*i*Journals: International Journal of Software & Hardware Research in Engineering (IJSHRE)
ISSN-2347-4890
Volume 9 Issue 11 November 2021

Microstructural Investigation of Cast 6063 Aluminium Rods Produced From Sand and Permanent Cast Moulds

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ABSTRACT

Experimental investigations were carried out to determine the effect of sand and permanent casting methods on the microstructural properties of AA6063 Aluminum. Sand and permanent cast moulds were fabricated and used to produce Aluminum rods. The test samples from cast rods were subjected to microstructural investigations. The metallographic results obtained showed better properties, in the sand cast samples than that of permanent cast samples. It was observed that the grain size of the microstructure of the cast products increased from those of Sand Casting to Permanent Casting. Conversely, the mechanical properties of the cast products improved from those of permanent casting to sand casting. Therefore, sand cast products could be used in as-cast condition in engineering applications requiring better quality parts while permanent casting may be used in as-cast condition for non-engineering applications or engineering applications requiring less quality parts.

Keywords: Cast Aluminium Rods, Microstructure, Permanent Mould, Sand Mould.

INTRODUCTION

Aluminium is the most abundant metal in nature. Some 8% of the weight of the earth crust is aluminium[1]. Aluminium is the most widely used non-ferrous metal, being second only to steel in world consumption [2]. The unique combination of properties exhibited by aluminium and its alloy make aluminium one of the most versatile, commercial and attractive metallic materials for a broad range of users, from soft, highly ductile wrapping foil to the most demanding engineering applications. Aluminium and many of its alloys can be worked readily into any form indeed and can be cast by all foundry processes. It accepts a variety of attractive, durable functional surface finishes. [3]

Aluminum alloys find extensive usage in engineering applications due to its high specific strength (strength/density). These alloys are basically used in applications requiring lightweight materials, such as aerospace and automobiles. The 6xxx-group alloys have a widespread application, especially in the building, aircraft, and automotive industry due to their excellent properties. The 6xxx series contain Si and Mg as main alloying elements. These alloying elements are partly dissolved in the primary α-Al matrix, and partly present in the form of intermetallic phases. A range of different intermetallic phases may form during solidification, depending on alloy composition and solidification condition[4]

Casting can be defined as a process whereby molten metal is poured inside a mould cavity and allowed to solidify to obtain required size and shape.Casting is one of the oldest manufacturing processes which dates back to approximately 4999BC. The manufacture and use of casting can be traced to both ancient and medieval history[5]. The basic simplicity of the casting process proves to be a boom for the growth of foundry industry and today a wide variety of products (or components) ranging from domestic to space vehicles are produced through foundry technique. The historical perspective of

foundry in Nigeria shows that foundry is the oldest engineering industry, starting over twenty centuries ago.[6]
Casting has remarkable advantages in the production of parts with complex and irregular shapes, parts having internal cavities and parts made from metals that are difficult to machine. Because of these obvious advantages, casting is one of the most important manufacturing processes, the various processes differ primarily in the mouldmaterial and the pouring method [5].

Sand casting utilizes sand as the mould material. The small sand particles will pack into thin sections, and sand also may be used in large quantities so that products covering a wide range of sizes and detail can be made by this method. In this process a new mould must be prepared for each casting desired, and gravity usually is employed to cause the metal to flow into the mould.

In sand casting, re-usable permanent patterns are used to make the sand moulds. The preparation and bonding of this sand casting involves the use of cope and drag and wooden patterns. The molten metal is poured into the mould cavity through an incorporated gating system. After the solidification of the molten metal in the cavity, the cope and drag housing the cavity is then dismantled or shaken out. [6]

