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Short Communication

On the anisotropic deformation of AZ31 Mg alloy under compression

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ABSTRACT

The anisotropy of Mg alloy is investigated using uniaxial compression experiments. The anisotropic behaviors of interest include the texture, deformed shape, constitutive relationship, and fracture characteristics, and all of them are related to the microscopic mechanisms which include the competition between twinning and slipping at different temperatures and strain rates. When the loading is perpendicular to the *c*-axis of the HCP lattice, the specimen yields at a low stress because twinning is favored at relatively low strain, the deformed shape is strongly anisotropic owing to the slipping at high stress along $\langle 1\,1\,\bar{2}\,3\rangle$, and fracture occurs along $\langle 1\,1\,\bar{2}\,3\rangle$. On the other hand, when the loading is parallel to *c*-axis, there is no twinning process and the plastic deformation is dominated by slipping which requires higher stress, the yield stress is higher, and the deformation is isotropic. Anisotropy is also more prominent upon lower temperature or higher strain rate, largely thanks to twinning.

1. Introduction

As one of the lightest metals, the deformation characteristics of magnesium alloy have attracted many attentions. Owing to the preferred orientation of the hexagonal close packed (HCP) crystal structure upon deformation, the anisotropic behaviors of Mg alloy, including dynamic property [1], low temperature superplasticity [2], residual strain [3], thermal expansion [4], and microstructure upon rolling [5], etc., were subjected to intensive research. Many of the previous studies focused on the anisotropic behaviors of Mg sheets under tension. For example, the mechanical anisotropy of an extruded AZ61 magnesium alloy sheet was studied by means of tensile tests on specimens with different tilt angles relative to the extrusion direction [6]. The mechanical anisotropy of an AZ31 magnesium alloy sheet was investigated using tensile samples in the rolling direction, at 45°, and in the transverse direction [7,8]. For Mg–Li–Zn thin sheets, uniaxial tension tests were also carried out in different directions with respect to the rolling direction to investigate their anisotropic behaviors [9].

Besides the tensile behavior, the anisotropic characteristic under compression also plays a very significant role during the forming of Mg alloy, including extrusion, forging, and rolling, etc. Compressive constitutive properties of Mg alloys have been investigated [10,11], however the study on anisotropy was still rare. Due to anisotropy, the cross-section of a cylindrical specimen can become elliptical after compression in the rolling and width directions [12,13], nevertheless the underlying microscopic mechanism was not analyzed. Yukutake [12] argued that the compressive anisotropy of plastic deformation of AZ31 magnesium alloy vanishes if the temperature is above 573 K with a strain rate of $4.6 \times 10^{-4}\,s^{-1}$; nevertheless, the plastic anisotropic deformation also depends on strain rate, and the exact temperature at which the anisotropy disappears is not yet clear. For a hot rolled AZ31 Mg alloy plate [14], uniaxial compression tests showed that the hot workability is anisotropic along the rolling, transverse, and normal directions, which may be due to the first order and second order pyramidal slip systems that are favored in the rolling direction; however the study of anisotropy was not explicitly related to material microstructure. An improved understanding of the anisotropic compressive deformation mechanism needs to rely on experiments along different directions and at different temperatures and strain rates, through which the constitutive behavior, cross-section geometry and fracture property are characterized, and eventually linked to the microstructure evolution during deformation. This is the main objective of the present study.

In this paper, we study the anisotropic compressive deformation of AZ31 Mg alloy specimens at different temperatures and strain rates. The anisotropy is characterized by relevant deformed configurations, texture, mechanical and fracture behaviors, and the microscopic mechanism is clarified via the interaction and competition between slipping and twinning.

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