Journal of Inventive Engineering and Technology (JIET)
ISSN: 2705-3865
Volume-1, Issue-5, August, 2021
www.jiengtech.com
Research Paper Open Access

NATURAL FIBER REGGRESSORS EFFECTS ON PHYSICAL AND STRENGTH PROPERTIES RESPONSES OF BIDIRECTIONAL FINGER ROOT FIBER REINFORCED EPOXY COMPOSITES

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***ABSTRACT**: Last few years, the interest in using natural fibers as reinforcement in polymers has increased dramatically. Natural fibers are not only strong and lightweight but also relatively very cheap. In this research work, an investigation has been carried out to make use of finger root fiber, a natural fiber abundantly available in Nigeria. The present work describes the development and characterization of a new set of natural fiber based polymer composites consisting of bidirectional finger root fiber as reinforcement and epoxy resin as matrix material. The composites were fabricated using hand lay-up and compression moulding techniques and were characterized with respect to their physical and strength properties. Experiments are carried out to study the effects of fiber reggressors on the physical and strength properties responses of bi-directional finger root fiber reinforced epoxy composites. Results show the significant effects of fiber reggressors on the physical and strength properties responses of finger root epoxy composites. Also, the formations of voids in the composites at different fiber reggressors were an influencing factor on the composites strength properties as responses.*

***KEYWORDS**: Natural fiber; Finger root fiber; Epoxy; Physical Properties; Strength Properties*

Date of Submission: 26-07-2021 Date of acceptance: 06-08-2021

Table1. Nomenclature of the present study

Abbreviations	Units	Meaning
$\Delta\upsilon$	%	Volume fraction percentage
W	Wt. %	Weight fraction
Greek symbols		
ρ	g/cm^3	density
Subscripts		
ct	-	composite
ex	-	experimental
f	-	fiber
M	-	matrix

I. INTRODUCTION

Over the past few decades there is a rapid increase in the demand of the fiber reinforced polymer (FRP) composites because of the unique combination of high performance, great versatility and processing advantages at favorable costs by permutation and combination of different fibers and polymers (Zaman et al, 2010). FRP composites possesses interesting properties like high specific strength and stiffness, good fatigue performance and damage tolerances, low thermal expansion, non-magnetic properties, corrosion resistance and low energy consumption during fabrication (Jawaid et al, 2011). Fiber reinforced composites made up of carbon, boron, glass and kevlar fibers have been accepted widely as the materials for structural and non-structural applications (Gowda et al, 1999).

Environmental concerns are increasing day by day and the demand of replacing the existing synthetic fibers with the biodegradable, renewable and low cost natural fibers for fabrication of composite materials increases (Sandhyarani et al, 203). In comparison to the traditional reinforcing materials natural fiber such as sisal, jute, abaca, pineapple and coir has acceptable specific strength properties, low density, low abrasion multi-functionality, good thermal properties, enhanced energy recovery and cause less skin and respiratory irritation ((Dey et al, 2011), (Chin et al, 2009)). Pervaiz and Sain (2003) examined the energy consumption of glass and natural fibers, and they found that by using vegetal fibers in place of glass fibers, energy could be saved at a rate of 60% per ton of product. The insulating characteristics of jute may find applications in automotive door/ceiling panels and panel separating the engine and passenger compartments (Hamada et al, 2005).

Finger root, a natural fiber in polymer composites would be suitable for the primary structural applications, such as indoor elements in housing, temporary outdoor applications like low-cost housing for defense, rehabilitation and transportation. The use of natural fiber like finger root not only help us in ecological balance but can also provide employment to the rural people in countries like Nigeria, India and Bangladesh where finger root is abundantly available.

In this study bi-directional finger root fiber has been used for the preparation of the composites. The purpose of this study was to investigate the potential utilization of finger root fiber as reinforcement in polymer matrix composites. Also, the effect of finger root fiber content on the physical and strength behavior of the composites were investigated.

II. EXPERIMENTAL DETAILS

The experimental details were as depicted below in the following sub-headings.

A. MATERIALS AND METHOD

Bidirectional finger root fiber has been obtained from northern Nigeria in 2014 as the local source for reinforcing material. Epoxy resin and the corresponding hardener are supplied by GeoChem CCRD. The polymer composites were fabricated by hand lay-up and compression moulding techniques. Composite samples with different fiber loadings (10wt %, 30wt %, 50wt %) and different fiber lengths (10mm, 30mm, 50mm) were prepared and subjected to post curing for 24 hours at room temperature.

B. PHYSICAL AND STRENGTH PROPERTIES CHARACTERIZATIONS

The theoretical densities of the composite samples were obtained in terms of the weight fractions and densities of the constituents, and is given by Eq. (2.2.1)

$$\rho_{ct} = \frac{1}{(W_f/\rho_f) + (W_m/\rho_m)} \qquad (2.1)$$

where ρ *and W are the density and weight fraction, respectively. The suffix ct, f* and *m* correspond to the composites, fiber and matrix, respectively.

Water immersion techniques were used to determine the actual density of the prepared composite samples experimentally.

The volume fraction of voids in composites were obtained by the relation below

$$\Delta\upsilon = \frac{\rho_{ct} - \rho_{ex}}{\rho_{ct}} \qquad (2.2)$$

where ρ_{ex} is the experimental density of the composite fabricated.

Hardness measurement was done using a brinell-hardness tester equipped with a carbide ball indenter. Tensile test was performed as per ASTM D 3039-76 test standards using universal testing machine Instron 1195.Three point bend test was carried out in the same machine at a cross head speed of 10 mm/min to obtain the flexural strength and inter laminar shear strength (ILSS). Impact strength of the composites were evaluated by a low velocity impact tests conducted in an impact tester as per ASTM D 256 test standards.

