International Journal of Current Science, Engineering & Technology
ISSN : 2581-4311
Original Research Article | Open Access | AMCT 2017 Malaysia | *Special Issue*

The Effect of Reinforcement Amount and Sintering Temperature on Mg Matrix Composite Fabricated by Powder Metallurgy

Nazirah RASHID[a] and Zuhailawati HUSSAIN[b*]

Structural Materials Niche Area, School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia, Engineering Campus, 14300 Nibong Tebal, Penang, Malaysia.

[a]nazirahrashid@yahoo.com, [b]zuhaila@usm.my

ABSTRACT. A metal matrix composite (MMC) is known as high tech composites and useful and magnesium (Mg) is among the suitable metal for producing composites. Combining Mg, Zinc (Zn) and Alumina (Al_2O_3) powders will yield a composite with improved corrosive resistance, mechanical properties and abrasive wear behavior. So, the aim of this research is to study the effect of reinforcement (Al_2O_3) and sintering temperature (300 °C and 550 °C) on Mg-Zn alloy matrix composite fabricated by powder metallurgy. The powder mixture of pure Mg, Mg-Zn alloy and Mg-Zn/15% Al_2O_3 composite was milled separately in a planetary mill under gas argon atmosphere using a stainless steel container and balls. Milling process was carried out at 220 rpm for 2 hours and 3% of n-heptane solution was added prior to milling process to avoid the excessive cold welding of the powder. The powder was compacted under 400MPa and sintered with different sintering temperature with 300 °C and 550 °C in a tube furnace for 1hour under the flow of argon. The density of the sintered pellets was then determined by Archimedes principle. Mechanical properties of the sintered pellets were characterized by microhardness and compressive test. The results shows that the density, hardness and compressive strength of Mg-Zn/15% Al_2O_3 composite was higher compared to pure Mg and Mg-Zn alloy at temperature 300 °C compared to 550 °C.

***Keywords**: Metal matrix composites, Zinc, Alumina, Powder metallurgy;*

Received: 15.10.2017, Revised: 15.12.2017, Accepted: 30.02.2018, and Online: 20.03.2018;

DOI: *10.30967/ijcrset.1.S1.2018.516-521*

Selection and/or Peer-review under responsibility of Advanced Materials Characterization Techniques (AMCT 2017), Malaysia.

1. INTRODUCTION

In order to limit the fuel consumption and carbon dioxide emission, the structural weight of the vehicles need to be reduced [1]. Mg as the lightest metallic structural material, low density, excellent damping capacity and good machinability [2,3] becomes potential candidates for a variety in engineering application. However, the limitations of Mg which include poor elastic modulus and high temperature strength properties [4] restrict its utilization in critical engineering application [3-6]. In order to minimize these limitations, Mg metal matrix being developed with reinforced Mg with Zn and Al_2O_3. In the past, to manufacture MMC, ceramic reinforcing phases such as oxides (Al_2O_3, SiO_2), carbides (SiC, B_4C) and nitrides (Si_3N_4) were used in order to optimize their structure and properties [6].

Powder metallurgy (PM) is one of the best methods in preparation of MMC [7]. The main advantages of PM are relatively low processing temperature, provide great freedom degree in tailoring the microstructure such as volume fraction and morphology, where better distribution of the reinforcement is possible in PM compacts [8]. It also approved by experiment and theoretical studies. For composite fabricated by the powder metallurgy method, it is possible when the matrix to reinforcement particle size ratio is close to unity [9]. With increasing metal working characteristics, particulate reinforced MMCs improved both mechanical and physical properties. Besides that, powder metallurgy processing is one of the methods for fabricating these materials [10]. MMCs are important because of their high Young modulus, high abrasive properties and high ratio of strength and weight [11]. The present study aims to investigate the effect of Zn and Al_2O_3 content on Mg and to study the effect of sintering temperature on the density, relative density, hardness and compressive strength of Mg.

