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AL LM6 HOLLOW CYLINDER FABRICATED USING CENTRIFUGAL CASTING

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ABSTRACT

The main purpose of this study was to investigate the silicon (Si) particles distribution of LM6 Aluminum Casting Alloy (Al LM6) cylinder produced by centrifugal casting method. Al LM6 cylinder fabrication started by melting Al LM6 ingots. The melt is then poured into a rotating mould with constant speed of 1700 rpm (100 times of gravity value, 100G) at room temperature. After five hours left to freeze, LM6 Al cylinder is removed from the mold. The result is an Al LM6 hollow cylinder with the outer and inner diameter of 60 mm and 20 mm, respectively and the thickness of 35 mm. The temperatures of the molten ingot used in this study were 690 °C, 710 °C and 725 °C. The microstructure differences due to different melting temperatures observed using an optical microscope (OM). Microstructural observations show that the Si particles content are almost the same on the inside, center and outside the specimen. However, the sizes of Si particles in these three parts are different. The particle size of the specimens has a size larger than in the middle and the outside. The difference in size is due to the low density of Si particles than Al and the expansion of Si particles due to rapid melt cooling rate in the mold during centrifugal casting process. The three specimens with different values of melt temperature shows different size Si particles. The difference of Si particle size and distribution expected will influences the mechanical properties of Al LM6 fabricated.

Keywords: functionally graded materials, (FGMs), centrifugal casting, aluminum, silicon.

INTRODUCTION

Al LM6 an engineering material that is widely used in related industries as aerospace, automotive, construction and many others because the properties of natural light, good durability, high strength and high corrosion resistance either in the atmosphere normal or in the water. These alloys are usually very difficult to machine due to high Si content and tendency to distort and eventually cause wear on the tool quickly.

In addition to having high corrosion properties, Al LM6 also has good ductility, casting ability and fluidity. Good ductility alloy able to produce the desired casting form. The good fluidity makes it enables poured into a thin mold, complex parts. Indirectly, this allows the alloy produces a larger surface and free of any defects. Among the casting process in accordance with the use of Al LM6 is sand casting, gravity and centrifugal casting.

In this study, the centrifugal casting method on the horizontal axis is used to produce a hollow cylindrical Al LM6. Casting of this type is typically used to produce hollow products such as bearings, bushings and disc cutter. Product hollow cylinder produced by this method will usually have a precise result; the surface is smooth and free from any defect in the inner and outer diameter.

Chirita *et al.* [1] discusses the advantages of using a centrifugal casting device for the production of structural components of Al-Si alloys. The study focused on the mechanical properties of the material produced by centrifugal casting technique compared to the mechanical properties of materials resulting from traditional gravity casting techniques. As a subject of study, an aluminum alloy AS12UN were used. From the results of experiments conducted, it was found that the use of a centrifugal casting capacity to increase by 35% breaking strength, breaking strain of 160% and a Young's modulus of 18%. This clearly shows that the production of mechanical properties by using centrifugal casting is better than the traditional gravity casting techniques. The study also showed a difference of mechanical properties of both types of castings are due to parameters of centrifugal force, vibration and fluid dynamics.

Watanabe *et al.* [2] have analyzed the magnesium alloy ZK60A (Mg-Zn-5.5 mass% 0.6 mass% Zr) functionally graded materials (FGMs) cylinder fabricated using a centrifugal casting method. Centrifugal force used was 40G, 80G and 120G. The length and diameter of cylinder fabricated are 18 mm and 13 mm, respectively. The fabrication process started with placing ZK60A in a mold and heated at 680 °C for the melting process. Then the centrifugal force is applied to the molten ZK60A and allowed to cool to form the desired cylinder. The cooling rate is at 0.05 ºC/s. The results of the tests show that there are no significant changes in the microstructure at the set values of G. The examination of microstructure using EDX showed that the Zn particles distribution along the cylinder for the three different G value are almost same pattern. Zr particles only exist on the outer wall of the cylinder. The factors that cause this to happen is due to the difference in density between the particle and the direction of centrifugal force. The higher the density of the particles, the easier to disperse particles to the outer wall of the cylinder.

