Abrasion and Physical Properties of Rattan Cane (*Calamus deeratus*) Fibre Based Epoxy Composites

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Abstract: The effects of fibre content (5–30 wt%) and fibre treatment on abrasion, water absorption, specific gravity, and density properties of epoxy/rattan cane fibre composites were studied. Epoxy resin reinforced with the alkaline treated rattan cane fibre fibres was produced by compression technique in predetermined proportions. Abrasion and physical properties tests were carried out on the developed composites. The results showed that the reinforced composite samples have better enhancement in all the properties tested than the unreinforced control sample. Least Water Absorption (WA) value of 1.4 % were obtained within the 1 week and 2 week for the reinforced samples. Samples reinforced with 10 wt. % rattan fibres had the highest abrasion resistance, while the sample with 5 wt.% rattan fibre addition had the best water absorption resistance. The products of this research could find applications in automotive fields where exposure to moisture and wear are encountered.

Introduction

Natural fibre reinforced polymer composites have been gaining considerable attention as compared to conventional synthetic fibre composites owing to its economic, environmental, technical advantages, suitability and adaptability to different applications and processes [1]. Fibre-reinforced composite materials use fibre materials to mechanically enhance the strength, elasticity and physical appeal of polymer composites. The extent to which strength and elasticity are enhanced in a fibre-reinforced polymer depends on the mechanical properties of fibre and matrix, their volumes relative to one another and the fibre length and orientation within the matrix [2]. A great variety of natural fibre obtained from cellulose-rich plants have in recent years not just investigated but effectively employed in varying engineering applications [3]. Various types of lignocelluloses fibres that have been exploited include wood flour, henequen, Kenaf, hemp, sisal, flax, rice husk, jute and others [4,5]. Natural fibre composites in recent times have a wide range of applications and can effectively replace wood and other construction materials in most applications. They are used in decking, cladding, automotive, building, and residential applications. The applications and end-uses of these composites and their exposure to atmosphere and wear has made it necessary to evaluate the abrasive resistance of natural fibre filled HDPE with the aim of improving its service life, and desirable properties for their specific end-uses. Despite these advantage of natural fibres, their use as reinforcement agents, particularly in hydrophobic polymeric matrices, have several drawbacks such as poor wettability, incompatibility with some polymeric matrices and high moisture absorption by the fibres because of the hydrophilic nature of natural fibres. One important factors bedevilling the proper and effective harnessing and utilization of composites made of lignocellulosic fibers is its poor resistance to moisture [6]. Water absorption behaviour of natural fibre reinforced composite determine their applications. Outdoor applications have raised the interest on this property since moisture absorbed by the composite led to dimensional changes and to decreasing mechanical performance. The objective, therefore of this study is to examine how the negative effect of water absorption can be improved by varying the fibre content.

The addition of a compatibilizer has been a useful tool for achieving adhesion. Akash & Kumar [4] developed a sisal-coir hybrid composites with epoxy resin matrix to study their fire retardant, water/moisture absorption behaviours at different weight percentages (10,20,30,40 and 50 wt. %) sisal-coir

with epoxy resin. Traditional cold pressing method was used to fabricate the hybrid composite to a density of 410.4kg/cm³. The natural fibre used in this research is the rattan canes fibre. Rattan has thirteen genera with over 600 species; four of these genera are endemic to Africa in the tropical rainforest regions. The species in Nigeria in descending order of availability are *Calamus deeratus*, *Eremospatha macrocarpa*, *Oncocalamus manni* and *Laccosperma secundiflorum*, having average stock densities per plot of 100 square metres of 6, 22, 12 and 18 clumps respectively. *Calamus deeratus* is the most abundant specie in Nigeria with small stemmed diameter ranging from 7.2 – 17.8mm [7]. Rachchh et al [8], published a study dealing with rattan fibre composites. They observed that addition of rattan fibre into polymer matrix led to improvement in mechanical properties up to 12.5% fibre level but decreased above that due to inability of resin to sufficiently transfer load between fibres. The composites made are lighter compared to the resin alone and cost effective too. Abrasion and mechanical properties of keratinous based polyester composites was studied by Oladele et al [9]. The results indicates Optimum abrasion and mechanical characteristics were obtained with the addition of the cow hair fibre at higher content within 10-20 wt. %, this indicates that the reinforcements improved the abrasion resistance of the developed composites by impacting the matrix with the potential to resist abrasion.

