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Crystal Plasticity Modelling and HR-DIC Measurement of Slip Activation and Strain Localisation in Single and Oligo-crystal Ni Alloys under Fatigue

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Abstract

Single crystal (CMSX4) and oligocrystal (MAR002) nickel have been studied using three-point beam bending under conditions of cyclic loading. SEM images have enabled identification of slip activation, and high resolution digital image correlation has been utilized to quantify the developing strain fields and the strain localization in both single and oligocrystals in fatigue. The single and oligocrystal microstructures have been replicated within crystal plasticity finite element models and the fatigue loading analysed such that grain-by-grain comparisons of slip may be carried out. Single and multiple slip activation, slip localisation and microstructure-sensitive stress evolution have been examined.

Single crystal bend fatigue gives rise to non-symmetric slip fields and localisation depending on crystallographic orientation. Modelling correctly captures slip activation and the developing non-symmetric slip fields. Oligocrystal slip is markedly heterogeneous, with grain misorientations driving strong variations, also reasonably captured by the model. Microstructure behaviour is found to vary spatially and include elastic-plastic hysteresis which is stable, and which undergoes mean stress relaxation so that plastic shakedown occurs. Remarkable variations occur between locations either side of grain boundaries, providing appropriate opportunities for fatigue crack nucleation.

Keywords: Nickel alloys, single crystals, polycrystals, crystal plasticity, slip localization, fatigue