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# PERFORMANCE CHARACTERISTICS OF ECO-FRIENDLY AGROBIO-WASTES AS MOLD ADDITIVES ON MECHANICAL PROPERTIES OF AlSiMg ALLOY

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**Abstract:** *Sand mold additives like Furan and phenol-formaldehyde resins enhance the performance of foundry sand but are hazardous, environmentally unfriendly, and costly, especially in developing countries where they are often imported. For this purpose, the performance characteristics of snail shell and rice husk ash as an eco-friendly agrobio-wastes mold additives on mechanical properties of aluminum alloy is experimentally investigated and presented in this work. Varying compositions with 0%, 1%, 2%, 3%, 4% and 5% wt% rice husk ash while keeping snail shell constant at 1 wt%, were used as additives to prepare the different sand molds for the casting of aluminum alloy. The performance characteristics of the prepared sand molds were carried out by evaluating the permeability and water moisture content. In addition, samples of cast aluminum alloy from varying sand compositions were also subjected to tensile, compressive, impact and wear test under constant load following ASTM standard to optimize the most suitable additives composition. Results revealed that the incorporation of the molding additives influence the water moisture and permeability properties of the molding sand and as well as mechanical properties of the cast products. The molding sand composition with 1 wt% snail shell and 2 wt% rice-husk has the lowest water moisture and highest permeability property respectively. Furthermore, the peak tensile (142.45 MPa), compressive (427.616 MPa) and hardness (142.45 HV) value with improved wear resistance were obtained when 1 wt% of snail shell and 2 wt% of rice-husk ash additives was added to the molding sand. This implies an enhanced performance of 22.8%, 11.60% and 4.40% in tensile, compressive and hardness strengths. This study therefore suggests 1 wt% of snail shell and 2 wt% of rice-husk ash as an eco-friendly agro-bio additives in molding sand preparation for the production of aluminum alloy with improved strength and wear resistance.*

**Keywords:** *Sand mold additives, Sand casting, Aluminum alloy, Agrobio-waste, Wear and Mechanical properties*

## 1. INTRODUCTION

Aluminum metal and its alloys is one of the most widely used and most preferred non-ferrous metal for the production of many household utensils, pistons, connecting rods, engine cylinders, electrical cable and appliances, building doors and windows [1]. This is due to its excellent characteristics such as light weight, high strength to weight ratio, good electrical and thermal conductivity as well as excellent corrosion resistivity in air environments [2]. Thus, its increasing demand in automobile, aviation, power, structural and other critical engineering applications has attracted researchers' attention. The primary means of producing aluminum and most metals into desired form is casting due to it versatility.

Casting involves melting and pouring of the prescribed metals at appropriate temperature into a desired mold to allow for solidification and cooling of the final products. Generally, casting could be expandable (non-reusable mold) and non-expandable mold (reusable mold) casting though, each is with associated pros and cons. However expandable casting technique such as sand casting is simple and suited for the casting of most metals into any desired shapes with high flexibilities. The versatility of this process has made it widely used in the production of metals such as aluminum alloys, cast iron, copper and brass in different sizes and geometries. It is most suited for the production of complex and intricate shapes at moderate cost which are difficult or unobtainable using other casting techniques [3-5]. Consequently, it has found wide applications in production of components used in automotive, aerospace, household utensils and other industrial sectors [6, 7]. It is worthy to note that, sand mold compositions comprises mainly of silica mixed with bentonite clay, water and additives in the correct proportions to have a good sand mold quality for casting operation [8, 9]. Meanwhile, the quality of sand cast product is highly influenced by the choice of process parameters such sand mold compositions, pouring rate and pouring temperatures [9]. Additives and its types play a significant role in sand mold compositions and characteristics at imparting some important properties into the final cast products [7]. However, conventional additives like Furan resin, bentonite clay and phenol-formaldehyde resins which are usually used have health risk consequence, environmental unfriendly and expensive especially in most developing countries where they are often imported at high exchange rate [4, 10, 11]. As a result, the use of industrial and agrobio-wastes as an alternative to conventional additives in foundry practices are gaining more attention in recent times and has attracted researchers' interest. This is due to its sustainability, environmental friendliness and huge potential at enhancing the sand mold properties for quality casting operations as evidenced in the literature [4, 9, 12, 13].