III. RESULTS AND DISCUSSIONS

A. PHYSICAL AND STRENGTH PROPERTIES

The theoretical density, experimental density and void fraction (in percentage) are reported in the Table 1. The presence of the voids affects the strength properties of the composites. The void formation in the polymer composites can occur due to air entrapment during the preparation of resin system and moisture absorption during the material processing or storage. A higher void content in the composites shows that resin has not thoroughly surrounded the fibers and resulting in weaker interfacial strength which in turn reduces strength and stiffness of composites. Mutual abrasion of fiber leads to fiber fracture and damage and crack initiation and growth due to void coalescence (Boey, 1990). From Table 1, it was found that epoxy with the addition of 50 wt.
% fiber 50 mm has the minimum void content, while epoxy with the addition of 10 wt. % fiber 10 mm has the maximum void content, but with the addition of 30 wt. % fiber 10 mm the void content decreases instantly to 3.5223% . But with the further increase in the fiber content from 30 wt. % to 50 wt. % the void content of the samples decreases across the different fiber lengths. The theoretical and experimental densities of the composites increase as the fiber loading increases across the different fiber lengths.

Table 1. Comparison between Experimental density and Theoretical density

Designation	Composite composition	Theoretical Density (ρ_{ct}) g/cm^3	Expt. Density (ρ_{ex}) g/cm^3	Void Fraction (%)
BFRFE – 1	Epoxy +10wt.-% finger root fiber 10mm (BD)	1.150	1.106	3.8261
BFRFE – 2	Epoxy + 30wt.-% finger root fiber 10mm (BD)	1.164	1.123	3.5223
BFRFE – 3	Epoxy + 50wt.-% finger root fiber 10mm (BD)	1.173	1.140	3.2258
BFRFE – 4	Epoxy +10wt.-% finger root fiber 30mm (BD)	1.192	1.157	2.9362
BFRFE – 5	Epoxy +30wt.-% finger root fiber 30mm (BD)	1.206	1.174	2.6534
BFRFE – 6	Epoxy +50wt.-% finger root fiber 30mm (BD)	1.220	1.191	2.3771
BFRFE – 7	Epoxy +10wt.-% finger root fiber 50mm (BD)	1.234	1.208	2.1069
BFRFE – 8	Epoxy +30wt.-% finger root fiber 50mm (BD)	1.248	1.225	1.8429
BFRFE - 9	Epoxy +50wt.-% finger root fiber 50mm (BD)	1.262	1.242	1.5848

BFRFE: bidirectional finger root fiber epoxy, BD: bidirectional

Figures 1 – 3 shows the effects of different fiber loading on the hardness of composites at different fiber lengths. It has been found that the hardness of the composite increases with the increase in the fiber loading. In general the fibers increase the modulus of composite which in turn increases the hardness of fiber. This is because hardness is a function of relative fiber volume and modulus (Bharath et al, 2011). Surface hardness values of 10 HRB, 11 HRB and 12 HRB were obtained from composites with 10mm, 30mm and 50mm fiber lengths. The surface hardness values increases by 40% for 10mm, 41% for 30mm and 40% for 50mm with the incorporation of 30 wt. % fibers in the matrix. The maximum surface hardness values of 28 HRB for 10mm, 40 HRB for 30mm and 63 HRB for 50mm were obtained from bidirectional finger root epoxy composites reinforced with 50 wt. % of finger root fiber.

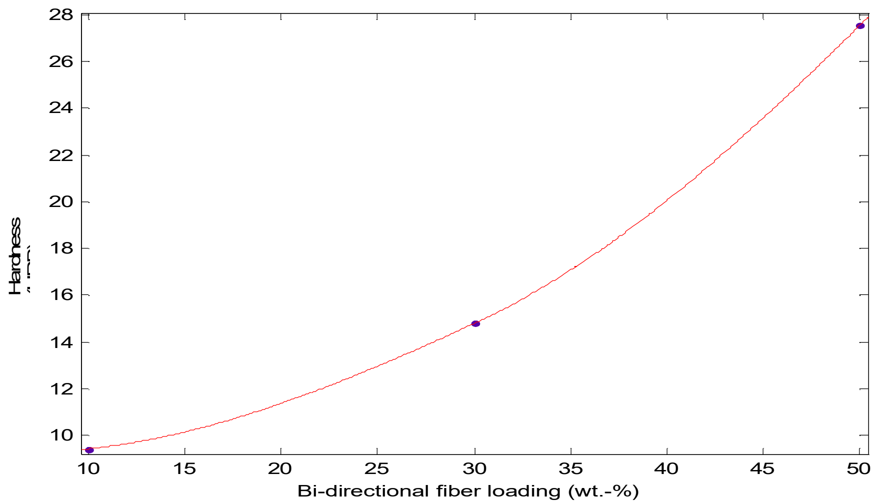

Fig. 1. Effect of fiber loading on hardness of composites with 10mm fiber lengths

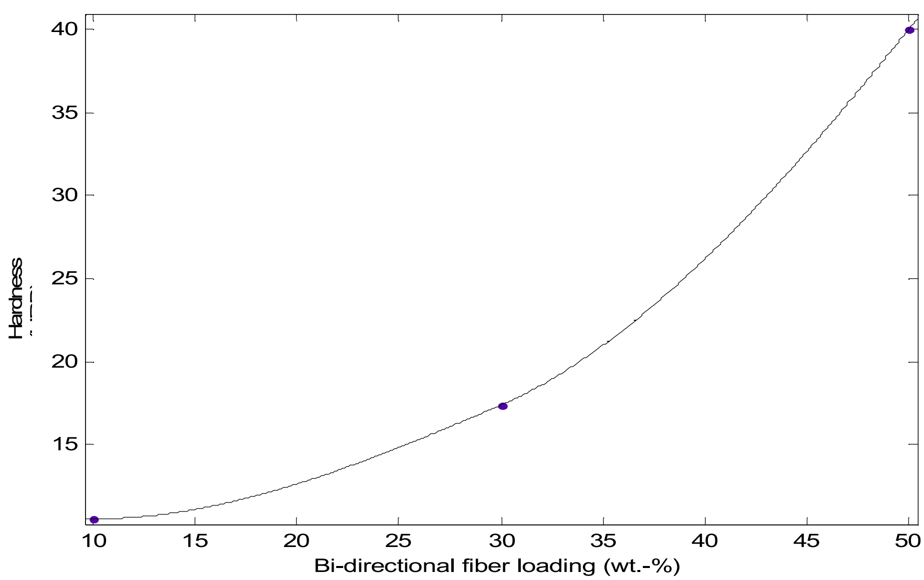

Fig. 2. Effect of fiber loading on hardness of composites with 30mm fiber lengths

