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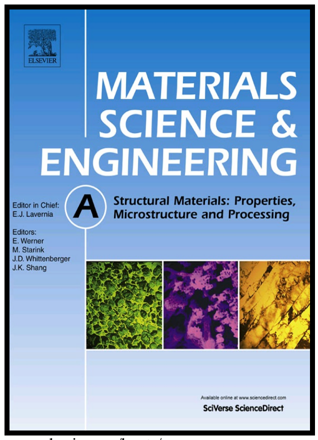

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Relating fracture mechanics and fatigue lifetime prediction

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Abstract: This article presents how to link together the results of fatigue crack growth tests, analytic fracture mechanics and experimental methods of fatigue lifetime predictions. The study at the beginning investigates the effect of mechanical load redistribution among failed and intact micro-structural bonds along fatigue crack growth to final crack at vulnerable locations in materials and structures under cyclic loads. The microstructural load redistribution model is analytically formulated as a mechanical interaction between fatigue crack growth and fatigue endurance on the macroscopic level. The article in continuation investigates how to link the parameters of fatigue crack growth in fracture mechanics to parameters of fatigue life directly from the work done on crack growth determined by testing. The article at the end illustrates the application of the analytic procedure for fatigue lifetime prediction that combines fracture mechanics and the load redistribution model for determination of S-N curve parameters important in structural analysis and design. In this research the fatigue life time parameters are derived from a single fatigue crack growth experiment instead from normally required sets of fatigue tests for different loading conditions.

Keywords: fatigue; fracture mechanics; crack growth; interaction; fatigue life; S-N curves;

1. Introduction

The aim of this work is to evaluate and verify fatigue characteristics of materials and structures under cyclic loads common to analytic fracture mechanics and experimental fatigue lifetime predictions straightforwardly from precisely recorded Fatigue Crack Growth (FCG) curves. The article keep hold of the characteristics of FCG and FCG rates as defined in fracture mechanics [1–3] by using Stress Intensity Factors (SIF) determined through investigation of stress fields in materials at the end of the crack [4-5]. Fatigue parameters in fracture mechanics in general can be determined analytically, by testing on carefully prepared test specimen [6–7] or computationally by using complex numerical models and finite element stress analysis [8-10]. The investigations in this article of practical analytical procedures in which fatigue parameters can be evaluated directly from FCG curves are encouraged through the reported improvements in precision of fatigue crack size measurements [11–12]. The article at the beginning presents the mechanical load redistribution model along the crack to its end on a lattice of microstructural particles in crystalline materials following the concept of crack growth kinetics [13]. The study reveals the empirical concept of Cause-and-Effect-Interaction (CEI) [14-17] for mathematical formulation of Fatigue crack growth and Endurance Interaction (FEI) induced by overstressing due to load redistribution under cyclic loads. The mechanical interaction model of load redistribution replaces in the article the commonly used numerical methods for fitting of crack growth and crack growth rate [18]. Lasting efforts and numerous experiments have been devoted since earlier [19] to investigation of fatigue life prediction methods [20] and of safer criteria for the prediction of fatigue failures [21].

It is recognized earlier in the energy-based approach how the local strain energy density can be taken as a consistent fatigue damage parameter [22- 26]. The strain energy-based life prediction criterion can be extended to include the effects of both mean stress and ratcheting [27]. Moreover, the Neuber's rule can be interpreted in terms of the total