A STUDY ON THE EFFECT OF FIBER LOADING AND ORIENTATION ON MECHANICAL BEHAVIOUR OF JUTE FIBER REINFORCED EPOXY COMPOSITES

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Mechanical Engineering

BY

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CERTIFICATE

This is to certify that the thesis entitled ***"A Study on the Effect of Fiber Loading and Orientation on Mechanical Behaviour of Jute Fiber Reinforced Epoxy Composites"*** submitted by ***Bijay Dhakal (Roll Number: 109ME0534)*** in partial fulfillment of the requirements for the award of ***Bachelor of Technology*** in the department of Mechanical Engineering, National Institute of Technology, Rourkela is an authentic work carried out under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to elsewhere for the award of any degree.

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A C K N O W L E D G E M E N T

It gives me immense pleasure to express my deep sense of gratitude to my supervisor ***Prof. Sandhyarani Biswas*** for her invaluable guidance, motivation, constant inspiration and above all for her ever co-operating attitude that enabled me in bringing up this thesis in the present form.

I am extremely thankful to ***Prof. K.P Maity***, Head of Department, and Department of Mechanical Engineering Department for providing all kinds of possible help and advice during the course of this work.

I am greatly thankful to Mr. **Vivek Mishra,** PhD Scholar, all the staff members of the department and my entire well-wishers, class mates and friends for their inspiration and help.

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ABSTRACT

Now-a-days, the natural fibers from renewable natural resources offer the potential to act as a reinforcing material for polymer composites alternative to the use of glass, carbon and other man-made fibers. Among various fibers, jute is most widely used natural fiber due to its advantages like easy availability, low production cost and satisfactory mechanical properties. For a composite material, its mechanical behavior depends on many factors such as fiber content, orientation, types, length etc. Attempts have been made in this research work to study the effect of fiber loading and orientation on the mechanical behavior of jute fiber reinforced epoxy composites. Composites of various compositions with three different fiber loading (20wt%, 30wt% and 40wt%) and three different fiber orientation (0°, 30° and 60°) are fabricated using simple hand lay-up technique. It has been observed that there is a significant effect of fiber loading and orientation on the mechanical behavior of jute fiber reinforced epoxy composites. Finally, the morphology of fractured surfaces is examined using scanning electron microscopy (SEM).

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CHAPTER 1

INTRODUCTION

1.1Overview of composites

Composites, plastics and ceramics are the main material that is being used by the present world. Composites have a more significant advantage because these are made by engineering processes and mainly helpful to reduce the weight and hence to increase the efficiency. Composite material consists of two or more materials in a different phase. In traditional engineering impurities in metal can be represented in different phase and by definition considered as a composite, but are not considered as a composite due to modulus of strength is nearly same as that of pure metal. Oldest known composites were natural composites, wood consist of cellulose fiber in lignin composites, human bone can be considered as a osteons embedded in an interstitial bone matrix.

1.2 Definitions of Composite

Composites are materials consisting of two or more chemically distinct constituents, on a macro-scale, having a distinct interface separating them. One or more discontinuous phases are embedded in a continuous phase to form a composite [1]. Composite mainly formed from two distinguished material one of which is in the particle or fiber or in sheet form are combined with other material known as a matrix. Fiber in the composites acts as a principle load carrying member due to its high strength modules while matrix in the composites acts as a load transfer medium between the fibers. Due to more ductility of the composite it gives matrix high toughness. The definition given by a different author can be summarized as follows.

1.3 Uses of composites

Due to weight saving advantage composites are mainly used in applications like automobile and aircraft where even a small amount in reduction of weight also count. Some uses of composites are described below:

i. In aircraft it is used in the door skin on the stabilizer box fin, in elevators, rudder, loading gear, tail, spoiler, flap body etc. 20-30% reduction in weight is possible by the use of composites.

ii. In aerospace it uses to make space shuttle, space station where it comprises the function of weight reduction. It is used because it shows low value of co-efficient of thermal expansion.

iii. In automobile it uses to make body frame, chassis components, engine components, drive shaft, leaf spring, exterior body part etc. and it performs different functions such as due to its high stiffness it has good damage tolerance, good surface finish and appearance, weight reduction hence higher fuel efficiency.

iv. In sporting goods it uses to make tennis and racquetball, racquets, golf club shaft, head bicycle frame, skis, canoe helmets, fishing poles tent poles etc. It is used because it helps to design weight reduction vibration damping design and has high flexibility.

v. In electrical it used to made printed circuit board, computer housing, insulators, radomes battery plates. And it is used because of portable weight saving.

1.4 Types of Composites

a) On the basis of matrix material

b) On the basis of reinforcement

Composites material formed from two different materials, matrix and fibrous system. And on the basis of matrix used composites may be categories into three different categories.

1. Metal matrix composites
2. Ceramic matrix composites

3. Polymer matrix composite

1. Metal matrix composites:

Composites material consists of two or more physical or chemically distinct phases. When metal is used as a matrix material with any of the reinforcing material it is termed as the metal matrix composites. It shows improved strength, stiffness, creep, hardness, high fatigue resistance and wear and tear resistance than other composites. Due to above mentioned reason it is used in the combustion chamber nozzle (in the rocket, space shuttle), housings, tubing, cables, heat exchangers, structural members etc.

