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Full length article

Influence of different extrusion processes on mechanical properties of magnesium alloy

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Abstract

AZ31 Mg alloy sheets were processed by the conventional symmetrical extrusion (CSE) and the asymmetric extrusion (ASE). Progressive-asymmetric extrusion (PASE) and severe strain-asymmetric extrusion (SASE) were employed for ASE processes. The texture at near-surface and mid-layer zones of ASE sheets was diverse penetrating the normal direction (ND). This was attributed to an additional asymmetric shear strain deformation during the ASE process. (0002) basal planes of PASE sheets tilt to the shear deformation direction. Meanwhile, the basal texture intensity of PASE sheets has been weakened compared with one in CSE sheets. Grain refinement and tilted weak basal texture obtained by SASE process dramatically enhances the room temperature strength and plasticity of the extruded AZ31 magnesium alloy sheets. The microstructure and mechanical responses were examined and discussed.

Keywords: Mg alloys; Texture; Microstructure; Extrusion; Shear

1. Introduction

As lightest metallic materials, Mg alloy has been interest for the important advancement in the aerospace, automotive industries and tool applications [1–3]. Fabrications of the structural components principally concentrate upon tubes and sheets for these Mg alloys. Generally speaking, the dominant slip system of Mg alloy is the slip in the close packed direction $<11\bar{2}0>$ or $<a>$ on the (0002) basal planes at room temperature [4,5]. Thus, the magnesium alloys sheet normally produces the forceful basal texture during the extrusion and rolling approach [6,7]. And this further restricts the ductility of Mg alloy sheets with respect to their hexagonal close packed (*HCP*) crystal structure at room temperature.

It is well-known that the extrusion is an economical and practical process to yield the sectional materials such as sheets and bars. This can be grown into the structural components for the wrought Mg alloys [8,9]. Nevertheless, conventionally symmetrical extruded (CSE) magnesium alloy sheets reveal the inferior plasticity because of the finite quantity of the valid plastic deformation modes at room temperature [10,11]. Besides, Mg sheets with strong (0002) basal texture usually process the prominent anisotropy, the tension-compression-asymmetry and so on [12,13]. The room temperature formability mainly relies on the effect of the primal (0002) basal texture of Mg alloy sheets. Therefore, ameliorating texture

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should be considered as a valid method to improve the plasticity during the primary processing for Mg alloy sheets.

Many technologies were applied to modify the basal texture of Mg alloy sheets during the severe plastic deformation (SPD). Some research methods have yet used a lot of cockamamie and repetitive processes and thus were not able to the fabrication of the Mg alloy thin sheet [14,15]. It was found that differential speed rolling (DSR) process has effectively enhanced the ductility of Mg alloy sheets [16,17]. During the DSR process, the velocity of the up and down rolls was so different, resulting in the additional asymmetric shear strain deformation throughout the direction of the sheet thickness. The basal texture can be weakened during the DSR process. This asymmetric extrusion process is recommended to bring in the extrusion step under the strain path in one pass. In our work, the novel designed extrusion process is determined to modify the strong texture-dependent mechanical responses of Mg alloy sheets.

2. Experimental procedures

Cylindrical cast ingots of AZ31 Mg alloys (Mg-3 Al-1 Zn, in wt.%) with 82 mm in diameter was homogenized at 703 K for 2 h. These Mg alloys was carried out by the conventional symmetrical extrusion (CSE), the progressive-asymmetric extrusion (PASE) and severe strain-asymmetric extrusion (SASE), respectively. These ingots were extruded to the sheets of 1 mm thickness and 56 mm width at 703 K. Meanwhile, the speed of all extrusion processes was 20 mm/s with the extrusion ratio of 101.

