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Improving mechanical properties of ZM61 magnesium alloy by aging before extrusion

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ABSTRACT

The effect of aging treatment before extrusion on microstructure and mechanical properties of Mg-6Zn-1Mn alloy was investigated. Results showed that the existence of dispersive fine $MgZn_2$ particles before extrusion promoted dynamic recrystallization in subsequent extrusion process and leaded to fine microstructures (grain size 1~2 μm). The rod-shaped and plate-shaped precipitates in aged alloys transformed to fine and dispersed spherical precipitates after extrusion process. With aging and extrusion treatment, ZM61 alloy showed an outstanding tensile strength and elongation balance (YS 281 MPa, UTS 378 MPa and elongation 19.3%); compressive yield strength increased from 148 MPa to 259 MPa. The tension–compression yield asymmetry was reduced at the same time. The strengthening effect of aging treatment before extrusion in ZM61 alloy proved in this paper provided a new method for the design of relatively inexpensive high-performance magnesium alloys.

1. Introduction

As the lightest structure material, magnesium (Mg) alloys have excellent properties such as high specific strength, high specific stiffness, good castability and machinability, high damping capacity and good electromagnetic shielding [1–3]. With the increasing of fuel efficiency and decreasing of CO_2 emissions, these advantages make Mg alloys very attractive as structural materials in a wide variety of applications, especially in automobile industry. However, due to their poor mechanical properties, applications of Mg alloys have been limited to some extent. Although great efforts have been done, the mechanical properties of Mg alloys still can't satisfy the needs [4]. For the applications of Mg alloys, their mechanical properties should be further improved.

Conventional thermo-mechanical treatments, such as extrusion, rolling and forging, are effective techniques for improving the mechanical properties of Mg alloys through refining grains, eliminating cast defects and homogenizing microstructure [5]. Nonetheless, with the help of conventional thermo-mechanical equipment and processing, the mechanical properties of Mg alloys are still not satisfactory. Aging hardening is widely used in aluminium (Al) alloys and Mg alloys. However, aging treatment, the final strengthen step, improves strength at the expense of ductility which confines its application.

Some works have been done to reveal the influence of particles on the recrystallization behavior and microstructure evolution in Mg and Al alloys [5–10]. Robson et al. [7] reported that in Mg–Mn alloys precipitates did not represent the principal sites for nucleation of new grains during hot deformation, and the orientation gradient in the vicinity of coarse particles resulted in the occurrence of new high-angle grain boundaries (HAGBs) during deformation. They also found direct evidence that particle-stimulated nucleation (PSN) around large particles and small particles had a minor effect on dynamic recrystallization (DRX) [7,8]. Tong et al. suggested that the DRX could primarily take place in the region close to the coarse phases and then gradually enlarged into the interior of original Mg grains with further straining during extrusion [5]. Yu et al. found that in Mg-11Gd-4.5Y-1Nd-1.5Zn-0.5Zr the plate-like Mg_5RE precipitates that introduced in pre-ageing treatment could cause grain refinement through grain boundary

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pinning [9]. Previous studies by T. Al-Samman have reported the particles in the modified alloy resulted in new orientated grains, and the new orientations were different from the deformed orientation [10]. All of these precursory studies reveal that particles have an influence on DRX behavior and microstructure of Mg alloys.

Mg-6Zn-1Mn (ZM61) alloy is a cost-effective, high-strength and age hardenable wrought Mg alloy. Due to high zinc content in ZM61 alloy, it shows noticeable age-hardening response [11]. The age-hardening response of ZM61 alloy results from Mg-Zn intermetallic compounds. The metastable rod-shaped $\beta_1^{'}$ precipitates are the key age-hardening precipitates, while extensive precipitation of stable plate-shaped $\beta_2^{'}$ phase causes overaging [11–14]. Based on our previous work, after double aging treatment the yield strength and ultimate tensile strength of ZM61 ally can be 336 MPa and 366 MPa, respectively [15,16]. However, the elongation decreased sharply due to the aging treatment.

