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Assessment of Polycrystal Plasticity Models of Deformation Twinning and Validation Using In-situ Neutron Diffraction

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abstract

The effect of deformation twinning has been incorporated within polycrystal plasticity models for over three decades. Initially, the interest was in explaining the different texture evolution within pure face centered cubic metals (e.g. copper) and their alloys (e.g. brass). A noteworthy demonstration was made by Van Houtte [1], who incorporated the ideas of prior authors into a generalized Taylor model and sought to minimize the number of new grain orientations, which were introduced into the polycrystal plasticity calculation over the course of incremental, large strain deformation. Tomé, Lebensohn, and Kocks [2] introduced two more strategies to overcome the problem of grain proliferation. One was termed the volume fraction transfer scheme and the other was termed the predominant twin reorientation (PTR) scheme. The former eliminates the proliferation of grain orientations by simply populating orientation space at the beginning of the calculation and then transforming volume fraction among the available orientations which describe the polycrystal. The latter involves reorienting entire grains when a threshold amount of twinning has occurred. Kalidindi [3] proposed quite a different scheme, which has been popular within finite element implementations of crystal plasticity. In this approach, the grains (nodal descriptions) are subdivided into matrix and twin domains with Most recently, Wang et al. [4] introduced a strategy to account not only for twinning during monotonic deformation but also detwinning which occurs during strain path changes. They dubbed their model the twinning-detwinning (TDT) model. The later developments (PTR, Kalidindi, and TDT) have been employed to simulate the mechanical response of hexagonal close packed (hcp) metals and alloys, as well as their texture evolution.

Throughout the lecture, specific attention will be drawn to the most common deformation twinning mode in hcp metals, including Mg, the {10.2} twinning mode. The twinning models will be evaluated relative to their ability to describe certain features of the mechanical response which are common to textured Mg alloys: 1) tension/compression yield strength asymmetry, 2) strain hardening plateau or yield point elongation [e.g. 5], and finally, 3) rapid strain hardening [e.g. 6]. In-situ neutron diffraction data will be used to validate the modeling, especially as pertains to characterizing the twin volume fraction evolution and the internal strains within twins, as originally demonstrated by Brown et al. [7] and Clausen et al. [8]. Particular attention will be paid to the notion of a "relaxation" or "back-stress" within the twins upon their formation and growth. Recently obtained data from conventional Mg alloy, ZK60A, will be used for many of these comparisons.

[1] P. Van Houtte, Acta Metall., 26, 591 (1978). [2] C.N. Tomé et al., Acta Metall. Mater, 39, 2667 (1991). [3] S.R. Kalidindi, J. Mech. Phys. Solids, 46, 267 (1998). [4] H. Wang et al., Mater. Sci. Eng. A, 555, 93 (2012). [5] O. Muránsky et al Mater. Sci. Eng. A 527, 1383 (2010). [6] A. Oppedal et al., Phil. Mag. A, 93, 4311 (2013). [7] D.W. Brown et al., Mater. Sci. Eng. A. 399, 1 (2005). [8] B. Clausen et al., Acta Mater. 56, 2456 (2008).