

Development of High Strength Mg Alloys

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ABSTRACT

Mg₉₆Zn₂Y₂ cast alloy is composed of an α -Mg phase, Mg₁₂ZnY phase and Mg₃Zn₃Y₂ phase. The coarse dendritic Mg grains have transformed into small cellular Mg grains with the addition of an increasing amount of Zr. Furthermore, increasing the cooling rate led to the precipitation of the fine Mg₃Zn₃Y₂ phase and the Mg₁₂ZnY phase forming a net-like structure. We found that this alloy has mechanical properties equivalent to those of commercial aluminum alloys with good tensile and fatigue properties at temperatures above 473 K.

INTRODUCTION

From an environmental point of view, Mg alloys are considered promising as an ecological material because of their lightweight and high specific strength properties. Recently, Mg cast alloys with good mechanical strength have been developed in Mg-RE-Zn systems (where RE represents rare earth element). However, castings of Mg alloy products are still restricted to a few chassis components because of their low strength compared to commercial Al alloys. In this work, the effects of Zr addition and cooling rate on microstructures and mechanical properties of Mg₉₆Zn₂Y₂ (at. %) alloy are investigated in order to develop Mg cast alloys with high strength and heat-resistance.

EXPERIMENTAL PROCEDURE

Mg-Zn-Y alloys were melted by high-frequency induction melting using a graphite crucible under an argon atmosphere, and then cast into two kinds of copper dies (32 mm D x 140 mm L and step-like die shown in figure 1). The microstructure of the cast alloy was investigated by X-ray diffraction (XRD), scanning electron microscopy

(SEM) and transmission electron microscopy (TEM). Orientation image mapping (OIM) was observed using electron back scattering diffraction (EBSD), where sample preparations were made using a cross-sectional polisher. Tensile tests were performed with strain rates of $5 \times 10^{-4} \text{ s}^{-1}$ at room temperature, 473 K and 523 K. The dimensions of tensile specimens were 2.0 mm in thickness, 4.0 mm in width and 4.0 mm in length. The strain was measured with an electrical strain gauge. Elevated tensile specimens were soaked at testing temperatures for 30 min, prior to the tests. Tension compression fatigue tests were performed with a stress ratio of -1 at 473 K. The dimensions of tension compression fatigue specimens were 2.0 mm in thickness, 4.0 mm in width and 4.0 mm in length. Rockwell hardness (HRB) was measured with the load of 980 N.

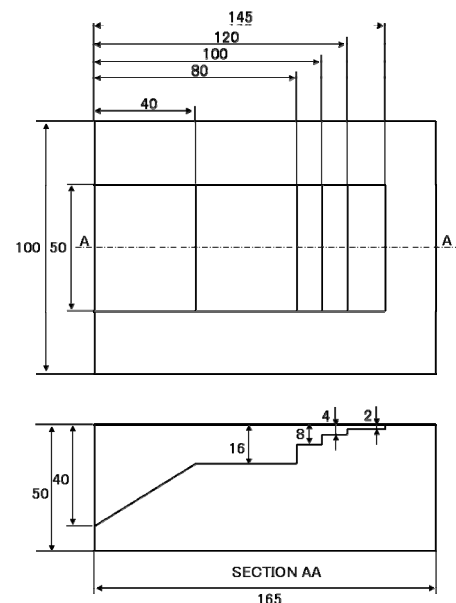


Figure 1 Dimensions of step-like die [mm].

RESULTS AND DISCUSSION

It is well known that Zr is effective in improving the microstructure of Mg-Zn-RE alloys [1]. In order to investigate the effect of Zr addition on microstructures of the $Mg_{96}Zn_2Y_2$ alloy, $Mg_{96}Zn_2Y_2$ and $Mg_{95.8}Zn_2Y_2Zr_{0.2}$ alloys (32 mm D) were prepared. Figure 2 shows XRD patterns of $Mg_{96}Zn_2Y_2$ and $Mg_{95.8}Zn_2Y_2Zr_{0.2}$ alloys. $Mg_{96}Zn_2Y_2$ and $Mg_{95.8}Zn_2Y_2Zr_{0.2}$ alloys consisted mainly of an α -Mg phase, $Mg_{12}ZnY$ phase and $Mg_3Zn_3Y_2$ phase. There was no structural difference in the Zr contents.

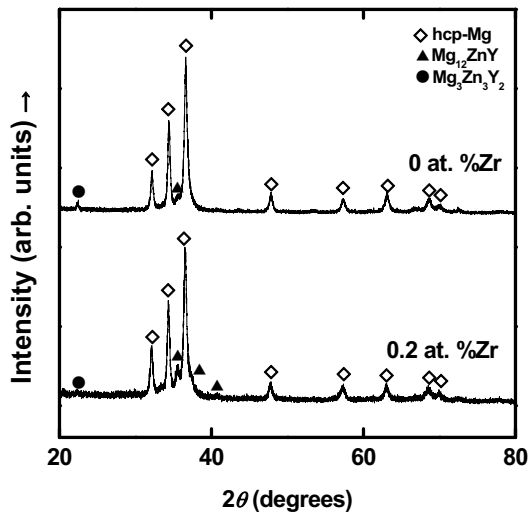


Figure 2 XRD patterns of $Mg_{96}Zn_2Y_2$ and $Mg_{95.8}Zn_2Y_2Zr_{0.2}$ alloys.

