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Studies on the Properties of Short Okra/Glass Fibers Reinforcedepoxy Hybrid Composites

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Abstract:
This paper presents an investigation on the mechanical and water absorption properties of okra and glass fibersreinforced epoxy hybrid composite as a potential material for engineering applications. The properties of randomly oriented okra fibers were studied as a function of different fiber lengths (10mm, 20mm, 30mm, 40mm, and 50mm) and okra: glass hybridization ratios (90:10, 80:20, 70:30, 60:40 and 50:50)at 15 wt % total fiber loading using the hand lay-up method followed by compression. The results indicated that fiber lengths and hybridization ratios do greatly influence the properties of reinforced hybrid composites, as the error analysis showed that generally, there were significant differences in the properties at different fiber lengths and different hybridization ratios. The 20mm fiber length composite exhibited the highest tensile strength (10.707MPa), modulus of elasticity (698.84MPa) and minimal water absorption (4.3%) properties compared to the other fiber length used in the composites. The 40mm composite had the highest elongation at break of 10.24mm. The 50: 50 hybridization ratios exhibited the highest tensile strength of 12.358MPa, Modulus of elasticity of 751.98MPa, 2.466mm elongation at break and the least water absorption of 2.59%. The composite have properties which suggest their suitability for application in the building and construction industries as panels for portioning and flooring or wall coverings, architectural landscaping to replace the hardwood currently used hence, preserving the environment.

Keywords*: Glass fibers, Okra Fibers, Hybrid,Resins, Mechanical properties,Lay-up (manual/automated)*

1. Introduction

Natural fibers are assuming much significance as processing materials for engineering applications today due to growing environmental consciousness and their high strength and stiffness. They also possess some good advantages over synthetic fibers such as their low cost, low density, renewability, manufacturing ease and biodegradability [1].

There is a growing interest in the use of natural fibers as reinforcing components for thermoplastics and thermosets. Although thermoplastics have the added advantage of recycling possibilities; thermosetsare targeted to obtain much improved mechanicalproperties as compared to thermoplastics in the resulting bio-composites [2]. One of the most important focuses in achieving this goal is to develop a new material, with an improved strength to weight ratio over any of the materials presently in use [3].There are various types of natural fibers today, and the variety continues to increase. Some examples in use include ramie, hemp, kenaf, jute, sisal, bamboo, banana, and oil palm fibers [4]. The mechanical properties of natural fiber composites are much lower than those of the synthetic fiber composites and they are hydrophobic. Synthetic fibers have very good mechanical properties, moisture repellency, but these are difficult to recycle. To take advantage of both natural and synthetic fibers, they can be combined in the same matrix to produce hybrid composites that take full advantage of the best properties of the constituents. Studies are still ongoing in the use of established natural fibers in composites materials development and also in the establishing some new ones as potential reinforcement candidates in composites materials, okra fiber is one of such.

De Rosa et al., [5] studied the Morphological, thermal and mechanical characterization of okra (Abelmoschusesculentus) fibers as potential reinforcement in polymer composites and concluded that these fibers show potential as reinforcement in polymer matrix composite. Shamsul et al., [6] studied the chemical analysis of okra fiber and its physico- chemical properties. The chemical compositions of okra fiber values are 67.5 % cellulose, 15.4 % hemicellulose, 7.1 % lignin, 3.4 % pectic matter, 3.9 % fatty and waxy matter, and 2.7% aqueous extract. The effect of varying fiber length and hybridization ratio on the mechanical properties of natural and hybridized fiber composites have been studied by many researchers.These include the use of flax in polypropylene [7],

sisal in polypropylene [8], kenaf in unsaturated polyester resin [9], hybridized bamboo/glass in epoxy [10] and hybridized sisal/glass in epoxy [2].
However, the use of okra fiber as reinforcement is sparingly reported despite its established potentials. In this work, a relatively new fiber, okra is exploited for the preparation of okra/glass fibers reinforced hybridized epoxy composite with specific focus on establishing the optimum fiber length and the hybridization ratio in relation to mechanical and water absorption properties.

