Effect of Permanent and Squeeze Casting Methods on Impact and Fatigue Properties of Cast 6063 Aluminum Rods

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ABSTRACT

This paper presents an experimental investigation to determine the effect of permanent and squeeze cast methods on the impact and fatigue properties of AA6063 cast rods. The cast moulds (permanent and squeeze cast moulds) were fabricated and used to produce Aluminum rods. The test samples from cast rods were subjected to impact and fatigue test. In impact strength analysis, the toughness increased from 5.2J to 14J with increase in pressure in squeeze casting. The fatigue life also increased from 5 cycles to failure at 1532.8MPa to 11 cycles to failure at 2115MPa with increase in pressure in squeeze casting as well. 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.

(Keywords: permanent mould, squeeze cast mould, impact properties, fatigue properties, cast rods)

INTRODUCTION

Aluminum is the most abundant metal in nature. Some 8% of the weight of the Earth's crust is aluminum (1). Aluminum is the most widely used non-ferrous metal, being second only to steel in world consumption (2). The unique combination of properties exhibited by aluminum and its alloys makes aluminum 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. Aluminum 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 4999 BC. 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).

Squeeze casting is a process in which an alloy melt solidifies under the application of external pressure, in order to prevent the formation of shrinkage porosity.

Raji and Khan (7) investigated the properties of the squeeze castings 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.

Experimental investigation on squeeze cast product by Chatterjee and Das (8) (9) and Frankl and Das (10) showed that improved mechanical properties were due to modification of microstructure of the squeeze cast product by pressure application. Aniyi, et al. (11) investigated effects of pressure, die, and stress-relief temperatures on the residual stresses and mechanical properties of squeeze-cast Aluminum rods.

Avalle, et al. (12) worked on static and fatigue strength of a die cast Aluminum 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 Aluminum alloy. Raji and Khan (13) 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.

Although many studies have been carried out on various Aluminum alloys, little information had been published on effects of squeeze casting on AA6063. In this research, the effect of permanent and squeeze cast methods on impact and fatigue properties of cast AA6063 Aluminum rods are experimentally investigated using a fabricated permanent and squeeze cast rigs.

MATERIALS AND METHODS

The material used for the study was AA6063 Aluminum ingot obtained from Aluminum 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 research work were designed and fabricated. The rigs comprise of squeeze cast mould and permanent mould. 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 Figure 1.

The mould was made from a steel plate of 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 Figure 2.

Table 1: Chemical Composition of the Aluminum Ingot.

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

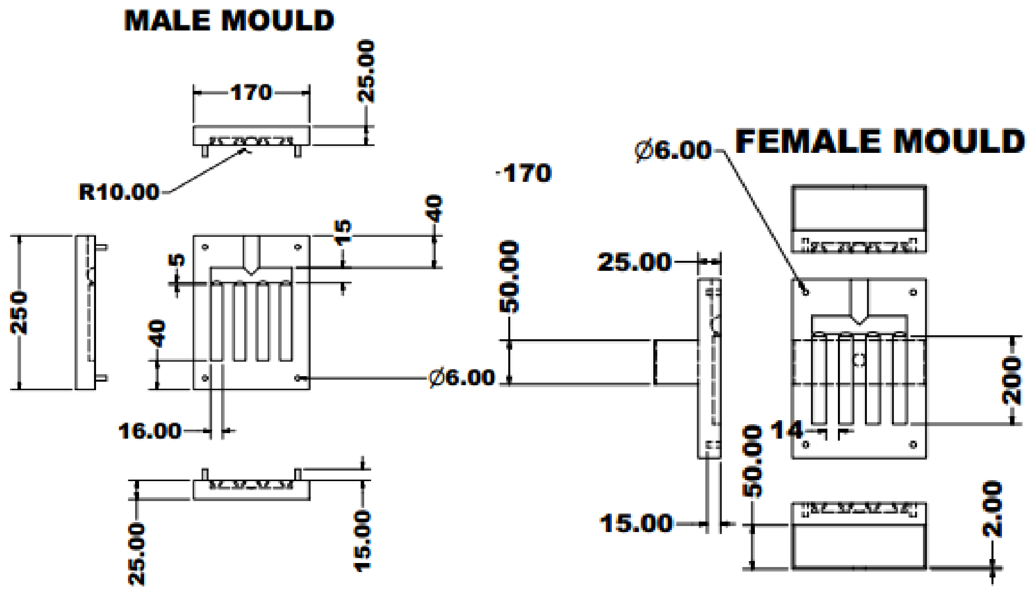


Figure 1: Male and Female Moulds for Permanent and Squeeze Cast Moulds.