Permanent-mould casting also utilizes a mould made of metal or graphite into which the molten metal is poured, usually under gravity. The same mould can be used repeatedly to produce a large number of duplicate castings. Permanent moulds are made of dense, fine-grained, heat resistant cast iron, steel, anodized aluminium, graphite or other suitable refractories. A permanent mould is made in two halves in order to facilitate the removal of casting from the mould. The design may be with a vertical parting line or with a horizontal parting line as in conventional sand moulds.
Adeyemi [6] investigated the mechanical properties of Aluminium produced from sand casting under different pre-heat temperatures and shake-out times. AlsoSowole and Aderibigbe[13] found that a range of mechanical properties can be obtained in commercially pure Aluminium 1200 by temper-annealing process and that it is possible to select an appropriate temper-annealing schedule that would impart improved strength and provide acceptable ductility of AI-1200 sheets at different levels of cold work.

Avalle, et al. [7] worked on static and fatigue strength of a die cast Aluminium alloy under different feeding conditions. They investigated the influence of porosity and casting defects on the static and constant-amplitude fatigue strength of a die cast Aluminium alloy. Three batches of specimens, differing for the sprue-runner design and consequently for content and type of defects, are tested in as-cast conditions. Defects consist in gas and shrinkage pores as well as cold fills, dross and alumina skins. Casting defects are observed to significantly lower the static and fatigue properties of the material. While for the static characteristics the decrease is progressive with the porosity range, for the fatigue strength the decrease is most significant from the lowest to the middle porosity range. The batches are classified with regards to the porosity level, as the metallurgical defects are not detectable a priori through X-ray examination. However, content and size of metallurgical defects are observed to increase with the porosity level. SEM observation of the fracture surfaces proved the important role played by dross, alumina skins and, above all, cold fills on the fatigue fracture.

Gaurav[8] in his work, comparison of sand casting and gravity die casting of A356 AL-Alloy,investigated the possibility of improvement in the mechanical properties of hypo- eutectic Al-Si alloy. Grain refinement and modification of hypo-eutectic Al – Si alloy was achieved by the addition of Al–3%Ti–1%B grain refiner and Al–10%Sr modifier. For achievement of better grain refinement and modification with melt treatment mechanical Vibration set of mould was used. Vibration with different frequency and amplitude has given to the mold at the time of pouring and solidification of the hypo-eutectic Al-Si alloy. In this dissertation work, it is concluded compared to sand casting, permanent mold gravity die castings have high mechanical properties. Compared to only grain refined die casting, grain refined and grain modified castings have high mechanical properties. Finally it is concluded that increasing vibration frequency to 25Hz results into maximum. Grain refiner and modifier reflect with higher mechanical property.

Raji[9] in his study compared cast microstructures and mechanical properties of aluminium silicon alloy components cast by sand casting, chill casting and squeeze casting methods to produce similar articles of the same shape and size from an Al-8%Si alloy. It was observed that the grain size of the microstructures of the cast products increased from those of squeeze casting through chill casting to sand casting. Conversely, the mechanical properties of the cast products improved from those of sand casting through chill casting to squeeze casting. Therefore, squeeze cast products could be used in as cast condition in engineering applications requiring high quality parts while chill castings and sand castings may be used in as cast condition for non-engineering applications or engineering applications requiring less quality parts.

Obiekeaetal.[10] work on the mechanical properties and microstructure of die cast aluminium A380 alloy casts produced under varying pressure was investigated experimentally and compared. The results obtained show better mechanical properties i.e.hardness, tensile strengths and impact strengths in the die cast A380 alloy sample that solidified at high pressure when pressure was regulated. Across five samples of the castings. The hardness of the die cast A380 samples that solidified under different applied pressures varied from 76 to 85 HRN. Also tensile strength, yield strength and elongation of the samples showed an increase with increased pressure. Also the results of SEM and metallography show that at high pressure, structural changes occurred as a fine microstructure was obtained with increase of pressure.

