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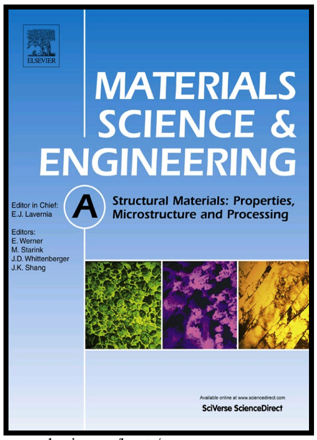

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Fatigue strain mapping via digital image correlation for Ni-based superalloys: the role of thermal activation on cube slip

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Abstract

A deformation mechanism map for a Ni-based superalloy is presented during cyclic loading at low (300 °C), intermediate (550 °C), and high (700 °C) temperatures for low (0.7%) and high (1.0%) applied strain amplitudes. Strain mapping is performed via digital image correlation (DIC) during interrupted fatigue experiments at elevated temperatures at 1, 10, 100 and 1,000 cycles, for each specified loading and temperature condition. The DIC measurements are performed in a scanning electron microscope, which allows high-resolution measurements of heterogeneous slip events and a vacuum environment to ensure stability of the speckle pattern for DIC at high temperatures. The cumulative fatigue experiments show that the slip bands are present in the first cycle and intensify with number of cycles; resulting in highly localized strain accumulation. The strain mapping results are combined with microstructure characterization via electron backscatter diffraction. The combination of crystal orientations and high-resolution strain measurements was used to determine the active slip planes. At low temperatures, slip bands follow the {111} octahedral planes. However, as temperature increases, both the {111} octahedral and {100} cubic slip planes accommodate strain. The activation of cubic slip via cross-slip within the ordered intermetallic γ' phase has been well documented in Ni-based superalloys and is generally accepted as the mechanism responsible for the anomalous yield phenomenon. The results in this paper represent an important quantifiable study of cubic slip system activity at the mesoscale in polycrystalline γ-γ' Ni-based superalloys, which is a key advancement to calibrate the thermal activation components of polycrystalline deformation models.

Keywords: Ni-based superalloys; cube slip; microstructure; digital image correlation; fatigue.

1. Introduction

Strain localization is a precursor to fatigue crack initiation. As opposed to elastic deformation, the primary mechanism for plasticity in polycrystalline materials is mediated by localized, inhomogeneous slip events. As discussed by Seeger, the flow stress in crystalline materials can be decomposed into athermal and thermal components [1]. At absolute zero temperature, the maximum resistance to dislocation glide is known as the mechanical threshold, while at finite temperatures, slip proceeds below the mechanical threshold with the assistance of thermal activation [2,3].