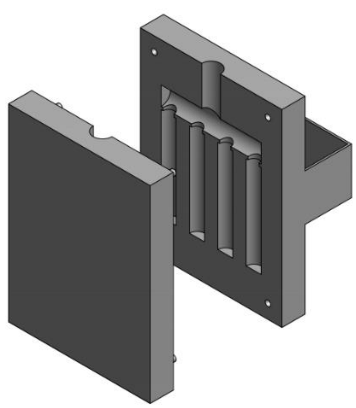


Figure 2: Permanent and Squeeze Cast Mould.

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 as in Figure 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 and vary the pressure exerted on the cast as shown in Figure 4.

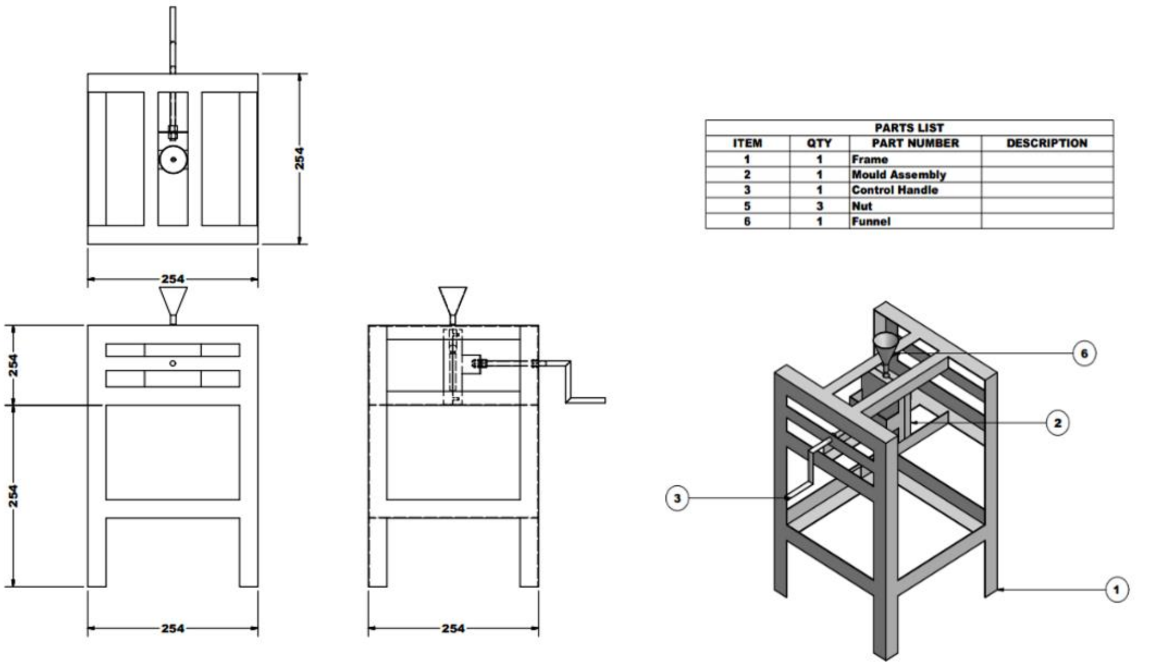
Experimental Procedures

The Aluminum ingot was melted using blacksmith open furnace. The hot liquid Aluminum metal was cast into solid rods by permanent 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 pressure on the properties of cast Aluminum.

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 both permanent and squeeze cast moulds. For simplicity and analysis sake, the samples were designated as shown in Table 2.



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

Figure 3: Permanent Mould.

