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Corrosion Performance of AA6061/Rice Husk Ash Composite for Engineering Application

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Abstract.
The major problem confronting aluminium alloy in various fields of engineering is based on the structural and continual failure of a component in service. The difficulties encountered are resolved through addition of RHA as strengthening agent to the aluminium metal matrix composite. The fabrication of MMC (AA6061/RHA) using metallurgical stir casting route in the array of 2, 4, 6 and 8 wt. % of RHA was done. Polarization test carried out in 0.75 M of H_2SO_4 on the composite shows enhanced corrosion susceptibility. Mechanical properties such as microhardness and tensile were performed on the developed composite. Corrosion analysis of RHA embedded in AA6061 revealed improved corrosion performance. Furthermore, the microstructural change through SEM shows that the incorporation of RHA in AA6061 aluminium alloy minimize corrosion effects. It also shows the homogenous dispersal of the fortification along the grain boundaries and reduced fracture propagation

Key words: MMC; AA6061; Rice husk ash; SEM; Mechanical properties; Corrosion.

1. Introduction

The need to augment the enormous expansion means of transportation, aviation and productions have necessitated the urge to improve mechanical and structure such as hardness and enhanced corrosion performance [1, 2]. Recently, research has shown that metal matrix composites are applied in the industries to improved strength to weight ratio. The production of cheaper materials, particularly metal matrix composites with superior features have been on the mind of numerous scientists [3, 4]. AMMC has remained the best material for research in manufacturing feasible engineering mechanisms [5]. Due to its low-cost factors, shape, size, distribution, second phase nature, there is wettability between the matrix and the second phase and ease of fabrication. Aluminium copper and aluminium zinc based alloys are composite for the production of engineering parts [6]. For some structural applications with the purpose of either replacing products of aluminium alloy, recently material for the production are based on stiffness, strength and reduction in weight and energy efficiency. Al-Mg-Si alloys (AA6061 alloys) comprise of other elements in small % weight such as iron, copper, manganese, chromium, zinc and titanium with silicon and magnesium as its significant elements for alloys. Aluminium alloys are used mainly in the automobile and aircraft industries because of their perfect plasticity, resistance to corrosion, lightweight and medium strength. After proper working processes such as extrusion, forging and rolling, and heat treatments which include majorly ageing treatments, solution and quenching [7]. The use of aluminium metal with agro-industrial waste as reinforcement has been gaining more popularity because it improves the mechanical properties of the composite. This process reduces pollution, contamination of the environment and saves manufacturing costs.

Rice husk is a low-cost substance that can be employed to manufacture silicon carbide whiskers, which is in turn utilized to reinforce ceramic cutting tools. Rice husk ash (RHA) is well-known to comprise of silica. The silica composition is made of super strength ceramics and reduces the melting temperature. It provides high corrosion and wear resistance, low-cost, high-performance aluminium composite, increases in mechanical features such as tensile strength and hardness [8]. Furthermore, predominant study shows that eco-friendly agricultural by-products like rice husk ash particles are used to reinforce aluminium alloy [9]. The study aims to improve the life span of the aluminium alloy for high ability to withstand corrosion and damage.

2. Materials and experimental procedure

2.1 Raw materials

The production of AA6061/RHA composite involves using AA6061 aluminium alloy as the matrix. Table 1 shows the chemical configuration of AA6061. The RHA is washed with water to eliminate dust and dried at room temperature for one day and then heated to 200 ^{o}C for I hour to eradicate moisture. It is then heated to 600 ^{o}C for 12 hours to eliminate carbon content as shown in Figure 1.

Table 1: Chemical Properties of AA6061

Composition	Al	Si	Mg	Cu	Cr	Mn	Ti	Zn	Fe
Weight (%)	97	0.5	1.0	0.3	0.25	0.14	0.13	0.22	0.5

Figure 1: As received Rice Husk

2.2 Formation of AA6061/RHA composite

The stir cast arrangement is shown in Figure 2. Homogenous distribution of RHA in the AA6061/RHA composite was done by melting aluminium billet in the electric furnace and adding the RHA in the molten manufactured by a mechanical stirrer [10]. The molten AA6061 alloy with RHA was transferred and change to solid in the mould. The distribution of the RHA in AA6061 matrix is the result of the liquefy temperature, strength and place of the machine stirrer [11].