Rattan cane are often equated with synthetic glass fibres because of its similar tensile strength that ranges from 464 to 603 MPa, depending on the species [10]. It have bending modulus (846.7–4057 MPa), bending strength (31.05-91.0 MPa), compressive modulus (831.61–1571.18 MPa), compressive strength (17.81–33.6 Mpa) and impact toughness(177.27–193.82 Mpa)[11], which results in their relatively high variability in structural composition and load-bearing part. Although rattan fibres are predominantly used as cane furniture/handicraft weaving materials [12], new applications concentrate on high value-added utilization as superior substitutes to glass fibres in composites and carbon-based materials for energy storage [11,13]. Epoxy LY 556 (bisphenol A diglycidyl ether) resin on the other hand, , are widely being used for multitudes of applications in day-to-day life [14]. They are well known for good thermal and mechanical properties, excellent adhesion to various substrates and easy processability. Epoxy LY 556 (bisphenol A diglycidyl ether) resin are made mostly by the condensation of the epichlorohydrin and Bisphenol A [11]. Epoxies have many advantages over the other thermosets. They offer high strength, low shrinkage, excellent adhesion to various substrates, effective electrical insulation, chemical and solvent resistance, low cost, and low toxicity. They are easily cured without evolution of volatiles or by-products by a broad range of chemical species. Compatibility of epoxy resins with most substrates and their good wetting ability make them very suitable in many composites [15]. The widespread applications for Epoxy technologies satisfy a variety of nonmetallic composite designs in commercial and military applications [16], including rocket motor tubes, flooring panels, ducting, vertical and horizontal stabilizers, wings and even as fuselage. They are also used in many recreational applications such as, lightweight bicycle frames, golf clubs, snowboards, racing cars, and musical instruments [17, 18]. This paper aims at development of a fibre reinforced composite using rattan cane which have high strength and toughness and is available.

Materials and Methods

Materials. Epoxy LY 556 (bisphenol A diglycidyl ether) resin is used in this study due to its wider range of applications, its characteristic high adhesion, mechanical strength, heat and corrosion resistant abilities. Hardener used is HY-951(IUPAC name: NN – bis (2 aminoethylene 1, 2-diamine. Sodium hydroxide (NaOH), Distilled water and processing oil were obtained from Rovet Chemicals, Lagos State, Nigeria. Rattan Cane was obtained from the surroundings of Owerri in Imo state while foil paper was obtained from Pascal Scientific, Lagos.

Preparation of the Composites. The fibre were soaked for 4 hours and washed in water to remove the adhering dirt and peel the bark, they were dried in an oven at 70°C for 6 hours. After drying, they were cut with Warring Blender to reduce the length of the fibre to 2-4 mm. Fibres were pre-treated with alkali using 5 % NaOH solution for four hours (4 hrs.). After pre-treatment, the fibres were

washed with distilled water until all untreated sodium hydroxide was removed. After washing, the fibres were pre-dried, and oven dried at 80°C for 4 hours. The fibres were bow milled for 12 hours to get a sieve size of 70µm prior to compounding. The epoxy and the rattan cane fibre were weighed into various weight fractions using an electronic weighing balance. The rattan cane was mixed with the epoxy by stirring at room temperature in a glass beaker with the help of suitable glass rod. Hardener was added into the beaker containing mixture at a time of stirring. With proper stirring for ten minutes, uniform mixing of the reinforcing agent and the polymer matrix was ensured and they were poured into a suitable mould. The fibre content of the composition was varied from 5-30 wt. % at 5 wt. % interval while the matrix (epoxy and hardener) content of the composition used was in a ratio of 2:1 as shown in the Table 1. The photographic view of fabricated samples were as shown in Figure 1(a - f).

