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Mechanical Engineering Seminar Series

Coupling microstructure-sensitive modeling and in situ experiments to understand and predict fatigue behavior: Towards the rapid qualification of additive manufactured materials

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Abstract

The benefits of additive manufacturing have been well documented, but prior to these materials being used in critical applications, the mechanisms for fatigue failure must be identified and the life of these materials must be determined for use in a design context. Traditionally, the qualification of these materials is completed based on a time- and cost-intensive, trial-and-error testing program, which jeopardizes the implementation of new materials into service. In this work, the fatigue behavior of selective laser melting (SLM) IN718, 718Plus, and Ti-6Al-4V is investigated through detailed characterization and modeling efforts, to accelerate the qualification of these materials through simulation-based predictions of material performance. Advanced characterization is used to identify the unique defects and microstructural features produced by SLM of the various materials at the micron and sub-micron scales. Afterwards, many sets of simulations are created based on different combinations of the microstructure that faithfully represent the distributions observed in the SLM materials. Specifically, the simulations track the evolution of accumulated strain and dissipated energy relative to the microstructural features with applied cyclic loading, and as these values reach a critical value, crack initiation is predicted. Additionally, in situ loading is used to identify the strain evolution in these materials through high-energy x-ray diffraction (HEDM) and digital image correlation. For experimental validation, these in situ HEDM techniques are directly compared to simulated mirror replicates of the experiments, representing the exact same microstructure, in order to measure the point-by-point evolution of material damage over time and compare directly to the simulation results. The fatigue modeling framework is combined with uncertainty quantification and propagation efforts of the model's readiness level, in order to build trust in the predictive capabilities of the model. With the time remaining, other examples of coupling microstructure-sensitive modeling and in situ experiments are discussed, in the context of understanding plasticity and failure.

Bio

Michael D. Sangid received his B.S. (2002) and M.S. (2005) in Mechanical Engineering from the University of Illinois at Urbana-Champaign (UIUC). After his Master's degree, Dr. Sangid spent two years working in Indianapolis, IN for Rolls-Royce Corporation, specializing in material characterization, fatigue, fracture, and creep of high temperature aerospace materials before resuming his education in 2007. He received his PhD in Mechanical Engineering from UIUC in 2010 and continued as a post-doctoral associate. In the spring of 2012, Dr. Sangid started as an assistant professor at Purdue University in the School of Aeronautics and Astronautics with a courtesy appointment in Materials Engineering, where he continues his work on building computational materials models for failure of structural materials with experimental validation efforts focused at characterization of the stress/strain evolution at the microstructural scale during in situ loading. He is a recipient of the TMS Young Leaders Award, the ASME Orr Award, TMS Early Career Faculty Fellow, the NSF CAREER Award, and the AFOSR, ONR, and DARPA Young Investigator/Faculty Awards.

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