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# Influence of Millet Husk Ash and Heat Treatment on Corrosion Rate of Al-4.5%Cu Matrix Composite in Acid Environment

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**ABSTRACT**

The influence of millet husk ash and heat treatment on corrosion rate of Al-4.5%Cu/MHA in acid environment was investigated. The composites were produced by double stir casting with MHA at 0, 1, 2, 3, 4 and 5wt% in Al-4.5%Cu alloy a matrix. As-cast samples and the heat treated once at 400°C consisting four (4) sets of samples in each of these compositions were immersed in 1M HCl solution for a period of 1 to 4 days. Corrosion rate measurement was utilized in evaluating the corrosion behaviour of the composites. The results show that the corrosion rate of unreinforced Al-4.5%Cu was relatively lower than that of the reinforced Al-4.5%Cu. Similarly, corrosion resistance of aged hardened composites were superior to that of the as-cast composites in 1M HCl solution, and the corrosion rate increased with increase wt% MHA. The increase in the matrix/reinforcement interface with increase in wt% MHA in the composites was identified as the likely reason for the increase in corrosion rates observed with increase in wt%MHA.

**Keywords** : Millet husk ash (MHA), Aged hardened, Corrosion rate, Al-4.5%Cu/MHA

## I. INTRODUCTION

The development of Al based metal matrix composite is attracting a lot of interest from materials engineers in developing countries [1]. Majority of modern structural materials, used for marine, aerospace & automotive applications are made up of composite materials. The earlier concept of composites is simply the mixing of two or more materials so that there will be improvement in resistance to corrosive and mechanical properties [2]. Metal composite materials with the light metal matrix are characteristic of high mechanical properties and low density which makes it possible to use them for elements and subassemblies made so far from the traditional engineering materials [3-5]. Aluminium matrix composites (AMCs) are noted for their unique combination of mechanical, physical and chemical properties which are scarcely attainable with the use of monolithic material [6,7]. This has made AMCs a strong competitor of steel in terms of versatility for use in a wide range of engineering applications [8]. AMCs currently applied in the design of components for automobiles, aircrafts, marine structures and facilities, defence assemblies, sports and recreation among many others [9-11]. Other notable advantages of AMCs are the relatively low cost of processing in comparison to other matrices types such as magnesium, copper, titanium, zinc and its amenability to production utilizing processing techniques applied for the production of conventional monolithic metallic alloys (such as casting and powder metallurgy) [12,13]. Currently, the design of high performance aluminium based composites at significantly reduced cost is receiving much attention from materials researchers [14,15]. This is discernible from the dominant use of stir casting by most researchers from developing countries and the sustained interest in the consideration of industrial and agro waste as reinforcements in AMCs [16,17]. Agro waste ashes obtained by the controlled burning of agro waste products such as baggasse, bamboo leaf, coconut shell, groundnut shell, and rice husk among others; have the advantages of low density and processing cost compared with common synthetic reinforcing ceramics such as silicon carbide and alumina [18,19]. The agro waste ashes have been successfully utilized to produce Al matrix composites with property levels which can be improved with the complement of synthetic reinforcements such as silicon carbide and alumina [20]. Heat treatment such as hyperquenching and ageing are normally carried out to improve their mechanical properties. Composites materials precipitation hardening occurs due to hyperquencing and ageing as a result of precipitation of the hard dispersive particles of the intermetallic phases. Intermetallic phases occurring in the aluminium alloys matrix most often are: $Al_2Cu$, $Al_2CuMg$, $Al_2Mg$, $Al_3Mg$, $Cu_9Al_4$ and $Al_2Cu_3$ [4,5].

Generally, the corrosion performance of Al-based SiC composites has been a major concern to researchers as efforts made to understand the corrosion behaviour of these composites, yielded results which to a large extent are not matching [21-23].

In view of the importance of corrosion resistance for selection and application of metal-matrix composites, the study on the influence of corrosion rate on as-cast and thermally aged Al-4.5%Cu/Millet husk ash composite in 1M HCl solution was carried out.

## I. MATERIALS AND METHODS

### A. Materials

The materials utilized in the present study are 100 percent chemically pure aluminium and copper obtained from Northern Cable Company (NOCACO) Kaduna State. The millet husk which is an agro residue having maximum siliceous ash content and available in dry form. Millet husk (MH) is an agricultural waste material abundantly available in Kebbi State having particle size of 64μm were utilized as reinforcing particulates.

