Development and Characterisation of Polyester/Coconut Shell Particulate Composite

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***Abstract*: The development and characterisation of polyester/ coconut shell particulate composites was studied. Polyester/coconut shell particulate composites at different weight percentage (2%, 4%, 6% and 8%) of the particles were produced using the hand lay- up method. The as-cast samples consisting of varied weight percentage of 0, 2, 4, 6, and 8% amount of the particulate were tested for physical and mechanical properties such as density, hardness, impact and tensile tests and tribological 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 coconut shell particulate improved the mechanical and wear properties of the polyester composites but with a reduction in the density. The tensile test results showed the 8wt% composite having maximum tensile strength of 173.24 N/mm^2 and (unreinforced polyester) the least value of 131.32 N/mm^2. The impact strength of polyester is the highest with the value of 0.11 J/mm^2 and the strength is least for 8wt% coconut shell particulate composite with 0.0271 J/mm^2. The density of the composites are lower than that of the unreinforced polyester. The hardness was found to be maximum for the 8wt% composite with a value of 75.2 HRB and least with a value of 55.5 HRB for the unreinforced polyester. The wear results showed a lower wear rate and frictional coefficient for the composite compared with the unreinforced polyester. SEM microscopy revealed uniformly distributed and strong interfacial bonding, though agglomeration of particle between the polymer matrix and reinforcement were observed. The composites produced has light weight combine with good strength and can be used in engineering applications such as in pipe production for automobile industries.**

***Keywords*: Polyester, Coconut shell, Mechanical, Wear and Microstructure**

I. INTRODUCTION

Recent advancement in composite technology have mandated the need to explore varieties of materials as reinforcements with the intention of increasing the mechanical, physical, aesthetics and thermal properties of the resulting composite formation. Also taking into cognizance environmental concerns, most studies within the realm of composite material development are now focused on the utilization of environmentally friendly materials especially the bio-based materials in composite development (Usman *et al.*, 2016).

In its most basic form a composite material is one which is composed of at least two elements working together to produce material properties that are different to the properties of those elements on their own. In practice, most composites consist of a bulk material (the 'matrix'), and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix (White and Ansell, 1993). Polymer composite materials are multi-component materials comprising at least one type of continuous phase (polymer matrix) and fillers (fibres, plates, particles, etc.). Polymeric composites are widely used for structural, aerospace, and automobile sectors due to their good combination of high specific strength and specific modulus. These two main characteristics make these materials attractive, compared to conventional materials like metal or alloy ones. Some of their typical benefits include easy processing, corrosion resistance, low friction, and damping of noise and vibrations (Şahin, 2015).Organic fillers produced from agricultural wastes have gained tremendous attention from plastic industry, with primary advantages of low densities, low cost, non-abrasiveness, high filling levels, low energy consumption, biodegradability, availability of a wide variety of fibres throughout the world and generation of a rural/agricultural-based economy (Onuegbu and Madufor, 2012). Sathishkumar *et al.*, (2018), investigated the kenaf, glass fiber and silicon carbide mixed with araldite (polyester) resin in different reinforcement and different percentage and the effects were experimented, the resultant composite material was tested for its mechanical properties like tensile strength, flexural strength and impact strength using conventional testing machines and results were recorded; it showed an improvement in these mechanical properties after reinforcement by fibres and the value of the mechanical properties increased with increasing percentage of reinforcement. Rabiu *et al.*, (2020) carried out research on glass fibres, orange peel particulate of about 350µm sieve size, of varying weight percentage (3, 6, 9,12 and 15) wt.% and E-glass fibre of constant weight percentage 25.1wt% as reinforcements in a polyester matrix, the effect of the orange peel particulate on the physical and mechanical properties of the resulting composite such as tensile strength, bending strength, impact strength and hardness strength were increased as the weight percent of the reinforcement increases. Hassan *et al.*, (2012), investigated the development of polyester/eggshell particulate composites, uncarbonized and carbonized eggshell particles were used as reinforcement in polyester matrix; 10 to 50wt% eggshell particles at intervals of 10wt% were added to polyester as reinforcement and the microstructural analyses of the polyester/eggshell particulate composites were carried out using SEM and EDS; the mechanical properties and density were carried out by standard methods and improved results were achieved. The aim of this research is to study the influence of coconut shell particulates on the mechanical, microstructural and wear behaviour of polyester composites. Hence, the use of coconut shell particulate (uncarbonized) in producing polyester composites is therefore hoped to convert wastes to wealth, tackle the problem of environmental pollution, reduce the material cost and produce composites that can be used in production of pipes for automobile applications.

