Nonuniqueness of the Fatigue Threshold

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PII: S0142-1123(17)30327-4
DOI: http://dx.doi.org/10.1016/j.ijfatigue.2017.07.027
Reference: JIJF 4423

To appear in: *International Journal of Fatigue*

Received Date: 10 May 2017
Revised Date: 23 July 2017
Accepted Date: 25 July 2017

Please cite this article as: Alkan, S., Sehitoglu, H., Nonuniqueness of the Fatigue Threshold, *International Journal of Fatigue* (2017), doi: http://dx.doi.org/10.1016/j.ijfatigue.2017.07.027

Submitted to International Journal of Fatigue 2017

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Abstract

The fatigue crack growth prediction near the threshold regime remains one of the most challenging fields in fatigue research. In previous studies, the threshold effects have been incorporated into fatigue crack growth models upon modification of the Paris Law in an empirical fashion. In this work, without a-priori assumptions and empirical constants, we derived the threshold levels with a combination of molecular dynamics and continuum calculations. We illustrate that the threshold value is non-unique and depends on the state of the microstructure surrounding the crack. Also, in reality, we envisage very low fatigue crack growth rates near the 'threshold' and not a cut-off value, which is consistent with experimental trends. In the model, the microstructure is characterized by grain boundary types, grain size, and initial dislocation density. We derive friction stresses for forward and reverse motion of crack tip dislocations interacting with grain boundaries which allow determination of irreversible crack tip displacements. We illustrate the benefits of sigma-3 grain boundaries, finer grain sizes and shielding dislocations at the crack tip on improving the near-threshold fatigue crack growth behavior.

1 Introduction

1.1 Microstructure sensitive crack growth regime

Most structures undergo low crack growth rates and operate at stress intensity levels well below that are characterized by the Paris law. Commercial codes have deficiencies when trying to predict the FCG in the near threshold. It has been shown that near the threshold regime the growth rate exhibits substantial variability and a unique value of threshold stress intensity can not be defined. The fatigue crack growth curves are segmented and are affected by the material microstructure. There is a strong need for incorporating the near threshold fatigue crack growth behavior in a model for estimation of fatigue life or correctly deciding the inspection intervals within a damage tolerance approach methodology. Unless there is a description that encompasses the threshold region, the predictive capabilities have significant