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THE INFLUENCE AND MOULDING TECHNIQUES FOR DIFFERENT SECTION, THICKNESS AND MECHANICAL PROPERTIES OF THE AS-CAST A142 ALUMINIUM ALLOY

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Abstract

An investigation on the effect of different moulding techniques, section thickness and mechanical properties of as-cast A142 Aluminium alloy was carried out. The A142 Aluminium alloy was produced using green,

Keywords:
tensile strength, impact toughness and hardness number

INTRODUCTION

Metal casting forms integral components of devices that perform useful functions for human beings. 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 (Rundman, 2007). This process in its fundamental form requires a mould cavity of the desired shape and molten metal to pour into the mould human beings have been producing casting for thousands of years, most often pouring molten metal in the moulds

dry and loam sand mould castings at the foundry shop of department of metallurgical and material 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. The tensile strengths, hardness values and impact test of the various cast samples were determined. It was found that both tensile and impact strength properties decreases 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.

made of sand (Rundman, 2007).

For over fifty years, Aluminum has been a tonnage metal, second only to suet as a major factor in the metal industry. The growth has been based on the characteristics such as light weight, non-rusting properties, reasonably good strength and ductility, easy fabrication, modem metallurgical control of structure and properties, and favorable electronics (Henkel et al, 2002). Aluminium alloys are the largest proportion of non-ferrous alloys used in the production of automobile components, building and construction containers and packaging, marine, aviation, aerospace and electrical industries (Yaro, et al). They are highly reflective to radian energy, visible light, heat and electromagnet waves apart from possessing excellent machinability and good reserve to scratching (Yaro et al, 2006).

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 (Richard Carl and Philip 1962). 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 (Richard et at 1962). Since about 1915, a combination of circumstances-gradually decreasing cost, the expansion of air transportation, development of specific casting alloys improved properties. And the impetus provided by the two world wars has resulted in an ever-increasing use of aluminum casting (Richard et at 1962).

Aluminum is one of the few metals that can be cast by all the processes use in casting. These processes in decreasing order of amount of aluminium casting are: die casting, permanent mould casting, sand casting (green and dry sand), plaster casting, investment casting and continuous casting (Rundman,2007)

However, sand casting is the most versatile method for casting aluminum albys providing the greatest latitude for size, shape and alloy cast, (Madugu Abdulwahab 2007; Ekey 1968).

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. Consequently, excellent surface finish and dimensional accuracy may be obtaining even in large sand castings. 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 to 6in and 6in respectively (Richard et al 1962).

Aluminum alloys may be cast in dry sand mould, green sand mould and k›am-sand mould. However, the cooling rate of these sand moulding processes in relation to the variation in section thickness and the sand moulding techniques is quite different and thus influences the structures and properties of the castings. Due to the high application of Aluminum based alloys (e.g 92.5%Al, 4°%Cu, 2%Ni and 1.5%Mg) in aerospace industries and other light industries application, the need to develop a sand casting with optimum mechanical properties is very essential.

METHODOLOGY

Materials

Pure Aluminum scrap used for this investigation was obtained from NOCACO Nigeria limited, Kaduna, with 99.9% purity. While the magnesium and Nickel were obtained from chemical laboratory in Zaria, Kaduna state. The ligand (50%Al-50%Cu) used was obtained from NMDC Jos. Cylindrical steel pipes of various diameters (12-20mm) obtained from Zaria main markets were used as patterns. The composition of the Aluminum produced is given in the table below.

Table 3.1: Composition of as-cast (A142) Aluminium alloy

Element	% Composition
Cu	4%
Ni	2%
Mg	1.5%
Al	92.5%

Apparatus and Equipment.

The following apparatus and equipment were used for the investigation; 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, Polishing machine etc.

Methods

In the present investigation, various casting of A142 Aluminum alloy samples was produced using different moulding techniques and varying section thickness. The microstructure analysis of all the samples was done and mechanical properties test were carried out to assess the following.
The effect of various sand moulding practices (loam-sand, green-sand, and dry- sand) on the microstructure and properties of A142 alloys produced.
The effect of section thickness, based on each of sand-mould method, on the microstructure and properties characteristics of A142 alloy.

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 diameters and 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.

Charge Composition Calculation

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

Volume of mould:

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

$\text{volume of cylinder} = \pi r^2 h$ − − − − − − − − − − − − − − − −1

Where: $\pi = 3.142$

$\text{D} = 20\text{mm} = 2\text{cm}, \text{r} = 1\text{cm}$

$\text{h} = 300\text{mm} = 30\text{cm}$

$\text{volume} = 3.142 \times 1 \times 1 \times 30$

$= 94.26 cm^3$

Which is also the volume of the mould.

