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Fabrication and Characterisation of Eco-Friendly Coconut Fibre Reinforced Epoxy Composite

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ABSTRACT

The fabrication of composite materials that offer enhanced mechanical properties, sustainability, and adaptability for a variety of applications has gained popularity. One of such combinations that is promising is coconut fibers as reinforcement in an epoxy matrix as strengthening components. Epoxy composite was developed in this study with coconut fibre as reinforcement and its mechanical properties were evaluated. Coconut fibre was treated by boiling in NaOH for surface modification which was embedded in an epoxy with hardener in ratio 2:1 in proportion of 5,10,15,20 and 5 wt.% respectively, designated as TC5%-TC25%, while other composite was developed with untreated coconut fibre in the same proportion as the treated fibre, the composite was developed using open mold casting technique using the proportion above, the developed composite was allowed to cure for 24 hours and separated from the mold, control sample designated CS was developed without the reinforcement. Mechanical properties such as tensile, hardness, impact and flexural and the wear index was evaluated, From the results, most of the mechanical properties evaluated of the reinforced composites have better value than the control sample, the tensile strength, flexural strength, and hardness of the reinforced composite samples were better than that of the control sample. Sample denoted as UTC 20% have the optimum tensile strength 15.8 MPa, TC 20% with optimum flexural strength value of 26.45MPa and UTC 20% 69HS value of hardness respectively. Wear properties increase progressively with increase in the weight percent of the reinforcements in all the samples with wear index of 0.01 as the best for sample designated TC20%. While there was a decrease in the values of impact strength of the reinforced samples compared to the control sample with samples designated as UTC 5% having an optimum value of 29.52J/mm^2.

Keywords— **Composite, Mechanical properties, tensile strength, epoxy, coconut fibre.**

I. INTRODUCTION

A material formed of two or more physical components, with much better properties than those of the single components, i.e., the matrix and the filler is known as a composite. These are usually fabricated with different types of matrices, such as polymers, metals, and ceramics. Among them, polymers have advantageous properties, such as chemical resistance, low density, good wettability, and easy molding into desired and engineered shapes. Therefore, polymers are used as matrices to a greater extent, compared to metals and ceramics [1]. It is a combination of two materials in which one of the materials, called the reinforcing phase, is in the form of fiber sheets or particles and are embedded in the other material called the matrix phase. The primary functions of the matrix are to transfer stresses between the reinforcing fibers/particles and to protect them from mechanical and/or environmental damage whereas the presence of fibers/particles in a composite improves its mechanical properties such as strength and stiffness [2].

Polymer matrix composites (PMCs) are made by incorporating reinforcement into the matrix of thermoplastic and thermosetting materials. PMCs have broad applications due to their feature which are lightweight, high stiffness, high strength, good corrosion resistance, lesser environmental degradation, excellent thermal insulation, good acoustic damping, excellent design flexibility, and nonmagnetic properties. [3, 4].

An in-depth review has been provided on the chemical modification and characterization of natural fiber-reinforced composites [5]. The synergistic effect of combining coconut fibers with epoxy resins creates composite materials that exhibit improved strength, stiffness, and impact resistance. The development of coconut fiber reinforced epoxy composites holds significant potential in industries such as automotive, construction, and aerospace, where light weight, durable, and eco-friendly materials are desired, [6]. These composites offer a sustainable alternative to traditional materials while maintaining or even surpassing their mechanical performance. Moreover, the utilization of coconut fibers derived from agricultural waste aligns with the principles of circular economy and environmental sustainability [6].

The objective of this paper is to attempt to bring to the engineering and technology community the usage of coconut fibre as reinforcement for the development of composite for engineering application.

II. MATERIALS AND METHODS

Coconut fiber was sourced from a farm settlement in Ado-Ekiti, Ekiti State, Nigeria while the epoxy resin and hardener was from a commercial supplier in Lagos, Nigeria. Fig. 1 show the coconut fibre extracted which was used for this study.

A. Preparation of Coconut Fibre

Alkaline treatment was applied to modify the surface of the coconut fibers as conducted by [7], this was done by boiling the coconut fibre in NaOH solution and improve their compatibility with the epoxy matrix. The other composite was done with an untreated coconut fibre which was embedded within the epoxy matrix.

