RESEARCH PROGRESS IN MECHANICAL AND MANUFACTURING ENGINEERING VOL. 4 NO. 2
(2023) 217-225

RPMME

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773-4765

Fabrication of Aluminium LM6 Hollow Cylinder using Vertical Centrifugal Casting

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DOI: https://doi.org/10.30880/rpmme.2023.04.02.028
Received 01 July 2023; Accepted 01 Nov 2023; Available online 15 Dec 2023

Abstract: Centrifugal casting is an excellent fabrication method for producing cylindrical products. In this study, two Aluminium LM6 hollow cylinders were made using the vertical centrifugal casting method with different processing parameters. Specimen 1 was produced by setting the rotating mould speed to 1700 rpm without mould preheating. For Specimen 2, the rotating mould speed was set at 1800 rpm with preheating the mould at a temperature of 200°C. The Aluminium LM6 molten metal casting temperature for both specimens was set at 700°C. The mould was allowed to rotate for 30 minutes after casting and cool at room temperature before removing the specimen. From the physical observation, both specimens show good quality surface finish but have minor defects, which are veining and joint flash, possible causes of improperly heating mould. Overall, the quality surface area for both specimens has a smooth surface area and good dimensional accuracy. Moreover, the cross-sectional microstructure parallel to the radial direction of the two Al LM6 cylinders was observed using a Scanning Electron Microscope (SEM). Both specimens have a non-uniform Si distribution in the longitudinal radial, but the sizes in the outside, middle, and interior areas differ. Vickers microhardness test was conducted on the cross-section parallel to the radial direction of the two Al LM6 cylinders. Specimen 1 has a hardness value of 5.732 HV, whereas Specimen 2 has a lower hardness value of 6.437 HV. Both specimens have uniformity along the radial axis, although Specimen 2 has greater uniformity in rising than Specimen 1. The findings of this study show the importance of rotating mould speed setting and preheating in producing good Aluminium LM6 cylinders.

Keywords: Centrifugal Casting, Microstructure, Aluminum LM6

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1. Introduction

Centrifugal casting refers to casting processes that spread liquid metal to the periphery of a circular mould cavity, where it hardens to create a part. Centrifugal casting offers the highest level of material soundness. It has become the method of choice for metal casting processes in jet engines, compressors, and some military components [1]. Centrifugal casting will solve the issue of producing a solid cylinder. Mandrel deformation is reduced by centrifugal casting. Many hot sheet metal and composite constructions will develop around tooling, often a welded-fabricated structure [2]. When heat is produced throughout the production process, tools are vulnerable to distortion, just like major components are.

The rotating mould speed is one of the main parameters in centrifugal casting. In addition, the molten material's pouring temperature must be considered since it will influence the process's time for solidification. The requirement to pre-heat the mould is important since the topic's discussion of the solidification microstructure will justify it [3 – 7].

Determining the rotating mould speed to solidify hollow cylindrical casting well is important. A higher speed of rotating mould may improve casting quality. A compact uniform casting is produced because of the centrifugal force produced by the fast-spinning mould, which helps to eliminate impurities, air bubbles and superfluous materials from the molten metal. Better uniformity and repeatability in the casting process are made possible by monitoring and managing the mould and pouring temperature. In this study, Aluminium LM6 hollow cylinders were fabricated using vertical centrifugal casting. Aluminium is an excellent alloy for casting because of its strong thermal and electrical conductivity, superior mechanical qualities and corrosion resistance. This includes great fluidity, a low melting point, rapid casting cycles, low hot cracking tendency, good as-cast surface polish and chemical stability [8]. The specimen has been applied with grinding and polishing after being cut into small pieces before being analysed and tested using scanning electron microscope (SEM) and hardness test.

