Stochastic modeling of fatigue crack propagation by collective motion of dislocations

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Abstract

This paper presents a stochastic dislocation model of fatigue crack propagation in ductile alloys under variable-amplitude load. The model is built through collective motion of a large number of dislocations. Four basic dislocation mechanisms, the generation, gliding, annihilation and pinning of dislocations are accounted for through a series of constitutive rules and incorporated into this model. Model predictions are in agreement with leading fracture mechanics-based models and experimental data under both constant-amplitude and variable-amplitude loads. The load extrusion effect caused by overloads is explained using a push-off mechanism of pinned dislocations. The randomness of fatigue crack growth is also addressed in this paper by investigating the evolution of dislocation distribution in the grain at the crack tip of a specimen. Since it has been experimentally established that dislocations play a vital role in fatigue, the physics and micro mechanisms of fatigue crack growth can be better understood by such a stochastic dislocation model as presented in this paper. Dislocation model simulations in literature so far have been able to predict few fatigue trends but are not sufficiently accurate to be used in engineering, where fracture mechanics-based (bulk) models are deemed more reliable.