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Examination of an aluminum alloy behavior under different routes of twist extrusion processing

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ABSTRACT

Experiments were conducted to evaluate the effects of loading path during twist extrusion processing. The samples of aluminum 8112 were processed by different routes of twist extrusion. Two consecutive clockwise dies (route I) and alternative clockwise–counterclockwise dies (route II) were used. The grain sizes created by route II were significantly finer than those created by route I. Furthermore, the mechanical properties, including the strength and hardness, not only enhanced but also distributed more homogeneously across the transverse cross-section of the samples.

1. Introduction

Nowadays, severe plastic deformation (SPD) has been well known as a technique for producing bulk nano-grained and ultrafine-grained materials [1–3]. Twist extrusion (TE) is one of the most unprecedented techniques, belonging to SPD category. This method has been developed in recent years [4–6]. It is based on extruding a billet under hydrostatic pressure through a twisted channel including a rotation angle (α) and a slope angle (β). Fig. 1 shows a schematic representation of a workpiece during TE processing. Since the billet's geometry remains constant after the process, it is possible to deform it repeatedly in order to accumulate strain [7]. Investigations showed that by employing two different TE dies (clockwise die (CD) and counterclockwise die (CCD)), two different processing routes can be performed: route I which is created by using two clockwise dies (CD–CD) or two counterclockwise dies (CCD–CCD), and route II developed by employing clockwise–counterclockwise dies (CD–CCD) or counterclockwise–clockwise dies (CCD–CD) [8]. Experiments on the transverse cross-section of TEed specimens showed that performing route I gives a cyclic deformation with some amplitude A, while route II gives a cyclic deformation with amplitude 2A [8]. These different loading paths can lead to different structures and properties. Further experiments showed that conducting sequential passes of TE (route I) forms a vortex-flow, while TE passes with alternate directions (route II) create folds [9]. The work of Beygelzimer et al. [10] illustrated that in the case of alternate unlike dies (CD–CCD or CCD–CD), a certain improvement in the structural grain refinement is achieved.

Although previous experiment [10] showed some differences between two various routes of TE processing, there are still many uncertainties in relation to this matter. This work is aimed at investigating the effect of using two different routes of TE on the microstructure and mechanical properties of an Al 8112. Employing route II decreases the grain size more observably than performing route I. Route II, also, enhances the strength properties, and distributes the mechanical properties throughout the transverse cross-section more homogeneously than route I.

2. Experimental material and procedures

The sample used in this study was an Al 8112 with the composition mentioned in Table 1. The as-received billet with the dimensions of 70 mm × 32 mm × 18 mm was annealed at 723 K for 2 h, and cooled down in the furnace to produce fully annealed material. Then, it was pushed through a twisted channel with the rotation angle (α) of 90° and the slope angle (β) of 60°. The applied force was maintained at constant value of ~250 tones, corresponding to a pressure of ~4.3 GPa. Two and four TE passes were performed on prepared samples using two routes of TE:

Route I: clockwise die + clockwise die (CD + CD)
Route II: clockwise die + counterclockwise die (CD + CCD)

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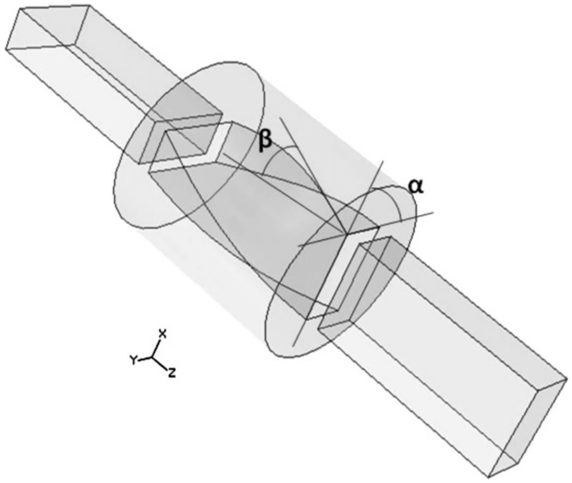

Fig. 1. Schematic of workpiece during the twist extrusion processing.

Table 1
Chemical composition of Al 8112 (at wt.%).

Al	Fe	Si	Mg	Cu	Zn	Cr	Ti	Mn	Other
96.03	0.90	0.86	0.73	0.44	0.43	0.26	0.23	0.11	Bal.

All of the TE passes were conducted at room temperature at a ram speed of 5 mm/s.

