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WEAR BEHAVIOUR OF Al/15% MELON SHELL ASH PARTICULATE COMPOSITE

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ABSTRACT

The wear behaviour of Al/15% melon shell ash particulate composite has been studied. The composite was fabricated by stir casting technique and the wear test was conducted under different sliding speeds (150, 200, 250 and 300 rpm) and loads (1 N, 2 N, 4 N and 5 N), using a three-body abrasive wear machine for a dwell time of 2 minutes. The surface morphology was examined by the scanning electron microscope (SEM). The effect of 15% melon shell ash was also investigated, and this resulted in a decrease of wear rate in the composite developed. From the results of wear test and microstructure analysis, the wear rate increased with increasing load for all the speed investigated with the lowest rate obtained at 2 N and a linear speed of 300 rpm, while resulst from microstructural study showed a uniform transfer film which became disrupted when subjected to wear. This suggests that the composite can be used as a reinforcing material for aluminum as observed in this study.

1. INTRODUCTION

Particles reinforced metallic composites have gained acceptance for use in many industries including aerospace, automotive, marine, and infrastructure (Umaru et al., 2016). In particular, aluminium and their composites are being increasingly employed in view of their relatively light weight and the fact that they can be tailored to have stacking sequences that provide high strength in all directions of loading (Callister, 2006).

Aluminium composite materials consist of matrix and reinforcement chosen according to the desired mechanical properties and the application (Callister, 2006). These composites in most cases have improved the product design and reduced the material and energy consumption. A special interest has grown in composites based on metallic matrix reinforced with raw lignocellulosic materials such as melon shell ash, pineapple, wheat straw, almond husk or rice husk (Umaru et al, 2016). This reinforcement introduces some advantages compared to traditional inorganic reinforcement such as their renewable nature, low density, non-abrasive properties, stiffness, biodegradability and low cost (Bledzki and Gassan, 1999).

In order to protect the individual reinforcement from surface damage as a result of mechanical abrasion or chemical reactions with the environment, a good matrix with ability to deform easily under applied load, transfer the load unto the reinforcement and evenly distribute stress concentration is required (Pamela, 2007).

Many metals and metal based composites are widely used for sliding couples against ceramics, polymers and other materials. However, when in contact, there is problem of friction and wear. The friction between metals can be attributed to two main mechanisms; deformation and adhesion (Zmitrowicz, 2006). The deformation mechanism involves complete dissipation of energy in the contact area while the adhesion component is responsible for the friction of metal and is a result of breaking of weak bonding forces between chains in the bulk of the material (Xue and Wang, 1997).

Aluminium exhibits poor wear and abrasion resistance, leading to early failure and structural problem in the machine parts. To minimize this problem, various suitable reinforcements such as carbon fibers, particulate reinforcement (such as melon shell ash) are added internally or incorporated into the aluminium matrix. According to Xue and Wang (1997) many investigators have reported that the coefficient of friction can generally, be reduced and the wear resistance improved when the metals are reinforced with carbon fibres. The tribological behaviour of aluminium composites is affected by environmental and operating conditions, and type, size, amount, shape and orientation of the fibres (Suresha and Chandramohan, 2004). A study of the relationship between the wear of the aluminium composites and operating parameters is desirable to obtain the better understanding on the wear behaviour. The present work intends to study the wear behaviour of Al/15% melon shell ash particulate composite.

2. MATERIALS AND METHODS

2.1. Materials and Equipment

Some of the materials used in this research include high purity aluminium electrical wire which was obtained from Northern cable company NOCACO (Kaduna, Nigeria), melon shell which was obtained from Samaru market in Zaria, Nigeria. Some of the equipment used include crucible furnace, stirrer, digital weighing balance, a cope and drag die cavity mould, hack saw, wear testing machine (tribometer) and scanning electron microscope (SEM).

2.2 Methods

2.2.1. Carbonization of the melon shell

The melon shell was collected, sun-dried for one day (24 hours) and ground to form powder. The powder was then packed into the crucible and fired at a temperature of 600 ^oC in the foundry workshop of the Department of Metallurgical and Materials Engineering, Ahmadu Bello University, Zaria for conversion into black ash which was used in this work. The ash was sieved using 75µm sieve size and a Min pal compact energy dispersive X-ray spectrometer (XRF) was used for elemental analysis of the melon shell ash.

2.2.2. Production of Al/Melon shell ash particulate composite

The composite was produced by using 15% melon ash with the balance being aluminium. High purity aluminium wire was charged into a crucible furnace which was raised to 700^oC so as to superheat the solid aluminium. The molten metal was continuously stirred in order to ensure a uniform melt. The crucible was first remove from the furnace and the melon shell was charged in and stirred continuously. A sand mould cavity was prepared with a hole diameter 30 mm and length 80 mm and was used to produce the bars. After casting, the bars were machined into the appropriate diameter of 25 mm and height of 5 mm for each composition and a total number of sixteen samples were used for the work.

