Journal of Materials Processing Tech. 254 (2018) 302–309

Contents lists available at ScienceDirect

Journal of Materials Processing Tech.

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

# Enhanced stretch formability of AZ31 magnesium alloy thin sheet by pre-crossed twinning lamellas induced static recrystallizations

Weili Cheng[a,b], Lifei Wang[a,b,*], Hua Zhang[b], Xiaoqing Cao[a]

[a] Shanxi key laboratory of advanced magnesium-based materials, Taiyuan 030024, China
[b] College of Materials Science and Engineering, Taiyuan University of Technology, Taiyuan 030024, China

ARTICLE INFO

*Keywords:*
Magnesium alloy sheet
Pre-compression
Recrystallization
Formability

ABSTRACT

In order to improve the stretch formability of AZ31 magnesium alloy thin sheet with thickness of 1 mm, a multidirectional pre-compressive deformation along rolling (RD)-transverse direction (TD) with various strain levels and sequent annealing at 450 °C are conducted. Besides, a special die is developed to avoid sheet bending-buckling during pre-compression. After TD-RD multidirectional pre-compression (T1.69%-R3.3%, T3.32%-R3.3%, T5.38%-R3.3%) and annealing, the grain size increases obviously with increasing TD pre-strain levels which may be related to the strain induced static recrystallization. However, grain coarsening was observed in R3.3%-T1.59% pre-compressed Mg sheets and then the grain size decreased gradually as the TD pre-strain levels increased (R3.3%-T1.69%, R3.3%-T3.32%, R3.3%-T5.38%). The microstructure evolution in the multi-directional pre-compression Mg sheets may be attributed to the twin–twin intersections serving as nucleation sits further to promote the recrystallization behavior. Due to the pre-induced twins and grain growth, the (0002) basal texture weakens obviously. The stretch formability (IE-value) of magnesium alloy sheet is enhanced greatly with the IE-value being improved by 112.4% in T5.38%-R3.3% pre-compressed Mg alloy sheet compare to that of as-received one.

## 1. Introduction

Due to the high specific strength, low density, good recyclability and so on, magnesium alloys have been paid increasing attentions in electronics, automobile, aerospace industries (Hou et al., 2016). However, there are limited independent slipping systems to be activated at room temperature owing to its hexagonal close packed (HCP) structure (Xu et al., 2013). The basal plane only provides two basal slipping systems, and non-basal slips are not easier to be activated which cannot meet the requirement of Von Mises Criterion. Therefore, Mg alloy sheets usually express a poor formability (Huang et al., 2015a,b). And how to improve the stretch formability of Mg alloy sheets is of great importance. Recently, the weakening of basal texture is considered to be an effective way and many related technologies are developed. In general, they can be summarized into two categories: alloying and introducing shear deformation. While, introducing shear deformation to weaken the basal texture has been proved to be efficient seriously. Through high speed rolling (Su et al., 2016), high temperature rolling (Huang et al., 2015a,b), asymmetry extrusion (Yang et al., 2014), unidirectional repeated bending (Zhang et al., 2011), equal channel angular rolling (Suh et al., 2015) and other processes, the basal texture is weakened and the stretch formability of Mg sheet can be improved as large as 60% after the induced shear deformation. However, the processes are much complicated and the devices available are limited.

Recently, some researchers reported that the basal texture of magnesium alloys can be also weakened by recrystallization behaviors. Both the nucleation and growth of new recrystallization grains have an important effect on the texture evolution (Sarker and Chen, 2014). Dong et al. (2014) reported that the basal texture was weakened slightly during initial nucleation of recrystallization, and the subsequent grain growth during annealing treatment resulted in more texture weakening in cold pre-stretched AZ31 magnesium alloy sheet. Therefore, the stretch formability was enhanced due to the grain growth and texture weakening. Furthermore, Chino et al. (2009) indicated that (0002) basal texture could be weakened by generation of coarse grains during recrystallization process so that the stamping formability of AZ31 magnesium alloy sheet was improved obviously. Note that Zhang et al. (2012) reported that 5% clod deformation might be a critical strain, when exceeding the degree, grain nucleation rate of Mg alloys during static recrystallization was larger than grain growth. Grains could grow up when pre-strain was less than 5% and the stretch formability of Mg sheet with coarse grains was improved by 65% comparing with initial

* Corresponding author at: Shanxi key laboratory of advanced magnesium-based materials, Taiyuan, 030024, China.
*E-mail address:* xiao618hai@126.com (L. Wang).

https://doi.org/10.1016/j.jmatprotec.2017.11.052
Received 15 September 2017; Received in revised form 21 November 2017; Accepted 24 November 2017
Available online 26 November 2017
0924-0136/ 

