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INFLUENCE OF BIO-SHELLS ADDITION ON THE MECHANICAL PROPERTIES OF ALUMINIUM ALLOY

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Abstract - Bio-wastes materials generation is on the increase and technology has made it possible for use as additives to other materials in order to improve mechanical properties of such materials. Snail and sea shells, regarded asbio-remnants, obtained from eateries and beaches normally constitute environmental nuisance when the shells are discarded after the consumption of the flesh. These bio-shell wastes were used as reinforcement materials in aluminium metal matrix composites (MMCs). The mineralogical compositions and other physical properties of the shells were carried out using thermo gravimetric analysis (TGA), Scanning Electron Microscopy/Energy Dispersive X-ray (SEM/EDS) and X-ray fluorescent (XRF). The density and mechanical properties of the specimens as determined at varying % wt addition of the bio-shells' powder to aluminium showed a significant improvement in properties. There was increase in hardness and tensile strengths with a recorded decrease in density when the shells' powder was addedto aluminium alloy.

Keywords - Bio-shell, mmc, reinforcements, sea shell, snail shell.

I. INTRODUCTION

The demand for light weight and low cost materials with enhanced performance strength in applications such as automotive, aerospace and structural applications are on the increase [1]. Aluminium and its alloys with corresponding characteristics of light weight, low cost, ease of recycling, good thermal and electrical properties are good materials in modern engineering applications which had equally attracted extensive research interests. Good resistibility to corrosion of aluminium and its alloys had further increased their applications and performance in many environmental conditions. However, aluminium alloys' strengths are still being considered insufficient in engineering applications where broad spectrum of improved properties are highly required [2].Improved properties of the material can be achieved through reinforcement of the metal which is the focus of this work [1], [2]. Increase in demand for low cost reinforcement materials in metal matrix composite was due to the abundance and presence of hard phases suitable for strength enhancement at low cost [3]. One major advantage of agro-allied waste reinforcement materials in MMCs is that they are available and renewable.

Combining metal (matrix) and hard particles (reinforcement) had led to obtaining properties of distinct physical and chemical characteristics which is tailored towards desired specifications[1], [2]. Metal Matrix Composites (MMC) are characterized by low density, high specific stiffness, high specific strength, increased fatigue resistance, superior dimensional stability at elevated temperature and controlled co-efficient of thermal expansion [3]. These properties have made MMC fit for use and attractive in automotive, aerospace, industrial and defence applications [4].Limited availability and high cost of commonly used synthetic reinforcement material in MMCs had hindered the industrial production of MMCs on a large scale for instance, in the automobile industry[4]-[6]. Synthetic reinforcement particles like silica carbide (SiC) and alumina (Al_2O_3) are the earlier and mostly investigated in MMCs [2].Ground nut shell ash between 3 to12 wt %was used to reinforce Al6063 matrix composite through liquid metallurgy route where an increase in the hardness, tensile and compressive strength of the material with the optimum tensile strength was obtained. Similar results were obtained using carbonized maize stalk as reinforcement material in Al–Si–Mg alloy[5]. Aluminium-rice husk and bagasse-ash reinforcement produced 19 and 15 % weight reduction with improved mechanical properties [7].

Discarded bio-shells of snail and sea animals are found in the environment and pose serious environmental and health challenges [8]. The chemical composition of bio-shells revealed that they can be used as metal matrix composites reinforcement materials [9]. Not much has been found in literature relating the influence of snail and sea shells reinforcement in aluminium alloys and its mechanical properties. This work therefore investigated the mechanical properties of the addition of snail and sea shells powder to aluminium alloy.