2.2.3. Wear analysis

The wear test was carried out on the surface of the samples using a three-body abrasive wear machine (tribometer). The machine used fine abrasive silica as abrasive medium. Applied load of 1, 2, 4 and 5 N at 150, 200, 250 and 300 r.p.m wheel speeds and a dwell time of 2 minutes were employed as shown in Table 1.

Table 1: Process parameter with their values at four levels

Stage	Linear speed (rev/min)	Load (N)
1	150 200 250 300	1
2	150 200 250 300	2
3	150 200 250 300	4
4	150 200 250 300	5

Weight loss method was adopted to study the wear behaviour and the weight of the specimen before and after each test was measured using a digital weighing balance. The weight loss was determined for each sample by finding the difference between the initial mass and final mass. The wear process which is a function of weight loss was used to estimate the wear rate according to Equation (1).

$$\text{Wear rate} = \text{Initial mass } (M_i) - \text{Final mass } (M_f) \tag{1}$$

2.2.4 Surface morphology examination using scanning electron microscope (SEM)
Two (2) samples of 25 mm diameter and 5 mm in height each were cut from the produced Al /melon shell ash particulate composites and the microstructural constituents of the samples were studied using a scanning electron microscope. The samples were firmly held on the sample holder using a double-sided carbon tape before putting them inside the sample chamber. The SEM was operated at an accelerating voltage of 15kV and the images were recorded.

3. RESULTS AND DISCUSSION

3.1. Chemical Analysis of the Melon Shell Ash by X-ray Fluorescence (XRF)

The result obtained from the XRF analysis of the melon shell ash as shown in Table 2 revealed that silica (SiO_2) had the highest percentage composition and this was followed by potassium dioxide (P_2O_5), while vanadium dioxide (V_2O_5) was the least. The analysis confirmed that SiO_2, Al_2O_3, P_2O_5, K_2O and CaO were found to be major constituents of the ash. Silicon dioxide, iron oxides, alumina and titanium oxide are known to be among the hardest substances (Popoola et al., 2012; Anasyida et al., 2009; Totten, 2006). Some other oxides viz. Na_2O, ZnO, BaO was also found to be present.

Table 2: Chemical analysis of carbonized melon shell ash by XRF

Oxides	Weight %
SiO_2	75.3
P_2O_5	9.87
SO_3	0.63
K_2O	4.70
CaO	2.11
TiO_2	0.16
V_2O_5	0.006
MnO	0.367
Fe_2O_3	1.30
ZnO	0.476
BaO	0.098
MgO	0.37
Na_2O	0.53
Al_2O_3	2.67
LiO	1.41

The presence of hard compounds like SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO and TiO_2 suggested that the melon shell ash can be used as particulate reinforcement in various metal matrices. Therefore, the present work suggests the possibility of melon shell ash as particulate in metal matrix composites since the chemical composition has similarity with the XRF analysis of rice husk ash, fly ash and bagasse ash currently used in metal matrix composite (Prasad, 2006).

3.2. Wear Analysis

The results of the wear test is shown in Figure 1. It can be seen from Figure 1 that for a load of 1 N, the wear rate increased with increase in linear speed from 150 to 300 rpm. The highest wear rate of 7.989 mm^3/N/m was obtained from one of the samples subjected to a load of 1 N at a linear speed of 300 r.p.m, while the lowest rate of 0.559 mm^3/N/m was from one of the samples subjected to a load of 2N at a linear speed of 300 r.p.m. Every surface, however smooth will be rough in the microscopic scale and contain a range of tops and lows, and when two surfaces meet then this contact takes place at these projections which are little and relatively isolated (Aigbodion and Hassan, 2010; Prabhudeva et al., 2014). Thus, when applying a load on these surfaces, locally there will be a high pressure and heat which will cause overtaking of the elastic limits of one surface or both surfaces and the deformation of the projections in a plastic way, so that, the real contacting areas are increased to a limit to support the applied load. The contacting areas are inclined to be damaged under the effect of the relative movements between the two surfaces. The reduction in wear behavior occurs usually at one surface, because of the resistance in between surface to breaking and to the reaction of strain hardness during the adhesion process.