2. Ceramic matrix composites:

Ceramic matrix composites are a subgroup of composite material which contains ceramics as a matrix material. Ceramic matrix composites have ceramic matrix such as calcium, alumina and alumino silicate reinforced by silicon carbide. They possess high hardness, strength high service temperature limits for ceramics, low density and chemical inertness [2].

3. Polymer matrix composites:

When different types of polymeric material use as a matrix material to make composite it is known as the polymer matrix composites. Polymers are the macromolecule formed by the linking together of a large number of smaller units know as monomers. It shows high tensile strength, high stiffness, fracture toughness, good abrasion resistance, puncher resistant, corrosion resistant and low cost. It shows low thermal resistance and has high co-efficient of thermal expansion. It is used in the field of automobile where we need damping and good shock absorbing function. It cannot be used in high temperature application due to its high CTE. It is further divided into two types.

a) Thermosetting polymer matrix composites.

b) Thermoplastic polymer matrix composites.

(a) Thermosetting polymer matrix composites: Usually thermostats are the material usually liquid or malleable prior to curing and designed to mold into their final form. Once it gets its final form it will not melt due to its well-developed 3D bonded structure. Generally used thermosetting polymers are epoxy and cyanate ester.

(b) Thermoplastics polymer matrix composites: Thermoplastic polymer becomes malleable and pliable above a certain range of temperature and returns to its original form below that temperature. These polymers have high molecular weight and often used in low temperature applications.

Latest technology not only involves information about new product but also in making at low cost so, for that particular reason before making any kind of polymer matrix based composites individual should know what is the advantages and disadvantages of this matrix over one another. Thermosetting resin is the first choice of any company nowadays due to its availability, ease of processing, the existence of large database and low material cost. Thermosetting resins like epoxies are available in a low viscosity liquid form that has excellent flow properties to facilitate the penetration of fiber bundles and wetting of fiber surface. The manufacturing cost of the thermoplastic composite is high in comparison to the thermosets due to its longer shelf life, hygroscopic nature and need of refrigeration before processing. Quality control in thermoset is much more difficult because it contains large no of ingredient such as, base epoxies, curing agent, catalyst, flow control agent and property modifier. The toughness of the thermoplastics is more than that of thermosets due to these thermoplastics shows good resistance to delamination. Thermoplastics are the high molecular weight material because of it before processing it ether to be heated at high temperature or should be treated with a polar solvent to lower its viscosity for ease of processing. Processing cost is also high in case of thermoplastics because it needs high pressure and temperature for processing.

Types of composites on the basis of reinforcement

1) Particle reinforced composites
2) Fiber reinforced composites

(1) Particle reinforced composite:

Particle reinforced composites comprises of discrete uniformly dispersed particles of a hard brittle material which are surrounded by a softer more ductile matrix. Reinforcing particles includes glasses and ceramics such as small mineral particles such as aluminum and amorphous material including carbon black and polymers [3]. Particles are used to increase the modulus of the matrix, to decrease the ductility of the matrix, or to decrease the permeability of the matrix. They are also used to produce low-cost composites.

(2) Fiber reinforced composite:

Fiber reinforced composites are advanced composites which consists of a polymer matrix reinforced with thin diameter fiber. If the reinforcement is in the form of fiber, then the composite material is called fiber reinforced composite. Fiber reinforced composites are advanced composites which consists of a polymer matrix reinforced with thin diameter fiber. A fiber is characterized by its length being much greater compared to its cross-sectional dimensions. It is again divided into two types:

- **Short fiber reinforced composites:** It consists of a matrix reinforced by a dispersed phase in form of discontinuous fibers (length < 100 diameter).
- **Long-fiber reinforced composites:** It consists of a matrix reinforced by a dispersed phase in form of continuous fibers.

1.5 Fibers

Fiber is the other main constituent in the composite system, due to its elastic nature it gives tensile strength to the composites. Figure 1 shows the classification of fibers [3].

