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ORIGINAL RESEARCH ARTICLE

EFFECT OF SHEA NUTSHELL ASH ON THE MECHANICAL PROPERTIES OF CAST Al6061

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ABSTRACT

Aluminium Matrix Composites (AMCs) has attracted much interest in aerospace, defence and automotive applications due to its high strength to weight ratio. However, the manufacturing technique, nature and combination of the matrix and reinforcements play a vital role in the success of AMCs. In this study, the mechanical properties of Aluminium metal matrix composites (AMMCs) reinforced with shea nutshell ash (SSA) was investigated. Different mix ratio constituting 0%, 5%, and 10% of SSA were used as reinforcement, with the matrix being Al6061 to compound different samples. The metal matrix composites were produced by stir casting technique. Mechanical properties such as Hardness, Tensile, Impact and Microstructure examination of the developed composites were evaluated. The results showed that with increasing % of SSA, the hardness, and impact energy of the composite increased for both 5 and 10%. However, with increasing SSA the tensile strength decreased slightly for both 5 and 10% SSA. The hardness and the impact energy increased by 166.74% and 76.38% respectively as the wt% of SSA varied from 0-10tw%. On the other hand, the tensile test showed a decrease from 115.67 N/mm^2 to 94.52 N/mm^2 as the % of SSA increase from 0-10%; which translates to 18.29% reduction in tensile strength. SSA however promises to be a good reinforcement material for hybrid aluminium matrix composites when the properties desired are hardness and impact energy

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1.0 Introduction

Current engineering applications require materials with higher strength, lesser weight, higher stiffness and higher toughness. Much interest has been shown, into research and development of materials that have good strength to weight ratio suitable for automobile applications, where fuel economy with improved engine performance is of paramount interest. Due to this rapid progress in scientific and technological development, new generation engineering materials are being developed to meet up with the required properties for such applications. In-service performances of these modern engineering systems have their workability rest on materials with broad spectrum of properties that are not obtainable in a monolithic system. On this backdrop, materials engineers and scientists have developed engineering materials with more attractive mechanical and tribological properties which supersede that of the base metal or alloy. To achieve the aforementioned feat, two materials with distinct physical and chemical properties are combined in a systematic manner to result into a material known as composite (Kaczmar et al., 2000; Tjong, 2014; Alaneme et al., 2013; Rahman and Al Rashed, 2013).
Aluminium hybrid composites are a set of new generation metal matrix composites (MMCs) known to have the potentials of meeting recent demands of advanced engineering applications. Such demands are mostly realised through improving the mechanical properties of the known materials. Amenability to conventional processing technique and possibility of reducing production cost has made aluminium hybrid composites, a better material giving rise to improved properties. The performance of such materials depends mostly on the selection and

the right combination of reinforcing materials; since some of the processing parameters are associated with the reinforcing particulates. If the appropriate combination of reinforcement and matrix material is chosen, manufacturers shall be able to produce properties that exactly fit the requirements of a structure for a particular purpose. In recent years, hybrid reinforced Aluminium matrix composites (AMCs) have attracted the interest of researchers and different design concepts have been considered and adopted in selecting the appropriate combination of reinforcing materials (Hossain et al., 2017; Alaneme et al., 2018).

Aluminium Hybrid Reinforcement Technology is a response to the dynamic ever-increasing service requirement of industries such as transportation, aerospace, automobile, and marine; this is largely due to its attractive properties which include high ductility, high conductivity, light weight, and high strength to weight ratio. When external loads are applied to the composites, the load is transmitted by the metal matrix to the reinforcements, which are carried by dispersed reinforcements bonded with the matrix. Strong interface bond between reinforcements and matrix is required to obtain high strength of composites (Alaneme et al., 2013; Niranjan et al., 2017; Pitchayyapillai et al., 2016).

Composites have become globally acceptable and widely used materials due to the ability to adapt to different conditions. More so, the relative ease of combination with other materials to produce exceptional properties to serve different purpose has earned it prominence; thereby giving it edge over known engineering materials. The development of low-cost Aluminium matrix composites reinforced with eco-friendly materials has also become one of the major innovations in materials engineering in order to check environmental pollution (Niranjan et al., 2017).

Alaneme et al. (2013) studied the behaviour of Al alloy when reinforced with rice husk ash (RHA) and alumina particles. They found that the introduction of these particles into the melt has decreased the density and hardness of the produced composites to an appreciable amount whereas the specific strength and the ultimate tensile strength have seen to be increasing with the increase of the reinforcements with the matrix.

