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Physical and Mechanical Properties of Bi-directional Jute Fiber epoxy Composites

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Abstract

During 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 jute fiber, a natural fiber abundantly available in India. The present work describes the development and characterization of a new set of natural fiber based polymer composites consisting of bidirectional jute fiber mat as reinforcement and epoxy resin as matrix material. The composites are fabricated using hand lay-up technique and are characterized with respect to their physical and mechanical properties. Experiments are carried out to study the effect of fiber loading on the physical and mechanical behavior of these composites. Result shows the significant effect of fiber loading on the mechanical properties of the composites. Also, the formation of voids in the composites is an influencing factor on the mechanical properties.

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Keywords: Natural fiber; Jute fiber; Epoxy; Mechanical Properties

Nomenclature

Δv	volume fraction percentage
W	weight fraction
Greek symbols	
ρ	density
Subscripts	
ct	composite
ex	experimental
f	fiber
m	matrix

1. 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 [1]. FRP composites possesses interesting properties like high specific strength and stiffness, good fatigue performance and damage tolerances, low thermal expansion, non-magnetic

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properties, corrosion resistance and low energy consumption during fabrication [2]. 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 [3].

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. 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 [4, 5]. Pervaiz and Sain [6] 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. Jute, 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 defence and rehabilitation and transportation. The insulating characteristics of jute may find applications in automotive door/ceiling panels and panel separating the engine and passenger compartments [7].The use of natural fiber like jute not only help us in ecological balance but can also provide employment to the rural people in countries like India and Bangladesh where jute is abundantly available.

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

2. Experimental Details

2.1. Materials and Method

Bidirectional jute fiber mat has been obtained from the local sources as a reinforcing material. Epoxy resin and the corresponding hardner are supplied by Ciba Geigy India Ltd. The polymers composites are fabricated by hand lay-up technique. Composite specimens with different fiber loading (0, 12, 24, 36 and 48 wt %) were prepared and subjected to postcuring for 24 hours at room temperature.

2.2. Physical and Mechanical Characterization

The theoretical density of the composites can be obtained in terms of the weight fractions and densities of the constituents, and is given by Eq. (1)

$$\rho_{ct} = \frac{1}{\left(W_f / \rho_f\right) + \left(W_m / \rho_m\right)} \tag{1}$$

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 technique has been used to determine the actual density of the prepared composites experimentally. The volume fraction of voids in composites is given by the relation

$$\Delta v = \frac{\rho_{ct} - \rho_{ex}}{\rho_{ct}} \tag{2}$$

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

Hardness measurement is done using a Rockwell-hardness tester equipped with a steel ball indenter. Tensile test is performed as per ASTM D 3039-76 test standards using universal testing machine Instron 1195.Three point bend test is 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 is evaluated by a low velocity impact tests conducted in an impact tester as per ASTM D 256 test standards.

3. Result and Discussion

3.1. Physical and Mechanical Properties

The theoretical density, experimental density and void fraction (in percentage) are reported in the Table 1. The presence of the voids may affect the mechanical 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[8]. From Table 1 it is found that pure epoxy has the minimum void content, with the addition of 12 wt. % fiber the void content increases instantly to 5.312 %. But with the further increase in the fiber content from 12 wt. % to 48 wt. % the void content of the specimens decreases. The theoretical density of the composites increases as the fiber loading increases.

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 (%)
BJFE-1	Epoxy + 0 wt.-% Jute Fiber (BD)	1.150	1.147	0.261
BJFE-2	Epoxy + 12wt.-% Jute Fiber (BD)	1.170	1.108	5.312
BJFE-3	Epoxy + 24wt.-% Jute Fiber (BD)	1.184	1.125	5.022
BJFE-4	Epoxy + 36wt.-% Jute Fiber (BD)	1.198	1.248	4.178
BJFE-5	Epoxy + 48wt.-% Jute Fiber (BD)	1.213	1.164	4.050

BJFE: bidirectional jute fiber epoxy, BD: bidirectional

Figure 1 shows the effect of fiber loading on the hardness of composites. 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 [9]. Surface hardness value of 40 HRB is obtained from pure epoxy specimen. The surface hardness value increases by 77% with the incorporation of 12 wt. % fiber in the matrix. The maximum surface hardness value of 85.5 HRB is obtained from bidirectional jute epoxy composites reinforced with 48 wt. % of jute fiber.

