IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 18, Issue 6 Ser. I (Nov. – Dec. 2021), PP 31-40
www.iosrjournals.org

Tensile and Hardness Characteristics of Cast 6063aluminium Rod Produced From Permanent And Squeeze Cast Moulds

Oladebeye, Dayo Hephzibah[1]; Adefidipe, Ebenezer Rotimi[1] and Michael Olabode, Ibiwoye[3]

[1]Mechanical Engineering Department, The Federal Polytechnic, Ado Ekiti, Nigeria, [2]Olusegun Obasanjo Centre for Engineering Innovation, The Federal Polytechnic, Ado Ekiti, Nigeria, [3]Mechanical Engineering Department, Kwara State University, Malete, Nigeria

***Abstract** - Experimental investigations were carried out to determine the effect of permanent and squeeze cast moulds on the Tensile and Hardness of AA6063 Aluminum rods. Permanent and squeeze cast moulds were fabricated and used to produce Aluminum 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 squeeze cast samples that were produced under varied pressure. The hardness of squeeze casting varied from 72.9 to 82.3Hv, while that of permanent casting had 66.5Hv. Also, Ultimate Tensile Strength increased with increased pressure in squeeze castings from 178.01 to 194.04MPa and 108.78MPa in permanent castings. Conversely, the Tensile and Hardness properties of the cast products improved from those of permanent casting to squeeze casting. Therefore, squeeze cast products could be used in as-cast condition in engineering applications requiring high quality parts while permanent casting may be used in as-cast condition for non-engineering applications or engineering applications requiring less quality parts.*

***Key words** - Aluminium Cast Rod, Hardness Characteristics, Permanent Mould, Squeeze Cast Mould, Tensile Characteristics*

Date of Submission: 12-11-2021 Date of Acceptance: 28-11-2021

I. 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].

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]

The squeeze casting process combines permanent mould casting and die forging operation. It utilizes punch pressures on the metal metered into a permanent mould to consolidate the metal during solidification; this eliminates defects due to shrinkage cavities and/or gas porosity [7]. Application of pressure improves mechanical properties of squeeze cast products provided the applied pressure exceeds a certain critical value. Some of the advantages of this process are higher casting yield, better mechanical properties, reduction in tooling cost, and higher dimensional accuracy.

Raji and Khan [8] investigated the effects of squeeze parameters on the properties of squeeze castings and the optimum parameters for producing squeeze castings from Al-Si alloy. It also compared the properties of the squeeze castings with those of chill castings. Squeeze castings were made from Al-8%Si alloy using pressures of 25- 150MPa with the alloy poured at 650o, 700o and 750oC into a die preheated to 250oC. Squeeze time was 30s. It was found that for a specific pouring temperature, the microstructure of squeeze castings became finer; density and the mechanical properties were increased with increase in pressure to their maximum values while further increase in pressure did not yield any meaningful change in the properties. Compared with chill casting process, squeeze casting enhanced the mechanical properties; it increased the hardness, UTS, 0.2% proof stress and elongation of the alloy to optimum values of HRF58.0, 232MPa, 156MPa and 3.8% respectively at squeeze pressure of 125MPa and pouring temperature of 700oC. The study concluded, among other things, that optimum pouring temperature of 700oC and squeeze pressure of 125MPa are suitable for obtaining sound Al-8%Si alloy squeeze castings with aspect ratio not greater than 2.5:1.

Other research works are the experimental investigation on squeeze cast product by Chatterjee and Das [10, 11] and Frankl and Das [12] which centred mainly on the variation of mechanical properties as a result of varying production parameters such as pressure, pouring temperatures, die temperature and lapse times between pouring and pressure application etc. The improved mechanical properties were due to modification of microstructure of the squeeze cast product by pressure application.

Abduwahab etal.[13] 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.

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.

