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Tensile and Hardness Characteristics 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 Tensile and Hardness characteristics of cast AA6063 Aluminium rods produced from sand and permanent cast moulds. Sand and permanent moulds were fabricated and used to produce Aluminium rods. The test samples from cast rods were subjected to Tensile and Hardness tests. The results obtained showed better Tensile and Hardness properties, in the sand cast samples than that of permanent cast samples. The hardness of permanent and sand casting varied from 66.5Hv to 70.0Hv. Also, Ultimate Tensile Strength increased from 108.78MPa in permanent casting to 161.97MPa in sand casting. Conversely, the Tensile and Hardness 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, Hardness Properties, Permanent Mould, Sand Mould. Tensile Properties

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 mould material and the pouring method (5).

Sand casting –This 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 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. The mould walls of a permanent mould have thickness from 15mm to 50mm. (1)

In a study by Oyetunji(7), the effect of foundry sand size distribution on the mechanical and structural properties of grey cast iron was examined. The results showed that cast sample from fine sand size-grade have highest impact energy value, best tensile strength value, better hardness value and fine surface finish.

Abduwahabetal. (8) investigated the effect of chromium addition and precipitation hardening on the mechanical properties of cast Al – Si – Fe alloy. This study revealed how the mechanical properties of Al-Si-Fe-Cr alloy changes with precipitation hardening treatment with the percentages of chromium in the alloy being varied from 0.1 to 0.5% while the Si-Fe ratio was kept constant. The as-cast bars were cut and machined into tensile, impact and hardness test samples and were then solution heat-treated at 490^0C for six hours before quenching into warm water. The solutionized samples were then aged at 200^0C for six hours and air cooled. It was observed that the tensile, impact and hardness properties of the as-cast alloys improved significantly after precipitation hardening for all levels of chromium addition considered. However, at 0.1% Cr addition highest values of impact and ductility for the two categories of the alloy produces cast and precipitation hardening alloy(s) was exhibited.

Adeyemi (6) investigated the mechanical properties of Aluminium produced from sand casting under different pre-heat temperatures and shake-out times. AlsoSowole and Aderibigbe(9) 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.

Oke(4) investigated the influence of rolling operations on the mechanical properties of Aluminium alloy 1200. As-received Aluminium ingots were subjected to rolling, a form of cold working, and thereafter annealed within a temperature range of 300-415^0C while others were annealed at temperature of 500°C. Rolling was found to have increasing effects on the strength and hardness but decreasing effects on percentage elongation, percentage reduction in area and impact energy. The tensile strength and hardness of as-received Aluminium ingot increased from 49.06MPa and 15.9BHN to 69.03MPa and 24.6BHN respectively, while the impact energy, percentage elongation and percentage reduction in area respectively decreased from 4.73J, 13.6 and 28.9 to 4.06J, 4.0 and 7.7 respectively due to the rolling operation. However, increase in annealing temperature was observed to decrease the strength and hardness of the as-rolled specimens, while increasing the ductility and impact energy. The tensile strength and hardness of the as-rolled specimen respectively decreased from 69.03MPa and 20.4BHN to 61.37MPa and 19.5BHN when annealed at 500°C, while the impact energy, percentage elongation and percentage reduction correspondingly increased from 4.06J, 4.0 and 7.7 to 4.60J, 25 and 52.9 respectively.

Agbanigo and Alawode(10) evaluated the mechanical properties of Aluminium-based composites reinforced with steel fibres of different orientations. This work was experimentally investigated, presented and compared with those of unreinforced Aluminium alloy. Unreinforced specimens and composites reinforced with longitudinal and transverse fibres were characterized by percentage elongation at fracture of 12.75, 27.50 and 11.00% respectively; ultimate tensile strength of 83.51, 96.75 and 66.71MN-^{2}, respectively; fatigue life of 209, 458 and16 cycles-to-failure, respectively at 550MNm-^{2} and impact energy of 47.80,51.20 and 45.00Nm, respectively. The least values of mechanical properties exhibited by composite specimens with transverse fibres is attributed to the fact that transverse fibres create areas of stress concentration, which aids initiation and propagation of cracks resulting in early commencement of deformation during testing and fibre matrix rebounding. However, the resistance to deformation offered by longitudinal fibres during testing is responsible for the highest values of mechanical properties displayed by composite specimen with longitudinal fibres. Abubakre and Khan (11) developed Aluminium based metal matrix particulate composites (MMPC) reinforced with alumina using stir-casting technique in an attempt to develop Aluminium-alumina metal matrix composite of particulate brand for the Nigerian economy. Various equipment and tools were designed and fabricated for the purpose of synthesizing Al-Si/Al_20_3 composite by stir casting technique. Series of trial experiments were carried out to establish the optimum processing parameters. The strongest among the successfully developed Al-$SiAl_20_3$ composite was the one reinforced with 5wt.% particles having the ultimate tensile strength (UTS) and yield strength values being 180.85MPa respectively. The produced composites were very brittle with percentage elongation close to zero.

