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ABSTRACT

A probabilistic finite element model is implemented to estimate microstructurally small fatigue crack growth in bridge steel welds. Simulations are based on a microstructure-sensitive crystal plasticity model to quantify fatigue indicator parameters (FIPs) at the slip system level and a fatigue model that relates FIPs to fatigue lives of individual grains. Microstructures from three weld zones, namely, fusion zone (FZ), heat affected zone (HAZ), and base metal (BM), are constructed based on their microstructural attributes such as grain morphology, size, and orientation. Statistical volume elements (SVEs) are generated and meshed independently for the three welding zones. Each grain within the SVEs is divided into several slip bands parallel to crystallographic planes. During the loading process, cracks nucleate at the slip bands (SBs) with the largest FIP next to the free surface. The crack extension path is assumed to be transgranular along SBs and the number of cycles required to crack the neighbor grain is calculated by the corresponding FIP-based crack growth rate equation. The simulation process is carried out using ABAQUS with a user defined subroutine UMAT for crystal plasticity. After the calibration of the constitutive model and irreversibility parameters, numerical simulations for small crack growth in three zones are presented. The crack length vs. the predicted fatigue resistance shows significant differences in the mean values and variability among the three weld zones.

Keywords: high cycle fatigue (HCF); small fatigue crack; probabilistic; microstructure; crystal plasticity

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