Abifarin and Adeyemi [14] used the longitudinal slitting technique to determine and compare the residual stresses in as-cast and squeeze-cast Aluminium rods. Residual stresses in the squeeze-cast Aluminium alloy rods are found to increase with applied punch pressures under a constant die-base thermocouple reference temperature. For the variations of residual stresses with varying die-base thermocouple reference temperature, a peak residual stress is found to occur at a die-base thermocouple reference temperature of 100°C. A semi-empirical formula was derived for the determination of the maximum longitudinal residual stress in the tapered cylindrical as-cast Aluminium alloy from which the maximum longitudinal residual stresses for squeeze cast can be determined, using the residual-stress ratios obtained experimentally.

Aniyi et al. [7] investigated effects of pressure, die, and stress-relief temperatures on the residual stresses and mechanical properties of squeeze-cast Aluminium rods. The effects of die heating and stress-relief temperatures in reducing residual stresses of squeeze-cast Aluminium alloy rods are experimentally determined by the longitudinal slitting method, and their reduction effects on the mechanical properties of the squeeze-cast alloy rods are investigated. Stress relief is much more effective than die heating in reducing residual stresses of the squeeze-cast alloy. Stress relief is substantially completed at 350°C in lh, but at the expense of reduction in strength and hardness. Appreciable reduction in strength and hardness is avoided by using a stress-relief temperature of 250°C for residual stress reduction of squeeze-cast Aluminium alloy. Die heating to a maximum of 200°C is considered adequate to substantially reduce the chilling effect of the metal mould on the solidifying molten metal and to avoid appreciable reduction of strength and hardness resulting from die heating effects.

Abubakre and Khan [15] 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 $Al\text{-}Si/Al_20_3$ composite by stir casting technique. Series of trial experiments were carried out to establish the optimum processing parameters. The strongest among the successfully developed $Al\text{-}SiAl_20_3$ 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.

Raji and Khan [16] designed and developed a squeeze casting rig. The study was carried out to modify workshop bending press into laboratory squeeze casting rigs for the purpose of producing high quality squeeze cast component with aspect ratio not more than 2.5: 1. Dies used in conjunction with an electrically operated hydraulic press were designed and constructed. The constructed dies were tested and used to produce squeeze castings from molten AL-8%Si alloy. The squeeze cast products were found to be satisfactory in physical and mechanical properties with average density of 2.86g/cm^3, hardness of HRF 58.0, ultimate tensile strength of 232MPa, 0.2% proof stress of 156Pa and elongation of 3.8%.

Obiekea etal. [17] 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.

Obiekea etal. [18] 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.tc. 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.

Dargusch etal. [19] 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.

Aweda etal.[20] 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^{0}C and 980^{0}C 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.

II. 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

Materials and Preparation

The material used for the study was AA6063 Al ingot obtained from Al 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.

Design and Fabrication of Experimental Rigs

The experimental rigs used in this work were designed and fabricated. The rigs comprise of squeeze cast and permanent moulds.

In the design and fabrication of the rigs, some basic 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 and squeeze cast are 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

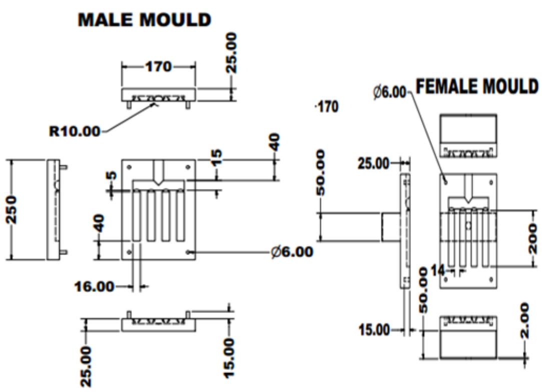


Fig. 1: Male and Female Moulds for Squeeze Cast Moulds

Fabrication of Permanent and Squeeze Cast Mould

The Permanent and Squeeze 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. (See Fig. 2).

