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Room temperature mechanical properties of Mg–Cu–Al alloys synthesized using powder metallurgy method

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ABSTRACT

Conventional powder metallurgy method was used to fabricate Mg–1Cu–*x*Al ($x=1$ wt%, 3 wt%, 6 wt%, 9 wt%) alloys to study the influence of copper and aluminum on mechanical behavior of pure magnesium. Microstructural evaluation revealed the presence of $Mg_{17}Al_{12}$ and Mg_2Cu intermetallic phases in synthesized alloys. Experimental results exhibited that the increase in aluminum content lead to increase in Vickers hardness, 0.2% yield strength and ultimate strength (both in tension and compression). The tensile failure strain of alloys increases till the threshold of 3 wt% Al is reached. The decline in failure strain for the alloys containing higher wt% Al contents (i.e., 6 and 9 wt% Al), might be attributed to the formation of brittle intermetallic phase $Mg_{17}Al_{12}$.

1. Introduction

Among all metals, magnesium is one of the lightest structural metal with a density of 1.74 g/cm^3. Magnesium alloys and composites have been developed as an advanced engineering material in aerospace and automotive industries due to their high specific strength, good ductility, high damping properties and good machinability [1–8]. In addition, commercially available magnesium alloys (AZ31, AZ61 and AZ91) and several new alloys such as Mg–Sn [9,10] Mg–Zn–Ca [11,12] and Mg–Al–Ca [13] alloys, have been extensively investigated for their high mechanical properties. Most of magnesium alloys were synthesized using stir casting technique. Application of metallic copper reinforcement for the magnesium matrix is found very limited in the literature. To best of our knowledge, there are only few reports about copper reinforced magnesium alloys. Hassan et al. [14] prepared magnesium–copper alloys using disintegrated melt deposition and hot extrusion techniques. Experimental results revealed that microhardness and tensile strength were improved with an adverse effect on ductility. In another report, for the magnesium matrix reinforced with metallic element copper [15], the results for mechanical properties indicated increase in hardness and tensile strength.

It was found that selection of inclusions and fabrication techniques are important factors which greatly influence the properties of resulting materials [16–18]. Most of magnesium based materials are synthesized using squeeze casting [19,20] and stir casting methods [1]. Powder metallurgy technique is commonly used to fabricate magnesium based composites [21]. Main advantage of powder metallurgy method is that we can mix any kind of materials despite of their wettability with matrix particles. This method involves mechanical blending, compaction, solidification and hot extrusion. Ball milling is commonly used for mechanical blending of composite/alloy powders. Since ignition temperature of magnesium powder is very low, therefore ball milling is not safe technique. In present work, alloying powders were blended using mechanical agitator in ethanol which is safe and green technique.

In the present work, the aim is to improve the mechanical strength of pure Mg by incorporating micron-size Al–Cu particles. The hot extruded magnesium alloys are investigated for their structural and mechanical properties. Presence of Al particles improve the copper's compatibility with Mg matrix, thus leading to simultaneous increase in tensile strength and ductility.

2. Experimental procedures

2.1. Processing

The magnesium powder (with 99.5% purity and 100 μm particle size) supplied by Shanghai Customs Golden Powder Material

