant intergranular corrosion but minimal general pitting of the matrix of 7000 series aluminum alloy. The crack-like intergranular fissures, visually similar to SCC or intergranular cracking (IGC), would be difficult to detect and independent of applied or residual stress. Component failure initiating from the fissures could be incorrectly identified as SCC.

In a study performed at Lambda Research, the Maitra-English grain boundary attack mechanism was observed in potentiodynamic testing of a 7000 series aluminum alloy, producing both crack-like fissures along grain boundaries and more general pitting. Galvanic couple testing of shot peened aluminum alloy and a more noble Al-bronze material exposed to the vapor phase of 3.5 wt% NaCl solution was also performed. In only 20 days, crack-like attack along grain boundaries developed and grew through the shot peened compressive layer, where it could then propagate as a fatigue crack to failure under in-service operating stresses.

Galvanic corrosion driven grain boundary attack is shown to be a possible cause of material failure in the absence of SCC conditions. The presence of residual compression is shown not to impede the galvanic grain boundary attack mechanism.

DC ELECTROCHEMICAL TESTING

Anodic polarization of a metal can occur as a result of galvanic coupling. In a galvanic couple potentials of the electrodes shift toward a shared mixed potential somewhere between their respective uncoupled corrosion potentials. By overlaying the polarization curves of two metals measured individually, this mixed potential (and galvanic corrosion current) can be approximated by the intersection of the anodic curve of the active metal with the cathodic curve of the more noble metal.

The plot in Figure 1 depicts an example of mixed potential theory applied to the 7000 series and Al-bronze materials. By overlaying the individual polarization response curves measured on each material, the mixed potential can be determined by the intersection of the cathodic portion of the Al-bronze curve with the anodic portion of the aluminum curve

The galvanic effect of the two alloy couple was directly measured using a potentiostat. Results indicate that a galvanic couple of the 7000 series aluminum and Al-bronze in a 3.5 wt% NaCl environment can anodically polarize the aluminum alloy to a state favorable for intergranular corrosion attack.

A cross-sectional SEM evaluation of this ZRA galvanic couple sample shows significant corrosion damage and crack-like fissures along grain boundaries in a sample containing high levels of compressive residual stress. Figure 2 shows SEM examples of the corrosion and fissures.

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GALVANIC EXPOSURE TESTING

Galvanic exposure testing was designed to simulate a condition in which a shot peened aluminum component not properly electrically isolated from a more noble Al-bronze component is exposed to a salt water environment. To preclude the possibility of SCC, no external stress was applied.

Aluminum component sections were mated with corresponding Al-bronze component sections and exposed to the vapor phase of 90 °F NaCl solution. An additional aluminum sample without a corresponding Al-bronze galvanic couple was also exposed as a control

Fine crack-like IGC fissures, shown in Figure 3, were observed in the aluminum containing high compressive residual stress of the galvanically coupled samples in as few as 20 days. No observable corrosion damage was found on an uncoupled control sample.