### B. METHODS

**Preparation of MHA**

The collected millet husk was dried in the sun and ground to a fine powder using electrical milling machine. The fine powder was carburized at a temperature of 1200°C in an electrical resistance furnace in order to form the millet husk ash. The millet husk ash was then sieved using a set of sieves arranged in descending order of fineness and particle size analysis was carried out in accordance with BS1377:1990. A particle size of 64μm was selected and used. The photomicrograph of the sieved millet husk ash particle is as shown in Plate 1.

Plate 1: Photomacrograph of the sieve millet husk ash

### Composites Production

The samples were made using two step stir casting process performed in accordance with Alaneme [20] was utilized to produce the composites. The 4.5%Cu was first melted followed by aluminium and millet husk ash addition from 1 to 5%. The stirring was performed manually for 5-10 minutes to help improve the distribution of the particulates in molten Al-4.5%Cu alloy. The molten composites were then cast into prepared sand mould.

Al-4.5%Cu alloy without reinforcement was also prepared as controlled sample. From each compositions, eight (8) different sets of samples were produced with four (4) of each compositions been heat-treated and the other four (4) used in as-cast condition. Both the as-cast and heat treated sample were cut to sizes of 15×10×5mm, after which the samples surfaces were mechanically polished with emery papers starting from 120 grit down to 640 grit size.

### Heat Treatment

Four (4) sets of samples from each composition were solutionized at 400°C soaked for 4 hours to homogenized and then quenched in water. The quenched samples were then aged at 200°C for 2 hours and slow cooled inside the furnace.

### Corrosion Test

The corrosion tests were carried out in 1M HCl prepared using standard procedure. The samples both as-cast and aged hardened were weighed, de-greased with acetone and then rinsed in distilled water before immersion in still solution of 1M HCl exposed to the atmospheric air. The first, second, third and fourth samples from each composition were removed after 24 hour, 48 hours, 72 hours and 96 hours respectively were washed in distilled water and re-weigh. The corrosion rate for each sample was evaluated from the weight loss measurements following standard procedures.

## II. RESULTS AND DISCUSSION

### A. Corrosion Behaviour

Figure 1 to 6 present the corrosion rate with time for the as-cast and aged hardened samples immersed in 1M HCl solution.

