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Effect of Periwinkle Particulate on the Mechanical Properties of Al7075 Alloy Composite

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Abstract: The mechanical evaluation of Al7075/ periwinkle ash particulate composites was studied. Al7075/periwinkle ash particulate composites at different weight percentage (2%, 4%, 6% and 8%) of periwinkle ash particles were produced using the stir casting method. The as-cast samples consisting of varied weight percentage of 0, 2, 4, 6, and 8% amount of periwinkle ash particulate were tested for mechanical properties such as hardness and tensile tests andtribological properties such as wear and friction test. The results were compared with the unreinforced sample under the same conditions. It was observed that the addition of periwinkle ash particulate increased the mechanical properties of the alloy composites. The tensile test results showed the 8wt% composite having maximum tensile strength of 493.1 N/mm^{2}while 0wt% (unreinforced alloy) had the least value of 242.55 N/mm^2. The hardness was found to be maximum for the 8wt% composite with a value of 77.2 HRB and least with a value of 61.5 HRB for the 0wt% (unreinforced alloy). The wear results showed a lower wear rate and frictional coefficient for the composite compared with the unreinforced alloy. Optical microscopy was used to examine the microstructure of the composites developed and uniform dispersion of the reinforcement was observed in the micrographs. The composites produced has light weight combine with good strength and can be used as bearings for brake disc.

Keywords: Al7075, Periwinkle, Mechanical properties, Stir casting, Wear

I. Introduction

With the current interest in the development of materials combined with the market inflationary trends, the basic materials used for composite development had led to a very high cost of production,therefore researchers are moving towards the use of locally available materials to substitute the costly conventional onesMatthews and Rawlins, 2014).. Metal-matrix composites (MMCs) are combinations of ametal or an alloy with a finite fraction (by volume or by weight) of second phase, generally ceramic, that is deliberately introduced into the metal in order to improve its properties. Aluminium MMCs (AlMMCs) find important applications in many engineering and technological applications. In addition, AlMMCs are also amenable to processing by conventional methods such as casting, rolling, forging, extrusion and as a final process, machining (Singh*etal.,* 2012).

The properties of aluminium matrix composites (AMCs) which have been explored for varied technical uses are: high specific strength and stiffness, good wear and corrosion resistance, low thermal coefficient of expansion, good high temperature mechanical properties, and excellent thermal management potentials among others (Alaneme*et al.,* 2014)

The reinforcements used in AMCs are usually ceramic materials which can either be continuous or discontinuous. However, the merits of using discontinuous ceramic reinforcements over continuous ceramic reinforcements for producing aluminium matrix composites are available in literatures (Sirahbizuyigezu*et al.*, 2013).

Particulate coconut shell was used to reinforce recycled aluminium cans to improve the tensile strength and wear resistance (Agunsoye*etal.,* 2014). Particulate periwinkle shell was reported to have high tensile strength, compressive strength, wear resistance and also lowers the density of aluminium alloys (Onyechi *et al.*, 2015). Higher mechanical properties were achieved with smaller particle sizes. Periwinkle shell is an external exoskeleton which protects the periwinkles from their predators and mechanical damage. These snails called periwinkle are found in the lagoons and mudflats of the Niger Delta between Calabar in the East and Badagry in the West of Nigeria. The people in this area consume the edible part as sea food and dispose the shell as a waste (Onyechi*etal.*, 2015).

The research is focussed on reinforcing Al7075 with periwinkle ash particulates to produce materials with improved properties which can be used in engineering applications like brake disc of automobiles.

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II. Materials and Method

Materials

Al (90.8%) –Mg (2.2%) –Cu (1.3%) -Zn (5.7%) alloy (7075) was selected as the aluminium alloy which serves as matrix for the investigation and the alloy was obtained in form of billets. The periwinkle shell was procured from a market in Lagos State. The periwinkle shells were carbonized into ash particulates.

Methods

Production of composite

The production of the composites was carried out at the foundry workshop using the gas-fired crucible furnace. Stir casting method was utilized in the course of this research for the production of the composites. Charge calculations were used to determine the required amount of periwinkle ash particulate to prepare 2 wt% to 8 wt% composites at 2 wt% reinforcements interval. Periwinkle ash particulate was pre-heated respectively at a temperature of 250^0C to remove moisture content and enhance improved wettability between the reinforcements and aluminum alloy matrix according to (Aku*et al*., 2012).

