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The Effect of Space Holder Content and Sintering Temperature of Magnesium Foam on Microstructural and Properties Prepared by Sintering Dissolution Process (SDP) using Carbamide Space Holder

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Abstract

Magnesium foam has gained a significant interest in structural application due to low density and greater strength than aluminium foam. In this study, magnesium foam was produced by sintering dissolution process (SDP) using spherical carbamide as the space holder. Magnesium foam was prepared using SDP at sintering temperatures (600˚C, 630˚C, 650˚C) and carbamide composition (30 wt.%, 50 wt.%, and 70 wt.%). The foams produced were characterized for morphology, density, porosity and compressive strength. Porosity of the magnesium foam increased with increasing amount of space holder at all the sintering temperatures while the density showed the reversed trend. Magnesium foam with 50 wt.% carbamide at all the sintering temperatures showed the acceptable range of density and porosity for energy absorbent which are in the range of 0.57-0.61 g/cm^3 and 64.7-67.3%. Magnesium foam with 50 wt.% carbamide at sintering temperature of 630˚C has density, porosity and compressive strength of 0.61 g/cm^3, 64.7% and 5 MPa.

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Keywords: Magnesium foam, mechanical properties, powder metallurgy, carbamide, sintering dissolution process

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1. Introduction

Porous material is a type structure and functional material that have better properties than solid materials. Magnesium foam and magnesium alloy foam have recently been studied for use in many applications, such as in the automotive and aerospace industries because of their low densities that provide opportunities for weight reduction. Magnesium metal has a lot of advantages, such as specific strength, stiffness, high modulus elastic, good defense noise and excellent vibration reducing performance. The density of pure magnesium is 1.74 g/cm3, which is the lightest metal in industrial applications [1]. Magnesium foam can be prepared by several methods, such as powder metallurgy [2], melt foaming agent [3], and melt gas injection [4]. Among the method, powder metallurgy was widely used to produce magnesium foam using natrium chloride, ammonium bicarbonate or carbamide as the space holder. Aghion and Perez [5] have produced Mg foams using NaCl as a space holder. In addition, Jaroslav and Vojtech [6] also have successfully produced Mg foams using ammonium bicarbonate as the space holder. Moreover, Wen et al. [7] and Hao et al. [8] have produced Mg foams using carbamide as space holder. They studied the variation size of carbamide on property of magnesium foam. It has been also reported that processing parameters such as cell size [9], sintering time [10], and temperature [11], solid [12] or liquid phase sintering [13], and employing reinforcement (e.g. Y_2O_3 or Al_2O_3) [14] have significant effects on mechanical properties of foams. Thus, the present work was attempt to study the effect of carbamide composition and sintering temperatures on microstructural and properties of magnesium foam produced by powder metallurgy method.

2. Experimental procedures

Magnesium powder with a purity of 99% and a mean diameter of <44μm was used as the parent material and the carbamide particles ($CO(NH_2)_2$) of rounded shape with size of 2.00-2.20 mm was used as space holder. In order to study the size and quantity of pore in the final foam, the carbamide powder was used in the composition of: 30 wt.%, 50 wt.% and 70 wt.%. The fabrication process consisted of four stages, i.e., mixing, compacting, dissolution and sintering, in which the sintering stage was divided into two steps. The processing in details was described as follows.

Firstly the magnesium powder and carbamide were mixed using a bottle mill for 1 hr. Ethanol (2 vol.%) was sprinkled on the carbamide particle to ensure homogeneity during mixing process.. The composition of mixture powder is listed in Table 1. Then the mixture was compacted in a die with diameter 13 mm at a given pressure of 300 MPa and kept for 2 min to form green compact. The third stage is to remove the carbamides in the green compact. The green compact was immersed in the distilled water for 2 hrs at room temperature. The final sintering operation was performed using a tube furnace under an atmosphere of high-purity argon at 250°C for 3 hrs to remove the carbamide residual by melting/decomposing of the carbamide, then followed by sintering at 3 different temperatures (600°C, 630°C, 650°C) for 2.5 hrs to reach metallurgical bonding among the Mg powder. The foams produced were characterized for morphology, density, porosity and compressive strength.

The morphology and average pore size of the magnesium foam was analyzed using stereo zoom microscope Kunoh Robo. The density of the foam was measured by fluid displacement method based on Archimedes principal. The density and porosity of the magnesium foam were calculated based on Equations 1 and 2 [15]:

$$\text{Foam density, } p_f = \frac{wa}{wc - wb} x\, P_{liquid} \tag{1}$$

$$\text{Foam porosity, } p_f = \left[1 - \frac{p_f}{p_{Al}}\right] x\, 100\% \tag{2}$$

$p_{Al} = 2.7 g/cm^3$, $p_{liquid} = 1\ g/cm^3$