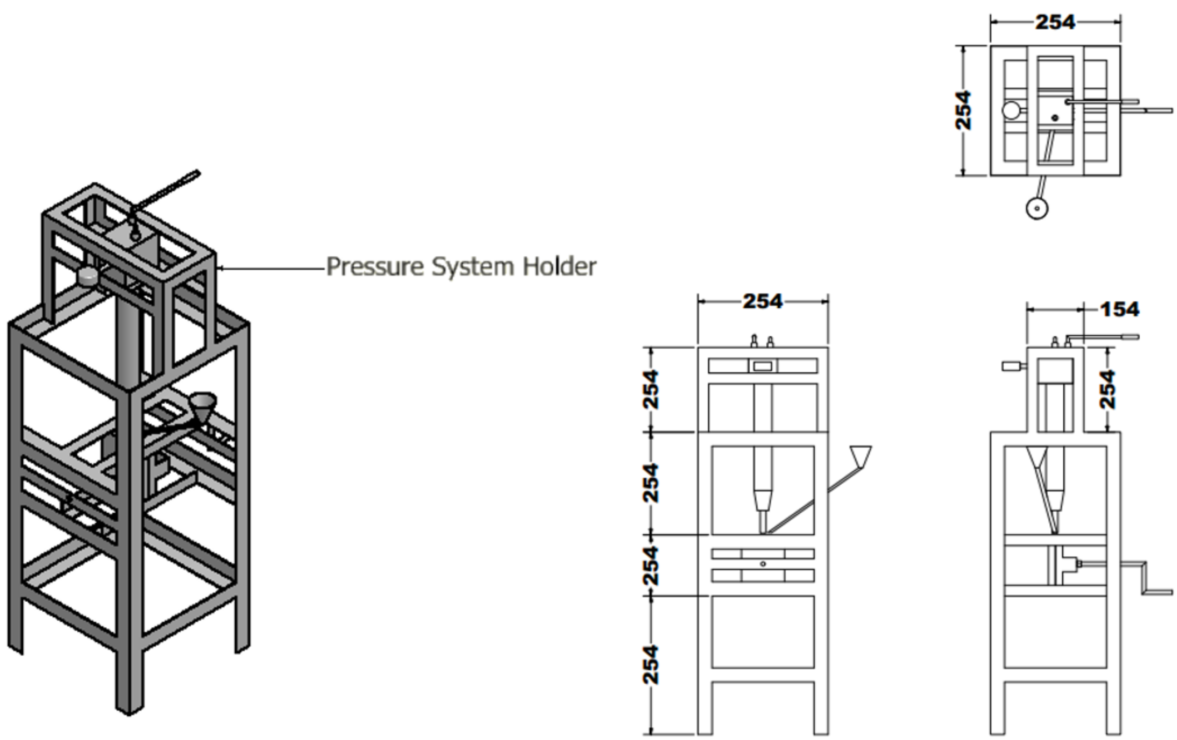


Figure 4: Pressure System for Squeeze Cast Mould.

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

Fatigue Test

Fatigue test specimen were machined from the bulk specimen in accordance with American Society for Testing and Materials E1942 - 98 (ASTM) as shown in Figure 5.

The machined specimens were loaded into the Avery Denison Fatigue Machine and subjected to fatigue test in accordance to ASTM test method. The fatigue properties obtained are shown in Figure 6.

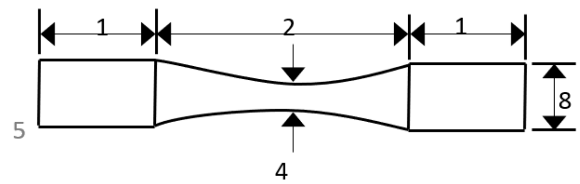


Figure 5: Fatigue Test Specimen (All dimensions in mm).

