

EFFICACY OF VARIOUS MOULDING TECHNIQUES AND SECTION THICKNESS ON MECHANICAL PROPERTIES OF AS-CAST A142 ALUMINIUM ALLOY CASTINGS

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ABSTRACT

Manufacturing/fabrication in other casting processes are limited by wall-thickness and design. Producing a complicated inner structure by using lost cores, is still not economically feasible in these processes. This study aimed at the efficacy of different moulding technique and section thickness on mechanical properties of A142 Aluminium alloy casting. The A142 Aluminium alloy was produced using green, dry and loam sand mould castings at the foundry shop of department of metallurgical and materials engineering Ahmadu Bello University Zaria (ABU). The alloy was cast into cylindrical bars of 12, 14, 16, 18 and 20mm diameter and 300mm by length each. The as-cast bars were cut and machined to standard tensile, impact and hardness test specimens. It was found that both tensile and impact strength properties decrease as the section size increases. While the hardness slightly increases with the section thickness. A142 alloys produced in dry sand mould have the highest tensile strength while alloys produced from green sand mould have the highest impact strength and A142 aluminum alloys produced in loam sand have the highest hardness. The overall result showed that the moulding techniques and section thickness had influence on the mechanical properties of the cast metal. It is therefore recommended that, before any sample should be subjected to any service, different test on such samples are required, and this is to avoid being deserved by the physical properties of such sample such as a shape, size, volume and dimensional accuracy. And further work should be carried out on the effect of moulding techniques and section thickness on the corrosion and various heat treatment on the A142 aluminium alloy.

Keywords: Casting, moulding, aluminium, green sand, dry sand, loam sand

1 INTRODUCTION

Sand casting is the most widely used metal casting process in manufacturing. Almost all metals can be produced by sand casting. Some examples of items manufactured in modern industry by sand casting processes are engine blocks, machine tool bases, cylinder heads, pump housings, and valves [1]. The unique combinations of properties provided by aluminum and its alloys make aluminum one of the most versatile, economical, and attractive metallic materials for a broad range of uses from soft, highly ductile wrapping foil to the most demanding engineering applications [2, 3, 4]. Aluminum alloys are second only to steels in use as structural metals. Metal casting forms integral components of devices that perform useful functions for human beings [5]. The metal casting process is the simplest most direct route to a near net shape product and often least expensive. The objective of metal casting has been to produce useful implements for human consumption [6, 7]. This process in its fundamental form requires a mould cavity of

the desired shape and molten metal to pour into the mould [8]. Manufacturers have been producing casting for thousands of years, most often pouring molten metal in the moulds made of sand [9]. [10, 11] Show that Aluminum alloys are the largest proportion of non-ferrous alloys used in the production of automobile components, building and construction containers packaging, marine, aviation, aerospace and electrical industries. They are highly reflective to radiant energy, visible light, heat and electromagnetic waves apart from possessing excellent machinability and good reserve to scratching [12]. Historically, the development of casting practices for aluminum and its alloys is a relatively recent accomplishment. Aluminum alloys were not available in any substantial quantity for casting purpose until long after the discovery in 1886 of the electrolytic process of reduction of aluminum oxide by Charles Maitin Hall in the United States and Pout Haroolt in France [13]. Although Halls invention provide aluminum at a great reduced cost, the full value of aluminum as a casting material was not established until alloys suitable for foundry process were developed [13, 14, 15]. Aluminum is one of the few metals that can be cast by all the processes use in casting [16]. These processes in decreasing order of amount of aluminum casting are: die-casting, permanent moulds casting, sand casting (green and dry sand), plaster casting, investment casting and continuous casting [17]. However, sand casting is the most versatile method for casting aluminum by providing the greatest latitude for size, shape and alloy cast [18]. Because of the low pouring temperature and specific gravity of aluminum alloys, moulds are less affected by heat than in the case of iron and steel [19]. Consequently, excellent surface finish and dimensional accuracy maybe obtain even in large sand castings than other casting processes [20]. The minimum section thickness for sand casting aluminum casting is $\frac{1}{8}$ in, $\frac{5}{32}$ in, and $\frac{3}{16}$ in for 3 the length below 3in, 3 to 6in and over 6in respectively [13]. Aluminum alloys may be cast in dry sand mould, green sand moulds and loam-sand moulds. However, the cooling rate of these moulding processes in relation to the variation in section thickness and the sand moulding techniques is quite different and thus influences the structure and mechanical properties of the castings [21]. The ease with which aluminum may be fabricated into any form is one of its most important assets. Often, it can compete successfully with cheaper materials having a lower degree of workability [22]. The metal can be cast by any method known to foundrymen. But many foundry men prefer using sand casting over many of the other forms of casting processes because, it is cheap and the sand used is readily available [23]. Many experienced foundry men have to use sand casting even though their abilities and resources allow them to use the other metal casting methods like Lost Wax Casting or Investment Casting [24]. Sand casting involves less material and less effort than the other casting methods. Sand casting is a gate way for new casters to get into the trade [25]. [26] Also reported that sand casting is an inexpensive method for the production of materials. Raw castings are transformed into finished products or components. The least costly of all casting methods is sand casting. Sand casting is used to manufacture a large range of metal parts of different sizes and weights in complicated geometries [17]. And due to the high application of Aluminum based alloys in aerospace industries and other light industries application, the need to develop a sand casting of aluminium alloy with optimum mechanical properties is very essential Therefore, the present study was carried out to evaluate the effect of different moulding techniques and section thickness on mechanical properties of A142 aluminium alloy castings.

