Data rich imaging approaches assessing fatigue crack growth mechanisms in a Ni base superalloy with varying γ' size

Donghyuk Kim(Dk2g17@soton.ac.uk)[1], Rong Jiang[2], Angelos Evangelou[1]
Philippa A.S Reed[1]
[1]University of Southampton, UK, [2] Nanjing University of Aeronautics and Astronautics, China

Abstract
Nickel base superalloys are used in turbine disc applications because of their excellent high temperature strength, oxidation resistance and damage tolerance. In service they experience high temperatures and cyclic loading stresses and their fatigue life is controlled by early stages of crack initiation and growth. The effect of varying γ' size on crack initiation and growth in Nickel based superalloys is often linked to variation in slip character as this affects the accumulation of damage which in turn affects initiation and growth processes. Temperature and environment also affect slip character as well as creep and oxidation, and slip character affects transport of oxygen to the crack tip. Thus the combined effects of temperature, environment and slip character (linked to γ' size) control overall fatigue life through varying effects on initiation processes and crack growth mechanisms.
In this work a non-commercial heat treatment has been used in RR1000 alloy to produce two different unimodal γ' size distributions. Fatigue tests have been conducted on polished plain bend bar, single edge notched bend and micro-tensile samples at test temperatures of 20oC and 725oC at frequencies of 20Hz and 0.25Hz. The fine γ′ variant had a slightly longer fatigue life linked to slower Stage I crack propagation linked to more planar slip at 20oC. Cracks initiated at pores or slip bands at 20oC, but shifted to oxidised grain boundaries at 725oC. A clarification of the effect of γ′ size on slip character and hence on crack initiation and growth at low and high temperatures is made by the combination of 3D X-ray computed tomography and traditional 2D observations, together with surface strain localization analysis. This provides a deeper understanding of the mechanisms of fatigue crack initiation and propagation behaviour in this model turbine disc alloy under a range of service relevant applications.

Keywords: *Turbine disc application, Ni based superalloys, short fatigue crack growth, microstructural effects, slip characters, X-ray CT scan*

References

[1] [1] H.T. Pang, P.A.S. Reed, Effects of microstructure on room temperature fatigue crack initiation and short crack propagation in Udimet 720Li Ni-base superalloy, Int. J. Fatigue. 30 (2008) 2009–2020 [2] R. Jiang, N. Karpasitis, N. Gao, P.A.S. Reed, Effects of microstructures on fatigue crack initiation and short crack propagation at room temperature in an advanced disc superalloy, Mater. Sci. Eng. A. 641 (2015) 148–159. [3] R. Jiang, D.J.Bull, A. Evangelou, A. Harte, F. Pierron, I. Sinclair, M. Preuss, X.T. Hu, P.A.S. Reed, Strain accumulation and fatigue crack initiation at pores and carbides in a SX superalloy at room temperature, Int J Fat. A. 114 (2018) 22-33.

Biography

Material engineering, PhD at University of Southampton, UK (24-09-2017 ~ Ongoing)
Mechanical engineering and design, MSc at University of Manchester, UK (24-09-2016 ~ 04-09-2017)
Mechanical engineering, Bachelor's degree at Korea Aerospace University, South Korea