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Discovery

Effect of Calcium content on the mechanical properties of Magnesium alloy

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Magnesium alloys of the type magnesium-aluminum have been widely used in various engineering application and continue to attract interest due their light weight and economic advantage. However, the correlations between microstructures, grains fractal dimensions and sphericities, and relation with performance during service have also been established for many commonly used Mg-Al alloys. This study therefore examined the effect of calcium extracted from animal bone on the microstructure and mechanical properties of Magnesium alloy. It was found that at 0.4 (wt.%) Calcium content structures with regular and random grain boundaries resulted to strengthening of the alloys. An optimal hardness and tensile strength of 50.1 BHN and 280.15 MPa was respectively obtained.

INTRODUCTION

Aluminum is the main alloying element in magnesium alloys being the one of the few metals that easily dissolves in magnesium. Mg-Al based alloys belong to the most widely used group for the foundry industry and they are the oldest of the foundry magnesium alloys (Blawert et al. 2006; Dobrzański et al. 2008). Magnesium alloys are very attractive engineering material because of their light weight and ease of recycling. It has seen increasing use in automobile and industries applications. The use of magnesium alloys in automobile parts is predicted to increase globally at an average rate of 15% per year (Liu et al., 2008). Grain size is an important factor affecting the properties of metals and its alloys. The mechanical properties such as tensile and yield strength increase remarkably as grain size decreases. In addition, grain refinement reduces the size of defects such as porosity and hot tearing tendency, and also improves resistance to corrosion (Singh *et al.*, 2003; Blawert *et al.*, 2006). However, Zirconium (Zr) addition is considered to be the most reliable and effective grain refiner for magnesium alloys especially Mg–Zn. According *to* Eslami *et al.*, (2013) and Adamkova *et al.*,(2013) Calcium has been found to be an important alloying element for magnesium and its alloys, due to the formation of a thermally stable second phase at elevated temperature and creep properties. Small amount of calcium can refine microstructure and increases mechanical properties. In this study, calcium obtained from animal bone was used has a grain refinement on Mg-Al alloy.

MATERIALS AND METHODS

In this study, alkaline hydrolysis was used to extract calcium from animal bone. 3 kg of animal bone was obtained from the local market. The animal bone was washed and oven dry for 48 hours at 100°C. The animal bone was grinded in a ball milling machine, mechanically sieved and 220 µm particle sizes was collected. 100 ml of sodium hydroxide (NaOH) was added to the particles, the reaction took place for 5 days and sun dried. 100 ml of diluted phosphoric acid (P) was later added, heated to about 80°C for 1 hour, allowed to cool prior to filtration. 570 ml of distilled water was added to the particle for further purification. The final particles obtained in form of Calcium phosphate was analyzed and used as grain refinement.

Preparation of the test samples

The prepared samples were melted in an electric resistance furnace in a metal crucible made from low-alloyed steel. The alloys are highly reactive and the melt was treated with white degassing agent having the trade mark EMGESAL which eliminate all possible inclusions. Samples were cast in a green sand compact to achieve sufficient fluidity of the metal. 5 samples were produced having the same compositions but different calcium. Samples with diameter of 30mm by 120 mm long were prepared. The chemical composition of the cast samples were given in Table 1.

In order to determine the variation of hardness based on casting technique, Leitz 8299 micro-hardness tester was used to perform the micro-hardness tests of the cast samples. The tensile tests were performed using a Monsanto Tensometer testing machine, equipped with a data acquisition system for recording the strain and load. The strain was measured with a strain gauge and extensometer attached at the center of each specimen (giving a very precise measurement but limited to the elastic region of the cast samples). An optical metallurgical microscope XJL-17 model with magnification 10×10 was used for taken the micrograph of the samples. All the samples were grounded, polished and etched using 2% NaOH solution. The analyses capture a square shape of approximately 3mm x 3mm of the specimen.