Density of Aluminium alloy

The density of Aluminium ($2.7 g/cm^3$) 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:

$\text{Density} = \text{mass/volume}$

$\text{Mass} = \text{density} \times \text{volume}$

$= 2.7 \times 94.26$

$= 254.502\text{g}$

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:

Total weight of metal required = 254.502g

Weight of copper $=\left(\frac{4}{100} \times 254.502\right) = 10.18g/bar$

Weight of Nickel$=\left(\frac{2}{100} \times 254.502\right) = 5.09g/bar$

Weight of Magnesium$=\left(\frac{1.5}{100} \times 254.502\right) = 3.82g/bar$

Weight of Aluminium$= 254.502 - 3.82 - 5.09 - 10.18$

$= 235.41g/bar$

Melting and Casting

The melting of the alloy was carried out in a charcoal fired crucible furnace. Aluminum scraps was into smaller sizes for the convenience in weighting and ease of charging into the crucible. The 92.5%Al, 4%Cu, 2o Ni and 1.5%Mg was measured totaled approximately 1.2Kg capacity and then charged into 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 of heat.

Sample Preparation

The cast samples were machined at the mechanical engineering workshop ABU, Zaria. The sample for tensile, impact and hardness tests were cut and machined to standard shapes and dimension as specified by the ASTM standard.

MECHANICAL PROPERTY TESTING

Determination of Tensile Strength

The tensile strength of the machined specimens was determined using tensile test machine. The test sample were machined to the ASTM standard with original diameter of 12.5mm and gauge length of 17mm (Khanna, 2002). The test was carried out by marking the specimen gauge length with prick punch marks and measuring the cross sectional area of the reduced part. The specimens were then locked securely in the grips of the upper and lower cross beams of the testing machine. A small load was initially applied to seat the specimen in the grips and then the load was increased until failure occurred. Then the load and elongation at failure were read and recorded.

Hardness Value Determination

The values for the hardness were determine using the Rockwell hardness tester on B,F,C scale with 5mm ball indenter and 101.2HRB was used as the standard block. The marking surface of the indented, plunger rod and test sample were thoroughly cleaned by removing dirt, scratches oil and calibration of the testing machine was done using the standard block.
The samples were placed on anvils, which act as a support for the test samples. A minor load of 10Kg was first applied to the sample in a controlled manner without inducing impact or vibration to seat the specimen and zero datum position was established, and then the major load 100Kg was then applied. The reading was taken when the large pointer came to rest or had slowed appreciably and allowed for up to two seconds. The Road was then removed by returning the crank handle to the latched position and the hardness value was read directly from the semi-automatic digital scale. Three reading were taken for each sample with the average value taken as the hardness value for a sample.

Impact Strength Determination

Impact test were conducted using Avery Denison testing machine with impact energies ranging from 0 to 300g The mass of the hammer was 22Kg and the striking velocity 3.5m/sec. Charpy impact test was conducted on notched specimens. Before the test specimen was mounted on the machine, the pendulum was released to zero the scale. The test specimen was supported as a beam in a horizontal position in a vice and loaded behind the V-notch by the impact of a freely heavy swinging pendulum. The value of the angle through which the pendulum swing before the test specimen was broken corresponded with the value of the energy absorbed in breaking the sample and this was read from the calibrated scale on the machine.

RESULTS AND DISCUSSION

Results

The experimental results of A142 aluminium alloys produced using green-sand, dry-sand and loam-Sand moulding techniques are contained in this section.

The results of the mechanical properties against the cast section thickness are presented as showed in figures 4. 1 to 4. 12.

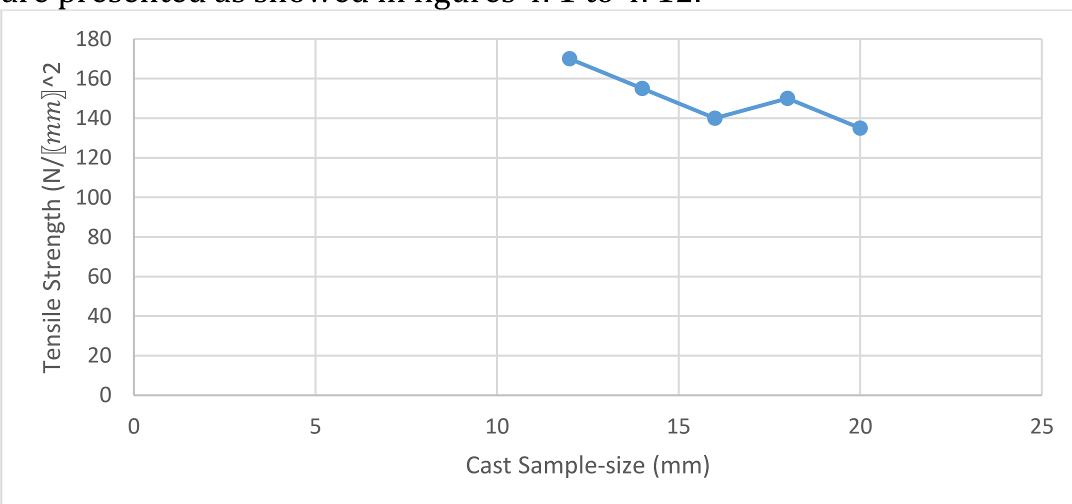

Figure 4.1 Variation of tensile strength with cast sample-size of A142 aluminium alloy produced in dry sand mould.