Centrifugal casting is a technique in producing functionally graded materials (FGMs). This techniques

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usually used in producing continuous graded materials type for metal-based FGMs. Continuous graded materials is refer to two different material ingredients change gradually from one to the other side. Based on previous studies [1-6], it can be concluded that the centrifugal casting foundry is a very efficient tool for the formation of a hollow cylinder. The centrifugal casting process is more effective for casting two or more different materials with different density. It can also produce good mechanical properties. In addition, factors that affect the mechanical properties of casting are the centrifugal force, the melt temperature, viscosity and density of the metal particles.

In this study, Al LM6 hollow cylinder is fabricated using centrifugal casting and the Si particles distribution inside the cast is investigated. The process of forming a hollow cylinder started with melt Al LM6 ingot in the smelter. Al LM6 molten then poured into a mold which rotates at the speed set at room temperature. Al LM6 cylinder is removed from the mold after 5 hours to ensure that it solidifies and cools.

METHODOLOGY

The material used for centrifugal casting was an Al LM6 with the following alloying composition: Magnesium- 0.27%, Manganese-0.23%, Silicon- (10.50-13.00)%, Zinc-0.852%, Nickel-0.1% and Tin-0.2%. Figure-1 shows the schematic diagram of the centrifugal casting setup, which consists mild steel cylindrical mold that connected to the shaft of a motor. The speed of the rotating mold was 1700rpm and the flow of molten metal into the mold was confined in the horizontally oriented, axially rotating cylindrical mold. The procedure started by cutting the Al LM6 ingot into a smaller size to make it melting easier inside the induction furnace. The ingot with approx. mass of 160g material was melted at 690 ˚C, 710 ˚C, 715 ˚C and poured into the rotating mold which rotated by the speed of centrifugal force value 100G (100 times of gravity).

The dimensions of the castings made were 35 mm in length and 20mm in wall thickness with outer and inner diameter of 60mm and 40mm, respectively. The centrifugal casting part shown in Figure-2 were then cut using CNC wire cut in order to have specimens of 10mm height and 10mm length for microstructural observation. The microstructural observation was carried out using Optical Microscope (OM) in order for measurement of a volume fraction of silicon particles in aluminium Al LM6. The OM samples were grinded, polished and eroded by mixed acid-water solution (5% HF and 95% H2O). The centrifugal casting conditions of each Al LM6 cylinder fabricated are listed in Table-1.

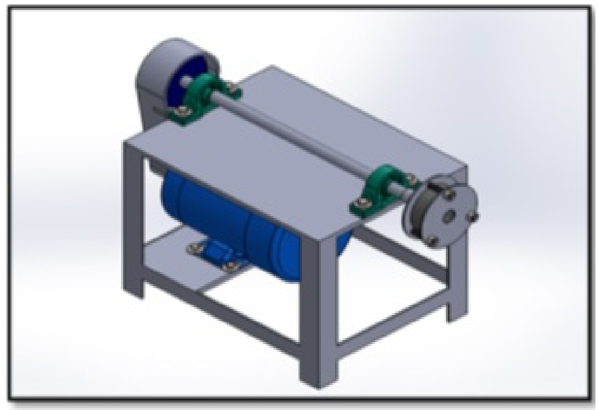

Figure-1. Schematic of centrifugal casting setup.

Table-1. Parameter of centrifugal casting process.

Specimen No.	Material /mass	Centrifugal force	Melting Temperature (°C)
1	Al LM6 / 160g	100G (1700rpm)	690
2			710
3			725