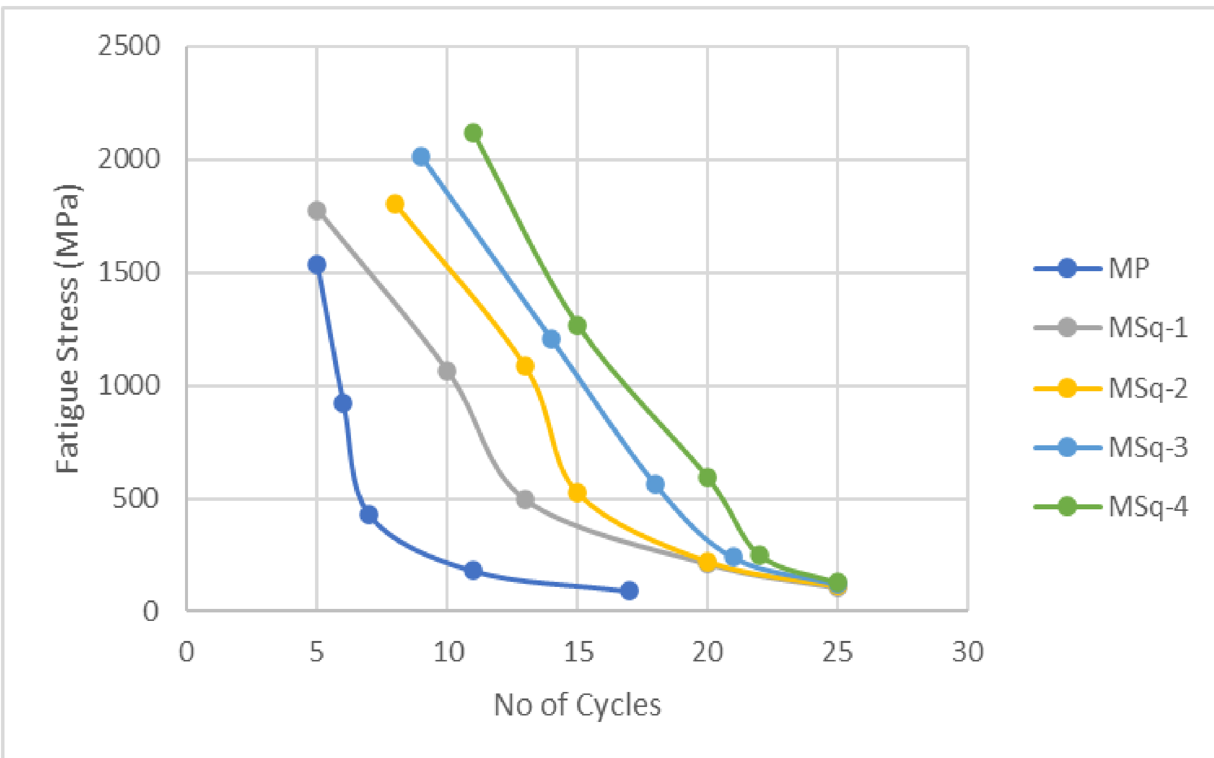


Figure 6: Fatigue Properties of Cast 6063 Aluminium Rods from Permanent and Squeeze Casting Mould.

Impact Test

Impact test specimen were machined from the bulk specimen in accordance with American Society for Testing and Materials D256 (ASTM D256) as shown in Figure 7. The machined specimens were loaded into the Izod Impact Machine and subjected to Impact test in accordance to ASTM test method.

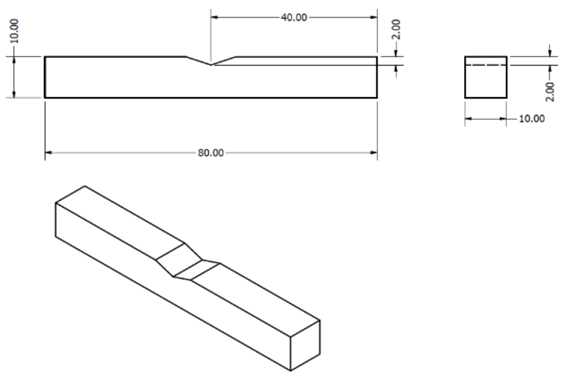


Figure 6: Impact Test Specimen (All dimensions in mm).

RESULTS AND DISCUSSION

Fatigue Properties

Variation of fatigue properties of the castings from permanent and squeeze casting techniques are shown in Figure 6. Increase in fatigue stress was found to shorten the fatigue life of the respective castings. The number of cycle-to-failure is a measure of the fatigue life of the test materials.

Castings from squeeze casting exhibited longest fatigue life with fatigue stress of 2115MPa, and corresponding N_f of 11 to fatigue stress 1778 MPa and N_f of 5, Permanent Casting has fatigue stress of 1532.8MPa, N_f of 5. The trend of variation shows that as pressure increases, the fatigue strength increases.

Impact Properties

Figure 8 shows variation of impact energy for permanent and squeeze casting techniques. It is revealed that Squeeze Castings have highest impact values from 7.9J to 14J and 5.2J in permanent moulds. This indicated that increase in pressure improves the toughness of the Cast Aluminum.

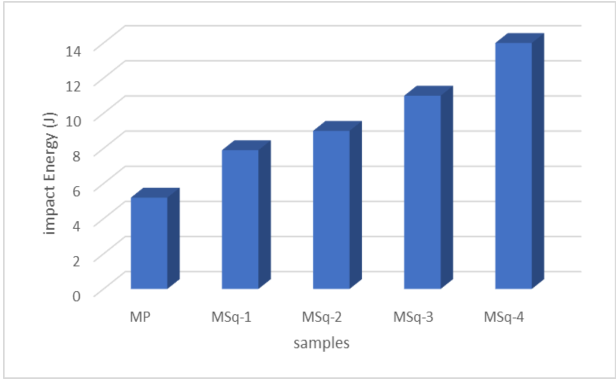


Figure 8: Impact Energy of Cast 6063 Aluminum Rods from Permanent and Squeeze Casting Moulds.

CONCLUSION

This experimental investigation of AA6063 cast Aluminum 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.

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