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*Research Paper*

# COMPARISON OF THE MECHANICAL PROPERTIES OF SAND AND GRAVITY DIE CAST ALUMINIUM SCRAPS

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This report covers the "Comparison of the Mechanical Properties of Sand and Gravity Die Cast Aluminium Scraps". Two different categories of scraps of aluminium piston and aluminium pots were sourced locally, melted and cast using Sand and Gravity Die casting methods. The cast specimen were machined to standard testing dimensions. The tensile test was carried out using universal testing machine while Rockwell hardness B scale testing machine (HRB) was used for the hardness test. The results show that the ultimate tensile strength of the specimens from aluminium piston was 191.19 N/mm$^2$ and 163.59 N/mm$^2$ for die and sand cast specimen with percentage elongation of 10.15% and 9.82% respectively. This was compared with specimen from aluminium pot scraps with ultimate tensile strength of 172 N/mm$^2$ and 161 N/mm$^2$ for die and sand cast specimens respectively. The hardness test results show that specimens from aluminium piston were harder than the specimen from the aluminium pot with 52 and 51.0 HRB compared with 26.7 and 23.2 HRB for die and sand casting specimens respectively. The specimens from permanent mould were discovered to have a better surface finish and mechanical properties with closely packed grain size. However solidification in the permanent mould casting or gravity die – casting is done under gravity giving rise to less porosity and as such increase the tensile strength and hardness values more than what is obtained in the sand mould casting.

***Keywords:*** Gravity, Hardness, Casting, Tensile Strength, Aluminium

## INTRODUCTION

Aluminium has been one of the major materials used in modern engineering. Hence, the knowledge of aluminium and its alloys, together with its properties cannot be over emphasized. The properties especially mechanical properties of the material provide a solid basis for predicting its behavior under various service conditions.

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The mechanical properties of any material describe the response of the material under applied load/force. These properties may or may not depend on the microstructure of the material. In the selection of materials for engineering applications, the properties of the material are highly considered. Therefore, this important light, non-ferrous metal of Face-Centered Cubic (FCC) structure has been alloyed with one or more element. The purpose of this alloying element is simply to modify or increase some of the properties of aluminium.

Most non-ferrous metallic products like aluminium alloy are commonly used for aircraft components, kitchen utensils, and beverages containers, and in the automobile industries because of their cherished advantages, including light weight, heavy load carrying capacity and resistance to corrosion. Although, the energy required to produce aluminium is higher than that of steel, it is estimated that a car produce from recycled aluminium scraps needs a life span of just 9,500 km to break even, but from primary aluminium, a life span of 60,000 to 120,000 km is required to break even. This is because of less fuel consumption, attributable to light-weight (Drossel *et al*., 1996, cited in Funken *et al.,* 2001).

Aluminium components if discarded when it is out of use, create environmental pollution and even pose danger to the user of the environment. If the deposition is allowed to continue, it would result into environmental hazard. It is from this environmental point of view that recycling of aluminium scraps became very popular. Apart from the environmental benefits, the cost and energy saving incentives associated with secondary manufacturing, especially aluminium (10-20 MJ/kg secondary instead of 186MJ/kg primary as per energy consumption), has attracted many component manufacturers to engage the use of secondary materials (Gaustad *et al*., 2012 and the references therein). Aluminium recycling has attracted many researchers and industries because in recycling the scraps, the ores are conserved (Gronostajski *et al*., 2000), moreover, recycling yield can be high (over 90%) without loss of quality as reported by Constellium (2013). No wander, it is presently rated as the "most recycled" among materials (The Aluminium Association, 2015). This research is focusing on recasting and examining the actual properties of the recycled scraps, for the purpose of comparing with standards to see the suitability of the secondary product, and further recommend it to aluminium component manufacturing industries. Since there is also a high demand for the reduction of imported goods to reduce foreign exchange, discovery of suitable aluminium recycling process will improve our locally produced goods with improved casting methods, and be another means of job creation for the masses.