Outcomes of previous investigations on the potential utilization of industrial and agrobio-wastes as sand mold additives reported have unveils enhancement in both the quality of sand mold and final cast products. Kumar Sinhna *et al*., [14] investigated the utilization of industrial solid waste of granular blast furnace slag, red mud and ferro-chrome slag in the foundry industries as sand mold additives. The results of the chemical and mechanical properties examination of the resulting sand mold beneficiated with different solid wastes as additive shows significant mold properties enhancement. Conclusion based on this findings indicated the resulting beneficiated sand mold can replace silica sand in the foundry industry for improved cast quality. In a related effort, Desai et al., [7] examined the use of flyash, coconut shell and tamarind as additives on the green sand mold properties using experimental investigation and statistical analysis. It was found that tamarind powder is more suitable amongst the selected trio-additives to obtaining a sound casting requirement. This finding was similar to that reported by Salihu et al. [15], where the effect of variation of different additives on some selected properties of sand mold for the manufacture of aluminum alloy was presented. It was inferred that, the inclusion of marula shell powder, silica flour, corn flour and shea butter shell powder varied from 1.0 to 6.0 wt% displayed improved physical and mechanical properties of molding sand. The shea butter shell power and silica flour possess better compaction strengths at 6 and 3 wt%

respectively as compared to corn flour and marula shell powder. Moreover, Kumar & Gandotra [6] investigated and compared the effect of sawdust and coal dust as an additive in sand mold on the mechanical properties of casted ZAMAK-3alloy. The results revealed that, the Zamak-3 alloy casted using sawdust as an additive in molding sand performed best compared to coal dust additive. An increased hardness of 16.36% with improved surface roughness compared with the control sample was obtained at 7.5% sawdust addition. In a related study, Ameen & Hassan [16] present the influence of sodium carbonates, glycerin and oat flour sand mold additives on some mechanical properties of carbon steel CK45 casts. The results revealed an highly improved mechanical properties of carbon steel CK45 casts with sodium carbonates and is less with oat flour while glycerin additives give an intermediate enhancement in comparison with control cast sample. In a recent work, a comparative influence of sand mold additives comprising of saw-dust, groundnut shell and eggshell between 0 and 35 wt% at 10 wt% interval on tensile properties of aluminum (6061) alloy cooled in different media (water, palm oil and engine oil) has been reported by [17]. The study outcome revealed that, the ultimate tensile strength increased with increased wt% of additive in sand mold for all proportions investigated and the water-quenched products had the highest ultimate tensile strength values (107.52 MPa, 100.5 MPa and 94.55 MPa) followed by palm oil and engine oil at 25% but decreases at 35% respectively. Based on this study, it will be very difficult to assess the strength enhancement performance of the respective additives because, the as-cast strength condition of the respective additives was not reported before the heat treatment evaluation in this study. Furthermore, the effect of two or more agro or bio-waste in combined or hybrid form as sand mold additives on the mechanical and wear properties of aluminum alloy has not been found in the literature to the best of the authors' knowledge. Therefore, the performance characteristics of eco-friendly agrobio-wastes of rice-husk and eggshell as mold additives on mechanical properties of AlSiMg alloys is presented.

## 2. MATERIALS AND METHOD

### 2.1 Materials and Equipment

Natural moulding sand (Fig. 1a) employed in the preparation of the green sand mold was sourced from Asa Dam riverbank of Ilorin, Nigeria. The rice-husk and snail shell (Figure 1b and c) used as additives in this work were respectively sourced from Ojagboro and Ipata markets both within Ilorin metropolis. Aluminum metal scraps (Fig. 1d) with chemical composition shown in Table 1, was procured at Ipata-Oloje market, Ilorin. Equipment used in this work include charcoal pit-furnace, tong, molding box, lathe machine, Universal Testometric Machine (UTM) and Optical microscopy.


(a)


(b)


(c)


(d)

**Figure 1.** Sand mold materials: snail shell (a), rice-husk (b), Asa river moulding sand (c) and purify aluminum alloy scrap (d)

**Table 1**. *Elemental Composition of Al-Scrap*

| Elements | Al alloy |
|---|---|
| Al | 91.84 |
| Mg | 1.94 |
| Si | 4.94 |
| Fe | 0.48 |
| Ni | 0.00 |
| Cl | 0.82 |

## 2.2 Processing of snail shell and rice-husk ash moulding sand additives

5 kg of snail shells were procured, washed with detergent to remove hard sticky dirt, sun-dried for three days in an open space, crushed, and grinded to fine powder. A 10 kg rice-husk was openly burnt into ashes, packed and heated in air-tight electric electric muffle furnace at 1000˚C for six hours. Both prepared fine snail shell powder and rice-husk ash with compositions shown in Table 2 and 3 were stored separately in an air-tight containers for later use in sand mould preparation.

