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EFFECT OF MAGNESIUM ON SOME MECHANICAL PROPERTIES OF 1200 ALUMINIUM ALLOY

[1]Shittu, M. D. [1]Olaniyi, A. E., *[1]Daniyan, A. A. [1]Isadare, D. A, [2]Oluwasegun, K. M. and [1]Ibitoye, S. A.
[1]Department of Materials Science and Engineering, Obafemi Awolowo University Ile-Ife, Nigeria
[2]Department of Mechanical and Manufacturing Engineering, University of Manitoba, Winnipeg, Manitoba, Canada.
*Corresponding author's e-mail: daniyan03@gmail.com, adaniyan@oauife.edu.ng

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ABSTRACT

This paper investigated the effect of magnesium as a dispersion strengthening material on some mechanical properties of 1200-Aluminium (Al-Fe-Si) alloy, a typical commercial aluminium alloy used in the production of household utensils. 1200-Aluminium (Al-Fe-Si) alloy containing varying percentages of the dispersion hardening material (i.e. Magnesium) were produced and mechanical tests namely; hardness, tensile strength and impact strength were carried out. Also, the microstructures of the cast materials were studied. The results showed that increase in magnesium content, as dispersion hardening material improved the hardness, tensile strength and caused a slight decrease in impact strength of the 1200-Aluminium alloy. It is inferred from this work that using magnesium as a dispersion hardening material brings about corresponding improvement in some mechanical properties of 1200-Aluminium (Al-Fe-Si) alloy.

Keywords: Magnesium, Aluminium alloy, dispersion strengthened, reinforced alloy, crystallographic formation Depth, Geothermal Energy.

INTRODUCTION

Increased demand for light weight components, primarily driven by the need to reduce energy consumption in a variety of societal and structural components, has led to increased use of aluminium and its alloys (Chee and Mohamad, 2009; Nwaokafor *et al.,* 2000; **Abdo,**). Aluminium in its pure state has extreme properties such as poor machinability and low strength whereas its alloys usually have some properties that are compromised in comparison with those of its constituents.

According to Stanley and Haupin (1982), aluminium is the third most abundant element on the surface of the earth after iron and steel. Aluminium can combine with a variety of other metals to improve on its mechanical properties. Many of the properties of aluminium alloy products depend on metallurgical structure which is controlled both by the chemical composition and processing methods. Because of its high strength to weight factor, a large part of the production of aluminium goes into transportation equipment and moving parts machinery. It is also used for ornamental and architectural work, containers, cooking utensils, chemical equipment, electrical conductors, and packaging. Aluminium is transparent to X-rays and is used in thin sheets as ray filters (British Standard BSEN 10002-1:1990). It extrudes easily and is used to replace tin alloys for collapsible tubes. In powder and flake forms, aluminium is used in paint and fire works, thermit welding and as a catalyst. Because of its high electrical conductivity and lightness, aluminum is used extensively in electrical transmission lines.

Consequent upon these applications of aluminium, it is very pertinent to study how to improve on its properties. Researchers have worked on the effects of so many alloying elements on the properties of aluminium alloys. The aim of this work is to investigate how the amount of magnesium on the matrix of 1200 Aluminium alloy affect some mechanical properties of the material.

Kissel (1997) classified aluminium alloys into heat treatable and non-heat treatable. Heat treatable alloys belong to systems with limited solubility in solid state. These are precipitation hardenable alloys. The main characteristic of this type of alloy system is a temperature dependent equilibrium solid solubility, which increases with rise in temperature. Non-heat treatable on the other hand, does not respond to heat treatment because they consist of a homogeneous solid solution with or without non coherent precipitate(s) and show low strength and high ductility. This type of aluminium may be stress hardened (Rajan *et al*, 1997).

It was asserted that the major alloying elements added to aluminium as alloys are Silicon, Copper, Manganese, Zinc, Iron, Titanium and Magnesium (Richard *et al*, 2005). Almost all these elements are added to make wrought or cast alloys, however, the amount of each element may vary, thus producing different properties in different alloys.

EXPERIMENTAL PROCEDURE

The materials used in this work are 1200 Aluminium alloy and pure magnesium. The chemical composition of the 1200 Aluminium alloy is as presented in Table 1.

Table 1: Chemical composition of the as-received 1200-Aluminium alloy

Alloy	Fe	Si	Mn	Cu	Zn	Ti	Mg	Pb	Sn	Al
Element %, weight	0.412	0.257	0.035	0.033	0.042	0.033	0.001	0.006	0.002	99.09

Five different categories of castings based on the magnesium contents were producrd and analysed to contain 0.2%, 0.3%, 0.4%, 0.5% and 0.6% Mg respectively.

A hardness test piece was cut from the as-received sample and also from each category of the castings produced. The hardness test was performed using Brinell hardness testing machine and average hardness values for each category was plotted against the magnesium content (Figure 1a).