## MATERIALS AND METHODS

### Equipment and Materials

Trowels, rammers, ventiore, swab, drawspixe, smoohtener and slecker, brush, straight, measuring tapes, jack plane, hand saw, silical sand ($SiO_2$), scraps of aluminium pots, scraps of aluminium pistons, mould, wooden pattern.

The equipment and instruments used for tensile test were: Universal tensile testing machine, micrometer, vernier calliper, dividers, Gauge mark, jig, standard sandcast aluminium alloy specimen, while Rockwell hardness testing machine was used for hardness.

## Methods

In carrying out this work, the following methods were adopted: Collection of aluminium scraps, preparing moulds for the casting, cleaning aluminium scrap and melting in a furnace, machining to standard test dimensions, carrying out the various property tests, collation and analysing of data from the tests results.

## Aluminium Scraps

Aluminium scraps are the already used pure aluminium products ranging from cooking utensils, automobile – parts, electric cables, spray can, etc. For the purpose of this work, light cooking Aluminium pots and aluminium pistons which are very common in our environments were utilized. Aluminium scraps generally melt at temperature of 660$^{o}$C.

## Casting Process

Two different casting methods were employed in this research, these are Sand casting and Gravity die casting. The following processes were involved in sand casting: pattern moulding, moulding process, melting, pouring, cooling and fettling.

The first step in Die casting (permanent mould) is the fabrication of a permanent mould (Die). A metal of 0.5 mm thickness was fabricated into a hollow die of 30 mm diameter and 50 mm long. It was then cleaned with sand paper, the die was inserted into the sand (acting as a support) while the molten aluminium scraps was poured under gravity to fill the mould which formed the shape of the die cavity after solidification. Die casting in the commercial sectors are basically of non-ferrous metal and their alloys including alloys of copper, magnesium, zinc, and aluminium, having low melting point and are not aggressive to dies made from metals (Mikharlov, 1989).

The rapidly solidified surface is usually harder than the interior and is usually sound and suitable for plating or decorative application. The basic principle of die casting was employed and this is for the die which contain cavity of the required shape to be filled with molten metal the die in two parts but has a moveable piece of cores. Gravity die casting was employed here where the molten metal was introduced into the die by gravitational force to ensure that the die cavity is completely filled in the same manner as for sand casting.

## Tensile Test Procedure

A test piece machined according to universal testing machine standard size for tensile test was used. A piece having a gauge length of 50 mm, 12.5 mm diameter, and gripping provision of 30 mm diameter was machine from the two different recast aluminium scraps pieces from the two different casting methods. Each of the test piece was gripped in the jaws of the universal testing machine and subjected to a tensile force which was traced on the attachment graph paper. Loading continued until fracture of the test piece occurred. The maximum force applied to the test piece before fracture was read from the digital display unit and recorded accordingly. The broken test piece was removed from the universal testing machine and the diameter of the neck was measured. In addition, the two parts were placed together and final length over the original gauge length was measured.

