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Effect of Magnesium on the Hardness of Cast Aluminium Alloy Using Sand Casting Method

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Abstract

This research paper deals with the casting procedures and testing process of two metals combined to increase the hardness properties of the base metal. These two metals comprise of Aluminum (Al) and Magnesium (Mg) with Aluminum being the base metal. Aluminum Alloys are preferred in various structural and construction works, also in the manufacturing of various industrial machine components and automobile parts due to their favorable properties like low density which results in their light weight, high strength and superior malleability compared to iron-carbon alloy like steel and cast iron. In this study 6 samples of different percentage (%) weight composition of magnesium alloyed with aluminum was prepared and studied, the casting process was done using sand casting method because of low cast and availability. The various compositions by weight of magnesium are added into the molten aluminum and stirred using stir casting machine. After solidification for a period of time the samples were cut and machined to specification to enable the hardness test to be carried out and this test was done using a Brinell hardness testing machine at Engineering Management and Development Institute (EMDI)and the various results inferred from the test were recorded and analyzed. It was observed from the results that at 4% Mg composition, the hardness value was lowest and increased gradually, and at 14% Mg composition the hardness value was highest. It is therefore concluded that the composition of magnesium greatly influences the hardness of the Al-Mg alloy cast part. As the % composition of Mg increases in the alloy, the hardness of the cast parts also increases.

1. Introduction

Most metals in their original state cannot be used in structural, construction and manufacturing or engineering work due to their various draw backs like high density, softness, brittleness, sonorous nature etc. So, there is need for alloying, which is a combination of two or more metals in other to improve mechanical properties and become fit for various engineering works. Aluminum and its alloy are widely used in industries because of their light weight, high strength and good corrosion resistance which are due to the formation of a protective oxide layer; this is according to [1]. The oxide layers formed on the surface of the cast aluminum alloy protect the cast from corrosion and easy wearing due to exposure to the atmosphere.[2] inferred that aluminum is chosen in most alloying process because of its superior strength to weight ratio. This characteristics of aluminum is the reason it is been chosen as the base metal in most alloying process. The precipitation hardening response of the alloys is very significant and hence control of precipitation during heat

treatment is critical for attaining optimum alloy performance [3]. High strength manganese-aluminum and austenitic steels is the reason for their perfect combination of high mechanical properties and good plasticity for the structural elements. Their good strength property is due to the addition of aluminum; [4]. Two most generally used manufacturing route for metal matrix composites are casting techniques and powder metallurgy. The casting technique is usually adopted because of its low cost and ready availability [5]. Fluidity and composition of metals are of the topmost importance for consideration if sound is to be achieved; this is according to [6]. Good castability for foundry alloys includes a relatively high fluidity, low melting point, short casting cycles, relatively low tendency for hot cracking, good as-cast surface finish and chemical stability [7]. According to [8] sand casting method is employed because it is less expensive compared to other fabrication methods. Magnesium is important because of its increasing use in the automotive industries [9]. This is because of its light weight properties, different metals are combined with aluminum because of its favorable effect on casting. In this study different composition of magnesium was alloyed with aluminum using a sand casting method and was machined to specification for the test to be carried out. The hardness testing was done using a Brinell hardness testing machine and results recorded and analyzed. This research is aimed at increasing the hardness property of magnesium and aluminum alloy using sand casting method.

2. Methodology

2.1. Mold Preparation

At first the molding sand was prepared which comprises of green sand; the green sand contains silica sand of 88%, binder (clay) of 6% and water 6%. The green (molding) sand was filtered using a mesh of 2.65mm and 1.7mm to sieve larger particles of the molding sand to obtain fine particles of the molding sand. The pattern is made of a hollow metallic rod of 250mm by 25mm for the hardness testing to be carried out, see Figure 1. The cylindrical check was made of plastic flask of 200mm by 154mm diameter was used in creating the mold. The pattern was placed inside the check and covered with the molding sand and rammed. After ramming the pattern was then withdrawn from the rammed molding sand generating cavity (mold) in the rammed molding sand. The floor acted as the drag to ease and quicken the removal of gases during casting solidification process; the cope having a cylindrical shape is created using the molding sand and rammed, this contains the sprue during pouring, the cope is an extension of the cheek.

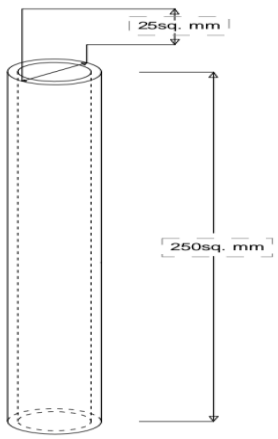

Figure 1: Pattern used for the study

2.2. Casting of Specimens

To study the effect of magnesium on the hardness of cast aluminum a total of 6 specimens were produced as follows:

Measured 2kg scrap aluminum consisting mainly beverage cans was placed in the crucible pot and heated in the furnace to a temperature above 750^0C to melt and taken down from the furnace and dirt removed using a skimmer. 4% weight composition of magnesium (Mg) was added to the molten aluminum (Al) and placed back in the furnace, stirred for 5minutes using a stir casting machine. It was then taken down from the furnace and allowed to cool to a temperature of 730^0C and the temperature was monitored using a thermometer. It was then poured into the mold cavity and allowed to solidify. This process was repeated for 6%, 8%, 10%, 12%, and 14%weight composition of magnesium under the same temperature.

2.3. Mechanical Testing

This test was carried out in Engineering Management and Development Institute (EMDI) Akure, Ondo State. It was done using Brinell hardness testing machine. The specimen 4%, 6%, 8%, 10%, 12%, & 14% weight composition of Al-Mg alloy was machined to testing specification of 20mm by 20mm as shown in Figure 2 below.