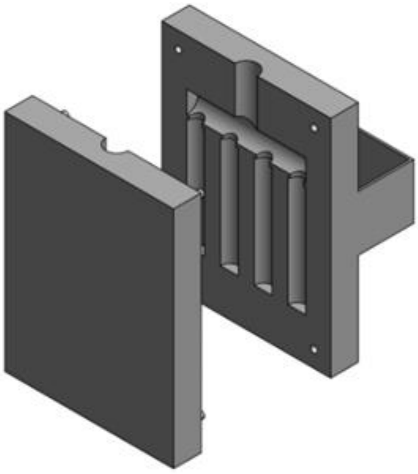
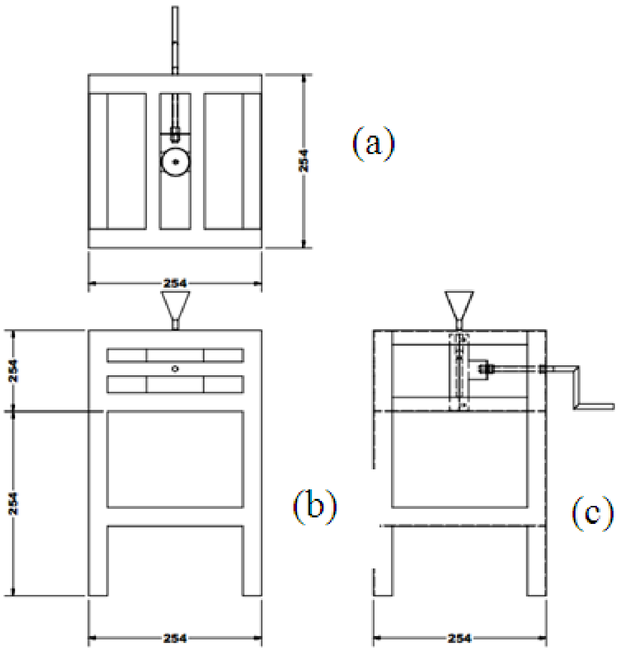
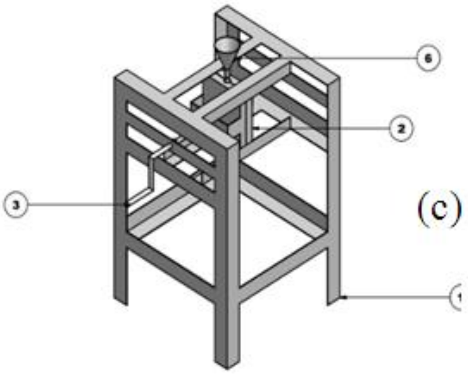


Fig. 2 Permanent and Squeeze Cast Mould

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 when no pressure system is attached. (See Fig. 3). However, the squeeze cast mould rig was similar to the permanent rig only that a system was attached to exert pressure on the cast material. This was done with the aid of hydraulic Jack incorporated with pressure gauge to measure the pressure exerted on the cast. (See Fig. 4)



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



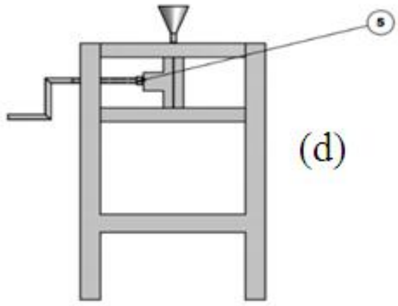
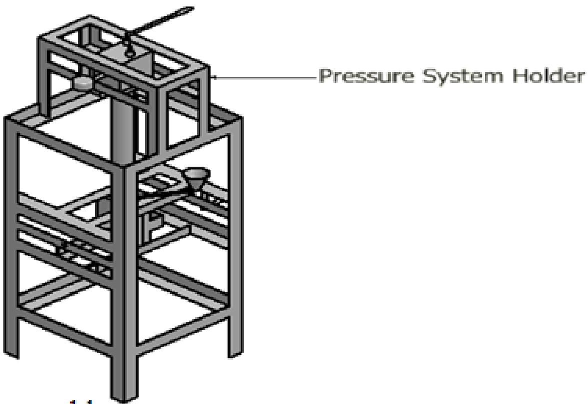
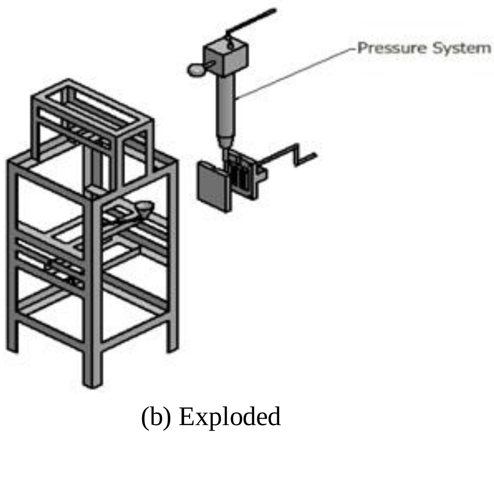


