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MECHANICAL BEHAVIOUR OF SHORT FIBER REINFORCED POLYMER COMPOSITE

[1] Pushpa Maurya, [2]Madhusmita Sahu
[1,2] School of Engineering and Technology, Department of Mechanical Engineering
Noida International University, Greater Noida, India
gnitpushpa@gmail.com

Abstract—**Natural fiber reinforced polymer composites are now in trend for various applications due to its good physical and mechanical properties. In this work, polymer composites using naturally available low cost jute fiber is fabricated by varying the contents of reinforced material by using simple hand lay-up technique. The composite is fabricated by varying 0%, 10%, 20%, 30% and 40% by weight percentage of jute fibers. The present research work is undertaken to study the physical and mechanical behaviour of jute fiber reinforced polymer composites. The form of jute fiber considered for the present research work is Short Jute Fiber. As the composite is made using bio-materials from local resources, it is less costly and environment friendly.**

Keywords— polymer composite, naturally available, hand lay-up technique, short jute fiber, environment friendly.

I. INTRODUCTION

Now-a-days polymer composites made from natural fibers have great interest for many diverse applications because of their excellent specific properties such as high strength to weight ratio, low cost, low density, design flexibility, non-corrosive nature, easy availability, long life, low maintenance etc [1-6]. All these properties of natural fiber reinforced composites have given an alternate solution to traditional monolithic reinforcing materials such as glass fibers, carbon fibers etc [7-11]. Despite, it has brought great attention in the development of renewable and ecofriendly composite materials due to the strong focus on environmental awareness worldwide [1-2, 12].

For developing an efficient light weighted natural fiber reinforced composite jute fiber is quite attractive for above mentioned concerns. The objective of the present paper is to develop a thermally insulating natural fiber reinforced composite and study the physical and mechanical behaviour of the composite that is reinforced with naturally available jute fiber which is of low cost, light weighted, easily available and ecofriendly.

II. MATERIALS AND METHODS

A. Materials Used:

For composite fabrication process the fibers of Jute (shown in figure 1(a)) are used as a filler material and Epoxy LY 556 resin (common name: bisphenol A diglycidyl ether) is used as matrix material. Hardener used here is HY-951(IUPAC name: NN′ -bis (2-aminoethylethane-1, 2-diamin). Epoxy Resin and hardeners are mixed in a ratio of 10:1 by weight. Short fibers of the jute (shown in figure 1(b)) that is nearly 10 mm length was prepared and used as the reinforcing agent in the composite preparation.

Fig:1 (a) Naturally available Jute Fiber

Fig:1 (b) Short Fibers of Jute

B. Preparation of Test Samples*:*

The short fibers of jute and epoxy were mixed in a glass beaker with the help of suitable steel rod and stirring properly at room temperature. Hardener was added into the beaker mixture at the time of stirring as shown in figure 2. For uniform mixing of the reinforcing material and the epoxy polymer matrix the mixture was stirred for 10 to 20 minutes.

Fig:2 Preparation of Composite Material

Fig:3 (a) Mould for test samples

After that, properly stirred mixture was poured into the suitable moulds (shown in figure 3) to get the typical dog-bone shaped test samples of 20 cm in length for tensile test. For easy removal of specimens Silicon Spray was used as the de-moulding agent. There were five different fiber-reinforced epoxy composite samples were fabricated by varying the amount of reinforcing material. The different composites prepared are described in Table 1.