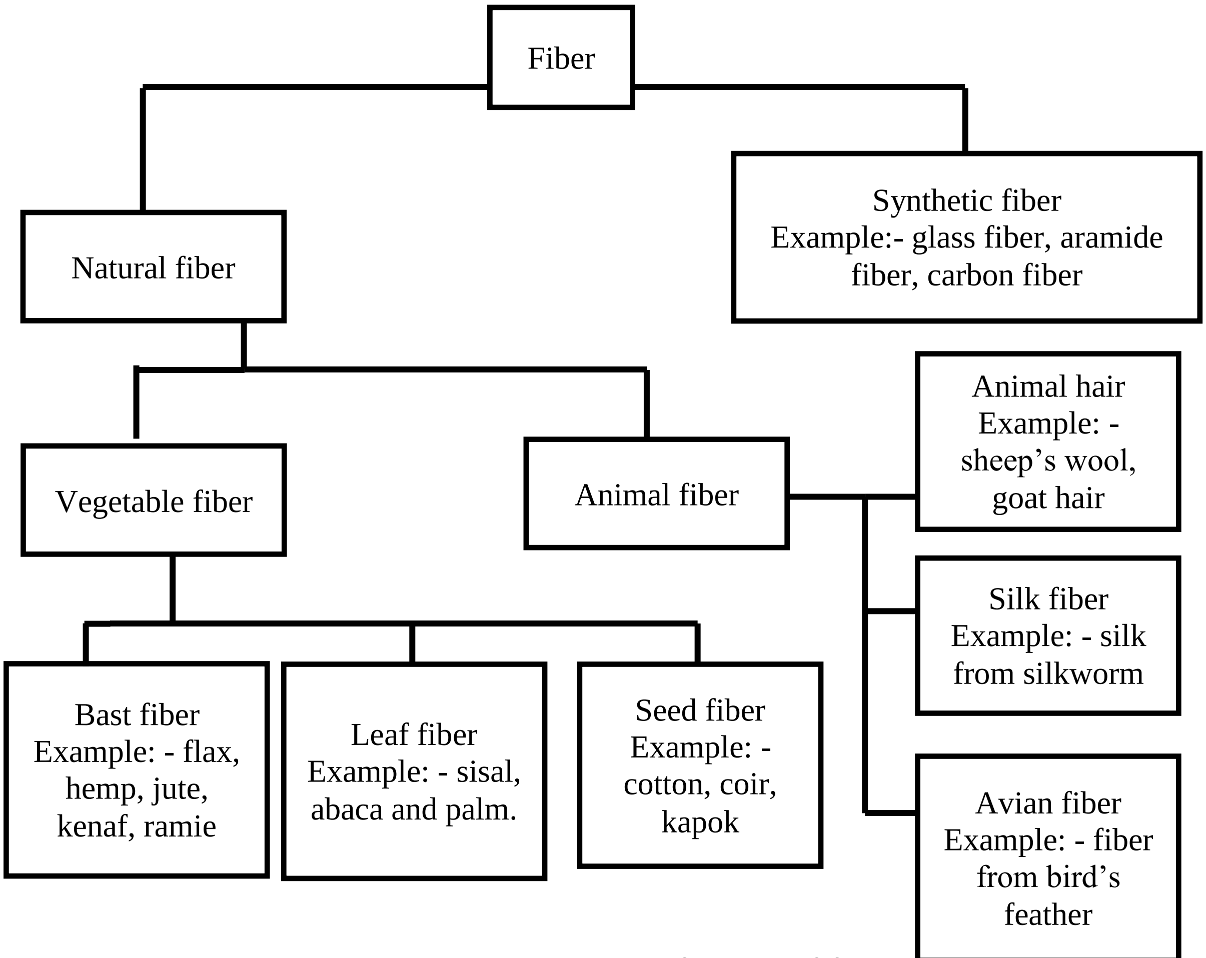

Figure 1.1 Classification of fibers

Comparison between natural and synthetic fiber

All natural fiber comes from the nature itself. The length of the fiber is determined by the nature itself. In case of synthetic fiber length of the fiber is determined by the man. Natural fiber is completely environmental friendly because after burning it converts into ash while synthetic fiber melts on application of heat. Natural fibers are generally hydrophilic in nature while synthetic fibers are hydrophobic in nature. While natural fibers are less durable than synthetic fiber.

Natural fiber

On the basis of origin natural fiber can be divided in to three categories

a) Vegetable fiber

b) Animal fiber

c) Mineral fiber

(a) Vegetable fiber

These are the material basically cellular in form and structure with the degree of inherent strength and stiffness built in naturally due to the geometrical internal structure. Basic cellular element in vegetable fiber is cellulose. It is a natural polymer and it posses high strength and stiffness per unit weight. Cellulose also forms a long fiber like cell structure and it is found in all parts of plants like stem, seed and leaf.

(b) Animal fiber

Animal fibers are directly taken from the animal body (mammals) example: animal hair, silk fiber from silkworms, and fiber from bird feathers.

(c) Mineral fiber

Mineral fibers are the strongest fibers known because they are formed with lower number of surface defect. Most commonly used fiber is Asbestos.

Now-a-days, the interest in natural fiber reinforced polymer composites is increasing rapidly due to its many advantages over other man-made fibers. The main advantages of natural fiber composites are:

- Production cost is low and these are easily available.
- Due to its low specific weight, it has higher specific strength and stiffness than glass fiber.
- The production requires little energy, and CO_2 is used while oxygen is given back to the environment therefore it is a renewable source.
- Low wages countries accept natural fiber because product can be produced with low investment at low cost.
- It acquires healthier working condition, reduced wear of tooling and no skin irritation.
- It can be recycle while, glass causes problem in combustion furnaces.
- It has Good thermal and acoustic insulating properties.