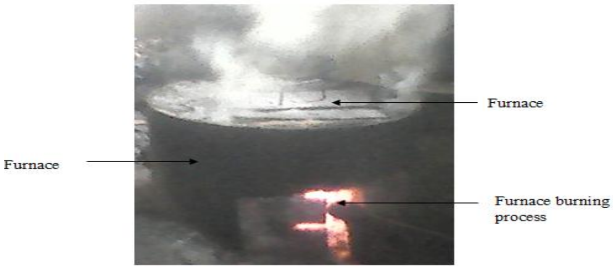

Figure 2: Stir casting set up

2.3 AA6061/RHA composite preparation procedure

The research involves using the stir casting method to heat aluminium in a furnace at 750 ^{o}C. Fabrication of AA6061/RHA composite involves melting of the matrix material, materials blending and casting of the composite. A 3.5kg of AA6061 billets obtained from aluminium rolling mill was transferred to the crucible fixed in the set-up arrangement. The heated furnace melted the aluminium billet to 750 ^{o}C. This was repeated for 98 %, 96 %, 94 % and 92 % AA6061 ingots aluminium alloy was stirred steadily at 450 rpm for 15 min. Nano-sized RHA added in the percentage of 0 %, 2 %, 4 %, 6 % and 8 % weight is shown in Table 2. The liquefied developed sample was moved to a good metal mould of cylinder-shaped size of (250 x 50) mm. The liquid composite solidified to about eight hours for proper solid conversion. Finally, the cast composite was taken for further characterization.

Table 2: Weight percentage of AA6061 alloy and RHA

Samples	AA6061 (%)	RHA (%)
A	98	2
B	96	4
C	94	6
D	92	8

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Characterization of AA6061/RHA composite

The surface morphology analysis of AA6061/RHA was formed using the SEM after etching the specimen with 0.1 M HCl. Corrosion characteristic of the samples was examined by Potentiodynamic. Brinell hardness and tensile testing machine were used in carrying out mechanical properties.

2.3.1 Corrosion test

For the electrochemical process study, an Autolab Potentiostat (PGSTAT 30) with the software (AuT71791) was used. A Potentiostat is an electronic hardware that composes of three-electrode cells to explore the reaction mechanisms of the working metal. The three electrodes include the reference electrode, working electrode and contact electrode. The test was performed four times on the samples to ensure accuracy in agreement with earlier research by [12]. From the result, substantial corrosion resistance of the produced composite was noticed and compared to the as-received sample.

2.3.2 Microhardness test

The hardness of the AA6061/RHA composites of size (20 x 5) mm was studied using Brinell hardness method to find their Brinell hardness values. This testing method usually uses a high test load of about 3000 kgf and an indenter of 10 mm diameter so as for the indentation outcome to be better than the most surface and sub-surface incompatibilities. The hardness measured at a load of 100 g for 15 seconds; the impression got is calculated with a Brinell microscope across at least two diameters, at mostly right angles to each other and the results computed The Brinell hardness number obtained from equation 1.

$$BHN = \frac{2P}{\pi D(D - \sqrt{D^2 - d^2})} \quad \text{...(1)}$$

where
P= applied load (kilo Newton)
D= indenter diameter (square millimeters)
d= indentation diameter (square millimeters) [13, 14].

2.3.3 Tensile Strength

Experiment was performed by SM1000 with the capacity of 100 KPa. The readings of the mean tensile strength were taken and analysed. It can be employed to do a lot of tensile and compressive tests on components, structures and various vast scope of materials from metals, concrete to rubber, hence its name. This machine has multiple load capacities ranging from 5 kN to 2,000 kN.

3. Results and discussions

3.1 Potentiodynamic polarization measurements

The results of the cast samples in 0.75 M of H_2SO_4 obtained through the interpolation of Tafel plot is shown in Figure 3. The outcomes show the effect of preventing corrosion by adding RHA in the test solution. It shows that the inclusion of RHA prevents energetic sites of the AA6061 aluminium alloy, reducing current exchange. It is interesting to know that RHA serve as a blended protection in AA6061/RHA matrix. The corrosion rate of specimen E with 92 % AA6061 and 8 % RHA has the lowest rate of 0.64076 (mm/yr) as shown in Table 3 while Specimen A with 100 % AA6061 and 0 % RHA has the peak corrosion rates.