TABLE 1: Test samples prepared

Samples	Compositions
Sample 1	Pure Epoxy
Sample 2	Epoxy +10% Jute Fibers
Sample 3	Epoxy +20% Jute Fibers
Sample 4	Epoxy +30% Jute Fibers
Sample 5	Epoxy +40% Jute Fibers

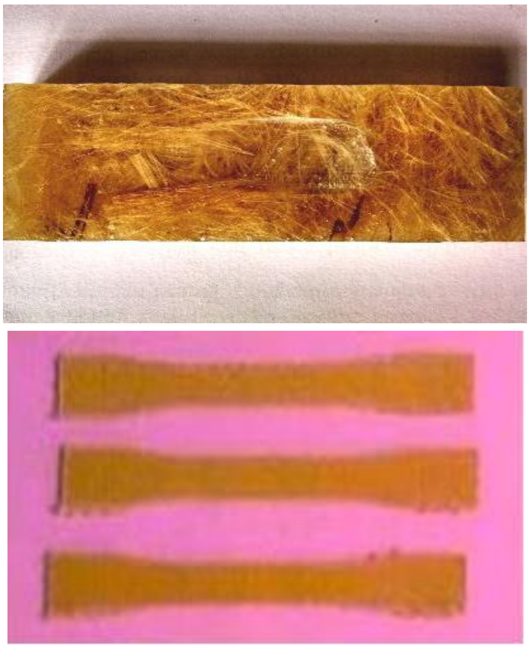


Fig 3(b): Short fiber reinforced epoxy composite

C. Methods Used:

Density is one of the most important factors for determining the different properties of the composites. The densities of composites mainly depend on the relative proportion of matrix and filler materials. The theoretical density (ρct) of composite materials in terms of weight fractions of different constituents can easily be obtained using the following equation given by Agarwal and Broutman.

$$\rho_{ct} = 1 \Big/ \left\{ \left(\frac{w_f}{\rho_f} \right) + \left(\frac{w_m}{\rho_m} \right) \right\} \tag{1}$$

Where, w and ρ represent the weight fraction and density respectively. The suffixes f and m stand for the filler and matrix respectively. The actual density (ρce) of the composite can be determined experimentally by the Archimedes principle i.e. the water displacement technique (ASTM D 792-91).

The volume fraction of voids (vv) in the prepared composites can be calculated by using the following equation:

$$v_v = (\rho_{ct} - \rho_{ce}) / \rho_{ct} \quad (2)$$

The Micro Hardness test was conducted by using a Vickers hardness tester machine, Leitz, Germany. A diamond indenter of a right pyramid shaped with a square base and an angle 136° between opposite faces, is forced into the testing material under a load F. The Vickers hardness numbers (VHN) of the composite were measured under a load of F=0.3 Kgf and Vickers hardness number was calculated by using the formula:

$$HV = 0.1889 \frac{F}{L^2}, \quad (3)$$

$$L = \frac{X + Y}{2},$$

Where F is the applied load, L is the diagonal of square impression (mm), X is the horizontal length (mm), and Y is the vertical length (mm).

In the present work, tensile tests were carried out on the specimens using Universal Testing Machine Instron 1195 at a cross head speed of 10 mm/minute and the results were used to calculate the tensile strength of the composite samples. Typical dog-bone shaped samples of required dimension (length 20 cm) were used for tensile testing as per ASTM E 1309 standard.

To determine the value of Flexural strength (FS), the 3-point bend test or short-beam shear tests were performed on the composite samples at room temperature. The Short beam shear test was carried out as per ASTM D2344-84 using the Instron 1195 UTM. The length of span was kept 40 mm, and the cross head speed was 10 mm/min. The FS of any composite can be calculated by using the following formula:

$$FS = \frac{3FL}{2bt^2},$$

Where F is the applied load, L is span length, and t and b are the thickness and width of the specimen, respectively.

