PROCESSING, CHARACTERIZATION AND MECHANICAL BEHAVIOR OF COIR 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 ***"Processing, Characterization and Mechanical Behavior of Coir Fiber Reinforced Epoxy Composites"*** submitted by ***Sonu Abhishek (Roll No.109ME0533)*** 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

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ABSTRACT

Fiber reinforced polymer composites has been used in a variety of application as class of structure material because of their many advantages such as relatively low cost of production, easy to fabricate and superior strength compare to neat polymer resins. Reinforcement in polymer is either synthetic or natural. Synthetic fiber such as glass, carbon etc. has high specific strength but their fields of application are limited due to higher cost of production. Recently there is an increase interest in natural composites which are made by reinforcement of natural fiber. Because the natural fiber give good property at lower cost of production In this connection an investigation have been carried out to make better utilization of coconut coir fiber which is very cheaply and easily found in India. The objective of the present research work to study the mechanical properties of coconut coir reinforced with epoxy composites. The effect of fiber loading and length on mechanical properties like tensile strength, flexural strength, hardness of composites is studied. Also, the surface morphology of fractured surfaces after tensile testing is examined using scanning electron microscopy (SEM).

CHAPTER 1
INTRODUCTION

1.1 Overview of Composites

Due to the development and growth of technology, the need of material having highly specific properties is increasing day by day and this challenge demand cannot be fulfill by use of polymers, ceramic and metal alloys. Therefore, recently composite materials are used as alternative in several light weight and high strength applications. Composites are naturally occurring or engineered materials which are made from two or more constituents. Generally, composites materials have strong load carrying reinforcing material imbedded in weaker matrix materials. The main constituent of composites have a continuous phase which is the major part of the composite is called matrix .Matrix are generally more ductile and less hard and these are usually either inorganic or organic. Secondary constituent of composites have discontinuous phase called reinforcement and they are embedded in the matrix. The constituents of composite materials have their own property however when they are combined together, they give a combination of properties that an individual cannot be able to give. Generally, composite materials are classified on the basis of matrix materials are as follows:

- Metal Matrix Composites (MMC)
- Ceramic Matrix Composites (CMC)
- Polymer Matrix Composites (PMC)

Among various types of composites, PMC is the most commonly used composites, due to its advantages such as simple manufacturing principle, low cost and high strength. PMCs have two types of polymer that have been used as matrix. These are thermoplastics and thermosetting polymer. Thermoplastic polymer is that polymer which are repeatedly softened and reformed by heating. Some examples of thermoplastics are PVC, LDPE and HDPE. Thermosetting polymer is the polymer which has hard and stiff cross-linked materials. They are not soften and moldable when they are heated. Epoxy is the most commonly used thermosetting polymer. They have many advantages such as better adhesion to other materials, good mechanical properties, and good electrical insulation. The other type of constituents of composites is reinforcements. Reinforcements are equally important as matrix materials. Reinforcement used to improve overall mechanical properties of matrix and give strength to composites of matrix and give strength to composites.

Recently, the natural fibers are gaining interest as reinforcement in polymer composites rapidly. The natural fiber used as reinforcement from very old time as man used grass and straw from beginning of civilization in reinforcing the bricks that are used to make mud wall. There are many advantages of natural fiber on traditional reinforcing material as such as low density, low cost, enhanced energy recovery, good thermal properties, acceptable specific strength and biodegradable [1]. These fibers are easily and abundantly available, biodegradable and these advantages make natural fiber popular over synthetic fiber such as glass fiber, carbon and other man-made fibers. Natural fibers are naturally occurring consisting mainly cellulose fibrils embedded in lignin matrix. The composition of some commonly used natural fibers are shown in Table 1.1

Table 1.1 Composition of Natural Few Commonly used Natural Fibers [2]

Fiber	Cellulose (wt%)	Hemi-cellulose (wt%)	Lignin (wt%)	Pectin (wt%)	Moisture (wt%)	Waxes
Cotton	85-90	5.7	-	0-1	7.85-8.5	0.6
Bamboo	60.8	0.5	32	-	-	-
Flax	71	18.6-20.6	2.2	2.3	8-12	1.7
Hemp	70-74	17.9-20.4	3.7-5.7	0.9	6.2-12	0.8
Jute	61.1-71.5	13.6-20.4	12-13	0.2	12.5-13.7	0.5
Kenaf	45-47	21.5	8-13	3-5		
Ramie	68.6-76.2	13.1-16.7	0.6-0.7	1.9	7.5-17	0.3
Banana	63-64	10	5	-	10-12	
Sisal	66-78	10-14	10-14	10	10-22	2

Coir	32-43	0.15-0.25	40-45	3-4	8	

On the basis of the source origin, natural fibers are classified into three categories they are

- Mineral Fibers
- Animal Fibers
- Plant Fibers

Mineral Fibers: Mineral fibers are the naturally occurring fiber or slightly modified fibers obtain from minerals. It has various categories they are following: Asbestos is the only naturally occurring mineral fiber. The Variations in mineral fiber are the serpentine and amphiboles, anthophyllite. The Ceramic fibers are glass fibers, aluminum oxide, silicon carbide, and boron carbide. Metal fibers include aluminums fibers.

