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Wear Resistance Analysis of Coconut Shell Ash (CSA) Particulate Reinforced AL-Si-Fe Composite

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ABSTRACT
The wear resistance analysis of Al-Si-Fe particulate reinforced composites was performed using coconut shell ash as the reinforcement. Al-Si-Fe matrix alloyed with 5-20 weight percent coconut shell ash were produced using stir casting method. The composites were heat-treated at 510^oC and soaked for 3hours, quenched in warm water at 70^oC and aged between 95^oC to 350^oC at ageing time of 60 to 660minutes. The wear resistance of the samples was examined at varying aging time, temperature and volume of the reinforcement. From the results obtained, it was observed that the wear resistance increased as the particulate increased at different aging time and temperature and decreased due to over aging. The Al-Si-Fe/CSA composite has better properties at 18wt% CSA and 20wt% CSA. This work acknowledged coconut shell ash that is an agricultural waste, as a dependable reinforcement for Al-Si-Fe, hence the encouragement of the production of low cost aluminium composite with improved wear resisting properties.

Keywords: Aluminium, Particulates, Metal, matrix, Coconut ash, composite, wear.

I. INTRODUCTION

Metals reinforced with other metal, ceramic or organic compounds are referred as metal matrix composites.

They found applications in the aerospace and automotive industry. Studies have shown that particulate reinforcements are the most effective in improving the wear resistance of metal matrix composites, provided that good interfacial bonding between the reinforcement and the metal matrix exists [1]. Due to the presence of the particulate, the wear resistance of the composites is improved by preventing direct contacts with the metal that introduces subsurface degradation. The presence of hard elements like SiO_2, Al_2O_3, MgO and Fe_2O_3 as characterized by P.B Madakson, et al, 2012, suggests that coconut shell ash can be used as particulate reinforcement in various metal matrixes [2]. Previous works studied the possibility of using it as particulate in metal matrix composites since the chemical composition has close similarity with rice husk ash, bagasse ash and fly ash currently used in metal matrix composites [3-5].

This research aims at reinforcing Al-Si-Fe matrix with silicon carbide (SiC) and coconut shell ash (CSA) to improve its wear resistance for engineering applications.

II. MATERIALS

Coconut Shell Ash (CSA) sourced locally from Emene, iron scraps of 99.6% purity (Fe) bought from the market, aluminium profile of 99.5% purity (Al) bought from the market. The equipment includes crucible furnance, electrical furnace, wear resistance testing machine, photo type digital tachometer DT-2234A+ .

III. METHODS

3.1 Samples Production

The coconut shell was dried and grounded to powder, then the powder was heated to 1300^oC using an electric furnace to form coconut shell ash. The composite used in this study was produced by stir-casting method carried out at Scientific Equipment and Development Institute (SEDI) Enugu. The Al-Si-Fe alloy was produced by melting 94wt% of aluminium profile, 4.6wt% of silicon and 1.4wt% of iron. In order to solve the problem of wettability between the liquid metal and the particulates, the particulates were pre-heated before introducing it into the melt. Stirring time for each melt was 15minutes. The oxides and impurities were removed. In other to avoid the alloying elements from settling down, the molten metal was continuously stirred. The composite was formed using 280g of charge materials. A pre-heated sand mould was used to produce cast bars. After casting, the samples were machined into hardness, wear resistance, impact and microstructural test specimens for the purpose of determining the mechanical and microstructural properties.

3.2 Heat Treatment of the Samples

The test samples were solution heat-treated at temperature of 510^{o}C, soaked for 3 hours at this temperature and then rapidly quenched in warm water at 70^{o}C. Ageing of the test samples were carried out at temperatures of 95^{o}C, 150^{o}c, 250^{o}C and 350^{o}C, for various ageing times of 60 to 660minutes, and then cooled in air. The ageing characteristic of these grades of composites was evaluated using hardness values obtained from solution heat-treated samples of the investigated composites subjected to the aforementioned temperature conditions. The wear resistance test, impact tests and microstructural analysis were conducted on the samples with highest hardness values at different aging temperature and time.

3.3 Wear Resistance test

Wear resistance samples of the composites that recorded higher hardness values at different aging temperature and time were analyzed. The samples were weighed and gripped with a vice. An abrasive material mounted on electric motor was in contact with the gripped samples. The machine was switched on, and the samples robbed against the rotating abrasive material. The revolution was measured using photo type Digital Tachometer DT-2234A+ for 3minutes. The weight of the samples was measured again, the loss of weight of the samples under the same revolution for the same time was used to ascertain the samples with higher wear resistance values.