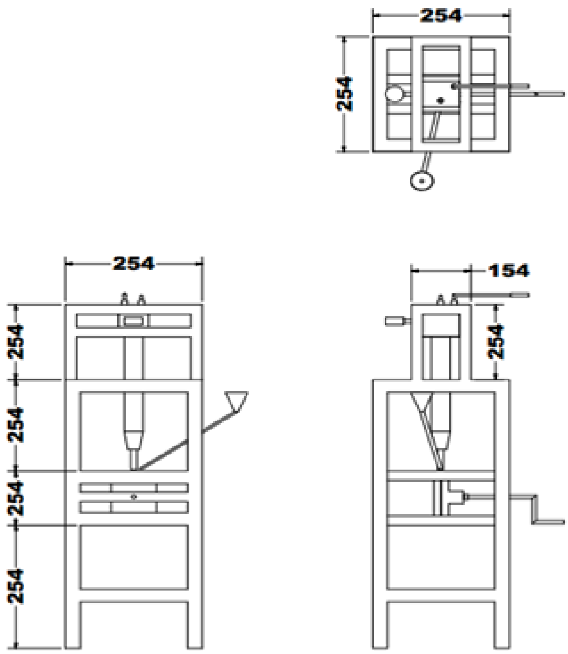
Fig. 3 Permanent Mould



(a) Assembly



(b) Exploded



Orthographic View
Fig. 4: Squeeze Cast Mould

Experimental Procedures

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

In case of squeeze casting, the casting pressure was varied from $35N/m^2$to $110N/m^2$in order to determine the effect of cast pressure on the properties of cast Aluminium.

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 permanent and squeeze cast 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_{sq-1}	Squeeze casting @ $35N/m^2$ pressure
3	M_{sq-2}	Squeeze casting @ $60N/m^2$ pressure
4	M_{sq-3}	Squeeze casting @ $85N/m^2$ pressure
5	M_{sq-4}	Squeeze casting @ $110N/m^2$ pressure

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 result presented in Appendix A. Tensile Properties obtained such as UTS etc. are presented in Fig. 6

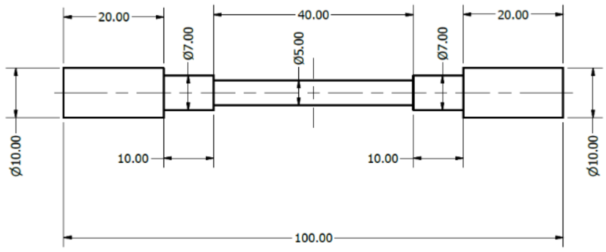


Fig 5. Tensile Test Specimen (All dimensions in mm)

Hardness Properties

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. 6. 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 7.

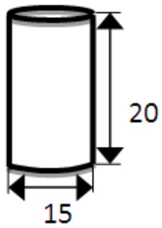


Fig. 6: Hardness Test Specimen (All dimensions in mm)

