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EFFECT OF DIE AND SAND CASTING ON MECHANICAL BEHAVIOUR OF Al-Mg-Si ALLOY

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Abstract: This paper investigated the effects of die and sand casting methods on mechanical behaviour of Al-Mg-Si alloy, using die, sand and spin casting. The pure aluminium scrap, magnesium and silicon were subjected to chemical analysis using spectrometric analyser, thereafter the charge calculation to determine the amount needed to be charged into the furnace was properly worked out and charged into the crucible furnace from which as-cast aluminium was obtained. The mechanical properties of the casting produced were assessed by hardness and impact toughness test. The optical microscopy and experimental density and porosity were also investigated. From the results it was observed that magnesium and silicon were better dispersed in aluminium matrix of the die casting. It was observed from visual examination after machining that there were minimal defects. It was also observed that out of the three casting methods, spin casting possesses the best mechanical properties (hardness and impact toughness).
Keywords: Al-Mg-Si alloy, die, sand, mechanical properties, spectrometric analyzer

INTRODUCTION

Casting is a fabrication process whereby a totally molten metal is poured into a mould cavity having the desired shape; upon solidification, the metal assumes the shape of the mould but experience some shrinkage [1]. Casting is the most economical.

A number of different casting techniques are commonly employed, including sand, die, investment, continuous and spin casting. Sand Casting probably the most common method, ordinary sand is used as the mould material [1]. A two-piece mould is formed by packing sand around a pattern that has the shape of the intended casting. A gating system is usually incorporated into the mould to expedite the flow of molten metal into the cavity and to minimize internal casting defects. It has been stated that when pouring temperature is lower than optimum, the mould cavity will not fill the gate or riser will solidify too rapidly and intercept directional solidification.

Die casting is a versatile process capable of being used in mass production of alloys having properties unobtainable by other manufacturing method [2].

Spin casting is both gravity and pressure independent since it creates its own force feed using a temporary sand mould held in a spinning chamber at up to 300-3000rpm as the molten metal is poured. The molten metal is centrifugally thrown towards the inside mould wall, where it solidifies after cooling. The casting is usually a fine-grained outer diameter, owing to chilling against the mould surface. Impurities and inclusion are thrown to the surface of the inside diameter which can be machined away [3].

Aluminium alloys have great use potential in the structural components in the aerospace and automobile industries mainly because of their low density and high specific strength [4], also aluminum alloys have a wide diversity of industrial applications because of their high specific strength, light weight and corrosion resistance. Therefore these alloys motivate considerable interest to the aviation industries [5, 6]. Aluminium alloy for a cast component is based upon mechanical and corrosion properties it can achieve. Aluminium alloy casting properties result from three primary factors: casting alloy, melting and casting methods. The properties obtained from one particular combination of these factors may not be identical to those achieved with the same alloy in a different casting facility.

EXPERIMENTAL MATERIAL AND METHODS

The materials used for the work were scraps of Aluminium purchased from Northern Nigeria Cable Processing Company Limited (NOCACO), Kaduna also Magnesium used. The silicon used was obtained from Engineering Materials Development Institute (EMDI), Akure, Nigeria.

Table 1. Chemical composition of basic materials (after casting)

Si	Fe	Cu	Mn	Mg
0.40	0.24	0.03	0.04	0.55

Zn	Cr	Ti	Al
0.03	0.01	0.02	98.68

The two casting methods were carried out for the work, they are:
 (i) Die
 (ii) Sand casting.

The patterns used were made of wood with diameters of 20 mm by 150 mm long. The patterns were made larger than the original dimension to compensate for shrinkage during solidification and machining operation.

Natural sand was used to prepare the sand mould, a mixture of silica sand with considerable amount of bentonite. The addition of bentonite improved the bonding strength. The moulding of the pattern was carried out using a moulding box comprising of cope and drag that gave rigidity and strength to the sand. Parting sand was properly applied for the easy removal of the mould from the pattern. The gating system was properly designed for smooth channeling of the molten metal into the mould cavities through the sprue, runner, in-gates and riser that were perfectly placed in position. The die mould was prepared using cast iron.

