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Creep–fatigue crack growth behaviour of a nickel-based powder metallurgy superalloy under high temperature

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ABSTRACT

Creep–fatigue crack growth behaviour of a nickel-based powder metallurgy superalloy has been investigated. Experiments were conducted at 750 °C with various dwell times. Results show that dwell time induced creep damage is significant by transforming a transgranular dominating cracking mode into a completely intergranular one. The observed dependence of crack growth rate on the dwell time and ΔK is complex indicating that the interaction between creep and fatigue is significant. Therefore, a factor reflecting the degree of the interaction was proposed to help modelling the creep–fatigue crack growth rates. The results are encouraging.

1. Introduction

Components operating at high temperature (e.g. aero turbine engines) are often subjected to cyclic loads with dwell time at the maximum load that can exacerbate fatigue crack growth through creep damage. Fracture mechanics method, as an effective tool for failure analysis of these components, has been widely investigated [1,2]. It therefore creates the opportunity for a clear understanding of the material creep–fatigue crack growth behaviour as well as quantitatively describing the crack growth rate.

In recent years, considerable studies have revealed that the creep–fatigue crack growth behaviour varies considerably with changes in some intrinsic or extrinsic variables, such as the material microstructure [3,4], temperature [5] and dwell time [6–8]. In particular, it is shown that the presence of a dwell time at peak stress may affect the crack growth behaviour in different ways, e.g. increased crack growth rate was found by Lu et al. [9], whereas unchanged crack growth rates [10], or even decreased growth rates [11] were also observed. For the case of increased growth rate, various observations have been reported. For a superalloy close to IN100, a linear increase of the crack growth rates with increasing dwell time was found by Wei and Huang [12]. For 2650 aluminium alloy, Henaff et al. [13] observed a critical value of load period as a function of temperature. Above this critical value, crack growth rate is proportional to the loading period, while below this value, crack growth rate is completely independent of the loading period. It can be seen that the relationship between the crack growth behaviour and the dwell time depends on the material properties of different alloys.

As for the quantitative description of creep–fatigue crack growth rate, several models have been developed. Tong et al. [6] and Mcgowan and Liu [14] proposed single term models, in which creep damage is taken into account by modifying the coefficient of the basic fatigue model. Other researchers [15,16] have used an alternative approach. They assumed that creep–fatigue behaviour is governed by competing mechanisms of creep and fatigue crack growth, and whichever gives a higher

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