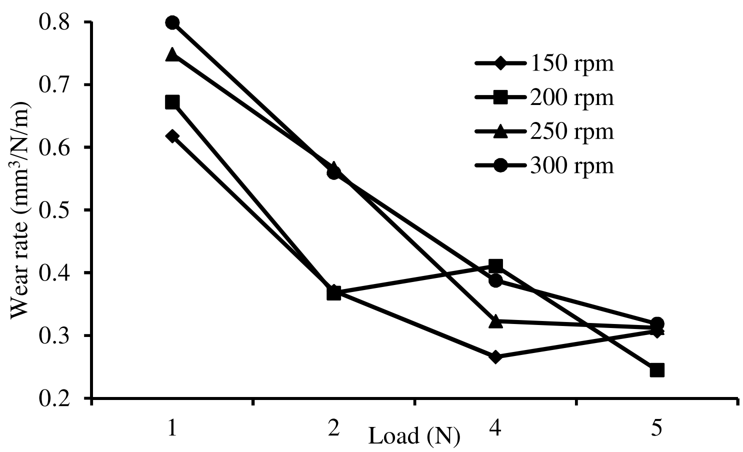

Figure 1: Variation of wear rate of Al/melon shell ash particulate composite with increase in loads

3.3. SEM Examination

From the micrographs, it can be seen that the Al/melon shell ash particulate composite not subjected to wear form a good thin and uniform transfer film (see micrograph in Figure 2). In the case of Al / melon shell ash particulate composite subjected to wear (see micrograph in Figure 3), there appear to be some disruption of transfer film, which has affected the wear rate performance. The worn out surface of the materials could be described as classical rachetting wear, as defined by Bledzki and Gassan (1999). The transition in wear rate observed for many metal matrix composites (MMCs) is faster and test temperature dependent and is believed to be the result of voiding/cracking between reinforcement and the matrix, both of which lead to fragmentation and separation of the surface (Clyne, 2001).

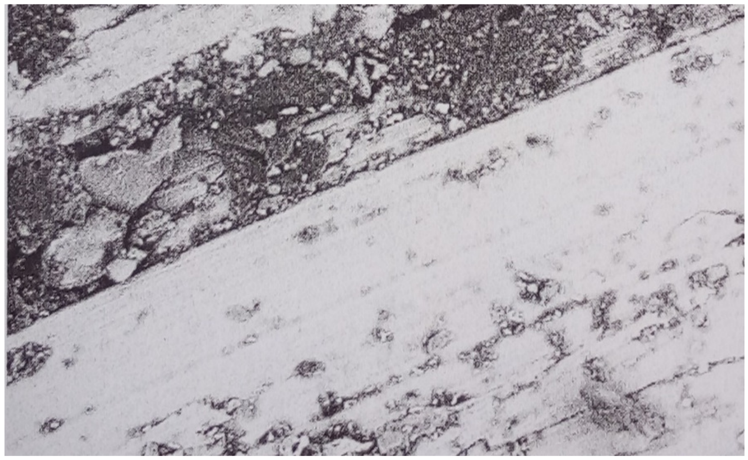

Figure 2: SEM examination of Al / melon shell ash composite before being subjected to wear ×1000

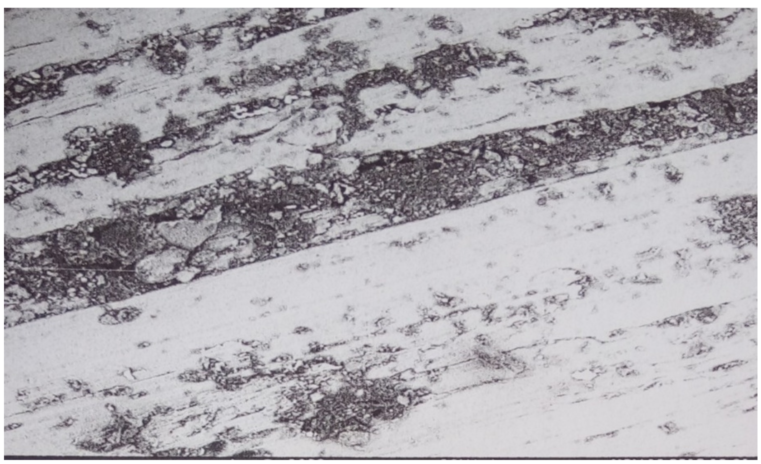

Figure 3: SEM examination of Al / melon shell ash at an applied load of 2N at a linear speed of 300rev/min ×1000

4. CONCLUSION

For all the linear speeds investigated, wear rate increased with increasing load. The highest wear rate was obtained at a load of 1 N and a linear speed of 300 rpm, while the lowest rate was obtained at 2 N and a linear speed of 300 rpm. Microstructural study shows that the Al/melon shell ash particulate composite not subjected to wear form a good thin and uniform transfer film which becomes disrupted when subjected to wear thereby affecting the wear rate performance.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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