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Table 1 Chemical composition (wt-%) of experimental alloys

Alloy	Ca	Al	Mn	Zn	Si	Mg
Sample A	0.1	8.5	0.17	0.45	0.05	89.45
Sample B	0.2	9.5	0.30	0.70	0.05	88.95
Sample C	0.3	9.5	0.30	0.70	0.05	88.95
Sample D	0.4	9.5	0.30	0.70	0.05	88.95
Sample E	0.5	9.5	0.30	0.70	0.05	88.95

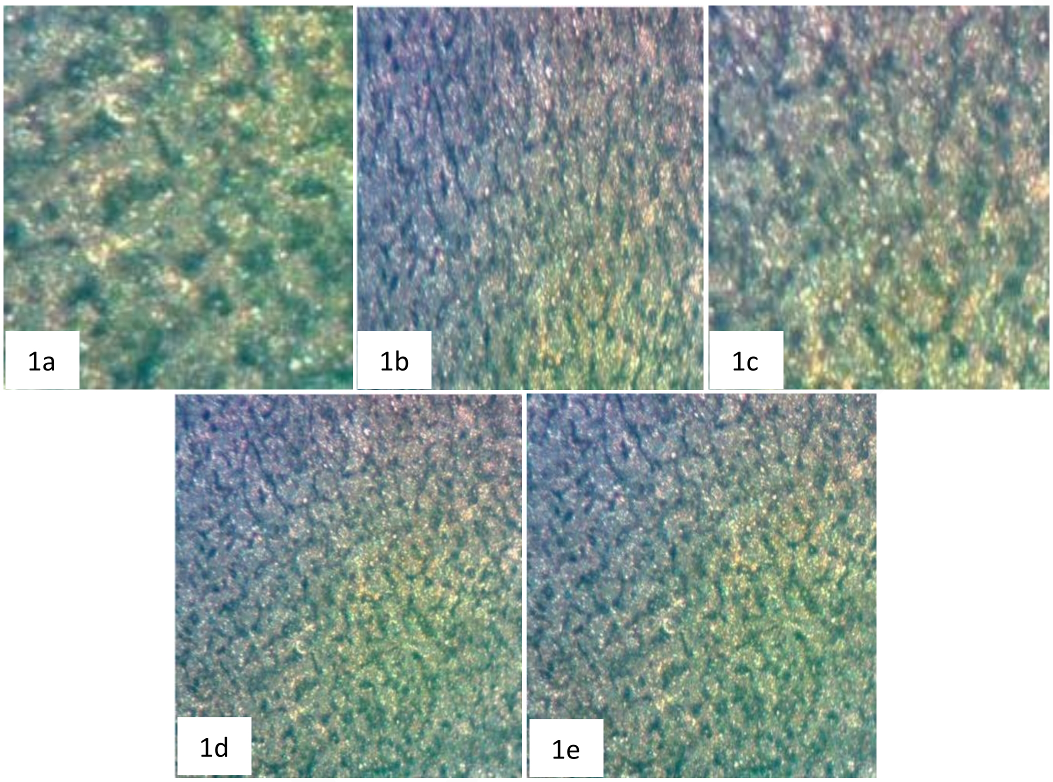

Figure 1 Micrograph of Mg-Al Alloy Treated with Calcium Extracted from Animal Bone

