Materials Science & Engineering A 578 (2013) 14–17

Contents lists available at SciVerse ScienceDirect

Materials Science & Engineering A

journal homepage: www.elsevier.com/locate/msea

Rapid communication

Twinning and mechanical behavior of an extruded Mg–6Al–3Sn alloy with a dual basal texture

Lei Zhang, Chun-Guo Liu, Hui-Yuan Wang *, Xiao-Long Nan, Wei Xiao, Qi-Chuan Jiang

Key Laboratory of Automobile Materials of Ministry of Education, School of Materials Science and Engineering, Nanling Campus, Jilin University, No. 5988 Renmin Street, Changchun 130025, PR China

ARTICLE INFO

Article history:
Received 19 March 2013
Received in revised form
5 April 2013
Accepted 8 April 2013
Available online 17 April 2013

Keywords:
Magnesium alloys
Mechanical characterization
Twinning
Orientation relationships
X-ray diffraction

ABSTRACT

Uniaxial compression tests were performed on an extruded Mg–6Al–3Sn (AT63) alloy with a dual basal texture, along the extrusion direction (ED), transverse direction (TD) and normal direction (ND). Unlike the single basal texture commonly seen in rolled Mg alloys, for which either extension or contraction twinning is favored in one compression, the dual basal texture appreciates both extension and contraction twinning. Nevertheless extension and contraction twinning display different activities among the three compressions. The results suggest that extension twinning propagates largely for ED compression while it displays limited propagations for TD and ND compressions, although it nucleates at the onset of plasticity for all the three compressions. In contrast, contraction twinning nucleates early and widely for TD and ND compressions while it is largely suppressed for ED compression. It is the wider propagations of extension twinning and belated contraction twinning that result in a larger drop and a higher peak in the strain hardening curve for ED compression. Our results shed some light on deformation mechanisms of the Mg alloys consisting of multiple texture components.

1. Introduction

Due to the limited number of basal slip systems in hexagonal close packed (HCP) structure, magnesium and its alloys exhibit a strong propensity of deformation twinning to accommodate their plastic deformation [1–3]. Two types of twins are frequently reported in Mg alloys: $\{10\bar{1}2\}\langle\bar{1}011\rangle$ extension and $\{10\bar{1}1\}\langle10\bar{1}\bar{2}\rangle$ contraction twins [4,5]. Extension twins are formed when there is an extension strain component parallel to the *c*-axis, while the contraction twins are activated when there is a contraction strain component parallel to this axis. Their polar nature, in conjunction with the strong deformation textures, leads to a high level of mechanical anisotropy in wrought Mg alloys [6–9]. Although influences of extension and contraction twinning on mechanical behavior have been widely investigated [10–13], the works generally applied deformations on Mg alloys with a single basal texture, and assumed that either extension or contraction twinning is favored under a selected loading direction. However, some texture spreading and several deviant orientations are inevitable in textured Mg alloys, which thus may activate the extension and contraction twinning simultaneously.

It is clear that rolled Mg alloys generally show a single basal texture with most basal planes aligned parallel to the rolling plane [10–13]. For extruded Mg alloy plates, material cut from the central parts also exhibits such a single basal texture [8]. It was recently found that the marginal parts of an extruded Mg–6Al–3Sn (AT63) alloy plate exhibit a dual basal texture consisting of two mutually perpendicular (0002) texture components. Unlike the ring fiber texture typically seen in extruded Mg alloy tubes [7,14,15], which presents consecutive distributions of basal planes, the dual basal texture consists of two separate texture components. As such, the material with dual basal texture is more suitable for modeling the deformations favoring both extension and contraction twinning. In this work, compressive behaviors of an extruded AT63 alloy with the dual basal texture were investigated through three uniaxial compressions along various directions, with attention particularly paid on the deformation twinning and mechanical behavior.

2. Material and methods

The material used in this study was an extruded AT63 Mg alloy (Mg–6.47Al–3.26Sn) plate with a size of 36 mm width and 8 mm thickness (extrusion ratio $R=24.6$), which was homogenized at 250 °C for 1 h. Three sets of samples (7.5 mm × 5 mm × 5 mm) were cut out from the marginal parts of the as-annealed plate for

* Corresponding author. Tel./fax: +86 431 8509 4699.
E-mail addresses: wanghuiyuan@jlu.edu.cn, wanghy_jlu@yahoo.cn (H.-Y. Wang).

0921-5093/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.msea.2013.04.026

uniaxial compression tests, with respective loading axes parallel to the extrusion direction (ED), transverse direction (TD) and normal direction (ND). Information on the microstructural characteristics of the marginal material is presented in Fig. 1a and b. This material has a twin-free equiaxial grain structure with an average linear intercept grain size of ~30 μm, and exhibits a dual basal texture with one group of basal poles parallel to ND (called $ND_{\parallel}$ component) and another group parallel to TD (called $TD_{\parallel}$ component).

Uniaxial compression tests were conducted on a MTS-810 testing system at a constant strain rate of $1\times10^{-3}\,s^{-1}$ at room temperature. The microstructure and macrotexture were examined by an optical microscope (Carl Zeiss-Axio Imager A2m, Germany) and X-ray diffraction (XRD), respectively. The XRD measurements were performed on a Rigaku 2500PC X-ray diffractometer with Cu Kα radiation at 40 kV and 150 mA.

