The Effects of Reinforcing Sand Mould with Coconut Pod Ashes on Mechanical and Microstructural Properties of Aluminium Alloy

Adeyemi G. J., Stephen J. T. and Adebayo A.
Department of Mechanical Engineering
Ekiti State University
Ado-Ekiti, Nigeria.
*gbenga.adeyemi@eksu.edu.ng

***Abstract*—The introduction of additives technology to foundry works in the past decade has in time account for improved quality as well as better control measure in obtaining a desirable casting as the additives in sand mould plays an important role to ensure a better casting. This work presents the effect of adding coconut pod ashes to sand mould on the mechanical properties of aluminium alloy. It shows the merits and demerits of the utilizing coconut pod ashes as the additive in sand mould during casting to improve the mechanical properties of cast aluminium alloy. The tensile strength and hardness decreases, whereas the ductility increases, as the concentration of the additive in the sand mould increases. Tensile strength of 157.0 MPa, 150.4 MPa and 139.0 MPa were recorded for the cast aluminium alloy from the mould without additive, mould with 4% additive and mould with 8% additive, respectively. Whereas, the percentage elongation of 5.7%, 8.5% and 9.4% were recorded for the cast alloy from the moulds, respectively. Furthermore, microstructural analysis showed increase in grain size as the concentration of additive in sand mould increased during casting which was due to decrease in cooling rate that prolonged the time required for formation and solidification of the molten cast alloy. Hence, this work has shown that the inclusion of coconut husk ash to sand mould resulting in the improved ductility of values of low-cost aluminium.**

Keywords— Aluminium, coconut pod ash, tensile strength, hardness, metallography

I. Introduction

The discovery of iron in about 1300 BC has in time contributed greatly to the economic development of mankind through foundry and metallurgical practices [1]. Foundry technology is one of the oldest ways of producing engineering and mechanism components, thus it is referred to as the mother of all industries.

Foundry is a manufacturing process by which metallic products are formed by preparation of mould, melting the required metal, pouring it into a prepared mould cavity and allowing the molten metal to solidify in order to obtain a predetermined casting as product. In this process the molten metal takes the shape of the cavity. The cast is then cleaned and machined to required dimension. Every product which is consumable for both commercial and domestic use in this universe goes through either one or some series of manufacturing processes in which metal casting stands at the core of other manufacturing processes [2, 3]. Metal casting is a manufacturing process that has been used over the centuries to provide mankind with a means to turn various shapes of metals into useful parts and mechanisms.

Additives are composites added to either sand mould during mould preparation or added to the ingot during melting process to provide improved component properties. Additives are added to the moulding components to improve the surface finish, dry strength, refractoriness and cushioning properties of the cast material. Furthermore, the use of additives prolongs the solidification rate of molten metal in mould cavity, this actually give room for proper molecular and grain arrangements in its microstructure. Up to 5% of reducing agents such as coal powder, pitch, creosote and fuel oil or 3% of cushioning materials like wood flour, saw dust, powdered husks and straw as well as 2% of either binder (dextrin, starch, sulphite lye etc.) or iron oxide powdered maybe added to the moulding material to prevent wetting, prevent mould cracking, decrease metal penetration, and burn-on defects [4]. These additives were able to accomplish these by producing gases at the surfaces of the mould cavity which prevent the molten metal from adhering to mould sand.

II. Literature Review

Additives play a very important role in bringing desirable changes to the properties of sand mould and quality of cast produced. Additives are mixed with sand during mould preparation to obtain certain characteristics in the moulding sand according to specific requirement of molten metal. Fly ash, coal dust, coconut shell iron fillings, wood flour, sea coal, starch, husk etc. have been used as additives in sand mould in limited quantity to enhance green strength, dry strength, high temperature plasticity, metal penetration property, surface finish etc. [5-9].