Among various natural fibers, jute is considered as one of the most potential reinforcement for polymer composites due to its many advantages such as its easy availability, its low production cost and satisfactory mechanical properties as compared to others fibers. For a composite material, its mechanical behavior depends on many factors such as fiber content, orientation, types, length etc. Attempts have been made in this research work to study the effect of fiber loading and orientation on the mechanical behavior of jute fiber reinforced epoxy composites. The morphology of fractured surfaces is examined using scanning electron microscopy (SEM).

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CHAPTER 2
LITERATURE SURVEY

This chapter outlines the recent work done in the field of mechanical properties of natural fiber reinforced composites. For a composite material, its mechanical behaviors depend upon many factors such as fiber content, fiber orientation, fiber loading. Experimental investigation carried out by Biswas et al. [4] revealed that the composites with 30° fiber orientation shows better micro-hardness, tensile strength, flexural strength, inter-laminar shear strength and impact strength. Mechanical properties of the fiber reinforced composites are controlled by the elastic properties and the strength of the matrix, the fibers and fiber-matrix bond, which governs the stress transfer [5, 6]. Green strength measurement is carried out by Geethamma et al. [7] to measure the extent of fiber orientation. The efficiency of the stress transfer is higher when fibers are aligned in parallel to the direction of application of force. Ren et al. [8] studied the effect of fluctuation of fiber orientation on tensile properties of flax silver reinforced green composites. It has been reported that although it is well-known that tensile strength of unidirectional composites decreases with increasing fiber orientation angle, the tensile strength obtained in the study did not show any appreciable relation to the statistical properties of measured fiber orientation angles such as standard and average deviation. Mansur et al. [9] described that the inclusion of bamboo mesh imparts significant toughness and ductility to the cement mortar and considerably increases its tensile, flexural and impact strengths. However, such enhancements, particularly in tension are related with wide cracking. Poor bond strength between mortar and bamboo and low elastic modulus of bamboo are the factors held responsible. The volume changes of bamboo caused poor bond strength and it can be improved by applying some cheap water sealing agent. Tungjitpornkull and Sombatsompop [10] were manufactured E-glass fiber reinforced wood/poly (vinyl chloride) (WPVC) composites either by compression molding or by twin-screw extrusion process, and the mechanical properties of the composites from these two processes were then compared. The tensile and flexural modulli for particular fiber content in WPVC composites were much higher than those with the twin-screw extrusion technique. The composites with 0° fiber orientation angle were found to provide the maximum mechanical properties, the reason being related with a continuity of fiber length to bearing the applied load and minimum fiber-end defects. Garkhail et al. [11] investigated the influence of fiber content and fiber length on stiffness, strength and impact strength of natural-fiber-mat-reinforced thermoplastics, and compared with data for glass mat reinforced thermoplastics. The effect of use of maleic-anhydride grafted PP has also been studied in order to obtain improved interfacial adhesion. Luo and Netravali [12] studied the effect of fiber loading on the tensile and flexural properties of the green composite prepared with pineapple fiber. It has been found that the tensile and flexural strength of the green composite increased with increase in fiber loading along the longitudinal direction whereas, strength decreases in transvers direction with the increase in fiber loading. Schneider and Karmaker [13] reported that polypropylene composites prepared from jute fiber exhibit better mechanical properties than kenaf fiber. Mohanty et al. [14] reported that the tensile strength of BAK is enhanced by more than 40% with alkali treated jute fabrics. Chawla and Bastos et.al [15] studied the effect of fiber volume fraction on Young's modulus, maximum tensile strength and impact strength of untreated jute fiber in unsaturated polyester resin. A number of experiments carried out in the past by different researchers for study of effect of different parameters on the mechanical properties of the natural fiber (sisal, cotton, coir, bamboo and jute henequen) composite [16-19]. Xian et al. [20] studied the mechanical properties such as tensile, compressive, flexural and inter laminar shear strength of bamboo fiber reinforced composites. In this study composites with three, five and seven layer of unidirectional bamboo fiber were fabricated. Tensile and flexural tests on banana - epoxy composites were carried out by Sapuan and Leenie [21]. Jute polyester composites possess better strength than wood composites and some plastics [22]. Interfacial properties of the coir /epoxy composites were studied from scanning electron micrograph taken from fracture surfaces and these properties is compared with the glass fibers composites[23].

2.2 Objectives of the present research work

The knowledge gap in the existing literature review has helped to set the objectives of this research work which are outlined as follows:

1. Fabrication of bi-directional jute fiber reinforced epoxy composites.
2. Evaluation of mechanical properties such as tensile, flexural, inter laminar shear strength and micro-hardness of composites.
3. Study on the effect of fiber loading and orientation on the composites.
4. To study the fracture surface morphology using SEM.

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CHAPTER 3
MATERIALS AND METHODS

3.1 Composite Fabrication

In this study, bi-directional jute fiber taken as reinforcement is collected from local sources. The epoxy resin (matrix material) and the hardener are supplied by Ciba Geigy India Ltd. The epoxy resin (LY556) and corresponding hardener (HY951) is mixed in a ratio of 10:1 by weight percentage. Composites of various compositions with three different fiber loading (20wt%, 30wt% and 40wt%) and three different fiber orientation (0°, 30° and 60°) are fabricated using simple hand lay-up technique. The castings are put under load for about 24 hours for proper curing at room temperature. After curing, the specimens of suitable dimension are cut for mechanical tests. The composition and designation of the composites prepared for this study are listed in Table 3.1.