**Figure 1: Specimen for Tensile Test (before test)**

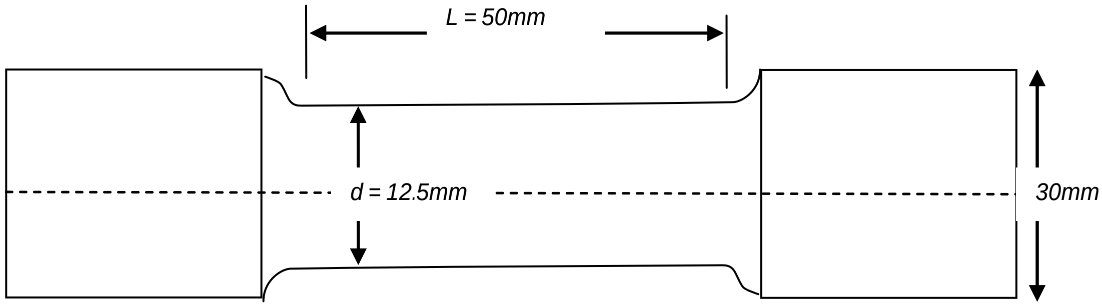



**Figure 2: Shape of the Specimen After Elongation**

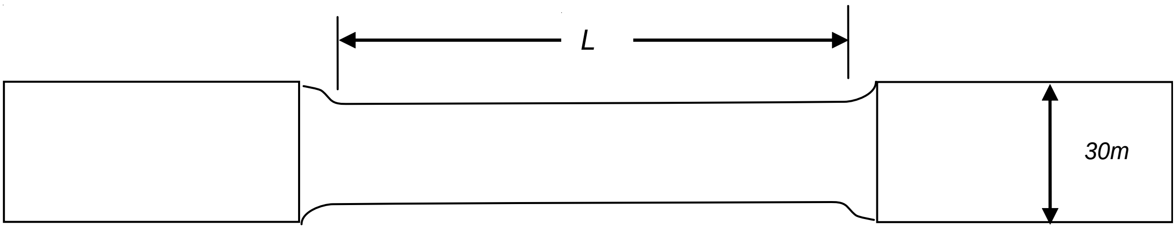
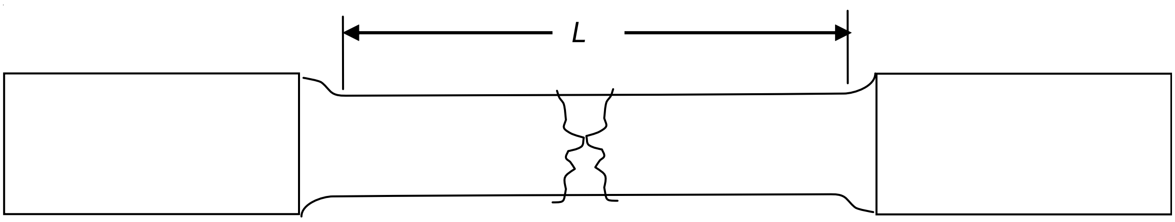



**Figure 3: Shape of the Specimen After Fracture**




## Hardness Test Procedure

Hardness is an indication of the way in which the surface of a material deforms under specific types of localised loading. The extent of materials' hardness are demonstrated by several indices, factored by the materials' loading conditions. In metals, hardness is usually expressed by the resistance to indentation. Hardness may also be estimated by resistance to cutting, crushing, wear, etc.

The hardness test was carried out using Rockwell tester. Each of the specimens (test pieces) was positioned on the machine test bed, and it surface first preloaded to 9.81 N (10 kgf) by a special ball, called the indenter, to clear off the "slack". The dial gauge was tuned to zero after which continuous significant loading was applied until a steady reading was noted on the gauge. This reading which is an equivalence of the depth of penetration is read off as the hardness rating of the material from which the specimen is made. Scale B which is one of the most popular among the nine scales available in hardness testing (Rao, 1998) was used in this work.

## RESULTS

The tests results here include; tensile test and hardness test of a sand and die-cast aluminium alloy samples. The test results are shown in Table 1 to 4.

### Tensile Test Results

Tables 1 and 2 below summarize the results obtained for the two samples. The ultimate tensile strength, yield strength, elongation and reduction in cross-sectional area results are given in Tables 1 and 2 respectively.

### Hardness Test Results

In testing for the hardness properties of the samples, Rockwell hardness testing machine was used, and the Table 3 and 4 below summarizes the results obtained.

