Microstructures and Mechanical Properties of Consolidated Mg-Zn-Y Alloy

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Abstract

The microstructure and mechanical properties of the $Mg_{97}Zn_1Y_2$ alloy prepared by spark plasma sintering of gas atomized powders have been investigated. After consolidation, precipitates were observed to form in the α-Mg solid solution matrix of the $Mg_{97}Zn_1Y_2$ alloy. These precipitates consisted of $Mg_{12}YZn$ and $Mg_{24}Y_5$ phases. The density of the consolidated bulk Mg-Zn-Y alloy was 1.86 g/cm^3. The ultimate tensile strength and elongation were dependent on the consolidation temperature, which were in the ranges of 280 to 293 MPa and 8.5 to 20.8 %, respectively.

Keywords : Mg-Zn-Y, consolidation, powder, spark plasma sintering

1. Introduction

Mg-based alloys have attracted as much attention as lightweight materials because of their low density, high specific strength and stiffness. So far, great efforts have been made to develop the Mg-based alloys with high strength and sufficient ductility for the application in the engineering field [1]. Rapid solidification is one of the ways to further improve mechanical properties compared to conventional Mg-based alloys, due to its effectiveness in the modification of microstructure such as refinement of grain size, reduction of segregation and increase in solid solubility [2]. Rapidly solidified Mg-based alloys have been found to exhibit the good mechanical property [3], which is not generally observed in conventional Mg-based alloys. Recently, it has been reported that the rapidly solidified Mg-Zn-Y alloys by a closed powder metallurgy exhibit high strength and good ductility [4,5].

In this study, we report the microstructure and mechanical properties of the consolidated Mg-Zn-Y alloys. The Mg-Zn-Y alloy powders were prepared using an industrial scale gas atomizer and consolidated into bulk materials by spark plasma sintering.

2. Experimental and Results

$Mg_{97}Zn_1Y_2$ alloy powders produced by high pressure gas atomization process were used as starting materials. The details of the atomization processing procedures have been given elsewhere [4]. The sizes of the gas atomized powder used in this study are smaller than 63 μm, as shown in Fig. 1. The $Mg_{97}Zn_1Y_2$ powders show near spherical morphology with a smooth surface. Occasionally, fine satellite particles were present on the surface of powders. The powders were pre-compacted, and then consolidated to form the disc-shape samples with 20 mm in diameter and 5 mm in thickness using SPS method. The SPS process was performed under applied pressure of 300 MPa for 600 s and temperatures ranging from 673 to 773 K.

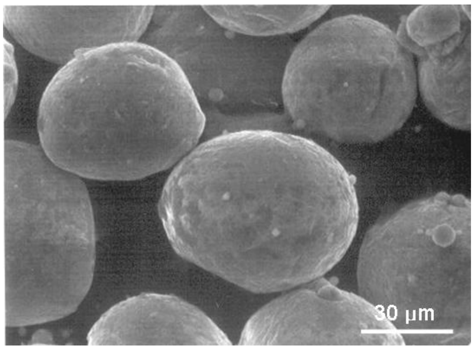

Fig. 1. SEM images of the $Mg_{97}Zn_1Y_2$ powders.

Fig. 2 shows SEM micrograph of the polished cross section of the $Mg_{97}Zn_1Y_2$ alloy consolidated at 698 K for 600 s. No defect such as pores and cavities was observed at the interface between the powders, suggesting that the SPS process caused a sound plastic deformation of the powders at the experimental conditions, expecting the almost full densification. The density of this consolidated $Mg_{97}Zn_1Y_2$ alloy was measured as 1.86 g/cm^3, which is higher than that of as-extruded $Mg_{97}Zn_1Y_2$ alloy [4]. The average Vickers hardness of the consolidated material was about 105 Hv similar to that of as rapidly solidified $Mg_{97}Zn_1Y_2$ alloy ribbons [5]. Increasing the sintering temperature at the same loading time, the density of the samples was increased.