Hardness test

The hardness values of the produced composites were evaluated using Rockwell Hardness Tester (Identec, ((Model: 8187.5 LKV(B)) with hardness scale of HRB. The samples were exposed to a direct load of 0.3 kgf for 10 seconds on the mounted transverse sections to determine the hardness profile through the depth. Three indentation points hardness tests were performed on each sample and the average value was computed.

Tensile test

The tensile test of the composites were evaluated at room temperature using an Mosanto testing machine with dimensions 5 mm diameter and 30 mm gauge length in accordance with ASTM E8M-15 standard(Owoeye and Folorunsho, 2018).. The tensile properties evaluated from the stress-strain curves developed from the tension test are - the ultimate tensile strength, the yield strength, % elongation and % reduction in area.

Microstructure examination (Optical micrograph)

A Zeiss Metallurgical Microscope with accessories was used to examine the microstructure of the produced composites. The samples for the test were ground using 80, 120, 360, 600 and 800 grits emery paper, while polishing was carried out using polishing cloth and paste with alumina particles until a mirror-like surface is obtained. The mirror-like polished surface samples were then etched in Keller's reagent and viewed under microscope.

Tribological test

Anton Paar TRN tribometer was used to determine the wear and friction results of the unreinforced Al7075 and the 8wt% periwinkle composite. Dry sliding wear test was evaluated with four constant parameters which are applied load (8N), sliding speed (20cm/s) and sliding distance (80m). The samples for the wear test were ground and polished before test, the responses are wear rate and frictional coefficient

III. Results and Discussion

Hardness test results

The hardness test result of Al7075/Periwinkle ash particulate is presented in Figure 1.

The results show that the hardness of the composite increased with increase in periwinkle reinforcement content as shown in Figure 1. The hardness test was maximum for the 8wt% periwinkle composite with a value of 77.2 HRB and least with a value of 61.5 HRB for the unreinforcedAl7075 alloy (0wt%), the hardness value for the 2wt% was 65.96 HRB, 69.9 HRB value for 4wt% and the value for the 6wt% was 73.8 HRB.The presence of such hard particles offers more resistance to plastic deformation by indentation which leads to increase in the hardness of compositesas reported by (Gopal*et al.*, 2012).

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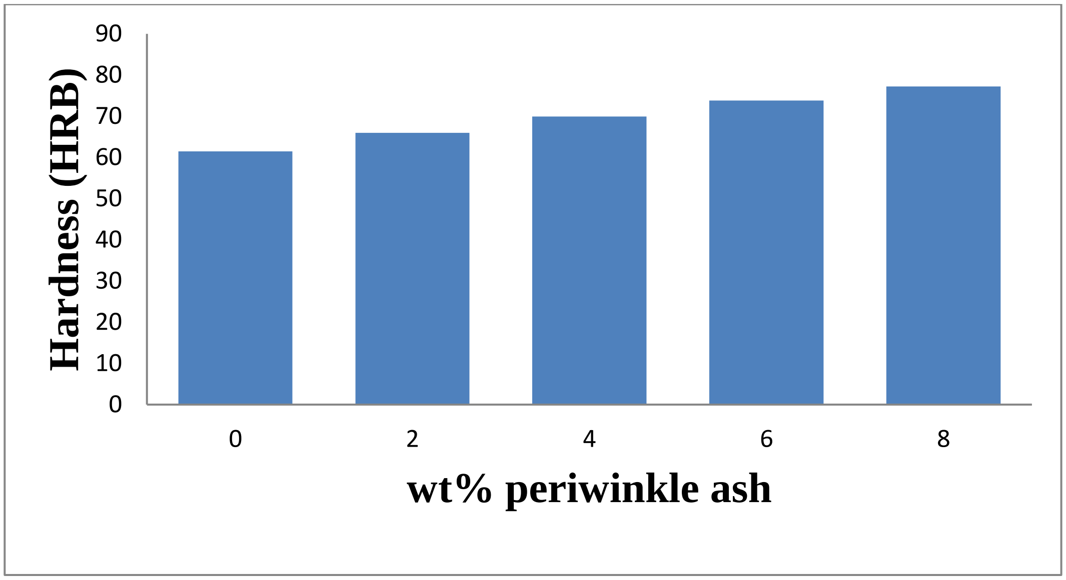

Figure 1: Variations of hardness with Al7075/ periwinkle ash composite

Tensile test results

The results of the tensile test of Al7075/periwinkle ash particulatecomposites are presented in Figure 2.