IV. RESULTS

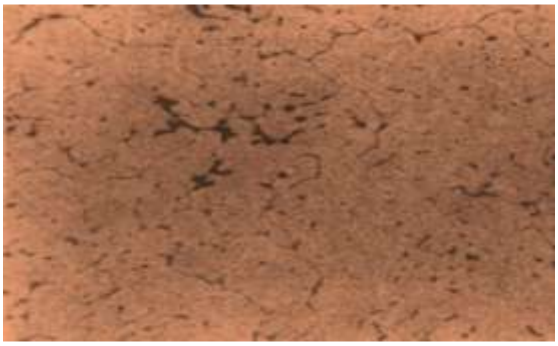

Plate 4.1: Microstructure of Al-Si-Fe matrix

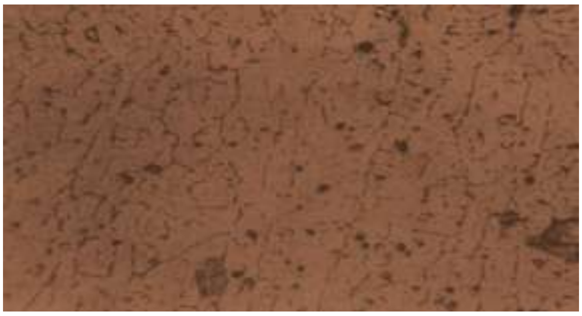

Plate 4.2: Microstructure of 18wt% of CSA reinforced Al-Si-Fe composite at 95 ^{o}C and at a holding time of 120 mins.

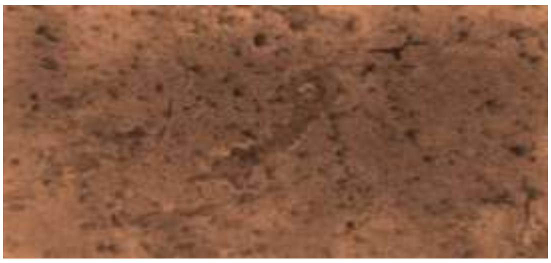

Plate 4.3: Microstructure of 18wt% of CSA reinforced Al-Si-Fe composite at 250^{o}C and at a holding time of 120mins.

Plate 4.4: Microstructure of 18wt% of CSA reinforced Al-Si-Fe composite at 350 ^{o}C and at a holding time of 120 mins.

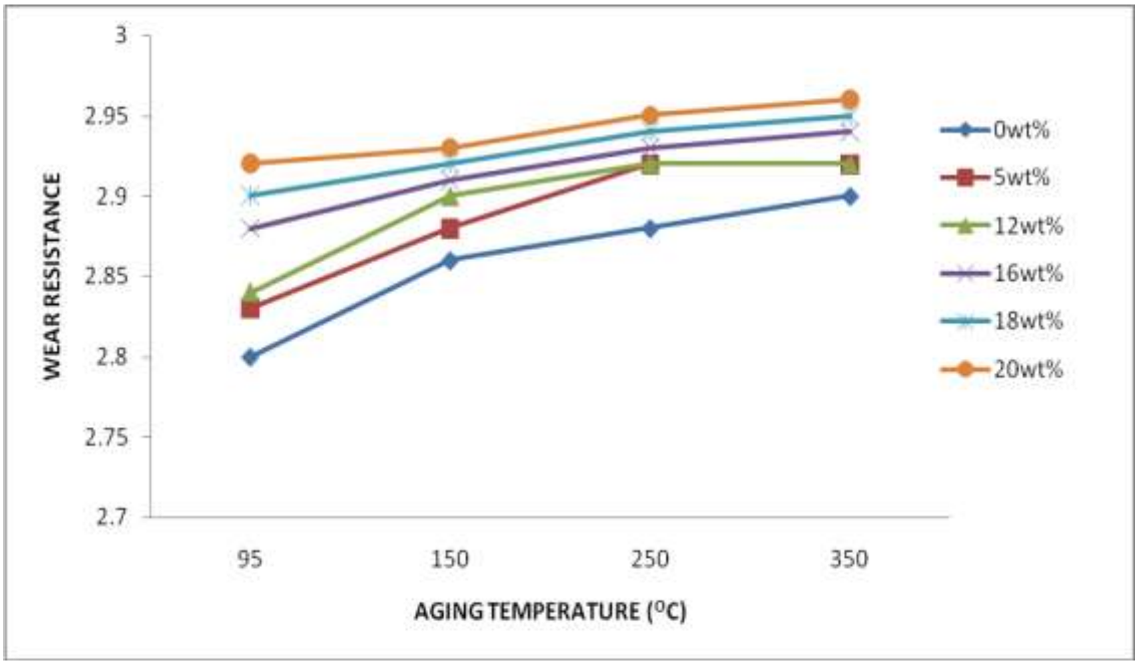

Chart-1: Effect of aging temperature on the wear resistance of Al-Si-Fe reinforced with varying percentage of CSA at a holding time of 300mins.