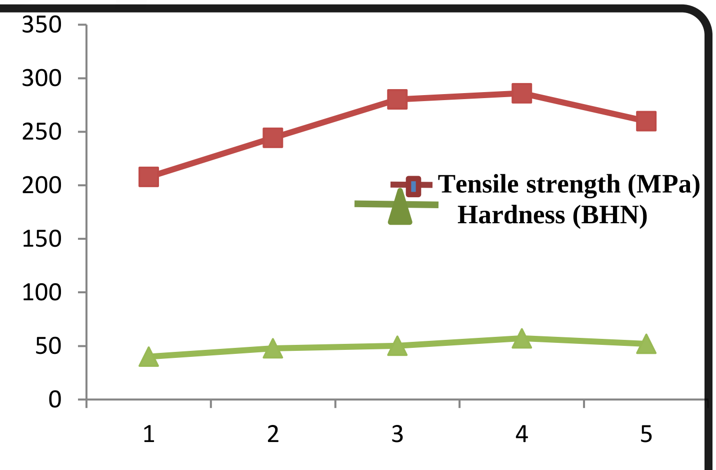

Figure 2: Variation of Tensile strength and Hardness against Calcium contents

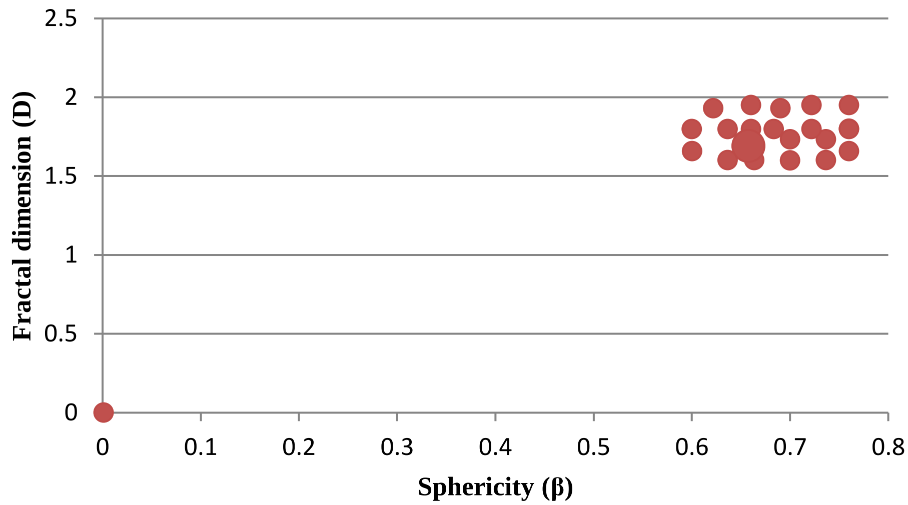

Figure 3a: Grain size distribution map for 0.1 wt.% Ca content

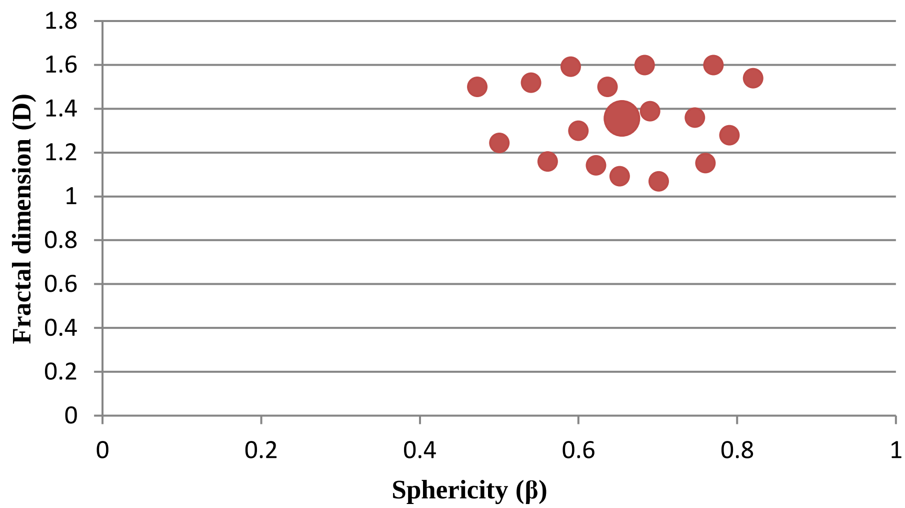

Figure 3b: Grain size distribution map for 0.4 wt.% Ca content

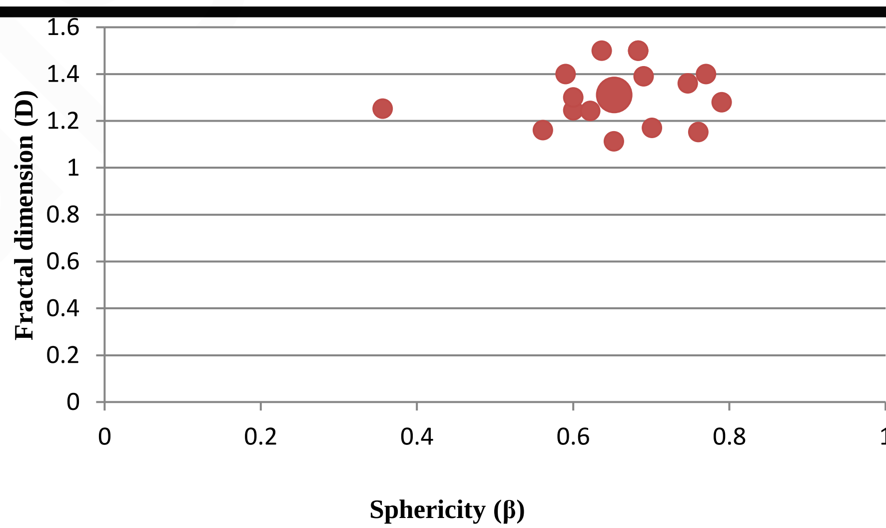

Figure 3c: Grain size distribution map for 0.5 wt.% Ca content

RESULT AND DISCUSSION

Micrograph of the Cast Samples

The microstructures of cast magnesium alloys observed under optical microscope are shown in Figure (1a to 1e). Presence of α-Mg matrix, Mg17Al12 inter-metallic compound with dark grey appearance and irregular precipitate were revealed. The intensities of α-Mg peaks in Figure (1d and 1e) are roughly proportional at 0.4 and 0.5 (wt. %) Ca contents indicating random distribution of grain orientations.