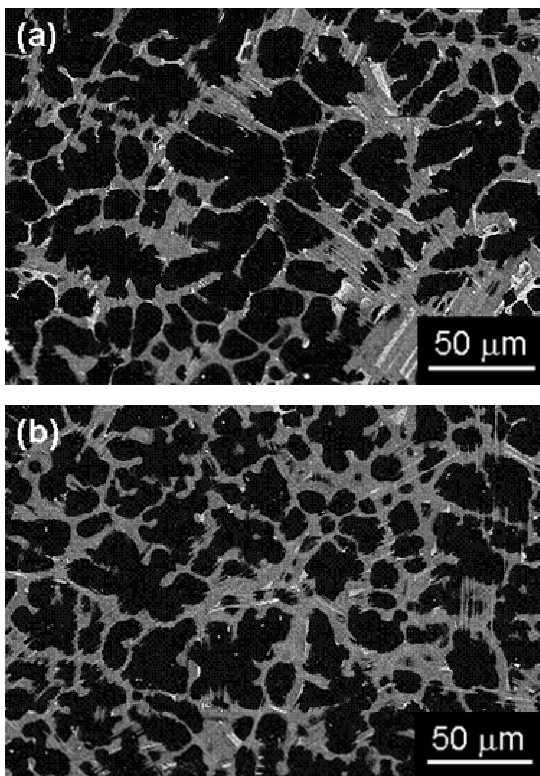


Figure 3 BSE-SEM images of (a) $Mg_{96}Zn_2Y_2$ and (b) $Mg_{95.8}Zn_2Y_2Zr_{0.2}$ alloys.

Figure 3 shows backscattered electron (BSE)-SEM images of the (a) $Mg_{96}Zn_2Y_2$ and (b) $Mg_{95.8}Zn_2Y_2Zr_{0.2}$ alloys. According to the literature [2], gray and white contrasts in BSE images are considered to be $Mg_{12}ZnY$ phase and $Mg_3Zn_3Y_2$ phase, respectively. It can be seen in figure 3(a) that the $Mg_{96}Zn_2Y_2$ alloy has coarse dendritic Mg grains. Figure 4(a) shows a TEM image of the $Mg_{96}Zn_2Y_2$ alloy. Black and white contrasts in this image correspond to $Mg_3Zn_3Y_2$ phases and α -Mg. $Mg_3Zn_3Y_2$ phases and α -Mg grains are assumed coarse pearlitic configurations. After only 0.2at% Zr was added, the microstructure of the alloy apparently changed. In figure 3(b) it can be seen that the coarse dendritic Mg grains have transformed into small cellular Mg grains. Figure 4(b) shows a TEM image of the $Mg_{95.8}Zn_2Y_2Zr_{0.2}$ alloy. Coarse pearlitic $Mg_3Zn_3Y_2$ phases have changed into small rod-shaped $Mg_3Zn_3Y_2$ phases by adding 0.2 at. % Zr. In order to investigate Mg grain sizes in $Mg_{96}Zn_2Y_2$ and $Mg_{95.8}Zn_2Y_2Zr_{0.2}$ alloys, EBSD was conducted. Figures 5(a) and 5(b) show OIMs obtained from $Mg_{96}Zn_2Y_2$ and $Mg_{95.8}Zn_2Y_2Zr_{0.2}$ alloys. Each color in this image designates the crystallographic orientation according to the color key of the unit triangle (figure 5(c)). In these figures, the areas of black or irregular aggregation of dots with various colors correspond to the regions where the OIM system could not analyze their diffraction patterns, which indicates that the areas should consist of $Mg_{12}ZnY$ phase and $Mg_3Zn_3Y_2$ phase.

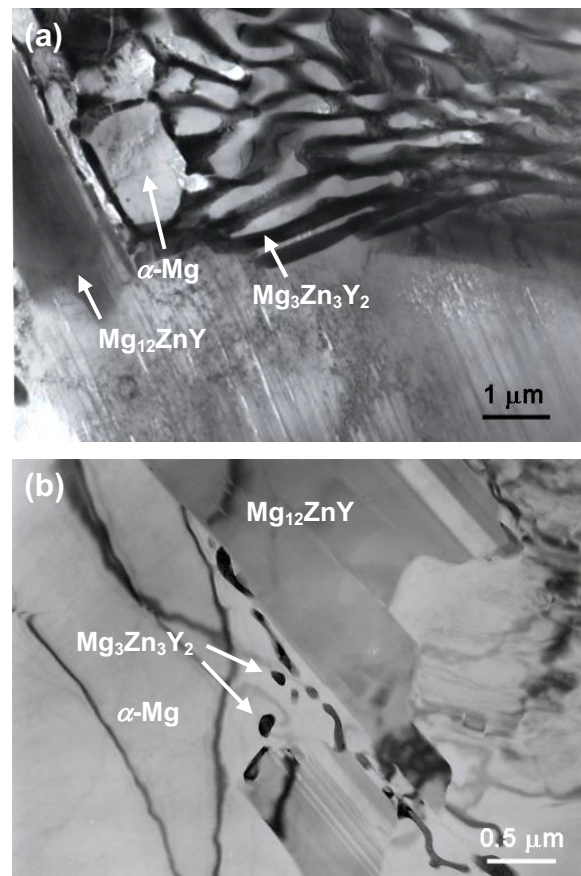


Figure 4 TEM images of (a) $Mg_{96}Zn_2Y_2$ and (b) $Mg_{95.8}Zn_2Y_2Zr_{0.2}$ alloys.