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Effect of Magnesium on Tensile Strength of Cast Aluminum Alloy Using Sand Casting Method

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Abstract

It has been proven over the years that pure aluminum is ductile, light weight, brittle and has low tensile strength. This study was carried out and aimed at improving the mechanical properties with focus on tensile strength of the cast aluminum by alloying it with magnesium. This is as a result of its high strength and low density. The alloying aluminum-magnesium (Al-Mg) was carried out using sand casting method because of cost effectiveness and ease availability. The sand mold was prepared with green sand which is made up of silica sand, binders and water. The pattern for the casting is 200mm by 14mm; it was then placed in the mold cavity and rammed. Aluminum craps of 2kg by weight is placed in the crucible furnace and heated to a temperature of 750^{o}C. Powdered magnesium of 45% composition is added to the molten aluminum and mixed together using a stir casting machine and poured into the mold cavity at a temperature of 730^{o}C and allowed to solidify. This process was repeated for 6%, 8%, 10%, 12% and 14% weight composition of magnesium alloy. The cast specimen was then machined to specification and dimension to enable the tensile strength test to be carried out using Avery-Dimensional Universal Testing Machine. It was observed that at 4% Mg composition the tensile test result value was lowest and this value increase as the composition of Mg was varied and at 14% Mg composition, the tensile test result value was at highest. It was concluded therefore that the composition of Mg in Al-Mg alloy has a positive effect on the cast material, that as the composition of Mg increases from 4%-14%, the tensile strength of the cast material also increases.

1. Introduction

An alloy is a combination of metals or metals combined with one or more other elements to improve the mechanical properties of metals. Also alloy as a substance made by melting two or more elements together; at least one of them is a metal. An alloy crystallizes upon cooling into a solid solution, mixture or intermetallic compound. Aluminum is light weight, non-toxic, ductile, corrosion resistant and good electrical and thermal conductivity. It cannot be used for engineering construction work because of its softness and brittle nature except strengthened by alloying. [1] reported that pure aluminum has a low tensile strength and it's of little use for structural purposes. Hence, it is therefore combined with small percentage of other materials by alloying to improve its strength.

It has been scientifically proven that when reinforced with other material property, aluminum alloy will be enhanced 2]. According to [3] pure aluminum obtained from bauxite is relatively

expensive to produce and is too soft and weak to serve as a structural material. To overcome its low strength, it is alloyed with elements such as magnesium that has a positive effect on the mechanical properties of the alloy. [4] stated that in casting magnesium alloy up to 90% of magnesium are produced as casting, which is widely used in the aerospace industries with Mg-Al alloys containing 8-9% Al. in structural analysis to reduce weight, the Al-Mg alloy is adopted on the main hull according to the rules for construction and classification of sea going high speed craft [5]. Magnesium cycling has become more important because of the increasing use of the material in the automotive industries; according to [6]. This is as a result of its light weight properties. Different metals are alloyed with aluminum because of its favorable effect on casting. The American Foundry Society (AFS) defined casting as a manufacturing process in which a liquid material is usually poured into a mold which contains a hollow cavity of the desired shape and then allowed to solidify. This research work presents an investigation on the cast nature of aluminum alloyed with different composition of magnesium in other to study the effect of magnesium content on the mechanical property of tensile strength of Al-Mg alloy. In most structural works the cost of the materials used are usually expensive, this high cost and sourcing of materials usually pose a setback in the time frame for the completion of most structural works. This study is aimed at eliminating these setbacks by alloying of two metals Al-Mg using a less expensive casting method i.e sand casting method, to obtain high tensile strength property of the material at lower cost.

2. Methodology

2.1. Material Sourcing and Preparation

Aluminum scraps used in this research work was purchased at Uwelu Motor Spare Parts, in Edo State. The scrap parts consist of mainly beverage cans (1% Mn, 0.4% Fe, 0.2% Si, 0.15% Cu) having 98% aluminum. It was cleaned from grease and dirt using Premium Motor Spirit (PMS). The magnesium used for this research work was purchased from Owode-Onirin Market, in Lagos State. The magnesium was grinded into dine powder, which allow for easy addition and mixing with the molten aluminum.

2.2. Mold Preparation

The molding sand consists of green sand, which contains silica sand 88%, binder (clay) 6% and water 6%. This was done in the Production Engineering Foundry Workshop, University of Benin. The green sand is filtered using a mesh of 2.65mm and 1.7mm to remove solid particles and also to get a fine grain particle of the green sand. The pattern is made of a hollow metallic rod of 200mm by 14mm for the tensile test to be carried out, as shown in Figure 1.

A cylindrical cheek made of plastic flask of 200mm by 154mm diameter is used to create the mold. The pattern is then placed inside the cheek and covered with the green sand and rammed with a wooden rammer. The pattern is then withdrawn from the rammed molding sand, generating cavity (mold) in the molding sand. The floor acted as the drag to facilitate the removal of gases during casting solidification.

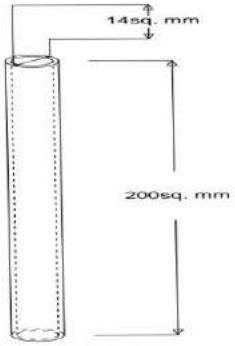

Figure 1. Pattern used for mold creation

2.3. Casting Process

Aluminum scrap of 2kg was measured and placed in the crucible pot that fits the inner diameter of the furnace, and it is then heated to a temperature above 750^{o}C to melt. It is then taken out of the furnace, all dirt and unwanted materials is removed using a skimmer. The 4kg weight composition of magnesium is added to the molten aluminum (Al) and placed back in the furnace and stirred for 5minutes using a stir casting machine. It is then taken down from the furnace and allowed to cool to a temperature of 730^{o}C in the open air; this temperature is monitored using a thermometer. The molten metal alloy is then poured into the mold cavity and allowed to solidify. The process was repeated for 6%, 8%, 10%, 12% and 14% weight composition of magnesium.