Fig. 1: Coconut fibre

B. Fabrication of Composite

The composite samples were produced using open mould casting method by dispersing the coconut fibre into the epoxy matrix in predetermined proportions of 5, 10, 15, 20, and 25 wt.%. The mixing ratio of the epoxy with hardener is ratio 2:1 according to Kolawole et al; 2019. [8]. Before pouring into the mould, the mixture was stirred properly to ensure homogeneity and allowed to cure for 24 hours. The developed composites were separated from the mould allowed to cure further at room temperature for 27 days. Three samples were made for each formulation and the samples were designated as TC5%, TC10%, TC15%, TC20% and TC25 % respectively for the treated coconut fibre while untreated was designated as UTC 5%, 10%, 15%, 20% and 25%. A control sample which was formulated without reinforcement is designated CS. Fig. 2a & b shows the samples of the developed composite with treated and untreated coconut fibre respectively.

C. Mechanical Property Testing

Tensile, flexural, and hardness tests were used to determine the mechanical properties of the developed composite. The tensile properties and stress-strain behavior of the developed composites were determined using tensile test performed in accordance with ASTM D3038M-08 procedures [9]. The test was performed using a universal testing machine, Instron incorporated USA model; Instron-series 3369 operated at a crosshead speed of 0.3mm/mm and at a strain rate of 10-3/s at room temperature [9] Flexural strength was determined using three-point flexural tests according to ASTM D7264M-07 standard [10] using a tensiometric universal testing machine with a crosshead speed of 0.3 mm/min and at a specific strain rate of 10−3/s. The hardness test was conducted using a Digital (Shore D) Hardness Durometer with a 30o cone and 5kg ± 0.5 kg force according to according to ASTM D2240. Each sample was placed on the stand of the machine and pressure was applied on the handle for a dwell time of 3 seconds, to ensure the material was well indented in accordance with [11]. After which the hardness value was read and noted.

Fig. 2a: Treated composite

Fig. 2a: Untreated composite

D. Wear Test

Taber Abrasers, Model ISE-AO16.was used to determine the wear-resistance of the composites. The samples were mounted on a turn table platform that rotates at a fixed speed in accordance with [12]. The sample was weighed using an analytical weighing balance for the initial weight of the sample, after which it was fixed on the turn table which was made to rotate at 1000 rpm for 5 hours, and then, the samples were removed and weighed to obtain the final weight of the sample. The differences in the initial and final values of the samples were used to determine wear behavior.

III. RESULTS AND DISCUSSION

A. Mechanical Properties

(i)Ultimate Tensile Strength

Fig. 3 showed the tensile strength of the developed composite samples from where it was observed that, reinforced samples has better tensile strength than the control sample in most of developed composite samples. However, it was observed that 20wt.% samples with untreated coconut fibre have the best result with optimum value of 15.8 MPa. The enhancement of the 20wt% reinforced composites may be attributed to good fiber-matrix interaction at the interface due to the influence of chemical treatment on the fiber surface. The good interfacial adhesion between the fiber and the matrix allows easy transfer of load from the matrix to the fiber effectively, by this means, improving the strength of the developed composite materials [13].

(ii) Flexural Strength at Peak

The result of flexural strength at peak is shown in Fig. 4, the flexural strength at peak for the developed composites increases with increase in the fiber fractions with the composite samples with 20 wt.% treated coconut fibre reinforcement had the highest flexural strength value of 26.45 MPa, followed by the 15 wt.% treated coconut fibre composites with a value of 22.56 MPa. The control sample had a flexural strength value of 3.54 MPa. This is of course due to the increased load bearers in the composite as fiber fraction increases.

(iii) Hardness Property

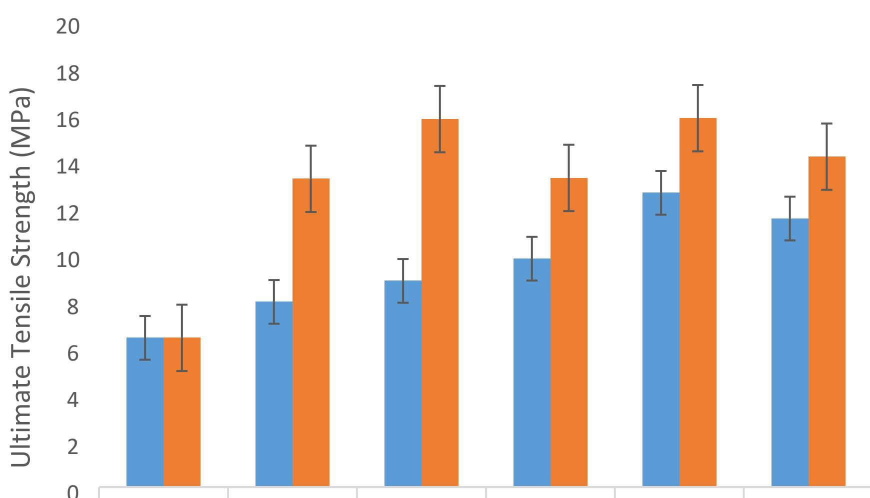
Fig. 5 showed the hardness value of the developed composite samples from where it was observed that, reinforced samples have better hardness value than the control sample in most of developed composite samples. Hardness value of the samples increases with increase in the reinforcement up till 20 wt% with optimum value of 65.2HS for treated coconut fibre and 69.4 HS for untreated coconut fibre composite and dropped in value for 25wt.% reinforcement. This enhancement may be due to good interfacial adhesion between the filler and the matrix, this in tandem with the ultimate tensile strength result in accordance with previous researcher [13].