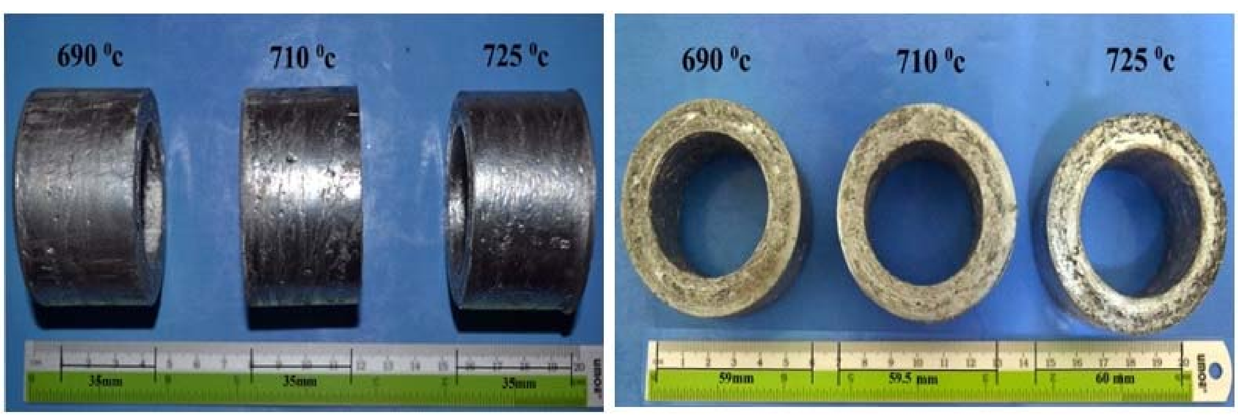

Figure-2. The Al LM6 cylinder fabricated.

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RESULTS AND DISCUSSION

Figure-2 shows the Al LM6 cylinders fabricated at different melting temperature. There are little different in dimensions. The outer and inner diameter of the casting with melting temperature of 690 °C is 59mm and 39mm, respectively. For the casting at melting temperature of 710 °C and 725 °C, the outer diameter is 59.5mm and 60mm, respectively. Meanwhile, for the inner diameter is 40mm and 41mm, respectively. Besides that, the height of each casting is same, which is 35mm. The factors that causes the geometry size not constant is the volume of Al LM6 which is predetermined is not entirely successful poured into the mold. Moreover, the mold which not preheated first also causes the differences in geometry size.

Figures-3 to 5 show the physical appearances of Al LM6 cylinders fabricated. It can be seen from these figures, there are casting which having defects on its surface. Figures-3(a), 4(a) and 5(a) show the hot tear defects which concentrated on the inner surface of the casting. This kind of defect is due to the metal shrinkage inside the mold. In addition, there is also a banding defect on the outer surface as seen in Figures-3(c) and 4(c) .This is caused by the motor introduced vibration during casting.

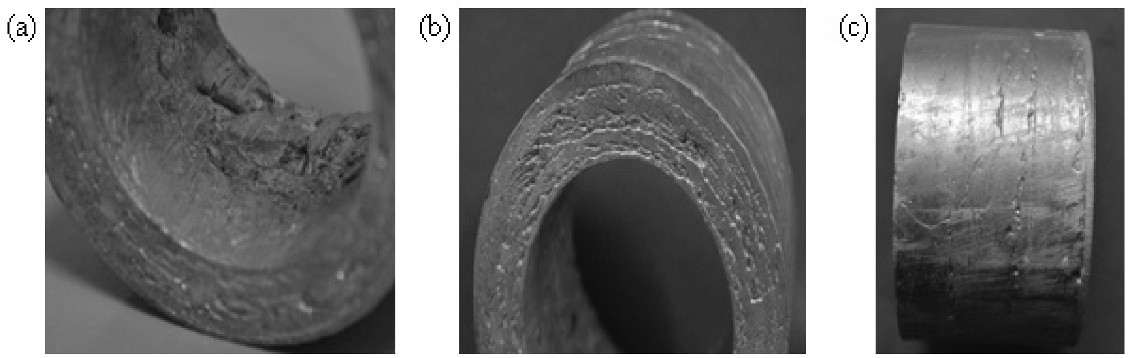

Figure-3. Physical properties of casting with temperature 690 °C. (a) Inner surface; (b) side surface; (c) outer surface.