2. Materials and Methods

2.1 Materials

Aluminium LM6 has been chosen as the selected material for this study. Aluminium LM6 displays strong corrosion resistance in both typical atmospheric and marine situations. Anodic therapy can improve this feature even further in the worst circumstances [9, 10]. With these characteristics, it is used in various applications, including maritime, manifolds, motor casings, cast doors, and pumping operations. Additionally, it works particularly well when castings are required for being welded connected. Cast iron is a vast family of ferrous material alloys. The material, which belongs to the family of aluminium-silicon alloys, is widely used in various sectors due to its exceptional strength, resistance to corrosion, and thermal conductivity. The cast alloy identified as LM6 is mostly composed of silicon and aluminium, with small amounts of magnesium, copper, and manganese added to enhance certain properties. The qualities that come from this combination of ingredients make LM6 a preferred choice for many casting applications.

The bulk of an iron alloy known as cast iron (Si) comprises more than 2% carbon and more than 1% silicon. This may enhance the molten metal's casting capabilities. There may also be a small quantity of manganese and certain impurities, like sulphur and phosphorus. Some variations will be between wrought iron and cast iron [10].

Aluminium LM6's high fluidity and relatively low melting point allow for the formation of complex structures from it. It can also be an alloy to strengthen and increase its corrosion resistance [11]. Table 1 shows the range of chemical composition for Aluminium LM6 as conforms to BS 1490:1988 LM6.

Table 1: Range of Chemical Composition for Aluminium LM6 (%) [12]

Item	Percentage (%)
Copper	0.1 max
Iron	0.6 max
Zinc	0.1 max
Titanium	0.2 max
Magnesium	0.1 max
Manganese	0.5 max
Lead	0,1 max
Silicon	10.0 – 13.0
Nickel	0.1 max
Tin	0.05 max
Others	0.15 max
Aluminium	balance

2.2 Methods

The aluminium alloy was chopped into small pieces and accelerated to attain its melting point. In addition, the mould must be preheated to reduce thermal shock in molten metal structures. This may be done by preheating the mould in some molten aluminium alloy at a temperature of 700 degrees Celsius [13]. For the centrifugal casting machine to properly accomplish the goal, it must also adhere to the developed system. The centrifugal casting machine must be operating before the entire process is started to ensure that the rotating shaft and mould will revolve smoothly without causing any harm to the molten metal**.** Figure 1 shows how the cover was made and positioned to cover the molten metal splash.

Figure 1: Centrifugal Casting completely set up

The molten metal starts to harden as it fills the mould cavity. By encouraging directed solidification from the outer surface towards the centre, the centrifugal force aids in the solidification process. The spinning of the mould is halted after the casting has solidified enough, and cooling is then permitted. The cooling time may change depending on the casting's size and intricacy. The casting is removed from the mould when it has cooled.

The sample should be properly cut into sections to reveal the area of interest, such as a cross-section or a particular area with potential flaws. Start taking SEM photos of the LM6 sample after the sample is in the ideal location, and the microscope settings are perfect. A range of imaging methods has been used to capture various microstructure and surface morphology facets. Record of the findings, including any pertinent observations, photos and the outcomes of the elemental analysis. These records can be employed for quality assurance, problem-solving, or additional study and analysis.

The Vickers hardness test is a typical technique for determining the hardness of materials, especially metals like aluminium. For instance, a Vickers hardness test with a 25 gram weight would provide the hardness value HV10. There are three different locations places applied on the surface area of the specimen, which are upper, middle and lower. Each spot has been taken for five measurements to get the data more accurately. The holding time is ten seconds for each different place.

3. Results and Discussion

3.1 Scanning Electron Microscope (SEM)

The % range of the elements present in Specimen 1 and 2 is shown in Figures 2 and 3, respectively. They are presented within a suitable voltage range and are counted in seconds per electron volt.

Element	Weight%	Atomic%
C K	22.88	39.53
O K	2.87	3.72
Al K	62.80	48.29
Si K	11.45	8.46
Totals	100.00	