2. MATERIALS AND METHODS

A mixture of elemental Mg powder (99.0% pure), Zn powder (99.0% pure) and Al_2O_3 (99.0% pure) corresponding to Mg-Zn was mechanically milled. Proper proportional of the powders were placed in a planetary ball mill for 2 hours and 220 rpm using high-energy Fritsch Pulverisste P-5 planetary mill under argon atmosphere. 3% of n-heptane solution was used as a process control agent to prevent excessive cold welding of the elemental alloy powders. A number of 20 mm diameter stainless steel balls were loaded together with all the powders in a 250 ml stainless steel vial and the vial was sealed with rubber O-ring. Ball to powder ratio was 1:8.75 was kept constant during the milling process. Conventional powder metallurgy (uniaxial pressing) was employed to produce the samples. Green compacts were cold pressed under 400 MPa and were sintered in argon at 300 °C and 550 °C for 1 hour. Density measurements were done using pycnometer density equipment according to Archimedes's principles. Vickers microhardness test was carried out by applying an indentation load of 300 gf for 10 s. Compression test were done using machine instron 5982 with diameter 10 mm and length of 10 mm.

3. RESULTS AND DISCUSSION

Fig. 1 portrayed the sintered density of the pure Mg, Mg-Zn alloy and Mg-Zn/15% Al_2O_3 composite that was sintered with different sintering temperature of 300 °C and 550 °C. The sintered density was found to increase as two particles Zn and Al_2O_3 were added into Mg. The sintered density for Mg-Zn/15% Al_2O_3 composites increased as compared to pure Mg and Mg-Zn alloy. The sintering temperature at 300 °C shows higher sintered density as compared to 550 °C in pure Mg, Mg-Zn alloy and Mg-Zn/15% Al_2O_3 composites. The addition of 15% Al_2O_3 increased the sintered density as compared to pure Mg and Mg-Zn alloy. This is due to the fact that the density of alumina is higher than that of magnesium. However this phenomenon is not comparative to the amount of alumina since alumina additions leads to the formation of pores. The density of Al_2O_3 is 3.97 g/cm^3 while the density of pure Mg is 1.736 g/cm^3. So, the sintered density with addition of alumina gave affect to the result of sintered density compared to pure Mg and Mg-Zn alloy.

Fig. 2 displayed the relative density of pure Mg, Mg-Zn alloy and Mg-Zn/15% Al_2O_3 composite. Relative density of Mg-Zn/15% Al_2O_3 composite showed lowered compared to pure Mg and Mg-Zn alloy. Five readings were taken for each run and the average density was reported. The relative density (pr) was calculated by;

$$\rho_r = \rho_{ac} / \rho_{th} \times 100\,\% \quad (1)$$

$$\rho_{th} = \rho_{Mg} V_{Mg} + \rho_{Zn} V_{Zn} + \rho_{HA} V_{HA} + \rho_{Al2O3} V_{Al2O3} \quad (2)$$

$$V_{Mg} + V_{Zn} + V_{HA} + V_{Al2O3} = 1 \quad (3)$$

Where ρ_r, ρ_{ac} and ρ_{th} represent the relative density, actual density and theoretical density of the samples, respectively; ρ_{Mg} = 1.74 g/cm^3, ρ_{Zn} = 7.14 g/cm^3, ρ_{HA} = 3.16 g/cm^3 and ρ_{Al2O3} 3.97 g/cm^3.The addition of alumina reduced the relative density in 300 °C compare to 550 °C. This may be due to the reduction in compressibility of the powder during sintering process. Besides that, this may be due to inhibiting effect of alumina in the rearrangement of the particles during sintering process. Furthermore, the melting points of the matrix and the reinforcement also give effects to the relative density. The melting point of alumina is 2072 °C and at higher sintering temperature 550 °C, the activation energy required for sintering mechanism to proceed neck growth and gave result to the surface and volume diffusion.