Table 2: Mg content of the alloy samples

Sample	Mg Content, %
As-received	0.001
Sample A	0.2
Sample B	0.3
Sample C	0.4
Sample D	0.5
Sample E	0.6

Similarly, after casting, five standard tensile test pieces were machined from each of the categories including that from as-received aluminium alloy according to British Standard BSEN 10002-1:1990. These were tested on Monsanto Tensometer. The average values obtained from each category were plotted as the ultimate tensile stress (Figure 1b). Also, the percentage elongation (a measure of ductility) was recorded for each of the specimen (Figure 1c).

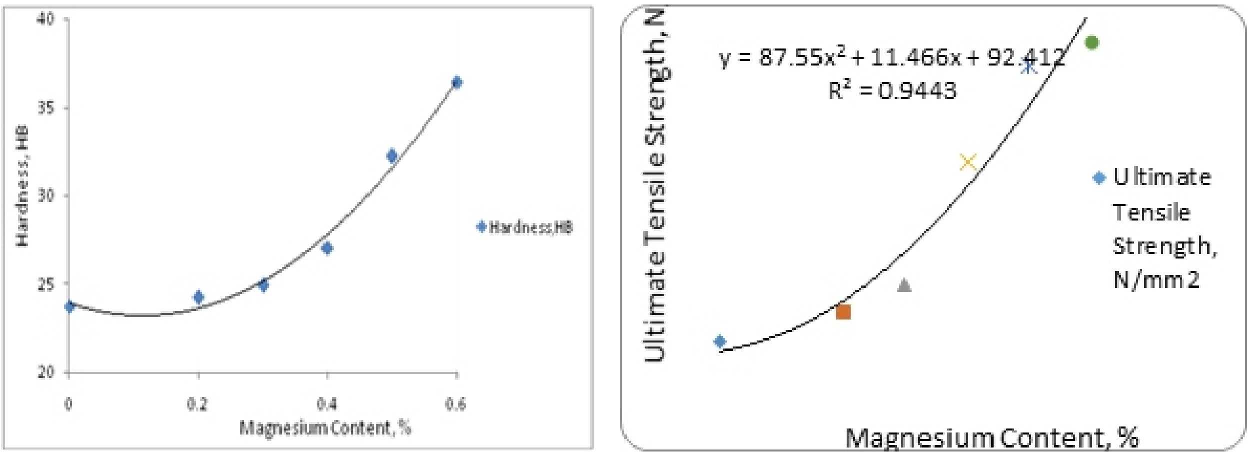
The Charpy method of impact test using Hounsfield machine was carried out on five test pieces of each category of the castings and as-received aluminium alloy. These test pieces were notched V-shaped to 2mm depth at 45° and tested according to ASTM Standard E-602-91 and the average test results on them were then taken as values for impact strength (Figure 1d).

Test pieces from each category of castings were also cut and taken through the metallographic processes of sampling, flattening, grinding, polishing and etching operations. The microstructures of the samples were then observed and taken using Olympus optical metallurgical microscope model C5050Z.

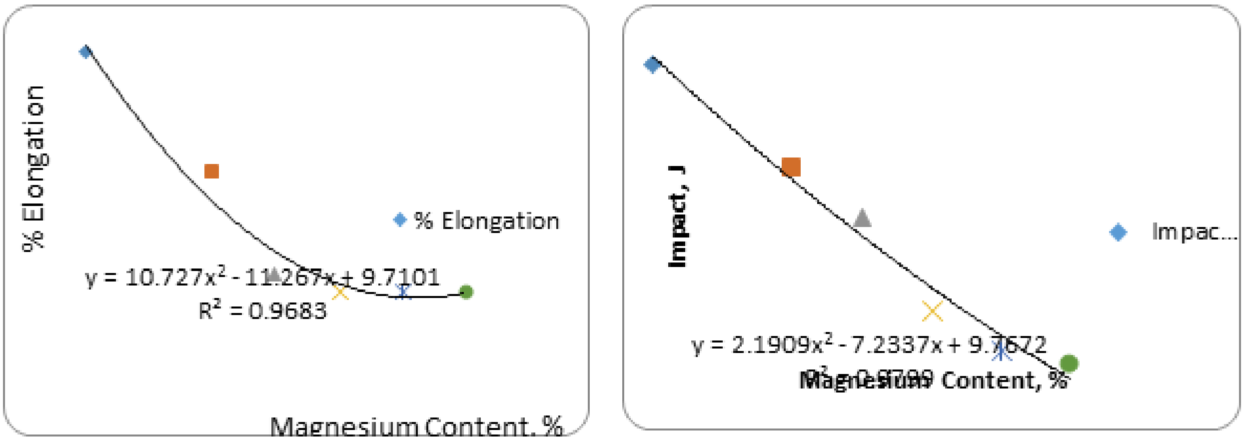
RESULTS AND DISCUSSION

Results

The chemical analysis of the as-received 1200-Aluminium alloy used is presented in Table 1 while the modified (that is, the alloys with increased magnesium contents) alloys used are presented in Table 2. Figure 1 (a-d) represents the curves of the respective mechanical tests (that is hardness, tensile, ductility and impact performed. Figure 2 (a-f) shows the microstructures obtained from different category of the castings based on their magnesium content.