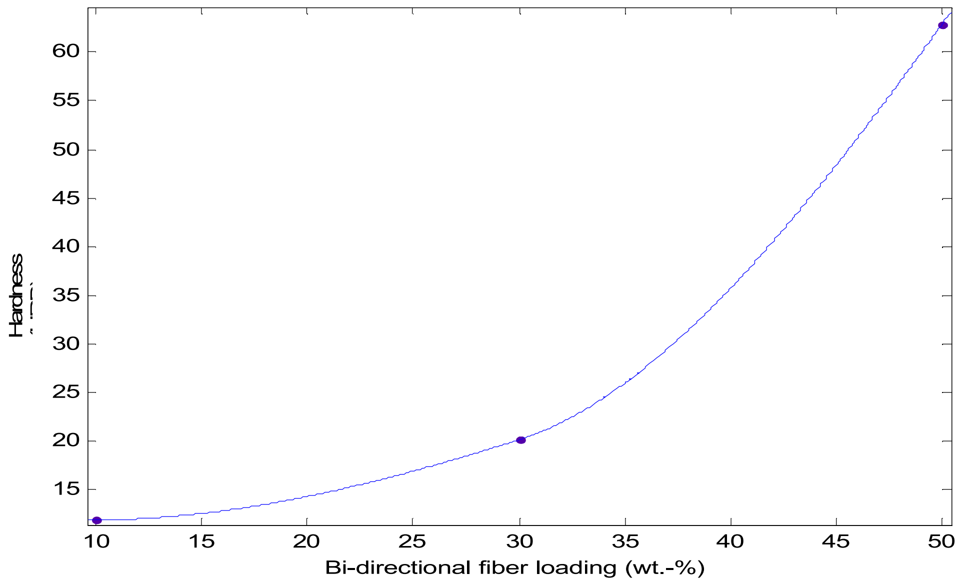

Fig. 3. Effect of fiber loading on hardness of composites with 50mm fiber lengths

The variations in tensile strengths and tensile modulus of composite with increase in fiber content at different fiber lengths were shown in Fig. 4 - 9. It is clearly visible that with the increase in fiber content at different fiber lengths in the epoxy matrix, the tensile strengths and modulus also increases. There were a proper transmission and distribution of the applied stresses by the epoxy resins resulting in higher strengths across the lengths. Similar observations have been made by (Bijwe et al, 2006) in case of aramid fabric/polyethersulfone composites. The bidirectional finger root fiber composites at higher fiber loadings and fiber lengths bear's higher loads before failure compared to those at lower fiber loadings and fiber lengths. The tensile strength varies from 7.50 N/mm^2 to 27.19 N/mm^2 for 10 mm fiber lengths, 7.81 N/mm^2 to 10.63 N/mm^2 for 30 mm fiber lengths and 10.13 N/mm^2 to 11.88 N/mm^2 for 50 mm fiber lengths while tensile modulus varies from 302.40 N/mm^2 to 803.10 N/mm^2 for 10 mm, 340.30 N/mm^2 to 357.30 N/mm^2 for 30 mm and 733.20 N/mm^2 to 823.80 N/mm^2 with the fiber variation from 10 to 50 wt.%.

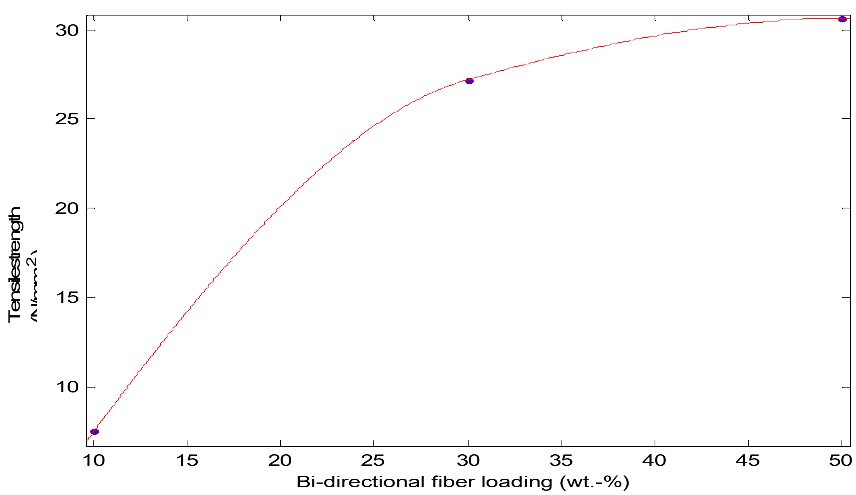

Fig. 4. Effect of fiber loading on tensile strength of composites with 10mm fiber lengths

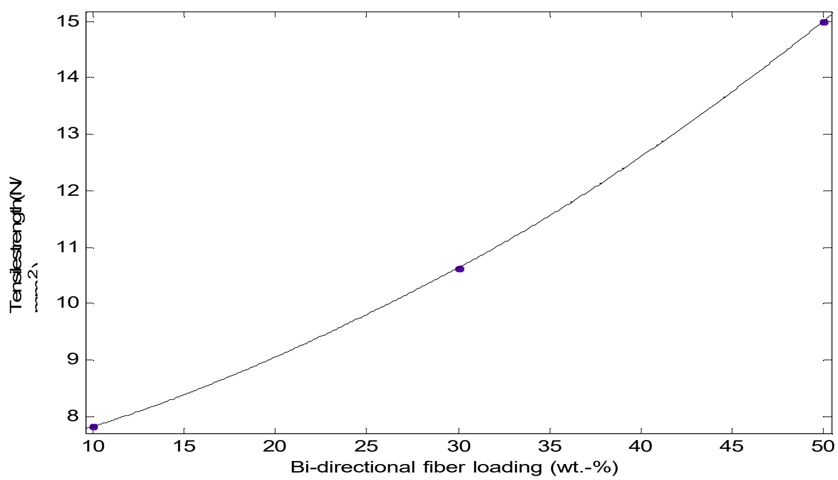

Fig. 5. Effect of fiber loading on tensile strength of composites with 30mm fiber lengths

