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[1] F.P.E. Dunne, D. Rugg and A. Walker "Lengthscale-dependant, elastically anisotropic, physically-based hcp crystal plasticity: application to cold-dwell fatigue in Ti Alloys" in International Journal of Plasticity 23 6 (2007) [2] J. Qiu, Y. Ma, J. Lei, Y. Liu, A. Huang, D. Rugg and R. Yang "A comparative study on dwell fatigue of Ti-6Al-2Sn-4Zr-xMo (x = 2 to 6) alloys on a microstructure-normalised basis" Metallurgical and Materials Transaction A 46 13 (2014)

Understanding rate sensitivity in dual phase titanium alloys – a combined experimental and computational micro-pillar study

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Titanium alloys are used as structural load bearing components in aeroengines. In service, these alloys are subjected to significant cyclic loading, with high thrust (i.e. stress) excursions during take-off, a load-hold during flight and unloading on landing. The load-hold has been shown to have a significant effect on the fatigue life performance of many dual phase titanium alloys, where a significant hold at maximum load can reduce the number of cycles to failure by an order of magnitude or more when compared with simple 'saw-tooth' load-unload fatigue cycle. This is known as the dwell debit.

Recently, it has been demonstrated that failure is dominated by local microstructure in these alloys, including the presence of a rogue grain combination. During the load-hold, stress is shed from a 'hard' grain to a neighbour 'soft' grain and local regions of very high stress form [1]. Time dependent stress amplification at local microstructural regions during this load shedding process near the interface is thought to play a prominent role in facet formation. In practice this effect is mitigated by use of dwell insensitive alloys and careful maintenance schedules but management of this phenomena costs the aerospace industry significantly (~£100ms / year).

The motivation of this study is to understand the dwell process and in particular to characterise fundamental mechanisms within dwell sensitive Ti-6Al-2Sn-4Zr-2Mo and dwell insensitive Ti-6Al-2Sn-4Zr-6Mo alloys [2]. These alloys have complex dual phase (alpha-HCP and beta-BCC) microstructures that make interpretation of large scale experimental macro-mechanical test specimens especially complicated. We have chosen to fabricate 'simple' single colony micro-pillars (~2µm in width and ~5µm in height) containing different internal microstructures of pure-alpha phase and mixed alpha+beta phase of particular crystallographic orientations to trigger (near-) single slip in ~uniaxial deformation. These micro-pillars have been tested in an Alemnis displacement controlled nanoindentation system within the SEM. Tests have been performed with variable strain rates and load-relaxation tests to extract out rate sensitivities of the different slip systems and to understand the role of the alpha and beta phases and local interfaces. To complement and aid interpretation of these tests we have performed crystal plasticity finite element modelling (CP-FEM), with the aim of gaining physical insight into these important micro-mechanical mechanisms. We will present our combined measurements of the different rate sensitivities of these individual slip systems in these alloys.

These studies are performed within the EPSRC HexMat consortium (www.imperial.ac.uk/hexmat, EP/K034332/1) with the express aim of understanding component level performance in hexagonal alloys.

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