Bhagyashree et al., studied the effect of additives on compression strength, shear strength, permeability number properties of green sand moulding. The selected input parameters were water and additive powders (Tamarind, Coconut shell and Fly ash). The study revealed that these parameters have significant effect on the sand properties with the quality loss associated with the tamarind powder was lesser compared to other additives selected for the study. Comparison among fly ash, coconut shell powder and tamarind powder showed that tamarind powder which gives highest sand strength [10]. Also, the study conducted by Tataram et al. shows that Fly ash shows the good permeability number for moulding sand whereas coconut shell powder has the higher compression strength [11].

Effects of addition of iron (Fe) filings to green moulding sand on the microstructure of grey cast iron was studied by Adeleke [12]. Five sand samples with iron content varying from 1 wt% to 5 wt% and a control sample were prepared, and used to cast grey cast iron samples. It was concluded that could be added to green moulding sand to improve its thermal storage capacity without any negative effects on the vital properties of green moulding sand.

The properties of cast aluminium alloys are influenced by alloying elements present in them and manufacturing techniques. Casting of aluminium alloys, as a production process, can be carried out through different process [13, 14]. Aniyi et al. described the evaluation of mechanical properties and residual stress of squeeze cast aluminium using longitudinal slitting technique. It was found that higher residual stresses normally occurred more often in the cast aluminium product. He concluded that the use of squeeze casting process lowers the residual stress and improve the mechanical properties of aluminium [15]. Adeyemi and Adeyemo studied the effect of sand preheat temperature and shake-out times on the tensile, impact and hardness properties of cast aluminium alloy [16]. In the experiments, preheat temperature were varies with a view to control the mechanical properties of cast specimen of aluminium alloy where it was concluded that increase in mould preheat temperature and shakeout times leads to increase in impact energy and percentage elongation at fracture as well as decrease in tensile strength and hardness of the specimen which are function of accumulated heat in the mould thereby decreasing the thermal gradient and the cooling rate.

The effect of mixing additives with sand during mould preparation on mechanical properties of 6351 aluminium alloy investigated by Sanjeev et al. [17]. In their investigation, experiments were performed to investigate the effect of additives (tamarind powder, starch powder and coal dust) addition to green mould on the mechanical properties during the casting process of aluminium alloys. It was concluded that the addition of additives to sand during casting enhanced the hardness of aluminium alloy. Starch powder affects the hardness of aluminium alloy to a great extent as compared to other additives. Also, the addition of additives to sand mould decreases the tensile tension of the aluminium alloy. Only the starch having a percentage of 1% in sand mould gives the highest value of tensile tension according to the test reports.

Kingsley et al. [18] investigated the effect of mixture bentonite clay, moisture content and dextrin organic additive in different proportions with local silica sand on mechanical properties of aluminium 6351. Green moulding sand mixtures which contain water (3% - 5%) bentonite clay (10% - 12%) and dextrin organic additive (7% - 9%) were produced and the results showed that the green sand mixture contents had effects on the properties of the cast produced. Mixture with 5% water content, 12% bentonite and 8.85% dextrin organic additive gave the most effective hardness whereas mixture with 3% water, 12% bentonite clay and 9% dextrin additive gave most toughness.

Despite several research works, few scholars worked on the utilization of waste organic materials like coconut pod husk and scraps in generating a commercial and industrial balanced product which can in time boost the recycling sector in maintaining a balance ecology and as well generate products capable of handling industrial purposes. Therefore, the aim of this study is to investigate the effect of coconut pod ashes mixed with sand mould on the mechanical and microstructural properties of aluminium alloy.

III. Materials and Method

A. *Materials*

Dried 23kg coconut pod husk was source from Ijebu Jesa, Osun State, Nigeria. Coconut pods husk which are agricultural waste from coconut were collected and sun-dried for 12 days to ensure all pods are completely dried for ease burning.

After sun drying, these coconut pods were burnt down to ashes in a cleaned dry metallic container (Figure 1(a)) to obtain a complete ash as shown in Figure 1(b). The ashes obtained were sheaved so as to get rid of the solid or unburnt particles of the pod. The aluminium scrap used are the scraps from aluminium frame used for making modern glass window. These scraps weight 10.6 kg were collected from the aluminium works technician.

