Fracture in aluminum alloys for aerospace application

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ABSTRACT

Complex structural aerospace components are high-speed machined out of (thick) hard alloy plate. A majority of the material is removed from an integrated unit, providing considerable weight savings. However, the demand for increased performance and reduced weight has lead to more complex loading scenarios – and the development of localized stress states that drive complex microstructure-related mechanisms of failure. Fault-tolerant design is (in turn) complicated by interplay of kinetics of plasticity and deformation incompatibility at the mesoscale. The presentation will begin with a review of experimental research conducted on hard aluminum alloys targeted for use in aerospace structures (a story that follows from the efforts of many graduate students and colleagues). Topics to be detailed include (i) fracture and fatigue response, studied at both the macroscale (Digital Image Correlation) and mesoscale (Electron Back-Scatter Diffraction); (ii) characterization of kinetics through cyclic testing; and (iii) in situ study of lattice strain on a grain-by-grain basis, using high-energy X-ray diffraction microscopy (HEDM) at a synchrotron source. The application of modeling techniques to interpretation of data will be given. In particular, the stress state at the mesoscale will be related to crack turning behavior. Model validation follows from agreement with HEDM results. Simulations of fracture highlight driving forces for crack growth, plasticity developed at grain boundaries and the effect of T-stress. The combined experimental and modeling program provides guidance in fault-tolerant design.