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Effect of processing route on texture and cold formability of AZ31 Mg alloy sheets processed by ECAP

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ABSTRACT

The present work investigates the influence of different shearing patterns on mechanical and forming behavior at room temperature of equal channel angular pressing (ECAP) processed AZ31 sheets. Hot-rolled AZ31 (Mg-3Al-1Zn, wt%) sheets, with dimensions of $200 \times 200 \times 1.8\ mm^3$, were processed at 225 °C with channel angle of 110° regarding processing routes A, C and D. Shear deformation induced by ECAP weakens the texture and promotes a broad angular distribution of basal planes in the pressing direction on routes A and C. Especially, processing on route D makes basal planes tilted towards the rolling direction and transverse direction by 90° rotation in the sheet plane. Due to the increased activity of basal $<a>$ slip, ECAP processed sheets exhibit the decrease in yield strength and *r*-value and increase in uniform strain and *n*-value in the pressing direction. As a result, route C has the largest uniform elongation in the rolling direction and route D provides a quasi-isotropic hardening behavior at room temperature. The improved formability of the ECAP processed sheets is attributed mainly to low *r*-value and high *n*-value. At Nakajima tests, route D provides higher forming limits than the as-rolled sample. The microstructure on route D exhibits a drastic reduction in the fraction of {10−12}-{10−11} double twins. This twinning mode leads to premature failure of the as-rolled sample under biaxial stretching. Consequently, microstructure-texture control induced by ECAP can enhance the cold formability of AZ31 sheets.

1. Introduction

Magnesium alloys provide high specific mechanical properties such as high specific tensile strength and buckling resistance comparable to those of Al alloys [1]. Despite the lightweight potential, wrought Mg alloys play still a minor role in industrial application. With emphasis on Mg sheets, their limited formability at room temperature is one of the main reasons hindering industrial applications. This low formability is due to the limited number of active slip systems at room temperature in the hexagonal close-packed lattice [2]. Typical wrought Mg alloys such as Mg-Al-Zn system develop strong basal textures during rolling processes [2,3]. Here the basal planes are predominantly aligned parallel to the sheet plane [4,5]. Such a preferred orientation is unfavorable for basal $<a>$ slip to accommodate plastic strain, causing high mechanical anisotropy and low ductility at room temperature [6,7]. Texture weakening and grain refinement can improve the forming characteristics of Mg alloy sheets [6].

Recently, the potential of equal channel angular pressing (ECAP) has received remarkable attention for improving the forming properties of Mg alloys through grain refinement [8,9] and texture change [10–12]. Processing by ECAP can impose intensive shear strain on a sample without any concomitant change in the cross-sectional dimension [13]. As a sample is pressed through an angularly designed die, it is primarily deformed by simple shear along the intersection plane between the entrance and exit channels [10]. Several studies have reported the processing of Mg alloys by ECAP regarding the effect of the processing temperature [13–15], the channel angle [16–18] and the processing route [12,15,18,19]. For instance, AZ31 alloy exhibited a two-three times improvement in the tensile elongation after ECAP and annealing [14]. The grain refinement and texture weakening induced by ECAP improved the ductility of AZ61 alloy bars at room temperature [19]. Moreover, Jufu et al. [15] have investigated the effect of processing routes, temperatures and extrusion passes on room temperature mechanical properties of AZ91 alloy. They showed

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that the texture change and grain refinement induced by ECAP lead to high enhancement of tensile properties. However, the existing studies on ECAP for Mg alloys are limited to bulk materials (rectangular or circular bars). There is still a lack of knowledge on the effect of ECAP on the microstructure and mechanical properties of Mg sheets with thickness below 2 mm. One of the principal technical difficulties is unfavorable buckling or transverse loading during pressing sheet metals due to their high slenderness ratios.

For the application of ECAP to Mg sheets, it is necessary to investigate systematically the influencing parameters. This brings basic understanding to tailor the microstructure and texture of Mg sheets for the enhancement of their cold formability. In this respect, Suh et al. [20] have developed a novel ECAP tool, and investigated the influence of the processing temperature on the microstructure and correlated mechanical behavior at room temperature of AZ31 sheets, which were processed by ECAP at 175, 200 and 225 °C with a channel angle (Φ) of 130°. Grain structure becomes more homogeneous and finer with increasing processing temperature. Particularly, shear deformation induced by ECAP leads to a broad angular distribution of the basal planes from the normal direction (ND) towards the pressing direction (PD), which was in that study parallel to the rolling direction (RD). Consequently, the yield strength (YS) in the RD of AZ31 sheet, which was processed by ECAP at 225 °C, was ~45 MPa lower than that of the as-rolled sample. Particularly, the uniform elongation (ε_u) was improved by 31% compared to the as-rolled condition.