**Table 2.** Chemical Composition of Snail shell

| Elements | ASA |
|---|---|
| CaO | 66.368 |
| $Fe_2O_3$ | 0.051 |
| NiO | 0.007 |
| $Al_2O_3$ | LOD |
| MgO | LOD |
| ZnO | 0.001 |
| $SiO_2$ | LOD |
| LOI | 23.523 |

**Table 3.** Chemical composition of Asa-river moulding sand and Rice-husk ash

| Elements | ASA | RHA |
|---|---|---|
| $SiO_2$ | 65.45 | 76.42 |
| $Fe_2O_3$ | 11.27 | 1.10 |
| $Al_2O_3$ | 16.14 | 2.05 |
| CaO | - | 5.99 |
| $P_2O_3$ | - | 11.34 |
| $K_2O$ | 4.20 | - |
| $SO_3$ | 1.52 | 3.10 |
| $TiO_2$ | 1.44 | - |

## 2.3 Preparation of sand mould for casting of Al alloy

Six identical sand mould compositions (Fig.2a) were prepared from Asa-river silica sand with chemical composition shown in Table 4, mixed or not with snail shell, rice-husk ash additives and water at varying weight proportions as depicted in Table 4. The moulding sand preparation was preceded by weighing 97 wt% of Asa River sand and 3 wt% water on a digital weighing balance (Fig.2b) for the control sample. It was thoroughly mixed using a manual technique from bottom-top and top-bottom order sequence for 10 minutes (Fig.2c). The mixture was thereafter packed around 5 wooden patterns at equal distance concentric to the centre of mold flask and rammed in a 100 x 300 mm steel cylindrical flask to create 15 x 120 mm mold cavities as shown in Fig. 1d. Similarly, 1 wt% each of snail shell and rice-husk was weighed and mixed with 95 and 3 wt% moulding sand and water respectively in a manner described above to make the second molding sand composition and cavity. Similar procedure was adopted for the preparation of other sand mold compositions as contained in Table 4 by varying rice-husk ash by 2, 3, 4 and 5 wt% while keeping snail shell powder at 1 wt%.

**Table 4.** Moulding sand formulations

| S/N | Silica sand | Snail shell (wt%) | Rice-husk (wt%) | Water(wt%) |
|---|---|---|---|---|
| **1** | 97 | 0 | 0 | 3 |
| **2** | 95 | 1 | 1 | 3 |
| **3** | 94 | 1 | 2 | 3 |
| **4** | 93 | 1 | 3 | 3 |
| **5** | 92 | 1 | 4 | 3 |
| **6** | 91 | 1 | 5 | 3 |

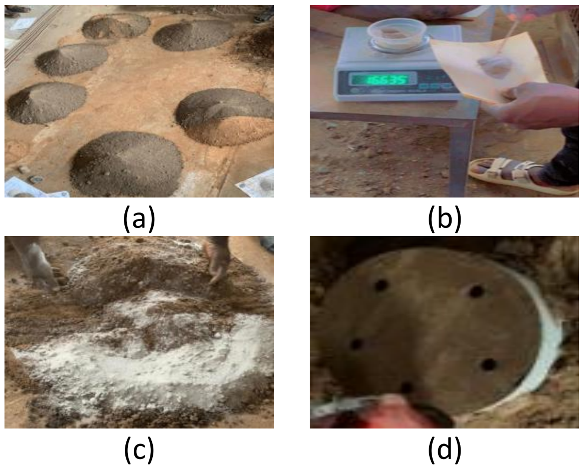


**Figure 2**. Sand mould preparations: (a)weighed sand (b)weighing of additives (c) mixing process (d) prepared mould with 5-cavities

## 2.4 Production of sand cast AlSiMg alloy

2.5 kg of AlSiMg alloy was weighed on a digital weighing balance and melted in a crucible placed in a charcoal fired furnace (Fig.3a) at 768 °C as detected by an infrared thermometer.

The available slag on the molten metal was skimmed off and then wait till the temperature dropped to 710 °C before being poured into the prepared sand molds with 5 hollow cavities with varying mold additives. After 20 minutes of solidification and cooling, the cast alloy samples were shaken out (dismantled) of the mold to have the different cast samples as discernible in Fig. 3b.