2 METHODOLOGY

2.1 Materials

Pure Aluminum scrap used for this investigation was obtained from NOCACO Nigeria limited, Kaduna State, with 99.9% purity. While the magnesium and Nickel was obtained from chemical laboratory in Zaria. The ligand (50% Al-50% Cu) used was obtained from NMDC Jos. A 2Kg charged-fired pit furnace, Mould assembly, Pattern of cylindrical steel pipes of various diameter, Lathe machine, Grit papers of different grades (60,120, 180, 240, 320, and 600), 2% nital solution (etchant), Polishing cloth, Hand gloves, Tensile test machine, Impact test machine, Rockwell hardness test machine and Polishing machine.

2.2 Methods

The following steps as outlined below were followed during the experimental process.

2.2.1 Sand and Mould Preparation.

The sand that was used for the production of mould was obtained from foundry workshop of metallurgical and materials department ABU Zaria. Three types of castings technique were used in this research work; Green, Dry, and Loam sand castings. The sand as received was mixed with water in appropriate proportion. The combination of the water and sand was mixed thoroughly until the required plasticity was obtained. Cylindrical steel pipes were used as patterns. The prepared sand was then rammed round the pattern of different diameter ranging from 12-20mm diameter and 300mm length each with due consideration of allowance for shrinkage. The green sand was sufficiently rammed for sufficient permeability of the sand to allow the gases produced during pouring to escape. For the dry sand, the prepared sand was rammed round the pattern of different diameter sand left for six days to dry. For the loam, 40% of clay was mixed thoroughly with 60% of silica sands and rammed round the pattern of different diameters. It was also left for six days to dry.

2.2.2 Charge Composition Calculation

The charge composition and weight per heat of material charge into the crucible was determined as follows:

Volume of mould:

The volume of the fabricated mould was calculated using the relationship given below (with consideration of losses).

$$\text{Volume of cylinder} = \pi r^2 h \quad (1)$$

Where: $\pi = 3.142$; $D = 20\text{mm} = 2\text{cm}$, $r = 1\text{cm}$; $h = 300\text{mm} = 30\text{cm}$. This is also the volume of the mould.

Density of Aluminium alloy

The density of Aluminium ($2.7\text{g}/\text{cm}^3$) was used since it is the major element (metal) in the alloy.

Mass of the casting

The approximate mass of the casting per mould was determined as shown below:

Density = mass/volume

$$\text{Mass} = \text{density} \times \text{volume} \quad (2)$$

Calculation of weight percentage:

The calculation of the percentage weight of charge material (92.5%AL, 4%Cu, 2%Ni, and 1.5%Mg) was done in the following sequence: $W_r = 254.502\text{g}$. Where W_r is the total weight of metal required. The weight required for each composition per bar was calculated using equation below:

$$\text{Weight of each element} = \left(\frac{\% \text{Composition}}{100} \times W_r \right) \quad (3)$$

2.2.3 Melting and Casting

The melting of the alloy was carried out in a charcoal fired crucible furnace. Aluminum scraps was cut into smaller sizes for the convenience in weighting and ease of charging into the crucible. The 92.5% Al, 4% Cu, 2% Ni and 1.5% Mg was measured totaled approximately 1.2Kg capacity and then charged in to the crucible. The ligand (50%AL-50%Cu) was added when the aluminum had melted followed by Nickel and magnesium. With the charged in the crucible, the material was heated up to 690°C in order to have uniform liquid state and to give consideration for heat loss during pouring of the melt. Upon removal of

slag from the top of the liquid melt, the molten alloy was carefully poured into the already prepared moulds. Cooling took about 30 minutes before the sand was broken down to recover the cast alloy of 12mm, 14mm, 16mm, 18mm, and 20mm diameter and 300mm length each. The Same procedures were repeated for other batches.