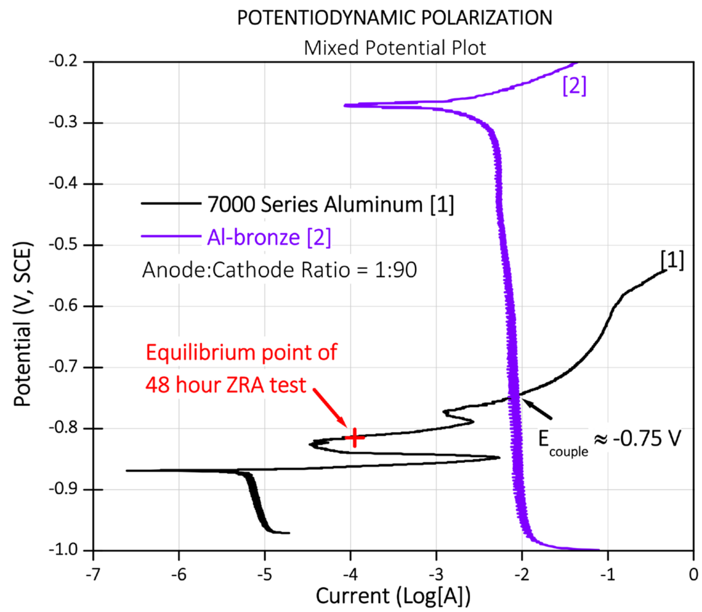

Figure 1

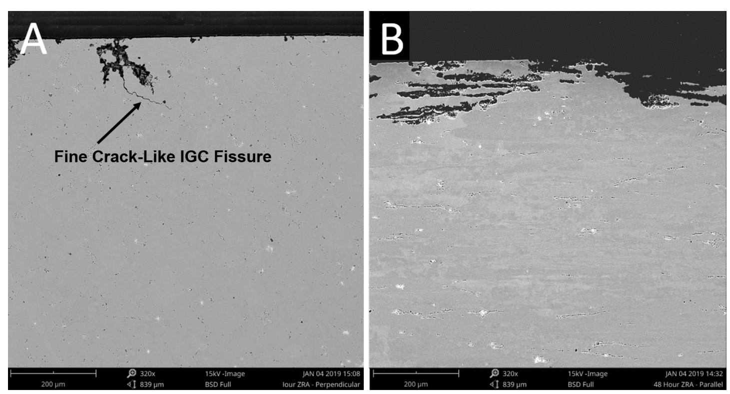

Figure 2

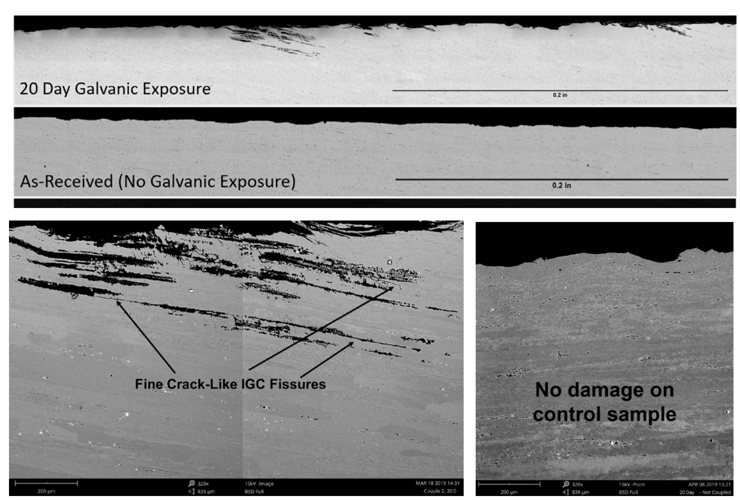

Figure 3

CONCLUSIONS

Anodic polarization driven intergranular corrosion, as described by Maitra and English in AA7075-T6, was produced in a separate 7000 series aluminum alloy containing high levels of surface residual compression in laboratory controlled DC electrochemical testing, producing crack-like fissures following grain boundaries. Galvanic coupling between the aluminum alloy and a more noble Al-bronze alloy caused similar damage with only 20 days of exposure to salt water vapor. It was shown that galvanic grain boundary corrosion of this 7000 series aluminum can manifest as crack-like fissures visually similar to SCC but in the presence of a highly compressive surface layer.

This investigation reveals that residual compression does not inhibit the galvanic grain boundary attack mechanism for this 7000 series aluminum alloy. This investigation demonstrates that proper identification of the failure mechanism is crucial when determining appropriate compressive residual stress mitigation methods.

Read the full paper

Lambda Technologies • 5521 Fair Lane, Cincinnati, OH 45227 • Tel (513) 561-0883 • Toll Free/U.S. (800) 883-0851 • info@lambdatechs.com