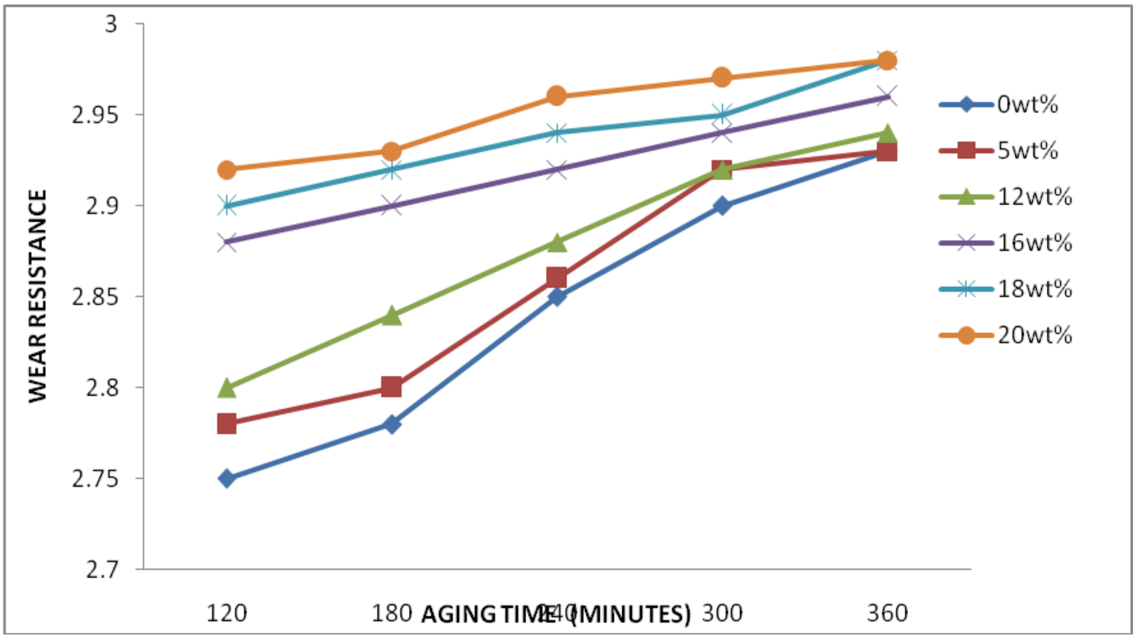

Chart-2: Effect of aging time on the wear resistance of Al-Si-Fe reinforced with varying percentage of CSA at 250^{o}C.

V. DISCUSSION

Microstructures of the unreinforced Al-Si-Fe alloy and composites at various ageing temperatures and peaking ageing time were examined by the use of a metallurgical microscope. The microstructures revealed uniform distribution of SiC, CSA and SiC/CSA hybrid particles. The ceramic phase is shown as dark phase, while the metal phase is white. These structures are in agreement with the co-continuous interlaced phases studied by other researchers The formation and presence of precipitates at the particles- matrix interfaces may be appreciated by comparing micrographs of the unreinforced Al-Si-Fe alloy and the composites. The micrographs reveal precipitates covering the surface at the particles-matrix interfaces.

The microstructure of the composite clearly shows a uniform distribution of coconut shell ash in the aluminium alloy matrix. In the composites examined, no effects of unfavorable phenomena were observed, which frequently form in the structures of cast composites, such as the sedimentation or flowing out of the reinforcing phase, as well as the formation of particle agglomerates or gas blisters. This showed that there was good interfacial bonding between the particles and matrix

During the wear test, there were occasional high pitch sounds coming from the contact region. It is most likely to be caused by hard ceramic particles becoming exposed to the surface and being in direct contact with the abrasive paper. Unlike the softer matrix material phase, the ceramic does not deform plastically because of high strength ionic bonding between its constituent atoms. Much less noise was heard in the case of matrix material. In this case, soft rubbing

The results clearly show that the composite has enhanced wear properties over the unreinforced matrix. The matrix material is susceptible to gross abrasive wear during the early stages of the experiment. The overall wear resistance of the composite under all control conditions can be attributed to the ceramic particles which have the ability to restrict the deformation and to prevent hard asperities from causing abrasive wear. The aluminium metal composite are shown to support the formation of metallic oxide films on their surfaces. This can be a valuable feature of the aluminium metal composite if it is used in brake pads for vehicles. Since oxygen will always be available under these conditions, the brake pads will lose less mass of material because of continuous re-oxidation of worn surfaces

The results of the wear resistance test carried out on these samples at varied aging temperature and time, revealed significant increase on the wear resistance of the composite and decreased due to over aging. The decrease in the wear resistance at different aging temperature differs due to the rate of precipitation of the particulates at different aging temperature. The time to obtain peak wear resistance is shorter according to the sequence: $95^oC > 150^oC > 250^oC$. This is to say, the higher the temperature, the faster the precipitation.

VI. CONCLUSION

Presently, particulate reinforced metal matrix composites are widely used in bearing, bushings, cylinder liners and brake pads hence, it is recommended that the grades of Al-Si-Fe/CSA composite with 18wt% and 20wt% be used due to the availability of coconut shell ash and its light weight. Among all the fabrication techniques, liquid stir casting process is the simplest and more economical. It can be concluded from this study that Al-Si-Fe particulate reinforced composites possess good wear resistant properties and durability.

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