Table 3.1 Composition and Designation of Composites

Composites	Compositions
C1	Epoxy (80wt%) + Jute Fiber (20 wt%) at 0° orientation
C2	Epoxy (70wt%) + Jute Fiber (30 wt%) at 0° orientation
C3	Epoxy(60wt%) + Jute Fiber (40 wt%) at 0° orientation
C4	Epoxy (80wt%) + Jute Fiber (20 wt%) at 30° orientation
C5	Epoxy (70wt%) + Jute Fiber (30 wt%) at 30° orientation
C6	Epoxy (60wt%) + Jute Fiber (40 wt%) at 30° orientation
C7	Epoxy (80wt%) + Jute Fiber (20 wt%) at 60° orientation
C8	Epoxy (70wt%) + Jute Fiber (30 wt%) at 60° orientation
C9	Epoxy (60wt%) + Jute Fiber (40 wt%) at 60° orientation

3.2 Mechanical testing of composites

The tension test was performed on all the three samples as per ASTM D3039-76 test standards. The tension test is generally performed on flat specimens. A uni-axial load is applied through the ends. The ASTM standard test recommends that the length of the test section should be 100 mm specimens with fibers parallel to the loading direction should be 11.5 mm wide and. To find out the flexural strength of the composites, a three point bend test is performed using Instron 1195. The strength of a material in bending is expressed as the stress on the outermost fibers of a bent test specimen, at the instant of failure. Leitz micro-hardness tester is used for micro-hardness measurement on composite samples

3.3 Scanning electron microscopy (SEM)

Scanning electron microscope of Model JEOL JSM-6480LV (Figure 3.2) was used for the morphological characterization of the composite surface. The samples are cleaned thoroughly, air-dried and are coated with 100 Å thick platinum in JEOL sputter ion coater and observed SEM at 20 kV. To enhance the conductivity of the composite samples a thin film of platinum is vacuum evaporated onto them before the micrographs are taken. The fracture morphology of the tensile fracture surface of the composites were also observed by means of SEM.

Figure 3.1 SEM Set up

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CHAPTER 4

MECHANICAL CHRACTERISTICS OF COMPOSITES: RESULTS & DISCUSSION

4.1 Mechanical characteristics of composites

The mechanical properties of the jute fiber reinforced epoxy composites with different fiber loading and orientation under this investigation are presented in Table 4.1.

Table 4.1 Mechanical properties of the composites

Composites	Micro-hardness (H_v)	Tensile strength (Mpa)	Tensile Modulus (GPa)	Flexural strength (Mpa)	Inter-laminar shear strength (Mpa)
C1	15.3	28.62	2.6	40.01	1.77
C2	17	30.53	2.7	43.02	2.08
C3	13.5	31.11	2.58	39.96	1.94
C4	19	22.46	2.52	50.68	2.53
C5	19.8	28.73	2.83	68.43	2.68
C6	15.5	17.44	1.74	47.78	2.18
C7	10.8	29.67	2.69	43.26	2.47
C8	17.6	25.96	2.76	61	2.87
C9	14.3	28.42	2.87	66	2.7

4.1.1 Effect of fiber loading and orientation on hardness of composites

Hardness of the composites is considered as one of the most key factors that govern the erosion resistance of the composites. Figure 4.1 shows the effect of fiber loading and orientation on hardness of composites. It is evident from the figure that the composites with 30wt% fiber loading shows better hardness properties as compared to others irrespective of different fiber orientation. As far as effect of fiber orientation, composites with 30° fiber orientation show maximum hardness value of 19.8Hv as compared to others irrespective of fiber loading.