Table 3: Potentiodynamic Data for AA6061/RHA Composite

Samples	Ecorr (V)	icorr (A/cm^2)	Cr (mm/year)	Rp (Ω)
A	-0.72367	$1.26x10^{-4}$	1.4869	211.23
B	-0.62825	$5.51x10^{-5}$	1.0132	235.59
C	-0.63232	$5.76x10^{-5}$	1.4692	265.91
D	-0.64415	$1.29x10^{-4}$	0.66975	448.64
E	-0.62394	$8.72x10^{-5}$	0.64076	481.95

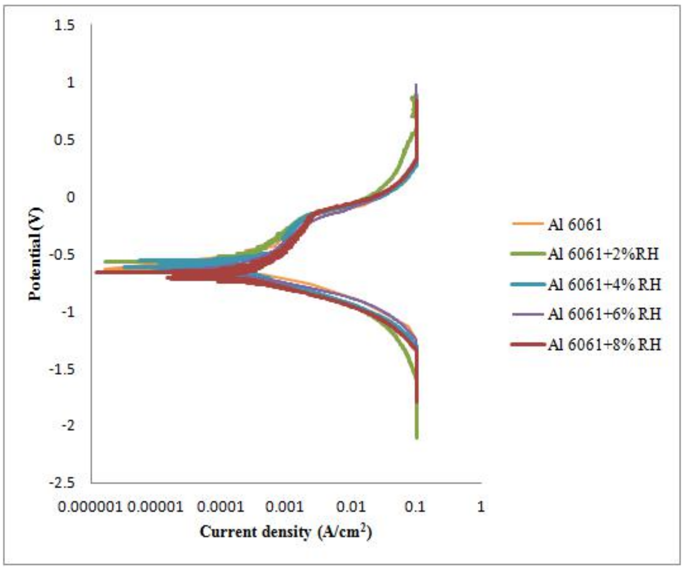

Figure 3: Potentiodynamic polarization curves for AA6061 alloy and AA6061-RHA composite**.**

3.2 Microhardness behaviour AA6061 alloy and AA6061/RHA composite

Figure 4 shows the microhardness values for AA6061 alloy and AA6061/RHA composite. The result of the analysis revealed that sample E with 92 % AA6061 and 8 % RHA has the maximum value of 188 BHN. The inclusion of RHA has a noticeable effect on the AA6061 alloy. Figure 4 shows that the as-received material improved from 141 BHN to 188 BHN which signifies a 25 % improvement in hardness. The enhancement in the hardness was due to the high silica of the RHA. However, a remarkable rise in the hardness value was noticed for 6-8 % RHA composition compared to the 0-2 and 2-4 % RHA inclusion as shown in Figure 5. The hardness was enhanced at a particular reinforcement weight when compared to the as-received sample. Due to the higher hardness value of the reinforcing particle (RHA), an opposition produced against plastic deformation which led to an increase in the reinforced composite's hardness. This result of increased hardness of the alloy composite is similar to other experiments conducted by [8].