Gaurav(12) 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 thisdissertation work, it is concluded compared to sand casting, permanent mold gravity die castings have high mechanical properties. Compared to only grain refined die casting, grainrefined and grain modified castings have high mechanical properties. Finally it is concludedthat increasing vibration frequency to 25Hz results into maximum. Grain refiner and modifierreflect with higher mechanical property.

Awedaetal.(13) Investigated the performance evaluation of permanent steel mould for temperature monitoring during squeeze casting of non-ferrous metals.

Permanent steel mold was designed, machined and evaluated by monitoring the temperature of squeeze cast aluminium and brass rods on a Vega hydraulic press. The operation was performed with and without pressure on the cast specimen at pouring temperature of 700^0C and 980^0C for aluminium and brass metals, respectively. The solidification rate (temperature with time) was monitored with a three-channel digital temperature monitor data logger while the tensile strengths of both samples were also determined.

The results showed an increase in the solidification rate for both samples with increase in the applied pressure. The maximum solidification rate for aluminium was obtained at an applied pressure of 127 MPa and 95 MPa for brass. The tensile strength of both samples increased with increase in applied pressure. The maximum tensile strength of 34.38 MPa was obtained for aluminium at applied pressure of 127 MPa and 80.21 MPa for brass at an applied pressure of 95 MPa. Above these values there was no significant increase in the tensile strength with increase in applied pressure. The results obtained were similar to that already established in the literature which make the machined permanent steel mold suitable for squeeze casting of non-ferrous metals.

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 work were designed and fabricated. The rigs comprise of permanent and sand moulds.

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 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

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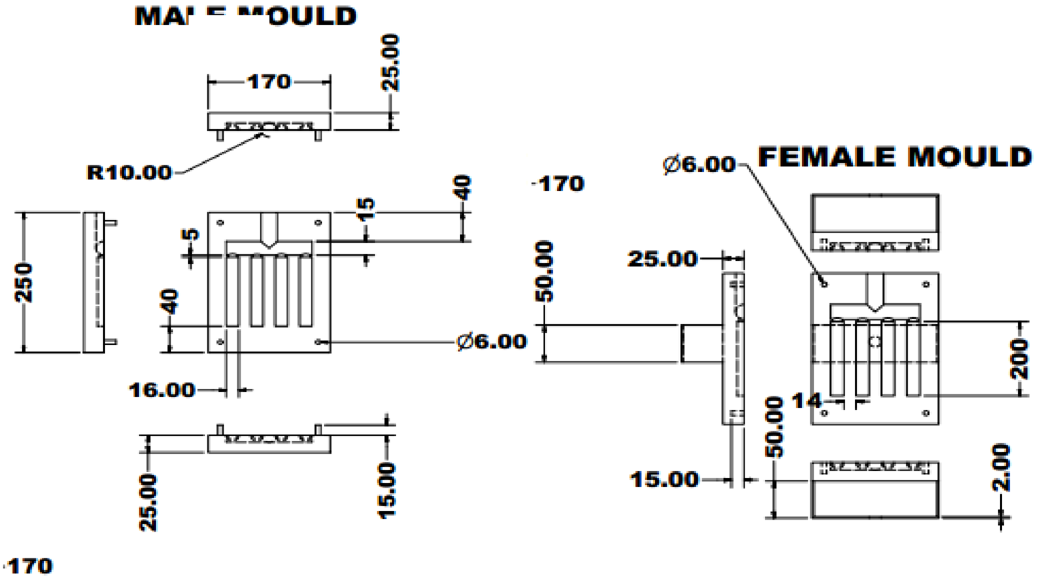