(a) (b) (c) (d)

**Figure 3.** Melting (a) pouring and solidifying (b) shaking out (c) and cast AlSiMg alloy sample (d)

### 2.5 Performance evaluation of AlSiMg cast alloy using snail shell/rice-husk as Sand mould Additive

The water moisture and permeability test were used to assess the physical characteristics of the prepared snail shell/rice-husk sand mould. While, the tensile, compressive, impact, hardness and wear tests were carried out to evaluate the mechanical property performance of sand-cast AlSiMg alloy produced using the prepared sand moulds of different compositions.

### 2.6 Water moisture and permeability test

The water moisture ($W_m$) characteristics of different moulding sand compositions as presented in Table 4 were assessed by taking samples of prepared sand moulds with varying additive and weighed ($W_b$) before drying. The weighed sand sample was then oven dried at 115° C for 6 hours. The dried sample was then removed and allowed to cools in an air-tight container after which it was reweighed ($W_a$). The water moisture of the various samples was determined using Equation 1.

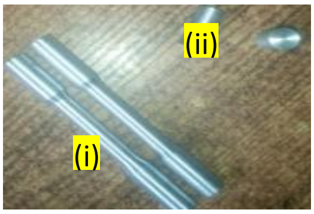
$$W_m = \frac{W_b - W_b}{W_b} \times 100 \quad (1)$$

The permeability test was performed at the department of civil Engineering Laboratory, University of Ilorin, Kwara Sate, Nigeria. The evaluation was preceeded by firstly preparing a standard tube specimen size of 50 mm diameter by 50 mm height. It was then mounted on a permeability meter which uses an orifice principle to measure the permeability of the sand mould specimen. The air at the constant pressure was applied on a freshly prepared specimen. The drop in pressure was then observed and noted on the pressure gauge calibrated in permeability numbers and recorded as the permeability property of the sand mould.

### 2.7 Mechanical property performance of AlSiMg sand cast alloy

The as-cast samples of various moulding sand compositions were prepared to standard testing specimen of tensile, compressive and impact test piece on the lathe machine at the Department of Mechanical Engineering's workshop, Faculty of Engineering and Technology of Kwara State University Mechanical workshop. Three (3) tensile specimen each per moulding sand compositions were machined as per the ASTM E8-E8M13a standard size specifications for mechanical properties tests as showed in (Fig. 4). The tensile strengths were performed on a 50kN computerized Testometric Universal machine (UTM) having a model number (TUE-C-500) at $10^{-3}s^{-1}$ strain rate until a fracture occurs in line with the work of Kolawole et al., [18]. The compressive specimen was prepared and tested in accordance with ASTM E9-19 standard of 2.0 length/diameter ratio at a strain rate of 0.005 mm/min. The impact specimen size of 10 mm diameter x 75 mm height notched to a depth of 2 mm at the middle with 45° v-file was prepared and tested following the ASTM E23 standard. The hardness and wear characteristics were performed on a flat smoothened and polished 10 mm diameter x 20 mm height sample with five indentations. The average hardness value of five indentations was recorded and reported in this work. The wear test of the control sample (without additive) and sand mould with 1 wt% snail shell and 2 wt% rice-husk as additive was evaluated on a fabricated pin-on-disc at a constant load of 17N. The prepared sample was weighed using an electronic weighing balance before the experiment as $m_1$. The specimen was inserted into the sample holder and pressed against the rotating disc of radius $(R)$ after which it was loaded. The experiment was conducted at a load 17 N for 60, 120 and 180 s time $(t)$ with running speed $(N)$ of 300 rpm to determine the wear characteristics of the cast samples. The final sample weight after the run of experiment taking on a digital weighing balance was recorded as $m_2$. The loss in weight ($\Delta m = m_1 - m_2$) was then used to calculate the wear rate of the cast sample using Equation 2.

$$W_r = \frac{(\Delta m/\rho_s)}{(2\pi NR/60)t} \tag{2}$$



(a)


(b)

**Figure 4.** Machined tensile (ai), compressive (aii) and impact (b) strength specimen

## 2.8 Morphological Optical Examination

The morphology of selected AlSiMg alloy was examined using optical microscopy at the Department of Materials and Metallurgical Engineering, University of Ilorin, Nigeria. This was achieved by polishing the surface of each sample using electric polishing machine (Fig.5a) with an emery paper of 400, 800, 1200 and 1500 descending grit sizes. Thereafter, each sample was etched in 2% Nital solution for 5 seconds before examination on optical microscope incorporated with system for data aquisition (Fig.5b).


