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Effects of Magnesium on the Microstructure of Cast Aluminum Alloy Using Sand Casting Method

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Abstract

In this study, the effects of magnesium (Mg) addition to aluminum (Al) alloy at different percentage composition on the microstructure of this alloy were examined. For this experimental study, the different alloys of 4%, 8% and 14% by weight with various composition of magnesium were prepared through casting process using sand casting method. The sand casting method was employed in the casting process due to its low cost of setting up and availability. The high reputation of Al-Mg (LM25) alloy in automotive industries stems from its light weight (density), high strength to weight ratio, excellent casting characteristics, high corrosion resistance, low coefficient of thermal expansion, good thermal and electrical conductivity and good mechanical properties including high machinability and workability. The microstructure of this alloy depends strongly in its composition and solidification rate. The specimens used for this research was prepared using sand casting method. It was machined and grinded using a series of silicon carbide paper and then polished using emery paper. The emery paper is used to obtain a mirror finishing of the surface of the specimens. The specimens were etched in an aqueous solution of sodium hydroxide (Na0H) and was washed and rinsed with alcohol and water. Various micrographs of the surface of the cast specimen were taken with a light optical microscope with different magnification in other to examine the surface finishing of the cast specimens. This was done in the Engineering Management Development Institute (EMDI) Akure, Ondo State. The 4% Mg in Al-Mg alloy consists of dendrites of aluminum and solid solutions as the primary phase and eutectic mixture filling the interdendritic spaces. The 8% Mg in A-Mg alloy shows the presence of eutectic magnesium and the dendritic structure forms a network of dendrites all over the surface, while the 14% Mg shows white fields which are primary aluminum solid solution with a uniform distribution of magnesium, this causes complete fusion with the primary aluminum grains. These various attributes in the variation composition of Mg in Al-Mg alloy is responsible for the formation of dendrites along the regions, it also causes a decrease in the average value of the dendrite arm and grain size; and these variations in Mg composition increases the mechanical properties of the cast material.

1. Introduction

Microstructure is the very small scale structure of a material, defined as the structure of a prepared surface of material as revealed by an optical microscope of above 25x magnification. Microstructural analysis is widely used in industries to elevate products, material Performance, response to environment and failure mechanism are just some of the areas in which

microstructural analysis can be utilized to assess and develop products. According to [1], microstructure has a major influence on the properties of engineering materials and some of these microstructural features include grain size, crystal structure and type of appearing interface, nucleation and growth process etc. Microstructure determines the mechanical, physical and chemical properties of materials; this is according to [2]. Microstructure influences virtually all aspect of the behavior of materials [3]. In Al-Mg alloy, the microstructure reveals that with increase in aluminum (Al) content, the number of magnesium ($Mg_{17}Al_{12}$) phase distributed into α-Mg phase are increased with more distribution in microstructure of Mg alloy [4]. The increase of the magnesium content of the commercial alloy resulted in an increase of the magnesium concentration in the interior of the α1-Al globules of the SSM castings; this is according to [5]. According to [6], the magnesium concentration in the interior of primary α-Al is very low in the temperature range from the liquids to the start of the eutectic reaction. [7] increasing the aluminum concentration results in uniform distribution of the phase throughout the matrix regardless of the aluminum content. Application of aluminum casting alloys for structural components require high strength and suitable high elongations. Grain size, their morphology, interdentritic, distances and distribution of secondary phase are crucial factors affecting mechanical properties of the cast parts, [8] and [9].
Over the years specialisthave been working earnestly to improve mechanical properties of light alloys through the microstructure controlling using special casting techniques (sand casting, high pressure die casting, mold casting), adding micro-additions that enhance obtaining finer grained microstructure, applying surface treatments or using heat treatments, all these should ensure increase in material properties [10] and [11]. Scientists have described precipitation sequence accurately during artificial ageing of aluminum -magnesium alloys and proposed sequence.

$$SSS\alpha \longrightarrow GP\ zones \longrightarrow \beta^{l} \longrightarrow \beta^{ll} \longrightarrow \beta$$

Where Supersaturated Solid Solution is SSSα, GP forming of Guinier-preston Zones, β^{l} is a Li_2 (Al_3Mg) and β^{l}forming of phase Al_3Mg_2which directly increases mechanical properties of Al-Mg alloys.
It was found also that when Al-Mg alloy with (18%) Mg content is aged at a temperature between 100 and 250 ^{0}C, the β^{l} form first and the presence of β phase could be observed only when Mg depletion of the matrix is almost complete [12] and [13]. This research was carried out to determine the effect of magnesium at different composition on the microstructure of the cast aluminum alloy. This study is aimed at addressing the problem of lack of good surface finishing of cast material. Over the years it has been proven that surface finishing of most materials has a great effect on the mechanical properties like corrosion resistance, wear and tear resistance, thermal conductivity and expansion, tensile strength and hardness etc.

2. Methodology

2.1 Mold Preparation

The molding sand used was prepared and comprises of green sand which contains silicon, binder (clay) and water at 88%, 6% and 6% respectively. The molding (green) sand is filtered using 2.65mm and 1.7mm mesh to sieve the molding sand for larger properties in other to obtain fire grain particles of the molding sand. The pattern is made of plastic hollow rod measuring 250mm by 25mm for the microstructural testing to be carried out as shown in Figure 1. A plastic cylindrical cheek of 250mm by 154mm diameter is used in creating the mold. The pattern was placed inside the cheek and covered with the molding sand and rammed. The pattern is then withdrawn from the rammed molding sand generating cavity (mold) in the molding sand. The cope of cylindrical shape is created with the molding sand and rammed, this contains the sprue which facilitate pouring, the floor acted as the drag to ease and quicken the removal of gases during cast solidification.