The results in Figure 2 show the composite with 8wt% periwinkle ash had maximumtensile strength of 493.1 N/mm^2 and 0wt% had least value of 242.55 N/mm^2, for 2wt% composite, the tensile strength value was 254.41 N/mm^2, 4wt% tensile strength was 273.27 N/mm^2 and 6wt% was 385.34N/mm^2.The increase in tensile strength was due to alloy strengthening and strain hardening behaviour of periwinkle ash particles resulting in the increase of strength in the composites (Auradi*et al.*, 2014).

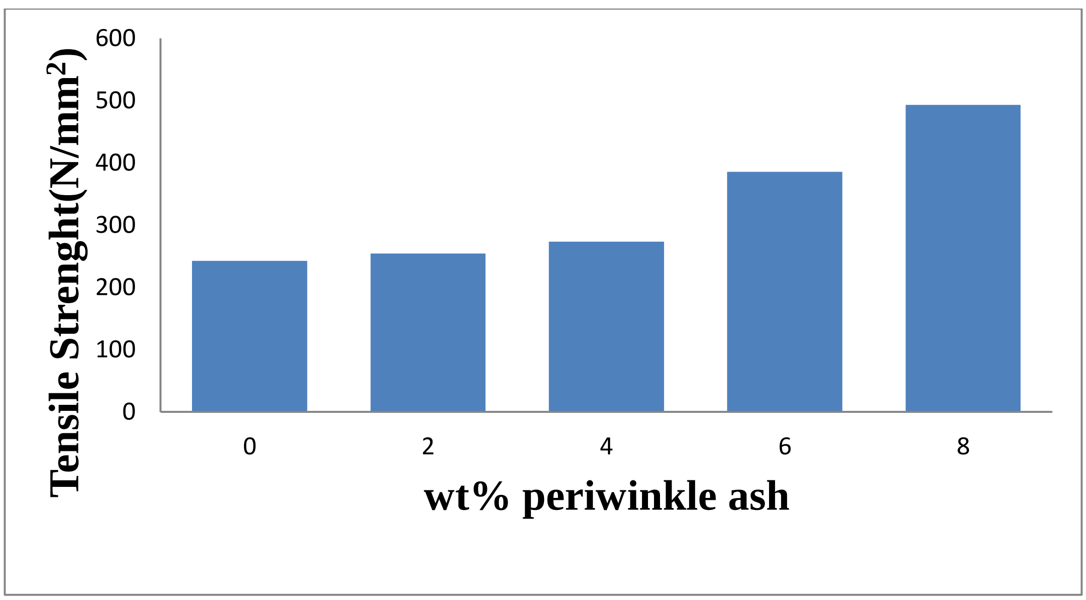

Figure 2: Variations oftensile strength with Al7075/ periwinkle ash composite

Microstructure examination

The solidification pattern and the grain morphology are shown in Plates I-V. The unreinforced alloy is composed of developed integral dendrite of primary Al rich phase (α - FCC). It can be observed that there is a good dispersion of the periwinkle ash particulates in the Al7075 alloy matrix; however the microstructures showed similar solidification pattern.

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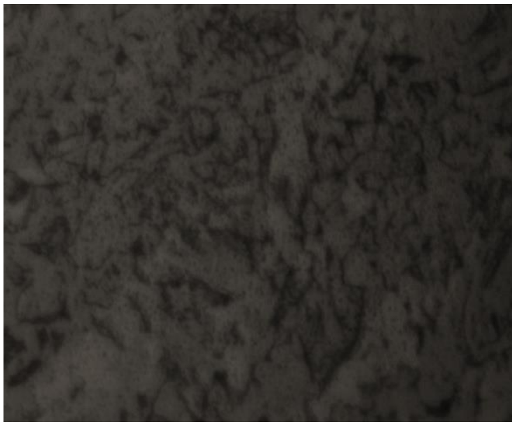
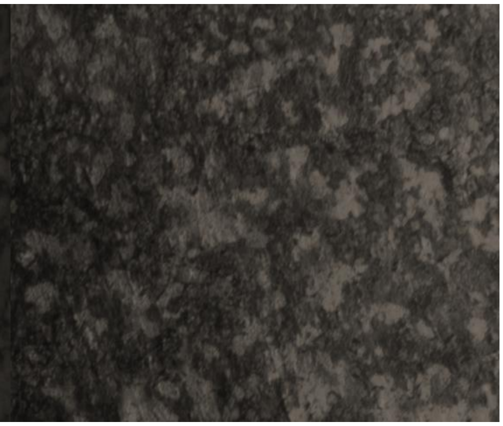