(a)

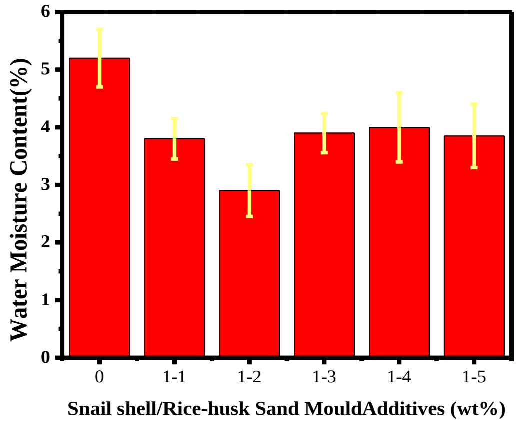

(b)

**Figure 5.** Polishing (a) and optical viewing (b) of sample morphologies

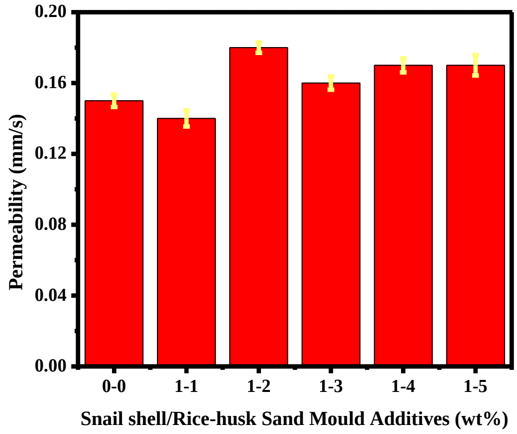
## 3. RESULTS AND DISCUSSION

### 3.1. Water moisture and permeability determination

Figure 6a and b revealed the water moisture and permeability characteristics of snail shell/rice-husk ash (SnS-RHA) moulding sand used for the casting of AlSiMg alloy. It is worthy to note that, the use of snail shell and rice-husk as additives in Asa moulding sand influences its water moisture and permeability properties. The highest (5.80%) water moisture was observed in the mould with no additives. This value decreases to 3.80% when 1 and 2 wt% of snail shell, rice-husk ash was added as additive into the moulding sand. A more decrease in water moisture was recorded by increasing the SnS-RHA content by 1-2 wt%, to 2.90%. Further additions beyond this range, slightly raises the water moisture up to 1-5 wt% SnS-RHA additions. Meanwhile, the permeability of the sand mould as displayed in Fig. 6b unveils higher magnitudes with all sand moulds containing additives with exception of 1-1 wt% SnS-RHA additive compared to the control moulding sand. The highest permeability (0.18 mm/s) was noted in sample with 1-2 wt% SnS-RHA additives. This implies that sand mould with with 1-2 wt% SnS-RHA additives can permit the passage of more air-gases than others when used for casting operation with potential of minimising casting defects. This characteristic feature of 1-2 wt% SnS-RHA moulding sand can be attributed to addition of snail shell powder which contains mainly CaO in a carbonate form as displayed by the chemical composition (Table. 2) has enhances the water moisture reduction of RHA due to its effervescent nature thereby acting as an insulating binder. However, with increasing addition of RHA, the bindery property of RHA losses strength which account for a slight change in both the moisture content and permeability property of the moulding sand. This observation is in line with earlier work of Salihu et al., (2020) where they reported an increase in permeability number with increasing additions of moulding sand additives.




(a)

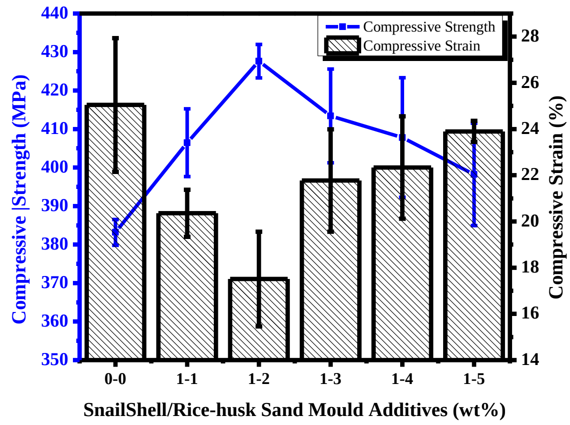



(b)