II. EXPERIMENTAL PROCEDURE

A. Materials and production, equipment and sample preparation

The polyester resin used in this research was purchased from Steve-more Chemical Shop in Zaria, it is the thermosetting type in paste form and was cured using curing agents and catalyst and coconut shell was sourced from a market in Lokoja, Kogi State, Nigeria. The coconut shells were washed thoroughly and dried for four days before it was ground to particulate size, and sieved to obtain a uniform size. The charge materials used for this research study were polyester and coconut shell particulate. These charge materials were calculated before charging to determine each amount of the material that constitutes the produced composites. Charge calculations were done to determine the amount of the particulate needed to prepare 2, 4, 6 and 8wt% composites. 2 % each of solution of cobalt nephthalate and Methyl-ethyl-ketone (MEK) peroxide were used as accelerator and catalyst respectively. The polyester resin was then mixed with a varying amount of ground particulate from 2wt% to 8wt% at interval of 2wt% to produce the polyester/coconut shell particulate composites. Tensile tests were performed and evaluated on each composite test sample produced in accordance with ASTM 8M-91 standard specifications. The samples for the test were machined to specimen configurations with 5 mm diameter and 30 mm gauge length. The tensile test was performed at room temperature (25^0C) tensometer operated at a strain rate of 10^{-3}/s, data and graphs were generated from the machine during the test. The density of the composites was determined by measuring the mass and the volume of the sample based on Archimedes principles, samples were weighed using an electronic weighing device and the samples were submerged in a calibrated cylinder and the displaced volume was measured; the densities were calculated using the Equation $Density = \frac{mass}{volume}$. Hardness test was performed in accordance with ASTM E92 standard; the samples were exposed to a direct minor load of 0.3kgf for 10 seconds on the mounted transverse sections to determine the hardness profile. Three indentation points were performed on each sample and the average values were computed. Impact test was done using izod specimen which was machined and notched according to ASTM E23 standard (Madheswaran *et al*., 2015), the izod specimen placed with the V notch facing the specimen was hit above the V notch until fracture occurs. XRF analysis was used to determine the elemental composition of the produced composite. The microstructural features present in the polyester matrix composite test sample were studied using a JEOL JSM 5900LV Scanning Electron Microscope equipped with an Oxford INCA, and the microstructure was taken at different magnifications. Anton Paar TRN tribometer was used to determine the wear and friction results of the unreinforced polyester and the 8wt% coconut shell composite. Dry sliding wear test was evaluated with four constant parameters which are applied load (8N), sliding speed (20cm/s) and sliding distance (40m) and the responses were wear rate and frictional coefficient.

III. RESULTS AND DISCUSSION

A. Results and discussion of the analysis of the polyester/ coconut shell particulate composite

Impact test analysis

The results of the impact strength of polyester/coconut shell particulate composites are shown in Figure 1

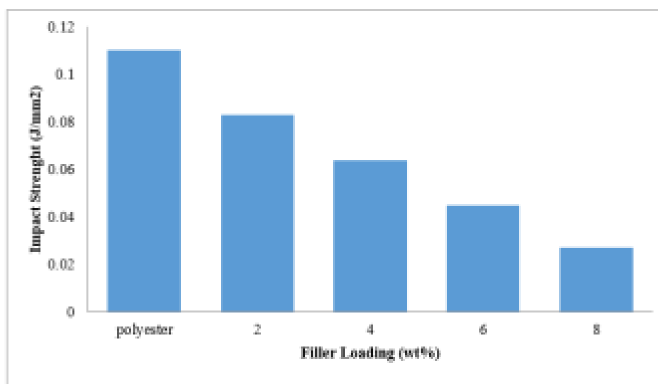

Figure 1: Variations of impact strength with filler loading

The impact strength for the polyester is the highest with the value of 0.11 J/mm^2 and the strength is least for 8wt% coconut shell composite with 0.0271 J/mm^2. 2wt% coconut shell particulate composite was 0.083 J/mm^2, 4wt% coconut shell particulate composite was 0.064 and 8wt% coconut shell particulate composite was 0.0271 J/mm^2. The decrease fracture toughness may be linked to the increase amount of relatively harder and brittle coconut shell particulate in the composites. Rapid crack propagation tendency is a characteristic inherent in most hard and brittle ceramics (Madheswaran *et al.*, 2015).

