Fabrication & Evaluation of Mechanical Property of Unidirectional Jute Reinforced Epoxy Composite

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Abstract*- The manufacturing of composites has been a wide areas of research and it is mostly preferred due to its outstanding properties like stiffness, low density, light weight and possesses good mechanical properties. During last couple of years, the appeal in using natural fibers as reinforcement in composites has increased significantly both in terms of their industrial applications and basic research. In the present unsustainable environmental condition, natural fiber composite are serving better material in terms of biodegradability, low cost, corrosion resistance and high strength when compared to conventional materials. The present work explains the fabrication and characterization of a new set of natural fiber based polymer composite consisting of bidirectional jute fiber mat as reinforcement fiber and epoxy resin as matrix material. Hand lay-up technique was used to manufacture the composite. The prepared composites were tested to study the mechanical properties of the composite.*

Keywords- Bio-composite, epoxy, hand lay-up, jute, unidirectional.

I. INTRODUCTION

A composite is a material which is fabricated by combining two or more dissimilar materials in such a way that the resultant material is enriched with properties superior to any of its original ones. Natural fiber reinforced composites (NFRC), owing to their enhanced properties, are normally applied in different fields like defence, aerospace, engineering applications, automotive, sports goods, etc. NFRC have come a long way in replacing the conventional materials like metals, woods etc. The replacement of steel with NFRC can save a 60-80 percentage of component weight and 20-50 weight percentages with the aluminium components [5]. The mechanical properties of a NFRC are controlled mainly by the efficiency of the bonding at the fiber and matrix interfacial boundary. The principal function of the interface is to facilitate shifting of stress from fiber to fiber, across the matrix. NFRC are comparatively cheaper to manufacture and there are various manufacturing processes available for it. The surface finish of the NFRC is comparatively much higher and it can be manufactured in various techniques. The use of NFRC has given more flexibility to design engineers in developing new design and for modifications in the existing design since NFRC's are easier to handle and synthesize. Thereby natural fiber composite laminate have gained tremendous interest due to their eco-friendly nature. More work has been carried out by researchers on these natural fibers. Naturally available fibers like jute, sisal, silk, coir, etc. are low cost, renewable & abundant, with low density, light in weight, higher toughness, and biodegradable. These fiber offer remarkable opportunities as a reinforcement material for composites [6]. It provides positive benefit to ecological and environmental advantage and attractive mechanical properties. Demands for natural fibers in plastic composites is forecast to grow 15–18% annually with a growth rate of 15 - 18% in automotive applications, and 50% or more in selected building applications. At the moment, two quarters of agricultural fibers used in composites is wood fiber with the remaining one quarter kenaf, jute, hemp and sisal etc. Wood fibers are progressively being replaced by sustainable long natural fibers, such as jute [8]. With a view to replacing the wooden fittings, fixtures and furniture's, natural composites reinforced with jute can be used instead of the conventional polymer composites reinforced with man-made fibers such as glass fiber. Development of new composite products from the existing resources has a strong potential to deliver a novel bio-degradable and readily recyclable material suitable for the automotive and packaging industry to replace non-renewable fossil fuel-based polymers plastics [4]. The objective of this work is to fabricate unidirectional jute reinforced epoxy composite by hand lay-up method. Characterisation of jute fiber reinforced composite laminate by using experimental technique to evaluate elastic constant of unidirectional fiber. To study the potential utilization of jute fiber as reinforcement in polymer matrix composites by doing real time replacement of automotive component.

II. EXPERIMENTAL PROGRAM

A. Material & Method

Untreated uni-directional jute fiber mat has been prepared with help of a fixture as shown in below fig. 1b. The matrix used for manufacturing the fiber specimen was epoxy Lapox L-12 (3202) of density 1.162 g/cm^3, mixed with hardener Lapox K-6. The weight ratio of mixing epoxy and hardener was 2:1. The composites were fabricated by hand lay-up technique with the help of a mould. A specific mould was used for the fabrication process so as to get superior mechanical properties as shown in below fig. 1a. The composite laminate were subjected to 24 hours curing at room temperature.