(a)

(b)

Figure 1: (a) Coconut pods husk and (b) the burnt Coconut pods husk.

B. Pattern Selection

Figure 2 shows the specification of the pattern selected for the casting sample. The specimens obtained from the pattern was later machined to UTM specification test samples. The pattern was designed taking consideration that the production of identical and exact specification casting using hand moulding is impossible. Nevertheless, the selected pattern would give proper reference to suitable machining allowance such that the minimum machining tolerance will be maintained on the cast test sample.

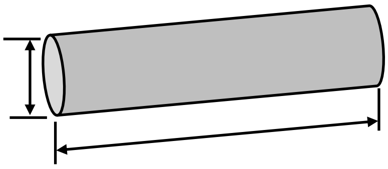


Figure 2: Pattern specification

C. Mould Preparation and Casting of Specimen

The moulding preparation and settings were carried out at The Federal Polytechnics Ado-Ekiti. The sand used contain 75% loamy sand, 11% clay, 6% bentonite and 8% of coconut pod ashes (additive). Three moulds were prepared for the experimentation; one of the moulds consist of 83% moulding loamy sand without any coconut pod ashes as additive, and the other moulds consist of additive composite of higher concentration (8% of coconut pod ashes) and lower concentration (4% of coconut pod ashes) respectively. The drag spare of the moulding set was placed on the moulding board, then it is filled with sand as required by each labelled mould with the pattern was placed horizontally in the moulding box set.

D. Casting of Specimen

The aluminium alloy scrap was melted in a crucible of 8 kg capacity, fired in a pit furnace with charging temperature ranging from 690oC to 810oC until a complete molten aluminium alloy is achieved. The molten alloy inside the crucible was then poured into the three already prepared different moulds of identical cavity but peculiar sand-additive compositions. Upon introduction of the molten metal into the moulds, temperatures of the specimens inside the mould were taken at an interval of 50s, 100s, 150s, 250s, and 450s respectively to evaluate the cooling rate using a digital thermometer as shown in Figure 3. The sand mould was dismantled (shaken-out) after 25 minutes after pouring the molten metal into the cavity. The obtained solidified cast aluminium alloy specimens were then cleaned.

The solidified cast metals were allowed to cool down to room temperature before they were taken out of the mould (shaken-out) and then labelled as Sample A (the control sample. i.e., cast aluminium alloy from mould with no additive added), Sample B (cast aluminium alloy containing from mould with low additive concentration) while Sample C was the cast aluminium alloy from mould with high additive concentration.

Figure 3: Measuring the cooling rate of molten Al alloy

IV. MECHANICAL TESTING AND MICROSTRUCTURE EXAMINATION

A. Tensile Test

The cast aluminium rods were machined on lathe machine to form standard tensile test specimens (Figure 4) as required by the UTS specification set through the manufacturing process. The tensile test was conducted on the specimens according to according to ASTM E-8 standard.

The tensile test of specimen commenced by applying an equal load with a fixed increasing value of 0.5 kN. For the loads, readings were taking from extensometer as well as the positive displacement indicator in relation to the corresponding applied load value. This procedure was repeated until the specimen reaches the peak load and fractured.

Figure 4: Machined tensile test specimen

B. *The Brinell Hardness Testing*

The hardness test was conducted according to ASTM E10-14 standard. Test specimens (cast from non-additive, low concentrated and high concentrated additive) were produced for the hardness test. Each specimen was cut to a size 3 cm x 3 cm surface area and 2 cm length. The test surface was filed, stage grinded and polished. During the test, a hardened steel ball indenter was forced into the test specimen polished surface for a dwell period of 15 seconds using Mosanto Testing Machine setup. The indented diameter was measured by eye scope. The conversion table was used to determine the Brinell or hardness number of the material. For each specimen, an average value of three readings taken from different position on its surface was use to evaluate the hardness.