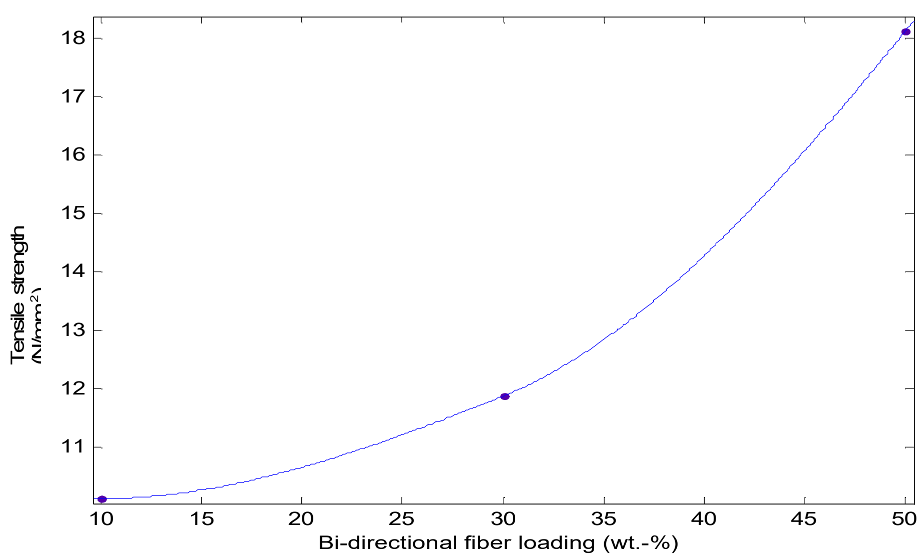

Fig. 6. Effect of fiber loading on tensile strength of composites with 50mm fiber lengths

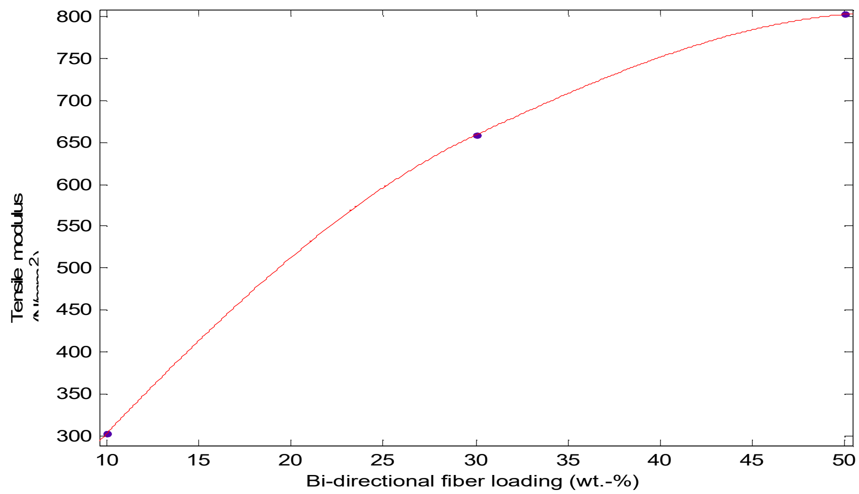

Fig. 7. Effect of fiber loading on tensile modulus of composites with 10mm fiber lengths

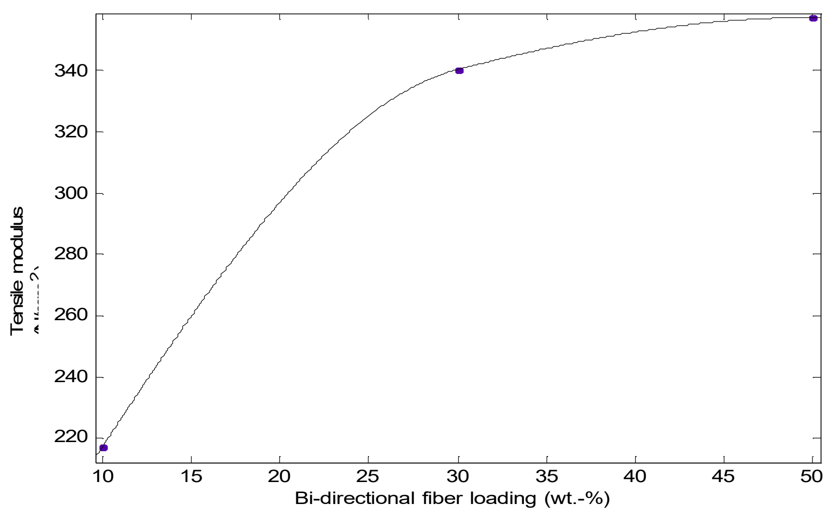

Fig. 8. Effect of fiber loading on tensile modulus of composites with 30mm fiber lengths