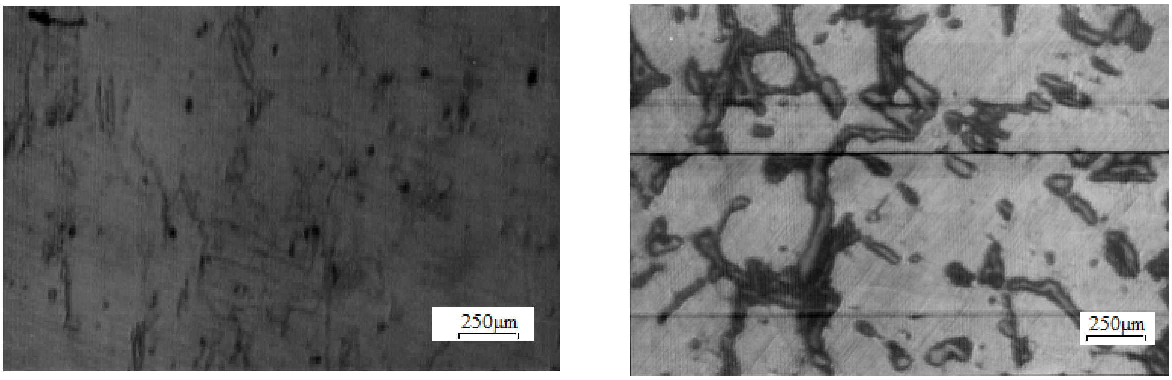


(a) **Hardness** **(b) UTS**

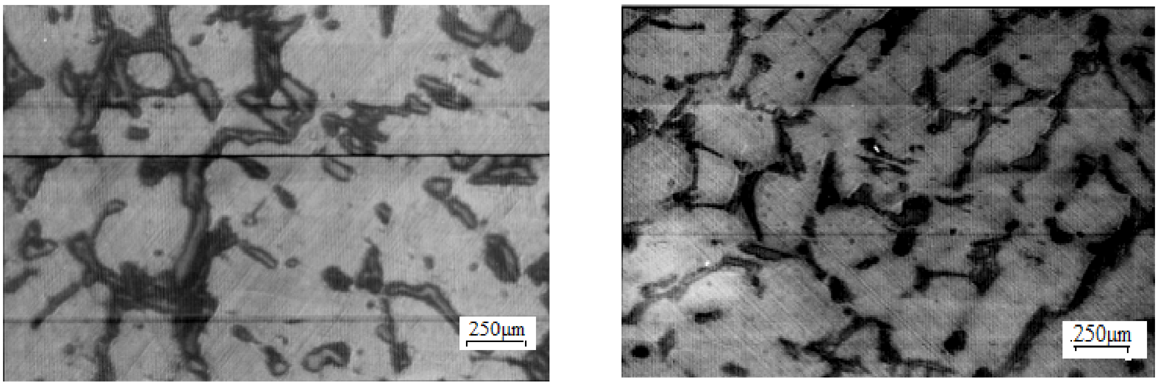


(c) Ductility **(d)** **Impact**

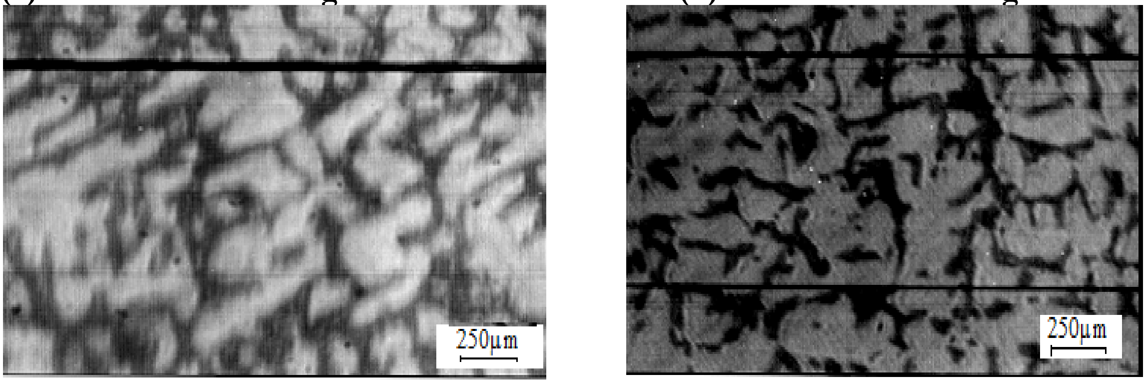
Figure 1: Effect of Magnesium Content on (a) Hardness (b) UTS (c) Ductility and (d) Impact strength of 1200 Aluminium Alloy