C. *Microstructural Examination*

The primary stage of this examination involves the sample preparation processes. The samples were cut to 3 cm x 3cm surface dimensions and then gradually grinded to produce a flat and smooth surface using grinding machine with emery cloth in reducing coarseness. Thereafter, a universal polishing machine with polishing cloth (selvt cloth) initial swamped with alcohol solution and then followed by silicon carbide paste of 1µm and 0.5µm, progressively, until was employed to polish the specimens until mirror-finish appearance was obtained. The samples were then washed in alcohol solution and dried.

Etching was carried out on each polished samples to reveal its microstructural surface. The mirror-like surface was etched in concentrated Keller reagent, washed, dried for 10 seconds. The samples were then viewed under the metallurgical microscope and recorded at 600 magnifications.

V. RESULTS AND DISCUSSION

A. *Cooling Rate Analysis*

The cooling data of the cast aluminium alloy from each moulding box (casting) containing the cast sample A, sample B and sample C as obtained from the thermocouple at various time interval during the solidification process are shown in the Table I. It can be noted from the table that the solidification time of the casting decreases with increase in the quantity of coconut pod ashes added.

TABLE I: THE COOLING DATA FROM THERMOCOUPLE

Time (s)	Temperature (^oC) Moulding sample A	Moulding sample B	Moulding sample C
0	750	748	753
50	630	642	692
100	549	571	644
150	461	490	582
250	337	352	460
450	203	210	308

At the end of 450 seconds after pouring, the temperature decreased by 445oC, 538oC and 547oC from initial temperature for cast from mould sample A, mould sample B and mould sample C, respectively. This indicates that heat retention of the mould increased with addition of coconut pod ashes in the cast mould.

Furthermore, the cooling rate was calculated from the cooling data as follows [19]:

$$\text{Cooling rate } (^oC/s) = \frac{\Delta T}{\Delta t} \quad (1)$$

where ∆T (oC) is change in temperature between two consecutive temperature points during the cast solidification and ∆t (s) is the time difference between the two points. The cooling rate curve of the solidification of the cast samples is as shown in Figure 5.

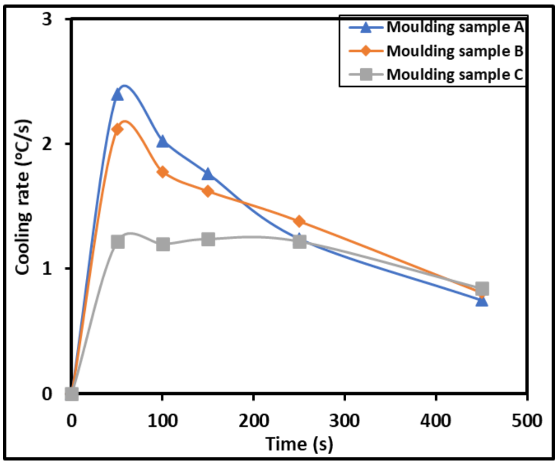


Figure 5: Cooling rate of cast alloy from moulding sand with different additive concentration

The cooling rate curve shows the effects of different concentration of coconut pod ash additive in the mould sand on the cooling of the cast metal. It could be observed that at the early stage of the solidification, the cast from the mould with on addictive cool highest whereas the cast from mould with high concentration of addictive has the least cooling rate. This can be attributed to the additive which practically block the air expose vacancies in the sand grain structure and, thus, prolonged the time required for heat transfer from the molten metal to the sand creating more time formation and solidification of the molten cast alloy.

At the later stage of the solidification of the cast (450oC), small difference in the cooling rate was observed as a result of different concentration of the additive. This shows that the additive effect on cooling rate reduces as the system tends towards temperature equilibrium due reduction in temperate gradient between the cast and the mould.

B. Tensile Strength Result Analysis

The stress-strain curves of the tensile test carried out on the specimens on the universal testing machine (UTM) were plotted on a shown in Figure 6. From the curves, the specimen from the mould with higher concentration displayed higher strain value per point on the graph when compared to samples from the mould with low concentration and control sample respectively.