Fig. 1: Male and Female Moulds for Mould for Permanent Cast

The 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 inFig. 2

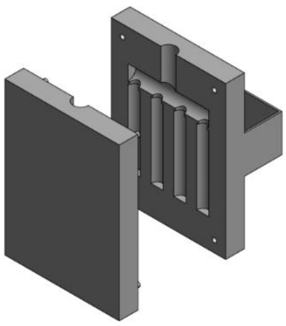
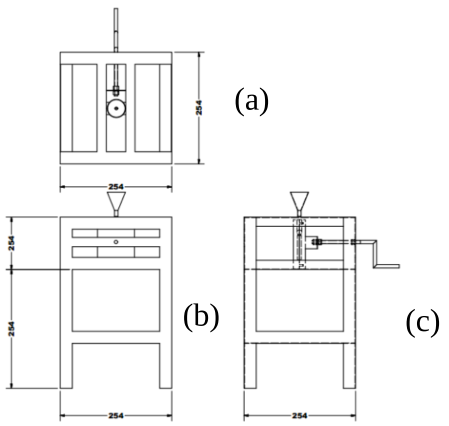


Fig. 2 Permanent Mould

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 when no pressure system is attached as shown inFig. 3.



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Frame	
2	1	Mould Assembly	
3	1	Control Handle	
5	3	Nut	
6	1	Funnel	

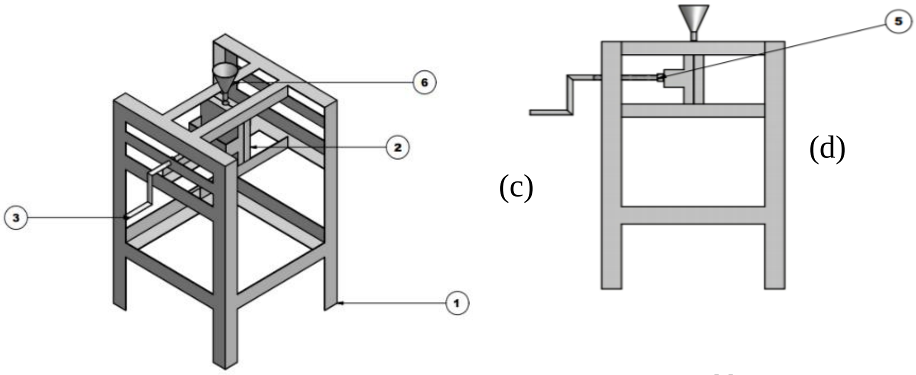


Fig. 3: Permanent Mould

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 shown in Fig 4.

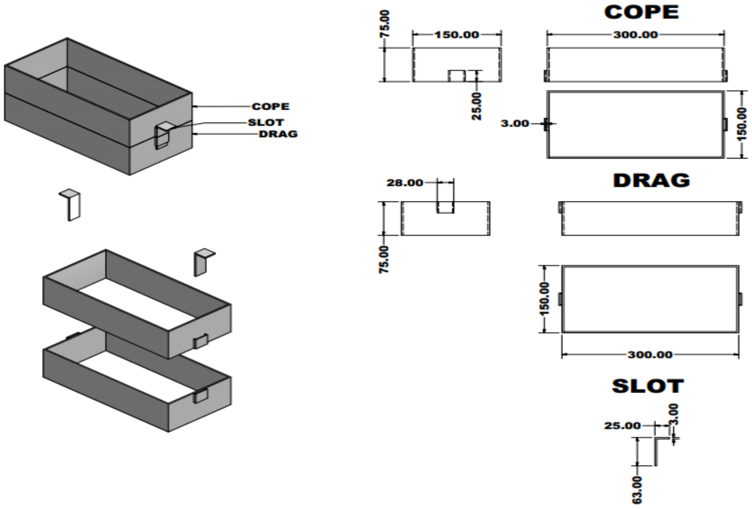


Fig. 4: Sand Cast Flask

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 using various mould techniques. 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

Tensile Properties

Tensile test specimens were machined from the bulk specimen in accordance with America Society for Testing and Materials E8(ASTM E8) as shown in Figure 5.

