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CONSOLIDATION OF GAS ATOMIZED Mg ALLOY POWDERS

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Abstract. This work is to investigate the extrusion behavior of $MgZn_{4.3}Y_{0.7}$ alloy powders prepared by gas atomization, a rapid solidification process (RSP). In order to modify the intrinsic poor mechanical properties of Mg alloys, we combine the effect of composition and process. As the extrusion ratio increases from 10:1 to 15:1, the powders have better deformed plastically, and the mechanical properties such as tensile strength and elongation were increased.

1. INTRODUCTION

Mg alloys stand on the center of investigation due to their high potential of industrial application structurally as well as functionally, corresponding to the low density and abundance [1]. However, the intrinsic low strength and corrosion resistance have limited to extend the application area of Mg alloys. Among a lot of attempts to modify the disadvantages, an addition of rare earth elements to the Mg was reported to improve the strength remarkably [2]. For example, Mg-Zn-Y alloy presents high strength and hardness, low friction coefficient and low interfacial energy in both the ambient and elevated temperature, as the result of a homogeneous distribution of metastable icosahedral phase (I-phase) in the Mg phase [3].

However, the progress has rarely been reported to improve the properties further. Thus, it is necessary to identify whether the rapid solidification (RS) is effective to improve the properties of the cast Mg-Zn-Y alloys or not, since RS is known to enhance the mechanical properties corresponding to the microstructural refinement. In addition, a recent advance in RS powder metallurgy (PM) technique regards as a promising alternative in overcoming the drawback of cast alloy, but also the low productive and complicated procedure of melt spinning commonly used [4]. In this investigation, we report the material property of flammable $MgZn_{4.3}Y_{0.7}$ alloy powders prepared via the gas atomization. Variation of microstructure and mechanical properties of the extruded powder bars were studied as a function of extrusion ratio.

2. EXPERIMENTAL

$MgZn_{4.3}Y_{0.7}$ alloy powders were fabricated using a high pressure gas atomizer constructed by a boron nitride melt delivery nozzle of 5 mm in diameter and an annular Ar gas nozzle. The melt flow rate, as estimated from operating time and weight of atomized melt was about 1.0 kg/min., while the gas pressure was about 5 MPa. The powders were canned and degassed at 500K for 20 min, followed by extrusion at 300K with an external pressure 280 MPa under an area reduction ratio upto 15:1.

The structure of the atomized powder and its extruded bars was characterized using a Philips 1729 X-ray diffractometer (XRD) with monochromatic CuK_α radiation over 2θ range of 20-80°. The microstructure was examined by optical microscopy

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(OM ; Simazu) and scanning electron microscopy (SEM; JSM 5410). Tensile strength and elongation of extruded bar were measured at room temperature using Instron type machine.

3. RESULTS AND DISCUSSION

The average size distribution of gas atomized $MgZn_{4.3}Y_{0.7}$ alloy powders were about 55 μm in diameter. The shape of powders as atomized was almost spherical with no severe change with the variation of initial powder size (Fig. 1a). The powders of 46~63 μm consist of grains of about 3 μm in diameter (Fig. 1b). On the other hand, the powders belonging to the range of 64~90 μm and ~33 μm contain the grains of about 4~5 μm and 2 μm, respectively. The variation of grain size with the initial powder sizes occurs due to the difference in solidification rate, in which the finer the size of powders, the quicker the cooling rate. The alloy powders are identified to consist of I-phases (Icosahedral, $Mg_3Zn_6Y_1$) and very small fraction of W-phases (Cubic, $Mg_3Zn_3Y_2$) by XRD. It is known that embedding both the phases is an effective way to lower the coefficient of friction and interfacial energy, to enhance the corrosion resistance and thermal stability, and to improve the strength and hardness, simultaneously [3]. It also affects to increase the high temperature strength and to delay the onset of overaging [5].

Fig. 1c is an Auger electron trace of Mg alloy powder, which is to identify the thickness of oxide formed along the surfaces. It is necessary for the Mg alloy powders to form the magnesium oxide film intentionally on the surface of powders, inhibiting the easy reaction of Mg or Mg alloys with oxygen. In order to measure the depth of oxide layer, the atomized powders were etched from the surfaces using Ar gas. The etching rate was 0.47 nm/s. As the depth of sputtering increases, the atomic concentration of oxygen reduces, whereas the Mg becomes rich, (Fig. 1c). Considering the error range of 10% for the Auger detection, the thickness of Mg oxide measured to be about 48 nm. The thickness of oxide layer is almost same with the initial powder size distribution.