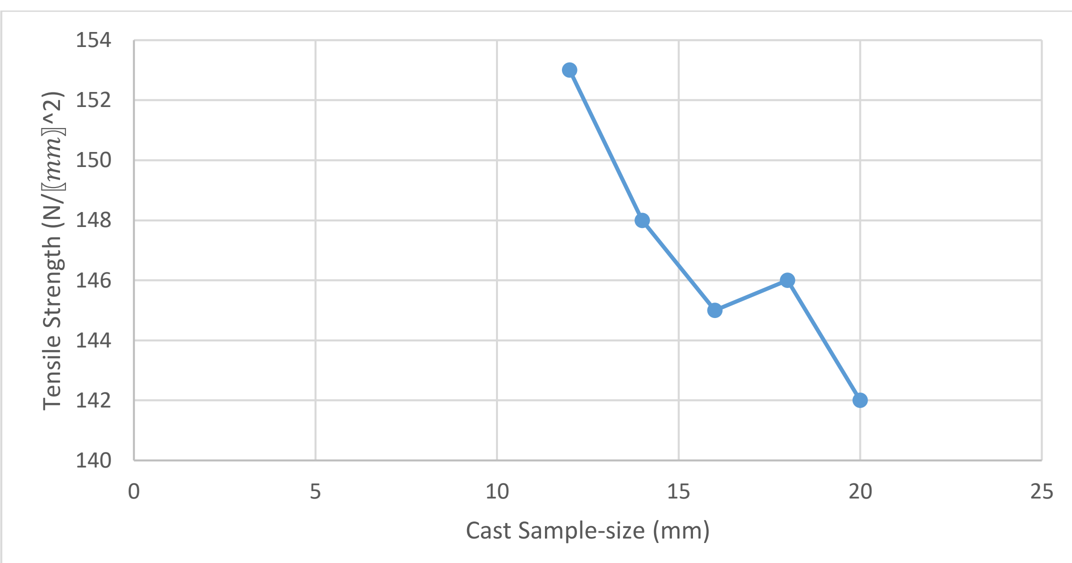

Figure 4.2 Variation of tensile strength with cast sample-size of A142 aluminium alloy produced in green sand mould.

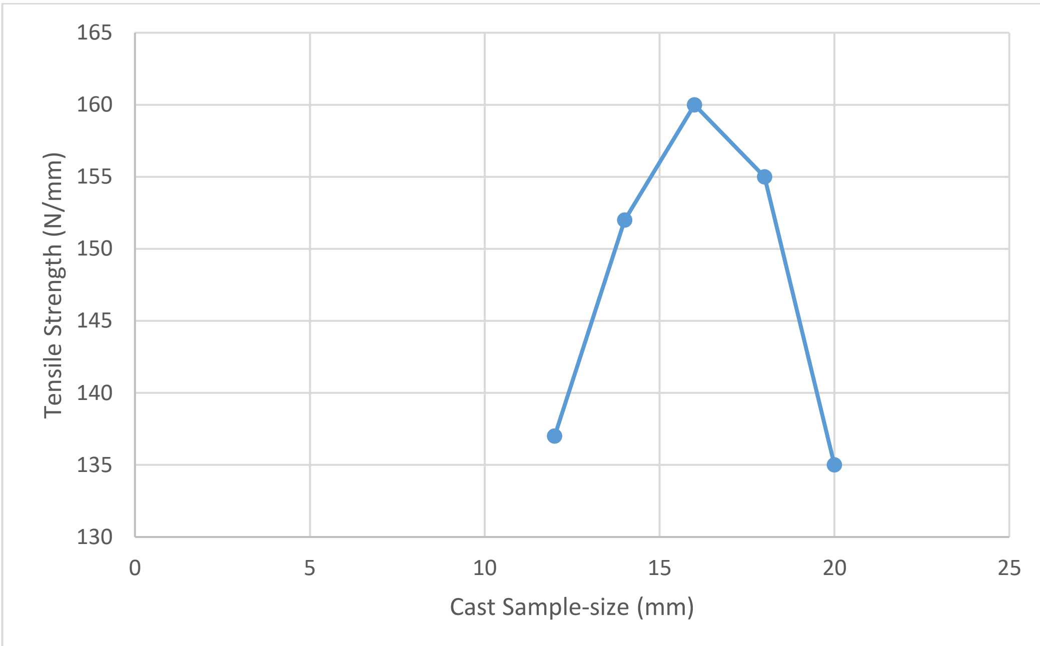

Figure 4.3 Variation of tensile strength with cast sample-size of A142 aluminium alloy produced in loam sand mould.