The machined specimens were loaded into Universal Testing Machine (UTM) and subjected to tensile load in accordance to ASTM test method. The test was monitored in a computer system and the Tensile properties obtainedare presented in Fig. 8-10

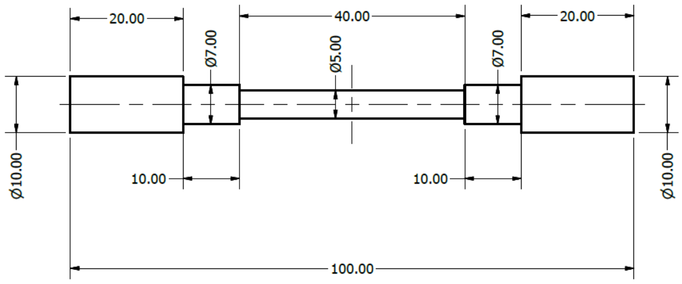


Fig5. Tensile Test Specimen (All dimensions in mm)

Hardness Properties: Hardness test specimen were machined from the bulk specimen in accordance with American Society for Testing and Materials E18 (ASTM E18) as shown in Figure 6.
The machined specimens were loaded into the Vickers Hardness Testing Machine (VHT) and subjected to hardness test in accordance to ASTM test method. The hardness properties obtained are presented in Fig. 7

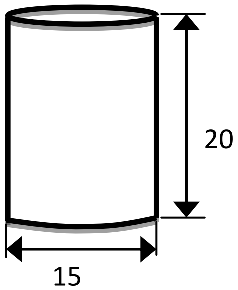


Fig. 6: Hardness Test Specimen (All dimensions in mm)