Table 1. Formulation of Epoxy / Hardener /Rattan Cane Fibre ratios

Filler Wt./%	Epoxy Wt./%	Hardener Wt./%
00	66.66	33.34
05	63.33	31.67
10	60.00	30.00
15	56.67	28.33
20	53.33	26.67
25	50.67	25.33
30	46.67	23.33

Figure 1. photographic view of fabricated samples (a) 5 wt.% (b) 10 wt.% (c) 15 wt.% (d) 20 wt. % (e) 30 wt. % (f) Control 0 wt.%

Abrasion Resistance Determination

For carrying out this test, the Wallace Test Abrader Equipment S/NO084025/1 by Brooks Inspection Equipment Limited England was used in accordance with ASTM D-5707 and ASTM G-65-77/G-99 (rubber wheel abrasion). The composite samples to be abraded were cut and placed over a rotating drum of about 150mm diameter that moves a lateral distance of about 42mm. The drum was to rotate at 40 rev/mins thus achieving abrasion of about 0.32m/s. An abrasive material of 60 abrasiveness value was placed on the sample and a constant pressure of 10N was applied. The start button was then pressed and the test ran automatically. Each sample had to be weighed before and after the test to an accuracy of 1mg. The abrasiveness of the abrasive sheet had to be tested with two-three tests before and after each test series using rubber comparison samples. Abrasion Resistance AR%. The difference in weight of the composite sample before and after the determination was recorded and the A. R. deduced from equation (1).

$$\text{Abrasion Resistance (A. R.) \%} = \frac{100(X-Y)}{Y} \quad (1)$$

X= Initial abraded weight and Y= Final abraded weight.

Specific Gravity and Density. The specific gravity (Sp) was carried out according to the ASTM D792-08. An electronic weighing balance was used for specific gravity measurements, while a beaker served as an immersion vessel. A thread was used in suspending composites in air, while immersed into water during measurements. For this, individual test samples of 50 × 30 × 3.0 mm dimension previously weighed to 4 decimal places were first suspended in air and later immersed in H₂O held in a beaker. The samples were thereafter removed from the water, wiped with tissue paper and weighed again. The specific gravity/density was calculated from the equations (2) and (3):

$$\text{Specific gravity} = \frac{\text{soaked weight} - \text{dry weight}}{\text{soaked weight} - \text{suspended weight}} \times 100 \quad (2)$$

$$\text{Density} = \frac{\text{dry weight}}{\text{soaked weight} - \text{suspended weight}} \quad (3)$$

Water Absorption. Water absorption was carried out according to ASTM D 570. After conditioning individual test samples of 50 mm x 15 mm x 10 mm dimension in an oven at 50 °C for 24 hours, they were removed and cooled in a desiccator for another 24 hours before weighing (W₀) to 4 decimal places using a weighing balance. The samples were immediately immersed in distilled H₂O held in separate plastic containers at RT and the set up allowed to stand for 56 days during which period individual samples were taken out and weighed at 7 days intervals. Prior to weighing to obtain the sample weight after immersion (W₁), the H₂O adhering to the sample surface was gently wiped using tissue paper. At the end of each weighing process, the sample was returned to the H₂O for the next determination and the amount of H₂O absorbed by each sample W. A.(S) was calculated and expressed as a percentage (%) using the equation (4):

$$\% \text{ W. A. (s)} = \left[\frac{(W_1 - W_0)}{W_0} \right] \times 100 \quad (4)$$

Results And Discussions

Water Absorption Determination. The result in figure 2 shows the amount of water absorbed (WA) by the rattan-epoxy composites which is in compliance with some other investigation [19]. The results showed that the rattan-epoxy composites absorbed more H₂O than the 0.00 % FW or unmodified epoxy resin. The chemical composition of natural fibres is the reason for the uptake of H₂O molecules by the rattan cane. The results obtained shows that the control sample has reduced water absorption of 1-2% after which a progressive increase in percentage water absorption was observed as the percentage filler loading increased from 5- 30 wt. %. The progressive increase in water absorption

could be related to the hydrophilic nature of the fibre which is expected to have the possibility of moisture absorption property. According to Ghali et al. [20], the presence of numerous and free -OH groups in cellulose and lignin facilitates rapid water assimilation into the fibre cell walls through -H bonding. This means that like other materials of similar nature, persistence exposure of the rattan-epoxy composites in this study to humid environment can result to its deterioration by water absorption and the affect will result to compromised mechanical properties as reported by Saw et al. [21]. Reports by various authors [21,22,23,24] signified that the least WA value of 1.4 % demonstrated by the rattan-epoxy composites in this study is an acceptable indication of good resistance to water.