III. RESULTS AND DISCUSSIONS

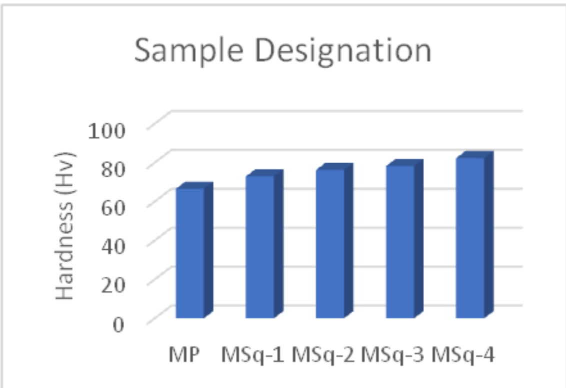


Fig. 7: Response of Permanent and Squeeze cast moulds on hardness of aluminium

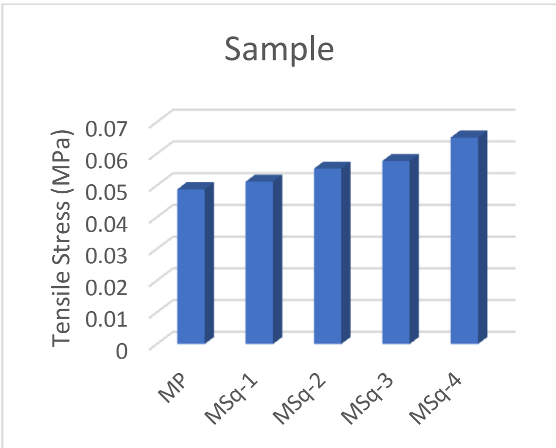


Fig. 8: Effect of Permanent and Squeeze Cast moulds on Tensile Strain at UTS

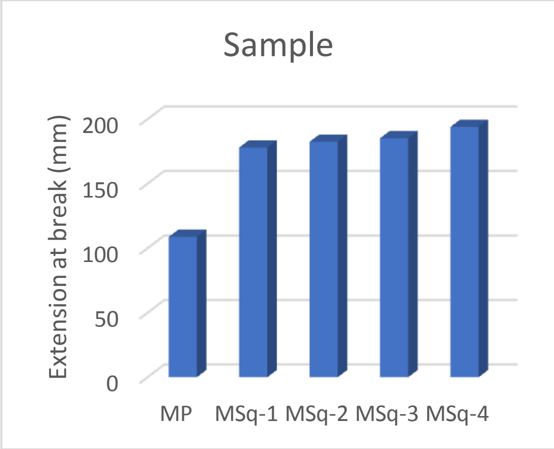


Fig. 9: Effect of Permanent and Squeeze cast moulds on UTS of Various Samples

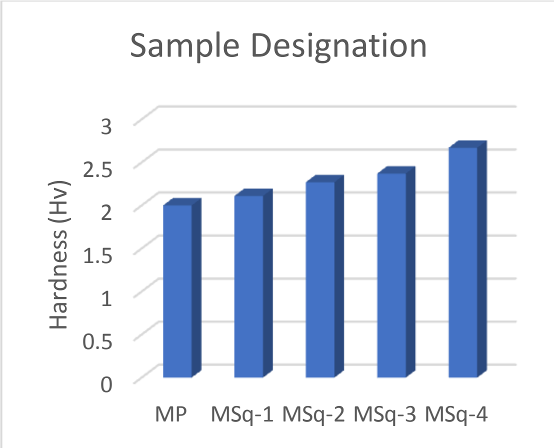


Fig. 10: Extension at break

Hardness Properties:

In Figure 7, it was observed that squeeze casting technique exhibited the highest hardness value of 82.3Hv as against the 66.5Hv exhibited by the product from Permanent mould however. This shows that as pressure increases the hardness increases.

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 those of the squeeze casting. UTS of squeeze casting varied from 178.0.1MPa to 194.04 MPa as the pressure increased from 35N/m^2 to 11035N/m^2. The results of UTS showed that squeeze casting enhances the strength of cast materials. Permanent casting has 108.78MPa. The percentage of elongation for the squeeze castings varied between 5.12 to 6.51%. The increase in elongation of squeeze cast products is brought about by rapid cooling leading to grain refinement as compared to permanent casting.

IV. Conclusion

This experimental investigation of AA6063 cast Aluminium from fabricated rigs of permanent and squeeze cast moulds, shows that fatigue and impact properties of AA6063 are significantly improve in squeeze castings than that of permanent castings. The notable effect is recorded as pressure increases in squeeze castings. Squeeze casting can be employed in as-cast condition where high fatigue and impact properties are required in engineering applications.

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.

References

[1]. Khama, O.P. (1997) “A textbook of Foundry Technology (for Engineering Students)", Ish Kapur, for Dhanpat Rai Publictions (P) Ltd., New Delhi - 110002.

