Fabrication and Characterization of Bi-directional Flax Fiber Reinforced Epoxy Composite

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***Abstract*- In recent days, the petroleum by-products like carbon fiber and glass fibers are extensively used in construction and automotive industries. These products are harmful to human being and the environment as the manufacturing of such fibers evolves a lot of poisonous gases. Hence, the best alternative for this synthetic fiber can be a natural fiber like flax, jute, kenaf, sisal, etc. The present work describes the fabrication and characterization of natural fiber-based polymer bio-composite consisting of bidirectional flax fiber mat as reinforcement and epoxy resin as matrix material. The bio-composite material is fabricated by using a hand-layup technique with the help of a closed mould. The fabricated bio-composites were tested to evaluate the mechanical and physical properties of the laminate.**

Keywords— Bio-composite, Flax, Bi-directional, Epoxy, Hand Lay-up.

I. Introduction

A composite is a material which is fabricated by combining several different materials in such a manner that the consequent material amplifies the properties superior to any of its prototype. Natural fiber reinforced composites (NFRC), owing to their enhanced characteristics, are usually applied in various fields like engineering applications, aerospace, automotive parts, sports, goods, defense, etc. NFRC has ability to replacing conventional materials like wood, metals, etc. flax fiber is agreed to be one of the strongest natural fiber has been showed greater specific strength as compared to glass fiber as (1300 vs 1350 MPa/g-cm^{-3}), specific modulus (20-70 vs 30 GPa/g-cm^{-3}), cost savings by weight (0.5-1.5 vs 1.6-3.25 USD/kg) and energy consumption in production (11.4 vs 50 MJ/kg). A hand lay-up and compression moulding procedure provide composite plates with void content averaging 3.5%. Flax fiber tensile strength and modulus is estimated to be around 585 MPa and 60 GPa, respectively [1]. The percentage by weight of nano TiO_2 was varied as 0.5, 0.7 and 0.9. The most appropriate weight percentage for maximum performance was obtained at 0.7. The percentage increase in impact, flexural, tensile and interlaminar shear strength values for TiO_2 added flax composites were 10.45%, 20.05%, 10.95% and 18.80% respectively [2]. The hybrid composite has moderate mechanical properties between kevlar composite and flax composite. The compressive modulus found in the bending test is 30% lower compared to tensile modulus, which corresponds to the difference found in kevlar composite. The compressive strength is 47% lower than that of the tensile strength, whereas in kevlar composite the compressive strength is lower by 760 % [3]. The occurrence of damage in the unidirectional flax-epoxy composite samples was observed at a significantly lower shock load as 0.255 MPa compared to cross-ply flax-epoxy as 0.569 MPa [4]. At the moment two territories of agricultural fibers used in the composite are wood fiber with the remaining one territory as flax, jute, kenaf, hemp and sisal, etc. wood fibers are progressively being substitute by sustainable long natural fibers such as flax. With an aim to replace the wooden fixtures, furniture and fittings, bio-composites reinforced with flax can be used as an alternative to conventional polymer composites reinforced with synthetic fibers such as glass fiber. Development of new composite products from the present resources has a strong capability to deliver a new biodegradable and readily reusable material suitable for the construction and automotive industry to substitute non-renewable fossil fuel-based polymer plastics. The aim of this work is to fabricate bidirectional flax fiber reinforces epoxy composite by hand lay-up method. Characterization of bidirectional flax fiber reinforced with epoxy composite laminate by using an experimental technique to evaluate the elastic constant of bidirectional flax fiber. To study the potential utilization of flax fiber as reinforcement in polymer matrix composite by doing real-time replacement of petroleum by-product.

II. EXPERIMENTAL PROGRAM

A. Material & Method

Untreated bi-directional flax fiber mat is ordered from Go Green Products, Chennai, India. The matrix used for manufacturing the flax fiber specimen was epoxy HSC-7160 of density 1.16 g/cm^3, mixed with hardener HY-951. The ratio of a weight of mixing epoxy and hardener was 10:1. The composite laminates were fabricated by using the hand lay-up process with the help of a closed mould. A specific mould was used for the fabrication of composite laminates so as to get better mechanical properties as shown in fig.1. The prepared composite laminates were subjected to 24 hours curing at room temperature.

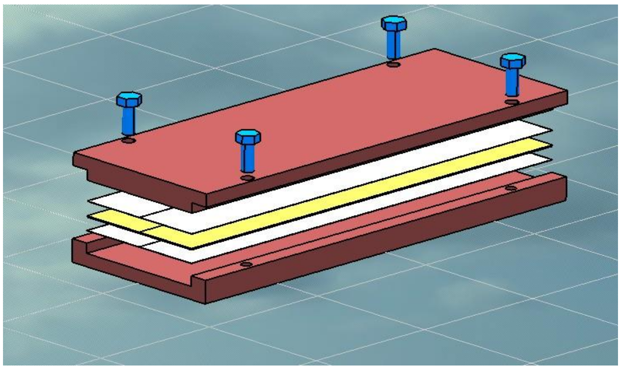

Fig 1 - CAD model of mould

Fig 2 – Manufacturing Process

Fig 3 – Prepared Laminates

B. Physical & Mechanical Testing

The theoretical density of the composite laminate is calculated in the form of weight fractions by the following equation:

$$\rho_{ct} = \frac{1}{\frac{W_f}{\rho_f} + \frac{W_m}{\rho_m}}$$

where W and ρ are weight fraction and density. The suffix f, ct and m represent the fiber, composite and matrix respectively. The fabricated composite laminates were subjected to a tensile test. The tensile test and flexural test was performed using Universal Testing Machine (UTM) according to ASTM D-3039 and ASTM D-790 standard respectively. The impact test was performed on the Charpy impact test machine according to ASTM D-256 standard. Water absorption test was performed to evaluate how much amount of water is getting absorbed by the composite under given conditions according to ASTM D-570 standard.

III. RESULT & DISCUSSION

A. Density & Void Fraction

One of the main factor that determines the properties of the composite laminate is density. Usually, it is found that the theoretical values of density merely matches with the measured values. This is may be due to the presence of air bubbles in the composite. This has an important contribution to affect the mechanical properties and performance of composite in the actual workplace. The experimental and theoretical densities of the fabricated composite laminate along with the volume fraction of voids for the present work are tabulated in Table 1. From Table 1, the volume fractions of voids seem to be low.

Table 1 - Comparison between theoretical & measured density

Sample	Theoretical Density (g/cm^3)	Measured Density (g/cm^3)	Volume Fraction of Void (%)
5 Layer	1.3263	0.9469	0.286
6 Layer	1.3150	0.9711	0.2615
7 Layer	1.31159	0.9721	0.2587

B. Tensile Test

The fabricated composite laminates were tested in the UTM and the specimens were left to break till the ultimate tensile strength appears. A graph of stress-strain curve is plotted for finding modulus of elasticity as shown in Fig. 4. The tensile test results inform that the maximum and minimum tensile strengths are 82.2 MPa and 65 MPa respectively. The elastic constant obtained for the samples on an average was 6 GPa.

Table 2 - Summary of Tensile Test Result

Sample	Width (mm)	Thickness (mm)	Area (mm^2)	Peak Load (KN)	Tensile Strength (MPa)
5 Layer	24.38	2.0870	50.881	3.8	74.7
6 Layer	24.87	2.0270	50.412	4.14	82.2
7 Layer	23.72	2.68	63.57	5.03	79.1

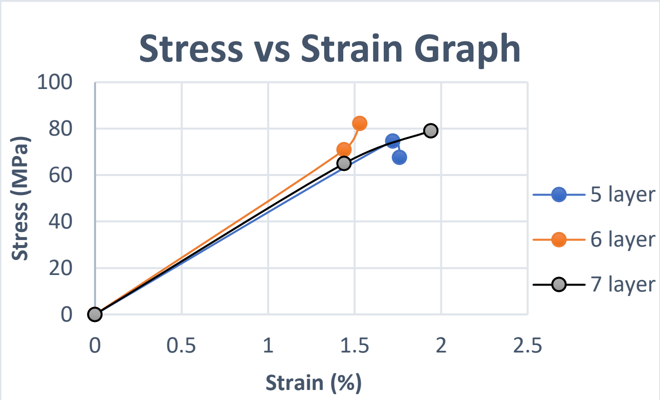

Fig.4 – Stress vs Strain Graph

C. Flexural Test

The fabricated composite laminate was tested to evaluate flexural strength by using UTM according to ASTM D-3039 standard. A graph of load vs deflection is shown in fig.5. The flexural test results inform that the maximum and minimum strengths are 8.79 GPa and 4.65 GPa respectively.

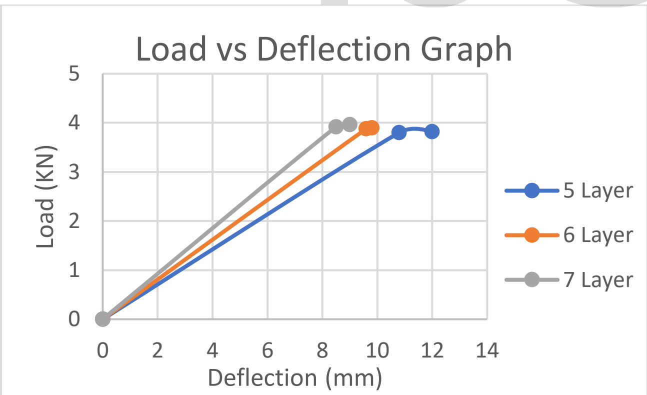

Fig.5 – Load vs Deflection Graph

Table 3 - Summary of Flexural Test Result

Sample	Thickness (mm)	Peak Load (KN)	Flexural Strength (GPa)
5 Layer	2.0870	3.82	6.425
6 Layer	2.3670	3.9	5.100
7 Layer	2.68	3.96	4.039

D. Impact Test

The impact test was carried out along the thickness of the specimen on a Charpy impact test machine according to ASTM D-256 standard.

