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MICROSTRUCTURE-SENSITIVE MODELING OF MAGNESIUM ALLOYS UNDER FATIGUE CONDITIONS

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Scattering of fatigue life in ductile crystalline materials is mainly related to the heterogeneity of strain localization at the grain scale which is highly dependent on microstructural and crystallographic features. Because of its hexagonal close-packed (hcp) structure, magnesium (Mg) alloys sheets exhibit a significant anisotropic mechanical response. Under cyclic conditions, this peculiar behavior is manifested by a tension/compression asymmetry due to the presence of twinning/detwinning as an additional plastic deformation mechanism. It was recently shown that twinning deformation plays a major role in the localization of cyclic plastic deformation and therefore on the initiation of fatigue crack [1]. Numerical studies have mainly focused on the modeling of the mechanical behavior of Mg alloys using crystal plasticity model and mean-field schemes [2]. While they manage to reproduce the macroscopic behavior of the material, these studies fail to capture the heterogeneous localization of strain within individual grains. Hence, the purpose of this work is to numerically investigate the role of twinning/de-twinning on the localization of plastic deformation in AZ31 Mg alloys under fatigue conditions using crystal plasticity finite element (CPFE) simulations.
A size-independent phenomenological crystal plasticity model including twinning/detwinning and subsequent slip in twinned region is presented. It is implemented in the DAMASK toolbox for Abaqus [3]. The model assumes that twinning is crystallographic and follows a Schmid type law and that slip in twinned region only occurs in the most active twin system. The model is first validated against plane strain compression of pure Mg single crystals and then calibrated against low-cycle fatigue experiments of rolled AZ31 Mg alloys. Two-dimensional polycrystals are generated based on a developed anisotropic tessellation [4] and microstructural data obtained from EBSD analysis. They are loaded under cyclic conditions and critical plane fatigue indicator parameters (FIP) are evaluated to target the influence of microstructural attributes on fatigue crack formation. The results suggest that the role of twinning in plastic strain localization and therefore damage initiation has a significant importance.

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