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Comparison of fatigue crack growth stress ratio effects under simple variable amplitude loading using fractographic and strain measurements

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Abstract

Crack closure, the contact between opposing crack faces above zero load, has traditionally been used to explain the observation that higher stress ratio fatigue cycles have faster growth rates than lower stress ratio cycles. Using new techniques to investigate the dependance of stress ratio on crack closure, we tested simplified variable amplitude loading sequences containing segments of 100 cycles at different stress ratios in AA7050-T7451 alloy. We compared the crack growth at different stress ratios at the start of a coupon with no closure and after 5 mm or more of crack growth where significant closure had developed as inidicated by side and back-face strain gauges mounted on the coupon. Fractographic measurements of the fatigue growth from these sequences show the same stress ratio effect at the start of loading and after 5 mm of growth, suggesting that the stress ratio effect occurs soon after the commencement of growth and that crack closure is not the dominant cause of the stress ratio effect in the AA7050-T7451 alloy. Results from these tests using constant and varying maximum stress intensity $K_{\max}$ also showed significantly different stress ratio effects. Traditional constant amplitude load tests over-predict the rate of crack growth for cycles in which the maximum load is varying. Obtaining crack growth rates for a range of different stress ratios from variable amplitude testing in this way can allow greater accuracy to be achieved in predicting the rate of crack growth for arbitrary variable amplitude loading sequences.

1. Introduction

The variation in the rate of fatigue crack growth as a function of the stress ratio $R = S_{\min}/S_{\max}$, where the maximum and minimum stress in a cycle is $S_{\max}$ and $S_{\min}$, was explained by Elber [1] as being partly due to *crack closure*, the premature contact occurring between mating fracture surfaces. From this observation he was able to propose a modification to the Paris-Erdogen equation [2] for the rate of crack growth to allow for the crack being closed below a threshold stress level known as the crack opening stress S_{op}, resulting in a reduction of the stress intensity range ΔK also known as the crack driving force, to produce an effective

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