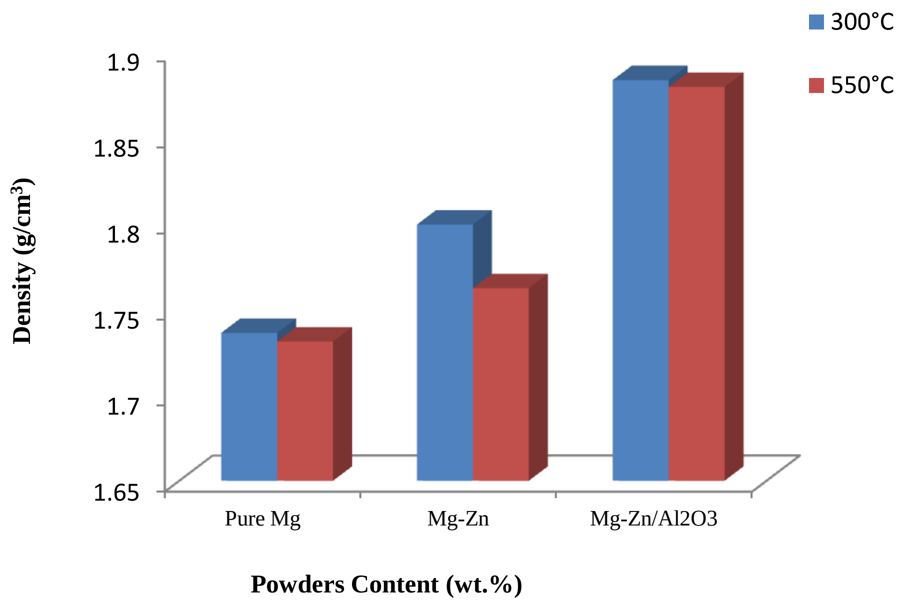

Fig. 1 Sintered density of pure Mg, Mg-Zn alloy and Mg-Zn/15% Al_2O_3 composite

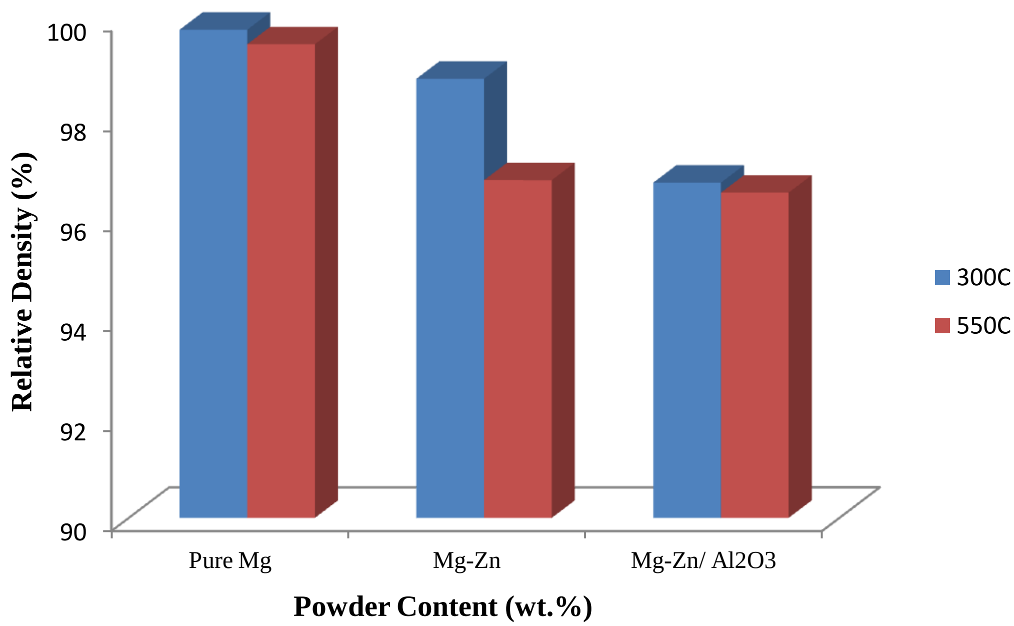

Fig.2 Relative density of pure Mg, Mg-Zn alloy and Mg-Zn/15% Al_2O_3 composite.