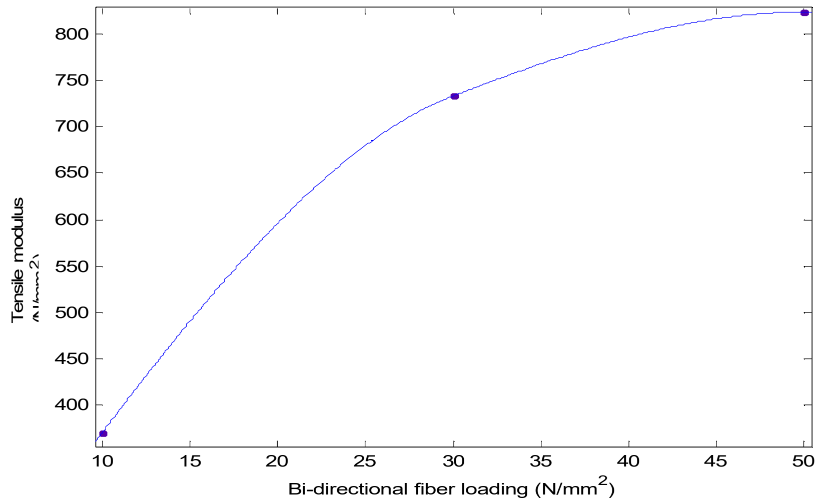

Fig. 9. Effect of fiber loading on tensile modulus of composites with 50mm fiber lengths

The result obtained from the three point bend test is shown in Fig. 10 - 15. It had been found that there was a reduction in the flexural properties of specimen with 10 wt. % fiber loading. Similar observations have also been made by Dong and Davies (Dong et al, 2011). According to their study, the reduction in the flexural properties of the composites is due to weak interfacial bonding and existence of voids. The flexural strength and modulus of the composites increases with the increase in the fiber loading starting from 10 wt. % fiber loading across different fiber lengths. The maximum flexural strengths and moduli at different fiber lengths were 61.52 N/mm^2 for 10 mm, 43.02 N/mm^2 for 30 mm, 37.70 N/mm^2 for 50 mm and 46.97 N/mm^2 for 10 mm, 29.9 N/mm^2 for 30 mm, 14.79 N/mm^2 for 50 mm fiber lengths, respectively, were obtained at 50 wt. % of fiber loading. The flexural strengths and moduli of 50 wt. % fibers loading are increased by 46 % for 10 mm fiber length, 22 % for 30 mm fiber length, 23 % for 50 mm fiber length and 63 % for 10 mm, 57 % for 30 mm, 47 % for 50 mm in comparisons with 10 wt. % fiber loading. The finger root fiber inclusions enhanced the load bearing capacity and ability to withstand bending of the composites (Mantry et al, 2010).

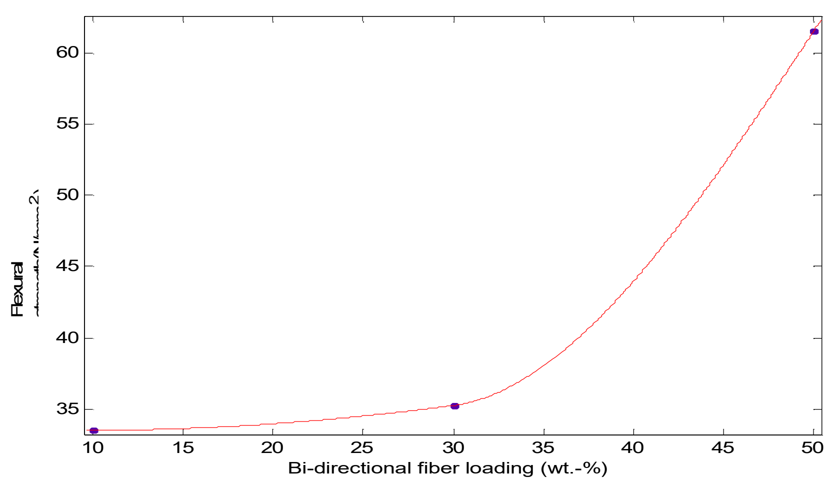

Fig. 10. Effect of fiber loading on flexural strength of composites with 10mm fiber lengths

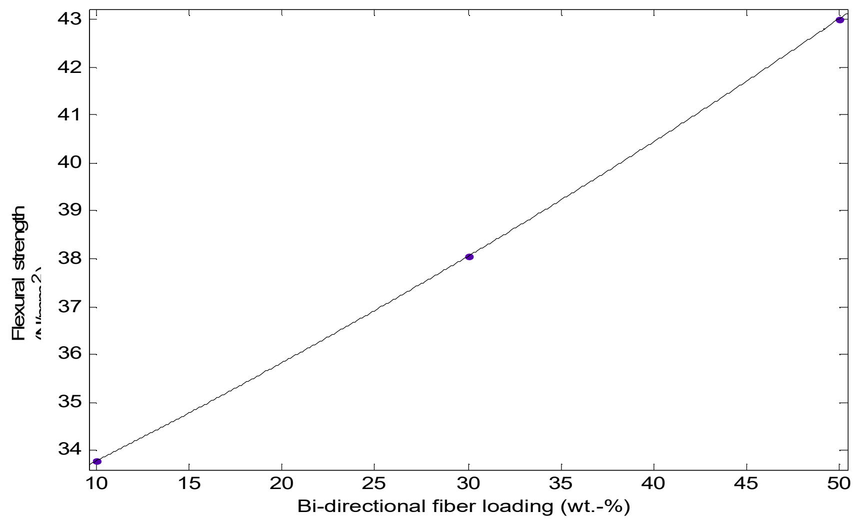

Fig. 11. Effect of fiber loading on flexural strength of composites with 30mm fiber lengths