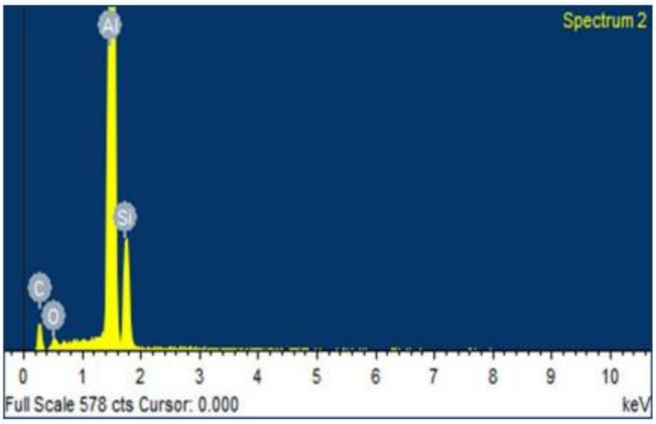

Figure 2: Weight and atomic in % for Specimen 1 at Spectrum 2

Oxide did not appear in Specimen 2. Only 1.48 % of weight and 1.26 % atomic appear for Si in spectrum 2 for Specimen 2. The alloy LM6 is based on aluminium and generally has silicon as one of its main alloying components. So, there are 73.32 % total average atomic number of aluminium appears for both spectrums.

Element	Weight%	Atomic%
C K	11.80	23.42
Al K	83.84	74.09
Si K	1.48	1.26
Fe K	2.88	1.23
Totals	100.00	

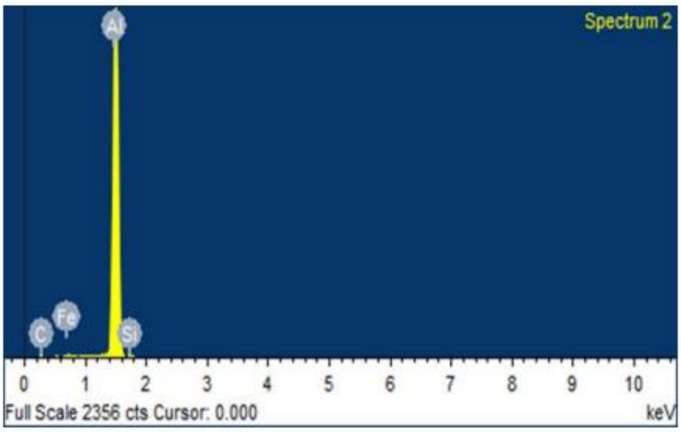

Figure 3: Weight and atomic in % for Spectrum 2 in Specimen 2

To summarise, both specimens demonstrate the crucial element, aluminium, which has the largest weight and atomic number compared to other elements. However, even if oxidation might interfere with the data experiment, it is still important to note that utilising SEM to identify any elements that appeared in the specimen was effective.

