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Assessment of Mechanical and Corrosion Behaviour of Aluminum 6063 Reinforced with Rice Husk Ash in Brine Solution

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Abstract: - Corrosion behavior and Mechanical properties of Al6063 reinforced with rice husk ash (RHA) was investigated using stir casting method. The RHA was added in the variation of 3, 5, and 7 % by weight. Unreinforced samples were produced for control experimentation. Tensile strength, hardness and percentage elongation of the samples were obtained using electronic tensiometer and brinell hardness testing machine. Corrosion study of the samples was carried out using Versa-stat potentiostat with linear polarization technique. Results showed that the hardness and tensile strength of the reinforced samples decreased with increasing RHA content. Also, the percentage elongation of the reinforced samples increased slightly above the control samples. The corrosion results revealed that reinforcing 3 wt % RHA gave the highest resistance to corrosion in brine solution. Generally, corrosion rates were observed to reduce relative to the control sample.

Keywords: Rice husk, corrosion, casting, composites, stir casting

I. Introduction

Aluminium has a wide range of applications such as space industry, transportation and structural purposes. Also its remarkable low density and ability to resist corrosion has made it unique material for engineering application. Corrosion resistance can be excellent owing to the formation of a thin layer of aluminium oxide when the base metal is exposed to air, effectively preventing further, oxidation in a process termed passivation. However, the strongest aluminium alloys are less corrosion resistant and greatly reduced by aqueous salts, particularly in the presence of dissimilar metal. Hence it becomes corroded in aqueous chloride environment.

The development of aluminium metal matrix composites (AlMMCs) was one of the most notable breakthroughs in material science. This innovation was to improve the characteristics of aluminium alloys. Among the wide range of application of AlMMCs are aerospace industries, transportation equipment, marine, welded constructions, bridge railings, due to their attendant high strength and wear resistance over unreinforced aluminium alloys (Srivyas, *et al.*, 201; Singh and Chautan, 2016; Udoye *et al*., 2019). Reinforcing AlMMCs with agro waste derivatives such as walnut kernel, bamboo leaf ash, coconut shell ash, rice husk ash have gained prominence in recent times (Ikubanni et al., 2020; Akbar *et al*., 2020). Owing to low cost, easy accessibility, improved mechanical properties in comparison to conventional particulates, agricultural waste material rich in oxide content can be employed as substitute material in metal matrix composites (Sydow *et al*., 2021). Several studies have attempted to use Titanium carbide (TiC), Silicon carbide (SiC), graphite and Boron carbide (B_4C) as matrix in AlMMCs in past few decades improving wear resistance, hardness, elastic modulus and tensile strength (Saikrupa *et al*., 2021). However, these ceramic reinforced materials are costly, not environmental friendly and reduce interfacial strength of AlMMCs. Rice husk ash (RHA) is easily available all over the world and less expensive alternative to other conventional reinforcing material particles such as Silicon carbide. The Silicon dioxide (SiO_2) in agro waste ash is high with other components such as carbon and other metallic oxides. Therefore, this research attempts to study the corrosion and mechanical properties of aluminium 6063 reinforced with RHA.

Several studies on the corrosion behaviour of aluminium metal composite (AlMCs) were available in literature. Zakariah (2014), investigated the corrosion behaviour of AlMCs produced with Al powder and SiC immersed in 3.5 wt. % of NaCl at both ambient and high temperatures. The focus was to determine the effect of SiC reinforcement on size and volume fraction on the corrosion characteristics and micro structure of the produced metal metrix composite (MMCs). The result showed that the corrosion resistance of Al/SiC MMCs was higher than that of pure Al. Study on electrochemical examination of composite using Al-Si12 as a matrix carbonized eggshell fly ash as reinforcement in 3.5 wt% NaCl was carried out by Ononiwu et al. (2022). The result revealed that corrosion rate of the cast AMCs increased as the fraction of reinforcement increased. Nanjan and Muralia (2022), investigated the influence of reinforcing Al6061 with Al_2O_3 , graphite, B_4C and SiC as 4% and 5% using stir casting technique. The composite produced were tested in 3.5% NaCl and 1MHCl solutions. The result revealed enhanced corrosion performance and improved mechanical properties.

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II. Methodology

Preparation of Rice Husk The husk was collected into an oven and dried at a temperature of 800^0C for 2 hours. The dried husk was put in a ball mill with balls as a grinding media and milled. After grinding it was poured into a set of sieves and vibrated for sieving. -150 microns was obtained for the reinforcement.

