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Influence of equal channel angular extrusion processing parameters on the microstructure and mechanical properties of Mg–Al–Y–Zn alloy

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ABSTRACT

An as-cast Mg–Al–Y–Zn alloy was successfully processed by equal channel angular extrusion (ECAE) in the temperature range of 225–400 °C, and the influences of processing temperature on the microstructure and mechanical properties were investigated. The use of back pressure during one-pass ECAE of Mg–Al–Y–Zn alloy was favorable for eliminating the undeformed area in the billet. At the processing temperature below 250 °C, the microstructures were characterized by unrecrystallised structure and the precipitated phase $Mg_{17}Al_{12}$ was elongated along the extrusion direction. With increasing processing temperature to 350 °C, a large number of recrystallised grains were obtained. Increasing processing temperature promoted workability but led to decrease in the strength of Mg–Al–Y–Zn alloy. Then billets of as-cast Mg–Al–Y–Zn alloy were extruded at different numbers of ECAE passes. It was found that the microstructure was effectively refined by ECAE and mechanical properties were improved with numbers of ECAE passes increasing from one-pass to four passes. However, strengths decreased slightly after five passes though the grain size decreased considerably.

1. Introduction

Magnesium alloys have received much attention in various engineering applications because of their low density, high specific strength and stiffness [1–4]. Therefore, research on magnesium alloys has become very active nowadays. The problem with Mg alloys that is to be addressed is the poor ductility, especially at room temperature [5]. Grain refinement is one of most important methods for improving ductility.

Equal channel angular extrusion (ECAE) can enhance the room temperature ductility of magnesium alloys dramatically by grain refinement [6]. Recently many researchers [7–10] were interested in applying the ECAE technique to magnesium alloys. Liu et al. [7] found that the strength of the two-phase alloy Mg–8%Li–1%Al was improved by increasing numbers of ECAE passes after ECAE. The ECAE process could only refine grains of each phase, but could not change the dispersion of the phases significantly. Kim et al. [8] found that the yield strength of the eight-pass ECAE formed AZ61 alloy was lower than that of the as-extruded AZ61 alloy. Tensile ductility increased after ECAE and the effect of ECAE on ductility was more remarkable when the initial grain size was larger. Tang et al. found [9] that one-pass ECAE at 200 °C and 350 °C led to grain refinement in the Mg–Zn–Y–Zr alloy through dynamic recrystallisation. ECAE at the higher temperature of 350 °C led to a larger average grain size than that at 200 °C. Ding et al. [10] found that the grain refinement process of the AZ31 magnesium alloy fabricated by ECAE was dynamic recrystallisation, which was different from that of face-centered cubic (FCC) metals. During extrusion, once dynamic recrystallisation was completed, the excessive numbers of extrusion passes exerted a little influence on grain refinement.

The aim of the present research is to determine the effect of processing temperature and numbers of ECAE passes on the microstructure and mechanical properties of Mg–Al–Y–Zn alloy. To reach this aim, an as-cast Mg–Al–Y–Zn alloy was subjected to one-pass ECAE at various processing temperatures. Furthermore, the alloy was also extruded at 250 °C for different numbers of ECAE passes.

2. Experimental procedure

The chemical composition of the as-cast alloy was in weight percent of 8.92Al, 1.18Zn, 0.09Mn and 1.76Y and the balance of Mg. The temperature of eutectic melting for the Mg–Al–Y–Zn–Mn alloy was obtained as 434 °C from a differential scanning calorimetry experiment at 2 °C min^{-1}. The ECAE process was conducted using a split die, fabricated from tool steel, having an internal angle of $\phi = 90°$ and an additional angle of $\psi = 90°$ at the outer arc of curvature where the two channels intersect. These

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