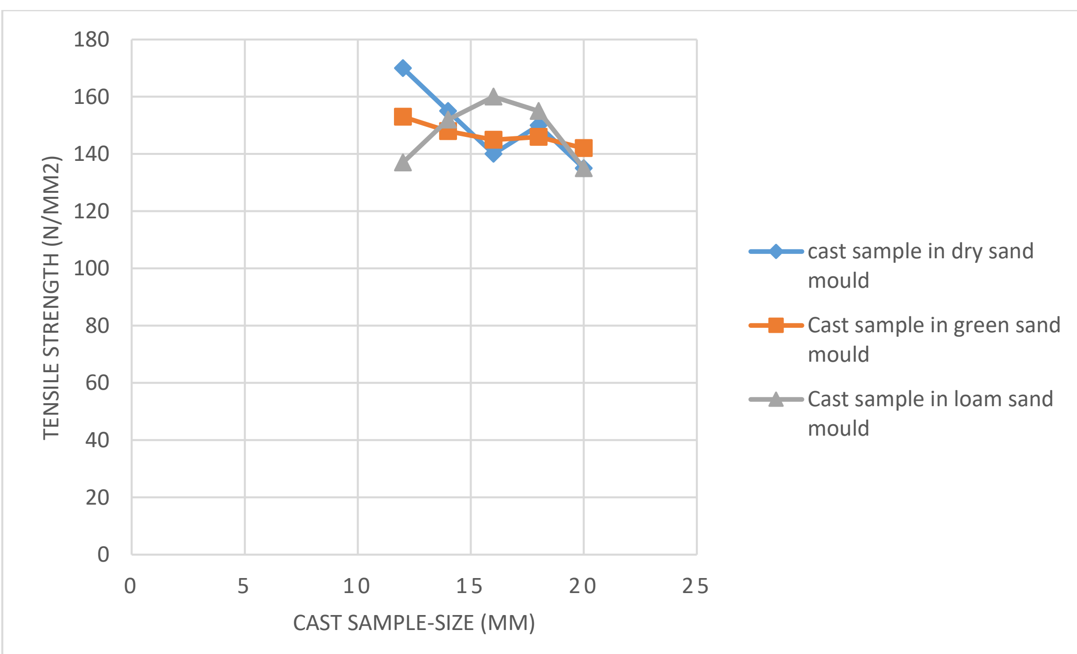

Figure 4.4 Variation of tensile strength with cast sample-size of A142 aluminium alloy produced in dry, green and loam sand mould.

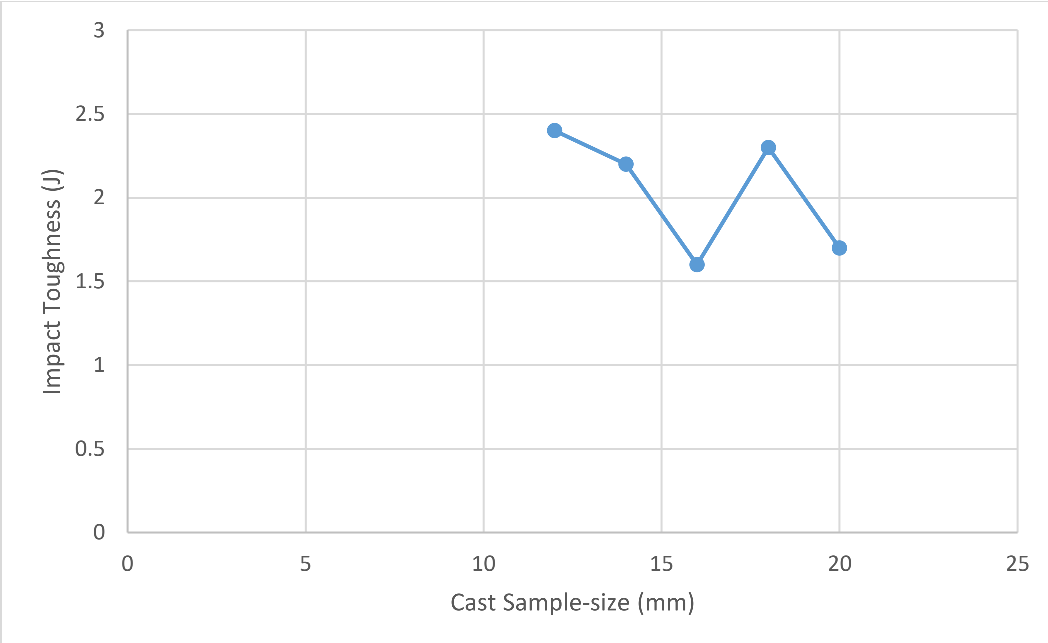

Figure 4.5 Variation of impact toughness with cast sample-size of A142 aluminium alloy produced in green sand mould.