Fatile et al. (2014) studied the micro structural and mechanical behaviour of Al-Mg-Si alloy matrix composites reinforced with silicon carbide (SiC) and corn cob ash (agro-waste) was investigated in their research. The research work was aimed at assessing the suitability of developing low cost- high performance Al-Mg-Si hybrid composite. Silicon carbide (SiC) particulates added with 0,1,2,3 and 4 wt% Corn cob ash (CCA) were utilized to prepare 10 wt% of the reinforcing phase with Al-Mg-Si alloy as matrix using two-step stir casting method. Micro structural characterization, density measurement, estimated percent porosity, tensile testing, and micro-hardness measurement was used to characterize the composites produced. From the results obtained, CCA has great potential to serve as a complementing reinforcement for the development of low cost and high-performance aluminium hybrid composites. The less dense Al-Mg-Si/CCA/SiC hybrid composites have estimated percent porosity levels as composite grade without GSA (maximum of 2.332% porosity). This indicated that the use of CCA did not arise in any significant rise in porosity level. Hardness, ultimate tensile strength, and percentage elongation of the hybrid composites decreased gradually in CCA content of the composites. However, the fracture toughness of the hybrid composites was observed to be superior to that of the composite sample without GSA. There is no significant difference between the percentage elongation of 1wt% CCA containing composite and the composite grade without CCA. This research however tends to develop an AMC, using sheanut shell ash (SSA) as reinforcement.

2.0 Materials and Method

2.1 Materials used

The materials used in this research work include shea nut shell which was obtained from the shea butter factory located in the Federal Polytechnic Bida, Niger State and Al 6061 procured from 5Star Technology Co., LTD, China and its chemical composition is presented in Table 1.

Table 1. Chemical Composition of Al 6061

Element	Mg	Si	Fe	Mn	Cu	Cr	Zn	Ni	T	Al
Composition (%)	0.93	0.53	0.21	0.14	0.17	0.09	0.08	0.01	0.01	Balance

2.2 Preparation of Shea Nutshell Ash (SSA)

The shell which is the desired material was obtained after the nut was removed/separated from the shea nut. After obtaining the shell, it was washed in order to remove the impurities and then sun dried for two days. The shell was milled into powder to obtain the fine particles. The powder portion was then used to obtain ash, adopting the method of Alaneme et al.(2018).

2.3 Casting of the Samples

The composite samples were produced by utilizing stir casting process performed in accordance with Zubairu et al. (2018). The Aluminium 6061 was cut into smaller size and weighed. Prior to the casting process, charge calculation was done to determine the amount of Al 6061 and shea nutshell ash (SSA) required for preparing the samples. The weight mix ratio was 5% and 10% respectively. Melting of the Al-6061 alloy was carried out in a charcoal fired crucible furnace at a temperature of about 750oC ± 30oC (above the liquid temperature of the alloy). Thereafter, the reinforcement particles of SSA was preheated and introduced into the melt. The composite was stirred manually while the melting was still taking place, after which the molten Aluminium was introduced into the cylindrical (35cm x 15cm) mould cavity. The molten metal was allowed to solidify inside the mould. Then the cast was removed and machined to samples for mechanical tests.

2.4 Mechanical Tests Procedure

The mechanical properties such as Tensile test, Hardness test, Impact energy and Microstructure of the composites were determined according to ASTM standards and methods reported in literature.

2.4.1 Tensile Test

Test specimens was prepared according to ASTM E8-82 standards, each specimen having 8mm in diameter and 60mm gauge length. The specimen was loaded in Hounsfield tensiometer; Monsanto, Type W, serial No. 9875. For conducting a standard tensile test, a specimen is placed in the testing machine and the extensometer is attached. Load is applied until the sample specimen fractures. The amount of load that caused the material to fracture is noted and the value of the force per unit area of fractured cross section is calculated as the tensile strength of the sample (Adamu, 2016).

2.4.2 Hardness Test

Identec universal hardness testing machine: MODEL 8187.5KV (B), Indenter; Diamond cone (120°), Scale A was used to determine the hardness properties of the developed composites in accordance with ASTM E384-11 standards. A load of 1N for a period of 10 seconds was applied on specimens. The hardness was determined by recording the diagonal lengths of indentation produced. The test was carried out at three different points on the specimens and the average value taken as the hardness of the cast specimens (Zubairu et al., 2018).

2.4.3 Impact Test

The impact test was conducted in accordance with ASTM E 602-91 standard method and definitions for mechanical testing of steel products. V-notches of 0.5mm depth were made on the samples each and the impact strength was carried out using Hounsfield balance Impact testing machine (Joules). Chapy Impact testing machine (Capacity 15-25 joules), serial No. 412-07-15269C was used to carry out the test on the samples.