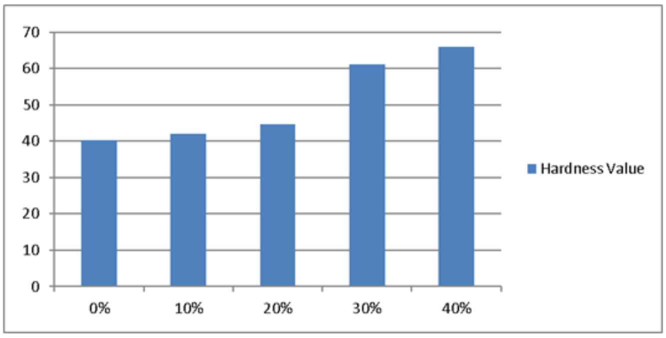
III. Result and Discussion

Density plays a vital role for designing an engineering component or deciding the application of a material particularly where weight is an important factor. The theoretical and experimental density along with the void fraction of short jute epoxy composites is reported in Table 2. The theoretical density of composite increases as the weight percentage of fiber increases. Theoretical density of composites ranges from 1.150 g/cm^3 to 1.254 g/cm^3. The experimental density of the composites varies from 1.147 to 1.175 g/cm3. The minimum void fraction is observed in case of pure epoxy. It is observed that the percentage of void fraction increases with the increase in percentage of fiber content. The voids considerably affect some of the mechanical properties and even the performance of the composites in the place of use.

Table 2: Comparison between experimental and theoretical density of short jute epoxy composites

Samples	Theoretical Density (ρct) g/cm^3	Experimental Density (ρex) g/cm^3	Void Fraction %
Sample 1	1.150	1.147	0.261
Sample 2	1.174	1.156	1.533
Sample 3	1.199	1.164	2.919
Sample 4	1.225	1.171	4.408
Sample 5	1.254	1.175	6.299

Hardness values of the samples are given in Figure 4.From the figure, it can be seen that the hardness of jute fiber-reinforced polymer composite is more than that of the neat epoxy and also increases with the increase in amount of reinforcement. Hardness is a function of the relative fiber volume and modulus. The composite with 0 wt% fiber loading i.e. neat epoxy has the minimum hardness value of 40.23 HV whereas composites reinforced with 40 wt% of fiber content exhibit maximum hardness value of 65.98 HV. The increase in hardness of the composite may be due to interface bonding of the jute fiber with epoxy resin.



Weight percentage of Jute Fiber

Figure 4: Variation of hardness (HV) of composites with weight percent of Jute fiber-reinforced epoxy composites.

The effect of fiber loading on the tensile properties of short jute epoxy composites is shown in Figure 5. It is found that the tensile strength of composites decreases with the increase in weight percentage of fiber. The decrease in tensile strength of short jute epoxy composite may be due to poor bonding between jute fiber and epoxy resin. Observations show that the tensile modulus of short jute fiber composite increases significantly with the increase in fiber content. Increase in tensile modulus of tested composite indicates that the stiffness of jute fiber reinforced composite increases with the increase in fiber loading.

