Statistically equivalent representative volume elements and multiscale modeling of Ni-based superalloys

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Most of metallic polycrystals have complex microstructures that govern certain behaviors of materials in different environmental and loading conditions. These complexities include distribution of grain and precipitate size, orientation of grains, and grain boundary character distribution. Deformation of Ni-based superalloys under cyclic loading results in accumulation of fatigue damage, which depends on microstructure and deformation modes. It has experimentally been shown that Ni-based superalloys microstructure comprises of elevated number of twins that play important roles in behavior of materials under cyclic loading. Thus, to develop models that can capture the mechanical response of such materials under fatigue loading, it is important to create synthetic microstructures that consist of such microstructural features. Using 2D/3D EBSD data and with the aid of statistical information of parent grain and twin distributions we create microstructure-based statistically equivalent representative volume elements (M-SERVEs). Then, by changing the size of so-called M-SERVE we compare the statistics of the SERVEs and EBSD data and study the convergence of the statistics of M-SERVEs. Finally, the M-SERVEs will be used to calibrate properties/parameters of a homogenized, activation energy-based crystal plasticity (AE-CP) model developed for modeling of mechanical response of Ni-based superalloys. The calibration of property/parameter-based statistically equivalent representative volume elements (P-SERVEs) using the experimental data along with the convergence study will result in finding the minimum size of P-SERVE required for simulation of polycrystalline aggregates. The final goal of this research is to come up with realistic criteria for fatigue crack nucleation from this model.