# THE EFFECT OF CORROSION MORPHOLOGY ON THE FATIGUE INITIATION AND SMALL CRACK GROWTH BEHAVIOR OF AA7050-T7451

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Complex airframe structures often require the use of stainless steel fasteners to assemble/join aluminum substructures. A galvanic couple is created when surface coatings/sealants are breached enabling ingress of an electrolyte; this leads to corrosion damage at these inherently high stress joints. Recent US Air Force studies have demonstrated that corrosion nucleated fatigue damage represents roughly 80% of airframe fatigue damage initiation sites [1]. Despite the critical importance of this failure mode the interaction of the mechanical and electrochemical interactions for a realistic galvanic couple configuration are poorly understood. This talk will report on a collaborative effort that aims to quantify the local galvanic environments, quantitatively characterize the corrosion morphology associated with such environments, and evaluate how such morphologies influence the fatigue behavior of a modern aerospace aluminum alloy. The primary focus will be on quantitatively evaluating the macro-features, micro-features, and microstructural interactions that govern the crack formation behavior and how the relative influence of each varies with different corrosion morphologies produced using electrochemical conditions pertinent to an in-service galvanic couple.

Leveraging collaborator inputs from experimental and computation analysis of the electrochemistry of a representative galvanic couple, three corrosion morphologies are considered: discrete pitting (small and large scale), a broadly corroded surface with surface recession and intergranular corrosion (IGC). Each damage morphology is induced on the SL surface of the AA7050-T7451 fatigue samples. Optical microscopy, white light interferometry, and x-ray computed tomography (XCT) are used to characterize the features of the corroded specimens. XCT is also used to identify the location of underlying constituent particles. Corroded specimens are fatigue loaded ($\sigma$max of 200 MPa, R of 0.5 and f of 20 Hz) along the L-direction in a high humidity (RH>90%) that is maintained inside a plexiglass chamber. A programmed fatigue loading sequence is used mark the crack front intermittently on the fracture surface of the specimens; these fatigue-sequence induced marker bands are analyzed using the scanning electron microscope to quantify crack formation location and life (($N_i$) to ≈10 μm) and crack growth rates (da/dN). Once fractography is complete the fracture surface is polished (roughly 15 μm deep) and electron back-scatter diffraction analysis is performed to enable characterization of the microstructure proximate to the crack formation site and how it intersects the growing small crack.

Overall fatigue life results show a substantial and similar reduction in fatigue life due to each of the corrosion morphologies; markerband analysis demonstrates that this strong reduction is primarily due to a vast decrease in the crack formation life. Similar small crack growth rates are observed proximate to each of the corrosion features. Analysis of the macro-features of the corrosion morphology show no clear trend between crack formation sites and the damage depth, width, 3D volume, density, or proximity to surrounding damage. Furthermore the similarity in the crack formation life between different morphologies suggests that the micro-features associated with each damage type results in a similarly deleterious local condition for crack formation. The proximity of local constituent particles and the local grain orientations are evaluated to determine if there is commonality between the crack formation location and a consistent microstructure feature(s).

The results and conclusion of this effort will quantitatively characterize the crack formation behavior of a relevant aerospace Al alloy in realistic conditions and leverage this data to further the mechanistic understanding of the factors governing the corrosion to fatigue crack transition. This understanding it critical to inform engineering scale prognosis strategies and provide guidance on the critical criteria for designing corrosion mitigation strategies in the context fatigue damage.

References:
[1] G.A. Shoales, S.A. Fawaz, M.R. Walters, in: M. Bos (Ed.) ICAF 2009 - Bridging the Gap Between Theory and Operational Practice, Springer, Rotterdam, The Netherlands, 2009, pp. 187-207.