2.5 Microstructural Analysis

Before the metallography and surface morphology examination, the surface of the samples was successively grounded using grit papers of different grades 12°C, 18°C, 32°C, 40°C, 60°C, 80°C and 120°C (Adamu, 2016). Being aluminium, grinding was carried out from the 40°C grit paper to the 120°C grit paper with the application of lubricant intermittently; this is to prevent overheating and provides a rinsing action, which flushes away the particles being removed from the surface. They were subsequently polished with the aid of a polishing machine using alumina to remove the scratches that are left during grinding. Etching was then carried out, which is the chemical attack on the surface of a polished metal, the etchant used for aluminium samples are "Keller's reagent, which is a solution of 1ml distilled water, 5ml nitric acid and 2ml hydrofluoric acid. A computerised photographic visual metallurgical microscope, MODEL NJF-120A, rating 230V-5V/60Hz was then used to view the microstructures of the polished samples (Zubairu, 2018).

3.0 Results and Discussion

3.1 Mechanical properties of Developed Composites

3.1.1 Hardness Value

The result of the variation of hardness values of the materials tested are presented in Figure 1. The hardness values of the developed materials are higher than that of the alloy as also observed by Kuburi et al. (2017) and Saravan et al. (2015); this is due to the addition of the reinforcement material (SSA) into the microstructure of the alloy. Highest hardness value of 187.60 HRB was obtained on sample C (Al6061+ 10% SSA) with the difference not much compared with the other developed matrix composites. The lowest hardness value of 70.33 HRB was observed for sample Control (Al6061). By implication, the hardness of the reinforced Al6061, with 10wt% SSA increased the hardness of the material by 166.74%. This is in accordance with Gladston et al. (2015) obtained, when he used Al6061and 8% Rice husk ash as reinforcement.

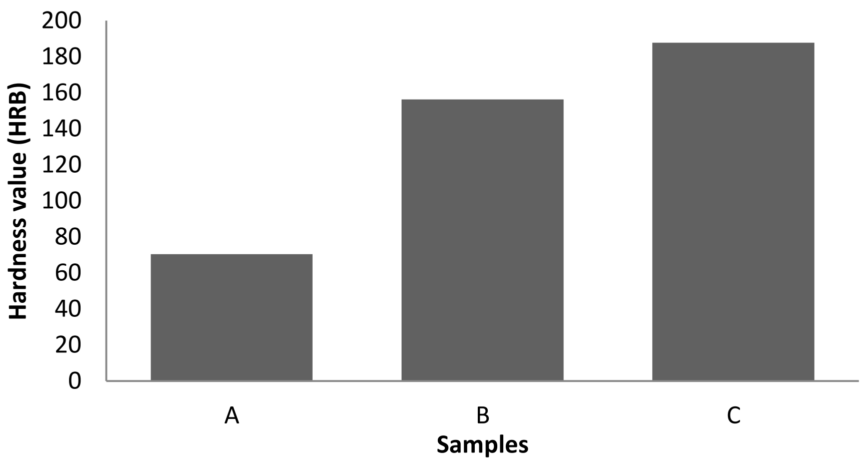

Figure 1. Variation of hardness of the cast composite with sample weight

3.1.2 Tensile Strength of Developed Composites

The variation of tensile properties of the materials with sample weight are presented in Figure 2. The tensile strength of the developed materials decreases with the increase in wt% SSA as shown in Figure 2. Sample Al6061+ 10% SSA, recorded the lowest tensile strength value of 94.52N/mm^2 compared to 'as cast' Al6061 (Al6061+0wt% SSA), with 115.67 N/mm^2. The strength of the developed composite with 10wt% SSA shows a reduction of 18. 29% compared to as cast Al6061.