2. Experimental

2.1. Materials

The Okra fibers, Glass fibers, the epoxy (Grade 3554A) and the hardener (Grade 3554B) were purchased from Juneng Nigeria ltd in Nssuka LGA of Enugu State Nigeria and used as purchased.

2.2. Method

2.2.1. Mould Preparation

A mould with dimensions 210mm x 160mm x 20mm mould cavity was used in this work. The mould cavity was cleaned to remove particles and then coated with layers of releasing agent (wax) for easy removal (Demolding) of the composite.

2.2.2. Okra-Epoxy Composite Specimen Preparation

The okra fibers were chopped to various lengths of 10mm, 20mm, 30mm, 40mm and 50mm respectively. Preliminary loading of the short okra fiber in the pre-calculated matrix showed that the mean loading capacity was 15 wt %, compared to the 20.4 wt % reported by Srinivasababu et al., [11].
The total fiber weight was maintained at 15 wt % of the total composite weight. The various lengths of the fibers were then weighed to the corresponding weight based on the total weight of the matrix required for the 4mm and 10mm composite samples thickness respectively.
The composite samples were made respectively by mixing the pre calculated volume of epoxy and hardener in the ratio of 5:1 by weight in a plastic cup and stirred thoroughly for 10 minutes. A portion of the mixture was poured into the prepared mould and some quantity of the weighed 10mm fiber was loaded in random orientation. Brush was used to apply the matrix to ensure the fibers were properly coated with the matrix. The procedure was repeated until the remaining fiber and the matrix was exhausted. The sample was cured at room temperature for 24 hours under load. It was then demoulded and further post-cured in an oven at 70^0C for 3 hours. The procedure was repeated for the 20mm, 30mm, 40mm and 50mm fibers lengths respectively.

2.2.3. Okra/Glass-Epoxy Hybridized Composite Specimen Preparation

The okra and glass fibers were chopped to 20mm fiber lengths respectively. Based on the 15 wt % fiber loading established, okra and glass fibers' weight were varied and calculated based on the following ratios (90:10, 80:20, 70:30, 60:40 and 50:50) respectively. The calculated amount of the various ratios were weighed and used to produce the hybrid composites.
The composite samples were made respectively by mixing the pre calculated volume of epoxy and hardener based on thein the ratio of 5:1 in a plastic cup and stirred thoroughly for 10 minutes. A portion of the mixture was poured into the prepared mould and some quantity of the weighed hybridized 90:10 (okra:glass) fiberwas loaded in random orientation using hand lay-up method. Brush was used to apply the matrix to ensure the fibers were properly coated with the matrix. The procedure was repeated until the remaining fiber and the matrix was exhausted. The sample was cured at room temperature for 24 hours under load. It was then de-molded and further post-cured in an oven at 70^0C for 3 hours. The procedure was repeated for the other hybridized okra: glass fibersratio of 80:20, 70:30, 60:40 and 50:50 respectively.

2.3. Characterization

Tensile testing of the composite specimens was carried out using an Instron Machine Model 3369, System Number 3369K1781, Capacity 50kN, Maximum speed 500mm/min, located at Center for Energy Research and Development (CERD) OAU Ile-Ife Osun State Nigeria using ASTM D638.
Water absorption test was conducted using the procedure outlined in accordance with ASTM D570-98. Equation 1 was used to establish the percent water absorbed. Where w_i is initial weight of dry sample and w_f is final weight of wet sample.

$$\% \text{ water absorption} = \frac{W_f - W_i}{W_i} X\ 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 1$$

All the results were taken as the average of 3 samples for each testing.

3. Results and Discussion

3.1. Tensile Strength

Figure 1 presents the effect of varying fiber length on the tensile strength of the short okra fiber composite. The result of the test showed that the 20mm fiber length composite has the highest average tensile strength value of 10.707MPa as compared to other composites reinforced with the 10mm, 30mm, 40mm and 50mm respectively. There was an increase in thetensile strength from the 10mm fiber to a maximum peak at 20mm and then a downward trend was observed. The observed decrease could be attributed to improper fiber wetting due to increased fiber entanglement with length as well as the possibility of increasing fiber-rich and/or matrix-rich areas within the composite [12].