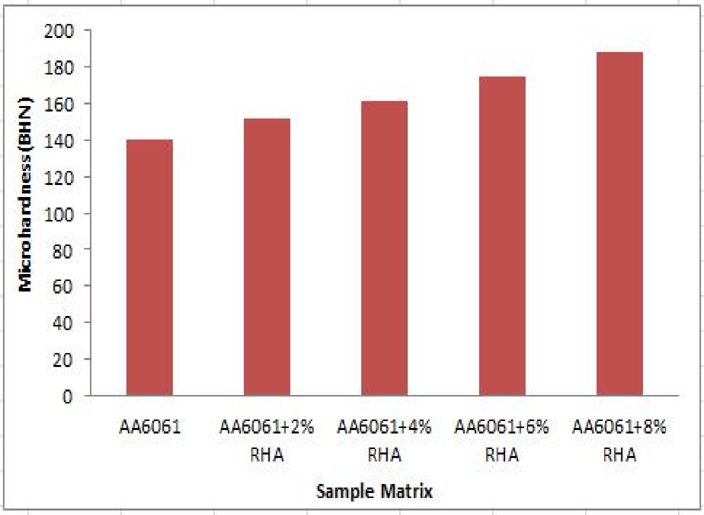

Figure 4: Brinell microhardness of AA6061-RHA composite

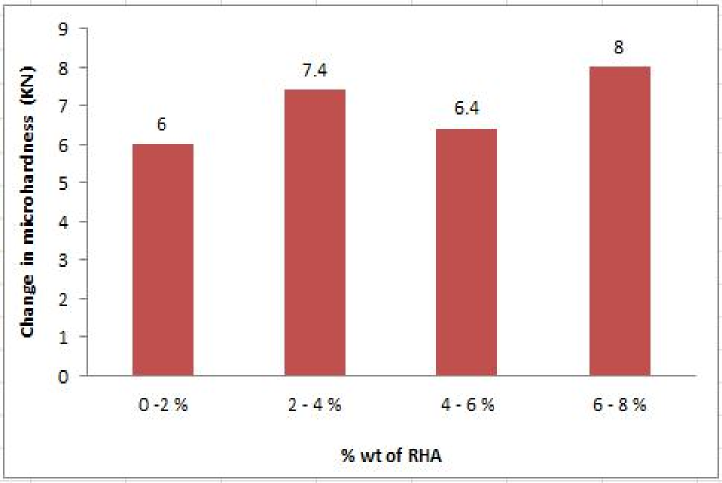

Figure5: Variations in microhardness values

3.3 Tensile strength of AA6061 alloy and AA6061- RHA composite

Figure 6 depicts the influence of RHA particles on the tensile strength for 0 %, 2 %, 4 %, 6 % and 8 % inclusion. From the graph, the tensile strength improved by the incorporation of RHA as reinforcement in comparison to the as-received sample. The tensile strength increased from 4453 KPa to 6339 KPa by the incorporation of RHA. This improvement in tensile strength shows that RHA can be used to reinforce AA6061 alloy. Moreover, Figure 7. shows the analysis RHA inclusion in percentage progression. There is a higher increase of tensile strength between 0 and 2 % additions of RHA. The addition of 0- 2 % RHA greatly changes tensile strength, similar to the ductility of composite [5].

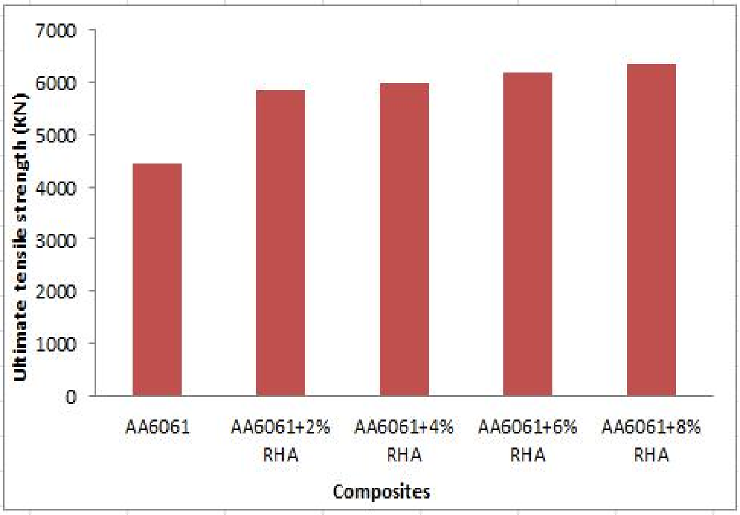

Figure 6: Tensile Strength of AA6061 alloy and AA6061/RHA composite.