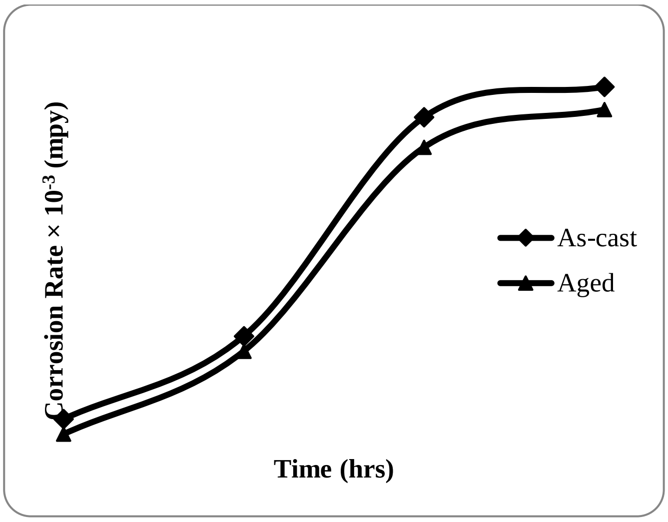


Figure 1: Variation of Corrosion Rate of Al-4.5Cu Alloy with Time

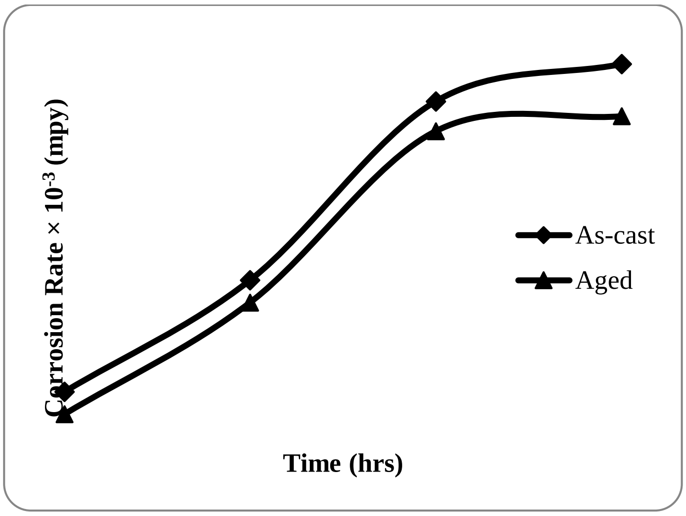


Figure 2: Variation of Corrosion Rate of Al-4.5Cu/1%MHA with Time

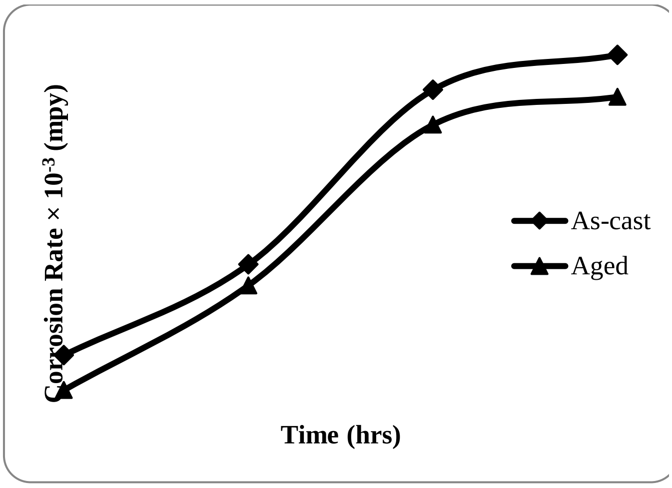


Figure 3: Variation of Corrosion Rate of Al-4.5Cu/2%MHA with Time

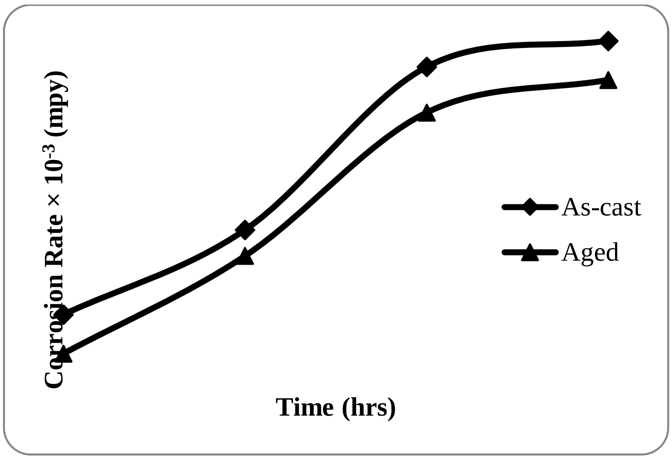


Figure 4: Variation of Corrosion Rate of Al-4.5Cu/3%Millet Alloy with Time

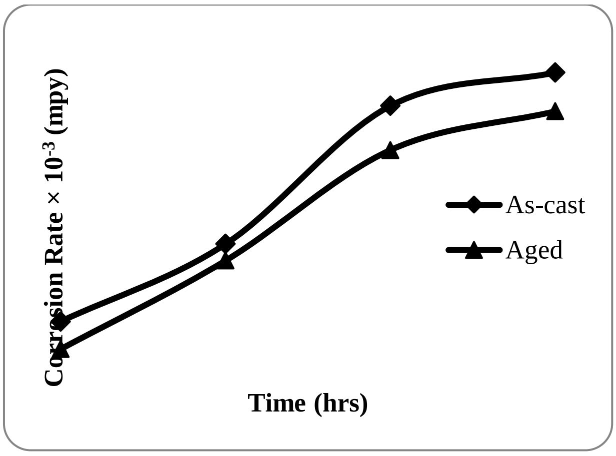


Figure 5: Variation of Corrosion Rate of Al-4.5Cu/4%MHA with Time

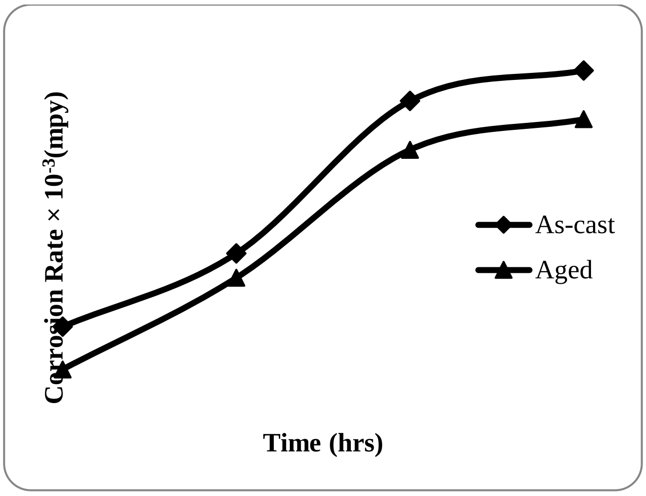


Figure 6: Variation of Corrosion Rate of Al-4.5Cu/5%MHA with Time

It was observed from Figure 1 that the corrosion rate of the unreinforced Al-4.5%Cu alloy in the as-cast and aged hardened condition were generally low compared to the reinforced composites (Figure 2 to 6). The low corrosion rate indicates that the passive films formed on the surfaces of the unreinforced Al-4.5%Cu alloy are stable and immune to attack when immersed in 1M HCl environment after the initial attack compared to the reinforced composites. Figures 2 to 6 show an increase in corrosion rate with increase time which could be due to the breakdown of passive films formed on the surface of the composites. Corrosion of MMCs almost always initiates at a physical or chemical heterogeneity such as reinforcement/matrix interface, defect, mechanically damaged region, grain boundary, inclusion, or dislocation [25,26]. Millet husk ash reinforced Al-4.5%Cu matrix composites corrosion mechanism may be due to the preferential initiation of corrosion in the millet husk ash/Al matrix interface. This often occurs in form of pits or micro-crevices in the matrix near the particle-matrix interface and form regions where there is particle dropout [27]. Grain boundaries (interface) are more chemically active (anodic) than the matrix. The reason for the anodic behaviour of the grain boundaries is that they have higher energies due to the atomic disarray in that area and also because solute segregation and impurities migrate to the grain boundaries [28].

Aged hardened Al-4.5%Cu/MHA composites (Figure 2 to 10) show a slight improvement in corrosion resistance compared with the as-cast Al-4.5%Cu/MHA composites at relatively same composition. The slight improvement in corrosion resistance can be attributed to the improved dispersion of the MHS in the Al-4.5%Cu matrix and the dissolution of second phase particles in the unreinforced alloy [29].