(iv) Impact Strength

Fig. 6 illustrates the impact strength of the developed coconut fibre reinforced epoxy composite and the control sample. The results show reduction in the impact strength on addition of coconut fibre to the epoxy (the control sample) which has 19.24 J/mm^2. From the developed composites, 5wt % untreated coconut fibre sample has 29.52J/mm^2 representing the optimum value for the reinforced composites. This decrease in impact strength compared to the control sample can be attributed to improper transfer of impact load from epoxy to coconut fibre, this agrees with a report from other researchers [14].

(iii) Wear Index

The wear index of the developed samples as well as the control sample is shown in Fig. 7. It was observed that most of the reinforced samples have lower wear index compared to the control sample with wear index of 0.07 m/g. Composite with 20wt% treated coconut fibre gives good wear index value of 0.01 which was the sample with the optimum wear index. This shows that the reinforced composites have better abrasion resistance.



	CONTROL	5wt%	10wt%	15wt%	20wt%	25wt%
TREATED COCONUT FIBRE COMPOSITE	6.39	7.93	8.83	9.78	12.6	11.5
UNTREATED COCONUT FIBRE COMPOSITE	6.39	13.2	15.76	13.24	15.8	14.15

Fig. 3: Ultimate Tensile Strength of the developed Composite

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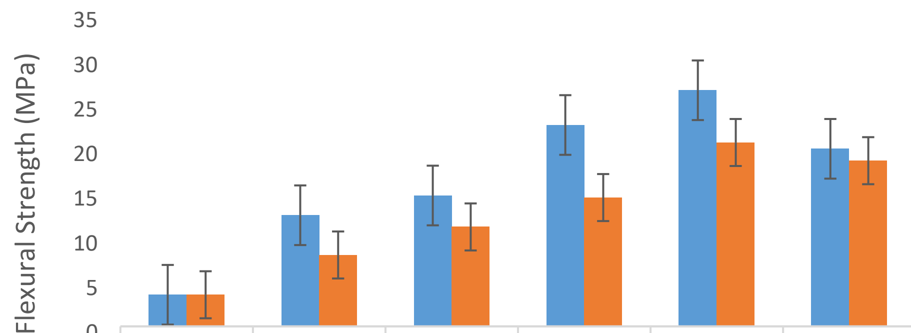
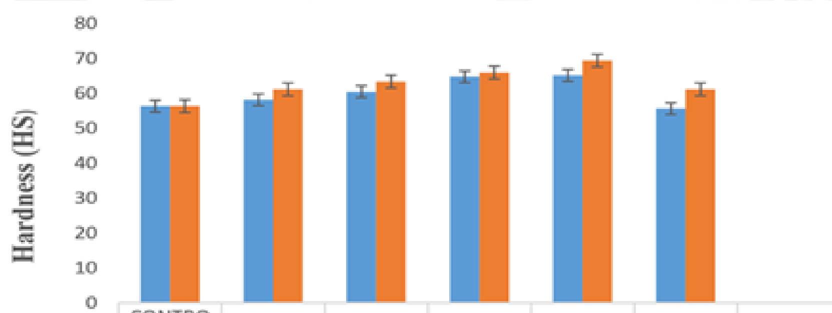