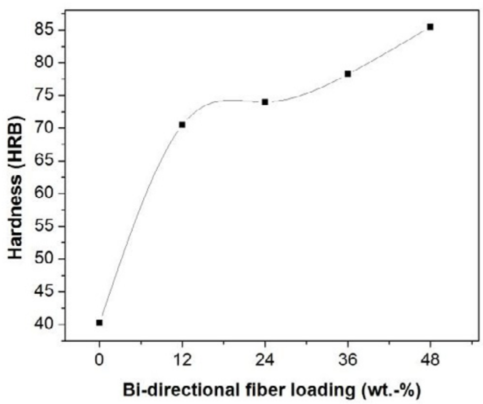

Fig 1. Effect of fiber loading on hardness of composites

The variation in tensile strength and tensile modulus of composite with increase in fiber content is shown in Fig 2. It is clearly visible that with the increase in fiber content in the epoxy matrix, the tensile strength and modulus also increases. There is a proper transmission and distribution of the applied stress by the epoxy resin resulting in higher strength. Similar observations have been made by Bijwe [10] in case of aramid fabric/polyethersulfone composites. The bidirectional jute fiber composite can bear higher load before failure compared to neat or unfilled epoxy. The tensile strength varies from 43 MPa to 110 MPa and tensile modulus from 0.15 GPa to 4.45 GPa with the fiber varies from 0 to 48 wt%.

The result obtained from the three point bend test is shown in Fig 3. It has been found that there is a reduction in the flexural properties of specimen with 12 wt. % fiber loading. Similar observations have also been made by Dong and Davies [11]. 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 after 12 wt. % fiber loading. The maximum flexural strength and modulus of 55.8 MPa and 3.02 GPa respectively, is obtained at 48 wt. % of fiber loading. The flexural strength and modulus of 48 wt. % fiber loading are increased by 20 % and 37 % in comparison to the neat epoxy. The jute fiber inclusions enhance the load bearing capacity and ability to withstand bending of the composites [12].

The effect of fiber loading on the inter-laminar shear strength (ILSS) of the jute epoxy composite is shown in Fig 4. The ILSS value decreases drastically for the composites with fiber loading from 0 wt. % to 12 wt. %, however it increases on further increase in fiber loading from 12 wt. % to 48 wt. %. The maximum ILSS of 66.5 MPa is obtained at 48 wt. % fiber loading.

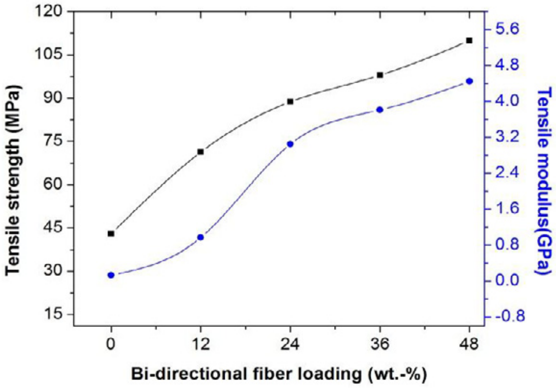

Fig 2. Effect of fiber loading on tensile strength and modulus of composites

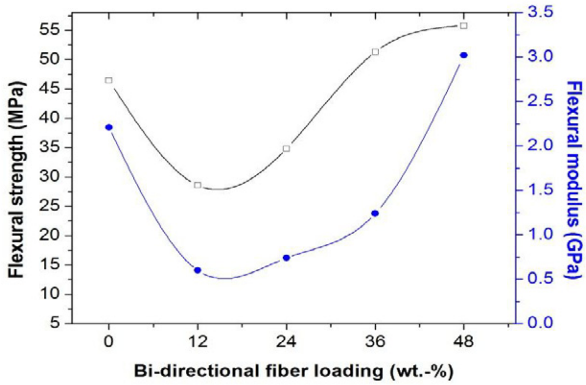

Fig 3. Effect of fiber loading on flexural strength and modulus of composites

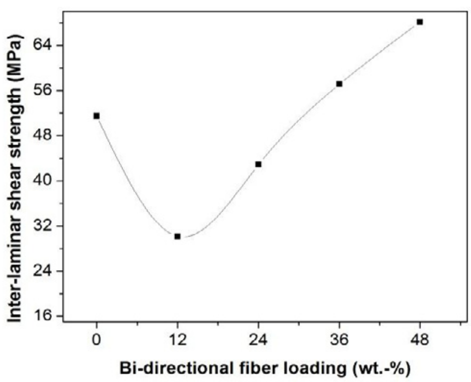

Fig 4. Effect of fiber loading on inter-laminar shear strength of composites

The impact strength of the bidirectional jute epoxy composites in shown in Fig 5. The energy absorbed by the composite due to impact load is 2.87, 3.69, 4.264, 4.59 times of pure epoxy matrix for composites with fiber content of 12 wt. %, 24 wt.%, 36 wt.% and 48 wt.% respectively. The maximum impact strength is of 4.875 J in the case of composite with 48 wt.% of fiber loading. The increase in the impact strength with the increased fiber loading 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 [15].

