Title:

On the Fatigue Behavior of Bifurcated Cracks Under Near-Threshold Conditions

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Abstract:

Fatigue crack bifurcation is a mechanism that can quantitatively explain retardation effects even when plasticity induced crack closure is not observed [1-2]. Analytical solutions have been obtained for the reduction in the SIF of some bifurcated cracks, however numerical methods [3] are the only means to predict the subsequent curved propagation behavior. Empirical equations have been proposed by the authors [4] to calculate the process zone size and SIF along the curved crack branches, based on extensive FE calculations on a CT specimen. The equations are a function of the bifurcation angle 2θ, ratio between the branch sizes c_0/b_0, and material crack growth exponent m. The equations can also include the interaction with other retardation mechanisms through the use of the limiting value K_{max}* of the Unified Approach [5], see Fig.1. In this work, the increase in fatigue life associated with bifurcated cracks under near-threshold conditions is studied. The equations presented in [4] are re-evaluated for other specimen geometries using a specially developed FE program, validated from 4340 steel ESE(T) specimens. This program calculates the path and associated SIF along the bifurcated crack path. The Levenberg-Marquardt algorithm is used to best fit non-linear equations to the FE results. The number of delay cycles is then obtained from the integration of the fitted equations, explicitly considering the effects of K_{max}*. The results show a competition between the effects of bifurcation and other retardation mechanisms under near-threshold conditions. Even though a higher K_{max}* level would lead to a slower crack growth rate, the smaller SIF range can lead to a premature arrest of the shorter branch, resulting in a smaller bifurcation process zone. The presented fatigue life calculation methodology can be used to predict the propagation behavior of bifurcated cracks in an arbitrary structure.

Keywords: Crack retardation model, Bifurcated cracks, Finite elements, Life prediction

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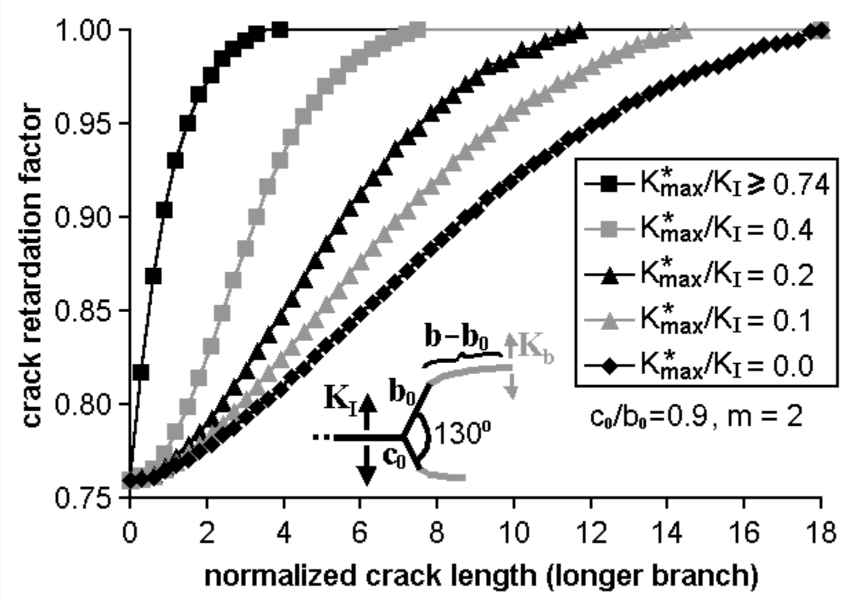

Figure 1. Normalized SIF of the longer branch during its propagation as a function of the normalized length $(b-b_0)/b_0$ for several K_{max}* levels ($c_0/b_0 = 0.9$, $m = 2$).