Obiekeaetal.[11] also investigated the influence of pressure on the mechanical properties and grain refinement of diecast aluminium Al350 alloy was carried out and subsequent analysis made. The results obtained from the microstructural analyses carried out on the A1350 alloy cast samples show that structural changes occurred as different morphologies of grains size and numbers were observed under the different applied pressures in the castings as some appeared granular, lamella, coarse e.t.c. Also the mechanical properties like the tensile, impact strength and hardness all showed variations under different pressures in the castings as the hardness increased with applied pressure from 77 to 86 HRN and tensile, yield strengths and elongation of the cast samples varied as maximum values were observed with applied pressures of 1400kg/cm^2 and the impact strength increased with applied pressures from 3.98 to 4.44 joules. Microstructure refining caused by more number of grains and finer grain sizes was observed in the micrograph in the sample at applied pressure of 1400kg/cm2 and porosity was not found due to microstructure refining as compared with those obtained at 0 kg/cm^2 and 700kg/cm^2 These results illustrate how the influence of pressure on the grain refinement and mechanical properties can be used to improve the qualities of die cast products.

Darguschetal.[12]Investigated the relationship between mechanical properties and microstructure in high pressure die cast binary Mg-Al alloys. As-cast test bars produced using high pressure die casting were tested in tension in order to determine the properties for castings produced using this technique. It was observed that increasing aluminium levels results in increases in yield strength and a decrease in ductility for these alloys. Higher aluminium levels also result in a decrease in creep rate at 150^{0}C. It was also observed that an increase in aluminium levels results in an increase in the volume fraction of eutectic $Mg_{17}Al_{12}$ in the microstructure.

MATERIALS AND METHODS

The material used for the study was AA6063 Aluminium ingot obtained from Aluminium Tower Company, Ota, Ogun State. The chemical compositions of the Al ingot was determined by using plasma spectroscopy metal Analyzer. The results obtained are presented in Table 1.

Table 1: Chemical composition of the aluminium ingot

Elements	Comp.(%)
Mg	0.538
Si	0.486
Mn	0.085
Cu	0.007
Zn	0.0018
Fe	0.284
Na	0.002
B	0.009
Pb	0.004
Sn	0.024
Al	98.543

Design and Fabrication of Experimental Rigs

The experimental rigs used in this research work were designed and fabricated. The rigs comprise of permanent mould and sand mould.

In the design and fabrication of the rigs, some factors were considered ranging from cost availability machinability, melting temperature, durability to maintainability of the materials used in the fabrication.The mould of the permanent cast is made up of a steel material of 150mm x 250mm x 50mm sliced into two making it a male and female mould as shown in Fig. 1

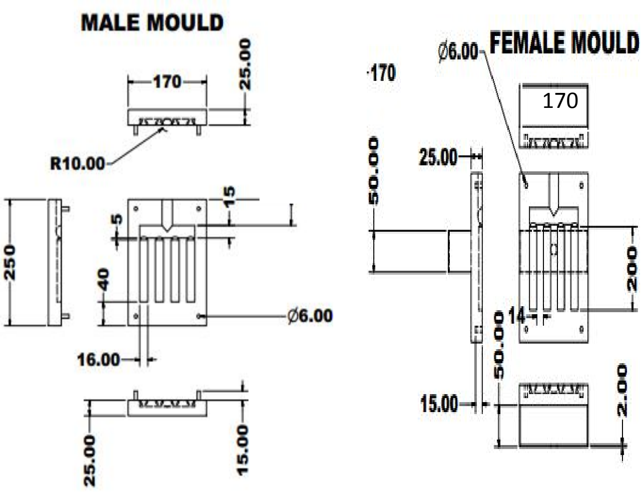

Fig. 1: Male and Female Moulds for Permanent Cast Mould.

The Permanent Cast Mould was made of steel plate 50mm thick sliced into two by milling operation. The steel plate block was drilled with the aid of 16mm drill bit in four different places equidistantly to leave a cavity for casting as shown in Fig. 2).