Rice is the seed of the grass species oryzaglaberrima or oryza sativa. Rice husks are the protective coverings of rice grains which are separated from the grains during the milling process. Rice husk constitutes about 20 % of the weight of rice and its composition is as follows: cellulose (50%), lignin (25-30 %), silica (15-20 %), and moisture (10-15 %). Bulk density of rice is low and lies in the range 90-150 kg/m^3. Researchers have shown that addition of rice husk ash in aluminium alloy matrix yield better mechanical and physical properties (Omole*et al.*, 2014)

Casting of the reinforced composite

A rod of diameter 15 mm was employed as a pattern for mould preparation using green sand. The prepared mould surface was allowed to air dry for 24 hours. The aluminium 6063 ingot was charged into a lift out crucible furnace and heated to a temperature of 670^0 C using cooking gas as fuel. The rice husk ash was then added to the melt, the slurry was mixed manually for about 5 minutes. The composite slurry was then heated to a temperature of 700^0 C and stirred using mechanical stirrer at a speed of 250 rpm for 10 minutes. This was to aid higher recovery of the husk in the melt. Slag was tapped from the surface of the composite slurry. It was then poured into the already prepared mould at a temperature of 700^0C and left to solidify to room temperature in the mould.These castings were produced by varying the composition of the of the rice husk of -150 microns as 3 %, 5 % and 7 % by weight composition of the casting. Before the addition of rice husk for reinforcement, aluminium 6063 ingot was melted and cast into mould at a temperature of 690^0 C to serve as control. Subsequently, the castings were knocked out of the mould after cooling to room temperature and fettled. Samples were further cut out for charactertization.

Corrosion Measurement

Sections of the developed samples were subjected to electrochemical corrosion test using Versa-Stat potentiostat with a conventional three electrode cell consisting of Ag/AgCl reference, counter and working electrodes. In the electrolytic cell containing 50 mL of NaCl solution, the prepared sample works as working samples, platinum which works as counter electrode and Ag/AgCl as reference electrode were used. The potentiodynamic potential scan was fixed for -250 mV to +250mV with scan rate of 1 Mv/s. The following equation is noted:

$$i_{corr} = \frac{1}{Rp}\left\{\frac{(\beta a\beta c)}{2.303(\beta a+\beta c)}\right\} \quad (1)$$

Modifying equation (1) with Faraday law,

$$CR = i_{corr}\frac{K.EW}{d} \quad (2)$$

where

i_{corr} is the corrosion current density in A/m^2; K is a constant that defines the units for the corrosion rate; EW is the equivalent weight in grams/equivalent; d is density in g/cm^3; CR is the corrosion rate and βa *and* βc is Tafel slopes of the anodic and cathodic reactions respectively.

Mechanical Testing

Hardness Test

Sample of about 20mm height was cut out from the as-cast and the produced composite for hardness test using brinell hardness testing machine. The surfaces were ground and polished after which multiple indentations were carried out on the test samples. The average hardness values were finally obtained.

Tensile Strength test

An electronic tensometer was used to carry out tensile test on the samples. Tensile samples were initially machined on lathe machine to the size that conforms to the shape which the machine can accommodate. The samples were machined with a gauge length of 40 mm and diameter of 5 mm. The tensile results were obtained by pulling the samples in tension to fracture and generating stress – strain curves for each sample. The tensile strength and percent elongation were then obtained from the stress strain curves.

Table 1: Chemical composition of aluminum 6063 alloy.

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Element	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Al
%Content	0.45	0.22	0.02	0.03	0.50	0.02	0.03	0.02	Bal

III. Results of Discussion

Mechanical properties (behaviour)

The mechanical properties of the produced composites are shown in Figures 1 – 3. The hardness value of the composites is presented in Figure 1. From the hardness values, it is noticed that the hardness of the samples reduces with increase in the weight percent of RHA in the composite. Hardness values of 23.4, 22.6 and 21.3 were exhibited by samples with RHA content of 3, 5 and 7 respectively. The reduction in hardness with increasing RHA may be due to low content of the hardening agents in the RHA such as silicon and other refractory metal oxides (Alaneme et al; 2013).

