# Mechanical Engineering Master's Defense

## Understanding Plasticity and Fracture in Aluminum Alloys and their Composites by 3D X-ray Synchrotron Tomography and Microdiffraction

School for Engineering of Matter, Transport and Energy


Peter Hruby

**Advisor:** Dr. Nikhilesh Chawla


## abstract


Aluminum alloys and their composites are attractive materials for applications requiring high strength-to-weight ratios and reasonable cost. Many of these applications, such as those in the aerospace industry, undergo fatigue loading. An understanding of the microstructural damage that occurs in these materials is critical in assessing their fatigue resistance. Two distinct experimental studies were performed to further the understanding of fatigue damage mechanisms in aluminum alloys and their composites, specifically fracture and plasticity.

Fatigue resistance of metal matrix composites (MMCs) depends on many aspects of composite microstructure. Fatigue crack growth behavior is particularly dependent on the reinforcement characteristics and matrix microstructure. The goal of this work was to obtain a fundamental understanding of fatigue crack growth behavior in SiC particle-reinforced 2080 Al alloy composites. In situ X-ray synchrotron tomography was performed on two samples at low (R=0.1) and at high (R=0.6) R-ratios. The resulting reconstructed images were used to obtain three-dimensional (3D) rendering of the particles and fatigue crack. Behaviors of the particles and crack, as well as their interaction, were analyzed and quantified. Four-dimensional (4D) visual representations were constructed to aid in the overall understanding of damage evolution.

During fatigue crack growth in ductile materials, a plastic zone is created in the region surrounding the crack tip. Knowledge of the plastic zone is important for the understanding of fatigue crack formation as well as subsequent growth behavior. The goal of this work was to quantify the 3D size and shape of the plastic zone in 7075 Al alloys. X-ray synchrotron tomography and Laue microdiffraction were used to non-destructively characterize the volume surrounding a fatigue crack tip. The precise 3D crack profile was segmented from the reconstructed tomography data. Depth-resolved Laue patterns were obtained using differential-aperture X-ray structural microscopy (DAXM), from which peak-broadening characteristics were quantified. Plasticity, as determined by the broadening of diffracted peaks, was mapped in 3D. Two-dimensional (2D) maps of plasticity were directly compared to the corresponding tomography slices. A 3D representation of the plastic zone surrounding the fatigue crack was generated by superimposing the mapped plasticity on the 3D crack profile.


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