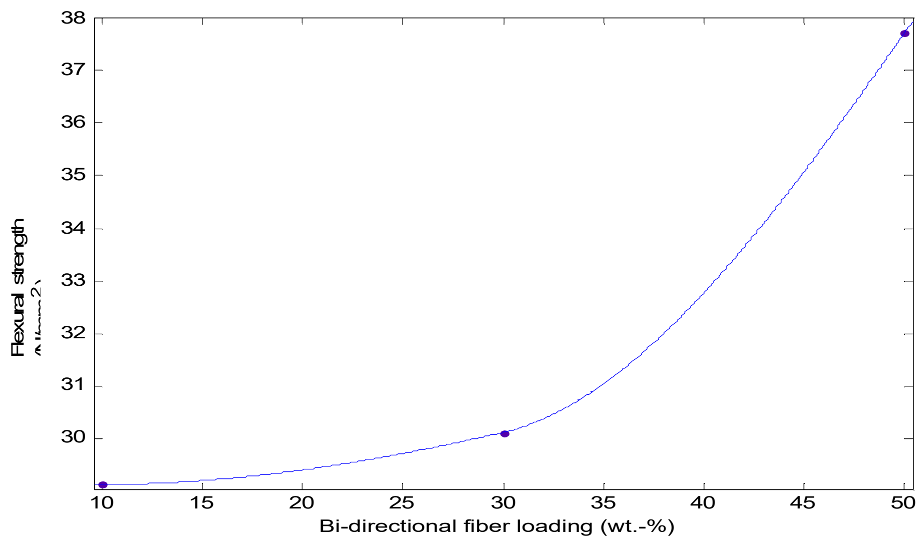

Fig. 12. Effect of fiber loading on flexural strength of composites with 50mm fiber lengths

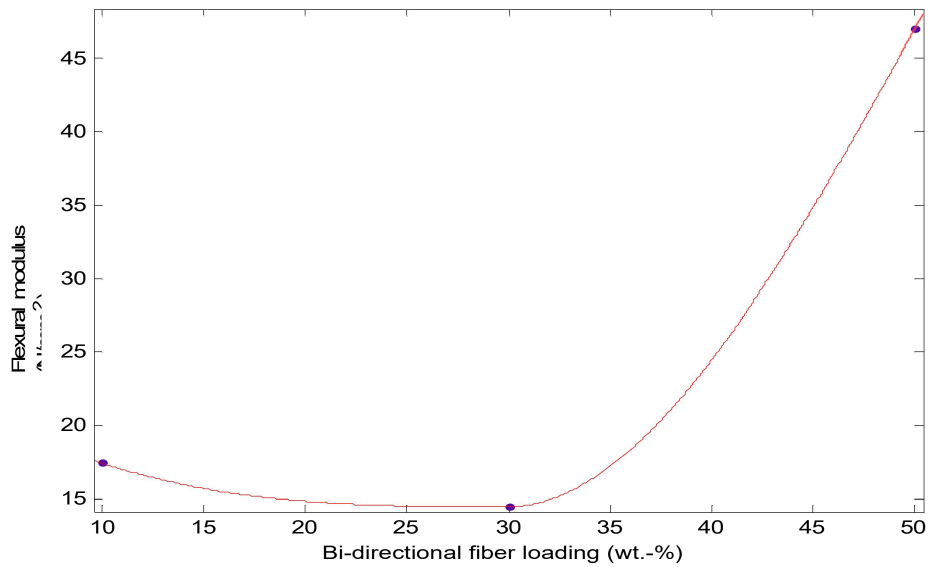

Fig. 13. Effect of fiber loading on flexural modulus of composites with 10mm fiber lengths

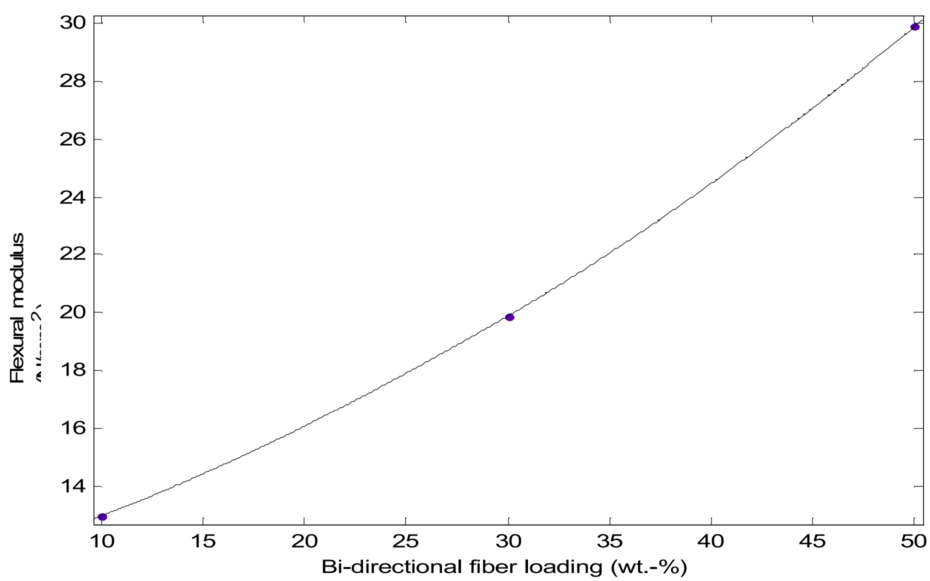

Fig. 14. Effect of fiber loading on flexural modulus of composites with 30mm fiber lengths

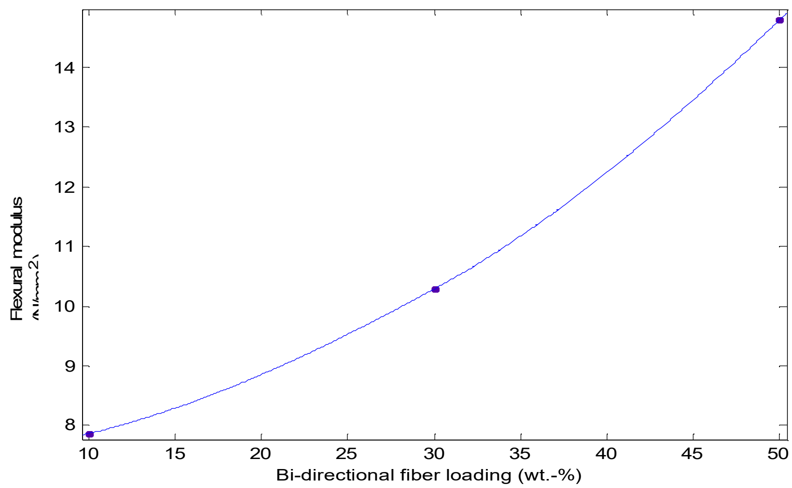

Fig. 15. Effect of fiber loading on flexural modulus of composites with 50mm fiber lengths

The effect of fiber loading at different fiber lengths on the inter-laminar shear strength (ILSS) of the finger root epoxy composites are shown in Fig. 16 – 18. The ILSS value increases drastically for the composites with fiber loading from 10 wt. % to 50 wt. % across different fiber lengths. The maximum ILSS of 46.97 N/mm^2 for 10 mm fiber length, 0.23 N/mm^2 for 30 mm fiber length and 0.20 N/mm^2 for 50 mm fiber length were obtained at 50 wt. % fiber loadings.