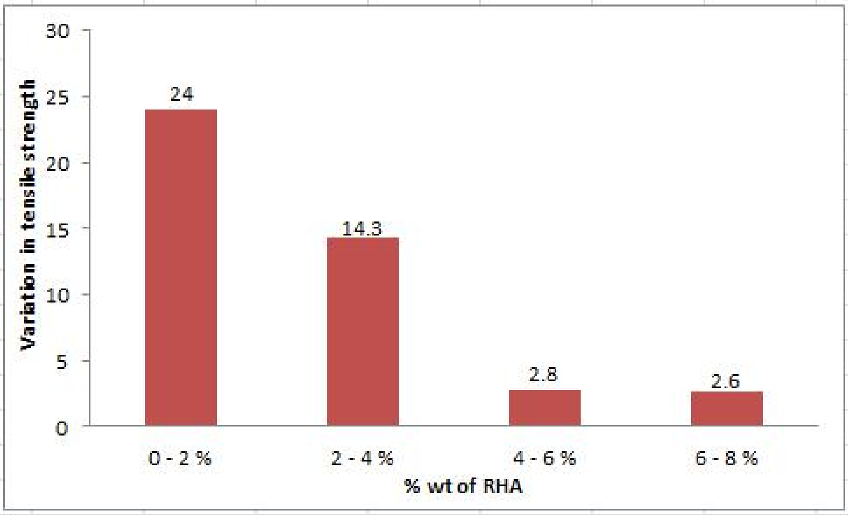

Figure 7: Change in level to level comparison of tensile strength

3.4 Microstructure analysis of AA6061/RHA composite

Figure 9 and Figure 10 a-d show the microstructure of 0 %, 2 %, 4 %, 6 % and 8 % addition of RHA. Figure 10 (a), (b), (c) and (d) show the existence of pit and crevices in the AA6061/RHA composite. The micrographs show that the RHA was uniformly distributed. The surface morphology revealed that the addition of RHA reduced the aluminium matrix particulate. Figure 10 a-d shows that the incorporation of RHA with nanoparticle decreases the particulate size of the as-received sample. The reduction in particulate dimension is due to the higher percentage of the grain periphery, which hinders grain development [16, 17]. As shown in Figure 9, there is dynamic recrystallization in AA6061 by the building of novel grains in the grain borders.

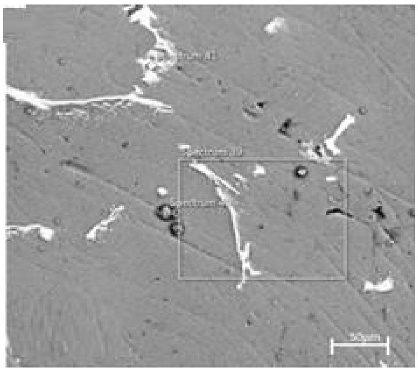

Figure 9: SEM of starting aluminium

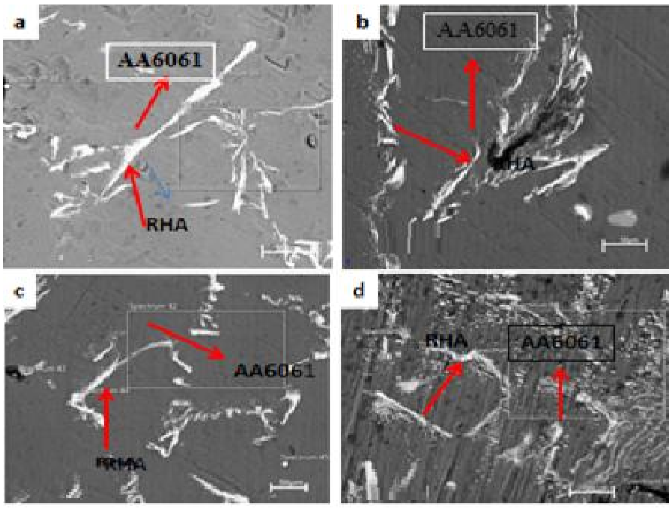

Figure 10: SEM micrograph of (a) Sample A (98 %AA6061 and 2 %RHA) (b) Sample B (96 % AA6061and 4% RHA) (c) Sample C (94 %AA6061 and 6 % RHA) (d) Sample D (92 % AA6061 and 8 % RHA).

4. Conclusions

The following conclusions were made from the analysis of AA6061/RHA composites:

- AA6061/RHA composites show extensive improvement on the corrosion performance of the developed material.
- The hardness increases with increasing the percentage reinforcement of RHA with 24 % increase on the incorporation of 2 % RHA. Also, the tensile strength improves on the inclusion of RHA.in the composite
- Finally, surface morphology changes as revealed by the SEM micrograph indicating the incorporation of RHA in the AA6061 aluminium alloy.

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