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Characterization of microstructural effects on small fatigue crack growth mechanisms in Ti-6242S

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ABSTRACT

Design and life management of fracture critical components are made difficult by small scale deformation responses to low applied stresses in the very high cycle fatigue (VHCF) regime, where the number of cycles exceeds 10^7 and fatigue life is dominated by crack initiation and the growth of microstructurally small cracks. Furthermore, fatigue crack formation is extremely sensitive to microstructural features. Existing models do not fully capture small scale microstructural influences on early fatigue deformation behavior. An understanding of the interactions between the local microstructure and the plastic zone present at the crack tip of a microstructurally small fatigue crack is critical to modeling fatigue crack growth mechanisms. Plastic zone sizes at this scale are highly influenced by local microstructural characteristics such as grain boundary misorientation, phase boundaries, and the presence of precipitates. The use of multiple experimental techniques that enable study of the interactions between the crack-tip plastic zone and local microstructural features in-situ will help develop a quantitative understanding of the underlying small crack growth mechanisms. The role of microstructure on small fatigue crack growth mechanics in the near a titanium alloy Ti6242S has been investigated in the VHCF regime. An experimental methodology for in-situ ultrasonic fatigue (20 kHz) in a scanning electron microscope (SEM) has been developed to investigate mechanisms of fatigue crack formation and the growth of microstructurally small cracks in vacuum and in varying partial pressures of water vapor. In-situ observations of small crack growth behavior from focused ion beam machined micronotches located at key microstructural sites indicated a significant microstructural dependence on crack growth rates. Fatigue crack propagation behavior is also correlated with crack opening displacement and cyclic strain accumulation as measured by advanced in-situ scanning electron microscopy digital image correlation techniques. The evolution of small-scale strain fields at crack tips and in the microstructural neighborhood of the advancing crack is also examined. The specifics of the ultrasonic fatigue SEM instrumentation and the influence of microstructure on small fatigue crack propagation, crack-tip plasticity, and strain localization in the VHCF regime will be described.