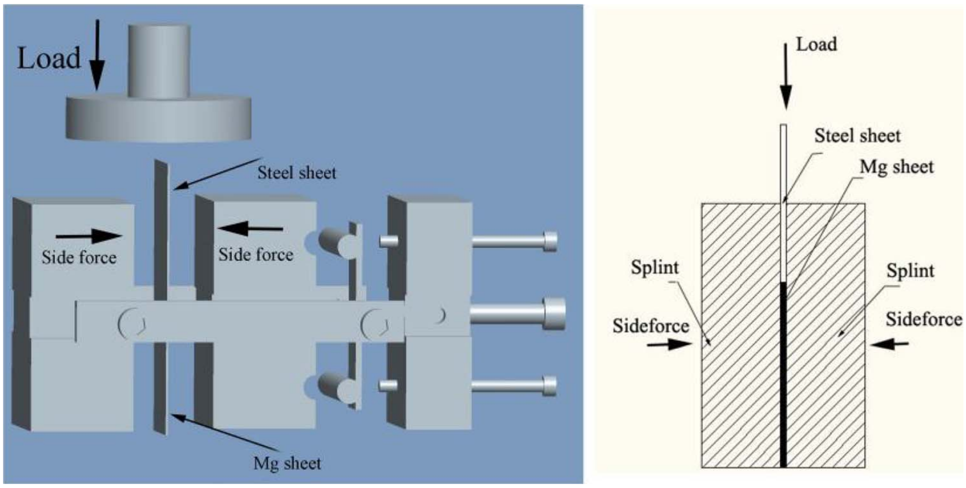


**Fig. 1.** Overview about the thin sheet compression die.

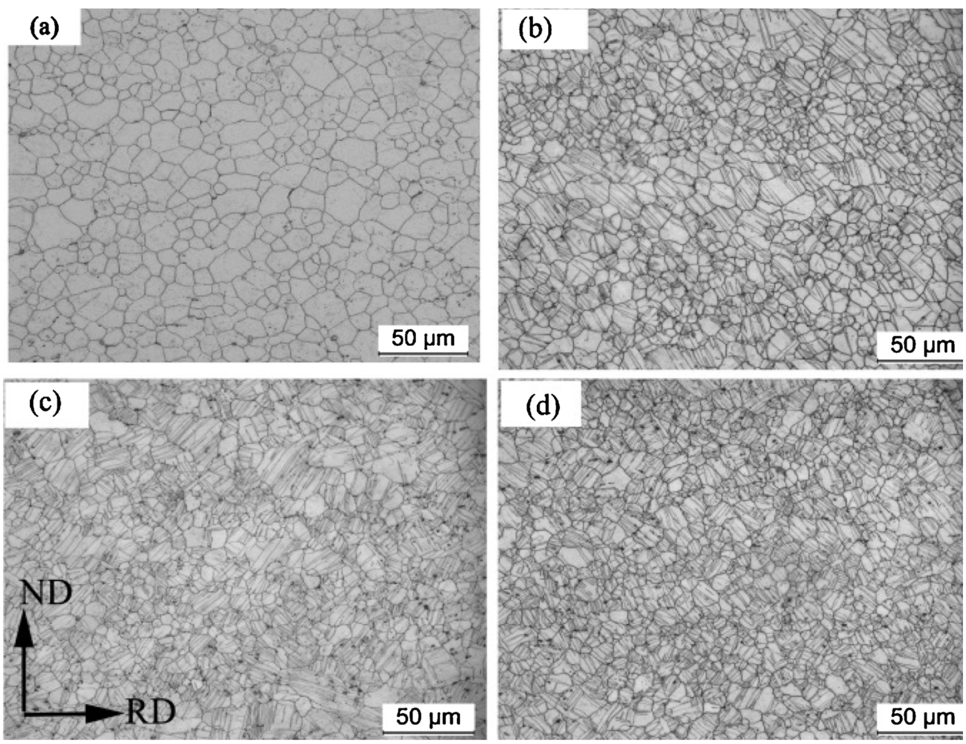


**Fig. 2.** Optical microstructures of various T-R pre-compression and annealed magnesium alloy sheets without annealing: (a) as-received, (b) T1.69%-R3.3%, (c) T3.32%-R3.3%, (d) T5.38%-R3.3%.

sheet. Thus, promoting both recrystallized grain nucleation and growth can be considered to be a powerful method to weaken basal texture and improve formability of Mg alloy sheet.

Besides, Zhang et al. (2014) indicated that twinning lamellae could promote the nucleation of recrystallization grains which enhance the mechanical properties of Mg alloy. In addition, Guo et al. (2016) hot rolled the pre-twinned Mg alloys sheets at 350 °C and found that dynamic recrystallization (DRX) was greatly promoted by initial twinning lamellae. Recently, Zhang et al. (2014) pre-cold rolled on AZ31 magnesium alloys to introduce {10–12} tensile twins and then conducted warm compression. Due to pre-induced twins, the number of nucleation sites for recrystallization increased. The basal texture weakened and mechanical properties were improved. Similarly, Jain and Agnew, 2007 indicated that the twinning lamellae not only promoted the nucleation of recrystallization grains, but also played an important role in grain growth. What is more, Yu et al. (2014) found that twin–twin intersections contained many boundary dislocations. The twin–twin intersected regions often possessed a high stored energy to promote the nucleation of recrystallization grains. However, it is much easier to be bending-buckling during pre-twinning process on Mg alloy thin sheet. Thus, the investigations about improving the stretch formability of Mg thin sheet through pre-twins as well as induced recrystallization behavior has been rarely reported thus far.

In this paper, initial tensile twins and twin–twin intersections are introduced by multidirectional pre-compression process on AZ31 magnesium alloy sheet to induced sequent static recrystallization. The effect of grain growth on the stretch formability of Mg sheet is investigated. In order to avoid the instability of Mg sheet during pre-twins, a special die for thin sheet pre-compression is developed as well.

## 2. Experimental procedure

The commercial as-rolled AZ31 (Mg-3 wt.%Al-1 wt.%Zn) magnesium alloy sheets with a thickness of 1 mm are used in this experiment. Rectangular specimens are cut from the initial sheet with dimension of 50 mm (length) × 50 mm (width) along rolling direction (RD). Then