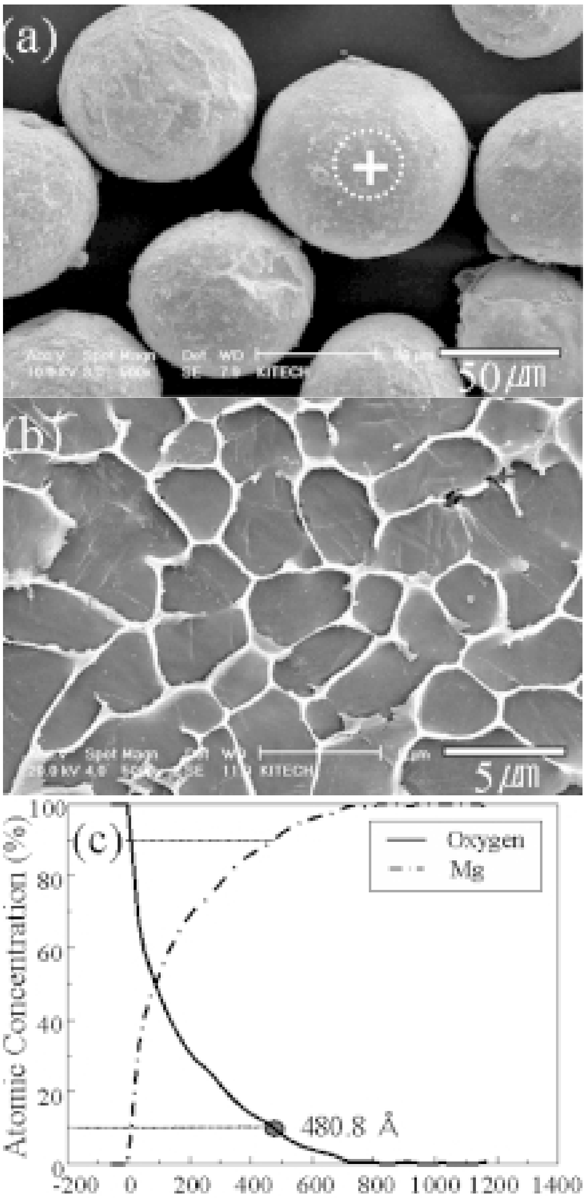

Fig. 1. Morphology (a), microstructure (b) and Auger electron traces (c) of rapidly solidified $MgZn_{4.3}Y_{0.7}$ alloy powders.

Fig. 2 shows the stress-strain curve of the extruded Mg alloy powder bars with the extrusion ratio of 10:1 and 15:1. The fracture strength and strain of the bar extruded with 10:1 are about 280 MPa and 3%, respectively. Both the properties are improved to about 325 MPa and 16%, respectively, as the extrusion ratio increases to 15:1. In order to identify reason of the improvement with the extrusion ratio, the microstructural observation is performed as seen in Fig. 3. The bar extruded with 10:1 shows a distribution of many raw powders without or with a little deformation. The powders undeformed may impede the plastic deformation of other powders. The poor deformation can be, however, remarkably modified by increasing the extrusion ratio to 15:1 (Fig. 3b), although a small fraction of initial powders undeformed are found to remain. To sum up, the increase of strength and

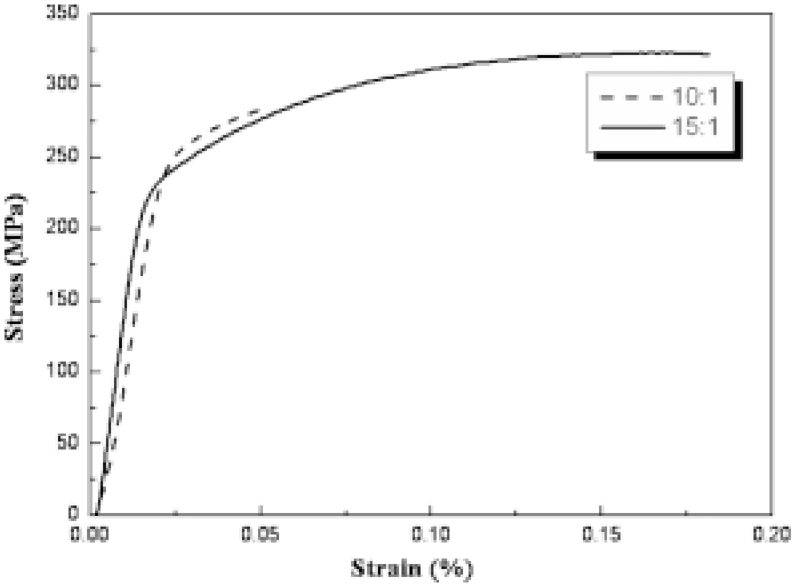

Fig. 2. Tensile curves of extruded Mg alloy powder bars with the extrusion ratio of 10:1 and 15:1.