Tensile strength

The results of the tensile strength of polyester/coconut shell particulate composites are shown in Figure 2

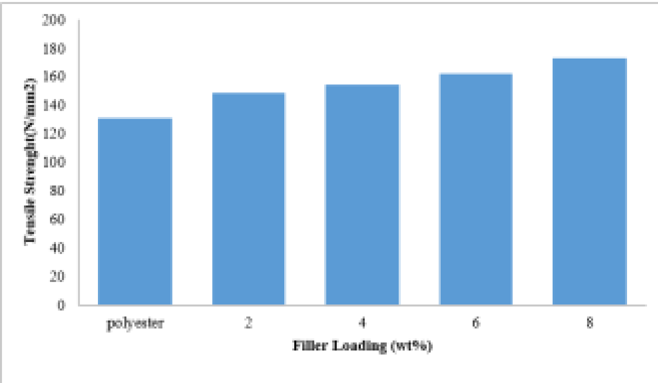

Figure 2: Variations of tensile strength with filler loading

From the plot of tensile strength versus volume % of filler, it can be observed from Figure 2 that there is general increment in strength values of the composites as compared with unreinforced polyester. The increase of tensile modulus from 131.23N/mm^2 for the polyester matrix to 173.24N/mm^2 8wt% coconut shell particulate composite may be attributed to the higher crosslink of the polyester and good distribution of coconut shell particulate in the polyester matrix. This uniformity of coconut particulate distribution has efficiently hinders the chains movement during deformation leading to high particulate orientation. The tensile strength of the composite increased with increasing percentage of the particles (Hassan *et al.*, 2012).

Hardness

The results of the hardness of polyester/coconut particulate composites are shown in Figure 3

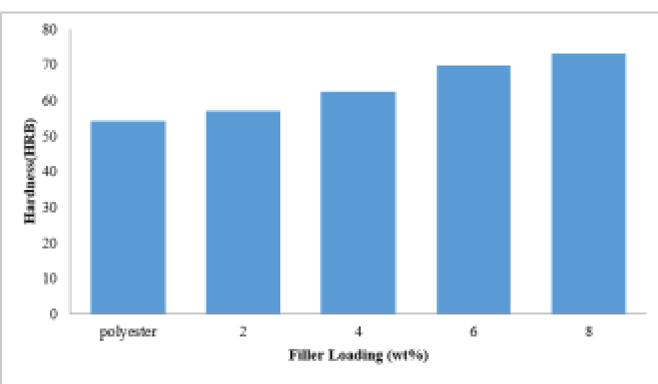

Figure 3: Variations of hardness with filler loading

Figure 3 shows the micro-hardness values for different compositions. It is seen that with the increase in filler content in the composite, its hardness value improves. The observed increase in the hardness value as the particulate reinforcement increases was due to high amount of the particulate reinforcement in the matrix. The improved hardness can be attributed to the presence of particulates in the matrix as reported by (Rabiu and Ramalan, 2020)

Density measurement

The results of the Density of polyester/ coconut shell particulate composites are shown in Figure 4

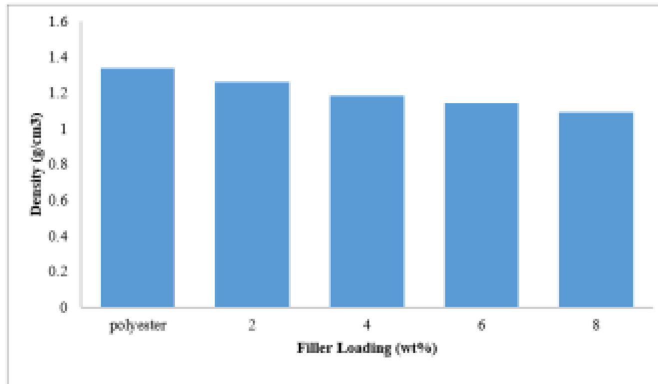

Figure 4: Variations of density with filler loading

From the density results (Figure 4), The polyester had a density of 1.34g/cm^3, 2wt% was 1.26g/cm^3, 4wt% was 1.18g/cm^3, 6wt% was 1.14g/cm^3 and 8wt% was 1.09g/cm^3 of the composites respectively. It is observed that densities of the composites are lower than that of matrix and all the densities decreased with an increase in the coconut shell particulate content. The decrease in density values can be attributed to the lower density of the particulate compared to the matrix (Ngargueudedjim *et al.*, 2015).

XRF studies

Table1 shows the XRF result of polyester/coconut shell composite

Table 1: XRF elemental composition of polyester/coconut shell composite

Element Name	Atomic Concentration	Weight Concentration
Carbon	61.23	57.14
Potassium	18.35	15.23
Calcium	5.2	4.78
Manganese	3.1	2.7
Nickel	4.3	3.12
Phosphorus	0.14	0.17
Sulphur	0.18	2.1
Titanium	0.56	1.4

The results of the XRF elemental composition is shown in Table 1 indicated that carbon had the highest % composition of 61.23, followed by potassium with 18.35% , sulphur with 0.18% and phosphorus the least with 0.14% . The XRF analysis ensure the reliability and accuracy of results (Pruthviraj and Krupakara , 2008).

SEM examination

Morphological study showed that the coconut shell particulate as a reinforcement having smooth surface area. There is a good dispersion of coconut shell particles in the polyester matrix, however agglomeration of particles were observed. Plate I shows a good interfacial bonding between the coconut shell particulate and the polyester matrix with respect to the 8wt% composites.