3. Results and discussion

The stress–strain curves for the compressions along ED, TD and ND are presented in Fig. 2a. The values of the yield stress (σ_y, 0.2% offset) and the ultimate compressive strength (UCS) for ED, TD and ND curves are 109, 83 and 117 MPa as well as 357, 295 and 298 MPa, respectively. The evolutions of flow stress for the three compressions are illustrated by the strain hardening rate–effective stress curve [16,17], as shown in Fig. 2b, where G is the shear modulus (measured to be 16.3 GPa for the present alloy) and σ_y is the yield stress.

To examine the microstructural development during the deformations, interrupted tests were conducted on the three compressions at ε=3.0, 6.5 and 9.5% respectively. The results suggest that extension twinning is widely activated at ε=3.0% in ED, TD and ND samples (see white arrows in Fig. 3a, d and g, respectively). In the ED sample (Fig. 3a), extension twins nucleate in almost all grains. In the TD (Fig. 3d) and ND samples (Fig. 3g), however, extension twins occur only in some dark grains and are absent in clear grains. For the clear grains, in contrast, contraction twins with thin and straight morphologies appear at further strains (see green arrows in Fig. 3e–i). To investigate the orientation of the clear grains, the interrupted samples at ε=9.5% are further characterized by pole figures. Note that, after compression along ED, both $ND_{\parallel}$ and $TD_{\parallel}$ components are transformed to a new texture with the c-axis parallel to ED (see Fig. 4a). In the case of the TD sample (Fig. 4b), the $ND_{\parallel}$ component disappears and transforms to $TD_{\parallel}$ component, which is confirmed by the enhanced intensity of $TD_{\parallel}$ component (Max=7.872). In the ND sample (Fig. 4c), $TD_{\parallel}$ component disappears while $ND_{\parallel}$ component intensifies. Therefore the clear grains in TD (or ND) samples should be $TD_{\parallel}$ (or $ND_{\parallel}$) component. Namely, when basal plane is parallel to the observation surface, grains are bright, but when the basal plane is normal to the observation surface, grains appear in gray.

It has been reported that, for extruded Mg alloy tubes (i.e. ring fiber texture), a ring hoop tension generally exhibits a nearly same yield stress with uniaxial compression along the extrusion direction, because extension twinning can occur in the two deformations [14,15]. Note that all grains have favorable orientation for extension twinning during the uniaxial compression, whereas only a part of the grains are favored during the ring hoop tension. For the present three compressions, due to the wide activations of extension twinning in the early plasticity, all the samples exhibit twinning-dominated yielding, and thereby weakening the yield anisotropy when compared with that for Mg alloys with an intense basal texture [6,10]. In the ED samples, as both $ND_{\parallel}$ and $TD_{\parallel}$ components are favored (see Fig. 4a), extension twinning exhibits rapid evolution from ε=3.0% to 9.5% (see white arrows in Fig. 3a–c). In TD and ND samples, however, only limited extension twins propagate in this strain range (see white arrows in Fig. 3d–i), because they can only take place in either $ND_{\parallel}$ or $TD_{\parallel}$ component (see Fig. 4b and c).

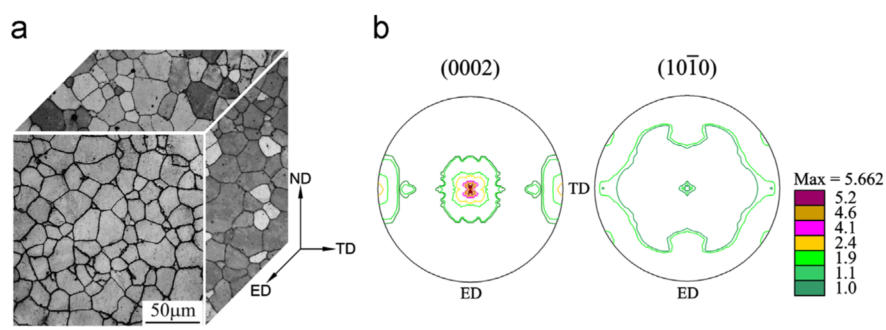

Fig. 1. (a) Optical micrographs and (b) (0002) and (10$\bar{1}$0) pole figures of the material cut from the marginal part of the as-annealed AT63 plate.

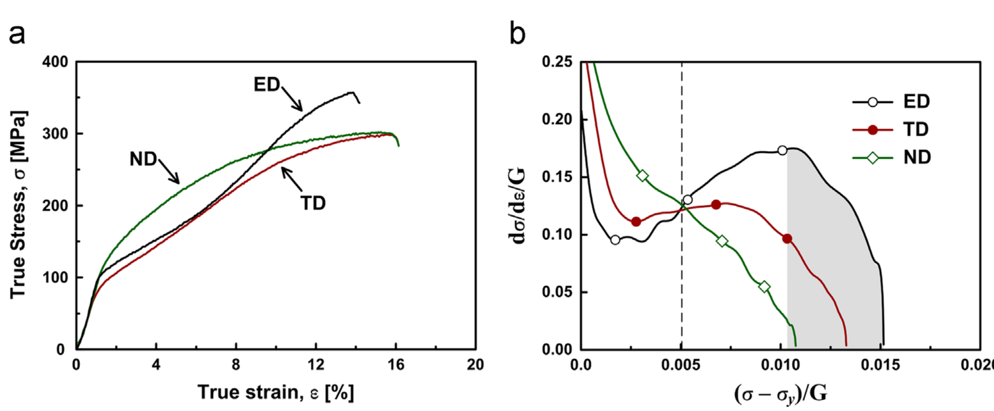

Fig. 2. Uniaxial compression along ED, TD and ND: (a) true stress–true strain curves and (b) strain hardening rate–true stress curves. The various points correspond to the strains of 3.0%, 6.5% and 9.5%, for ED, TD and ND compressions, respectively.