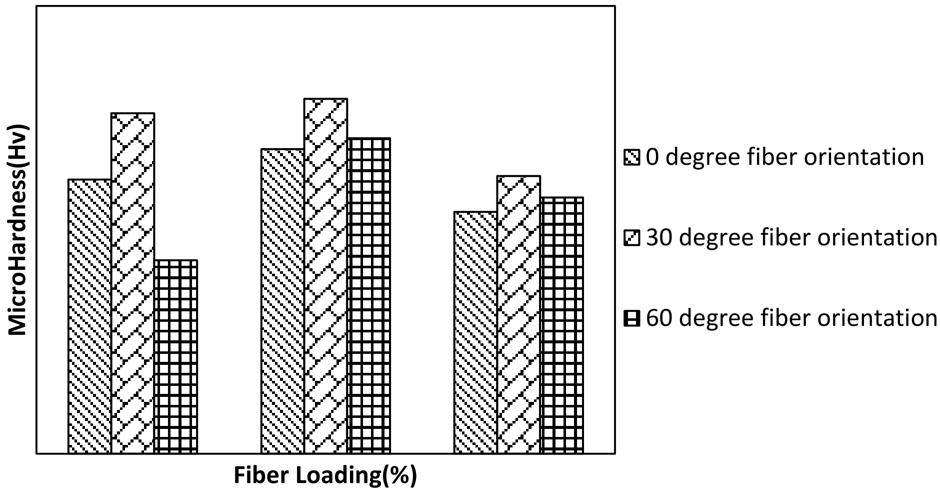

Figure 4.1 Effect of fiber loading and orientation on hardness of composites

4.1.2 Effect of fiber loading and orientation on tensile properties of composites

The variation of tensile strength and tensile modulus of composites with different fiber loading and orientation is shown in Figure 4.2 and Figure 4.3 respectively. It is clear from the Figure 4.2 that the tensile strength is increased for composites with 30% fiber loading, however further increase in fiber loading tensile strength decreased irrespective of fiber orientation. In case of 30° orientation and 30% fiber loading tensile strength is found to be maximum. This is may be due to proper resin-fiber mixing and good adhesion between resin and the fiber [4].

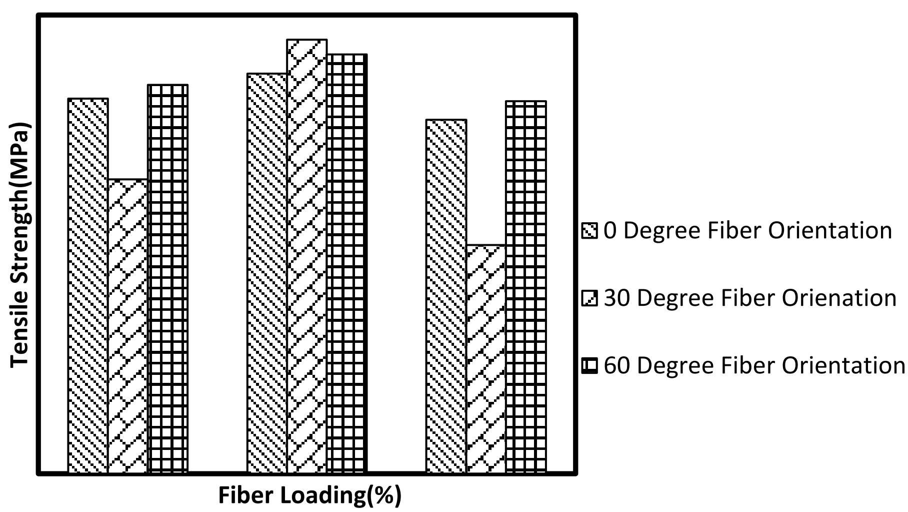

Figure 4.2 Effect of fiber loading and orientation on tensile strength of composites

Similar trend is also observed in case of tensile modulus of composites. The maximum tensile modulus is observed in case of composites with 30 wt% fiber loading at 30° fiber orientation.

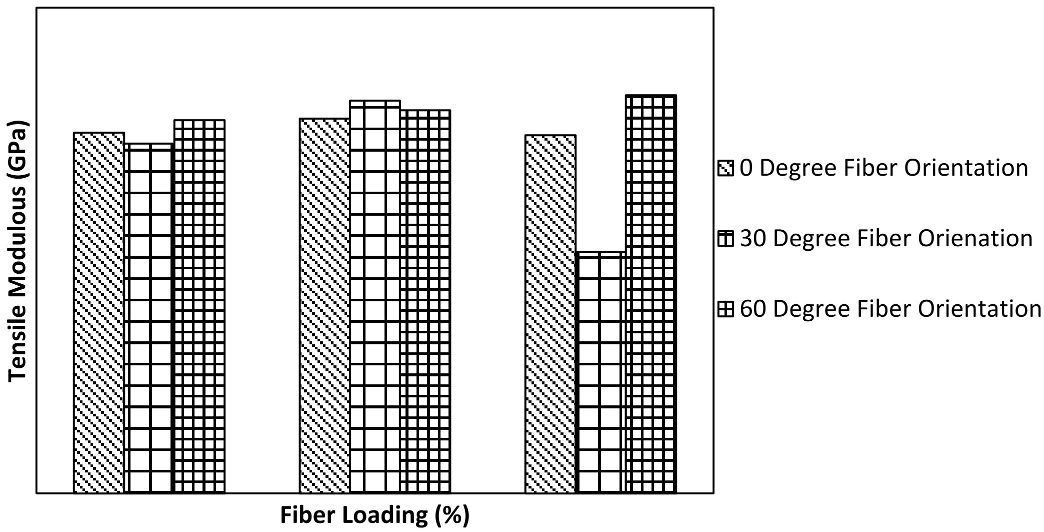

Figure 4.3 Effect of fiber loading and orientation on tensile modulus of composites

4.1.3 Effect of fiber loading and orientation on flexural strength of composites

Figure 4.4 shows the effect of fiber loading on flexural strength of jute fiber reinforced epoxy composites. It is observed from figure that a linearly increasing trend up to a certain value of fiber loading (30wt%) and suddenly drops due to failure of specimens and the arrest points correspond to breakage and pull out of individual fibers from the resin matrix. The increase in flexural strength is may be due to higher flexural stiffness of jute composite and the improved adhesion between the matrix and the fiber. The maximum flexural strength is observed for composites with 30wt% fiber loading at 30° fiber orientation.

