DWELL FATIGUE IN TITANIUM ALLOYS: AN ASSESSMENT OF RATE SENSITIVITY, TEMPERATURE, MORPHOLOGY AND STRESS STATE

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Abstract

It is well known that alloy Ti-6242 shows a significant reduction in fatigue life, termed dwell debit, if a stress dwell is included in the fatigue cycle whereas Ti-6246 does not; the mechanistic explanation for these differing dwell debits in these alloys has remained elusive. It has been argued that thermal activation for the escape of pinned dislocations [1] is the driver for the remarkable rate sensitivity displayed by Ti alloys even at low (<20^{o}C) temperature, and crucial to dwell fatigue. Other important factors remain crystallographic orientation of rogue grain pairs, alpha-beta morphology, the intrinsic rate sensitivities of the alpha and beta phases [2], temperature [3], and the stress state.

This paper presents an assessment of the key drivers for dwell fatigue crack nucleation utilizing recent crystal plasticity and new rate-sensitive discrete dislocation plasticity modelling integrated where possible with micromechanical pillar testing and characterization. It is shown that the intrinsic material rate sensitivity, and how it manifests itself over regimes of strain rate and temperature, is the key to mechanistic understanding and provides the explanation for the temperature sensitivity in dwell, its stress state dependence, and why Ti-6242 shows a strong dwell debit whereas Ti-6246 does not. Morphological alpha-beta effects are considered and shown to be second order in dwell and the primary driver to remain the crucial alpha-phase soft-hard grain orientation combination and the resulting load shedding. It is argued that the key physical phenomenon controlling all of the above behavior is the time constant associated with the thermal activation of dislocation escape with respect to that for the loading regime.

1. Zheng, Z, Balint, D, Dunne, FPE. Rate sensitivity in discrete dislocation plasticity in HCP crystals. Acta Materialia. 107, 17-26, 2016.

2. Jun, TS, Zhang, Z, Sernicola, G, Dunne, FPE, Britton, TB. Local strain rate sensitivity of single α phase within a dual-phase Ti alloy. Acta Materialia, 107, 298-309, 2016.

3. Zhang, Z, Cuddihy, M, Dunne, FPE. On rate-dependent polycrystal deformation: the temperature sensitivity of cold dwell fatigue. Proc. R. Soc. A, Vol 471, Issue 2181, 2015.