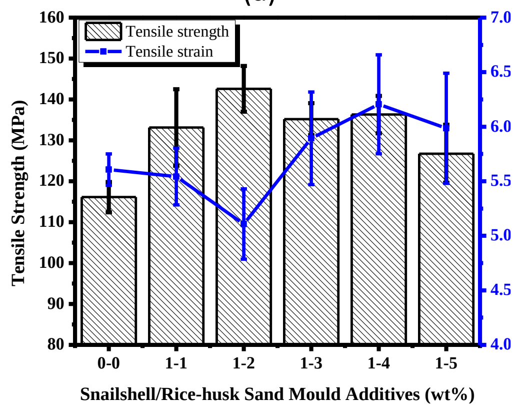
**Figure 6.** Water moisture content & permeability characteristics of snail shell/rice-husk sand mould

### 3.2. Mechanical Property Performance of AlSiMg Sand Cast Alloy

Mechanical property performance of AlSiMg alloy cast in different moulding sand compositions are shown in Fig. 7 and 8 repectively. Figure 7a and b respectively depicts the compressive and tensile strength characteristics of the alloy. The compressive strengths of AsiMg alloy produced with moulding sand with no additives is 383.172 MPa. When 1-1 wt% of SnS-RHA was added as additives into the moulding sand, the compressive strength increased to 406.454 MPa and the peak compressive strength (427.616MPa) was recorded in the sample cast with moulding sand containing 1-2 wt% SnS-RHA additives. This increament is equivalent to 11.60% when compared with the control sample. Further addition of SnS-RHA additives beyond 1-2 wt% does not further increase the strength but reduces it with a strength of 398.220 MPa noticed in sample produced with moulding sand having 1-5 wt% SnS-RHA additives. Similar behaviour was observed in Figure 7b where the least tensile strength (116.115 MPA) was recorded for AlSiMg alloy cast in moulding sand with no additive. The incorporation of SnS-RHA additives in Asa moulding sand resulted into corresponding increase tensile strength at all compositions though at varying magnitudes. The maximum tensile strength (142.585 MPa) was recorded at 1-2% SnS-RHA additive incoporation indicating 22.80% enhancemnt in tensile strength relative to control sample. Further addition of SnS-RHA into the moulding sand does not further increase the tensile strength but decreases it, up to 126.728 MPa when the additive was raised to 1-5 wt%. However, the strain characteristics of AlSiMg alloy in both compressive and tensile strenghts initially decreased from the sample cast with no additive to sample cast with moulding sand having 1-2 wt% SnS-RHA additives composition. Beyond this percentage, the strain characteristics slightly rises with increasing SnS-RHA additives. The characteristic increase in both compressive and tensile strengths in moulding sand with additives can be attributed to higher permeability indices as observed in moulding sand with additives (Fig. 6) which can enhnace faster solidification rate of AlSiMg alloy compared to control sample [19]. The increased solidifcation rate resulted into more nucleation sites which enhances grain size refinement as discernible in the optical micrograph shown in Figure 9. For instances, the average grain size as obtained from imageJ software are 293 ±59, 88 ±25 and 206 ±191µm for sample cast in moulding sand with no additive, with 1-2 wt% SnS-RHA and 1-5 wt% SnS-RHA respectively. Furthermore, the gradual increase in strain characteristics as the mould additives rose beyond 1-2 wt%, can be due to a more insulating property of the moulding sand rich in RHA which could form silical gel and decrease solidification performance of the sand mould. This result coroborates with earlier reports [6], [17], [20] where emhancement of strength was attributted to increase solidification rate of the moulding sand.




(a)



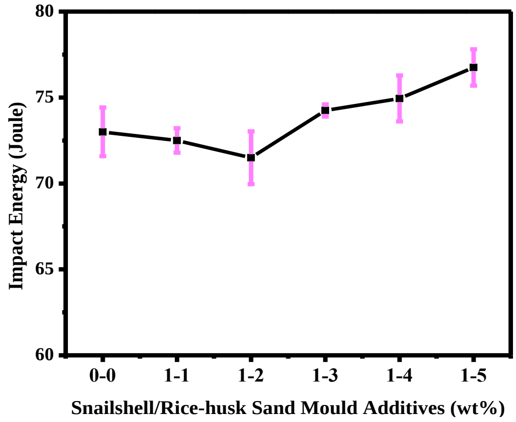

(b)