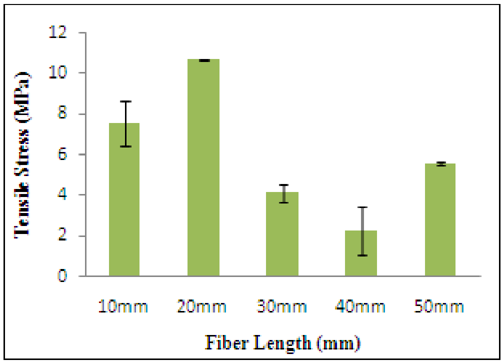

Figure 1: The effect of fiber length on the tensile strength of the composite

Figure 2 presents the effect of okra/glass fibers hybridization ratio on the tensile strength of the composite. There was an increasing tensile strength value with an increasing percentage of glass fiber content.The result showed that the 50:50 okra-glass fiber ratios exhibited the highest tensile strength of 12.358MPa.It was 15.42% higher than the un-hybridized composite. The increase could beattributed to the stronger and stiffer characteristics of the glass fibers compared to the okra fibers [13]. Glass fiber adherence to the matrix is better when compared to okra fiber and the interfaces between the fiber and the matrix is more (surface area of contact). Hence, it is difficult for the prevailing forces to pull glass fibers from the matrix in the hybrid composite compared to that of okra fibercomposite [14].

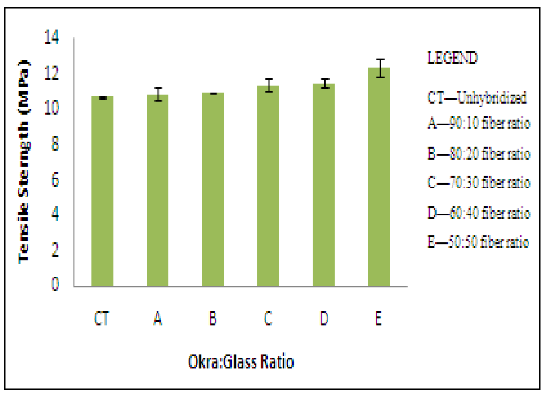

Figure 2: Effect of glass fiber hybridization on the tensile strength of the composite

3.2. Modulus of Elasticity (MOE)

Figure 3 presents the effect of varying fiber length on the MOE of the okra fiber epoxy composite. The 20mm fiber length exhibited the highest modulus of elasticity of 698.83MPa. This suggests that the 20mm fiber length composite exhibit higher degree of stiffness compared to the rest composites reinforced with the 10mm, 30mm, 40mm and 50mm fiber lengths. This was due to the fiber entanglements prevalent at longer fiber length [15] and this may also be attributed to the strong stress fields developed at the ends of the fibers in the composite beyond 20mm fiber length which made the composite samples less tough [16] and shorter fiber are said to move to optimized position in a composite than longer fiber [17].

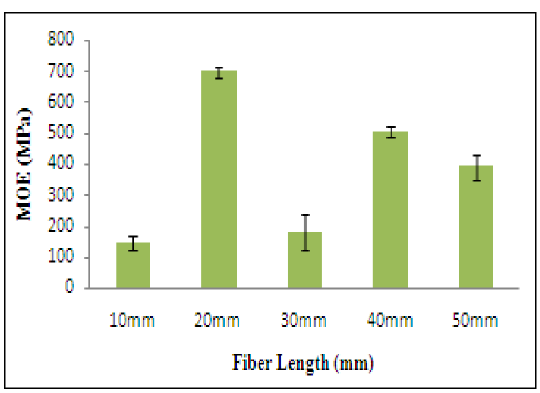

Figure 3: The Effect of fiber length on the MOE of short okra fiber reinforced epoxy composite

Figure 4 presents the effect of okra/glass fibers hybridization ratio on the MOE of the composite. The 50:50 ratios exhibited the highest MOE of 751.9823MPa.It was 7.6% higher than the un-hybridized composite. Glass fiber has a higher tensile modulus than the okra fiber and the incorporation of the high modulus glass fiber increases the modulus of elasticity of the composite. As glass fiber isthe stiffer component in the composite, resistance towards deformation increases with increase in glass fiber content,this consequently increased the stiffness of the composite [18].