II. MATERIALS AND METHOD

African giant snail shells (S_nS) (Archachatinamarginata) were sourced from Okitipupa andseashells (S_eS_r) (Pectenraveneli) from Victoria Island bar beach, all in Nigeria, see figs. 1(a,b). The shells were washed and sun dried for 3

days to significantly reduce the moisture content before crushing into fine particle sizes, [10], [11] as in figs. 1 c and d.The shell particles were calcined at 900 ^{o}C in electrical muffle furnace for 3 hours after which they were sieved into 100, 150 and 200 µm sizes before been used as reinforcement material on aluminium alloy. The chemical composition of aluminium alloy used is as in Table i.

Element	Al	Si	C	O	Na	Bi	Sr
% Composition	87.1	7.7	2.7	2.2	0.01	0.26	0.03

Table i: Elemental Compositions of Al alloy

III. EXPERIMENTAL PROCEDURE

A clean homogeneous melt of aluminium alloy was used as the metal matrix and powders of snail shell (S_nS) and sea shell (S_eS_r) as reinforcement materials. The % weight of reinforced powder addedto metal matrix was between 0–7.5 and was performed in a two-step stir casting technique[12]. The melting and stirring process was carried out in a furnace rotated at 450 rpm.Measured quantity of aluminium alloy (500 g) was charged into stainless crucible of the furnace and heated to 760 ±20 ^{o}C till the entire alloy melted. The temperature was monitored by type K-type thermocouples with the output temperature read on digital data logger incorporated into the furnace. At 760 ±20 ^{o}C, 0.1 wt% of magnesium ribbon was introduced into the molten aluminium to enhance wettability [7], [13]. Snail shell calcinedparticles,S_nS of 1.5 %wtof100 µm was preheated at 400 ±20^{o}C for 30 minutes before it was introduced into the melt [14].The molten aluminium was then taken out and allowed to cool below the liquidus temperature after which the preheated S_nS particles were added into the melt at constant rate while stirring manually until it became sticky and difficult to stir. The resulting slurry was returned back into the furnace and reheated to 760±20 ^{o}C. The stirrer was gradually lowered into the melt and stirred at 450 rpm for 120 s. The slurry mixture was poured into a preheated split cylindrical steel mould of 20 mm diameter and 150 mm long and allowed to cool freely before casting removal [15]. This same procedure was followed for different castings at varying % wt particle sizes for sea and snail shells.



Figure 1: Pictures showing uncrushed and powdered snail and sea shells

IV. CHARACTERIZATION OF BIO-SHELLS

The density of the aluminium alloy bio-shells composites was determined using Archimedes' principle [7] by weighing the samples in air on digital electronic weighing device (Kern: D-72336 Balingen, Germany) balance with serial number W1500761 andimmersed in graduated measuring cylinder to obtain the rise in volume using "(1)".

$$\rho = \frac{w_a}{w_a - w_l} \quad (1)$$

Where,
ρ =density, w_a = weight in air,w_l = weight in water
The thermogravimetric analysis, thermal stability and temperature of destruction/burning T_{des} of bio-shell powders($S_nSandS_eS_r$) were carried out on Perkin Elmer DTA/TGA4000 Thermogravimetric Analyzerat 10 ^{0}C/min constant heating rate between 31–900 ^{0}C in nitrogen atmosphere as stipulated in ASTM D6370 standard procedure.Rockwell hardness tester machine (HR-150A) serial number 15729; ISO19001 was used to determine the harness values of the samples. A 100 kgf load was applied to indent the prepared samples' surface measured 20 mm x 20 mm using 1/16" steel ball indenter at three different positions. The average readings was used as the hardness value for the sample.

The tensile tests were performed on Universal computerized UTM (TUE-C-500) while the impact strength of the materials was obtainedin accordance with ASTMD 256-93 standard on Avery Denison Universal Izod Impact – Testing machine, model number 6705U/33122.