**Table 1: Tensile Test Results of Aluminium Piston Scraps**

| Sample | Yield Stress (YS) ($N/mm^2$) | Ultimate Tensile Stress (UTS)($N/mm^2$) | %Elongation | % Reduction in Area |
|---|---|---|---|---|
| Die – cast | 138.05 | 191.19 | 10.15 | 17.8 |
| Sand – cast | 112.50 | 163.59 | 9.82 | 16.3 |

**Table 2: Tensile Test Result of Aluminium pot Scraps**

| Sample | Yield Stress (YS) ($N/mm^2$) | Ultimate Tensile Stress (UTS)($N/mm^2$) | %Elongation | % Reduction in Area |
|---|---|---|---|---|
| Die - cast | 125.15 | 172 | 10.4 | 18.3 |
| Sand - cast | 101.6 | 161 | 8.0 | 15.4 |

**Table 3: Hardness Test of Aluminium Piston Scraps**

| Sample | 1st Test | 2nd Test | 3rd Test | Average |
|---|---|---|---|---|
| Die - cast | 55.0 | 50.5 | 57.0 | 52.0 |
| Sand - cast | 50.0 | 53.5 | 49.5 | 51.0 |

**Table 4: Hardness Test Result of Aluminium Pot Scraps**

| Sample | 1st Test | 2nd Test | 3rd Test | Average |
|---|---|---|---|---|
| Die - cast | 26.5 | 27.0 | 26.5 | 26.7 |
| Sand - cast | 23.5 | 23.0 | 23.0 | 23.2 |

## DISCUSSION OF RESULTS

The tensile strength and the hardness value of the samples from the investigation are 191.19 N/mm$^2$, 163.59 N/mm$^2$ and 52, 51.0 respectively for both die – casting and sand – casting process as against 200 N/mm$^2$ and 179 N/mm$^2$ for tensile strength and 70 from the standard average value obtained for die and sand casting method (Rao, 1998). Table 1 reveals that the percentage elongation and percentage reduction in area are 10.15 and 17.8 for die cast aluminium piston scraps and 9.82 and 16.3 for sand cast aluminium piston, the differences in values and deviations could be as a result of variation in pouring speed, which greatly affect the solidification time of the casting. This invariably determines the arrangement of crystals which in turn affects the mechanical properties. Also it could be attributed to level of accuracy in design of the gating and rising which determine directional solidification towards the riser. The design may permits hot tears and internal shrinkage porosity to occur (Rakita and Han, 2009), affecting the mechanical properties. It could also be in the area of designing of sections. If the sections did not allow contraction or expansion and reduce the solidification rate, it can equally affects the mechanical properties. Another reason could be as a result of micro – porosity and blowholes defects which might have occur as a result of dissolve gases during the melting and pouring processes.

From Table 2 the YS, UTS, % elongation and % reduction in area are 125.15, 172, 10.4 and 18.3 respectively when compared with sand cast which has 101.6, 161, 8.0 and 15.4. It was discovered that the ultimate tensile strength and the hardness values increased in the order of sand casting and permanent mould casting. This may be due to difference in the rate of solidification of the molten metal in different moulding materials. In the sand – casting method, the slow solidification rate is due to the insulating properties of the sand mould results in coarse structure which reduced the tensile strength and hardness values. On the other hand, in the permanent mould and pressure die – casting methods, rapid solidification rate due to the conducting properties of the metallic mould leads to the formation of fine crystal, and ultimately bring about higher tensile strength and hardness values. Moreover, solidification in the permanent mould casting or gravity die – casting is done under gravity giving rise to less porosity and as such increase the tensile strength and hardness values more than what is obtained in the sand mould casting. These mean that, even though aluminium may retains its quality upon recycling as claimed by Constellium (2013), its properties it still influenced by the casting process. It is noteworthy that the yield strength and the percentage elongation of these recycled materials, from both casting methods fall within the acceptable values for most of the aluminium alloys, according to ASTM: B209 "14 Standard Specification forAluminum and Aluminum-Alloy Sheet and Plate.

## CONCLUSION

The comparative analysis of the mechanical properties of aluminium scraps using sand and permanent mould casting has been carried out. It was discovered that samples from permanent mould casting had better mechanical properties value than sand cast samples. The reasons could be as a result of those factors such as pouring speed, cooling and solidification rate, crystal arrangement, gating and rising design which affect proper directional solidification, etc. The coarse nature of the specimens from sand casting could also be as a result of slow rate of solidification from sand mould which in turn affects the mechanical properties.

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