2.3 Tensile Test measurement

Samples were machined to the standard dimensions prior to the heat treatment operation as specified in ASTM A370 [27]. The test method adopted is ASTM E8. The test sample was mounted at its ends onto the holding grips of the testing apparatus. The maximum loads were recorded directly from the Hounsfield tensometer. Following the fracture, the two broken ends of the specimens were fitted together and final gauge length was measured. The readings obtained were used to calculate the tensile strength and percentage elongation.

2.4 Hardness

The hardness values of the test samples were determined using Vickers hardness machine (MV1-PC model, Serial No.: 07/2012-1329). The test was carried out in accordance with ASTM E18 method. A diamond indenter was used to indent the surface of the test sample by the application of static load of 0.3kgf, which was maintained for fifteen minutes. Both diagonals of the impression were measured using a lower power graduated microscope. Using the mean value of the diagonal length, the machine gave the hardness value digitally. The procedure was repeated at 2 different points on the test piece and the average values were recorded [27].

2.5 Impact Test measurement

The toughness of each sample was determined using Avery impact testing machine with maximum capacity of 120 ft.lb (machine no. E 51425/9, type 6701). The test method used is in accordance with ASTM E23. Before the test, the pendulum was set to a potential energy position of 162.75J. The test sample was gripped vertically in a vice, the trigger was released and the registering pointer of the quadrant scale indicated the energy absorbed in Joules in breaking the sample. The energy was recorded. Impact strength (energy absorbed per unit area under the notch) was calculated from the impact energy and the sample dimension. The same was repeated for other test pieces.

3 RESULTS AND DISCUSSION

The chemical composition of the Aluminum alloy produced is given in table 1 below.

Table 1. Chemical composition of as-cast (A142) Aluminium alloy produced

Element	Cu	Ni	Mg	Al
Composition (%)	4	2	1.5	Balance

3.1 Tensile Properties

Figure 1 show the effect of different moulding techniques and section thickness on the A142 aluminium alloys produced. It was observed that tensile strength decreased as the section size increased. And A142 aluminium alloys produced in dry sand moulds have the highest tensile strength followed by the samples produced in loam sand while those produced in green sand moulds have the least tensile strength. The reason for this may be due to the fast cooling rate during solidification. This is in line with the finding of [28].

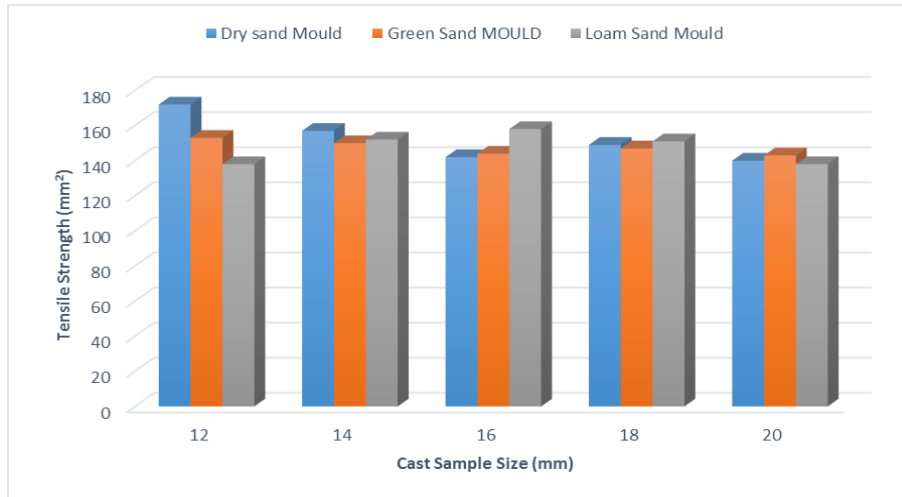


Figure 1. Profile of tensile strength of the cast sample-size of A142 aluminium alloy produced in dry, green and loam sand mould

3.2 Impact Strength

Figure 2 represent the effect of different moulding techniques and section thickness on the impact strength of A142 aluminium alloy produced. It was found that the impact strength decreased as the section size increased. It can be seen that the sample of A142 aluminium alloys produced from green sand moulds have the highest impact strength followed by the samples from loam and dry sand moulds have the least impact strength.

