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COUPLED CRYSTAL PLASTICITY PHASE-FIELD MODEL FOR DUCTILE FRACTURE IN POLYCRYSTALLINE MICROSTRUCTURES

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Abstract
A wavelet-enriched adaptive hierarchical, coupled crystal plasticity - phase-field finite element model is developed in this work to simulate crack propagation in complex polycrystalline microstructures. The model accommodates initial material anisotropy and crack tension-compression asymmetry through orthogonal decomposition of stored elastic strain energy into tensile and compressive counterparts. The crack evolution is driven by stored elastic and defect energies, resulting from slip and hardening of crystallographic slips systems. A FE model is used to simulate the fracture process in a statistically equivalent representative volume element reconstructed from electron backscattered diffraction scans of experimental microstructures. Multiple numerical simulations with the model exhibits microstructurally sensitive crack propagation characteristics.

1. Introduction
Crack propagation in polycrystalline microstructures include both intergranular cracks along grain boundaries and transgranular cracks that are characterized by crack propagating across grains with different crystal orientations. Preferred crack orientations within grains can follow crystallographic cleavage planes. Crack propagation in polycrystalline microstructures is inherently anisotropic and poses challenges from modeling perspective. In the last two decades, phase-field modeling of fracture in brittle and ductile materials has received considerable attention in the fracture modeling community, due to its ability to predict arbitrary crack propagation in 3D and its compliance with classical fracture mechanics. However, much of the work in literature has focused on modeling ductile fracture in homogeneous media at macroscopic length scales. It is of greater importance to predict the crack propagation paths and rates at microstructural level as significant fraction of lifetime of an engineering component is spent in short crack growths. A coupled crystal plasticity phase-field (CP-PF) model is developed in this work for transgranular crack propagation in polycrystalline microstructures of titanium (Ti) alloys. The deformation behavior is modeled using rate-dependent crystal plasticity constitutive relation while the crack evolution is governed by phase-field order parameter.

2. Results
Crack propagation studies are conducted for polycrystalline microstructures which reveal crystallographic crack growth. A polycrystalline microstructure consisting of 41 grains is subjected to monotonic tension loading in-plane and the crack path is shown in Fig. 1.

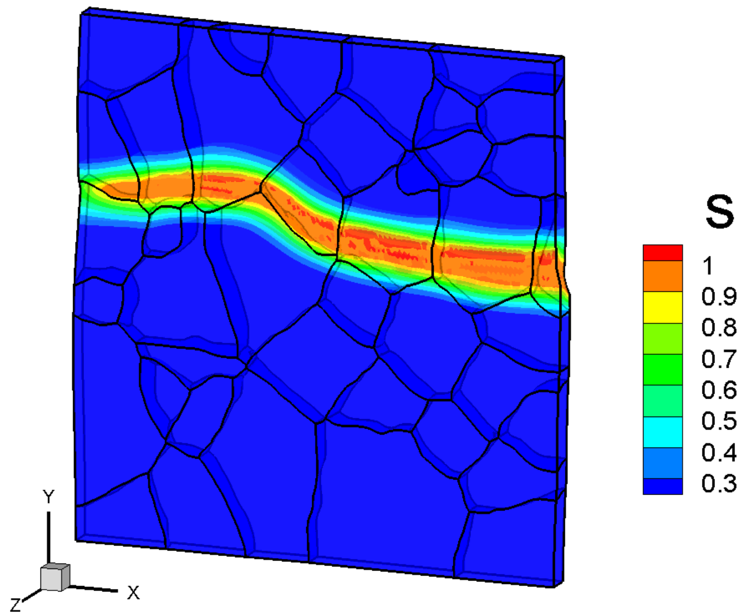

Fig.1 – Crack path characterized by kinking in a polycrystalline microstructure subjected to tension in +Y direction.

3. Conclusions

A coupled finite deformation crystal plasticity phase-field FE model is developed in this work and simulations capture crystallographic crack growth paths consistent with experimental observations.

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