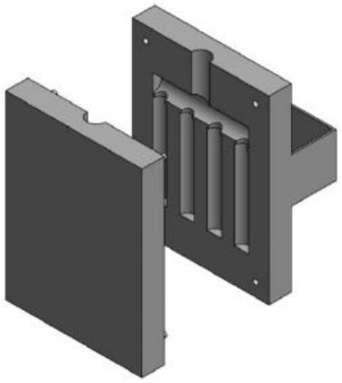

Fig. 2 Permanent Cast Mould

After slicing the steel block, gate and pouring hole were made.A system to hang and house the mould for easy pouring of molten metal and ejection of the solid cast material was constructed. The product of this rig was a permanent cast as in Fig. 3.

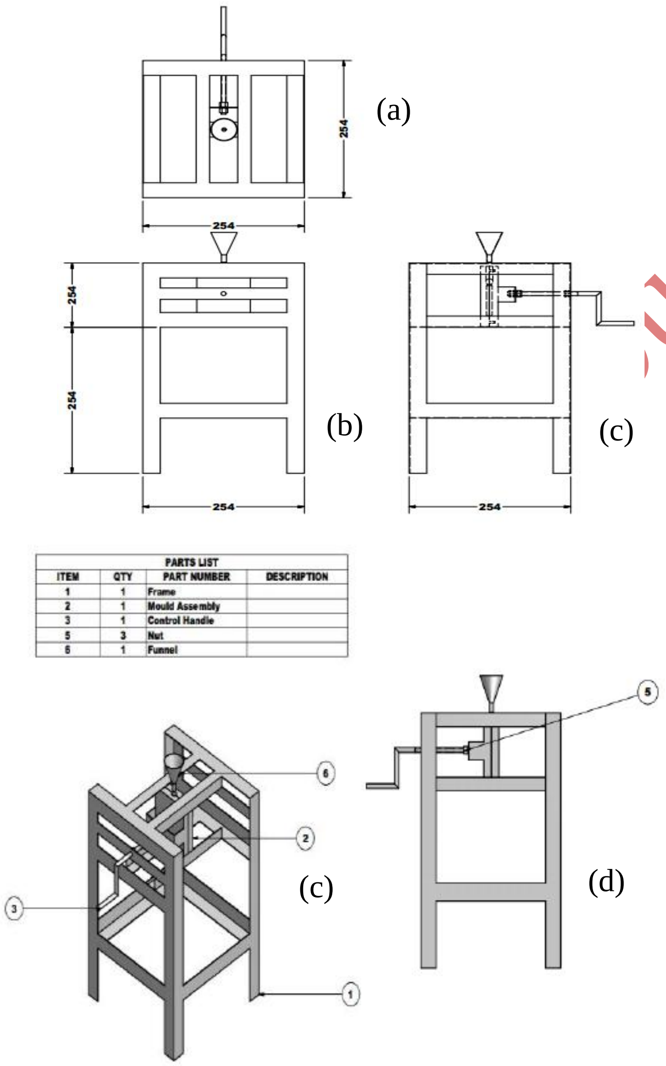

Fig. 3 Permanent Mould

However, the sand cast mould rig was produced from a mild steel sheet plate 3mm thick having dimensions of 300mm x 150mm x 75mm. This was made of two numbers to form cope and drag for the sand casting as presented in Fig. 4).