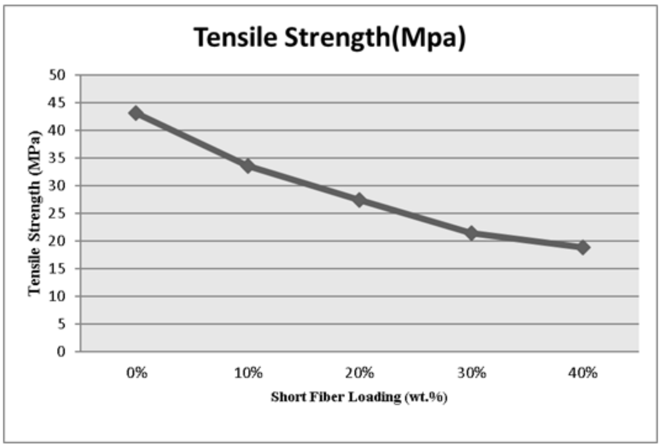


Figure 5: Effect of short jute fiber loading on tensile properties of composites

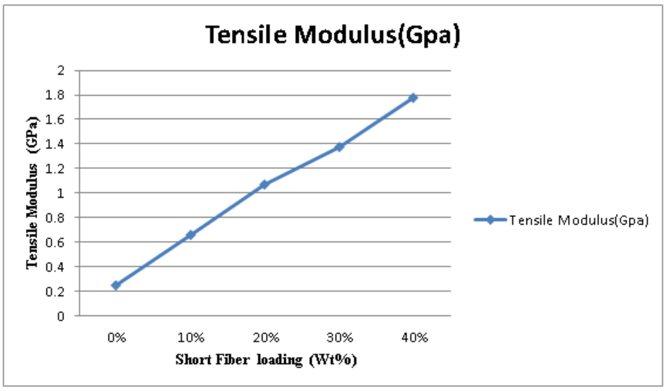
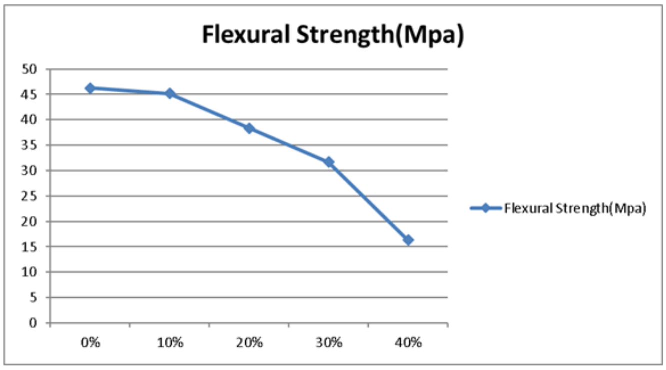


Figure 6: Effect of short jute fiber loading on tensile modulus of composites.

The effect of fiber loading on the flexural properties of short jute epoxy composites is shown in Figure 7. It is observed that there is a gradual drop in the flexural properties of the composites. According to the study, the decrease in flexural properties is due to the alignment of fibers, interaction between fiber– matrix and void arise during the processing of the composites.



Short Fiber Loading (wt.%)

Figure 7: Effect of short jute fiber loading on flexural strength of composites.

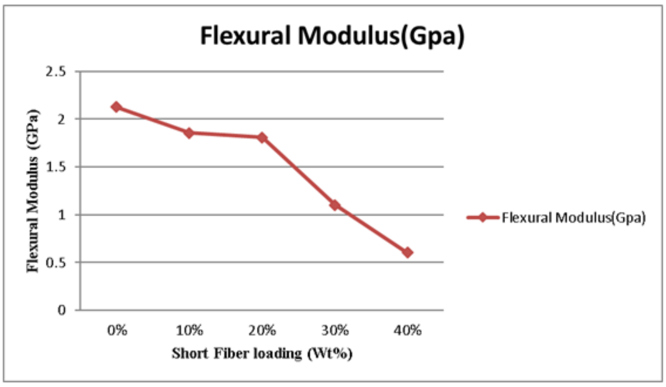


Figure 8: Effect of short jute fiber loading on flexural modulus of composites.

CONCLUSION

The study on physical and mechanical behavior of jute fiber reinforced polymer composites led to the conclusion that the Jute fiber-reinforced epoxy composites can be prepared easily with different weight percentage of reinforcement content. The cost of polymer composite will be low as the raw material is plant fiber based, and the processing technique is simple. The study on physical and mechanical properties of jute fiber reinforced epoxy composites revealed that these properties are affected by fiber type, fiber content and void content. The addition of short fibers in the epoxy matrix led to decrease in tensile strength, flexural strength and flexural modulus of the short jute fiber composites whereas the hardness of jute fiber-reinforced polymer composite is more than that of the pure epoxy and also increases with the increase in amount of reinforcement. The void fraction of the composites increases significantly with the increase in the reinforcement content. It might be due to the presence of pores/cavities in the composite. The present study reveals that the Composites made from short fiber can be used widely in non-load bearing applications to obtain complex geometry in aerospace and automobile industry. They have also got applications in general purpose and specialty products ranging from hoses, diaphragms, belts and seals to tyres.

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