Results of Mechanical Testing

In this study, it was observed that at 0.1 - 0.3 (wt. %) Ca contents, the material is very hard and strong with low level of ductility. As the percentage of calcium increases above 0.3 (wt. %), the materials become harder and tough due to the formation of grain boundary edges, thus experiences high level of ductility, that is long plastic deformation before fracture, (Figure 2). This tendency can be identified in the microstructure as an indication of small grain sizes results in the improvement of hardness and tensile strength as depicted in Figure 1.

However, in other to ascertain the effect of Ca refinement on Mg-Al alloy, fractal analyses of the grains were quantify to access the self similarity and complexity of grains. Following Mudasiru (2018), an interactive Matlab program developed was used to obtain the numerical values of the fractal dimension (D) and the sphericity (β) for grain sizes. It has been shown that when "β = 1 and D = 1", a perfect circular grain shape is formed by the Ca refinement in the microstructure. As "β" decreases, the grains become more elongated showing a departure from perfect sphere.

Figures 3 presented the grain size distribution maps of each of the microstructure as obtained from the fractal analysis. Each data point represents an individual grain and the big-sized data point represents the weighted average of the grains' sphericities and fractal dimensions respectively.

The grain size distribution map shown in Figure (3a) revealed that the grains in 0.1 (wt.%) sample are cluster having high values of fractal dimension (D). Similar phenomenon were observed in 0.2 and 0.3 (wt.%) addition of Ca content. Furthermore, when compared with samples modified with 0.4 and 0.5 (wt.%) Ca contents, fractal analysis performed revealed that the grains are regular and randomly distributed Figure (3a and 3b). The grains in Figure (3b) had weighted average values 0.6549 and 1.3556 for sphericity and fractal dimension.

Similarly, the grains in Figure (3c) had weighted average values 0.6526 and 1.3104 for sphericity and fractal dimension respectively, which is an indication that the grains were attaining better regular shapes.

CONCLUSIONS

In this study, micro-structural characterization of calcium magnesium alloy was carried out and the results obtained are given as follows:

a) The microstructure of samples (d and e), with composition 0.4Ca-88.95Mg-Al9.5 (wt. %) revealed a complete homogenous eutectic structure and the grains are evenly distributed.
b) Similarly, sample (d) gives an optimum hardness and tensile strength of 57.2HB and 286.536MPa.
c) Fractal analysis can be applied to the grain size measurement to describe the shapes and sizes of the grain in cast Mg-Al alloys using two dimensionless parameters, Fractal dimension, *"D"* and Sphericity, *"β"*. This method may complement with other conventional quantitative examinations.

REFERENCES

1. Adamkova, E., Jelinek, P., and Tudentova, S., (2013); Manufacturing Technology, Vol. 13, pp. 255 – 262.
2. Blawert, C., Hort, N., & Kainer, K. U. (2006); Automotive Applications of Magnesium and its Alloys, Vol., 4, pp. 397–408.
3. Dobrzański, L. A., Labisz, K and Olsen, A. (2008); Microstructure and mechanical properties of the Al-Ti alloy with calcium addition, Vol. 2, pp. 183–186.
4. Eslami, S., Mirshahi, M., Koleini, S and Hasbullah, M. (2013); Effect of Calcium Content on the Microstructure , Hardness and In-Vitro Corrosion Behavior of Biodegradable Mg-Ca Binary Alloy 3 . Results and Discussion, Vol. 1, pp. 11 – 18.
5. Liu, S. F., Li, B., Wang, X. H., Su, W., and Han, H. (2008); "Refinement effect of cerium, calcium and strontium in AZ91 magnesium alloy". *Journal of Materials Processing Tech.*, pp. 6 – 11.
6. Mudasiru, L. O., (2018); "Modification and Pore Distribution in Cast Al A356 Alloy Using WC Nanoparticles". *Journal of Material Sciences & Engineering,* 1(11 – 18).

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