The microstructures and the crystal orientation of Mg alloy sheets in the different extrusion processes were investigated by electron backscattered diffraction (EBSD) obtained using FEI Nova 400 FEG-SEM. The Mg alloy sheets were prepared for EBSD tests by electropolishing at 20 V for ~ 150 s in the AC2 solution. The (0002) basal texture was preformed on X-ray Rigaku D/Max 2500. The texture and EBSD datas were measured at upper surface, mid-layer and lower surface of ASE sheets (ND-ED plane). Here, ED, TD and ND respectively signify the extrusion direction, the transverse direction and the normal direction.

Dog-bone tensile samples with gage dimensions of 12 mm in length, 6 mm in width and 1 mm in thickness were machined from the Mg alloy sheets. Room temperature tensile tests were using by CMT6305-300 kN at the angles of 0°, 45° and 90° between the tensile and the extrusion direction at the strain rate of 10^{-3} s^{-1}.

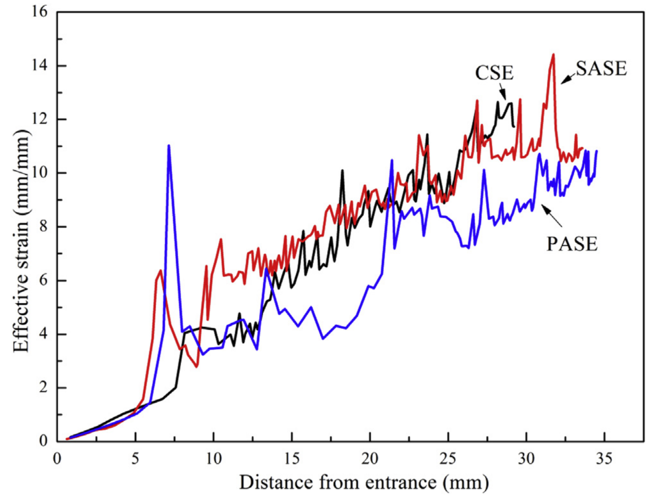

Fig. 2. The distribution of the effective strain of Mg alloy during the finite element models in the extrusion process.

3. Results and discussion

Fig. 1 reveals the schematic section of the flow passage in the conventional symmetrical extrusion (CSE), the progressive-asymmetric extrusion (PASE) and severe strain-asymmetric extrusion (SASE) dies, respectively. The velocity of the top and bottom surfaces during CSE process is the same because of a symmetric plane in the extrusion process. A great deal of the shear can be recommended through the space between the up and down surfaces along the parallel flow passage in the PASE and VASE dies equipped with a different length (L = 4 mm). Subsequently, this results in the asymmetric strain deformation in the normal direction of Mg alloy sheets in one pass extrusion during the ASE process.

The effective strain distribution of the Mg alloy sheet during the extrusion process was examined by the finite element model (FEM) in this work. For an easier comprehension of the extrusion process, the FEM results of CSE process were also analyzed to compare with those of ASE processes. Fig. 2 shows the effective strain of the workpiece processed by FEM during CSE, PASE and SASE processes, respectively. The waves in the effective strain curve are more uniform and stronger during the CSE process, while those of ASE express bigger ups and downs. In addition, it can be noted that the SASE process exhibits the highest value and PASE shows the lowest one. The effective strain curve shows the variation during the whole extrusion process for the AZ31

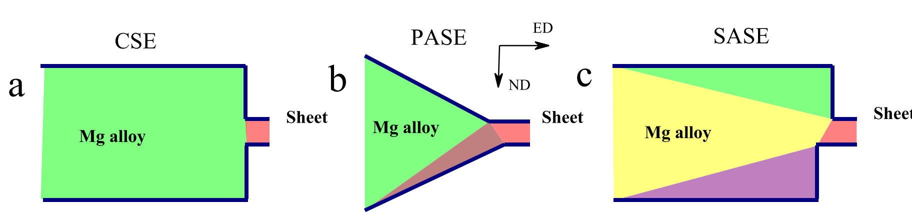

Fig. 1. Schematic section view of the extrusion die: (a) the conventional symmetrical extrusion (CSE), (b) the progressive-asymmetric extrusion (PASE) and (c) severe strain-asymmetric extrusion (SASE).