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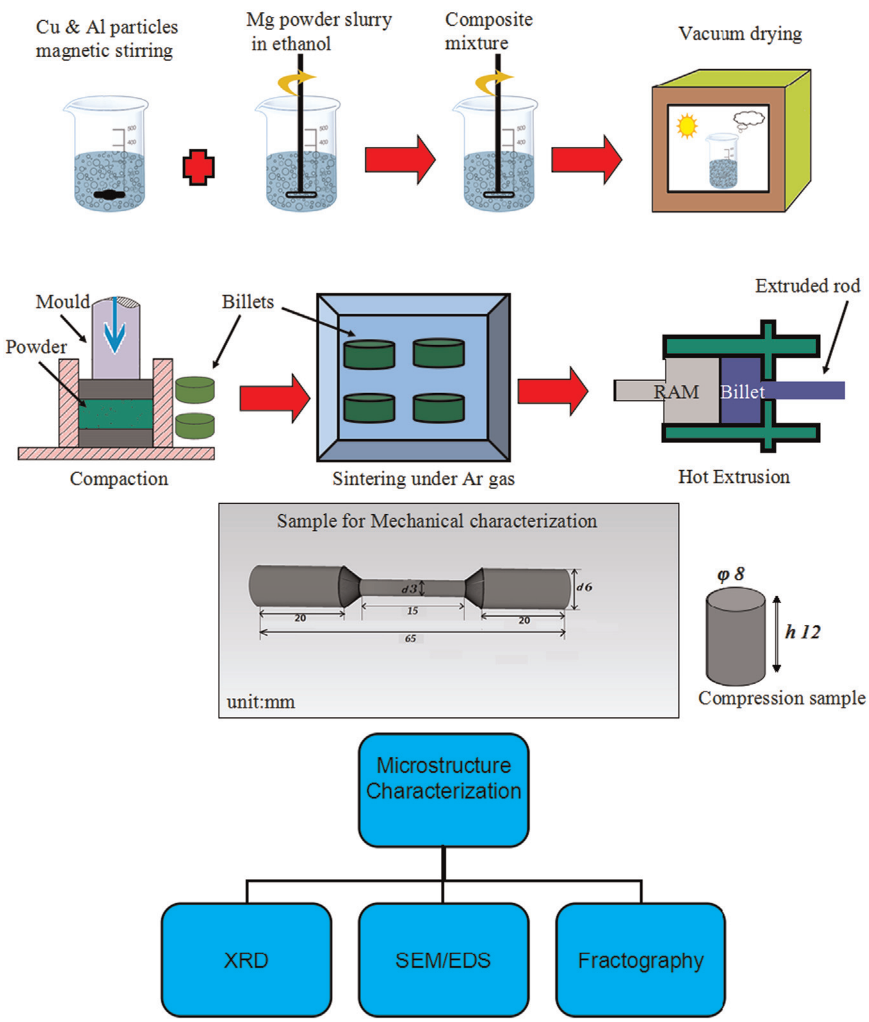

Fig. 1. Flowchart of semi-powder metallurgy method.

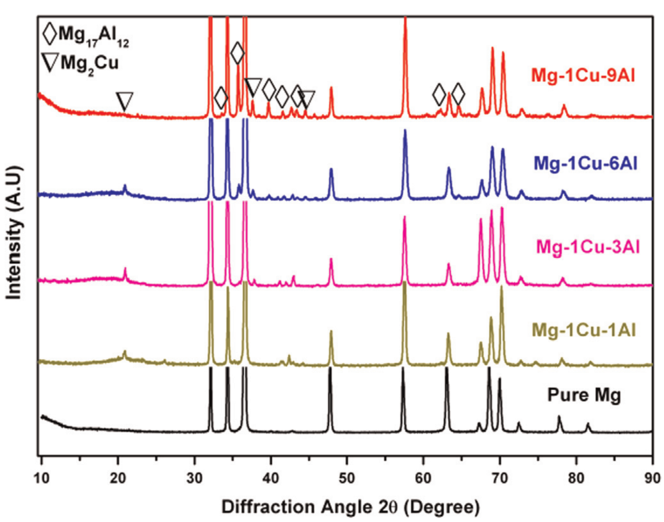

Fig. 2. X-ray diffraction spectra of pure Mg and its alloys conducted on extruded samples.

Co. Ltd. China, was used as matrix material. Aluminum and copper powders (with 99.3% purity and average particle size of 35 μm) were supplied by Tianjin Guangfu Fine Chemical Research Institute, China. In traditional powder metallurgy method, ball milling is commonly used to mix the constituent powders. Many processing factors, such as ball to powder ratio, time, speed etc., affect the properties of the resulting materials. The production of heat during grinding of the powders is the main disadvantage of ball milling technique. Therefore, explosive materials are somewhat difficult to mix using ball milling technique. In present work, a simple strategy is adopted to mix the highly explosive magnesium powder by the semi-powder metallurgy method. In semi-powder method, constituent powders are mixed in non-reactive solvent instead of ball milling, as shown in Fig. 1 [22–24].

The magnesium powder slurry was prepared in ethanol using mechanical agitator. At the same time, Al and Cu powders were magnetically stirred in ethanol. After 30 min, Al–Cu particles dispersion was added drop wise into the magnesium slurry in ethanol. The mixing process was carried out for 1 h using mechanical agitator at 2000 RPM. The mechanical agitated mixture was filtered and vacuum dried at 80 °C to obtain the Mg–Al–Cu powders. For comparison pure magnesium was also processed following the same procedure. The mixture powders were compacted in a steel mold under 600 MPa pressure to make compacts of 40 mm height and 80 mm diameter. The compacts were consolidated in a box furnace for 3 h at 630 °C under Ar gas atmosphere. In order to reduce the porosity, the sintered compacts were buried in graphite powder and heated to a temperature of 350 °C for 90 min and finally hot extruded at the speed of 1 m/min. Extrusion ratio was set at 5:1. The diameters of extruded rods were 16 mm.