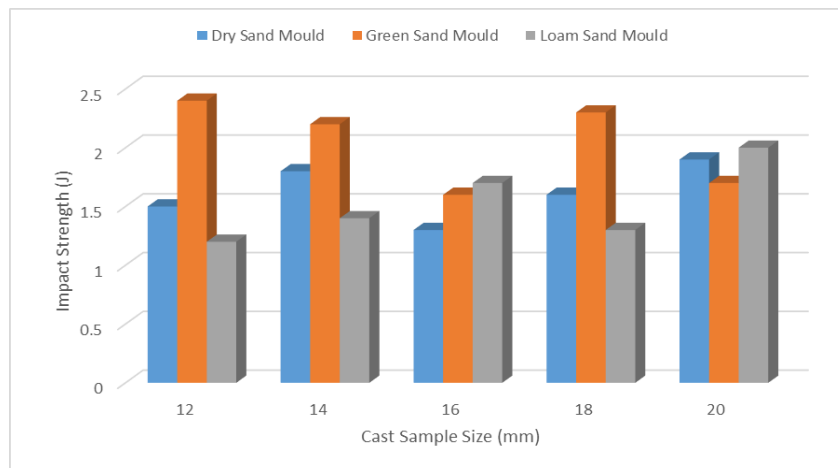


Figure 2. Profile of impact toughness of cast sample-size of A142 aluminium alloy produced in dry, green and loam sand mould

3.3 Hardness

Figure 3 indicated the effect of moulding techniques and section thickness on the hardness of A142 aluminium alloy produced. The result clearly shows that the hardness properties of A142 alloy castings slightly increased as the section thicknesses increased from 12mm to 20mm diameter. A142 aluminium alloys produced in dry sand mould have the highest hardness followed by those produced in green sand and loam sand have the least hardness. This may be due to the fact that, when liquid metal was poured into the dry mould and allow to solidify, the walls were able to extract heat faster, which resulted too many nuclei of crystals to form and grow fast, resulting to fine grain structure. This fine grain structure was responsible for the higher hardness. These observations are in line with what [29, 30] established.

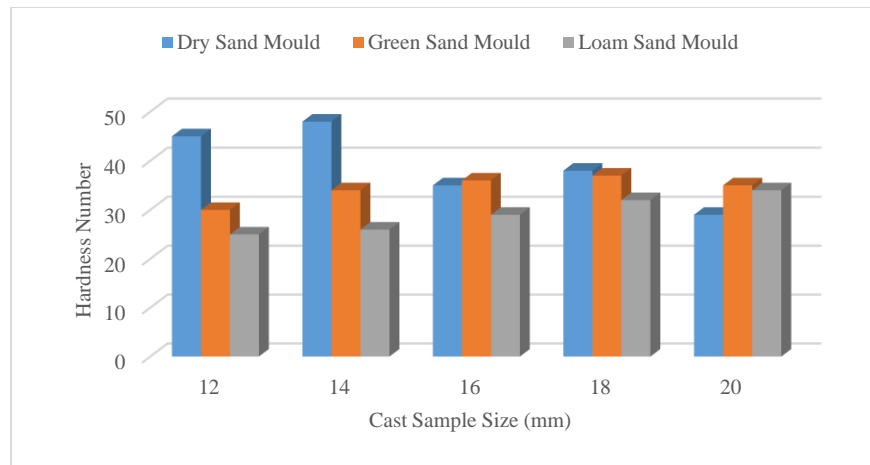


Figure 3. Profile of hardness of cast sample-size of A142 aluminum alloy produced in green, dry, and loam sand mould

4 CONCLUSIONS

Based on the results obtained from this investigation, it was found that the rate of cooling of the sample with variation of section thickness is quite different. However, both the tensile and impact strength properties of A142 aluminium casting produced by green, dry and loam sand mould decreased as the section thickness of cast samples increased. The hardness properties of A142 aluminium alloys produced slightly increased as the size of the cast samples increased. The dry mould casting has higher tensile strength while loam mould cast has higher hardness and green sand mould cast has higher impact strength, with due consideration of cast sample-size produced. The overall result showed that the moulding techniques and section thickness had influence on the mechanical properties of the cast metal.

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