Furthermore, it can be observed from Figure 6 that strengths of the cast samples are similar at small strain (≤ 0.03 mm) and independent of mould material used. However, significant differences in behaviour occurred beyond the 0.03 mm strain till the peak tensile strength is reached. This is in agreement with the observation from Wasiu et al. that at a small strain the strength of cast 6063 aluminium alloy does not depend on mould materials [20].

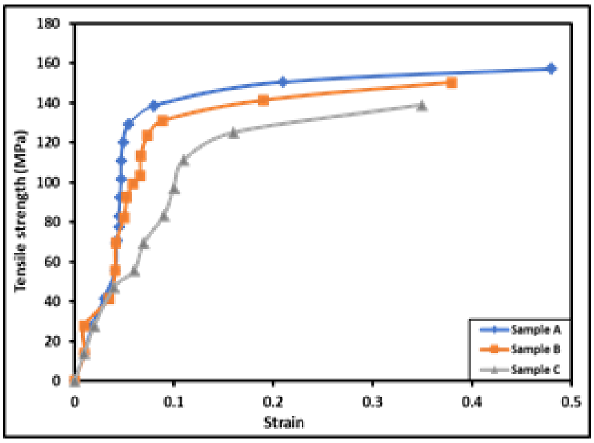


Figure 6: Stress-strain curves for cast samples from mould with different concentration of coconut ash additive

At a strain of 0.03 mm and above, the sample specimen exhibited different behaviour under equal stress. The tensile strength decreased with increase in coconut pod ashes additive content in the mould. As shown in Table II and Figure 7, ultimate tensile strength of 157.0 MPa, 150.3 MPa and 139.0 MPa were recorded for the cast aluminium alloy from the control mould (sample A), mould with 4% additive and mould with 8% additive, respectively. This behaviour was due to the difference in cooling rate and grain composition of the specimen which is influenced by the variation of the additive content used. The higher content of the additive the slower the cooling during the cast process of the alloy.

The recorded results of the percentage elongation (%) for the corresponding sample are shown Table II and Figure 8. The observed difference in the percentage elongation of the test samples, which is also an indication of the ductility of the cast material, increases with increase in additive content in the mould with 5.7%, 8.5% and 9.4% elongation factor for sample A, B, and C respectively, and this can also be attributed to heat accumulation and decrease in cooling rate of the cast material as influenced by the coconut ashes additives.

TABLE II: RESULTS OF MECHANICAL TESTS ON CAST SAMPLES FROM MOULD WITH DIFFERENT CONCENTRATION OF COCONUT ASH ADDITIVE

Test Sample	Ultimate Tensile Strength, σ_U (MPa)	Percentage Elongation (%)	Hardness (BHN)
A	157.0	5.7	62.7
B	150.3	8.5	52.8
C	139.0	9.4	53.2

Increase in cooling time due to fine grain size of coconut ash blocking the air expose vacancies in the sand grain structure and thus reduces the thermal permeability of the mould as additive content in the mould increases led to the reduction in tensile strength and increase in percentage elongation of the cast aluminium alloy. It has been observed that the time taken for the solidification of a cast alloy depends on the chemistry of the alloy and mould [4, 20]. The lower the cooling rate of cast aluminium alloy, the more the time for solidification and the coarser is its grains, hence lower the tensile strength and better the ductility of cast alloy [21-24].

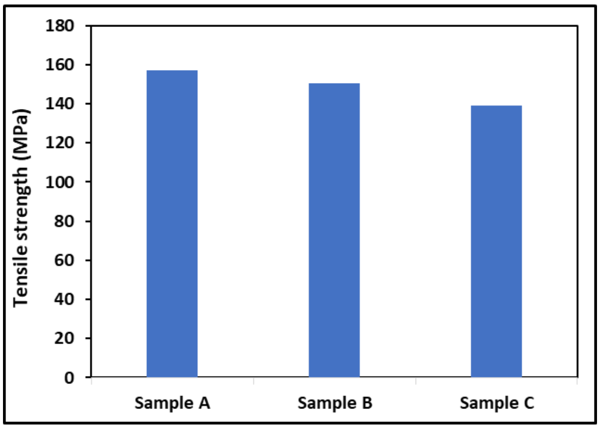


Figure 7: Tensile strength of the samples from moulds with different concentration of coconut ash additive