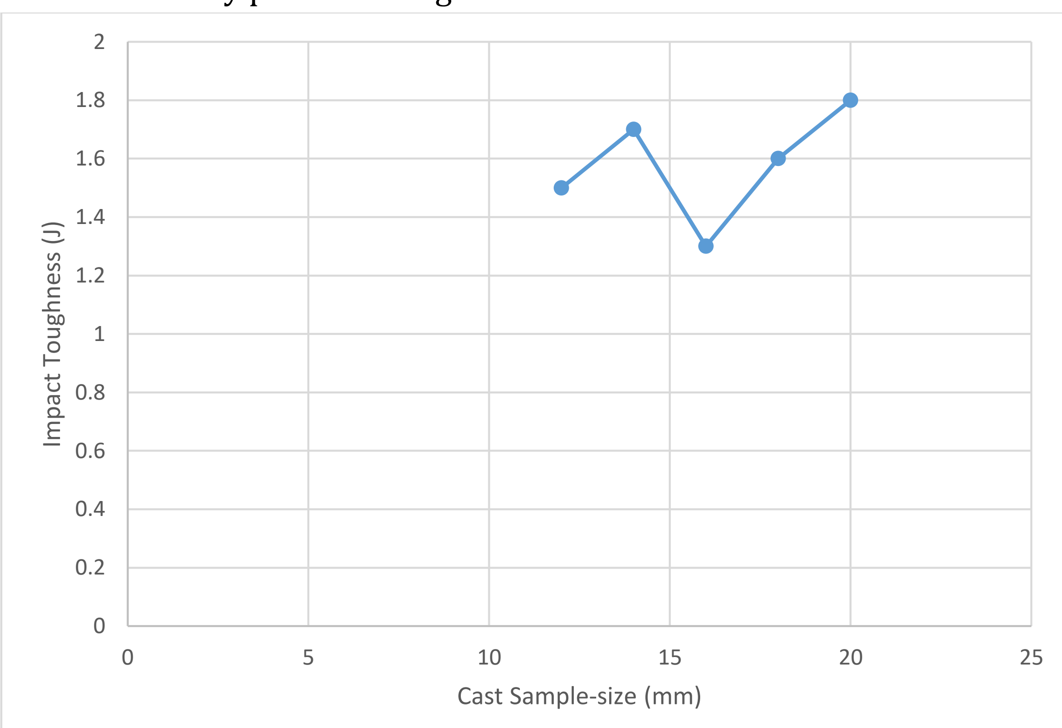

Figure 4.6 Variation of impact toughness with cast sample-size of A142 aluminium alloy produced in dry sand mould.

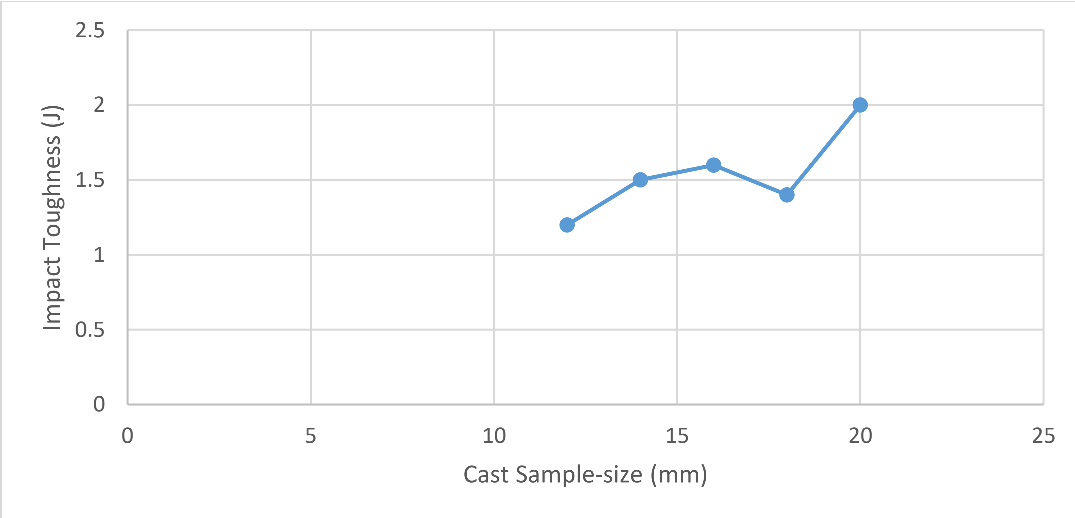

Figure 4.7 Variation of impact toughnesswith cast sample-size of A142 aluminium alloy produced in loam sand mould.

