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Perspectives on (1 1 0) channel die compression and analysis of the Goss orientation

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ABSTRACT

The set of geometrically based slip-systems hardening inequalities introduced in Havner [Havner, K.S., 2005. Philos. Mag. 85, 2861–2894] is applied to the analysis and prediction of experimental response of fcc crystals in the singular 'Goss' orientation of the channel die test – loading direction (1 1 0), lateral constraint direction ($\bar{1}$ 1 0). In addition, perspectives from my previous analyses of (1 1 0) channel die compression (2007–10) are presented and relationships between hardening moduli and compressive stress–strain curves evaluated for aluminum and copper in each lattice-orientation range. In the Goss orientation and for all orientation ranges in (1 1 0) compression, theoretical results for active slip planes, principal slip-rates, lattice rotation or stability, and finite crystal shearing are fully consistent with the gross-scale, finite-deformation experimental response of aluminum and copper crystals.

1. Introduction

As this paper is part of a special issue of the Journal in appreciation of Professor Akhtar Khan's leadership and service over more than a quarter century, and his own notable research contributions in plasticity, I begin by making a connection between the present work and one of his earliest research publications, Bell and Khan (1980). That paper is an experimental study of non-proportional loading of annealed polycrystalline copper tubes, in combined tension and torsion, through a moderate finite-deformation range (up to 20% nominal effective strain). Bell and Khan's experimental results were used to advantage by Al-Gadhib and Havner (1990) to investigate possible correlations among principal direction paths of Lagrangian and Eulerian strain ellipsoids (right and left 'stretch' tensors), Eulerian strain-rate, and Cauchy stress during non-proportional loading. This was followed by an investigation in Al-Gadhib and Havner (1992) of the predictions of several macroscopic plasticity theories against Bell and Khan's experimental results for copper.

The present paper also features analyses and experimental data on copper (and aluminum), but in this case for single crystals and in channel die compression. The close parallel, in principle, between this work and the experiments of Bell and Khan (1980) (and the related analyses by Al-Gadhib and Havner (1990, 1992)) may be expressed by quoting from the first paper in this series. "In the investigation of plastic deformation of materials under multi-axial states of stress, the channel die compression test plays the same role for single crystals as does the tension–torsion–internal pressure test of thin-walled tubes for polycrystalline metals. Each offers a potential for clarity of interpretation of constitutive behavior afforded only by an essentially uniform distortion and stress state (on a macroscopic scale)" (Havner, 2007a, p. 610). Thus, we move from the polycrystalline plasticity of Bell and Khan's (1980) notable experimental work to single crystals in channel die compression.

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