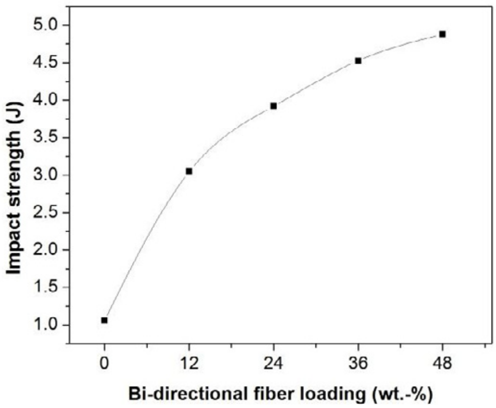

Fig 5. Effect of fiber loading on impact strength of composites

4. Conclusion

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

1. Successful fabrication of the bidirectional jute fiber reinforced epoxy composite has been done by the hand lay-up technique.
2. The minimum and maximum void content are in neat epoxy and 12 wt. % fiber loading specimens respectively. It is also found from the study that the void content decreases with the increase in fiber loading.
3. The hardness, tensile properties and impact strength of the jute-epoxy composites increases with the increase in fiber loading.
4. The properties like flexural strength and inter-laminar shear strength are greatly influenced by the void content of the composites. It has been found that these properties reduced from 0 wt.% to 12 wt.% fiber loading and with the reduction in the void content from 12 wt.% to 48 wt.% the properties are improved.

References

[1] Zaman H. U., Khan A., Khan R. A., Huq T., Khan M. A., Shahruzzaman Md., Mushfequr Rahman Md., Al-Mamun Md., and Poddar P., 2010. Preparation and Characterization of Jute Fabrics Reinforced Urethane Based Thermoset Composites: Effect of UV Radiation, Fibers and Polymers, 11(2), p. 258.
[2] Jawaid M., Abdul Khalil H.P.S., Abu Bakar A., Noorunnisa Khanam P., 2011. Chemical resistance, void content and tensile properties of oil palm/jute fibre reinforced polymer hybrid composites, Materials and Design, 32, p. 1014.
[3] Gowda T. M., Naidu A.C.B., Rajput C., 1999. Some mechanical properties of untreated jute fabric-reinforced polyester composites, Composites: Part A, 30, p. 277.
[4] Huq T., Khan A., Akter T., Noor N., Dey K., Sarker B., Saha M.,2011. Thermo-mechanical, Degradation, and Interfacial Properties of Jute Fiber-reinforced PET-based Composite, DOI: 10.1177/0892705711401846.
[5] Chin C.W., Yousif B.F., 2009.Potential of kenaf fibres as reinforcement for tribological applications, Wear, 267, p. 1550.
[6] Pervaiz M., Sain M.M., 2003. Carbon storage potential in natural fibre composites, Resources Conservation and Recycling 39(4), p.325.
[7] Khondker O. A., Ishiaku U S., Nakai A., Hamada H., 2005. Fabrication and Mechanical Properties of Unidirectional Jute/PP Composites Using Jute Yarns by Film Stacking Method, Journal of Polymers and the Environment, 13(2) , p. 115.
[8] Boey F.Y.C., 1990. Reducing the Void Content and its Variability in Polymeric Fibre Reinforced Composite Test Specimens using a Vacuum Injection Moulding Process, Polymer Testing, 9 , p. 363.
[9] Srinivasa C.V., Bharath K.N., 2011.Impact and Hardness Properties of Areca Fibre-Epoxy Reinforced Composites, Journal of Material Science and

Environment, 2(4), p. 351.
[10] Bijwe J., Awtade S., Satapathy B.K., Ghosh A., 2004. Influence of concentration of aramid fabric on abrasive wear performance of polyethersulfone composites, Tribology Letters, 17 (2), p. 187.
[11] Dong C., Davies I.J., 2011.Flexural Properties of Wheat Straw Reinforced Polyester Composites, American Journal of Materials Science, 1(2), p. 71.
[12] Mantry S., Satapathy A., Jha A.K., Singh S.K., Patnaik A., 2010. Processing and Characterization of Jute–Epoxy Composites Reinforced with SiC Derived from Rice Husk, 29(18), p. 2869.
[13] Åkesson D., Skrifvars M., Seppälä J., Turunen M., 2011.Thermoset Lactic Acid-Based Resin as a Matrix for Flax Fibers, Journal of Applied Polymer Science, 119, p. 3004.