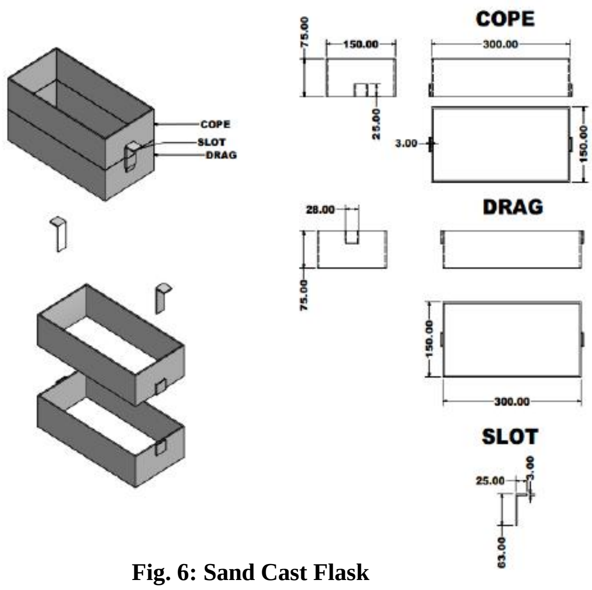

Fig. 6: Sand Cast Flask

Experimental Procedures: The Aluminium ingot was melted using blacksmith open furnace. The hot liquid Aluminium metal was cast into solid rods by sand casting and permanent casting processes using the fabricated rigs.

The cast rods were rid of excesses from gating, runners, risen, sprue and parting line to give the cast specimen a good shape.

Sample Designation: Aluminum rods were successfully produced from bottle sand and permanent moulds. For simplicity and analysis sake, the samples were designated as shown in Table 2.

Table 2: Sample designation

S/N	Symbols	Interpretation
1	M_p	Permanent mould
2	M_s	Sand mould

Metallographic Examination: Test specimen was first ground on emery paper of different grit sizes from 240μm to 600μm. The samples were rotated 90^0at each turn of the emery paper in order to remove the scratch produced at previous grit size using strip grinder. During grinding, water was added to remove chips from the surface of emery paper and to cool the sample. The grinding process was continued until a mirror-like surface was obtained. The sample was subsequently polished in succession with cloth sprinkled with 6μm and 1μm site silicon carbide particles. The polished sample was etched in 3% NaOH and surface observed under a high power metallurgical microscope at a magnification of 200.

Microstructural PresentationsMagnification X200

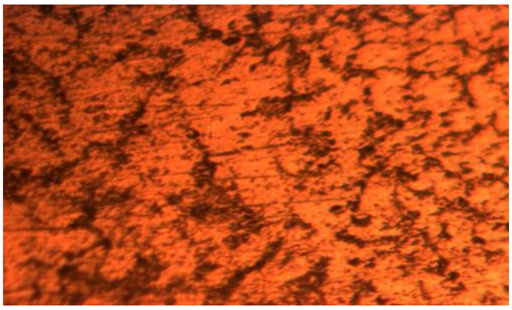

Plate 1: Micrograph of cast aluminum using permanent mould

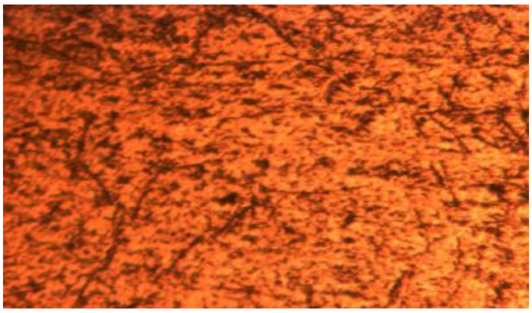

Plate 2: Micrograph of cast aluminum using sand mould

The photomicrographs of the Cast Aluminium AA6063produced from Sand and Permanent Moulds are as shown in Plates 1 &2. This is necessary in order to view the phase morphology of the internal structures of the product.

When considering the microstructure of Sand and Permanent castings, it was discovered that the grain size of the Aluminium obtained during permanent casting is very coarse. That of Sand Castings have a bit of refinement with the grain size still coarse but better than that of Permanent Casting.

CONCLUSION

This experimental investigation of AA6063 cast Aluminium from fabricated rigs of sand and permanent cast moulds, shows that the microstructural effects of AA6063 are significantly improve in Sand Castings than that of Permanent Castings.

ACKNOWLEDGEMENTS

The authors acknowledge the support of Aluminium Tower Company, Ota, Ogun State, Nigeria. We are also grateful to the authorities of the Olusegun Obasanjo Centre for Engineering Innovation, The Federal Polytechnic Ado Ekiti for providing conducive environment and necessary equipment for the work.

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