The cast aluminium scraps, magnesium and silicon were carefully worked out and charged into the furnace.

Crucible furnace was used for the melting of the charges. Prior to charging, the crucible furnace was checked to prevent leak of molten metal and also to guide against moisture, which can generate vapour during melting. Metallurgical factors in the choice of melting facilities related to the tendency of the charge to react with its surrounding, affecting composition control, impurity level and metallic yield were considered. The charged materials in the furnace were allowed to melt down (at 700^oC) and then the furnace was switched off. The molten metal was tapped from the furnace, poured into the die mould and sand mould. The die cast was allowed to air cooled [2], together with sand cast.

The removal of the sand which stuck on the surface of the sand cast was carried out with the aid of sand blasting bar, sprue and ingates were also removed using hacksaw. Cleaning operation was also performed by grinding to smoothen the surface and unnecessary attachment on the surface of the metal to improve the appearance.

The determination of the experimental densities of the various casting products were carried out measuring the weight of the test samples using a high precision electronic weighing balance with a tolerance of 0.1mg. The weights of the measured samples were divided by their respective volume.

Experimental density,

$$\rho = \frac{mass\_of\_sample}{volume\_of\_sample} \quad (1)$$

The percentage porosity of the cast aluminium was determined by use of equation

$$\%\ volume\ porosity = \frac{(\rho_{cal} - \rho_{exp})}{\rho_{cal}} \quad (2)$$

where ρ_{cal} = Theoretical Density (g/cm^3), ρ_{exp} = Experimental Density (g/cm^3) [7, 8]

The hardness for the sand and die cast were evaluated using a Vickers Hardness Tester (LECOAT 700 Microhardness Tester). The test specimens were polished to obtain flat and smooth surface finish after this, a direct load of 490.3 MN was applied on the specimens for 10 seconds and the hardness reading evaluated following standard procedures.

The specimens for the optical microscopy were properly polished using emery papers of various grit sizes ranging from 500µm to 50000µm. The fine polishing was equally ensured using a polycrystalline diamond suspension of particle sizes ranging from 10µm to 0.5µm with ethanol solvent, after which the specimens were etched in HNO_3. Hydrochloric acid was used to swab the surface before microstructural examination was performed using Datteng-Driven Metallurgical Software [9].

The toughness of the specimens were evaluated using (Honnsfield Balance) Impact Testing Machine, samples were machined to dimensions of 8mm diameter and 18mm length. The specimen was notched 2mm in (V shape) the value of the energies absorbed in fracturing the test - piece were measured in joule.

EXPERIMENTAL RESULTS - MICROGRAPH

Figure 1 - 2 shows representative optical micrograph for sand and die casting of Al-Mg-Si alloy. It is observed that magnesium and silicon were fairly dispersed in the aluminium matrix better in die casting than sand casting.

The microstructure of sand casting shows phases that were not evenly dispersed in the aluminium matrix while it is discovered there is strong clustering of Mg_2Si in certain area of matrix [10, 11].

