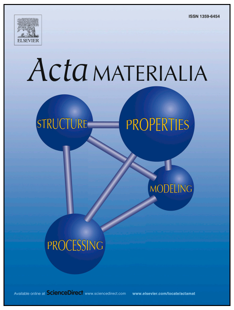

Microstructural effects on strain rate and dwell sensitivity in dual-phase titanium alloys

Sana Waheed, Zebang Zheng, Daniel S. Balint, Fionn P.E. Dunne

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Microstructural effects on strain rate and dwell sensitivity in dual-phase titanium alloys

Sana Waheed[a], Zebang Zheng[b], Daniel S. Balint[a], Fionn P. E. Dunne[a,b,*]

[a] *Department of Mechanical Engineering, Imperial College London, London SW7 2AZ, UK*
[b] *Department of Materials, Imperial College London, London SW7 2AZ, UK*

Abstract

In this study, stress relaxation tests are performed to determine and compare the strain rate sensitivity of different $\alpha - \beta$ titanium alloy microstructures using discrete dislocation plasticity (DDP) and crystal plasticity finite element (CPFE) simulations. The anisotropic α and β phase properties of alloy Ti-6242 are explicitly included in both the thermally-activated DDP and CPFE models together with direct dislocation penetration across material-interfaces in the DDP model. Equiaxed pure α, colony, Widmanstatten and basketweave microstructures are simulated together with an analysis of the effect of α grain size and dislocation penetration on rate sensitivity. It is demonstrated that alloy morphology and texture significantly influence microstructural material rate sensitivity in agreement with experimental evidence in the literature, whereas dislocation penetration is found not to be as significant as previously considered for small deformations. The mechanistic cause of these effects is argued to be changes in dislocation mean free-path and the total propensity for plastic slip in the specimen. Comparing DDP results with corresponding CPFE simulations, it is shown that discrete aspects of slip and hardening mechanisms have to be accounted for to capture experimentally observed rate sensitivity. Finally, the dwell sensitivity in a polycrystalline dual-phase titanium alloy specimen is shown to be strongly dependent on its microstructure.

Keywords: Dwell fatigue; discrete dislocation plasticity; morphology; texture; dislocation penetration; crystal plasticity.

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1. Introduction

Dual-phase $\alpha - \beta$ titanium alloys are widely used in the aeronautical, marine, biomedical implants and sporting goods industries due to their high specific strength, fracture toughness, weldability and corrosion resistance [1]. Nevertheless, these alloys have been shown to be susceptible to fatigue failure under load dwell conditions at ambient temperatures ($< 0.3\mathrm{T}_m$), a failure mechanism referred to as cold dwell fatigue failure. Analysis of the failure surface has shown the presence of quasi-cleavage facets occurring perpendicular to the applied principal stress direction with near basal α orientations [2–4]. Considering the anisotropy of the HCP α crystal, these observations have been partly explained using the Stroh model [5], suggesting that a dislocation pile-up at the grain boundary in a well-oriented prismatic, soft grain can lead to the build-up of a high stress state in an adjacent basal-oriented, hard grain which can cause facet nucleation [3, 6, 7]. In order to address the dwell sensitive nature of the failure mechanism, Bache et al. (1997) hypothesised that

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[*] Corresponding author.
Email address: `fionn.dunne@imperial.ac.uk` (Fionn P. E. Dunne)