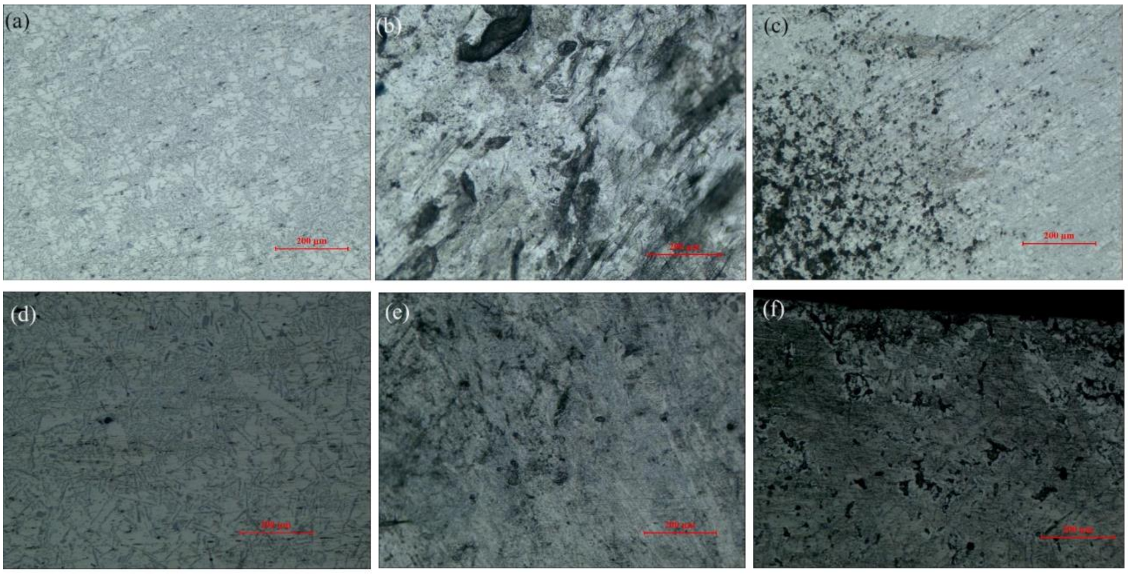

Figure 4: Microstructure of casting for Specimen 1 (a) inner, (b) middle and (c) outer, and Specimen 2 (d) inner, (e) middle and (f) outer side

Figure 4 depicts the microstructure for both specimens. Compared to Specimen 1, the microstructure of Specimen 2 shows good composition and is more organised. The dispersion of Si is not homogeneous along the radial direction.

3.2 Hardness Test using micro-Vickers Hardness Testing (VHT)

It is quite easy to capture a diamond dent that emerges after stress has been applied to the surface area for both specimens to make generating the data for the Hardness Value (HV) straightforward to compute. The exceptional rise in hardness results from the amazing grain refining during severe plastic deformation. Figure 5 illustrates the division of the cross-sectional area of each specimen for observation and hardness test.

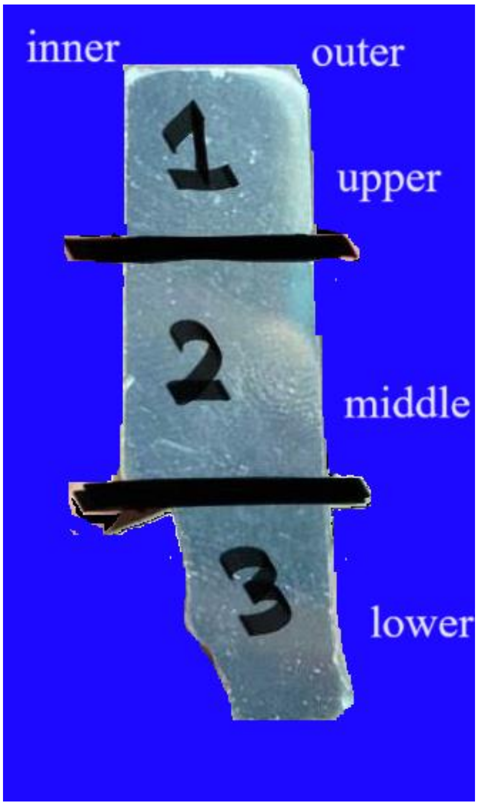

Figure 5: Division for each specimen

Figure 6 shows that Specimen 2 hardness value is still higher than Specimen 1, mirroring the Upper and Middle Area graphs. The fact that the hardness range is practically constant for Specimen 2 strongly supports the effectiveness of centrifugal casting. However, the hardness value of Specimen 1 was inconsistent.