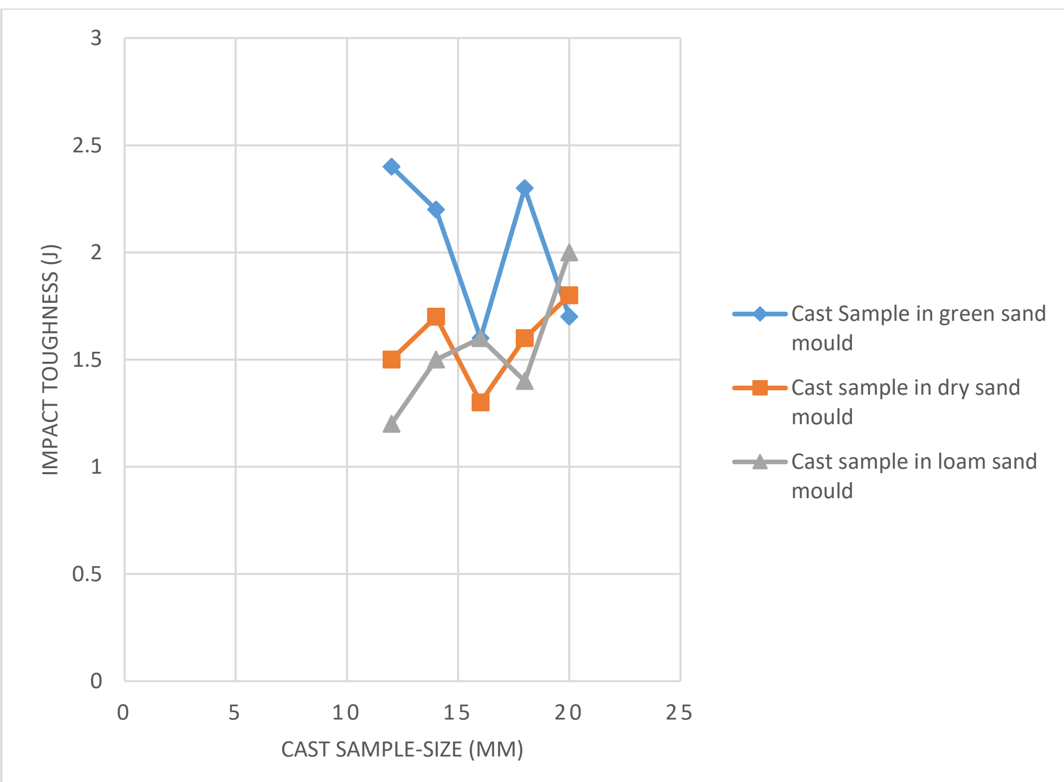

Figure 4.8 Variation of impact toughness with cast sample-size of A142 aluminium alloy produced in dry, green and loam sand mould.

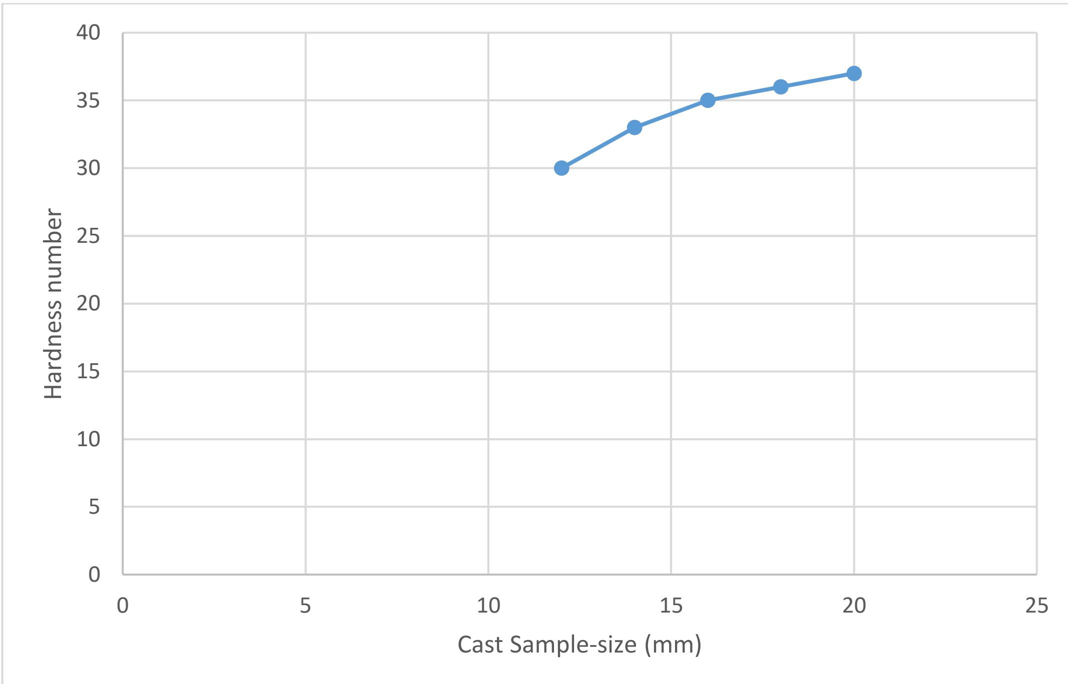

Figure 4.9 Variation of hardness with cast sample-size of A142 aluminium alloy produced in dry sand mould.