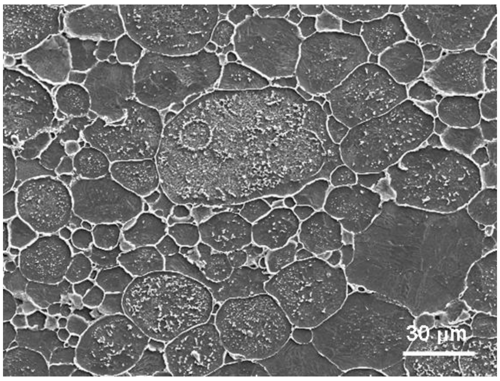

Fig. 2. SEM images of the consolidated $Mg_{97}Zn_1Y_2$ alloy.

Fig. 3 shows XRD patterns obtained from of the $Mg_{97}Zn_1Y_2$ alloy consolidated with the temperatures of 673, 723 and 773 K. Precipitation of a cubic $Mg_{24}Y_5$ phase occurred during the consolidation process by spark plasma sintering, which was not observed in the atomized $Mg_{97}Zn_1Y_2$ alloy powders. The intensity of diffraction peaks from the $Mg_{12}YZn$ phases became weaker with increasing the consolidation temperatures.

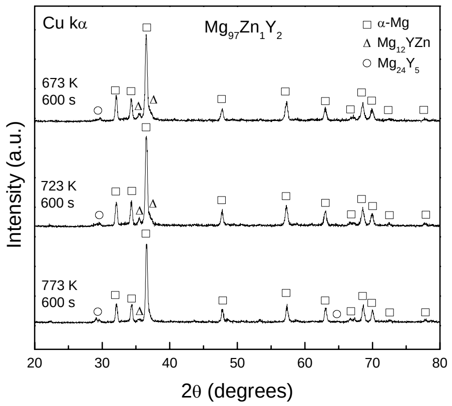

Fig. 3. XRD patterns of the consolidated $Mg_{97}Zn_1Y_2$ alloys.

Typical stress-strain curves of the consolidated $Mg_{97}Zn_1Y_2$ alloys tested at room temperature under a constant cross-head speed condition of an initial strain rate of 10^{-3} s^{-1} are shown in Fig. 4. The 0.2% yield stress ($\sigma_{0.2}$), ultimate tensile strength (UTS) and elongation to failure for the $Mg_{97}Zn_1Y_2$ alloy consolidated at 723 K for 600 s are 245 MPa, 293 MPa and 16.8 %, respectively. With increasing the consolidation temperature, the level of elongation increased, although the level of strength slightly decreased, which can be explained based on the good interparticle bonding of powders and grain growth, respectively. This result shows that good ductility can be obtained by spark plasma sintering process, suggesting that SPS process accelerates a flow deformation of the Mg-Zn-Y powders during the consolidation.

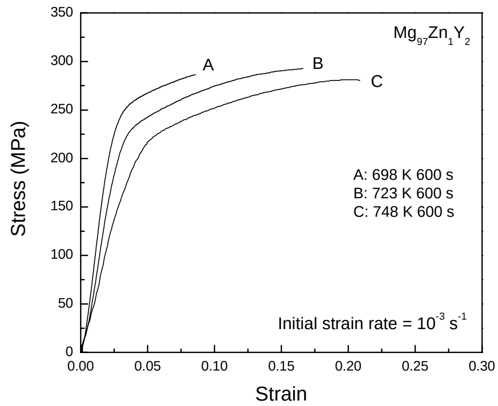

Fig. 4. Stress-strain curves of the $Mg_{97}Zn_1Y_2$ alloys consolidated at different temperatures.

3. Summary

The $Mg_{97}Zn_1Y_2$ alloy has been successfully consolidated by spark plasma sintering of gas-atomized powders. The consolidated $Mg_{97}Zn_1Y_2$ alloy was made up of supersaturated α-Mg solid solution, $Mg_{12}YZn$ and $Mg_{24}Y_5$ phases. Ultimate tensile strength and elongation to failure were in the ranges of 280 to 293 MPa and 8.5 to 20.8 %, respectively, which were dependent on the consolidation temperatures.

4. References

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