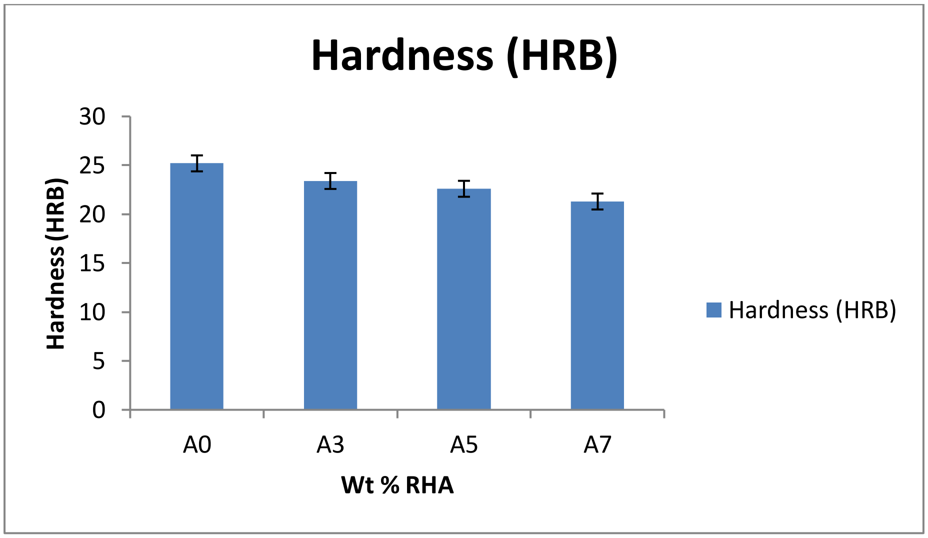

Fig 1: Variation of hardness for the Al6063 Composition produced

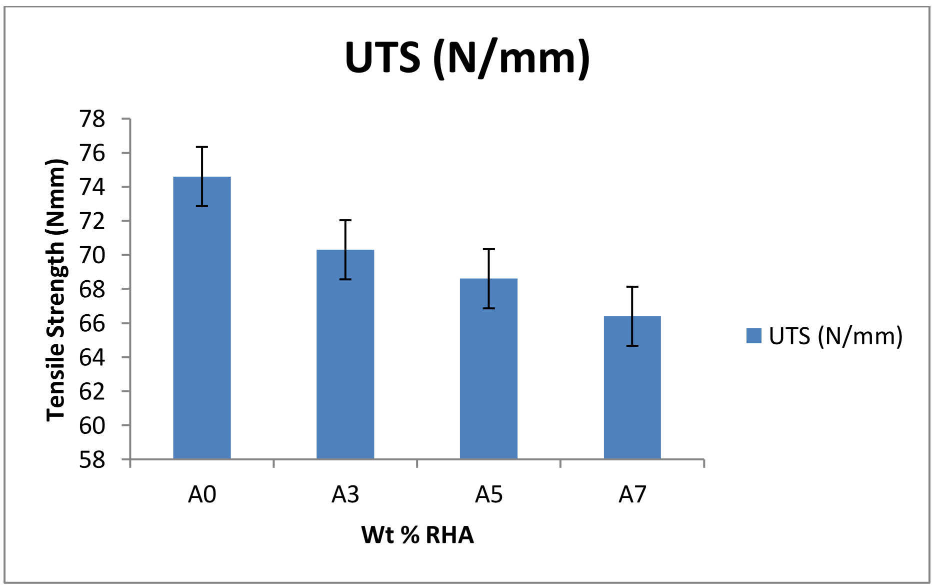

Fig 2: Variation of ultimate tensile strength for the Al6063 composition produced

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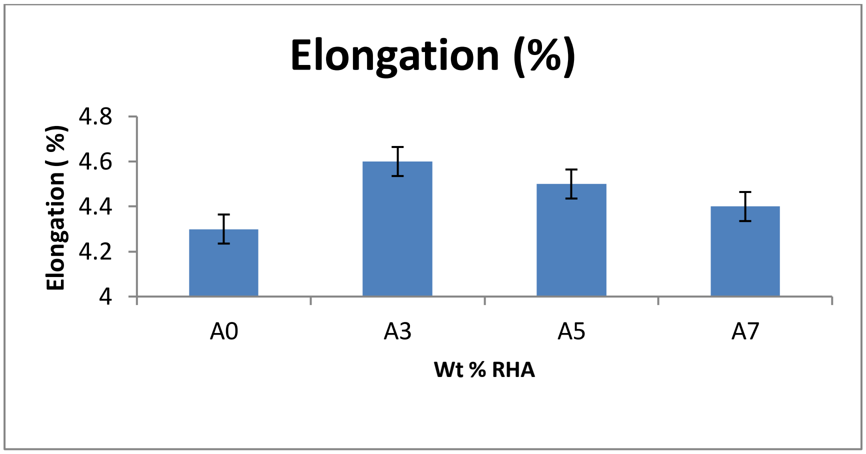