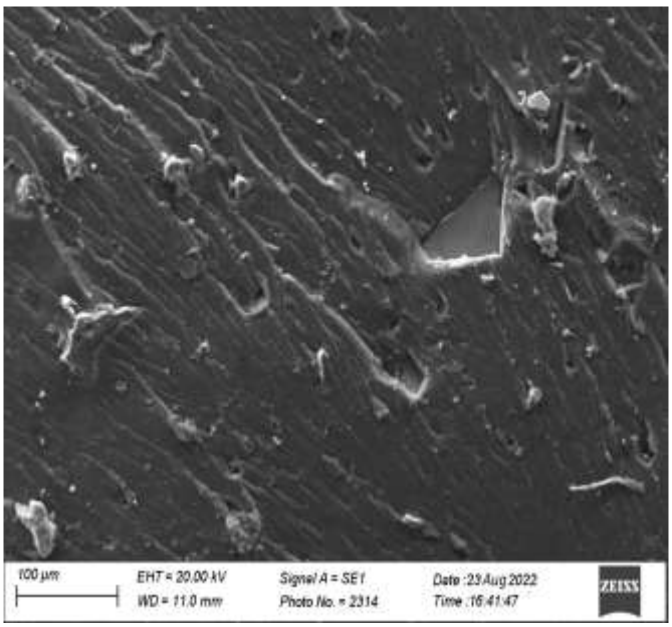

Plate I: SEM of 8wt % polyester/coconut shell particulate composite

Tribological Results

Tribological results of unreinforced polyester

Figure 5 shows the variation in tribological behaviour of the unreinforced polyester, a gradual increase in the frictional coefficient was observed up to 54.1s and 16m 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 polyester phase. A low wear rate and low and steady frictional coefficient are the main properties required of wear-resistant bearing materials (Zhu and Hong, 2017).

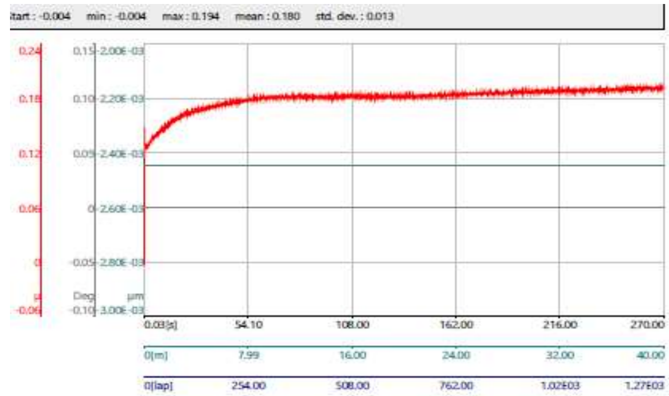

Figure 5: Variations of tribological results of unreinforced polyester

Tribological results of 8wt% coconut shell particulate particulate reinforced polyester composite

Figure 6 shows the variation of tribological behaviour of the 8wt% coconut shell particulate reinforced polyester composite. It can be observed from the plots that, with addition of the particulate, the wear rate of composite 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 coconut shell particles in 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 *et al.*, 2019).

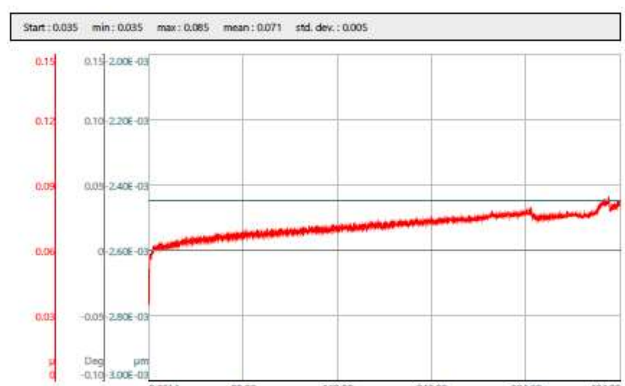

Figure 6: Variations of tribological results of 8wt % coconut shell particulate/ polyester composite

IV. CONCLUSIONS AND RECOMMENDATION

Conclusions

The following conclusions have been drawn:

I. The composites were developed by addition of coconut shell particles in the polyester matrix by hand lay-up method

II. The microstructure of the composite is uniformly distributed and strong interfacial bonding between the polymer matrix and reinforcement.
III. The density of the composites are lower than that of the unreinforced polyester
IV. The composites possess better tensile and hardness as compared with the unreinforced polyester.
V. The wear results showed a lower wear rate and friction compared with the polyester matrix.

Recommendation

I. Tests should be carried out on the corrosion and the thermal properties of the produced composites
II. Other production techniques like extrusion and injection molding can be utilized

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