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Modeling the evolution of microtextured regions during α/β processing using the crystal plasticity finite element method

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Abstract

Titanium alloy Ti-6242 (Ti-6Al-2Sn-4Zr-2Mo) is frequently used in the high-pressure compressor of aero engines. While exhibiting high strength at elevated temperatures, it is susceptible to dwell fatigue at temperatures below ~ 473 K due in part to the presence of microtextured regions (MTRs), also known as macrozones. This work investigates the role of forging direction on the mesoscale mechanical response of MTRs. The crystal plasticity finite element (CPFE) method was used to simulate large strain compression of MTRs with different initial crystallographic and morphological orientation with respect to the axial direction of the extruded billet. These simulations included cases where the c-axis of neighboring MTRs were (i) both perpendicular, (ii) one at 45° and one perpendicular, and (iii) one parallel and one perpendicular, to the compression direction. The effectiveness of each processing direction on the breakdown of MTRs is inferred through the extent of lattice rotation and the development of internal misorientations within the MTRs. The calculations reveal that case (i) leads to the most effective MTR breakdown but the c-axis remains similarly aligned; the c-axis is more scattered in case (iii) but the extent is limited by the high critical resolved shear stress of the pyramidal slip systems. Under uniaxial compression, competitive slip system activity correlates with positive divergence of reorientation velocity field in Rodrigues' space as well as efficient breakdown of MTR.

Keywords: `microstructures (A)`, `crystal plasticity (B)`, `finite strain (B)`, `finite elements (C)`, `microtextured region`

1. Introduction

The titanium alloy Ti-6242 (Ti-6Al-2Sn-4Zr-2Mo) has been the structural material of choice for use in high-pressure compressors for gas turbine engines of aircraft (Heckel et al. (2010)) due to its high strength-to-weight ratio and excellent mechanical properties. Jet engine efficiency is highly correlated to operating temperature, and Ti-6242 has demonstrated excellent creep and fatigue resistance at high temperatures up to 873 K. While the near α alloy Ti-6242 was developed for high temperature applications, its microstructural

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