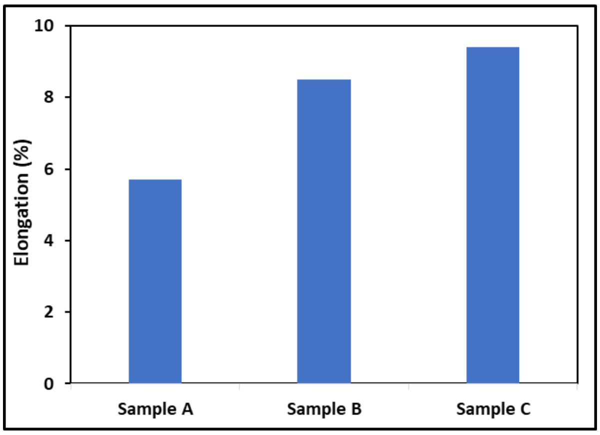
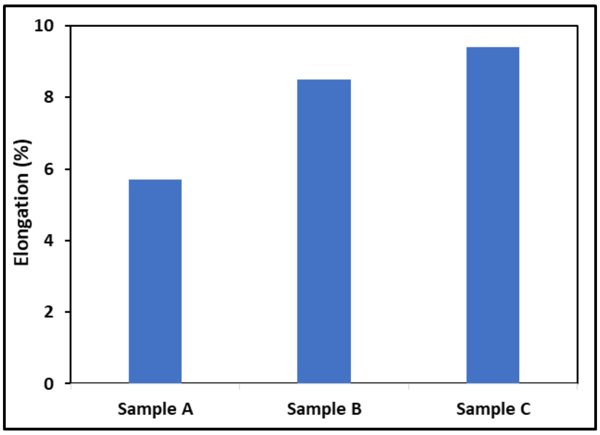


Figure 8: Percentage elongation of the samples from moulds with different concentration of coconut ash additive

C. The Brinell Hardness Results

The effect of adding coconut pod ashes to sand mould on the Brinell hardness property of cast aluminium alloy samples is depicted in Figure 9. It can be observed in the figure that the mould Sample C with high additive content possess the highest hardness value of 62.7 BHN which is also attributed to the cooling gradient of the cast sample compared to sample A which has 53.2 BHN. Coconut pod ashes addition to the sand mould decreased the air expose openings grain and thus prolonged the time required for heat transfer through the mould. Addition of finer grain size additive to sand mould, and reduction in rate of chilling and precipitation of the molten cast alloy lower the value of hardness of aluminium alloy as reported in previous works on cast aluminium alloys



[17, 20, 23].

Figure 9: Hardness of samples from moulds with different concentration of coconut ash additive

D. Microstructural Analysis

Microstructural examination of the cast alloy reveals the effect of concentration of coconut pod ashes additive to sand mould during casting on the microstructure properties of the aluminium alloy. The microstructure properties of aluminium alloy as observed from the metallographic image obtained from the Scanning Electron Microscope (SEM) at 600x magnification is shown in Figure 10.

In the Figure 10, sample A is an optical micrograph of the control sample which has no additive content during its mould preparation. The optical micrograph shows a finer grain size and narrow (needle-like) grain boundaries. Whereas sample B, as viewed under scanning electron microscope (SEM), shows the cast specimen with low mould additive composition display a scattered grain boundary. Sample C is an optical micrograph obtained of cast from mould with high concentration of additive content, the micrograph obtained shows a bigger grain size as well as more grain boundaries than the other two samples.

Comparing the microstructural images as obtained in Figure 10, reveals a slightly assembled crystals of □-aluminium and Mg2Si (eutectic phase) in the aluminium matrix with few inter-boundary vacancies but mean crystal size and shape of these crystals in the matrix for each specimen as shown are totally different.