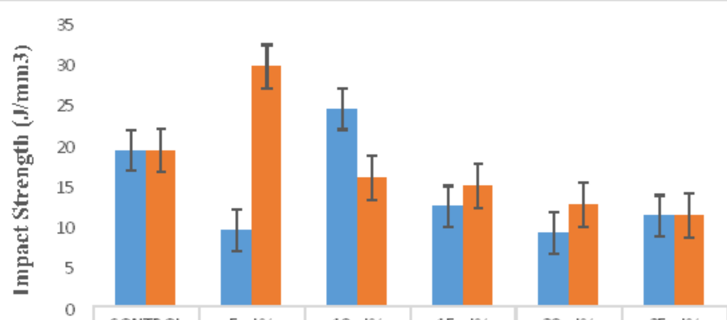
	CONTROL	5wt%	10wt%	15wt%	20wt%	25wt%
TREATED COCONUT FIBRE COMPOSITE	3.54	12.45	14.66	22.56	26.45	19.89
UNTREATED COCONUT FIBRE COMPOSITE	3.54	8	11.14	14.43	20.6	18.56

Fig. 4: Flexural Strength at Peak of the developed composite and Control Sample



	CONTROL	5wt%	10wt%	15wt%	20wt%	25wt%
TREATED COCONUT FIBRE COMPOSITE	56.4	58.2	60.5	64.8	65.2	55.7
UNTREATED COCONUT FIBRE COMPOSITE	56.4	61.2	63.4	66	69.4	61.2

Fig. 5: Hardness Value of the developed composite and Control Sample



	CONTROL	5wt%	10wt%	15wt%	20wt%	25wt%
TREATED COCONUT FIBRE COMPOSITE	19.24	9.42	24.3	12.36	9.08	11.2
UNTREATED COCONUT FIBRE COMPOSITE	19.24	29.52	15.81	14.84	12.59	11.2

Fig. 6: Impact strength of the developed composite and Control Sample

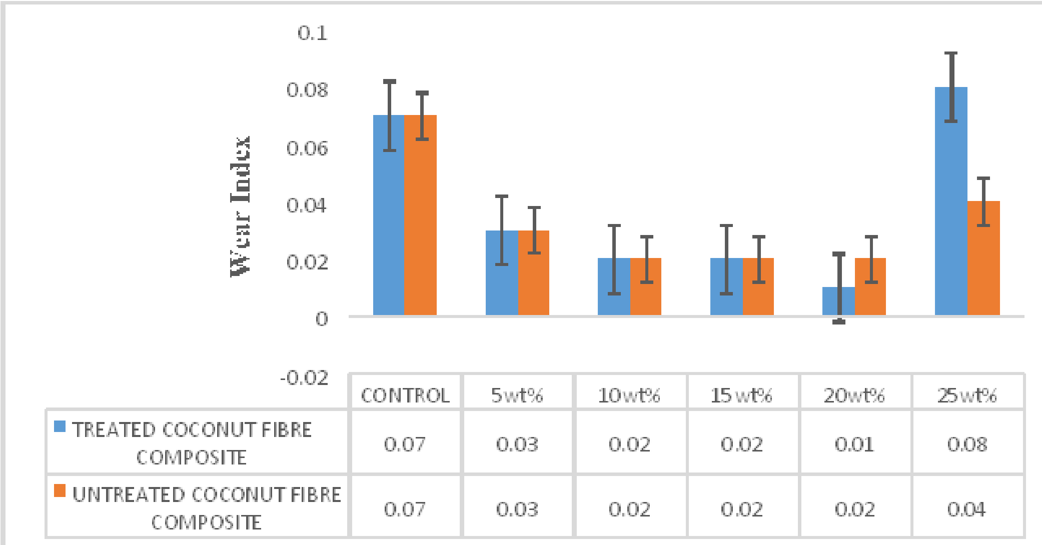


Fig. 7: Wear Index of the developed composite and Control Sample

IV. CONCLUSION

The following conclusion were drawn from the results obtained from the properties evaluated: all the mechanical properties evaluated was of better values for reinforced composites compare to the control sample; Tensile Strength and hardness was enhanced in the composites developed up to a threshold value of 20wt.% untreated coconut fibre. Flexural strength at peak composite samples with 20 wt.% treated coconut fibre reinforcement had the highest flexural strength value of 26.45 MPa, It is also seen from the impact strength of the developed coconut fibre reinforced epoxy composite and the control sample. The results show reduction in the impact strength on addition of coconut fibre to the epoxy (the control sample) which has 19.24 J/mm2. From the developed composites, 5wt% untreated coconut fibre sample has 29.52J/mm2 representing the optimum value for the reinforced composites.

It was observed that most of the reinforced composite samples have lower wear index compared to the control sample with wear index of 0.07 m/g. Composite with 20wt% treated coconut fibre gives good wear index value of 0.01 which was the sample with the optimum wear index. This shows that the reinforced composites have better abrasion and coconut (coir) fibre can be used as good reinforcing filler for epoxy resin.

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