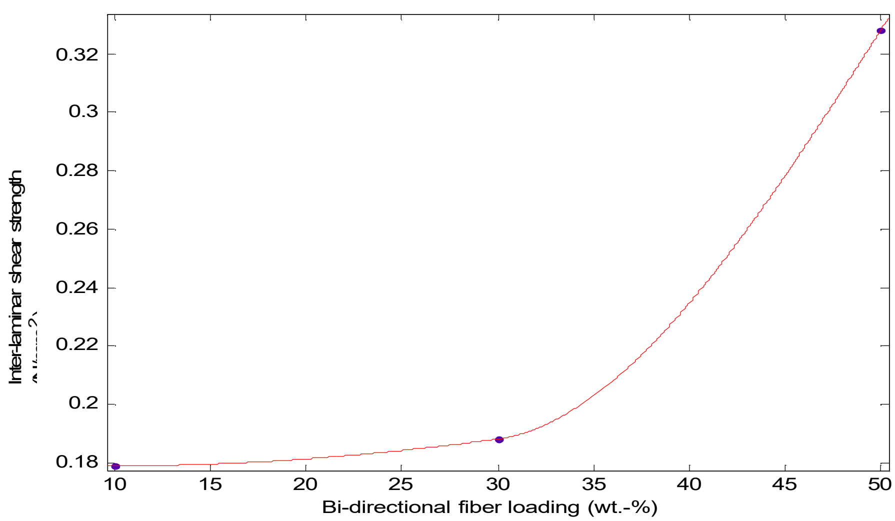

Fig.16. Effect of fiber loading on inter-laminar shear strength of composites with 10mm fiber lengths

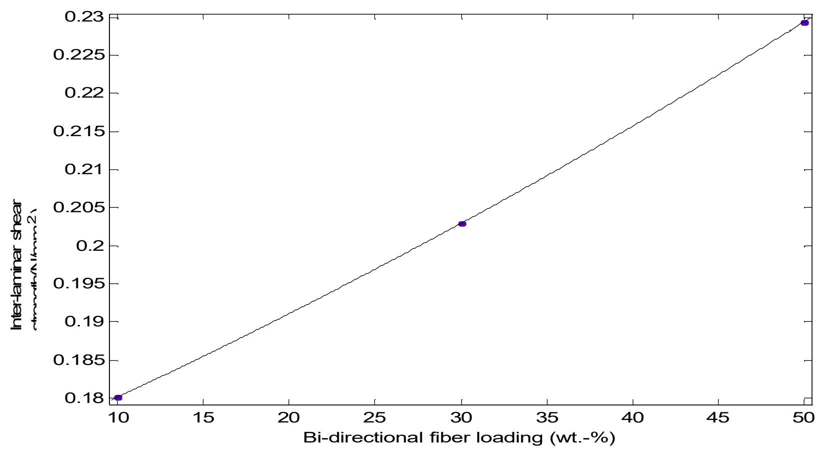

Fig. 17. Effect of fiber loading on inter-laminar shear strength of composites with 30mm fiber lengths

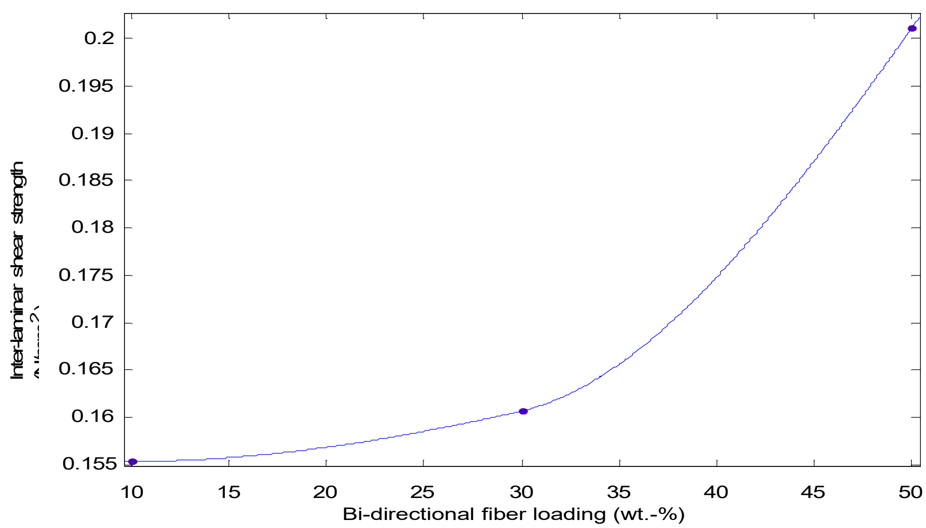

Fig. 18. Effect of fiber loading on inter-laminar shear strength of composites with 50mm fiber lengths

The impact strengths of the bidirectional finger root epoxy composites are shown in Fig 19 - 21. The maximum energy absorbed by the composites due to impact load at different fiber lengths are 537.95 J for 10 mm fiber lengths, 1,224 J for 30 mm fiber length and 481.25 J for 50 mm fiber length for composites with fiber contents of 50 wt. %, respectively. The maximum impact strength is of 314.69 J/m in the case of composite with 10mm fiber length, 504.69 J/m in the case of composite with 30 mm fiber length and 220 J/min the case of composite with 50 mm fiber length for 50 wt. % of fiber loading. The increase in the impact strength with the increased fiber loading at increased may be due to the fact that more energy will have to be used up to break the coupling between the interlaced fiber bundles. Good adhesion between the fiber and matrix is also responsible for the good resistance to crack propagation during impact test. The increased fiber content will increase the contact area between the fiber and matrix, if there is good impregnation of fibers in the resin. At higher fiber loading the impact transfer should be more efficient (Turunen et al, 2011).