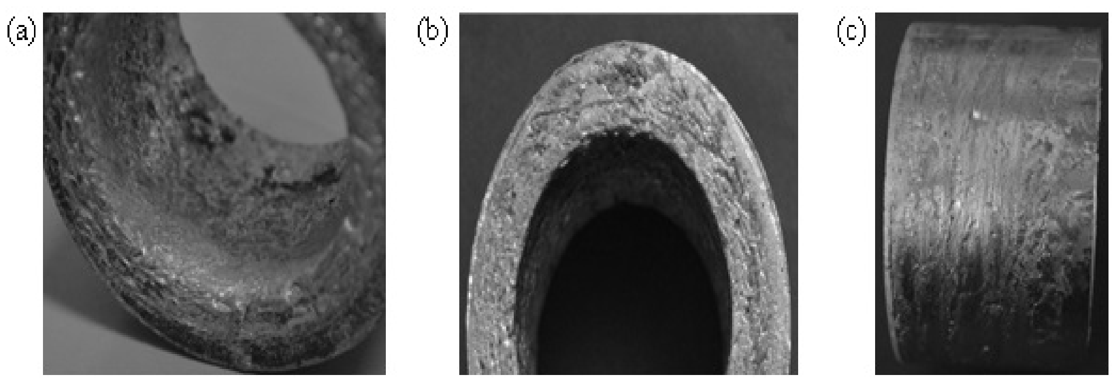

Figure-4. Physical properties of casting with temperature 710 °C. (a) Inner surface; (b) side surface; (c) outer surface.

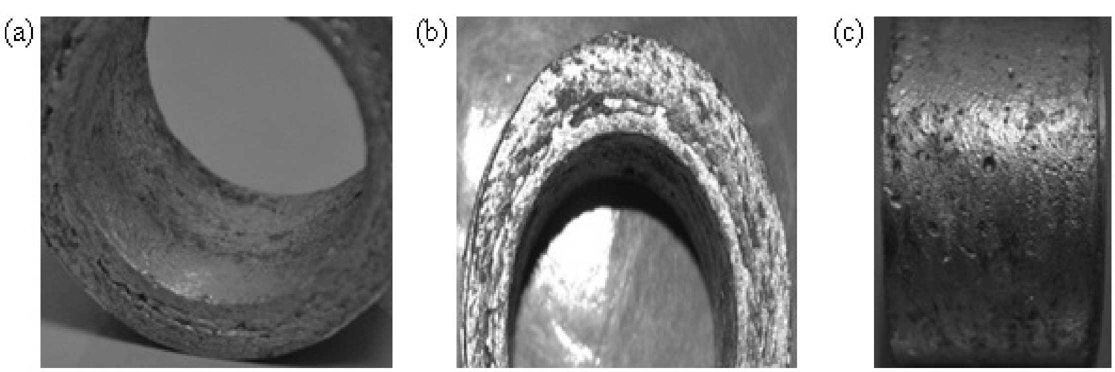

Figure-5. Physical properties of casting with temperature 725 °C. (a) Inner surface; (b) side surface; (c) outer surface.

The Al LM6 cylinders fabricated have a smooth outer surface. This can reduce the finishing work which no need to do machining for a smooth and fine surface. It thus can save time and reduce the cost of casting production. In addition, the castings produced by this process has a high density structure which can increase the lifetime of casting and resist over-load and high impact without breaking. The result of uniformity and extra features found on centrifugal casting, machining time and the remaining waste is minimized. Furthermore, the defect on the result of such notch cast, hollow porosity and surface can be reduced. Indirectly, this condition can reduce the effects of pollution on the environment.

Figures-6, 7 and 8 show the microstructure along the thickness of Al LM6 cylinder fabricated at different melting temperatures. From the observation, it indicates that the microstructure at outer and inner surface have same distributions pattern of Al and Si particles. However, in Figures-6(a), 7(a) and 8(a) the texture size of Si particle has more concentrated on inner surface compared to the agglomerates of Al where more concentrated along the outer surface. The factors that influenced this condition is due to non-uniform of grain size. Furthermore, the density of Al is higher than Si particles.

Besides that, the distributions movement of Si particles is not uniform. According to Bonollo [3], low melting temperature and high viscosity in Al LM6 will cause the particles move freely and this will result that almost all parts are filled with Si particles which distributed with inconsistent. Moreover, as seen in Figure- 6(c), the inner surface of the lower melting temperature casting has shown the presence of gas porosity. The gas bubbles present in the molten metal are thrown towards the inner surface of the casting by the centrifugal force due to their lower density [4]. Meanwhile, for the high melting temperature as seen in Figure-8(c) shows the absence of any form of porosity on the surface of the specimen. On the middle surface of the casting as seen in Figure-6(b), 7(b) and 8(b), specimens have a small amount of Si particles. Might probably this occurred due to inconsistent cooling rate at the middle part of the casting since the casting operate at room temperature.