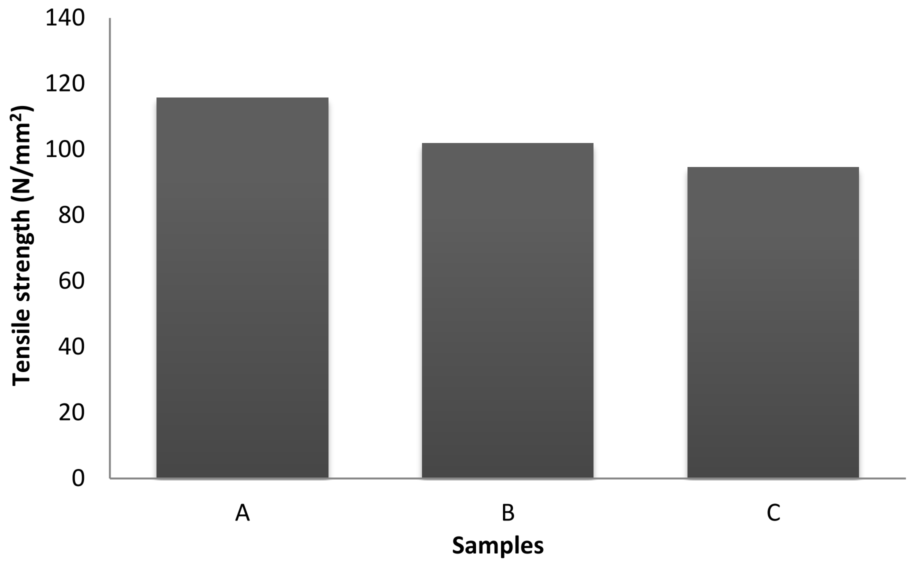

Figure 2. Variation of tensile strength of the cast composite with sample weight

3.1.3 Impact Energy of Developed Composites

Highest impact energy of 4.78 J was obtained on sample (Al6061+10% SSA) which is favourable compared to the value of 2.71 J observed on the as cast Al6061. Mechanical properties obtained shows clearly that the reinforced alloy will perform favourably well as against the as cast Al6061; resulting into an increase 76.38%. This conforms to the results obtained by previous researchers as reported in literature.

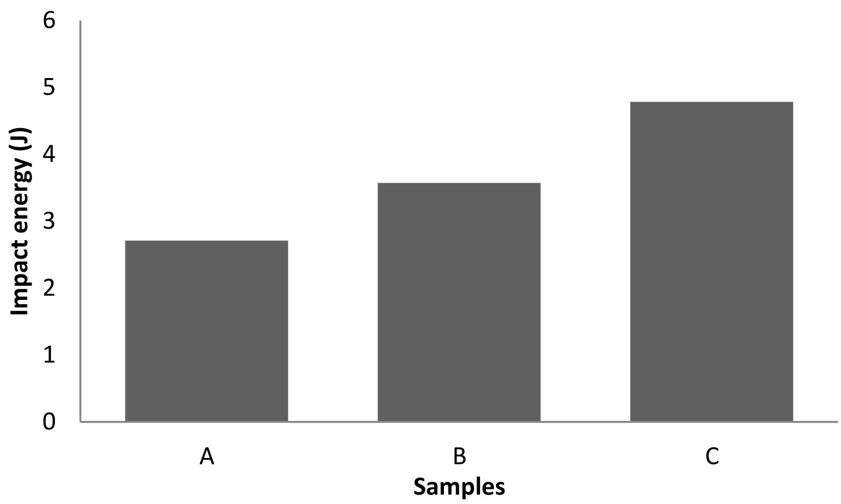

Figure 3. Variation of impact test of the cast composite samples

3.2 Microstructure of the Developed Al6061 composites

The microstructure of the developed cast Al6061 with the addition of sheanut shell ash (SSA) composites is presented in Figure 4a – c. The microstructure of Al6061 (Figure 4a) gives a fair distribution of the intermetallic phases (black) in α-Al (white) matrix.\

The microstructure analysis of sample A (Al6061 0%SSA) produced Al (white) and the intermetallic phases (black). The pattern of the microstructure of samples B, (Al6061 5% SSA), sample C (Al6061 10% SSA) presented in Figure 4b and 4c were similar to those of sample A (Al6061 0% SSA). Dendrites formation is observed and the reinforcing particles (SSA) is visible and clearly delineated in the microstructure. The particles are fairly well distributed in the Al-Mg-Si matrix and signs of particle clusters are minimal. The arrangement of the grains and phases geometrically in the material is in line with the findings of Kuburi et al. (2017).