The microhardness results of pure Mg, Mg-Zn alloy and Mg-Zn/15% Al_2O_3 composites are shown in Fig. 3. It can be noticed that adding of 15% Al_2O_3 particles into alloy matric increased the hardness value. This can be attributed to the presence of harder reinforcements which offer high constraints during indentation. The microhardness of Mg-Zn/15% Al_2O_3 composites revealed higher hardness values as compared to pure Mg and

Mg-Zn alloys at different sintering temperature of 300 °C and 550 °C. An Al_2O_3 particle acts as a barrier to the rearrangement, deformation and diffusion of the particles [12].

The harder Al_2O_3 particles provide sufficient strength to the soft matrices and hence the microhardness values increases due to the dispersion strengthening effect. With gradual increases on Al_2O_3 content the microhardness values increases as a result of uniform dispersion of the reinforcement within the matrices. The peak value of hardness was achieved with 15 wt.% Al_2O_3 compare to pure Mg and Mg-Zn alloy. This mainly due to uniform dispersion of Al_2O_3 and acts as hard particles that hinders the mobility of the defects (dislocations) in the matrix.

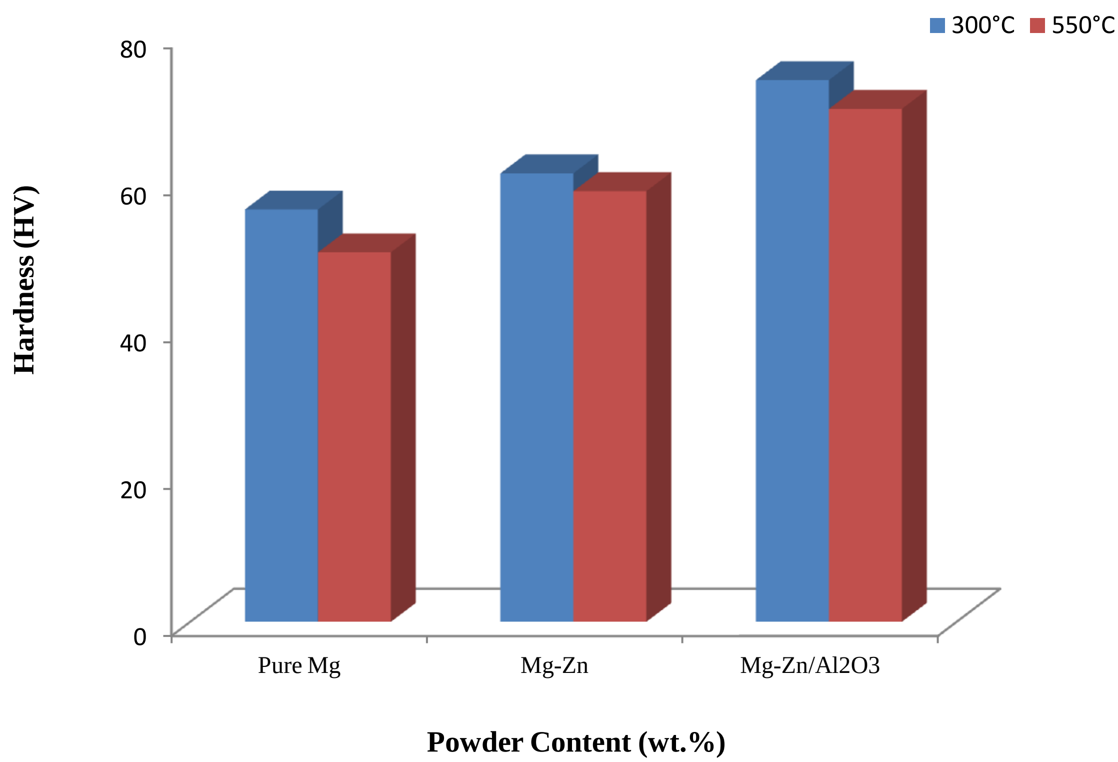

Fig.3 Microhardness of pure Mg, Mg-Zn alloy and Mg-Zn/Al_2O_3 composite

The results of compressive strength have been presented in Fig. 4. Ultimate compressive strength of the Mg-Zn/15% Al_2O_3 composite appeared to have an increment in the compressive strength at sintering temperature 300 °C compare to 550 °C. It shows that sintering temperature gave effect to the result of compressive strength. The addition of Al_2O_3 to Mg-Zn alloy increased the strength by a dispersion hardening mechanism. Al_2O_3 particles being hard and brittle lead to dispersion hardening of matrix. These particles act as second phase in the matrix and resist the movement of dislocations and hence harden the composites [13].

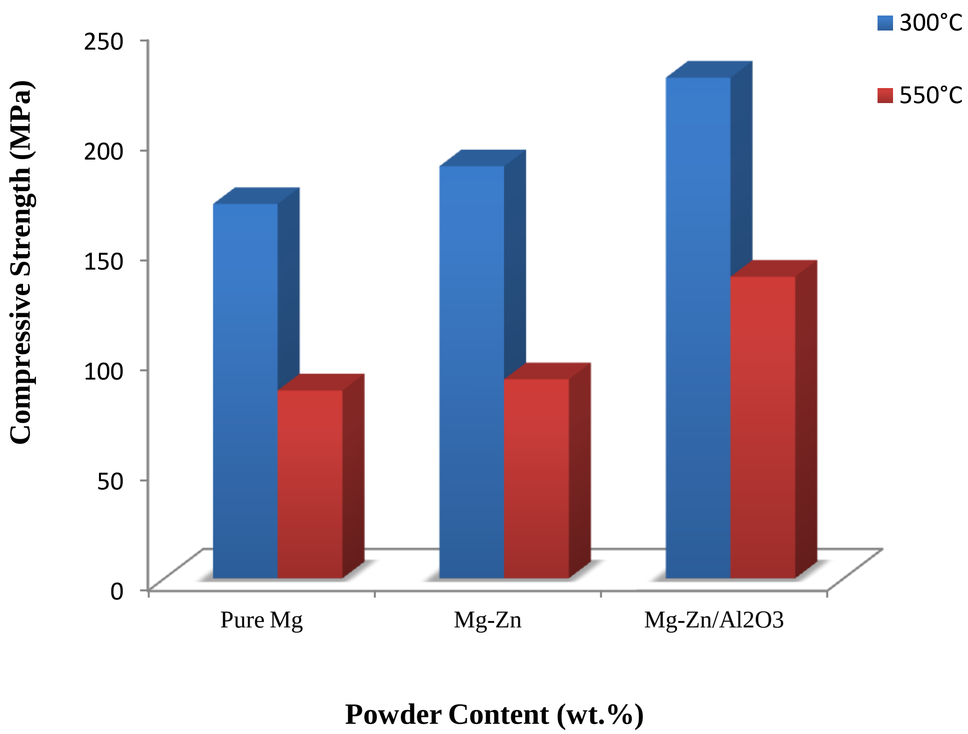

Fig.4 Compression test for Pure Mg, Mg-Zn alloy and Mg-Zn/Al_2O_3 composites

4. SUMMARY

In this study, pure Mg, Mg-Zn alloy and Mg-Zn/15% Al_2O_3 composites were synthesized through powder metallurgy method. Superior density, relative density, hardness and compressive strength were achieved in the case of Mg-Zn/15% Al_2O_3 at sintering temperature of 300 °C as compared to pure Mg and Mg-Zn alloys in 550 °C.