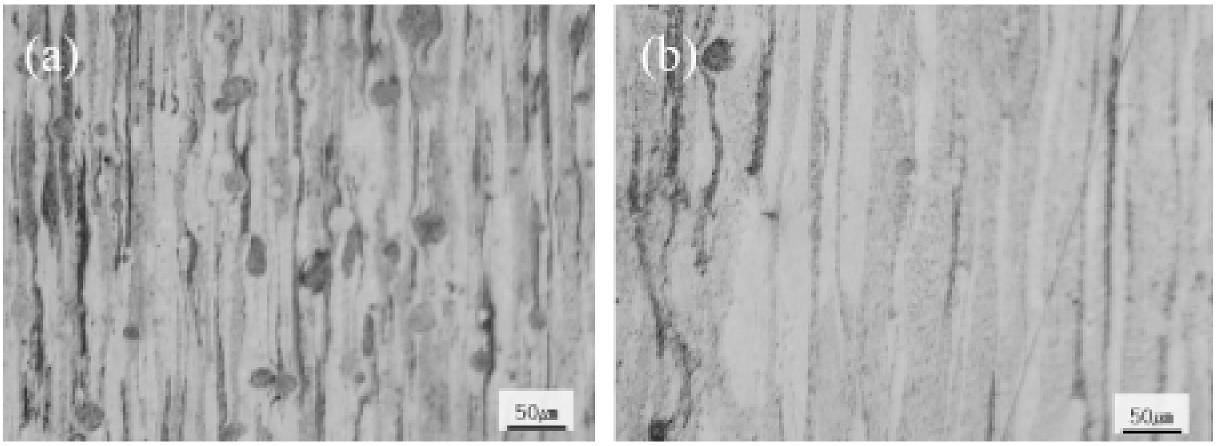

Fig. 3. Micrographs of atomized and extruded Mg alloy bars with the extrusion ratio of 10:1 (a) and 15:1.

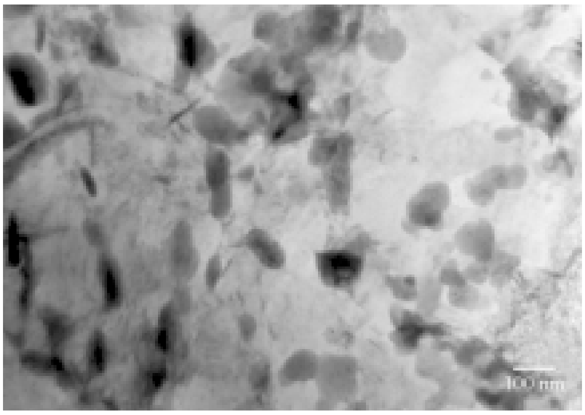

Fig. 4. TEM microstructure of rapidly solidified and extruded $MgZn_{4.3}Y_{0.7}$ alloy bars with the extrusion ratio of 15:1.

elongation with extrusion ratio is due to obtaining the homogeneously and near-completely deformed microstructure. Furthermore, better properties are expected to obtain by raising the extrusion ratio more than 15:1.

Fig. 4 is to identify the microstructure of rapidly solidified and extruded $MgZn_{4.3}Y_{0.7}$ alloy bars with the extrusion ratio of 15:1 using TEM. It is seen that the alloy bar consists of relatively round shape I phase particles less than 100 nm in diameter embedded in the Mg matrix having the sub grains of about 300 nm. The phases formed on the Mg base alloys were reported as a function of Zn/Y ratio by Singh *et al*. [5]. When Zn/Y ratio is in the range of 5~7, I phase would be formed in α-Mg matrix. If Zn/Y ratio increases, it forms I + W phases in α-Mg, and further results in only W phases distribution. This supports that the I-phases forms in the $MgZn_{4.3}Y_{0.7}$ alloy powders and its bars, since it has the Zn/Y ratio of 6.1.

4. CONCLUSION

$MgZn_{4.3}Y_{0.7}$ alloy powders atomized using an industrial scale gas atomizer presented almost spherical morphology, and the mean powder sizes accumulated were about 55 μm in diameter. The magnesium oxide layer formed on the Mg alloy surface has the thickness of about 48 nm. The grain size varied within 2~5 μm with the initial powder sizes. The as solidified powders consist of icosahedral (I-) phases with a small fraction of cubic W phases embedded in the α-Mg matrix. Both the strength and elongation were improved with increasing the extrusion ratio due to the increase in the plastic deformation. The alloy bar consists of round shape particles less than 100 nm in diameter embedded in the Mg matrix having the sub grains of about 300 nm.

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