(a) As-received with 0.001% Mg **(b) As-cast with 0.2% Mg**



(c) As-cast with 0.3% Mg **(d) As-cast with 0.4% Mg**



(e) As-cast with 0.5% Mg **(f) As-cast with 0.6% Mg**

Figure 2: Microstructure of aluminium alloy (a) As-received with 0.001% Mg (b) As-cast with 0.2% Mg (c) As-cast with 0.3% Mg (d) As-cast with 0.4% Mg (e) As-cast with 0.5% Mg and (f) As-cast with 0.6% Mg

Discussion

It is observed from Figure 1 that for every 0.1 % change in the magnesium content in the 1200-aluminium alloy, there is an appreciable increase in the hardness value of the alloy. The grains were observed becoming finer with corresponding increase in the magnesium content. The dispersoids were observed to be very effective obstacles to the dislocation movements. Also, the grain boundaries exhibit properties as strong obstacles for dislocation movement. In the present material, the grain boundary area is large due to the small grain size. In general, the smaller the grains, the larger the strength as in equation (1) propounded by Hall-Petch.

$$\sigma_y = \sigma_o + k_y d^{-\frac{1}{2}} \qquad (1)$$

$_y$ is the yield strength of the grains with diameter, d while $_o$ and k are material dependent constants (Callister, 2001). Also, Campbell and Fisher (1993) submitted that during cooling, precipitation of Al_3Mg_2 phase which is an intermetallic compound will also contribute to increase in the hardness number.

Generally, in materials that fail by necking, an increase in strength usually implies a decrease in ductility (Campbell and Fisher, 1993). From Figure 1(a) and 1(b), it was shown that both the hardness tensile strength of the aluminium alloy increased with increase in magnesium content. An increase in hardness as explained above coupled with a slight decrease in toughness when magnesium was added resulted to the increase in the ultimate tensile strength. The increase in strength was due to the formation of solid solution and also due to the slight effect of the presence of surplus phases (Ibitoye *et al*, 2010).

The Al-Mg-Si alloy can be considered as dispersion hardened materials, the Si particles playing the role of the reinforcing phase. When a particle reinforced alloy is deformed the particles remain elastic, while the matrix surrounding them deforms plastically. The matrix strength is increased in this alloy by increasing the Mg content.

It is evident in Figure 3 that the addition of magnesium to 1200-aluminium alloy slightly reduced the impact strength of the alloy and this is due to the large atomic radius of magnesium which only allowed low rate of diffusion of magnesium in the aluminium. The alloy as a result did not contain surplus phases after cooling instead consists mainly -solid solution. This results in a decrease in ductility (Figure 1(c)) which invariably shows a decrease in absorbed energy by the material (Figure 1d).

The representative microstructures of the compositions in the as received is depicted in Figure 2(a) while those of as-cast conditions are shown in Figures 2(b–f). All these figures are characterised by the homogeneity of the matrix with approximately equiaxed solidification structures free of micro segregation. The main components of the microstructure in Al-Mg-Si alloy are the dendritic cells and Si particles resulting from the eutectic reaction. Magnesium is added only to strengthen the alloy through dispersion hardening depending on the magnesium level. The change in magnesium content did not have significant effect on the -phase (Al_3Mg_2), this may be due to the fact that the precipitation of -phase is very low at the chosen magnesium contents (Campbell and Fisher, 1993). The as-received aluminium alloy (with 0.001% Mg) has less distinct grain boundaries (Figure 2a). However, it is clearly evident from the figures 2(b-f) that as the magnesium content increases, the grain boundaries become more pronounced, segmented and multiplied and acts as impediments to dislocation movement which resulted to harder material of relatively lower ductility, higher UTS and slightly reduced impact strength.

CONCLUSION

The general mechanical properties of aluminium-magnesium-silicon alloy are better than those without appreciable amount of magnesium because this alloy being a dispersion hardened alloy combined a lot of mechanical properties in very good proportion. Increase in hardness as a result of alloying with magnesium resulted in increase in tensile strength. There is a slight decrease in impact strength consequent to reduction in ductility. The combination of these properties makes the aluminium-magnesium alloy to be useful for applications where high strength and excellent resistance to corrosion are required. Some of such applications include fabrication of profile structures, manufacture of tubing for automobile gas and oil industry, and sheet metal fabrication of bus and tanker bodies.

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