Animal Fibers: Animal fiber generally consists of proteins; examples mohair, wool, silk, alpaca. Animal hair (wool or hair) are the fibers got from animals e.g. Sheep's wool, goat hair (cashmere, mohair), alpaca hair, horse hair, etc. Silk fiber is the fibers collected from dried saliva of bugs or insects during the time of preparation of cocoons. Examples silk from silk worms. Avian fibers are the fibers from birds.

Plant Fibers: Plant fibers are generally consists of cellulose: examples cotton, flax, jute, ramie, sisal and hemp. Cellulose fibers are used in the Manufacture of paper and cloth. The category of these fibers is as following: Seed fibers are the fibers obtain from the seed and seed case e.g. cotton and kapok. Leaf fibers are the fibers obtain from the leaves e.g. sisal and agave. Skin fibers are the fibers are obtain from the skin or bast surrounding the stem of the plant. This fibers having higher tensile strength than other fibers. Therefore, these fibers are used in durable yarn, fabric, packaging, and paper. Some other examples are flax, jute, banana, hemp, and soybean. Fruit fibers are the fibers are obtain from the fruit of the plant, e.g. coconut (coir) fiber. Stalk fiber are the fibers that are obtain from the stalks of the plant (straws of wheat, rice, bamboo and barley). Natural fiber composites are not new to mankind. The ancient Egyptians used clay that was reinforced by straw to build walls. In the early of the 20th century wood- or cotton fiber reinforced phenol- or melamine formaldehyde resins were fabricated and used in different electrical applications due to their non-conductive and heat-resistant properties. At present day natural fiber composites application are generally found in automotive and building industry and the place where load bearing capacity and dimensional stability under moist and high thermal conditions are of importance. For example, flax fiber reinforced polyolefin are widely used today in automotive industry. Here fiber acts as filler material in non structural interior [3]. Natural fiber composites used for structural purposes, but then usually with synthetic thermoset matrices which of course limit the environmental benefits [4, 5]. The natural fiber composites are very cost effective material for given applications:

• For the Storage devices: post-boxes, grain storage silos, bio-gas etc.
• For the Furniture: chair, table, shower etc.
• For the Electric devices: electrical appliances etc.
• For the Everyday applications: lampshades, suitcases etc.
• Transportation: automobile and railway coaches, boat etc.

Production of Natural Fibers

The information of other fibers and the countries of origin are presented in Table 1.2

Table1.2 Production of Natural Fibers [6]

Flax	Borneo
Hemp	Yugoslavia, china
Sun Hemp	Nigeria, Guyana, Siera Leone, India
Ramie	Hondurus, Mauritius
Jute	India, Egypt, Guyana, Jamaica, Ghana, Malawi, Sudan, Tanzania
Kenaf	Iraq, Tanzania, Jamaica, South Africa, Cuba, Togo
Roselle	Borneo, Guyana, Malaysia, Sri Lanka, Togo.
Sisal	East Africa, Bahamas, Antiqua, Kenya, Tanzania, India
Abaca	Malaysia, Uganda, Philippines, Bolivia
Coir	India, Sri Lanka, Philippines, Malaysia

Natural fibers such as jute, sisal, pineapple, abaca and coir have already been studied as a reinforcement and filler in composites. Among various natural fibers, coconut coir fiber is considered as a potential reinforcement in polymer composites. Husk of coconut is easily available in large quantities as residue from coconut production in many areas. Coir is a lingo-cellulosic natural fiber. Coconut fiber is the seed hair or husk. The total world coir fiber production is 250,000 tones. The coir fiber industry is the one of the important industry of some areas of the developing world because of the advantages like hard-wearing quality, durability etc. These have wide application in of floor furnishing materials, yarn, rope etc. However, these coconut coir uses consume only a small percentage of the potential total world production of coconut husk. Hence, research and development efforts have been going on to find out the new areas for coir, along with utilization of coir as reinforcement in polymer composites. Although there are so many discussion has been done in literature to know about the mechanical behavior of coconut coir. However, very limited work has been done on effect of fiber length on mechanical behavior of coir fiber based polymer composites. To this end, the present research work has been undertaken to study the potential use of coir fiber as a reinforcing material in polymer composites and to investigate their mechanical behavior. The aim of present work is to develop this new class of natural fiber based polymer composites having different fiber lengths and to analyses their mechanical behavior by experimentation. Also, using scanning electron microscopy (SEM) the morphology of fractured surfaces is studied.