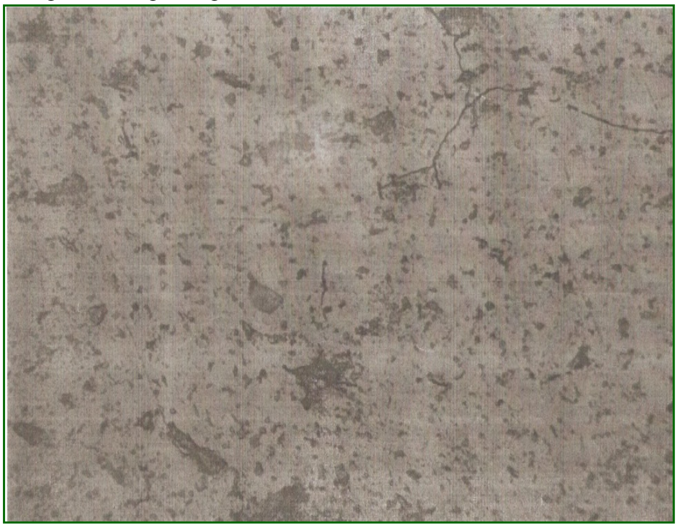

Figure 1. *Microstructure of Sand Casting (X400)*

Figure 2. *Microstructure of Die Casting (X400)*

EXPERIMENTAL RESULTS – MECHANICAL PROPERTIES

It was observed from Figure 3 that sand casting has the higher hardness than die casting. The crystal lattices of Mg_2Si precipitates show coherence with that of the α-aluminium, consequently, severe strain fields are created around these crystals which impede the motion of dislocations and thereby causing increased hardness of castings obtained in sand casting [11]. These two elements (magnesium and silicon) form the primary hardening phase (magnesium silicide, Mg_2Si) in aluminium alloy 6063 [12-13].

The variation found in hardness of the two cast products may also be attributed to their porosity, density and the microstructure.

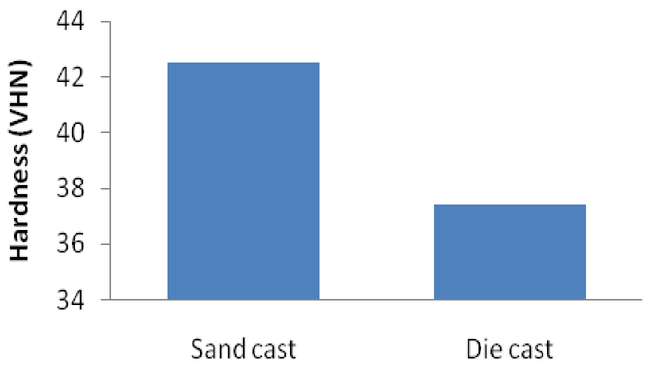

***Figure 3**. Hardness of Cast Aluminium Products*

***Table 2.** Hardness of Cast Al-Mg-Si alloy Products*

Specimen	Hardness (VHN)
Sand Casting	42.515
Die Casting	37.425

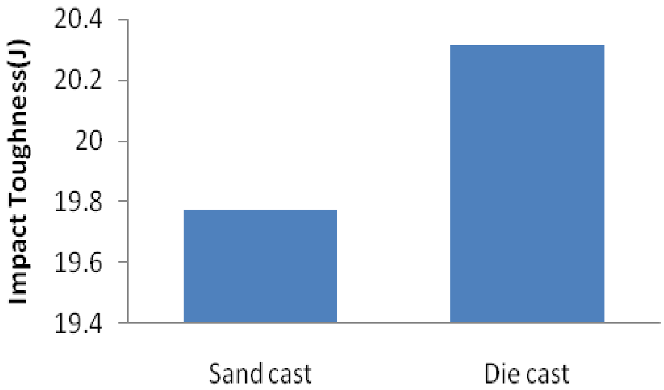

***Figure 4**. Impact Toughness of Cast Aluminium Products*

***Table 3**. Impact Toughness of Cast Al-Mg-Si alloy Products*

Specimen	Impact Value (J)
Sand Casting	19.773
Die Casting	20.314

From Fig 4, the impact toughness of die casting is superior to that obtained in sand casting. The results indicate that fairly distributed Mg_2Si crystals in α-aluminium in die casting, this alloy exhibited better impact toughness in the die cast condition as compared with the same alloy subjected to sand casting, this is in agreement with Basavakumar [14].

CONCLUSIONS

In the research work, the effect of die and sand casting on mechanical behaviour of Al-Mg-Si alloy was investigated. On the strength of the results presented, the following conclusions were drawn:

- *The microstructure of the die casting revealed that magnesium and silicon were fairly dispersed in the aluminum matrix as compared to sand casting.*
- *The hardness obtained from sand casting was better than that of die casting.*
- *The products through die casting had a better impact toughness than sand casting*

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