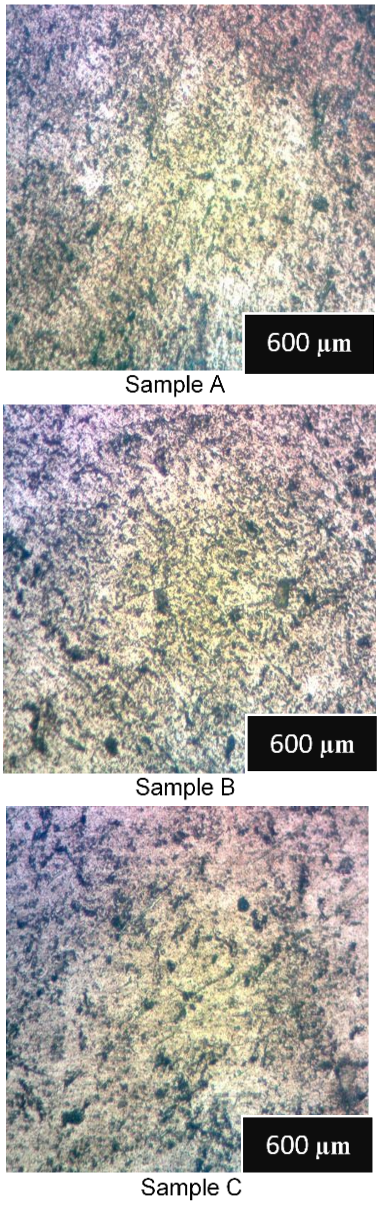


Figure 10: Optical micrograph of the cast aluminium alloy under SEM, plane perpendicular to the cylindrical samples' axes.

It can be observed that the closely pack grain size in sample A led to narrow grain boundaries which is a function of the relative fast cooling. This hindered dislocations movement and thus responsible for the superior tensile strength and hardness values [25].

However, comparing micrograph obtained for sample C with the most dispersed grain structure was obtained due to low thermal conductivity of the molten aluminium alloy to mould as heat transfer between the specimen and the mould occurred instantaneously. The dispersed Mg2Si grains in the matrix offered less tendency to obstruction movement of dislocations, and this mechanism accounts for the observed low tensile and hardness properties but better ductility. These results from the research show that change in microstructure of the aluminium alloys depends on the cooling rate and precipitation condition, and also the employed the heat treatment [19, 22].

VI. CONCLUSIONS

The mechanical and microstructural properties of cast aluminium alloy produced through the addition of coconut husk ash are additives to the sand mould were investigated. The results showed that the higher the concentration of the additive, the higher the inter-grain properties and lower are the tensile strength and hardness properties, but better is the ductility in general. The presence of the coconut shell ash particles in the mould produced bigger grain size in the matrix of the cast alloy. The mechanical properties of cast aluminium alloy can be improved for different applications by varying the casting method through the utilization waste agricultural product as additives in the sand mould thereby achieving different solidification rates which an improved metallurgical property for domestic and industrial application.

REFERENCES

[1] John, V., Introduction to engineering materials. 1992: Macmillan International Higher Education.

[2] Davis, J.R., Corrosion of aluminum and aluminum alloys. 1999, Ohio: Asm International.

[3] Beeley, P., Foundry technology. 2001: Elsevier.

[4] Jain, P., Principles of foundry technology. 2003: Tata McGraw-Hill Education.

[5] Aribo, S., Effect of varying corn cob and rice husk ashes on properties of moulding sand. Journal of Minerals & Materials Characterisation & Engineering, 2011. 10(15): p. 1449-1455.

[6] Ayoola, W., S. Adeosun, and A. Oyetunji, Investigation into foundry properties of Oshogbo and saki silica sand deposites. 2013.

[7] Ananthapadmanabham, K., B. Dharsan, and R. Somashekar. Effect of additives on silica sand mould for Aluminium casting. in Proc. of Int. Conf. on Current Trends in Engg., Science and Technology. 2017.

[8] Seidu, S.O. and B.J. Kutelu, Effects of additives on some selected properties of base sand. Journal of Minerals and Materials characterization and Engineering, 2014. 2(05): p. 507.