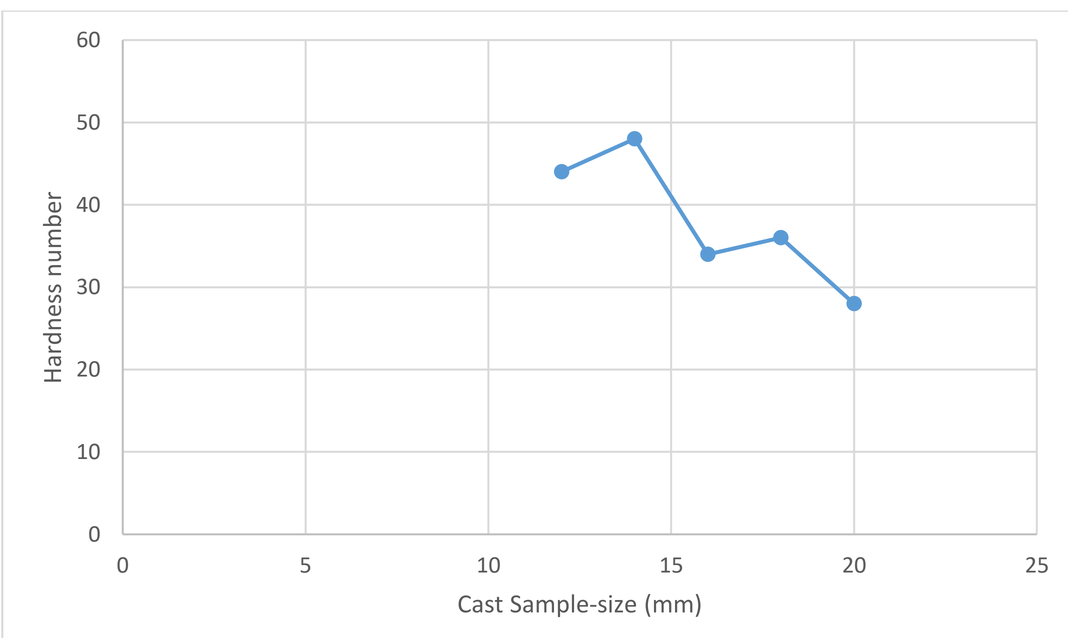

Figure 4.10 Variation of hardness with cast sample-size of A142 aluminium alloy produced in loam sand mould.

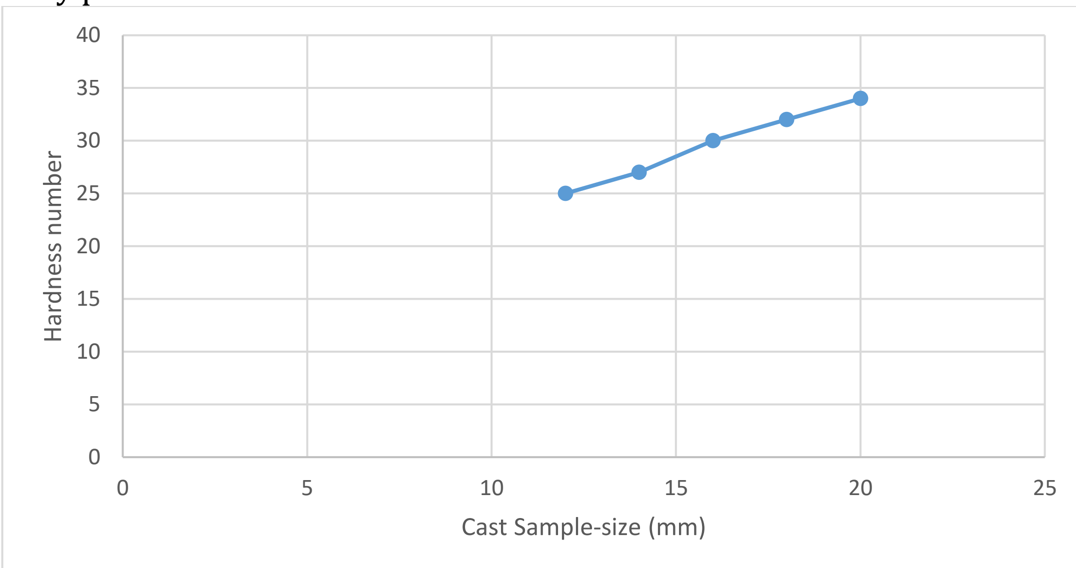

Figure 4.11 Variation of hardness with cast sample-size of A142 aluminium alloy produced in green sand mould.