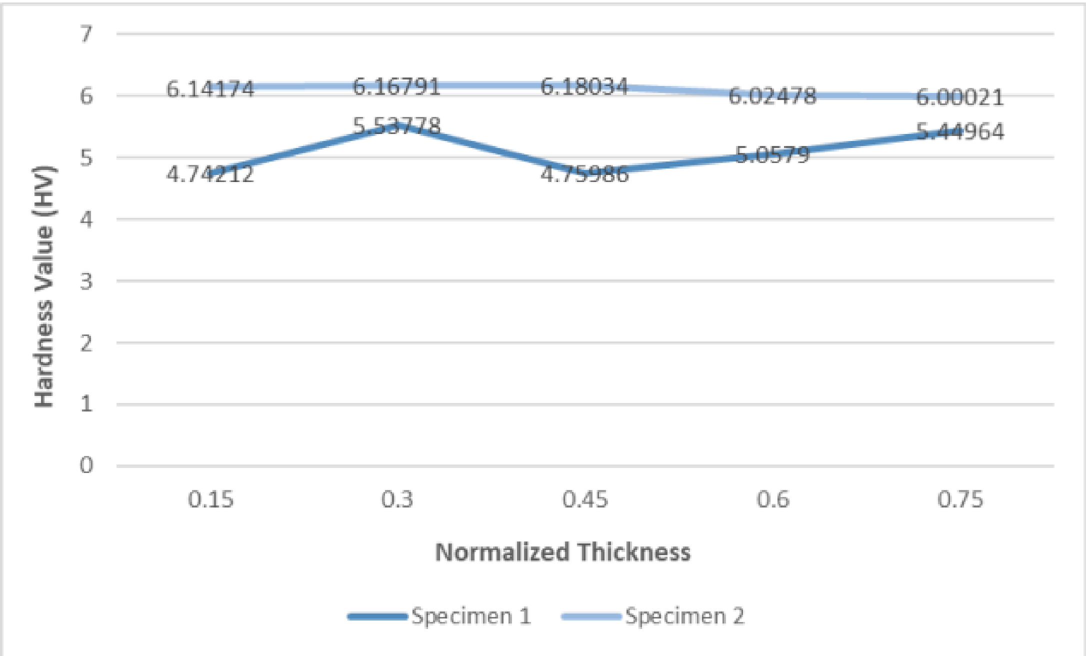

Figure 6: Comparison of Specimen 1 and Specimen 2 Upper Area.

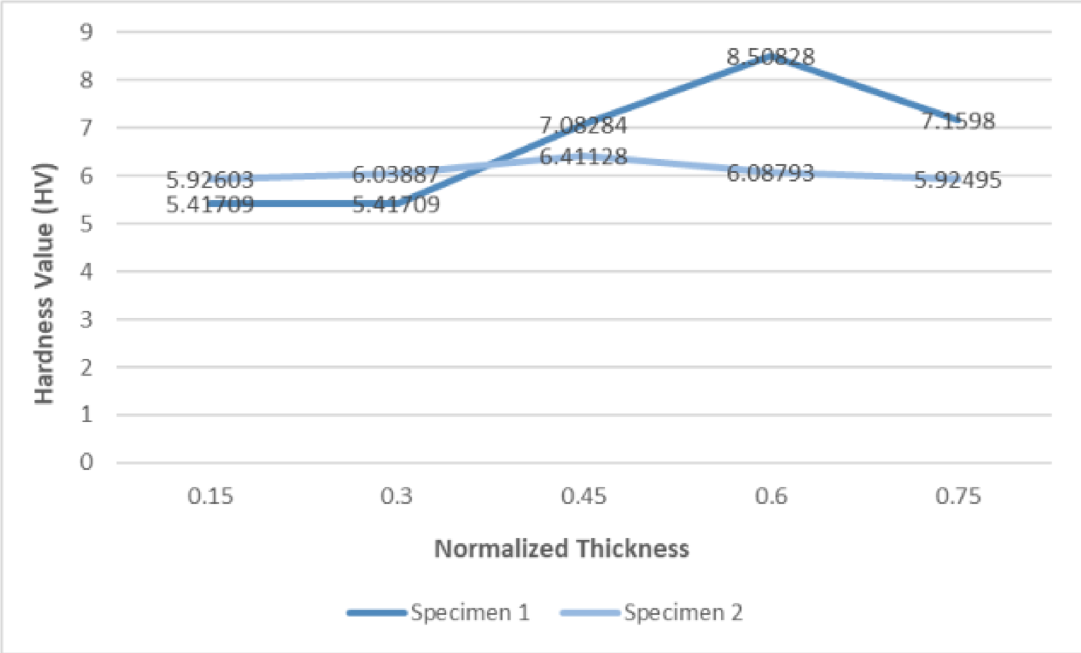

Figure 7: Hardness Value (HV) of Specimen 1 and Specimen 2 for Middle Area

Although specimen 2 had a little lower hardness value at the end of the test than specimen 1, which had a range of five to six, the hardness value for the middle area of the graph shows a different value. This might happen if a load is placed in an unsuitable position because the area's aluminium microstructure might not be as readily compressed. The values for both specimens are shown in full in Figure 8.