The 3 samples from each specimen are machined and cleaned with a piece of cloth, it was then mounted at right angle to the axis of the ball indenter plunger. The platform is turned to lift up the ball. A load of 1500kg was then applied by shifting the lever, after sometimes the load is released by shifting the lever; this creates an indentation in the specimen. The specimen was then taken out and the diameter of indentation measured by means of Brinell microscope. This test was carried out three (3) times for specimen samples of 4% weight composition of Al-Mg alloy and the average reading is used to calculate the Brinell hardness BHN. This process is repeated for the specimen 6%, 8%, 10%, 12%, and 14% weight composition with 3 samples each and the average reading used in calculating the Brinell hardness BHN.

$$BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} \quad (1)$$

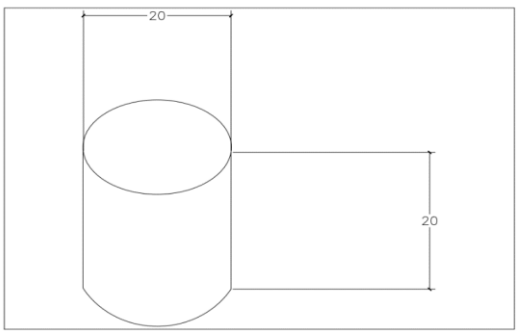

Figure 2: Hardness Test Specimen with diameter in mm

3. Results and Discussion

Using Equation 1 the following results was obtained for Brinell hardness testing as shown in Table 1.

Table 1 Brinell hardness Test Results of Al-Mg Alloy

Percentage Composition (%)	Load (kg)	Ball Diameter (mm)	Diameter of indentation on Alloy (mm)	BHN (Kg/mm^2)
4	1500	10	3.53	148.32
6	1500	10	3.48	153.66
8	1500	10	3.37	163.22
10	1500	10	3.30	170.44
12	1500	10	3.22	179.28
14	1500	10	3.10	193.82

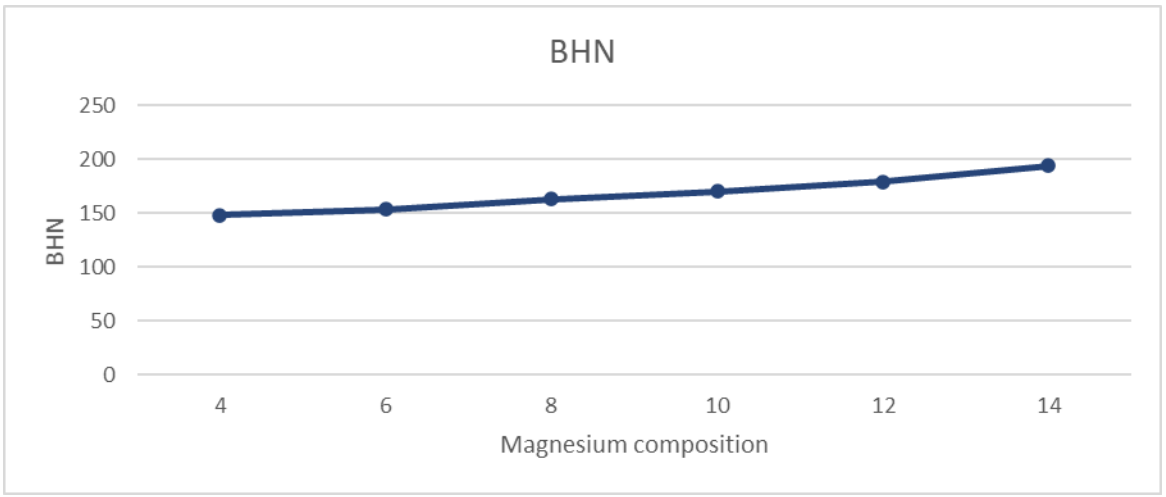

Figure 3. Increasing Hardness with increasing Magnesium Concentration

3.1. Mechanical Property

From the research conducted in Table 1, it is observed that at 4% composition of Mg, the Brinell hardness value is lowest and increased gradually and at 14% composition of Mg, the Brinell hardness value is highest. Figure 3 shows the graph of the Brinell hardness value against the different Mg composition. The slope shows a straight line, which depicts a simultaneous increase in the hardness value as the Mg composition increases from 4%-14%. It is therefore evident that increasing the composition of Mg in Al-Mg alloy increases the hardness of the cast material.

In a study by [10], varying the composition of Magnesium in Al-Mg alloy has a positive effect on the hardness property of the material. With increase in the concentration of magnesium alloy there is an increase in the hardness of the cast part and a decrease in the concentration of magnesium alloy result in a decrease in hardness. According to [11], it was concluded that the hardness of

aluminum metal matrix composite increases with increase in the composition of magnesium and also decreases with decrease in the amount of Magnesium concentration in the matrix composite.

4. Conclusion

It was found that altering the percentage weight composition of magnesium in Al-Mg alloy either increasing or decreasing it has a tremendous effect in the hardness of the material. Increasing the magnesium concentration also increase the hardness of the material and decreasing magnesium concentration also decreases its hardness. This can help in material selection for various construction and manufacturing work. To get various strengthen properties of material at low cost for different construction and structural work can simply be achieved by increasing the magnesium concentration and its corresponding aluminum concentration. At low Mg composition, the hardness of the cast material is low and has limited application in heavy duty construction and engineering works; while at higher Mg composition the hardness of the cast material is very high and hence it can be applicable in heavy duty construction and engineering works like bridges, road construction and pistons etc.

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