V. RESULTS AND DISCUSSION

A. Density of aluminium alloy bio-shells' composites

The graphs of bio-shell powder with specimens' density as in figs. 2 (a,b) showa drop in the density from 2.72 g/cm^3 to 2.61 g/cm^3 when the % wt of SnS powder was increased from 1.5 % wt to 4.5 % wt corresponding to 4.2% drop for 150 µm. Subsequent increase in % wt of SnS powder had no substantial influence on the density as it became 2.60 when the value of SnSadded became 7.5 % wt. This similar trend was observed for SeSr powder with a drop of 3.8% when %wt composition of the powder was increased from 1.5 to 4.5 %wt. The reduction in density observed was due to the lower densities of bio-shells reinforcement particles in the matrix [7], [9], [16]. The more the percentage addition of the reinforcement, the more will be the space occupied by the particle and the lesser the weight of the resulting composites.



Figure 2: Graph of bio-shells grain size and weight fraction on the density of Al alloy/ S_nS/S_eS_r composites

B. Influence of %wt on hardness on the composites

The hardness value of Al alloy-S_nS composites increases with increased percentage weight fraction of S_nS powder as depicted in fig. 3a.The maximum hardness value of 71.5 and 65.67 HRB were recorded at 7.5 % wtaddition of S_nS with 150 and 100 µm respectively as compared to 58.67 HRB obtained when there was no addition.The hardness of the composites increased to 66.4 and72.67 HRB at 7.5 %wtrespectively with100 and 150 µm for S_eS_r particles in aluminium alloy.The observed increase may be as a result of formation of harder phases within the matrix by the addition of hard snailand sea shell powders inthe form of calcite, lime and portlandite within the aluminium alloy matrix. The calcite has a good proportionate of carbon and calcium which tend to occupy the interstitial spaces and hence formation of harder phases may result due to inter-atomic and grain bonding. The harder phases tend to resist possible indentation and scratches andthus results in hardness increase as earlier observed [4], [13].

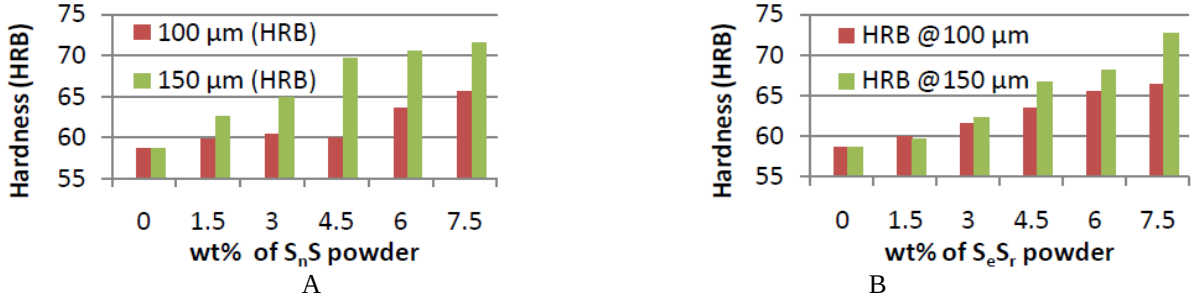


Figure 3: Effect of %wt on the hardness Al-alloy composite

C. Effect of %wt and particle size on tensile strength

Fig. 4ais the effect of %wt and particle size of Al-alloy reinforced snail shell composites where an increasein the %wt of snailshell particle additioninitially leads to an increase in the tensile strength followed by a marginal decrease thereafter. The rate of tensile strengthening in Al-alloy-S_nS reinforced composite is appreciable with 100 µm particle size as compared to that of 150 µm. For both figs. 4 a and b, the 100 µm produced higher tensile strength than that of 150µ m. The peaks of 211.373 MPa and 216.74 MPa were reached at 4.5 %wt for SnS and SeSr respectively.When the %wt of powdered bio-shells increased from 4.5 % wtfor both situations,a drop in the tensile strength was noticed with SeSr becoming steep. This behaviour could be attributed to high dislocation due because of due to increase in particle weight that tends to hinder the free sliding of material inter-grain movement leading to enhanced strength [7], [11], [13].