ECAP enables a multiple repetition so that accumulated shear strain leads to further development of texture and grain structure. Different slip systems and shearing patterns are associated with a change of the sample orientation, i.e. processing route. In this study, AZ31 sheets were processed by ECAP at 225 °C with $\Phi = 110°$ on different processing routes. The present work aims to investigate the influence of different shearing patterns on microstructure and resulting forming behavior at room temperature of the ECAP processed AZ31 sheets.

2. Experimental procedure

2.1. ECAP process

Commercial twin-roll cast AZ31 Mg alloy (3Al-1Zn-0.3Mn-Mg

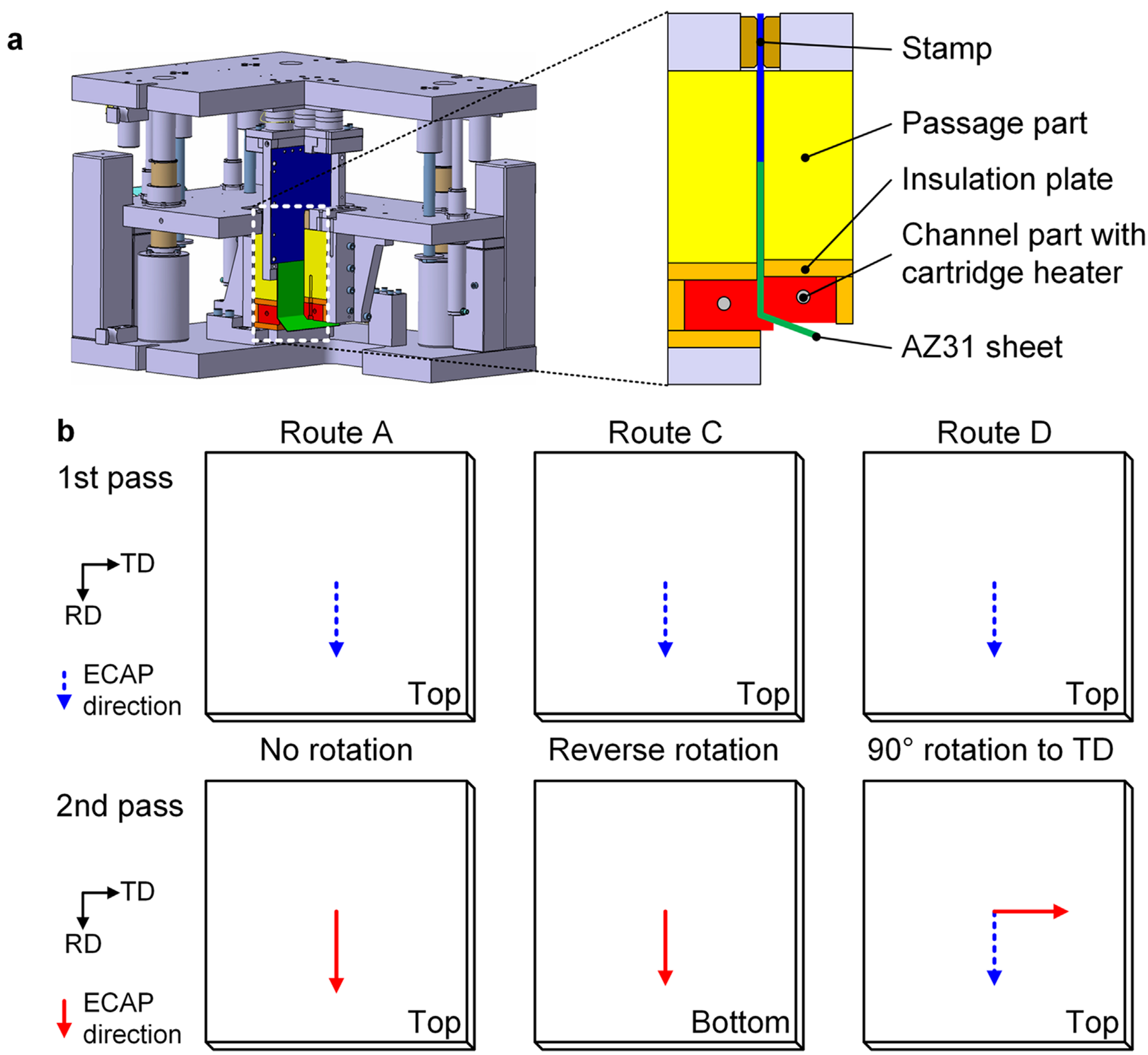

Fig. 1. Description of ECAP tool and processing route: (a) ECAP tool, (b) processing route.