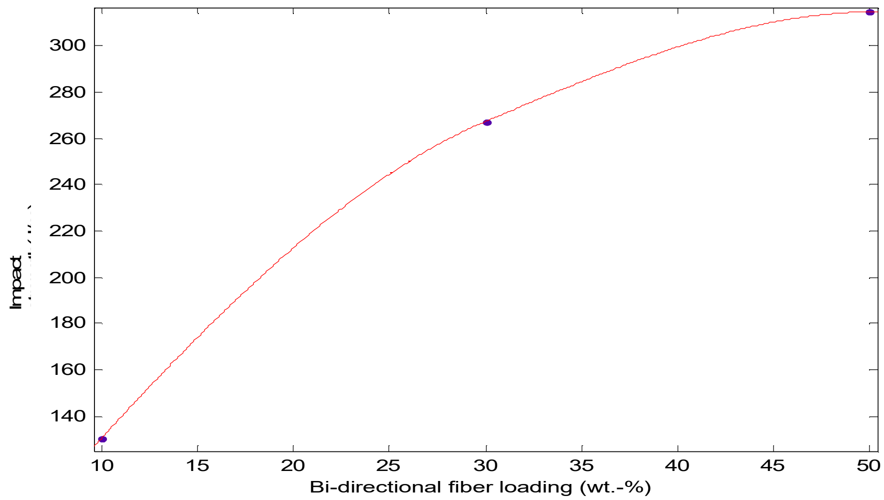

Fig. 19. Effect of fiber loading on impact strength of composites with 10mm fiber lengths

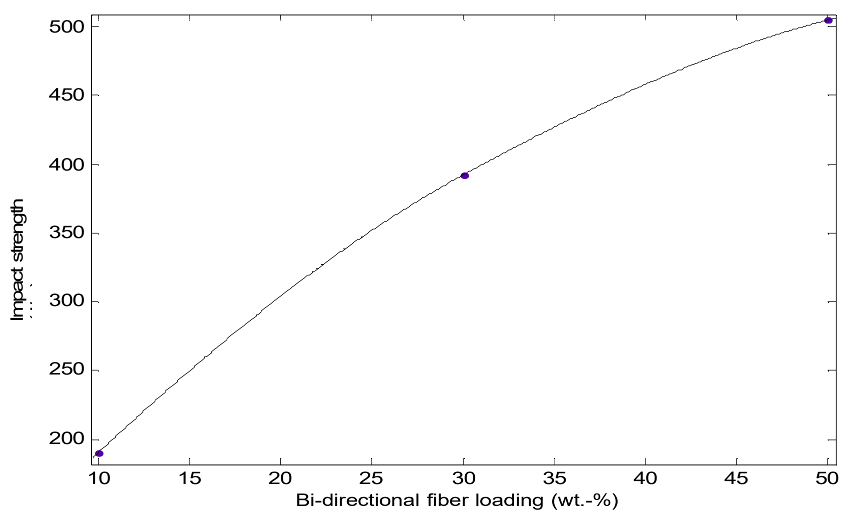

Fig. 20. Effect of fiber loading on impact strength of composites with 30mm fiber lengths

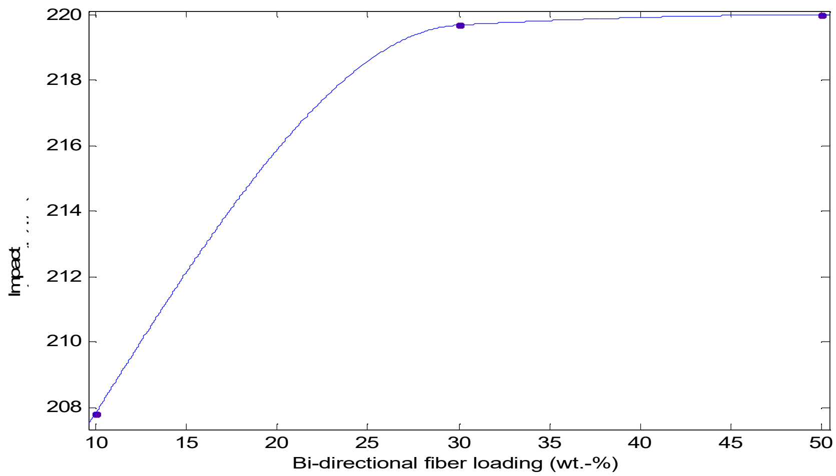

Fig. 21. Effect of fiber loading on impact strength of composites with 50mm fiber lengths

IV. CONCLUSION

The following conclusions have been drawn from the study of the finger root epoxy composite:

1. Successful fabrication of the bidirectional finger root fiber reinforced epoxy composite at different fiber lengths and fiber loadings had been done by the hand lay-up and compression moulding techniques.

2. The minimum and maximum void contents at different fiber lengths were 50 wt. % and 10 wt. % fiber loading samples, respectively. It was also found from the study that the void contents decreases with the increase in fiber loading across different fiber lengths.

3. The hardness, tensile properties and impact strength of the finger root-epoxy composites increases with the increase in fiber loading.

4. The strength properties like flexural strength and inter-laminar shear strength at different fiber lengths are greatly influenced by the void contents of the composites. It has been found that these properties increased from 10 wt. % to 50 wt.% fiber loading across different fiber lengths and with the reduction in the void contents from 10 wt.% to 50 wt.% across the different fiber lengths, the properties were improved.

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