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Estimation of thermo-mechanical fatigue crack growth using an accumulative approach based on isothermal test data

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Abstract

A procedure to estimate thermo-mechanical fatigue crack growth (TMFCG) rates in a coarse grain nickel-based cast alloy is presented. The implemented model relies on the linear accumulation of temperature dependent and independent crack growth contributions. Isothermal fatigue and creep crack growth experiments were performed to generate the model data base. To quantify oxidation damage, the formation of subsurface γ'-depletion was measured. For validation, TMFCG experiments on corner-crack specimen were conducted. The model gives reasonable estimations for the crack growth of an initial defect. Furthermore it allows the assessment of the causes of the crack growth and associate them to crack propagation characteristics observed from the crack path.

Keywords

thermo-mechanical fatigue; crack growth; nickel cast alloys; superalloys; linear accumulation model

1 Introduction

The determination and calculation of crack growth under thermo-mechanical fatigue (TMF) loading is a complex task. Multiple simultaneously active damage mechanisms must be considered and their contribution to the overall crack behaviour changes dramatically if parameters such as phase shift or temperature range are altered. Although there are international standards for fatigue CG testing [1,2] and for fatigue life testing under TMF conditions [3,4] the combination of both is not yet standardized. In the evaluation, an over- but also a substantial underestimation of the residual service life of flawed structures must be avoided. Nevertheless, manufacturers of heavy duty gas turbines are required to account for TMFCG when manufacturing turbine blades and vanes from nickel cast alloys. Amongst others, a fracture mechanics evaluation of the material is necessary to support material selection, define component assessment criteria, support the safe-life design of a new component, define repair criteria and manage non-conformities of new and ex-service components.

A common engineering approach to model crack growth in high temperature service conditions is the linear accumulation method. Nicholas et. al. used this method to describe TMFCG in wrought nickel-based alloys [5]. Another approach for the description of crack growth in wrought nickel component applications is given by Affelt et. al. [6]. In [7], the linear-accumulative crack growth model O.C.F. (O -

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