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COUPLING CRYSTAL PLASTICITY WITH STRUCTURAL MECHANICS FOR PREDICTION OF THERMO-MECHANICAL RESPONSE IN LARGE SCALE STRUCTURES

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In this work, we propose a reduced order multiscale computational approach to predict the response of large scale structures made of polycrystalline materials, in which the material microstructure (i.e., the scale of the representative volume) and all relevant microstructural response mechanisms are directly embedded and fully coupled with a structural analysis. The formulation is based on the eigenstrain-based reduced order crystal plasticity method (EHM) [1-3]. EHM achieves a reduced order representation of the microscale problem in a two-scale problem setting through the ideas of (1) precomputing microstructural information (e.g. localization and concentration tensors) by evaluating linear elastic microscale problems and considering piece-wise constant inelastic response within partitions (e.g., grains) of the microstructure; and (2) evaluating the reduced order nonlinear system of equations using sparse and scalable solver algorithms.

This approach has been employed to study the thermo-mechanical response of an aircraft structural panel subjected to dynamic loads and environment associated with supersonic flight. The panel is made of a high temperature titanium alloy (Ti-6242S). At the scale of the microstructure, a dislocation density based crystal plasticity model is adopted to capture the temperature and rate dependent viscoplastic flow in Ti-6242S. While the variation of the viscoplastic slip evolution as a function of temperature is directly considered in the constitutive equation, the dependency of coefficient tensors on temperature is accounted for through interpolation from a series of chosen base temperatures to maintain the computational efficiency. The model is fully verified with direct crystal plasticity finite element (CPFE) simulation and further calibrated using uniaxial tension tests of Ti-4242S at various temperatures and strain rates. The effect of temperature and fluctuations in the load on the response are thoroughly studied. The proposed multiscale approach is demonstrated to be effective in thermo-mechanical analysis of realistic structural components while keeping track of local response, which opens the doors for microstructure-informed damage prognosis at structural scale.

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