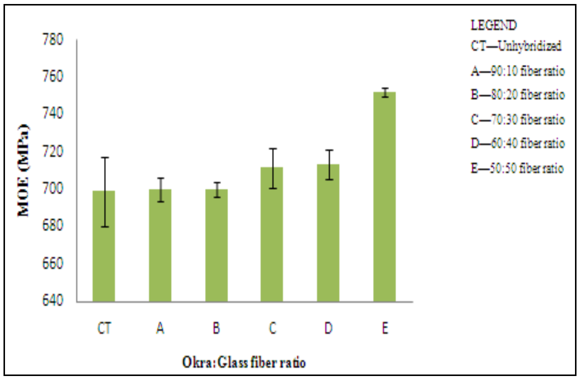

Figure 4: Effect of glass fiber hybridization on the MOE of the composite

3.3. Extension at Break

Figure 5 shows the variation of extension at break of the composite to the fiber length. It was observed that the 40mm has the highest extension at break of 10.2425mm corresponding to 25.6% elongation. The 20mm fiber length composite has the least extension at break which corresponds to 8.9% elongation. The stiff nature of the composite as was observed from the MOE result could be responsible for this observation. This could also be attributed to improper fiber wetting as well as the possibility of increasing fiber-rich and/or matrix-rich areas within the composite [12].

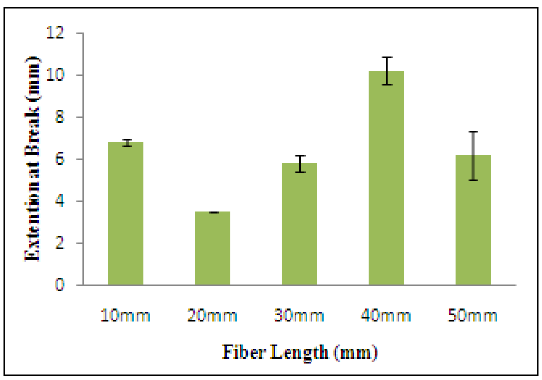

Figure 5: Effect of fiber length on the elongation at break of short okra fiber reinforced epoxy composite

Figure 6 presents the effect of okra/glass fibers hybridization ratio on the elongation at break of the composite.There was a decrease in the elongation of the composite by 59.5% at 90: 10 okra: glass fibers hybridization ratio when compared to the un-hybridized composite. The negative hybrid effect was observed up tothe 70: 30 okra: glass ratio and on further increase in the glass fiber content, a positive hybrid effect was observed. The decreasing elongation is attributed to the lower elongation value of the glass fibers compared to those of the natural fiber and the matrix used [19]. This also indicates that the ductile nature of the okra fibers decreases with the addition of the glass fiber.

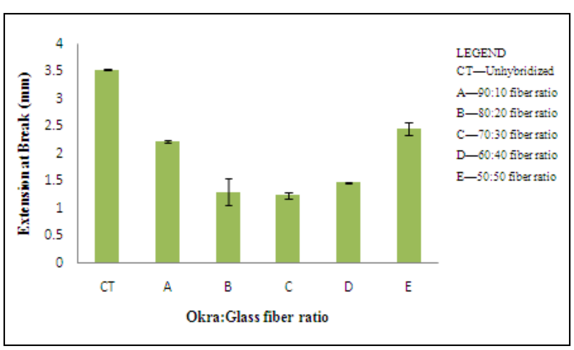

Figure 6: Effect of Glass Fiber Hybridization on the Elongation at Break of the Composite