**Figure 7.** Compressive (a) and Tensile Strength behaviour of cast Al alloy

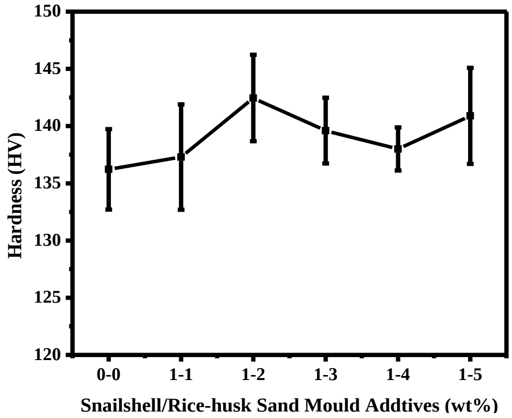
The impact strength and hardness behaviour of AlSiMg alloy cast in moulding sand with and without SnS-RHA additive was as presented in Fig. 8a and b. The impact strenght is a measure of toughness of a material to fracture. For the control sample, the impact strength is 73.00 J, with 1-1 SnS-RHA additive in moulding sand, the impact strength decreases to 72.50 J and the minimum impact strength was recorded in moulding sand beneficiated with 1-2 wt% additive equivalent to 2.05% reduction in toughness of the sample. The reduction in impact strength could be traced to decreasing strain properties and larger grain size characteristics leading to lesser grain boundaries formation to hinder the dislocation dislocation density, requiring low amount of force for deformation of the sample cast. Meanwhile, the hardness slightly increases from 136.22 HV with no additive and increased to 142.45 HV at 1-2 wt% additive in the moulding sand composition. The peak hardness value recorded can be linked to suspected faster solidification rate (fine grains) compared to other sample cast (Fig. 9). Beyond 1-2 wt% additives in sand mould, the impact strength slightly increases with maximum value recorded at 1-5 wt% additive in sand mould. This characteristic feature could be traced to evolution of moderate grain size intermingled with emergence of ductile-phase as observed in Fig. 9c which enhances the ductility property of the sample. The evolution of the ductile phase admist moderate grain sizes due to insulating power of high volume addition of rice husk ash which slows down the solidification rate for more ductile phase formation as noticed earlier [17], resulted in slight decline in hardness as presented in Figure 8b which is in line with existing findings [21, 22].

The wear rate of AlSiMg alloy cast in moulding sand without additives (control) and that cast in sand containing 1SnS-2RHA additive at a constant load and speed of 17 N and 300 rpm respecyively for 60, 120 and 180 s was as presented in Fig.9. It can be deduced that AlSiMg alloy cast with unbeneficiated moulding sand has higher wear rate for all durations of experimental runs conducted compared with sample cast with 1SnS-2RHA additive moulding sand. Meanwhile for both samples, the least wear rate was noticed when runned for 60s and increases with the duration of the wear test conducted. This implies that AlSiMg alloy sample cast with moulding sand containing

SnS-RHA additive is more resistance to wear compare to control sample.




(a)




(b)

**Figure 8.** Impact (a) and Hardness behaviour of cast Al alloy

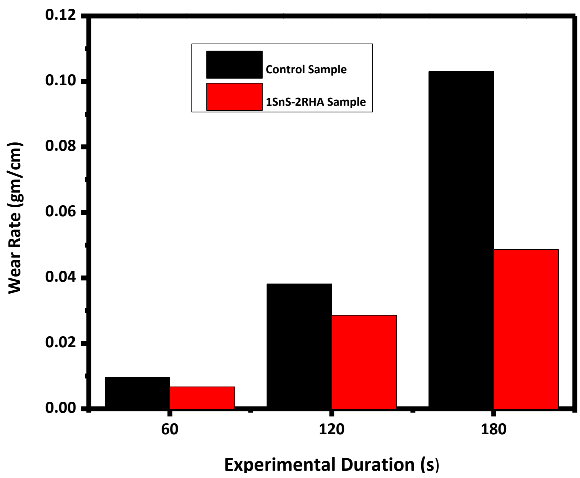



**Figure 9.** Wear rate characteristics of AlSiMg alloy

The characteristic high wear resistance of sample cast in moulding sand with additive could be traced to the high hardness value of sample produced fron 1SnS-2RHA moulding sand as a result of grain refinement and precipitation of harder second phase in the alloy structure (Fig.10b and d). This experimental outcome conforms with the work of [23], [24] where it was reported that wear rate increases with increase load and decrease with weight fraction of reinforcement in the alloy favoured by faster solidification rate.