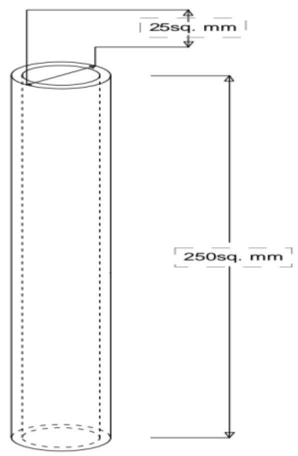

Figure 1. Pattern used for creating the mold

2.2 Casting of Specimens

A total of 3 specimens with different percentage composition of magnesium were produced, to serve for the microstructural testing. 2kg scrap of aluminum is measured consisting mainly beverages can (1% Mn, 0.4% Fe, 0.2% Si, 0.15% Cu) having 98% aluminum. It was placed in the crucible pot to be heated in the furnace to a temperature above 750^{0}C and taken down from the furnace; dirt is removed using a skimmer. Powdered 4% weight composition of magnesium (mg) which serves as the alloy is added to the molten aluminum (Al) and stirred for 5minutes using a stir casting machine. The specimen is then withdrawn from the furnace and allowed to cool to a temperature of 730 ^{0}C before pouring into the mold cavity. The temperature is measured using a thermometer. The specimen is then allowed to solidify. This process is repeated for 8% and 14% weight composition of magnesium (Mg) under the same temperature.

2.3 Microstructural Testing

The microstructural analysis testing was carried out in Engineering Management Development Institute (EMDI) Akure, Ondo State. The test analysis was carried out using a light optical microscope. The samples to be examined are 4%, 8% and 14% weight composition of Al-Mg alloy. The phases in the microstructure are to be identified by comparing their different shapes and green sizes. Prior to testing the specimens were machined to a diameter of 20mm by 20mm each. The specimen was then subjected to grinding using series of silicon carbide papers starting with 220, 320, 400, 500 and 600 grits, mounted on a flat plate under running water. The specimen were then polished to obtain a mirror finish on polishing cloth attached unto a rotating wheel using a diamond paste of 6, 3 and up to 1 micron. The specimens were then etched in an aqueous solution of Na0H (25g of Na0H) in 100ml of distilled water. The specimens were washed and rinsed with alcohol and water. They were then placed on a light optical microscope and a micrograph of 100X magnification taken for the different specimen.

3. Result and Discussion

In order to arrive at a clear understanding of the effect of Magnesium (Mg) content on the aluminum alloy, microstructural analysis was carried out and observations disclosed:
Figure 2 containing 4% Mg in Al-Mg alloy shows a micrograph consisting of dendrites of aluminum and solid solutions as the primary phase, with a eutectic mixture filling the intendendritic spaces. From Figure 3, it was observed that the micrograph shows the presence of eutectic magnesium in the intendendritic region. The dendritic structure forms network of dendrites all over the surface showing the arrangement of primary and secondary arms where the cavities are occupied with eutectic type phase. The white fields in Figure 4 micrograph are primary aluminum solid solution with a uniform distribution of magnesium in Al-Mg alloy which

causes a complete fusion with the primary aluminum grains and this changes its original course form. Due to the increasing amount of magnesium in the aluminum alloy, the average value of the dendrite arm and grain size deceases. Comparing with that of [14] stated that after the addition of magnesium, a distinct grain boundary appears in the α-Al phase and the grey eutectic is distributed around the grains to form eutectic groups. It was also stated that the smaller the grain size the higher the mechanical properties of the alloy.

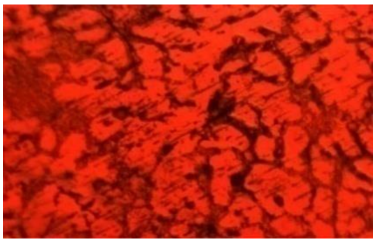

Figure 2. Micrograph of Al-Mg alloy with 4% wt composition of magnesium with 100% magnification

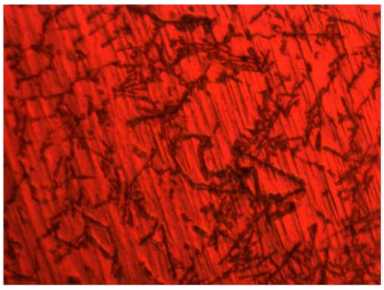

Figure 3. Micrograph of Al-Mg alloy with 8% wt composition of magnesium with 100% magnification

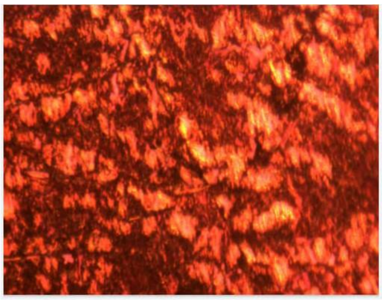

Figure 4. Micrograph of Al-Mg alloy with 14% wt composition of magnesium with 100% magnification

4. Conclusion

From the experimental results in this study and other corresponding results from other literatures pointed out in this research, it was observed that as the magnesium (Mg) content increases the morphology and size of eutectic Mg in the alloy changes significantly. The morphology changes from solid coarse solutions of Al as the primary phase to smaller grain sizes. The uniform distribution of magnesium in Al-Mg alloy is responsible for the complete fusion of the primary aluminum and also the smaller grain sizes in the alloy and these in turn induces the higher mechanical properties of the alloy.

The knowledge of the microstructure of materials helps predict areas where these materials can be effectively applicable, since the microstructure has a great influence on the mechanical properties of cast materials.

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