[2]. Budinski, K.G. (1983), “Engineering Material Properties and Selection”,Reston Publishing Company Inc., New York.

[3]. Norton, R.L. (1998), “Machine Design – An Integrated Approach” ,Prentice Hall Inc., New Jersey.

[4]. Oke, A.O (2005) “Influence of Processing Operations on Mechanical Properties of Aluminium Alloy , Nigerian Journal of Mechanical Engineering 3 (1) pp 46-52.

[5]. Callister, William D. (2010), “Mathematical Science and Engineering: An Introduction” Willey John Willey & Sons, Inc., New York.

[6]. Adeyemi G.J. (2009), “Effects of Sand Mould Preheat temperatures and Shake-out Times on the Mechanical Properties of Cast Aluminium Alloy” , Unpublished M.Eng Thesis, Mechanical Engineering Department, University of Ado Ekiti, Nigeria.

[7]. Aniyi J.A., Bello-Ochende F.L. and Adeyemi M.B., (1996), “Effect of Pressure, Die and Stress- Relief Temperatures on the Residual Stresses and Mechanical Properties of Squeeze-Cast Aluminium Rods”, Journal of Materials Engineering and Performance, Vol.5, No 3, pp 399-404.

[8]. Raji A. and Khan R.H. (2006), “Effects of Pouring Temperature and Squeeze Pressure on AL-8%Si Alloy Squeeze Cast Paits” AU J.T. Vol 9, No 4, Pp 229-237

[9]. Chatterjee S. and Das A.A. (1972), “ Effects of Pressure on the Solidification of Some Commercially Al-Base Casting Alloys”, Institute of British Foundryman, Vol.LXV, pp420-429.

[10]. Chatterjee S. and Das A.A. (1973), “ Some Observation on the Effects of Pressure on the Solidification of Al-Si Eutectic Alloys”, Institute of British Foundryman, Vol LXVI, pp 118-124.

[11]. Franklin J.R. and Das A.A. (1983), “Squeeze Casting – A Review of the Status” , Metallurgy and Materials Science, pp 150-158.

[12]. Abdulwahab, M. Ahmed, T.O and Suleiman I. Y. (2006) “Effect of Chromium Addition and Precipitation Hardening on Mechanical Properties of Al-S-Fe Alloy”, Nigerian Journal of Mechanical Engineering Vol.4, No 1, Pp. 15-27.

[13]. Abifarin M.S and Adeyemi M.B. (1993),” Residual Stresses in Squeeze Cast Aluminium Rods”, Experimental Mechanics, Vol 33 No 3 pp 174-180.

[14]. Abubakre O.K. and Khan R.H (2004), “Development of Aluminium Based Metal Matrix Particulate Components (MMPC) Reinforced with Alumina Using Stir Casting Technique”, NigerianJournal of Mechanical Engineering, vol. 2 No1pp 1-13.

[15]. Raji A. and Khan R.H., (2006), “Design and Development of a Squeeze Casting Rig”, Nigerian Journal of Mechanical Engineering vol. 4 No 1pp 78-94.

[16]. Obiekea K. N,Shekarau Y. A. And Danjuma S. Y. (2014), “Effect of Pressure on the Mechanical Properties and Microstructure of Die Cast Aluminium A380 Alloy” Journal of Mineral and Materials Characterization and Engineering Vol. 2, Pp 248-258.

[17]. Obiekea K. N., Aku S. Y and Yawas D. S. (2012), “Influence of Pressure on Mechanical Properties and Grin Refinement of Die Cast Aluminium Al1350 Alloy”, Advances in Applied Science Research, Vol. 3, No 6, Pp 3663-3673.

[18]. Darguch M. S, Pettersen K., Nogita K., Nave M. D and Dunlop G. L. (2006), “The Effect of Aluminium Content on the Mechanical Properties and Mcrostructure of Die Cast Binary Magnesium-Aluminium Alloys”, Materials Transactions, Vol. 47, No 4, Pp 977-982.

Oladebeye, Dayo Hephzibah, et. al. “Tensile and Hardness Characteristics of Cast 6063aluminium Rod Produced From Permanent And Squeeze Cast Moulds.” *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 18(6), 2021, pp. 31-40.