### 3.3. Optical Micrograph Examination

Optical examination of selected cast AlSiMg alloy in moulding sand without additive (Fig.10a) and with additive (1SnS-2RHA (Fig.10b) and 1-5 (Fig,10c) as well as their respective grain size distribution (Fig.10d) were as presented in Figure 10. It was noticed that, addition of SnS-RHA additive has influence on the morphology of the cast AlSiMg alloy by affecting the phase formation and grain size distribution. Although, the phases in the control sample characterised with larger grain size was not conspicously seen as noticed in other samples cast in moulding sand with additives. The 1-2 wt% SnS-RHA moulding sand (Fig.10b) cast sample, possess uniform formation of hard and soft phases with smaller grain size distribution. This characteristic morphological feature guaranteed high dislocation density at the grain boundaries that create greater obstacle for interattomic motion, hence increase strength as observed in the mechanical performance of the AlSiMg alloy and presented in Fig.7 and 8. However, AlSiMg alloy cast in 1SnS-5RHA moulding sand has a mixture of conscupious hard and more ductile phases with relatively large grain sizes. This lessen the dislocation density of the interatomic molecules which account for strength reduction in AlSiMg cast in moulding sand with higher additive as depicted in Fig.7a and b. In addition, the precipitation of more ductile phase as discernible in Fig.10c can be attributed to the insulating property of the moulding sand at higher level of additive which prolong the solidification rate of the cast sample and its precipitation. It is worthy to note that, the average grain size for the control sample and sample cast in moulding sand with 1-2 and 1-5 wt% of SnS-RHA additives were 293±59, 88±26 and 206±101 μm respectively. This quantitative assessment of grain size distribution (Fig. 10d) confirms the grain refinement power of moulding sand with aditives at a specific limit and beyond which it may not favour the strength enhance as display in this study. This results agree well with the earlier findings [25], [26] where enhancement of mechanical property was attributed to grain refinement and other associated factors such as solid solubility and second phase variations.

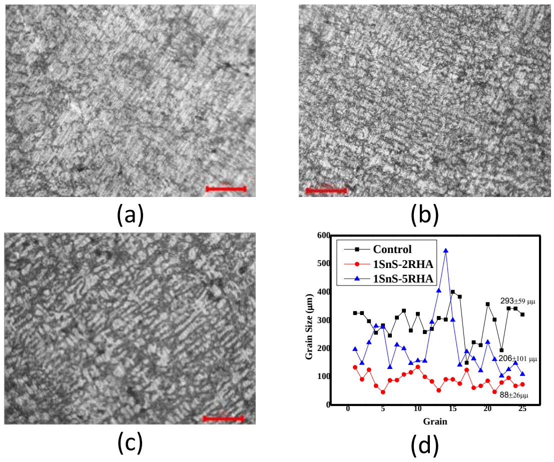



**Figure 10.** Optical Micrograph of AlSiMg alloy cast sand mould with: no (a), 1-2 wt%, (b) and 1-5 wt% (c) SnS-RHA additives

## 4. CONCLUSION

Performance characteristics of an eco-friendly agro-bio wastes (snail shell and rice husk ash) as moulding sand additives on mechanical property of AlSiMg alloy was experimentally carried out and the followings conclusions were drawn:

1. The inclusion of fine snail shell particle and rice-husk ash as sand mould additives influences the moisture content and permeability characteristics of the moulding sand. The peak permeability index (0.18 mm/s) and least water moisture (3.80%) was obtained in the mould containing 1SnS-2RHA additive which can permit a more passage of air-gasses which can minimise defect during casting operation.
2. 1SnS-2RHA additive in moulding sand formulation, enhance mechanical property with peak hardness, compressive and tensile strengths of 142.45 HV, 427.616 MPa and 142.45 MPa respectively. This indicated mechanical property enhancement of 11.60, 22.8 and 4.4% relative to control sample in compressive strength, tensile strength and hardness respectively.
3. AlSiMg alloy cast from 1SnS-2RHA additive in sand mould has an improved wear resistance under the same testing condition.
4. Therefore, the addition of 1 wt% snail shell and 2 wt% RHA when added as additive into a natural moulding sand can improve the mechanical and wear resistance of the resulting alloy.

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