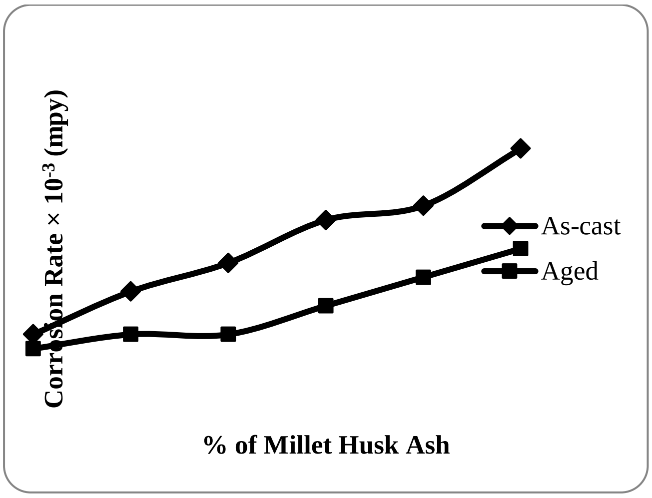


Figure 7: Variation of Corrosion Rate with % Millet Husk Ash at 24hrs

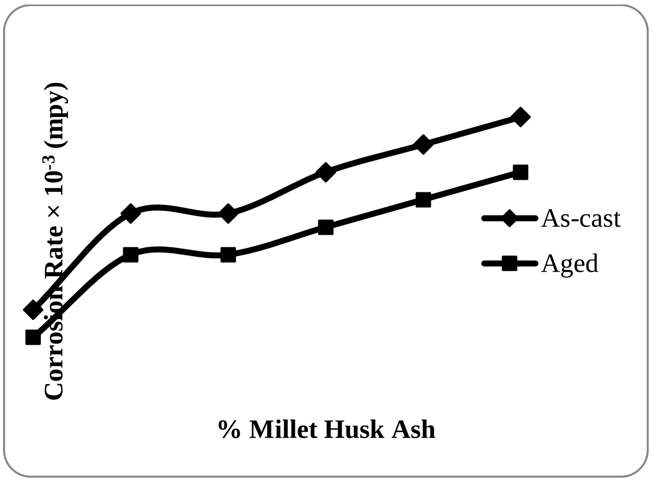


Figure 8: Variation of Corrosion Rate with % Millet Husk Ash at 48hrs

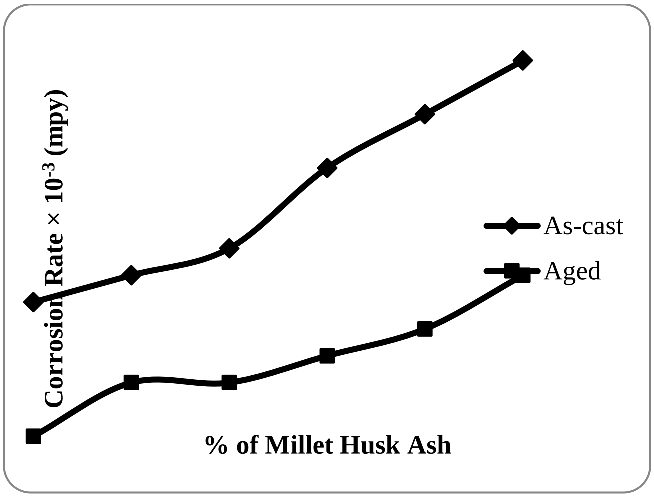


Figure 9: Variation of Corrosion Rate with % Millet Husk Ash at 72hrs

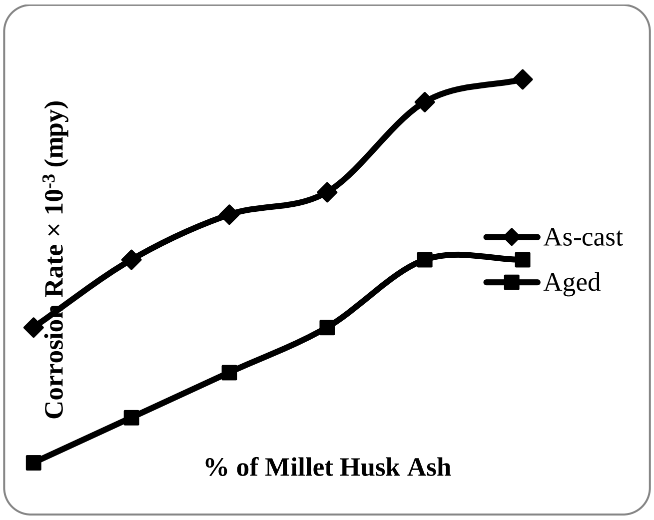


Figure 10: Variation of Corrosion Rate with % Millet Husk Ash at 96hrs

Figures 7 to 10 show the variation of corrosion rate with percentage millet husk ash for both as-cast and aged hardened samples immersed in 1M HCl solution. The Al-4.5%Cu/MHA composites experienced increase in corrosion rate with increase millet husk ash content from 0 to 5wt%. The more pronounced corrosion rate observed at higher MHA compositions could be attributed to the formation of localized galvanic cell at the Al-4.5%Cu matrix/MHA particulates interface which facilitates dissolution of Al matrix in such region [30].

## III. CONCLUSION

The corrosion rate of Al-4.5%Cu matrix composites containing 1, 2, 3, 4 and 5wt% MHA both as-cast and aged hardened and unreinforced was investigated.

The results show that:

1. The corrosion resistance of unreinforced Al-4.5%Cu alloy was superior to the reinforced Al-4.5%Cu matrix composites in 1M HCl, and the corrosion rates increased with increase in wt%MHA.
2. The increase in interface between the matrix/reinforcement with increase in wt%MHA in Al-4.5%Cu composites is responsible for increase in corrosion rate observed with increase in wt%MHA.
3. Corrosion started at places of mechanical damage, voids, and inclusions. Corrosion processes occurred mainly in the composite matrix although the local progress of corrosion was noticed in the micro-cracks.
4. Corrosion rate of aged hardened composites increases with increase in content of MHA.

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