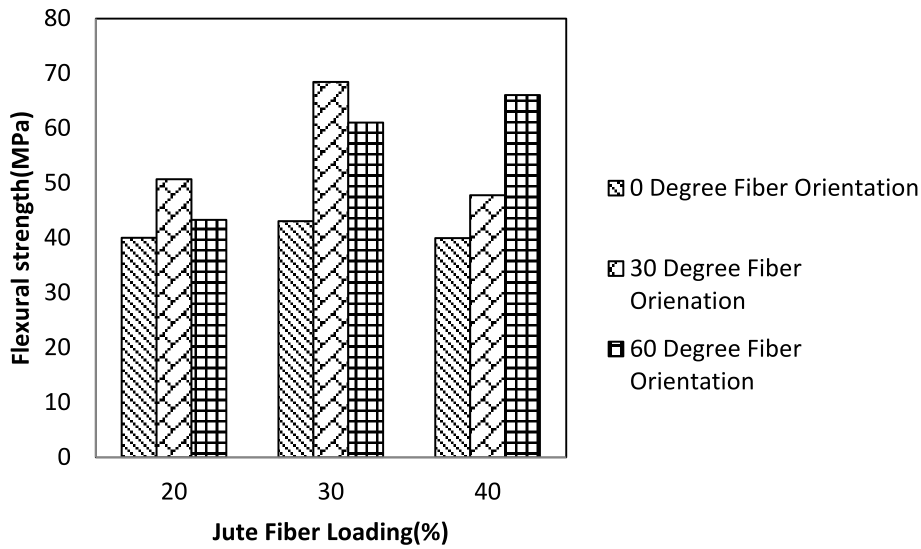

Figure 4.4 Effect of fiber loading and orientation on flexural strength of composites

4.1.4 Effect of fiber loading and orientation on inter-laminar shear strength of composites

The stress that acts on the joining interface of two laminae in layered composite is known as inter-laminar shear strength. This stress causes a relative failure between two adjacent laminae that is why it is taken in to a principle interest during manufacturing of the composites. The effect of the fiber orientation and fiber loading on the inter-laminar shear strength of the composites is studied and shown in Figure 4.5. In general, inter-laminar shear strength is found to be higher in case of 30 wt% fiber loading irrespective of the orientation. While considering fiber orientation it is found to be higher in case of 30° fiber orientation.

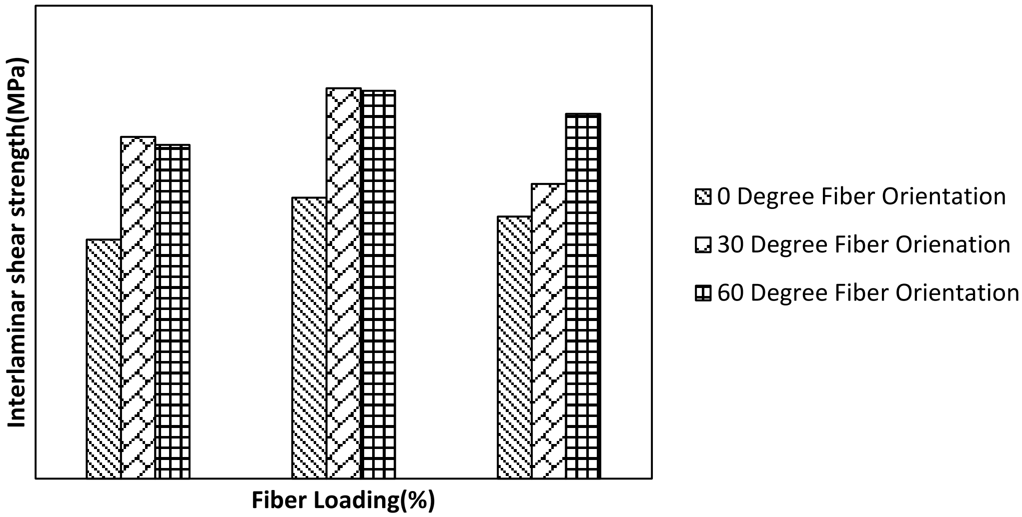

Figure 4.5 Effect of fiber loading and orientation on inter-laminar shear strength of composites

4.2 Surface morphology of the composites

Figure 4.6 a-c shows the fracture surfaces of jute fiber reinforced epoxy composite after the tensile test under different fiber loading and orientation. Figure 4.6a shows the tensile fracture of composite specimen at 20wt% fiber loading and 0° fiber orientation. It can be seen from the figure that the fibers are detached from the resin surface due to poor interfacial bonding. However, fracture surface of composites reinforced with 20wt% fiber loading at 30° fiber orientation shows the smooth surface indicating that the compatibility between fibers and epoxy matrices is good as shown in Figure 4.6b. Figure 4.6c shows the SEM image of fracture surface of composite specimen reinforced with 30wt% fiber loading at 30° fiber orientation. Smooth surface without any pulled out fiber is clearly visible in the figure which leads to the better compatibility of fiber and matrix as expected in case of composites with 30wt% fiber loading and 30° fiber orientation since the result also shows better mechanical property with this composition.

