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Effects of Ingate types on Some Mechanical Properties of Cast Aluminium 6063 Alloy

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Abstract

This study examined the effects of inner-gate (ingate) types on some mechanical properties of cast aluminium 6063 (Al-Mg-Si) alloy. In this work, rods of aluminium 6063 alloy were cast using top gating, bottom gating and parting line gating designs. Ingot of 6063 aluminium alloy was melted using crucible furnace and poured into already prepared sand moulds. The casting from each gating system design was machined and tested for tensile, hardness and impact energy. The results from the tensile test revealed strength of 133.29, 122. 46 and 101.26 MPa for bottom gating, parting line gating and top gating respectively. Also, the results from the hardness test gave 61.25, 43.25 and 36.25 BHN for bottom gating, parting line gating and top gating respectively while impact test revealed that castings from top gating, parting line gating and bottom gating systems gave impact energy of 38.800, 36.108 and 34.476 Joules respectively. The study showed that the bottom gating system design produces casting of high tensile and hardness strength but least impact strength, followed by castings from parting line gating system while castings from top gating system produced castings of low tensile and hardness strength but high impact energy. Therefore, bottom gating design is recommended for use in applications that require high values of tensile strength and hardness while top gating design is recommended for use in applications that require high impact energy.

Keywords: Crucible furnace, Gating system, Ingate, Tensile Strength, Impact energy

1. INTRODUCTION

Casting is a very versatile manufacturing process with a wide range of advantages over other processes of manufacturing. Metal casting advantages include

i) most intricate of shapes which are difficult to produce through other methods can be cast,
ii) some metals cannot be otherwise shaped except by casting due to their metallurgical nature,
iii) constructions are simplified by casting,
iv) metal casting is highly adaptable to mass production,
v) extremely large and heavy metal objects can be cast which otherwise would be difficult or economically unwise to produce and,
vi) an economic advantage may also exist in the choice for casting as a manufacturing process (Shittu *et al.,* 2018).

The production of castings necessitates making of a mould patterned after the part to be manufactured. The mould is subsequently filled with the liquid metal through a ‘liquid metal flow system’ known as gating system (that is, channels through which the molten metal flows from the ladle to the mould cavity), allowing it to solidify and removing it from the mould (Kalpakjian and Schmid, 2006). For production of good castings, the importance of gating system which composed of sprue, runners, ingates and overflows cannot be overemphasized (Anjo and Khan, 2013; Jain, 1979). The use of a good gating system is even more important if a casting is produced by a gravity process.

It is quite obvious from the nature of metal flow that an oversized gate allows the metal to enter the mould at a very low velocity whereas an undersized gate allows the metal to enter the mould at a very high velocity. If poor gating techniques are used, lower casting quality is achieved, because of damage the molten metal received during the flow through the gating system (Campbell, 1991). It could be even worse, if the molten material is a volatile and reactive metal, because of dross and slag formation (Hu *et al.*, 2002).

The requisites of a gating system include

i) the controlling of turbulence and prevent trapping of gases in the mould,
ii) accumulation of enough metal into the mould cavity before solidification,
iii) controlling of shrinkage by establishing the best possible temperature gradient so that shrinkage occurs in gating system and not in casting,
iv) incorporating a system for trapping non metallic inclusions,
v) preventing mould or core erosion,

vi) and preventing aspiration of air and mould gases in metal stream (Jain, 1979).

There are several types of gating systems but the most widely used are; top gating, parting line gating and bottom gating as illustrated in Figure 1.

This research work was aimed at investigating the three common types of ingates so as to know how they affect the mechanical properties of 6063 aluminium alloy and invariably other casting metals.

2. MATERIALS AND METHODS

The primary material used in this research work was aluminium 6063 obtained from Nigeria Aluminium Extrusion Company (NIGERLEX). Table 1 revealed the composition of the as-received sample. Other materials used include moulding sand and rod patterns of diameter 50 mm by 500 mm long made from wood with their calculated and designed gating elements for top, bottom and parting line gating systems. The equipment and machine used include crucible furnace, moulding boxes, lathe machine, hack saw, bench vice, impact tester and Instron machine.