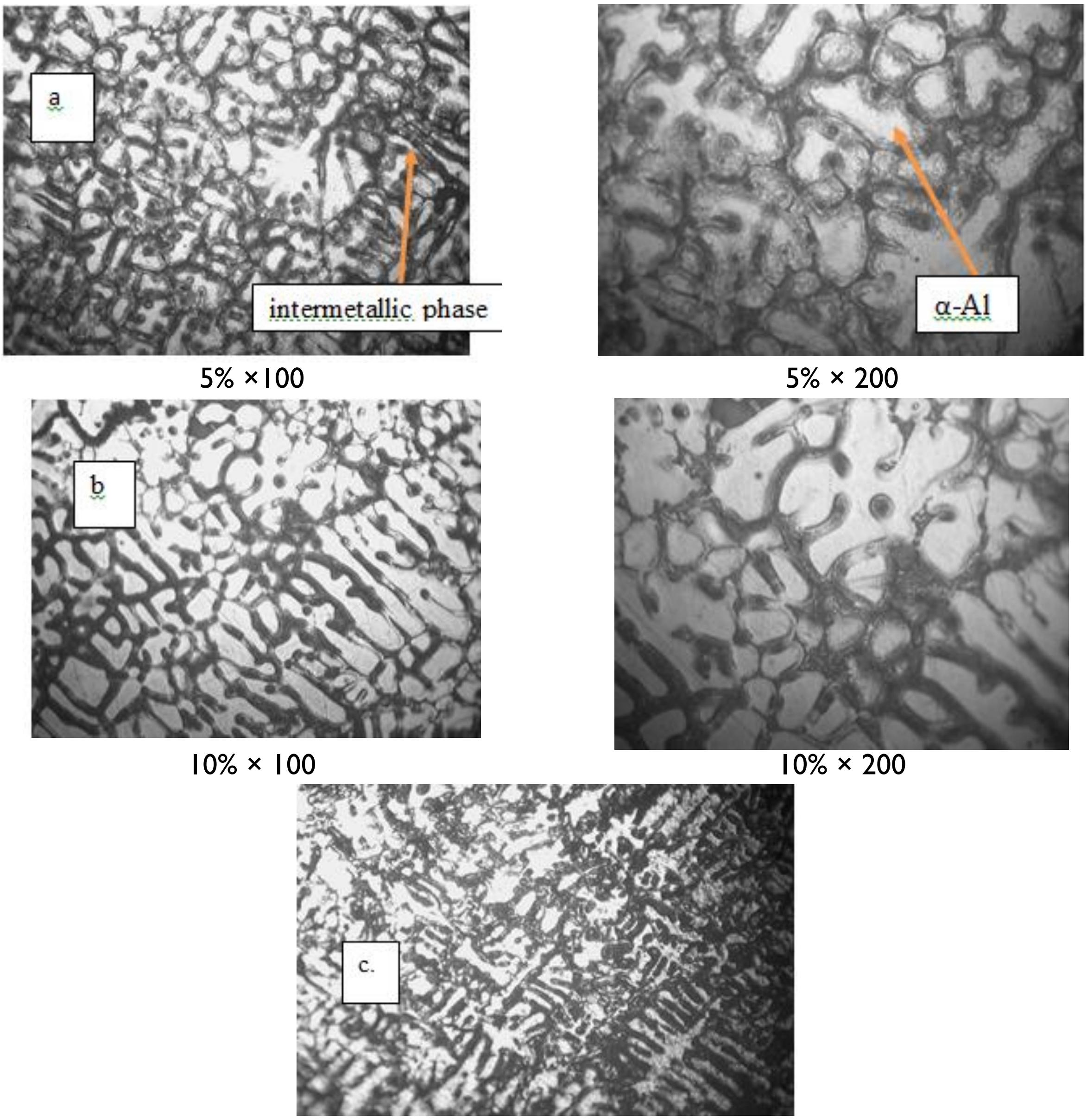

Figure 4. Optical micrograph of developed Aluminium alloy 6061/SSA, showing α-Al (white) and intermetallic phase (black), Mag X100: Control (a) Al6061+ 0% SSA (b) Al6061+5% SSA (c) Al6061+10% SSA.

4.0 Conclusion

Al6061/SSA Aluminium matrix composites were successfully produced using stir casting technique. The mechanical behaviour of the matrix composites containing 0, 5 and 10 wt % SSA as reinforcements was investigated. Microstructure of the developed composites showed that the SSA particles were homogeneously distributed in the aluminium matrix. The distribution was predominantly intra granular. However, SSA particles affected the mechanical properties of the Al6061. The hardness of the base alloy increased as the w% SSA increased; Such that Sample Al6061+10% SSA exhibited highest hardness value, giving a percentage increase of 166. 74%. In the same vein, impact energy of the as cast Al6061 increased as the wt% SSA increased. The percentage increase in impact energy was calculated to be 76.38%. However, the strength of the alloy decreased as the wt% of the reinforcement increased; the strength of the developed composite with 10wt% SSA shows a reduction of 18. 29% compared to as cast Al6061. Sheanut shell ash improves the hardness and impact energy of the as cast Al6061. SSA however promises to be a good reinforcement material, for hybrid aluminium matrix composites especially when the property desired is hardness and impact energy.

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