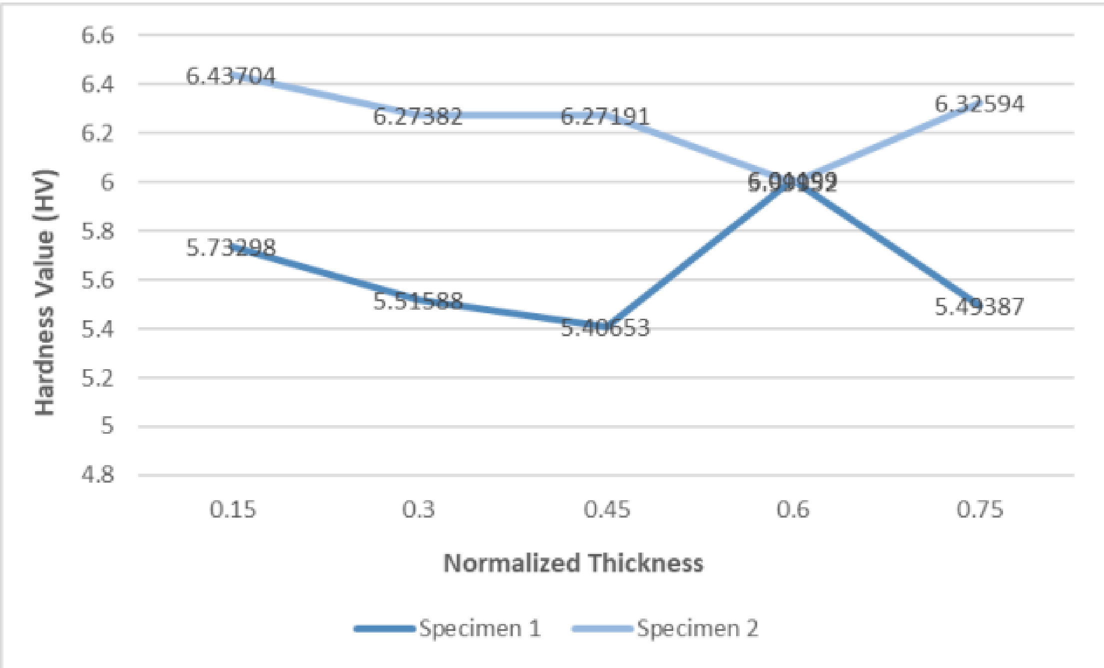

Figure 8: Hardness Value (HV) for Specimen 1 and Specimen 2 at Lower Area

Specimen 2 demonstrates that changing the parameters for example, increasing the preheat mould and motor speed will increase the molten metal's hardness value. This may be illustrated in Figures 6 to 8, which convincingly demonstrate how Specimen 2 surpassed Specimen 1 in hardness values.

4. Conclusion

In summary, the research on the ideal parameters for preheating the mould, speeding the motor and pouring temperature which are the best parameters in the casting process to manufacture hollow cylinders, has succeeded in achieving its goal. The successful centrifugal casting of the Aluminium LM6 alloy demonstrated its effectiveness and dependability. The centrifugal force generated by the mould spinning causes the molten metal to be distributed uniformly, resulting in solid, faultless castings. According to the microstructural analysis, the Aluminium LM6 has uniformly distributed alloying components.

Microstructure research has determined the specific weights and atomic percentages by which each element is recognised. Results from the Scanning Electron Microscope (SEM) and Micro-Vickers Hardness Test (VHT) on the Aluminium LM6 alloy composite were examined and interpreted in further detail. The composite material's hardness strength was more than two times more than that of the aluminium LM6 alloy material. Comparing specimen results reveals that the mechanical properties of the Aluminium LM6 composite have been enhanced.

The centrifugal casting technology may easily be used to mix composite materials, according to the findings of the current investigative study. The casting quality, mechanical characteristics, efficacy and efficiency of the vertical centrifugal casting technique are benefits. The 1800 rpm speed motor and molten metal with 700 Celsius temperatures are the most valuable parameters to use and focus.

Acknowledgement

The authors would also like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for the support in conducting this research.

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