Figure 2. Water Absorption of the composites

Specific Gravity (g) and density (ρ) of rattan-epoxy Composites. The result in figure 3 shows the Specific Gravity and density of the composites respectively. It shows that there was a general increase in the specific gravity and density of the composites with increase in filler content. Increase in the $Sp(g)/\rho$ with increased fibre content is ascribed to the sustained migration to and build-up of rattan fibre in the intramolecular spaces in the polymer chains and pendant groups during the mechanical agitation process of the compounding stage. Increases in the $Sp(g)/\rho$ of polymer composites through the incorporation of rattan fibre is widely reported in literature. In a study on oil palm empty fruit bunch fibre (OPEFB) filled polypropylene composites, Wirjosontono et al., [25] reported substantial increases in the $Sp(g)$ of the oil palm empty fruit bunch filled polypropylene composites. Opara et al. [26] also reported increase of the $Sp(g)$ on both corncob and coconut fibre - polypropylene composites with increasing fibre content and that the magnitude of the increase was larger in the coconut fibre. The density of the unfilled epoxy is 0.59 g/cm^3 , but a steady rise was witnessed as the fibre ratio increased, up to 2.89 g/cm^3 , about 80 % rise in weight. Since light-weight materials lead to significant cost savings, high-volume can be made with lignocellulosic fibres such as rattan. As the weight percentage of rattan cane fibre is increased, the volume fraction of voids is increased as shown in Figure 4. The voids are also factors that affect the abrasion and physical properties.

Figure 3. Density and specific gravity of the Composites

Figure 4. Variation of void fraction with weight percentage fibre reinforced epoxy composite

Abrasion Resistance Test. Figure 5 shows results of abrasion resistance for the produced composites. Abrasion resistance (AR) is ability of material to resist wear under constant shear force. The observed decrease in AR values signifies that the number of rubs needed to abrade 1g of the studied composite reduced as the percentage fibre content continued to be increased. This is attributable to the increase in the number of voids in the composites as a result of the increasing fibre content. Voids-rich materials are vulnerable to abrasion when they are subjected to the abrading process due to the presence of such voids in the structure [26]. Sample reinforced with 5 and 10 wt. % rattan fibres with values of 0.05 and 0.04 g weight loss, respectively had the best abrasion resistance. The better abrasion resistance observed at the samples filled with 5 wt. % could be due to proper filler-matrix distribution and strong interfacial adhesion that could have formed in the composite [27]. The control sample without reinforcement had the least abrasion resistance with a value of 0.23 g weight loss. This therefore, indicates that reinforcements improved the abrasion resistance of the developed composites.

Figure 5. Abrasion Resistance of the composites

Conclusions

In this study, the effects of rattan fibre reinforced epoxy composite on abrasion resistance and physical properties were investigated. Rattan cane fibre reinforced epoxy composites was produced with different weight percentage of reinforcement. The Composites have good abrasion and physical properties. The water absorbency studied indicated that the matrix used can reduce water absorption and also reduce degradation even though the amount of water absorbed by the composites increases with the increase in the weight percent of the reinforcement. Void fraction of the composites increases slightly with increase in the reinforcement fibres. The specific gravity of the composite increased with increased rattan cane fibre. Optimum abrasion characteristics were obtained with the addition of the rattan fibre at 10 wt. %. Thus the composite have potentials for some industrial and domestic applications where abrasive resistance and mild exposure to moisture are needed. They also have low specific gravity when compared to mineral-based polymer products. The utilization of these materials would not only provide a renewable alternate to petroleum products, but would also create job and some source of economic development since the fibres are locally available and cheap.

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