Plate I: Al7075 alloyPlate II: Al7075/ 2wt%periwinkle ash composite

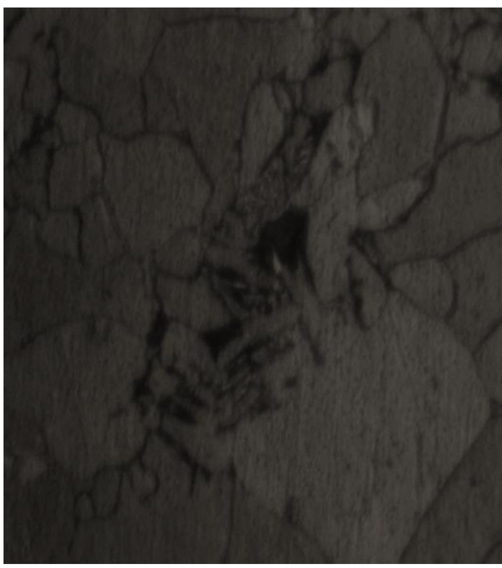
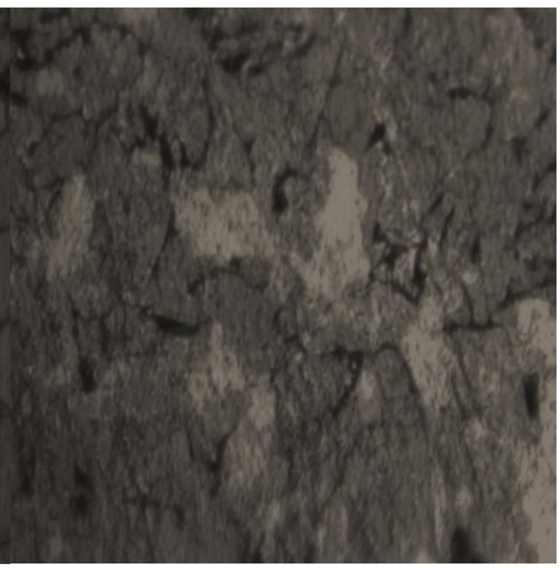

Plate III: Al7075/ 4wt%periwinkle ash composite Plate IV: Al7075/ 6wt%periwinkle ash composite

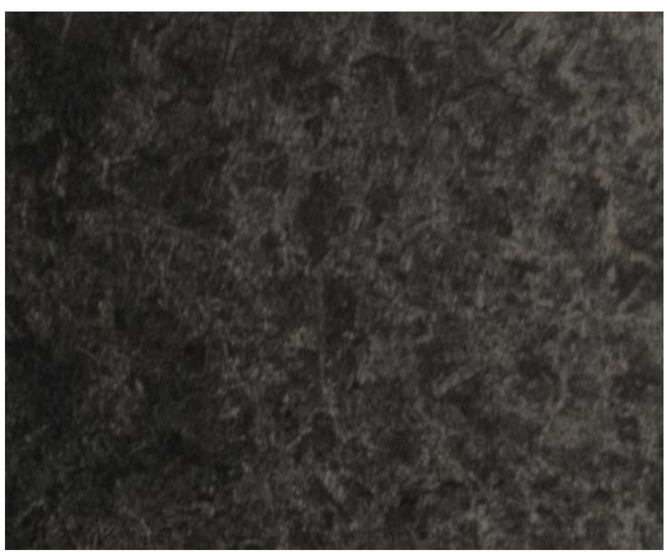

Plate V: Al7075/ 8wt%periwinkle ash composite

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Tribological results of unreinforced Al7075

Figure 3 shows the variation in tribological behaviour of the unreinforced alloy, a gradual increase in the frictional coefficient was observed up to 648 s and 32 m sliding distance; with a low wear rate. The wear rate decreases and attains a lower steady value as the sliding distance increased. The nearly stable friction can be attributed to non- presence of asperities to resist the movement of the alloy phase. A low wear rate and low and steady frictionalcoefficient are the main properties required ofwear-resistant bearing materials (Zhu and Hong,2017).

