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3-D simulation of spatial stress distribution in an AZ31 Mg alloy sheet under in-plane compression

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ABSTRACT

A complete 3-D crystal plasticity finite element method (CPFEM) that considered both crystallographic slip and deformation twinning was applied to simulate the spatial distribution of the relative amount of slip and twin activities in a polycrystalline AZ31 Mg alloy during in-plane compression. A microstructure mapping technique that considered the grain size distribution and microtexture measured by electron backscatter diffraction (EBSD) technique was used to create a statistically representative 3-D microstructure for the initial configuration. Using a 3-D Monte Carlo method, a 3-D digital microstructure that matched the experimentally measured grain size distribution was constructed. Crystallographic orientations obtained from the EBSD data were assigned on the 3-D digital microstructure to match the experimentally measured misorientation distribution. CPFEM captured the heterogeneity of the stress concentration as well as the slip and twin activities of a polycrystalline AZ31 Mg alloy during in-plane compression.

1. Introduction

Mg alloys exhibit excellent strength-to-weight and stiffness-to-weight ratios compared with those of several other structural materials. In particular, wrought Mg alloys have been applied to electric and lightweight structural parts during recent decades (Kainer, 2007; Luo et al., 2007). However, because of their inferior ductility at temperatures near room temperature (RT), their application is limited with parts that depend on warm-forming technology (Yin et al., 2005; Agnew et al., 2005). It is well known that the critical resolved shear stress (CRSS) of non-basal slip systems, which are favorable to the enhancement of ductility, is much higher than that of a basal slip system at temperatures near RT (Kelley and Hosford, 1968; Agnew et al., 2001; Jain and Agnew, 2007). Therefore, only a limited number of slip systems can be activated to accommodate the external deformation during plastic deformation at temperatures near RT. The various deformation modes, such as basal $\langle \mathbf{a} \rangle$ slip, prismatic $\langle \mathbf{a} \rangle$ slip, pyramidal $\langle \mathbf{a} \rangle$, pyramidal $\langle \mathbf{c+a} \rangle$ slip, and tensile twinning, mean that the deformation behavior of Mg alloys is complicated compared to, for example, cubic metals. When the c/a ratio of a hexagonal metal (Mg: 1.624) is less than $\sqrt{3}$ ($\cong$1.732), a tensile twin is easily activated by c-axis tension (Yoo, 1981; Yoo and Lee, 1991). Deformation twinning affects both strain hardening behavior and texture evolution (e.g. Reed-Hill, 1960; Wonsiewicz and Backofen, 1967; Kelly and Hosford, 1968; Hartt and Reed-Hill, 1968; Nave et al., 2004; Jiang et al., 2006; Wang and Huang, 2007; Lou et al., 2007; Khan et al., 2011). A number of simulation studies have been conducted to understand texture evolution in Mg alloys during plastic deformation. In particular, many studies have investigated the effect of twin reorientation on texture evolution, macroscopic stress–strain response and macroscopic shape changes during plastic deformation. The key point is that,

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