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Reduced-order microstructure-sensitive protocols to rank-order the transition fatigue resistance of polycrystalline microstructures

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Abstract

The transition fatigue regime between low cycle fatigue (LCF) and high cycle fatigue (HCF) is often addressed in the design and performance evaluation of load-bearing components used in many structural applications. Transition fatigue is characterized by elevated levels of local inelastic deformation in significant regions of the microstructure as compared to HCF. Typically, crystal plasticity finite element method (CPFEM) simulations are performed to model this phenomenon and to rank-order microstructures by their resistance to crack formation and early growth in the regime of transition fatigue. Unfortunately, these approaches require significant computational resources, inhibiting their use to explore novel materials for transition fatigue resistance. Reduced-order, microstructure-sensitive models are needed to accelerate the search for next-generation, fatigue-resistant materials. In a recent study, Paulson et al. [1] extended the materials knowledge system (MKS) framework for rank-ordering the HCF resistance of polycrystalline microstructures. The efficacy of this approach lies in the reduced-dimensional representation of microstructures through 2-point spatial correlations and principal component analysis (PCA), in addition to the characterization of the HCF response with a small set of performance measures. In this work, these same protocols are critically evaluated for their applicability to rank-order the transition fatigue resistance of the same class of polycrystalline microstructures subjected to increased strain amplitudes. Success in this endeavor requires the formation of homogenization linkages that account for the significantly higher levels of local inelastic deformation and stress redistribution in transition fatigue as compared to HCF. A set of 12 α-titanium microstructures generated using the open access DREAM.3D software [2] are employed for this evaluation.

Keywords: 2-point correlations, extreme value statistics, structure-property relationship, crystal plasticity, fatigue

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