Results and Discussion

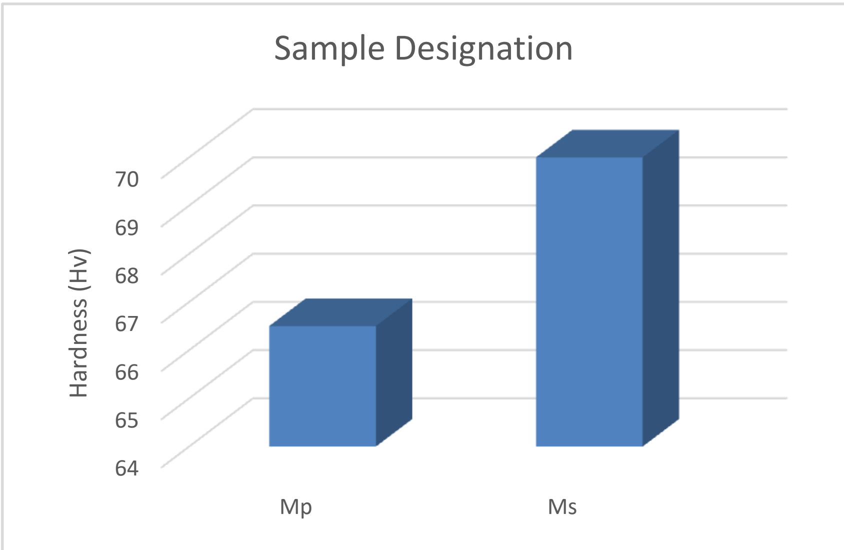


Fig. 7: Response of Permanent and Sand castingmoulds on hardness of aluminium

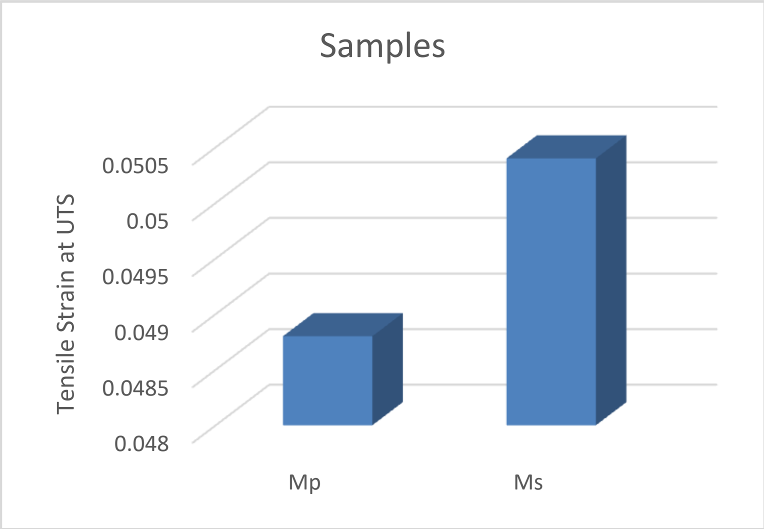


Fig. 8: Effect of Permanent and Sand casting moulds on Tensile Strain at UTS

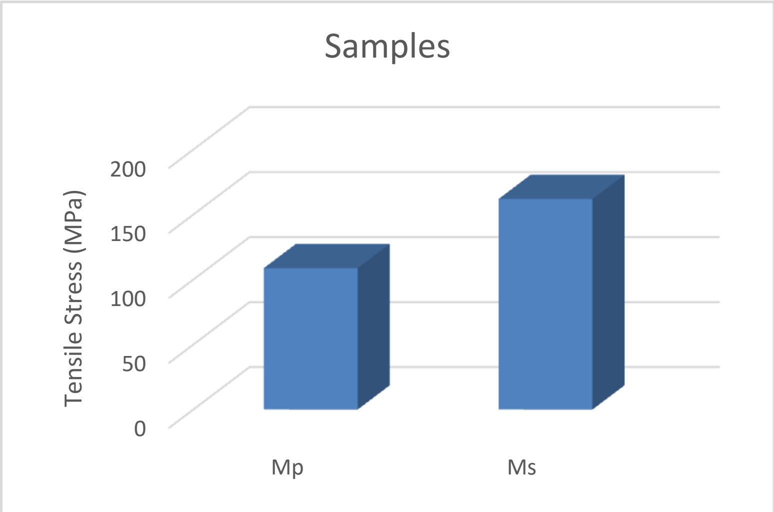


Fig. 9: Effect of Permanent and Sand moulds on UTS of Various Samples

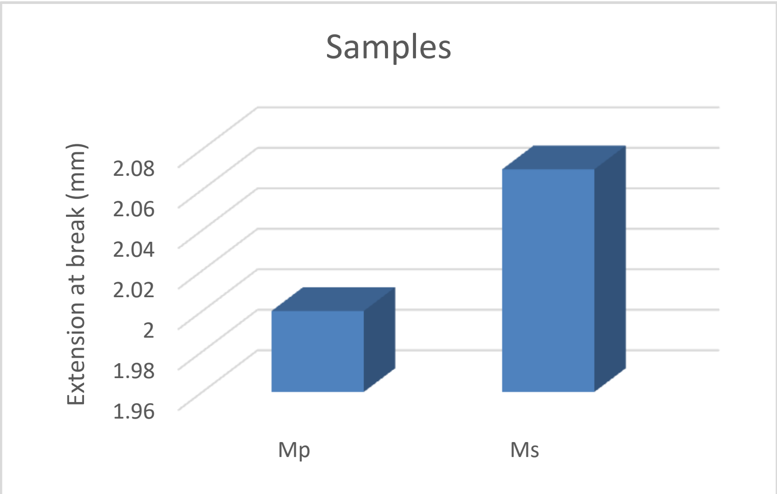


Fig. 10: Extension at break

Hardness Properties: Fig. 7 shows that variation of micro hardness values of sand casting product has highest value of 70.0Hv as against 66.5Hv exhibited by the product from permanent mould

Tensile Properties: In Figure 9, increment in values was observed when the Ultimate Tensile Strength of the Cast Aluminium AA6063 was examined. UTS of permanent castings was smaller than that of Sand. Sand casting and permanent casting have 161.97 and 108.78MPa respectively. The percentage of elongation of permanent casting and sand casting are 4.88 and 5.04%. The percentage elongation at fracture of permanent casting was found to be smaller than that of Sand Casting.

Conclusion

The Tensile and Hardness characteristics investigation of AA6063 Cast Aluminium from fabricated rigs of Permanent and Sand moulds are analysed. There are significant improve in Tensile and Hardness properties of Sand moulds than that of Permanent moulds. Therefore, Sand Casting can be employed in as-cast condition where better quality are required in Engineering applications and Permanent Casting be employed in as-cast condition for non-engineering or engineering applications where less quality parts are required.

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