CCMD Success Story

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Extreme Value Microstructure Sensitive Probabilities of Fatigue in Ni-base Superalloys and Ti Alloys for Gas Turbine Aero-Engines

As fatigue is of prime concern in rotating components in gas turbine engines for jet propulsion, the Air Force Research Laboratory (AFRL) has spent considerable resources to better understand the mechanisms of fatigue and how material variability on the microscale (i.e., scale of the dominate microstructure attributes at which the mechanisms of fatigue crack formation operate) influences the overall variability in fatigue response. To better understand how typical processing variations in the material structure influence the overall scatter in fatigue response, the AFRL partnered with the NSF I/UCRC Center for Computational Materials Design (CCMD).

To quantify how various coupled material attributes such as phases, inclusions, and grains are associated with the formation of fatigue cracks, the CCMD proposed and demonstrated new extreme value-marked correlation functions. Specifically, this special class of correlation functions can be employed to quantify the probabilities of various material attributes existing coincident at the fatigue “hot spots”, locations in the material predicted to form fatigue cracks. Multiple statistically representative material volumes were instantiated and simulated using microstructure-sensitive crystal plasticity simulations to predict the influence of texture on the driving forces for fatigue crack formation which were estimated using certain fatigue indicator parameters including maximum cyclic plastic shear strain.

This novel computational simulation approach gave great insight into the influence that coupled microstructure attributes have on fatigue variability. Moreover, it was demonstrated that simulations could provide an understanding in areas not easily amenable to experimentation. In this case hundreds of simulated material volumes were analyzed computationally at a fraction of the cost that it would have taken to perform a similar analysis experimentally. Existing experimental data was utilized for validating the simulation results. Upon completion of the project, the doctoral student at the CCMD who completed the work was hired by the AFRL and he continues to work similar problems for ceramic matrix composites.

The figure below shows a practical application of the materials modeling algorithm to simulate multiple statistically representative material volumes in gas turbine jet engine components.
Simulate Multiple Statistically Representative Material Volumes

Estimate Extreme Value Distribution of Fatigue Indicator Parameters

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