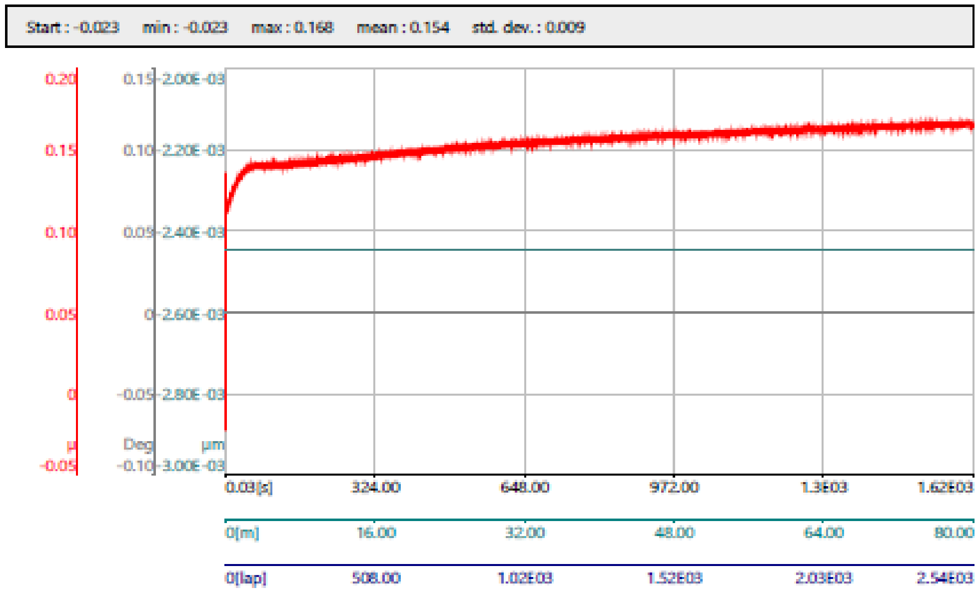

Figure 3:Tribological behaviour of unreinforced Al7075

Tribological results of 8wt% Al7075/ periwinkle ash composite

Figure 4 shows the variation of friction with sliding distance for the parameters stated. It can be observed from the plots that, with addition of periwinkle particulate the wear rate of Al7075 decreases. Also as the sliding distance increases, the frictional coefficient first increased and then almost remains same for the entire test period. There is less removal of material at longer sliding distances and this could be due to the less penetration of the indenter as a result of the periwinkle particles in to the composite sample. As the test continues the composite material become smooth due to filling of the space between abrasives by wear debris, which consequently reduce the depth of penetration (Saliu*etal.*, 2019).

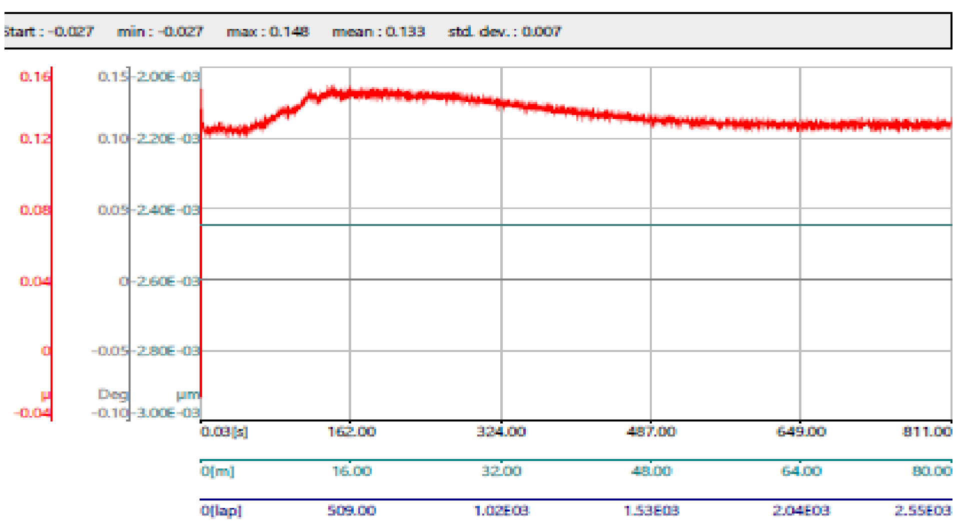

Figure 4: Tribologicalbehaviour Al7075/periwinkle ash composite

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IV. Conclusion

The following conclusions have been drawn:

I. The composites were developed by addition of periwinkle ash particles in molten Al7075 alloy by stir casting method

II. The microstructure of the composite is uniformly distributed and strong interfacial bonding between the matrix alloy and reinforcement.

III. The tensile strength of the composites show similar trend with hardness justifying correlation between hardness and tensile strength. The composites possess better tensile and hardness as compared with Al7075 alloy.

IV. The wear rate and frictional coefficient of the composite are lower compared with Al7075 alloy.

V. The developed composites have light weight combine with good strength which can beused in engineering applications**.**

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