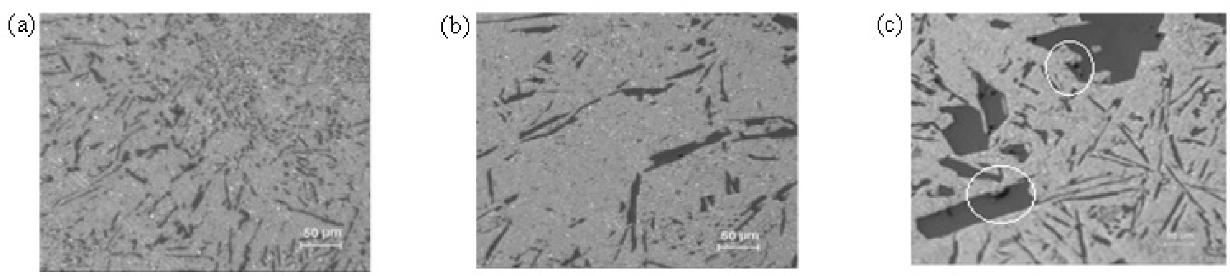

Figure-6. Micro structures of Al LM6 cylinder with melting temperature of 690 ^{0}C. (a) outer, (b) middle, (c) inner.

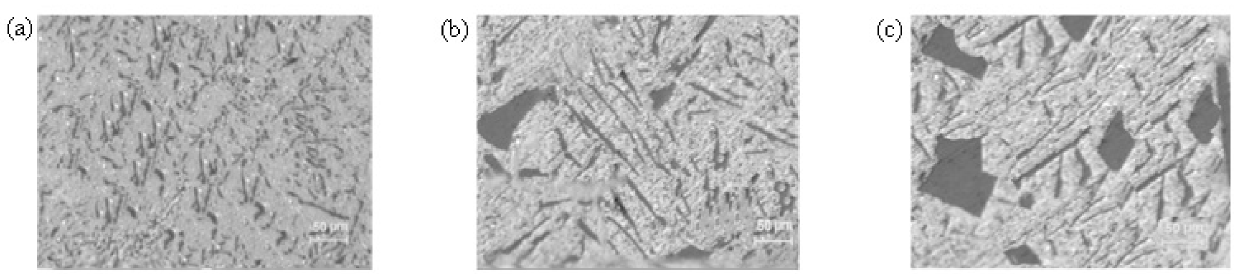

Figure-7. Micro structures of Al LM6 cylinder with melting temperature 710 ^{0}C. (a) outer, (b) middle, (c) inner.

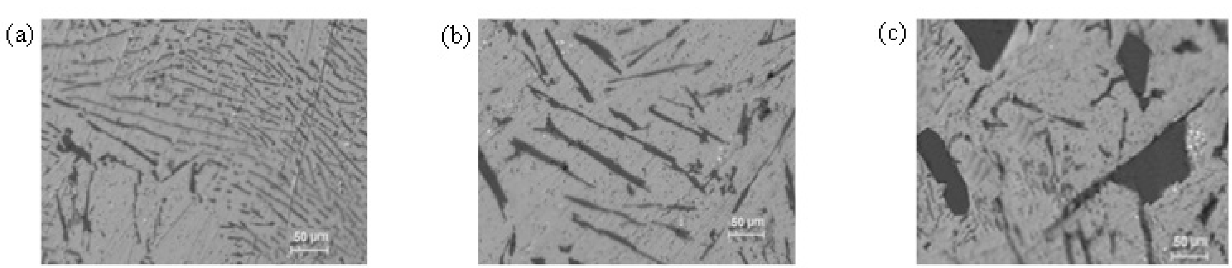

Figure-8. Micro structures of Al LM6 with melting temperature of 725 ^{0}C. (a) outer, (b) middle, (c) inner.

CONCLUSIONS

From the obtained results, it can be proved that the study has achieved its objective of producing a hollow cylindrical Al LM6 using centrifugal casting method. The distribution of Si particles is strongly depend on the melt temperature of Al LM6 ingot.

The melt temperature is an important parameter to produce a good casting. The results show that the microstructure of melt temperature for all three specimens microstructures matching the pattern of accumulation of Al in the outer surface and the accumulation of Si on the inside of the specimen. This is due to the different densities between Al and Si. In addition, the effect of low melt temperature causes the formation of large size of Si particles and thus lead to the hardness on the part of the specimen to be low. A cooling rate is too fast due to the high rotational speed of the mold also causes the differences in Si particles distribution and size.

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