The rod patterns were mould in green sand using top, bottom and parting-line methods of gating. The aluminium 6063 was melted in the crucible furnace and the molten metal poured into already prepared moulds at about 720°C (Shittu *et al.,* 2018). The moulds were allowed to cool down to room temperature, knocked out and the castings fettled.

Round tensile and impact test samples were machined from the three categories of rod cast according to British Standard BSEN 10002-1:1990 and ASTM Standard E 602-91 respectively. The tensile test samples have a gauge length of 30 mm and diameter of 5 mm. The impact test samples were V notched to a depth of 2 mm. Samples were also sectioned from cast rods for hardness tests.

The machined samples were tested for tensile, impact and hardness.

3. RESULTS AND DISCUSSIONS

The results obtained from the three gating systems for the tensile strength, impact strength and hardness tests are as presented graphically in Figures 2 to 4 respectively.

The microstructures of the castings from each gating system type are also shown in Figures 5 to 7.

Figures 2 and 3 have shown that the castings from bottom gating system have the highest values of both tensile strength and hardness respectively. These are followed by those from parting line gating system while the top gating system has the least values of both the tensile strength and hardness.

Figure 4 shows that the castings from top gating system have highest impact energy followed by those from parting line and the least impact energy is obtained from castings from bottom gating system.

Figure 5 is the microstructure of the castings from the top gating system and shows coarse grains. The grains of the castings from the parting line gating system (Figure 6) are finer than those from the top gating while the castings from the bottom gating system (Figure 7) have the finest grains.

The reasons for the observed trends in the tensile strength, the hardness and the impact strength could be linked with the microstructures vis-à-vis the grain size. According to Hall-Petch relation (Callister, 2001),

$$\sigma_y = \sigma_o + \frac{K_y}{\sqrt{d}}$$

where σ_y = yield stress.

σ_o, K_y = are material constants

d = diameter of the grain

This expression shows that the smaller the grain size, the higher will be the yield strength of the material. Also, in multiphase alloys, different types of microstructures result depending on the volume fraction, shape and distribution of the phases (Gleiter, 1996). It was also established that the microstructure of Al-Mg-Si alloys plays an important role in determining the mechanical properties. From the micrographs in Figures 5, 6 and 7, it is evident that grain boundaries impeded dislocation movement and that the number of dislocations within has significant effect on how easily dislocations can transverse grain boundaries and travel from grain to grain. The microstructure of samples from bottom gating system show finest grain and hence more grain boundaries. This shows why castings from bottom gating system has high tensile strength and hardness but least impact strength since impact strength decreased with increasing tensile strength as revealed by the value indicated in Figures 2 to 4 and corroborated by the investigation of Reed-Hill, (1991) and Li, *et al* (2013).

The finer the grain, the more the grain boundaries and according to Rosler, *et al* (2007) and Li, *et al.* (2013) these grain boundaries interfere with dislocation movement and once a dislocation reaches a grain boundary, it cannot continue its slip motion into another grain because of the differences in orientation of the slip plane and direction between neighboring grains (Ashby, *et al.,* 2007; Rosler, *et al.,* 2007). Hence, grain boundaries serve as obstacles to movement of dislocation which pile up near the boundaries (Ashby, *et al.,* 2007; Rosler, *et al*, 2007). Therefore with decreasing grain size (i.e.