ACKNOWLEDGEMENT

The authors would like to thank to Universiti Sains Malaysia for FRGS Grant No.203/PBAHAN/6071304 and sponsorship scheme of Ministry of Higher Education (Malaysia)

REFERENCES

[1] S. Chabri, S. Chatterjee, S. Pattanayak, H. Chakraborty, N. Bhowmik, A. Sinha, Development and characterization of Al_2O_3 dispersed Al/Mg/Cu/Ti matrix composite, J. Mater. Sci. Technol., 29 (2013) 1085-1090.

[2] M. Rashad, F. Pan, W. Guo, H. Lin, M. Asif, M. Irfan, Effect of alumina and silicon carbide hybrid reinforcements on tensile, compressive and microhardness behavior of Mg-3Al-1Zn alloy, Mater. Charact., 106 (2015) 382-389.

[3] B.M. Girish, B.M. Satish, S. Sarapure, D.R. Somashekar, Basawaraj, Wear Behavior of Magnesium Alloy AZ91 Hybrid Composite Materials, Tribol. Trans., 58 (2015) 481-489.

[4] R. del Campo, B. Savoini, A. Muñoz, M.A. Monge, G. Garcés, Mechanical properties and corrosion behavior of Mg-HAP composites, J. Mech. Behav. Biomed. Mater., 39 (2014) 238-246.

[5] S. Sankaranarayanan, S. Jayalakshmi, M. Gupta, Effect of addition of mutually soluble and insoluble metallic elements on the microstructure, tensile and compressive properties of pure magnesium, Mater. Sci. Eng. A, 530 (2011) 149-160.

[6] S. Sankaranarayanan, S. Jayalakshmi, M. Gupta, Effect of nano-Al_2O_3 addition and heat treatment on

the microstructure and mechanical properties of Mg-(5.6Ti+3Al) composite, Mater. Charact., 75 (2012) 150-164.

[7] S. Scudino, G. Liu, M. Sakaliyska, K.B. Surreddi, J. Eckert, Powder metallurgy of Al-based metal matrix composites reinforced with β-Al_3Mg_2 intermetallic particles: Analysis and modeling of mechanical properties, Acta Mater., 57 (2009) 4529-4538.

[8] K. Soorya Prakash, P. Balasundar, S. Nagaraja, P.M. Gopal, V. Kavimani, Mechanical and wear behaviour of MgSiCGr hybrid composites, J. Magnes. Alloy. 4 (2016) 197-206.

[9] M. Rahimian, N. Parvin, N. Ehsani, The effect of production parameters on microstructure and wear resistance of powder metallurgy Al-Al_2O_3 composite, Mater. Design, 32 (2011) 1031-1038.

[10] H. Abdizadeh, M. Ashuri, P.T. Moghadam, A. Nouribahadory, H.R. Baharvandi, Improvement in physical and mechanical properties of aluminum/zircon composites fabricated by powder metallurgy method, Mater. Design, 32 (2011) 4417-4423.

[11] M.O. Bodunrin, K.K. Alaneme, L.H. Chown, Aluminium matrix hybrid composites: A review of reinforcement philosophies; Mechanical, corrosion and tribological characteristics, J. Mater. Res. Technol., 4 (2015) 434-445.

[12] M. Rahimian, N. Ehsani, N. Parvin, H.R. Baharvandi, The effect of sintering temperature and the amount of reinforcement on the properties of Al-Al_2O_3 composite, Mater. Design, 30 (2009) 3333-3337.

[13] A. Baradeswaran, A. Elaya Perumal, Study on mechanical and wear properties of Al 7075/Al_2O_3/graphite hybrid composites, Compos. Part B Eng., 56 (2014) 464-471.