Fig 3: Variation of % elongation for the Al6063 composites produced

The tensile strength results shows in figure 2 exhibits similar trend to that of hardness. The tensile strength of the Al6063 composite reduced with increase in RHA content. The composites sample with 3, 5 and 7 % RHA recorded tensile strengths of 70.3, 68.6 and 66.4 N/mm respectively. For the percent elongation as displayed in Figure 3, there was no significant variation in % elongation as the RHA content of the reinforced samples increased. The % elongation values of the composites produced were within the range of 4.3 % and 4.6 % with some of the reinforced samples having slightly higher % elongation values compared with those without RHA.

Corrosion Characteristics

Figure 4 shows the potentiodynamic curves of aluminium 6063 reinforced with rice husk ash in 0.5 M NaCl solution while Table 2 presents the potentiodynamic polarization data obtained from the Tafel plot.From the polarization curves of the composite, a significant polarization potential E_{corr}value was attained. The control sample recorded corrosion potential of -789.884V;samples with 3 %, 5 % and 7 % RHA recorded corrosion potentials of -803.580 V, -809.545 V and -790.05 V respectively. The control sample is more prone to corrosion in the 0.3 M NaCl solution for the exposure period.The incorporation of rice husk ash gives a better corrosion resistance effect. The sample with 3 % RHA has the least corrosion rate of0.0094994 mm/year. A general look at the corrosion parameters measured also reveal that this sample exhibited the highest corrosion resistance out of all the reinforced samples (lower corrosion rate and current density). That simply shows the sample has the best corrosion resistance in the NaCl solution. According to Fayomi et al., (2016), this could be attributed to the ability of the reinforcement to form passive film on the aluminium alloy in NaCl solution. The samples reinforced with 5 % and 7 % RHA have corrosion rates of 0.051109 and 0,067814 mm/year respectively. All the reinforced samples recorded lower corrosion rates compared with the control sample which is 0.11884 mm/year. Although the corrosion rates of the aluminium composites increased with increase in wt. % of the RHA, however, a cursory look at the result shows that the inclusion of rice husk ash in the aluminium alloy yielded better resistance as against the as-received samples. The reduction in corrosion of the composite as compared to the unreinforced samples might be attributed to the formation of a protective film which retard ingress of chloride ions into the surface of the composite.

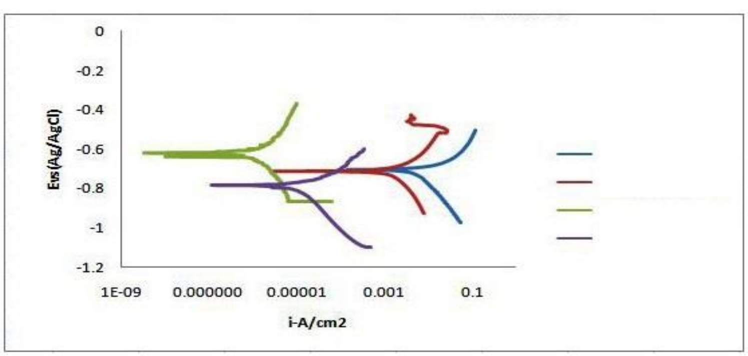

Fig. 4: Potentiodynamic polarization curves ofaluminium 6063 composite in NaCl solution.

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Table 2: Polarization data extrapolated from Tafel slope foraluminium 6063 reinforced with rice husk ash.

Sample in NaCl solution	E_{corr} (V)	i_{corr} (A/cm^2)	Corrosion rate (mm/year)
Control	-789.884	-10.241	0.11884
3 % RHA	-803.580	-818.66	0.0094994
5 % RHA	-809.545	-87.851	0.051109
7% RHA	-790.05	-5.8454	0.067814

IV. Conclusions

- The hardness of the reinforced samples decreased with increase in the weight percent of RHA.
- The tensile strength of the reinforced samples decreased with increase in RHA in the reinforced sample.
- The percent elongation showed no significant increase with variation in RHA content of the reinforced samples. However, the RHA reinforced samples exhibited slightly higher percent elongation compared with samples without RHA.
- The reinforced samples were more resistant to corrosion than the as-received samples.
- The reinforced material can be suggested for mitigating corrosion menace in marine environment.

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