Previous experiments showed that the strain distribution within transverse cross-section was not homogeneous and the strain value increased by moving from the center towards the corners [11–13]. The maximum and minimum of the strain after one pass of TE can be calculated by the following equations [11,12]:

$$\varepsilon_{\min} \approx 0.4 + 0.1 \tan\beta \tag{1}$$

$$\varepsilon_{\max} \approx \frac{2}{\sqrt{3}} \tan\beta \tag{2}$$

where β is the slope angle. Thus, according to the heterogeneity of strain distribution, all of the microstructure and mechanical examinations were performed at the corners and center of plane ***A*** (*X*–*Y* plane marked in Fig. 2(a)). It is worthy to note that the microstructure investigation was not carried out at peripheral regions. For the purpose of microstructure investigation, the outer layer of the

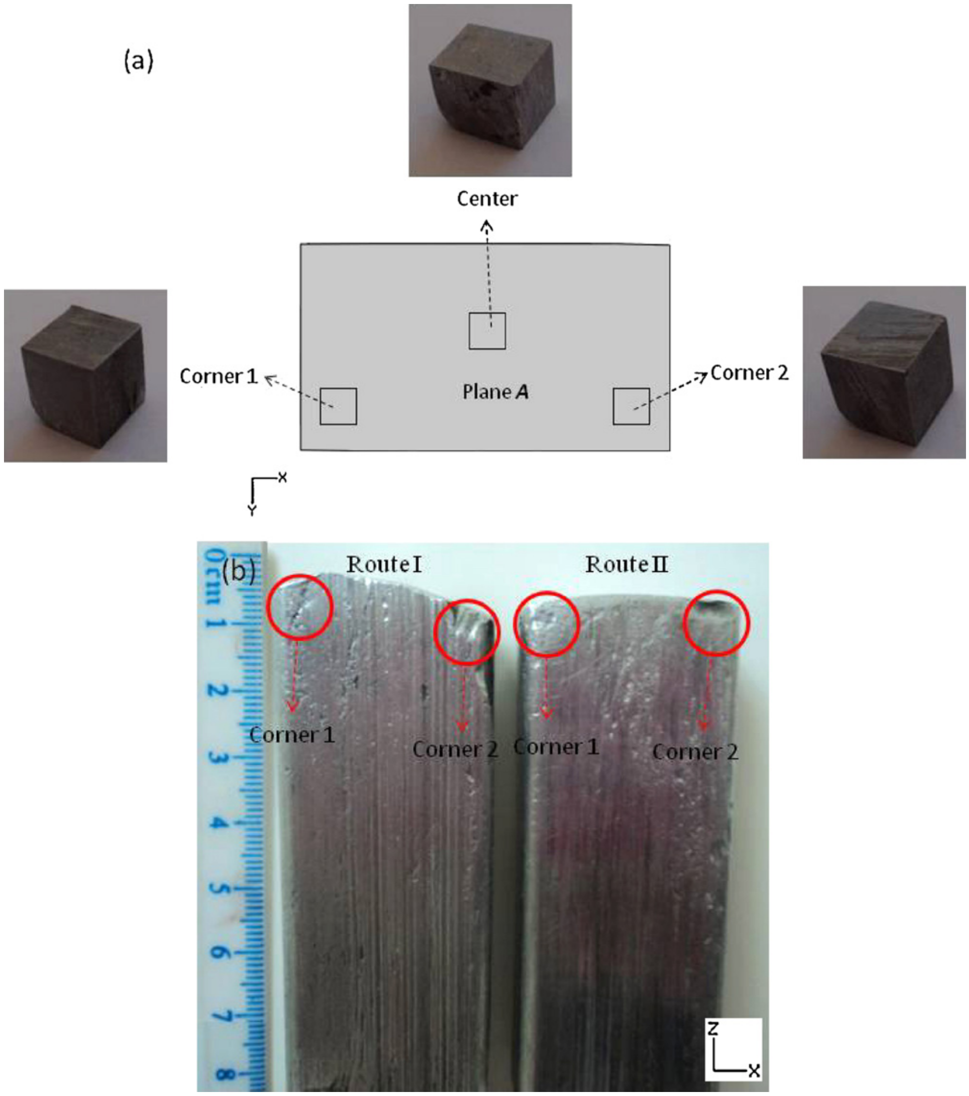

Fig. 2. (a) Partial discretized sample model with defined positions of the center, corners 1 and 2 on plane ***A*** (*X*–*Y* plane) with the schematic of the samples cutting from the billets at mentioned positions and (b) the positions of the two neighboring corners on workpieces.