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Atmospheric Corrosion and Cracking of 304 Stainless Steel in Controlled Marine Atmospheres

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Exposure of 304 stainless steel to atmospheric marine environments can result in localized corrosion leading to stress corrosion cracking. Recent work on ground 304 stainless steel has shown that relative humidity (RH) plays a key role in determining both the extent of corrosion damage and the nature of pit morphology.[1] In particular, low RH (40%) exposure resulted in higher corrosion damage, irregular pit morphologies and micro-cracking associated with pits. This was in contrast to the smooth, elliptical pits and no observed cracking after high RH (76%) exposure. The current study focuses on examining the origin of such micro-cracking and mechanical testing to characterize the stress corrosion cracking (SCC) initiation risk in these environments.

Cracking in these systems was considered with the two goals of understanding (1) why micro-cracking around pits occurs at low RH and not at high RH in the absence of externally applied loading on ground 304 surfaces, and (2) how SCC initiates under externally applied loads under these two humidity regimes. To investigate the first objective, pit morphologies corresponding to the RH of interest were generated by immersing 304 stainless steel coupons in solutions that mimicked the electrolyte chemistry of the corrosive brine at 40% RH and 76% RH.[2] In order to assess the effect of surface grinding on pit morphology, an additional set of ground coupons were annealed prior to immersion in order to remove deformation substructure. Post-exposure characterization was performed via optical profilometry (OP), scanning electron microscopy (SEM), and X-ray computed tomography (XCT). For comparison, XCT was also performed on specimens that had been previously characterized using OP following pitting under sea salt deposits in atmospheric environments.[1]

For the second objective, prior to SCC testing, pits were generated on the narrow faces of the gage length of tensile bars in three ways: (1) growth under galvanostatic control, (2) under atmospheric exposure conditions, and (3) under full immersion in electrolytes of chemistry similar to the corrosive brine. SCC testing comprised a sequence consisting of a constant load with intermittent high R ripple loads. Preliminary testing under atmospheric exposure conditions showed no cracking was observed even after 44 days for the pits generated under galvanostatic control. For the pits generated in atmospheric exposure, preliminary surface SEM imaging indicated that micro-cracking may occur associated with pits when SCC testing in atmospheric conditions is carried out for longer periods (approaching 6 months). SCC tests were performed with the gage section immersed in a solution simulating the chemistry of the corrosive brine, after pit generation either under atmospheric conditions or full immersion. This procedure was followed in order to observe cracking in a reasonable timeframe and to ensure constant electrolyte contact with the crack. Samples were pulled to failure at the end of the test and examined using SEM to determine the corrosion feature leading to crack initiation. Results from these tests are presented along with a discussion of possible electrochemical and metallurgical mechanisms causing SCC initiation in this system. Ongoing studies on extending this learning to weld-repaired 304 surfaces are also briefly discussed.

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References

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