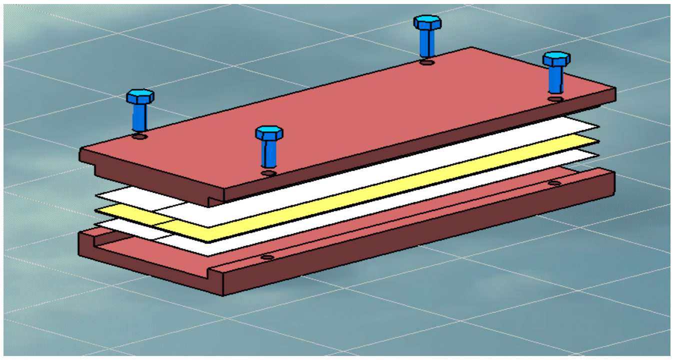

Fig 1 - CAD model of Mould

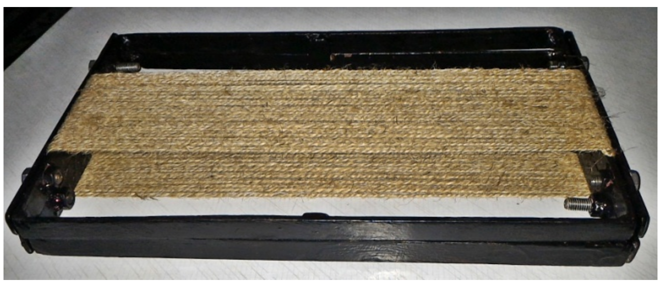

Fig 2 - Fixture

Fig 3 - Manufacturing process

B. Physical & Mechanical Testing

The theoretical density of the laminate were determined in terms of weight fractions by following equation [4]:

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

where W and ρ are weight fraction and density. The suffix m, f and ct represent the matrix, fiber and composite respectively. The manufactured laminates were subjected to tensile test. The tensile test was performed as per ASTM D3039 standard using UTM. Also, water absorption test was conducted to evaluate the amount of water absorbed under given conditions as per standard ASTM D570.

III. RESULT & DISCUSSION

A. Density & Void Fraction

One of the main factors that determine the properties of the composite laminate is density. Usually it is found that the theoretical values of density hardly matches with the measured values. This is may be due to the presence of air bubbles in the composite. This has a considerable contribution to influence the mechanical properties and the performance of the composite in the actual workplace. Elevated void contents usually mean lower fatigue resistance, greater sensitivity to water penetration [6]. Thus, the awareness of void content is desirable for the approximation of the quality of the composites. The experimental and theoretical densities of the fabricated laminate along with the volume fraction of voids for the present case are presented in Table I. As shown in Table 1, the volume fractions of voids are found to be reasonably low.

Table 1 - Comparison between theoretical & measured density.

Sample	Theoretical density (g/cm³)	Measured density (g/cm³)	Volume fraction of voids (%)
Epoxy	1.162	1.14	1.89
J1	1.178	1.15	2.38
J2	1.178	1.14	3.23
J3	1.178	1.14	3.23

B. Tensile Test

The fabricated laminate composites were tested in the universal testing machine and the samples were left to break till the ultimate tensile strength occurs. A stress-strain curve is plotted for finding modulus of elasticity. Fig. 2 shows the graph of modulus of elasticity of jute reinforced epoxy composite. The tensile test results show that the specimen exhibited maximum tensile strength of 72.98 MPa and minimum tensile strength of 66.62 MPa. The displacement yielded by the material was 6.75, 6.95, and 6.8 mm. The elastic modulus obtained for the samples on an average were 2.69 GPa respectively.

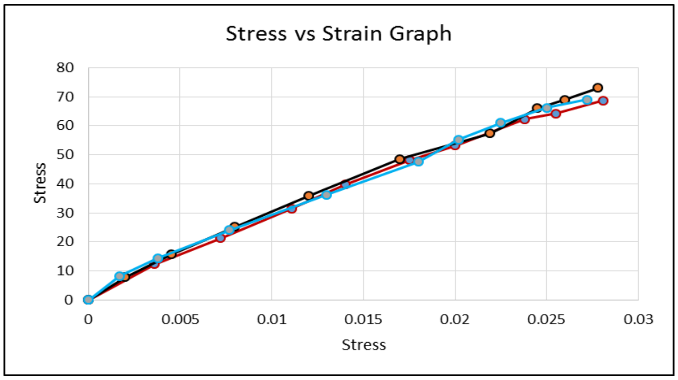

Fig.4 – Stress vs Strain graph

Now by Rule of Mixtures, theoretically the modulus of elasticity can be found out as follows,

