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Abstract

To understand the effect of temperature on the rate of fatigue crack growth in D16T and B95AT aluminum alloys, fatigue crack growth experiments using a constant load amplitude were carried out on hollow cylindrical specimens with induced external semi-elliptical surface cracks. The rates of fatigue crack growth in the specimens were determined as a function of temperature, ranging from low (-60 °C) to elevated (+250 °C), and were analyzed as a function of the elastic and plastic stress intensity factors (SIF). The process of numerical calculations includes the analysis of the elastic constraint parameters in the form of the non-singular *T*-stress and T_Z –factor, as well as the elastic-plastic constraint parameters in the form of the local stress triaxiality *h* and *In*-factors for the various tested materials at the different tested temperatures. The interpretation of the fatigue crack growth data in terms of the plastic SIFs results in a single general curve with a small scatter band over a wide range of temperatures.

Keywords

Surface crack; Aluminum alloys; Tension fatigue loading; Different temperatures; Crack growth; Fatigue fracture diagram; Plastic SIF.

Introduction

The resistance of materials to fatigue surface crack growth over a wide range of temperatures needs to be considered for many engineering applications, such as the design of aircraft structures, power engineering elements, pressure vessels, and piping. Often, partial-depth flaws or defects appear on the free surface of cylindrical components and are referred to as semielliptical cracks. The fatigue growth analysis of these semielliptical surface cracks under different temperature conditions is very important for accurate structural integrity prediction and determination of the residual fatigue life of components.

Some prior research provides detailed plastic limit load solutions for cylinders containing partial-depth external and internal surface cracks under combined axial tension, internal pressure, and global bending [1]. Numerical analyses were performed to calculate the changes in aspect ratio for different geometrical parameters of both cylinders and surface flaws [2]. In cylindrical specimens, fatigue failure often develops from surface flaws, and as a result, several analyses have been conducted to determine the stress intensity factors at the leading edge of a crack, upon which crack growth rate studies have then been based [3-7].

The sensitivity of aluminum alloys to environmental changes was first explored in the mid-1970s. At that time, some researchers reported a significant reduction in the toughness and crack growth rate of several 7000 series aluminum sheet materials at low temperatures [8-10]. Other researchers [11] reported that the relationship between temperature dependence and both fatigue crack formation and microstructure-scale growth in the constituent particles of 7075-T651 and 7050-T651 materials can be quantified using load-induced fracture surface marker bands.

The Paris law constants and threshold stress intensity range (ΔKth) were measured for S460 and S980 structural grade base plate materials at both room temperature and -70 °C. These results support the conclusions found in the literature that the fatigue crack growth rate decreases with decreasing temperatures until it reaches the fatigue ductile-to-brittle transition (FDBT), at which point it begins increasing [12].