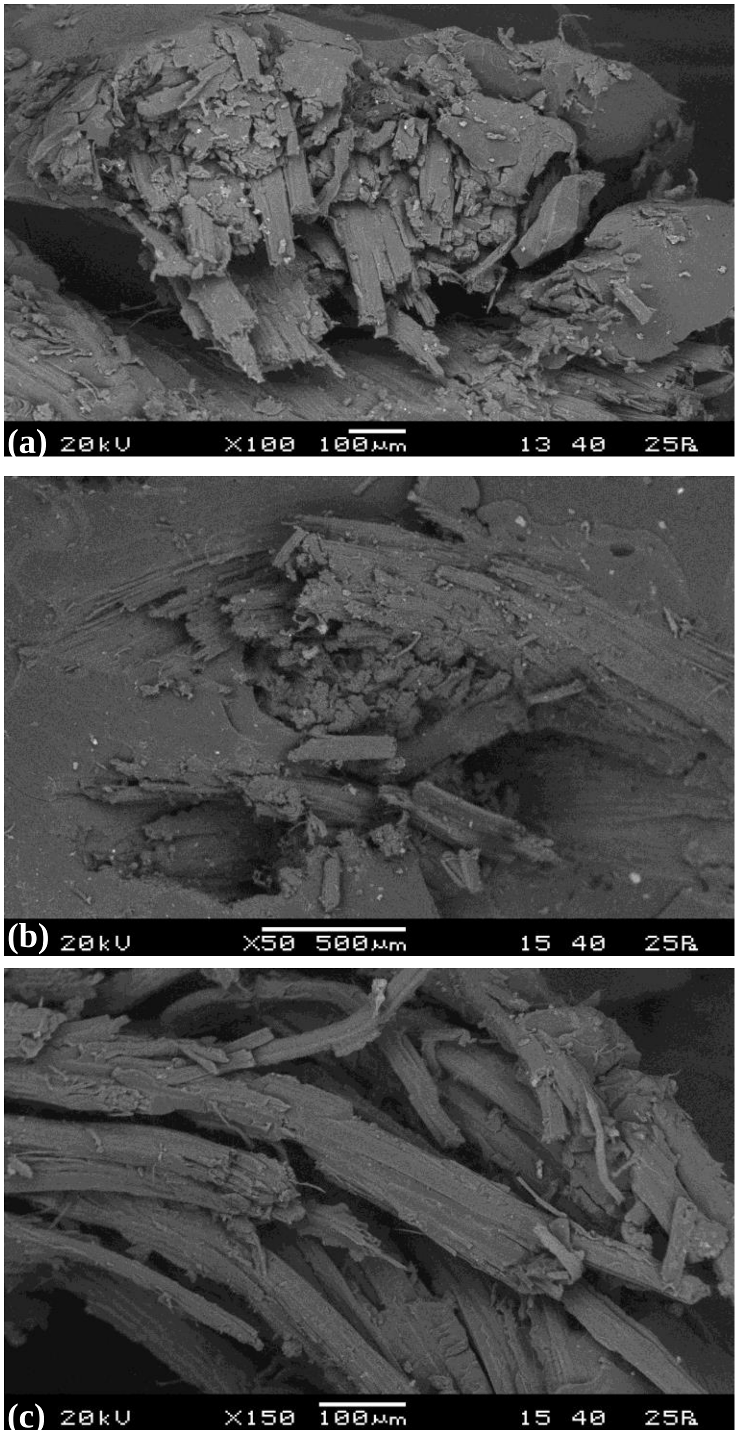

Figure 4.6 Scanning electron micrographs of jute fiber reinforced epoxy composite specimens after tensile testing at different fiber loading and orientation.

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CHAPTER 5

CONCLUSIONS

The experimental investigation on the effect of fiber loading and fiber orientation of mechanical behavior of bi-directional jute fiber reinforced epoxy composites leads to the following conclusions obtained from this study are as follows:

1. The successful fabrications of a new class of epoxy based composites reinforced with bi-directional jute fiber have been done.
2. The present investigation revealed that 30wt% fiber loading shows superior mechanical properties. As far as fiber orientation is concerned 30° fiber orientation shows better mechanical properties.
3. The fracture surfaces study of jute fiber reinforced epoxy composite after the tensile test has been done. From this study it has been concluded that the increase in mechanical properties of composites at 30wt% fiber loading at 30° fiber orientation is due to the better interfacial bonding.

5.1 Scope for future work

There is a very broad scope for future scholars to explore the current research area. This research work can be further extended to study other aspects of composites like use of other natural fibers and evaluation of their various properties and the experimental results can be similarly analyzed.

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