[9] Salihu, S.A., A. Usman, and I. Suleiman, Effect of variation of different additives on some selected properties of silica sand mould for aluminium castings. Journal of Engineering and Technology Research, 2020. 12(1): p. 24-36.

[10] Desai, B., P. Mokashi, R. Anand, S. Burli, and S. Khandal. Effect of Additives on Green Sand Molding Properties using Design of Experiments and Taguchi's Quality Loss Function-An Experimental Study. In IOP Conference Series: Materials Science and Engineering. 2016: IOP Publishing.

[11] Chavan, T.K. and H. Nanjundaswamy, Effect of variation of different additives on green sand mould properties for olivine sand. Int. J. Res. Eng. Adv. Technol, 2013. 1(4): p. 2320-8791.

[12] Adedayo, A.V., Effects of addition of iron (Fe) filings to green moulding sand on the microstructure of grey cast iron. Journal of the Brazilian Society of Mechanical Sciences and Engineering, 2010. 32(2): p. 171-175.

[13] Jorstad, J. and D. Apelian, Hypereutectic Al-Si alloys: practical casting considerations. International Journal of Metalcasting, 2009. 3(3): p. 13-36.

[14] Karabay, S., M. Yilmaz, and M. Zeren, Investigation of extrusion ratio effect on mechanical behaviour of extruded alloy AA-6101 from the billets homogenised-rapid quenched and as-cast conditions. Journal of Materials Processing Technology, 2005. 160(2): p. 138-147.

[15] Aniyi, J., F. Bello-Ochende, and M. Adeyemi, Effects of pressure, die, and stress-relief temperatures on the residual stresses and mechanical properties of squeeze-cast aluminum rods. Journal of materials engineering and performance, 1996. 5(3): p. 399-404.

[16] Adeyemi, G.J. and S.B. Adeyemo, The effect of sand preheat temperature and shake-out times on the tensile, impact and hardness properties of cast aluminum alloy. The Research Journal of Applied Sciences, 2008. 3(3): p. 382-391.

[17] Kumar, S., S. Gandotra, S. Kumar, and H. Tripathi. Investigate the effect of additives on mechanical properties during casting of 6351 Aluminium. In MATEC Web of Conferences. 2016: EDP Sciences.

[18] Ikebudu, K.O., S.K. Onyegirim, and P.I. Udeorah, Effect of green sand mixture with dextrin additives on mechanical properties of aluminum 6351. Global Journal of Engineering and Technology Advances, 2021. 6(2): p. 131-141.

[19] Yildirim, M. and D. Ozyurek, The effects of mould materials on microstructure and mechanical properties of cast A356 alloy. 2014.

[20] Ayoola, W.A., S.O. Adeosun, O.S. Sanni, and A. Oyetunji, Effect of casting mould on mechanical properties of 6063 aluminium alloy. 2012.

[21] Abed, E.J., Study of solidification and mechanical properties of Al-Sn casting alloys. Asian Transaction on engineering, 2012. 2(3): p. 89-98.

[22] Stephen, J.T., A. Adebayo, and G.J. Adeyemi, Influence of Solidification Rates and Stress-Relief Annealing on the Mechanical Properties of Cast 6063 Aluminium Alloy. European Journal of Engineering and Technology Research, 2018. 3(5): p. 71-76.

[23] Ajibola, A., D. Olayinka, and S. Olalekan, Production and microstructural analysis of as-cast and heat treated aluminimum alloy. Al-20% wt Mg) Advances in Applied Science Research, 2012. 3(4): p. 2196-2203.

[24] Isadare, A.D., B. Aremo, M.O. Adeoye, O.J. Olawale, and M.D. Shittu, Effect of heat treatment on some mechanical properties of 7075 aluminium alloy. Materials Research, 2013. 16(1): p. 190-194.

[25] Akhyar, H. and A. Farhan, Cooling Rate, Hardness and Microstructure of Aluminum Cast Alloys. Materials Science, 2018. 2(1): p. 1-6.