UNDERSTANDING CORROSION FEATURES AND ALLOY MICROSTRUCTURE EFFECTS ON FATIGUE INITIATION OF CORRODED AA7050-T7451 USING DATA SCIENCE

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Aluminum alloy 7050-T451 is generally used in aerospace structure due to its high strength-to-weight ratio and high toughness. Local galvanic coupling set up by wicking of electrolyte in between the stainless steel fastener used in the aircrafts and the aluminum substructure promote corrosion of AA7050-T7451. Fatigue crack initiation tend to occur on discontinuities in the aluminum alloy such as the corrosion damage created by the galvanic coupling. Previous study indicate that the individual metrics analyzed for the macro-scale (>250 μm) corrosion features such as pit depth, pit density, pit volume, area of the pit mouth, do not fully correlate to the location of the fatigue crack initiation [1]. The objective of this study is to verify if there is an interaction effect on the metrics analyzed using the macro-scale corrosion damage features using data science techniques. Another objective of this study is to determine if the micro-scale (<250 μm) corrosion features and the alloy microstructure play an important role in the fatigue initiation mechanism of AA7050-T7451.

In order to understand the mechanism governing the fatigue crack formation, corrosion damage mimicking the galvanic coupling effect of AA7050-T7451 and SS316 are artificially created on the surface of AA7050-T7451. A small area on the LS surface of the fatigue specimens are exposed to different environmental conditions to create four different corrosion morphologies, namely, shallow and deep discrete pits, fissures and general corrosion with surface recession. These corrosion morphologies are characterized using the optical microscope, white light interferometer, scanning electron microscope and X-ray computed tomography. The specimens are subjected to fatigue loading using a special loading protocol that creates marker bands on the fracture surface. The specimens are cyclically loaded along the L-direction with σ_{max} of 200 MPa, R ratio of 0.5 at a frequency of 20 Hz. The fatigue testing is done at 23°C and a controlled moist environment with >90% relative humidity during the entire test. After fatigue testing, the fractographs of the specimens are obtained using the SEM. The marker bands from these fractographs are analyzed to calculate the crack growth rate and the fatigue initiation life to create a 10 μm crack from the initiation point are estimated.

Data science approaches are employed to analyze the interaction effect of the individual metrics reported in the macro-scale corrosion feature analysis. Random forest and logistic regression modeling show that there is minimal significance between the macro-scale corrosion feature predictor variables and the fatigue crack initiation points. Even though data science indicate that these factors have less significance, these factors should not be neglected. The micro-scale corrosion features and the distribution of secondary phase particles as well as the grain character are individually analyzed and correlated to the location of the fatigue crack initiation for all the corrosion damage morphologies. Results show that these individual metrics does not fully dictate the location of the fatigue crack initiation. Future work of this study involves the use of data science techniques to understand the relationship between the micro-scale corrosion features, their possible interaction with the alloy microstructure, and the fatigue crack formation. This study will provide understanding on what governs the fatigue crack initiation and inform current micro-mechanical models to incorporate effects of pertinent parameters in predicting remaining life of corroded specimens.

Reference:

[1] Co NEC, Burns JT. Effects of macro-scale corrosion damage feature on fatigue crack initiation and fatigue behavior. Int J Fatigue 2017;103:234–47. doi:10.1016/j.ijfatigue.2017.05.028.