$E_c = E_f V_f + E_m V_m$

Where,
E_c = Modulus of elasticity of composite
E_f = Modulus of elasticity of fiber
V_f = Volume fraction of fiber
V_m = Volume fraction of matrix

First we find the volume fraction of fiber as

$V_f = (\rho_m \text{ x } w_f) / [(\rho_m \text{ x } w_f) + (\rho_f \text{ x } w_m)]$

Where,
ρ_f = density of fiber
ρ_m = density of matrix
w_f = weight of fiber
w_m = weight of matrix

$V_f = (1.162 \text{ x } 20) / [(1.162 \text{ x } 20) + (1.3 \text{ x } 91.1)]$
$V_f = 0.164$
$V_m = 0.836$

Therefore,
$E_c = 13(0.164) + 4.1(0.836)$
$E_c = 5.55$ GPa.

Theoretically, the modulus of elasticity of jute epoxy composite is 5.55 GPa. Now here there is a lot of difference between the practical and theoretical value. This may be due to poor adhesion between fiber and resin.

Table 2 - Summary of Tensile Test Result

Sample	Width (mm)	Thickness (mm)	Peak Load (KN)	Tensile Strength (MPa)
1	25.2	3.4	7.38	66.62
2	25.4	3.4	7.8	72.98
3	23.8	3.5	7.41	68.92

C. Water Absorption Test

Since moisture absorption of fibers plays a very important role in the reinforcement, the hydrophilic character of jute fiber was investigated. With the moisture absorption, the jute fibers swell laterally. Water absorption characteristic of laminate specimens was analyzed in terms of weight gain for the specimen immersed in distilled water for 48 hours as per ASTM D 570. The weight gains in percentage were compared in Table 3. From the result it was observed that jute reinforced epoxy composite specimen absorbed water only up to 30 hrs. The specimen weight increased up to an average of 0.65g in 30 hours only and after that, the weight of 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 seen that the saturation value of the jute reinforced epoxy composite reaches an average value of 10 wt. %.

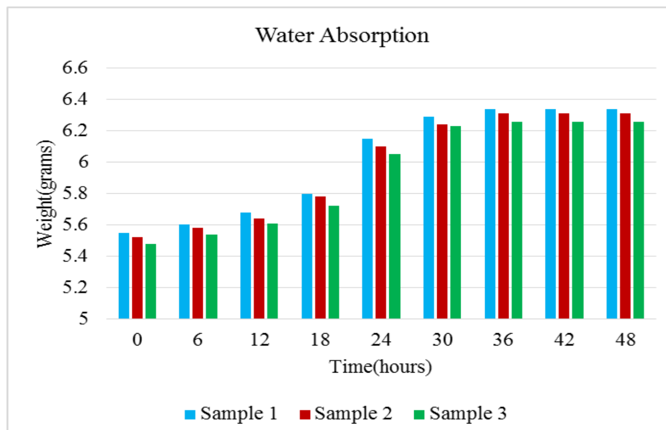

Fig. 5 - Water absorption of jute reinforced epoxy composite

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

Time duration	Increase in weight %		
	Sample 1	Sample 2	Sample 3
6	0.9	1.08	1.09
12	2.34	2.17	2.37
18	4.5	4.71	4.37
24	10.81	1.5	10.4
30	13.33	13.04	13.68
36	14.23	14.31	14.23
42	14.23	14.31	14.23
48	14.23	14.31	14.23

IV. CONCLUSION

Successful fabrication of the unidirectional jute fiber reinforced epoxy composite has been done by the hand lay-up technique. The jute-epoxy composite specimen was prepared as per ASTM standards subjected to mechanical testing, results were analyzed and compared. The average experimental elastic constant was found out to be 2.69 GPa whereas theoretical elastic constant was 5.55 GPa. The experimental value was significantly lower as compared to theoretical value. There may be various reason for such phenomenon. May be it was because of poor adhesion between fiber & matrix. Further research work needs to be carried out on fiber treatment so as to improve the adhesion properties. This is important if new improved materials are to be developed for safe usage against crack growth. Jute fiber composites, rather than glass fiber composite, may open up new applications for low load application. However, as inferred from the results presented here, significant improvements in strength characteristics must be realized for this class of materials.

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