According to aforesaid work, the pre-existence of precipitates has an influence on microstructure in the subsequent thermo-mechanical process. Precipitates can either promote or suppress recrystallization depending on their size, spacing and fraction [7]. For aged ZM61 alloy, it contains high density nano-sized Mg-Zn precipitates. If these high density precipitates can improve

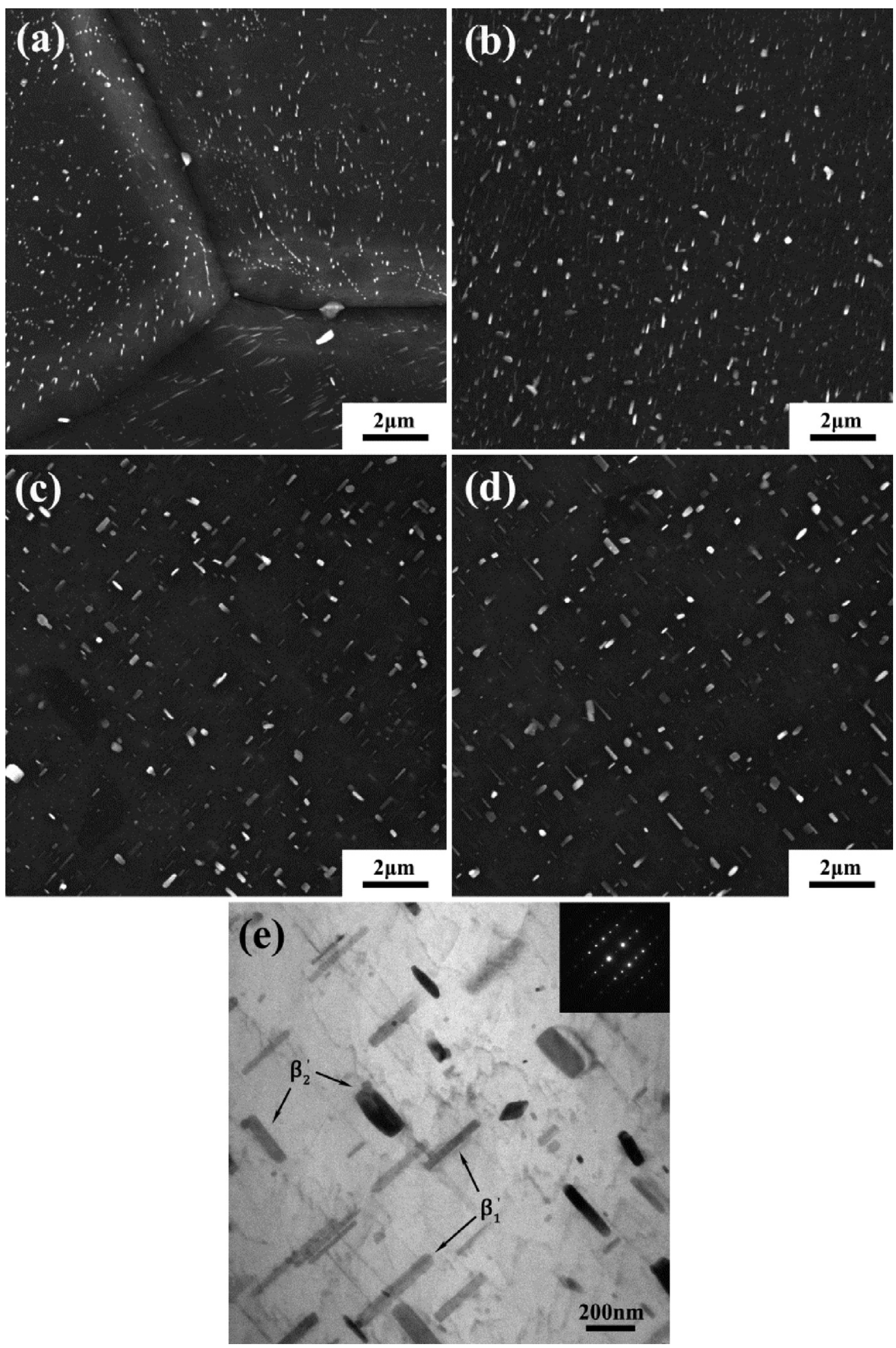

Fig. 1. Typical microstructures before extrusion: SEM micrographs of (a) 0h-aged alloy, (b) 6h-aged alloy, (c) 24h-aged alloy, (d) 48h-aged alloy and (e) bright field TEM image of 48h-aged alloy.