3.4. Water Absorption

The result of the effect of fiber length on the water absorption behavior of the composite is presented in Figure 7. It shows a decreasing trend from the 10mm composite with 7.6% to the 20mm composite having 4.3%. The 40mm fiber length composite has the highest percentage moisture uptake of 22%. The low moisture uptake of the 20mm fiber length composite is attributed to the improved interfacial adhesion that reduces water accumulation in the interfacial voids and prevents water from entering the composite [20] and the increasing moisture absorption may be attributed to the inability of the matrix material to completely saturate the fiber at higher fiber length [12].

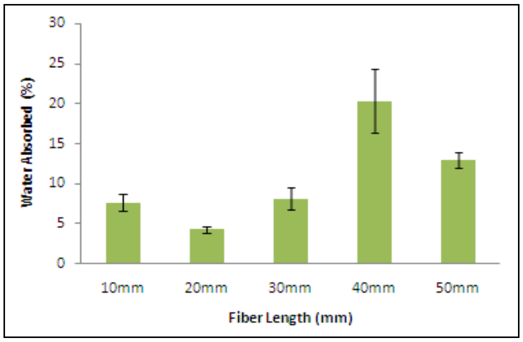

Figure 7: Effect of fiber length on water absorption of the short okra reinforced epoxy hybrid composite

Figure 8 present the effect of okra/glass fibers hybridization ratio on the water absorption behavior of the composite.The 50:50 okra: glass fiber ratio exhibited the least percentage water absorption capacity of 2.586%. It is 66.35% less than the un-hybridized okra fiber composite. This is due to the decreasing quantity of the hydrophobic component of the composite [13]. Fibers in these composites are arranged in a closed packed manner in which the water impermeable glass fiber acts as barriers and prevents the contact between water and the hydrophobic natural fibers, which explains the decreasing water absorption properties of the composite with increasing glass fiber content [2].

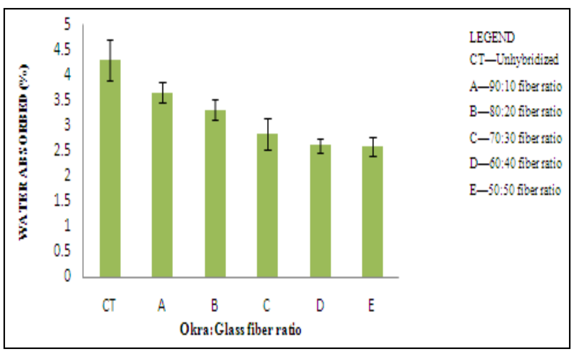

Figure 8: Effect of glass fiber hybridization on water absorption of short okra/glass fiber hybridized composite

4. Conclusion

Mechanical and water absorption properties of short okra fiber reinforced epoxy matrix composite at 15 wt % fiber loading and varying fiber lengths from 10mm to 50mm and hybridization ratios range of 90: 10 to 50: 50 okra: glass ratios have been investigated.

The tensile strength, extension at break, modulus of elasticity and the water absorption properties were observed to have been greatly influenced by the length of the fibers and the hybridization ratios used in the reinforcement.

The optimal tensile strength, modulus of elasticity and water absorption properties for the short okra fiber reinforced epoxy composite was observed at20mmand 40mm for the extension at break respectively. For the hybridized composite, the 50: 50 hybridization ratios exhibited the optimal properties for the tensile strength, modulus of elasticity, elongation at break and water absorption characteristics under the present experimental conditions adopted hence 20mm fiber length and the 50: 50 okra: glass hybridization ratios are the optimal critical fiber length and the hybridization ratios respectively.

The properties of the hybrid composite made it suitable for applications in the building and architectural sectors. The composite can be used as a substitute for hardwood, which is currently used as architectural features in buildings, hence preserving the environment. They can also be used as architectural landscaping in public and private constructions due to their minimal water absorption, swimming pool surrounding, walkway paths, and panels for partitioning.

5. References

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