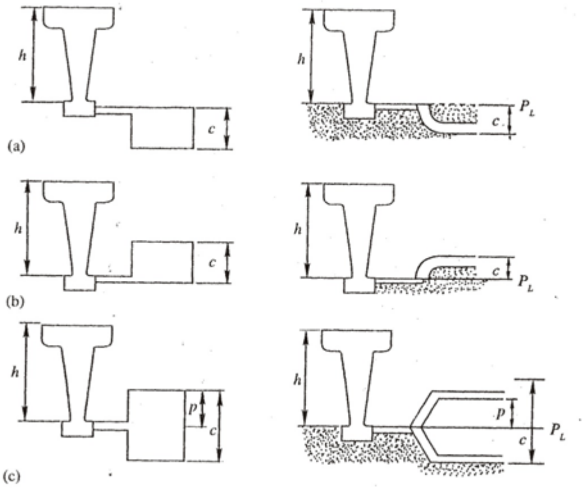

Figure 1: Gating Systems (a) Top gate (b) Bottom gate and (c) Parting gate (Rao, 2001)

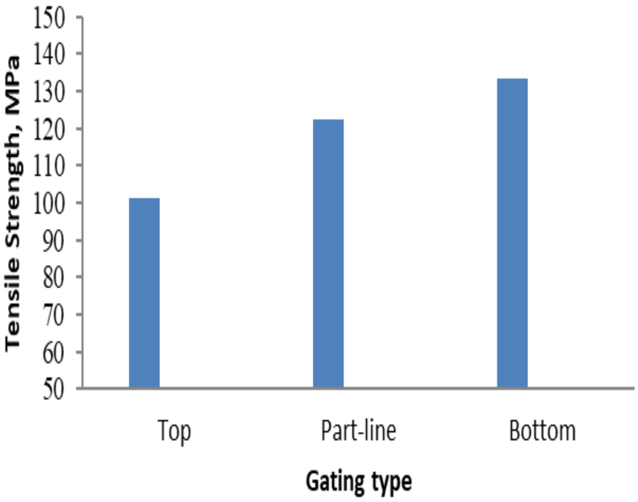

Figure 2: Tensile strength of the gating types

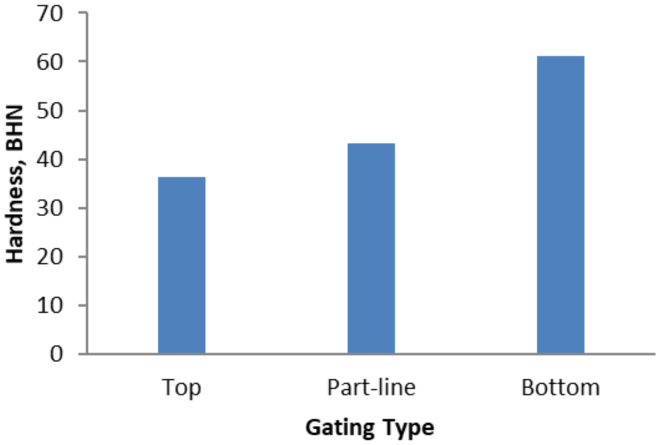

Figure 3: Hardness of the gating types

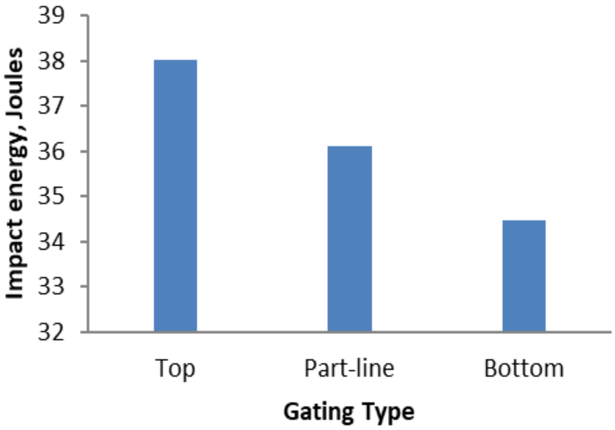

Figure 4: Impact energy of the gating types

Table 1: Chemical composition of Al-Mg-Si (6063) Alloy

Element	Al	Si	Mg	Fe	Cu	Mn	Cr	Zn	Ti	Pb	V	Zr
Weight (%)	98.66	0.445	0.462	0.242	0.005	0.016	0.005	0.002	0.006	0.034	0.007	0.001

