International Journal of Plasticity 27 (2011) 1072–1092

Contents lists available at ScienceDirect

International Journal of Plasticity

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

Crystal-plasticity finite-element analysis of inelastic behavior during unloading in a magnesium alloy sheet

Takayuki Hama [a,b,*], Hirohiko Takuda [a]

[a] Graduate School of Energy Science, Kyoto University, Yoshida-honmachi, Sakyo-ku, Kyoto 606-8501, Japan
[b] VCAD System Research Program, RIKEN, 2-1 Hirosawa, Wako-shi, Saitama 351-0198, Japan

ARTICLE INFO

Article history:
Received 13 May 2010
Received in final revised form 19 November 2010
Available online 4 December 2010

Keywords:
Magnesium
B. Crystal plasticity
C. Finite elements
B. Cyclic loading
B. Polycrystalline material

ABSTRACT

A crystal-plasticity finite-element analysis of the loading–unloading process under uniaxial tension of a rolled magnesium alloy sheet was carried out, and the mechanism of the inelastic response during unloading was examined, focusing on the effects of basal and nonbasal slip systems. The prismatic and basal slip systems were mainly activated during loading, but the activation of the prismatic slip systems was more dominant. Thus the overall stress level during loading was determined primarily by the prismatic slip systems. The prismatic slip systems were hardly activated during unloading because the stress level was of course lower than that during loading. On the other hand, because the strength of the basal slip systems was much lower than that of the prismatic slip systems, the basal slip systems would be easily activated under the stress level during unloading in the opposite direction when their Schmid's resolved shear stresses changed signs because of the inhomogeneity of the material. These results indicated that one explanation for the inelastic behavior during unloading was that the basal slip systems were primarily activated owing to their low strengths compared to that of the prismatic slip systems. Numerical tests using the sheets with random orientations and with the more pronounced texture were conducted to further examine the mechanism.

1. Introduction

Magnesium (Mg) alloys are the lightest materials used for structural components, and their specific strength and stiffness are high (Mordike and Ebert, 2001). Moreover, their functional properties such as recyclability (Mordike and Ebert, 2001; Chino et al., 2006a) and electromagnetic shielding (Mordike and Ebert, 2001; Chino et al., 2006a; Kim et al., 2008) are also superior. Mg alloys have recently received attention because of the increasing demand for lightweight materials for automobile and electrical devices (Mordike and Ebert, 2001) to reduce their environmental impact.

Conventionally, applications made of Mg alloys are manufactured by die casting and thixoforming (Kim et al., 2008; Kaneko and Sugamata, 2004; Lee et al., 2007). The press forming of Mg alloy sheets has recently attracted attention because it can further expand the use of Mg alloys for structural components. Many studies on the press forming of Mg alloy sheets (Kim et al., 2008; Kaneko and Sugamata, 2004; Doege and Droder, 2001; Chen et al., 2003; Lee et al., 2002, 2007; Chen and Huang, 2003; Bruni et al., 2006; Hama et al., 2010a) have been carried out, and various components are manufactured by press forming, such as the housing of laptop computers and cellular phones, and automobile body structures.

To increase the number of applications of press forming, it is essential to understand the mechanical properties of Mg alloy sheets. They are significantly different from those of conventional structural sheet metals such as steel and aluminum

* Corresponding author at: Graduate School of Energy Science, Kyoto University, Yoshida-Honmachi, Sakyo-ku, Kyoto 606-8501, Japan. Tel.: +81 (0)75 753 5418; fax: +81 (0)75 753 5428.

E-mail address: hama@energy.kyoto-u.ac.jp (T. Hama).

0749-6419/$ - see front matter
doi:10.1016/j.ijplas.2010.11.004