2.4. Mechanical Testing

Prior to this, the specimen was machined to the various dimensional sizes of 100mm by 13mm diameter for tensile strength test, as shown in Figure 2. The test was carried out in the Mechanical Engineering Workshop of the University of Benin. The test was conducted using an Avery-Dimensional Universal Testing Machine. The cast specimen of 4% weight composition of magnesium was inserted into the grip of the testing machine jaw, force was then added and the specimen pulled apart until fracture occurred, and the fracture force readings recorded from the dial scale attached to the machine. This process is repeated for the other cast specimen of 6, 8, 10, 12 and 14% composition of magnesium and the various readings recorded which is then used in calculating the tensile strength.

$$\text{Tensile Strength} = \frac{\text{TENSILE LOAD (F)}}{\text{Area (A)}} \quad (1)$$

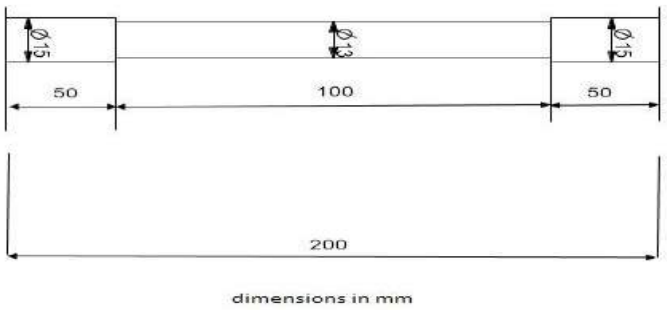

Figure 2. Tensile Test Specimen

3. Results and Discussion

The following result in Table 1 was obtained using Equation 1.

Table 1. Tensile Strength Test Results of Al-Mg Alloy

Percentage Composition	Sample 1	Sample 2	Sample 3	Average	Tensile Test (N/mm^2)
4	16	16	15	16	120.53
6	16	17	16	17	128.06
8	18	16	17	18	135.60
10	18	19	17	19	143.13
12	19	20	18	20	150.66
14	21	20	21	21	158.20

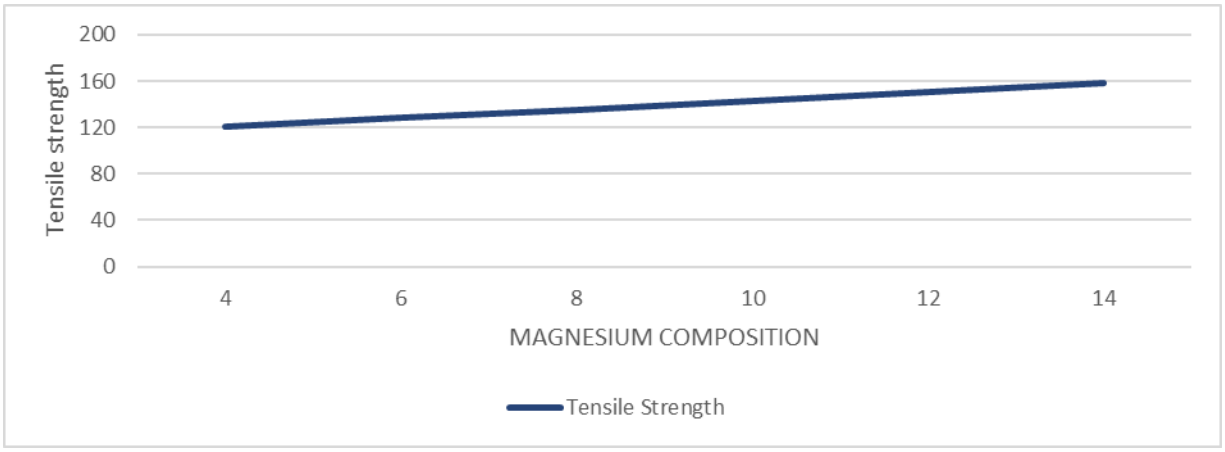

Figure 3. Increasing Tensile Stress with Increase in Magnesium Composition

3.1. Mechanical Property

The results deduced from this research shows that tensile strength increases simultaneously as the weight composition of magnesium increases. As observed in Table 1 above, at 4% composition of Mg the tensile test value is at lowest, this is due to low composition of Mg in the alloy; and at 14% composition of Mg the tensile test value is highest, this is due to the high Mg concentration in the alloy. In Figure 3 the graph indicates a straight line slope from left to right, this is as a result of increase in the Mg concentration from 4%-14% in the Al-Mg alloy. As the percentage by weight composition of magnesium increases in the alloy, the tensile strength also increases. This agrees with the study made by [7], that as the percentage composition of magnesium increases in the Al-Mg alloy, the tensile strength also increases. It therefore follows that an increase in the composition of magnesium alloy has a significant increase on the tensile strength of the aluminum cast parts. This result can be useful during material selection for different structural applications.

4. Conclusion

From the experimental results obtained from this study and other corresponding results from other literatures pointed out in this research work, it is evident that as the percentage composition of magnesium in Al-Mg alloy when altered either increasing or decreasing, the corresponding results for tensile strength either increases or decreases. This result goes a long way in the selection of various materials for different structural work. Al-Mg alloy can be used for corrosion resistance due to the absence of impurities like nickel and copper; this is one of the major reasons pure aluminum is recommended for alloying. Tensile strength property plays a major role in most structural and engineering works, like high impact buildings, high load resistant materials, bridges, elevators etc. This tensile strength property can be achieved using low cost material i.e Al-Mg with low cost of fabrication.

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