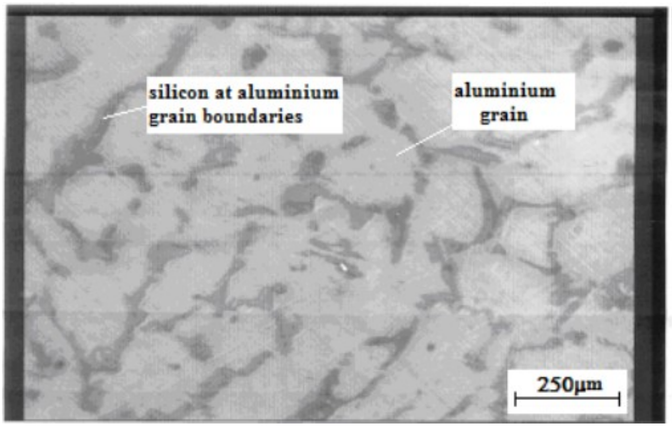

Figure 5: Microstructure of casting from top gating system

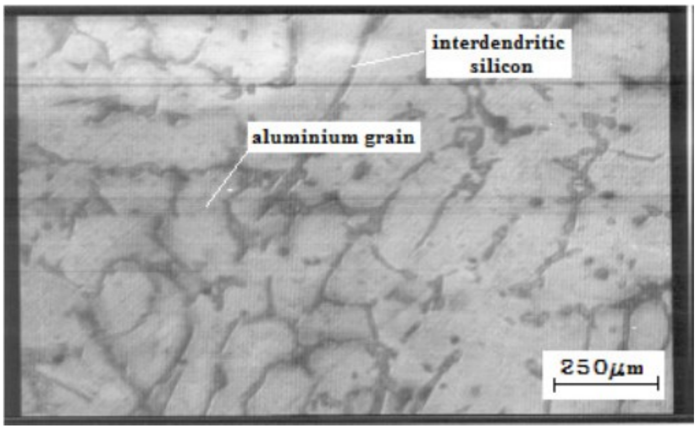

Figure 6: Microstructure of casting from parting line gating

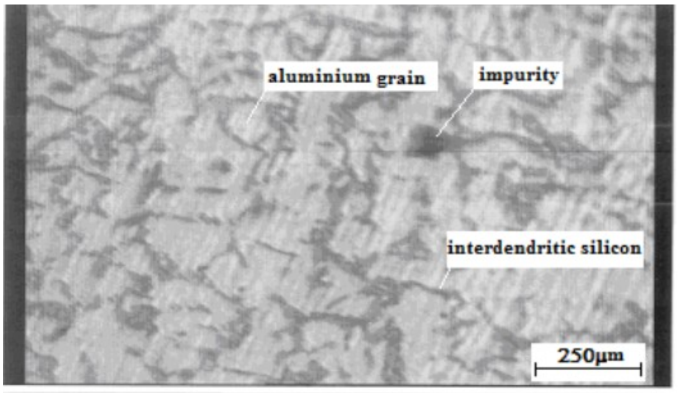

Figure 7: Microstructure of casting from bottom gating system

more finer grain) less distance is covered by dislocation before reaching a grain boundary resulting in higher strength and hardness. This is called the grain size hardness (Martin, 2006; Totten and Mackenzie, 2003).

4. CONCLUSIONS

In conclusion, the study showed that the type of gating system design has significant effect on some mechanical properties (tensile strength, hardness and impact energy) of cast aluminum alloy. Bottom gating system design produces castings of high hardness and tensile strength while it produces low impact energy castings. Top gating on the other hand has high impact strength but low in both the tensile strength and hardness. Parting gate tries to derive the best of the top and bottom gates; therefore it produces castings of mid mechanical properties between the top and bottom gating systems.

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