Table 4 – Summary of Impact Test Result

Sample	Thickness (mm)	Impact Strength (MPa)
5 Layer	2.0870	26.61
6 Layer	2.3670	24.50
7 Layer	2.68	23.69

E. Water Absorption Test

Since moisture absorption of fibers plays a very significant role in the reinforcement, the hydrophilic character of flax fiber was investigated. With the moisture absorption, the flax fibers swell laterally. Water absorption characteristic of composite specimens were analyzed in the form of an increase in weight for the specimen submerged in distilled water for 48 hours according to ASTM D-570 standard. The increase in weight in percentage were compared in Table 3. From the result, it was found that flax reinforced epoxy composite specimen absorbed water only up to 30 hrs. The specimen weight increased up to an average of 0.11g in 24 hours only and after that, the weight of the specimen shows that there is no increase in weight that is specimen weight is constant. This phenomenon is shown in fig. 3. In this experiment, it is found that the saturation value of the flax reinforced epoxy composite reaches an average value of 1.66 wt. %.

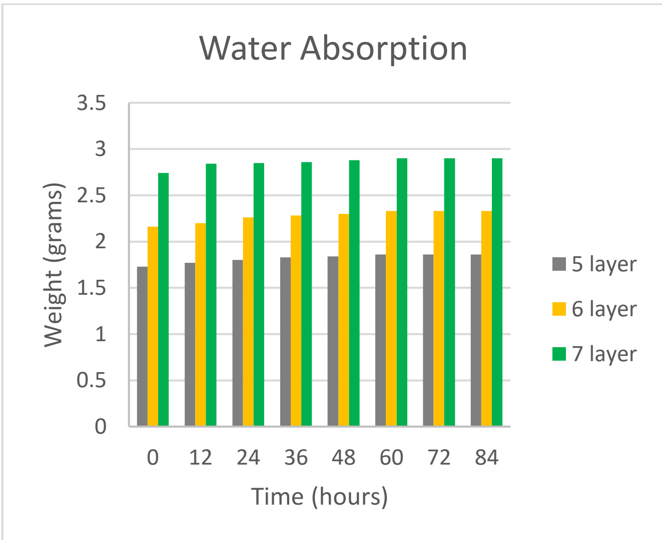

Fig. 5 - Water absorption of Bi-directional flax reinforced epoxy composite

Table 3 - Percentage Increase in Weight of Jute Reinforced Epoxy Composite

Time Duration	Increase in Weight (%)		
	Sample		
	5 Layer	6 Layer	7 Layer
12	1.0231	1.0185	1.0364
24	1.0404	1.0462	1.0401
36	1.0578	1.0555	1.0437
48	1.0635	1.0648	1.0510
60	1.0751	1.0787	1.0583
72	1.0751	1.0787	1.0583

IV. CONCLUSION

Successful fabrication of the bidirectional flax fiber reinforced epoxy composite has been done by the hand lay-up process with the help of a closed mould. The flax-epoxy composite specimen was prepared according to ASTM standards subjected to physical and mechanical testing, results were analyzed and compared. The average experimental elastic constant was found out to be 6 GPa. The tensile strength for laminate using 6 layers of fiber is 82.2 Mpa which is greater than that of the laminate using 5 & 7 layers. The impact and flexural strength for laminate using 6 layers of fiber are greater as compared to laminate 5 & 7 layers. Hence, we concluded that the laminate using 6 layers of fiber have better strength as compared to 5 & 7 layers laminate.

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REFERENCES

[1] Zia Mahboob, Ihab El Sawi, Radovan Zdero, Zouheir Fawaz, Habiba Bougherara, “Tensile and Compressive Damaged Response in Flax Fiber Reinforced Epoxy Composite’’, JCOMA 4479.
[2] Vishnu Prasad, M.A. Joseph, K. Sekar, “Investigation of Mechanical, Thermal and Water Absorption Properties of Flax Reinforced Epoxy Composite with Nano Tio2 Addition’’, Department of mechanical engineering, national institute of technology, Calicut-673601, India.
[3] Clement Audibert, Anne-Sophie Andreani, Eric Laine, Jean-Claude Grandidier, “Mechanical Characterization and Damage Mechanism of A New Flax-Kevlar Hybrid Epoxy Composite’’, COST 9615.
[4] Kede Huang, Abhishek Vishwanath Rammohan, Umeyr Kureemun, Wern Sze Teo, Le Quan Ngoc Tran, Heow Pueh Lee, “Shock Wave Impact Behaviour of Flax Fiber Reinforced Polymer Composites’’, Composites Part B 102 (2016) 78-85.
[5] Sreejith S., N. K. Gavde, Shivaji Gholap, “Fabrication and Evaluation of Mechanical Property of Unidirectional Jute Reinforced Epoxy Composite”, IJSART, 2, 2016, 2395-1052.