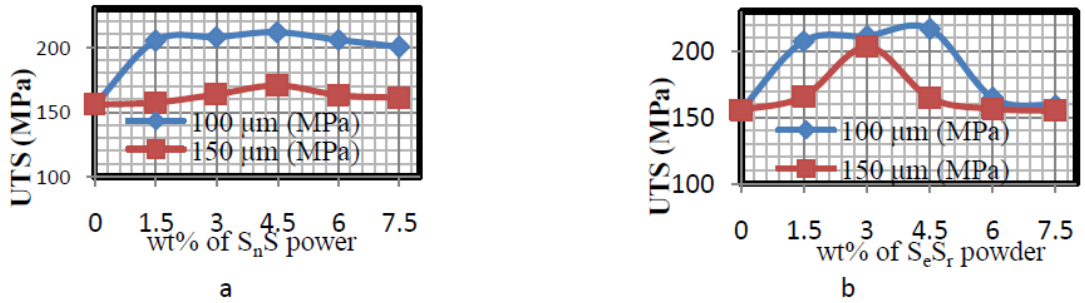


Figure 4: Effect of %wt of bio shell on the tensile strength of Al-alloy/S_nS composite

D. Effect of %wt and particle sizes on impact strength

Impact strength increases with increase in the %wt addition of bio-shells into the aluminium alloy as recorded in figs. 5a and b. The rate of increase was more with the 100 µm as compared to 150 µm shell particle in the reinforcements. For both bio-shells, smaller particle size at higher %wtaddition leads to higher rate of increase on the impact strength of aluminium bio-shells reinforced composites. The increase could be explained to the presence of hard (cementitiousportlandite) constituents capable of providing strong bonding between hard particles in the form of calcite and continuous ductile phase of the matrix [17], [21] where it was reported that the impact strength increases with increase in %wt fraction of SiC in the matrix.

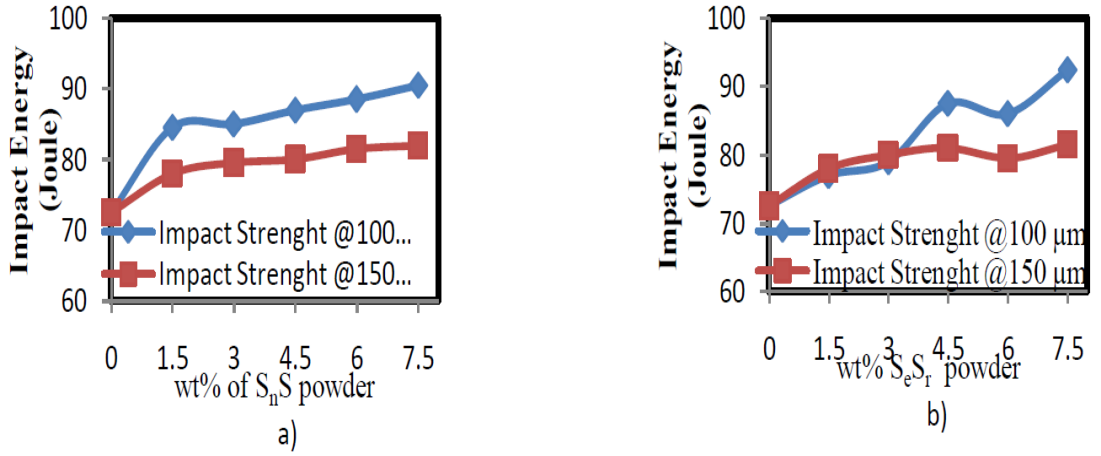


Figure 5: Effect of %wt on the impact strength of Al-alloy/S_nS composite

VI. CONCLUSION

Addition of bio-shells particles into Al-alloy has effects on the density, tensile strength, impact strength and hardness of the composite produced and would find applications in the areas of automobiles and aerospace industries where lighter with higher performance materials are required. The % wt of the powder addition and its particle size affects the composite and depend on the application.

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