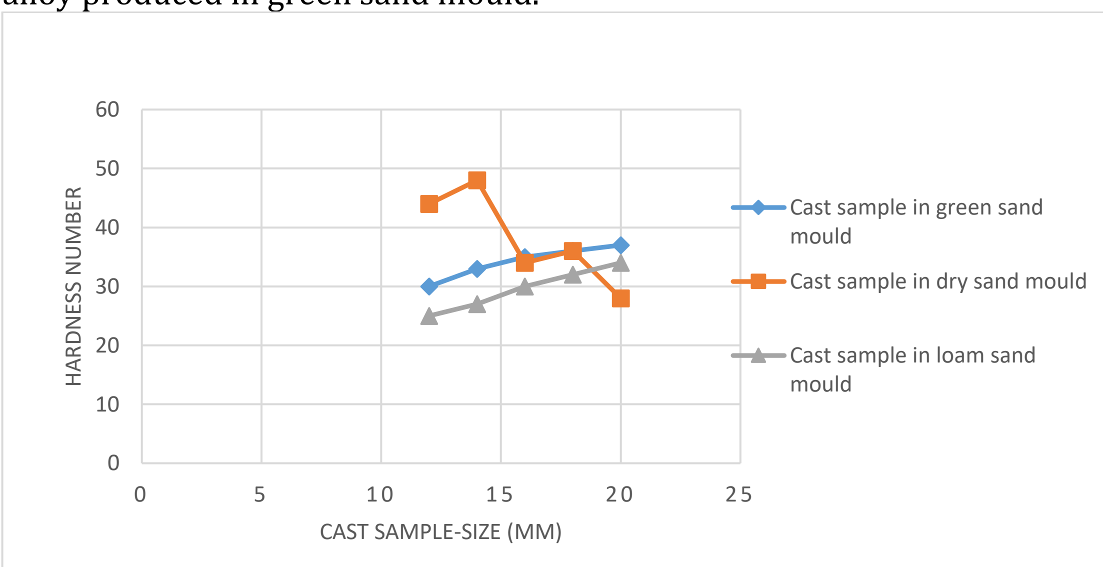

Figure 4.12 Variation of hardness with cast sample-size of A142 aluminium alloy produced in green, dry, and loam sand mould.

DISCUSSION

Considering the utmost utility of material testing to engineers concerned with the design of structures in order to ensure their reliability in service, mechanical properties of material are widely used to provide basic design information and an acceptance test for the specification of materials (Dieter, 1988). Therefore, the understanding of the properties of material is highly essential (khanna, 2002).

From the results of the mechanical property tests carried out on the casts produced, it can be shown that types of mould and samples section thicknesses have marked effects on the properties of the A142 aluminium alloy.The detail is discussed below;

Effect of Moulding Techniques and Section Thickness on Tensile and Impact Properties of A142 Aluminium Alloy

Figures 4.1 to 4.4 and Figures 4.5 to 4.8 showed the tensile and impact strengths of A142 aluminium alloy casting produced in different moulds and at varying section thicknesses. It was found that both tensile and impact strength properties decreased as the section size increased. A142 alloys produced in dry sand mould have the highest tensile strength followed by the samples produced in loam sand while those produced in green sand moulds have least tensile strength.

From figure 4.8, it can be seen that the samples of A142 aluminium alloys produced from green sand mould have the highest impact strength followed by the samples from loam and the dry sand mould have the least impact strength.

Effect of Moulding Techniques and Sectionthicknes on the Hardness of A142 Aluminium Alloy

Figure 4.9 to4.12 shows the results of hardness testsofA142aluminium alloy produced at varying sample-size in green sand, dry sand and loam sand moulds. The result showed that the hardness properties of A142 alloy castingshtly increased as the section thicknesses increased from 12mm - 20mm diameter. A142 aluminium alloys produced in loam sand have the highesthardness followed by those produced in dry sand and green sand have the least hardness. This may be due to the fact that, when liquid metal was poured into the loam mould and allowed to solidify, the loam sand mould walls were able to extract heat faster which resulted to many nuclei of crystals to form and grow fast resulting in the fine grain structure. This fine grain structure was responsible for the higher hardness.

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, the following conclusions can also be drawn;

1. 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.
2. The hardness properties of A142 aluminium alloys produced slightly increased as the size of the cast samples increased.
3. 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.
4. 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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