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CHAPTER 2

LITERATURE SURVEY

This chapter outlines some recent work and report published in literature on mechanical behavior of natural fiber based polymer composites with special attention on coir fiber reinforced polymer composites

The mechanical behavior of a natural fiber reinforced composite depends on many parameters, such as fiber strength, fiber length, orientation, fiber-matrix interfacial bond strength etc. For better mechanical properties of composites a strong fiber-matrix interface bond is important. Some surface modification to the fiber also improves the resistance to moisture induced degradation of the interface and the composite properties. In addition, factors like processing conditions or techniques have very significant influence on the mechanical properties of fiber reinforced composites. The mechanical properties of some natural fibers like flax, jute, hemp and sisal, are very good and may withstand with glass fiber in specific strength and modulus [7, 8]. A series of investigations have been conducted on different types of natural fibers such as kenaf, hemp, flax, bamboo, and jute to study the effect of fiber on the mechanical properties of composites [9-12]. Mansur and Aziz [11] studied on bamboo-mesh reinforced cement composites and reported that this reinforcing material could enhance the ductility and toughness of the cement matrix, and increase significantly its flexural, tensile, and impact strengths. Composites of jute fabric-reinforced polyester were studied for the evaluation of mechanical properties and compared with wood composites, and it is concluded that the jute fiber composite has better strengths than wood composites [12]. Laly et al. [13] have investigated banana fiber reinforced polyester composites and reported that the optimum content of banana fiber is 40%. Corbiere-Nicollier et al. [14] has studied the physical and mechanical properties of banana fiber cement composite. It was reported that kraft pulped banana fiber composite has better flexural strength. The effect of fiber length and fiber content on short banana fiber reinforced polyester composite was studied by Pothan et al. [15]. The tensile strength was observed maximum at 30 mm fiber length while impact strength was observed maximum at 40 mm fiber length. Incorporation of 40% untreated fibers gives 20% increase in the tensile strength and a 34% increase in impact strength. Joseph et al. [16] evaluated the effect of fiber length and fiber content on banana fiber and glass fiber. Belmeres et al. [17] found that sisal, henequen, and palm fiber have similar chemical, physical, and tensile properties. Cazaurang et al. [18] carried out a systematic study on the properties of henequen fiber and reported that these fibers have mechanical properties which are suitable for reinforcing thermoplastic resins. Ahmed et al. [19] carried out different research work on filament wound cotton fiber reinforced for reinforcing high-density polyethylene (HDPE) resin. Khalid et al. [20] has studied the use of cotton fiber reinforced epoxy composites in addition to glass fiber reinforced polymers. Fuad et al. [21] investigated the new type wood based filler derived from oil palm wood flour (OPWF) for bio-based thermoplastics composites by thermo gravimetric analysis and there results are very promising. Schneider and Karmaker [22] has developed composites using jute and kenaf fiber and polypropylene resins and they point that jute fiber provides better mechanical properties than kenaf fiber. Sreekala et al. [23] performed a study on the mechanical performance of treated oil palm fiber-reinforced composites. The alkali treated (5%) sisal-polyester bio composite showed 22% increase in tensile strength [24]. Ichazo et al. [25] found that adding silane treated wood flour to PP produced a sustained increase in the tensile modulus and tensile strength of the composite. Joseph and Thomas [26] studied the effect of chemical treatment on the tensile and dynamic mechanical properties of short sisal fiber reinforced low density polyethylene composites. It was reported that the CTDIC (cardanol derivative of toluene diisocyanate) treatment reduced the hydrophilic nature of the sisal fiber and enhanced the tensile properties of the sisal-LDPE composites. They conclude that peroxide and permanganate treated fiber-reinforced composites showed an enhancement in tensile properties. They concluded that a suitable fiber surface treatment result in the improvement of the mechanical properties and dimensional stability of sisal-LDPE composites. Mohanty et al. [27] studied the influence of different surface modifications of jute on the performance of the bio composites. More than a 40% improvement in the tensile strength occurred as a result of reinforcement with alkali treated jute fiber. Jute fiber content also affected the bio composite performance and about 30% by weight of jute showed optimum properties of the bio composites.

Many aspects of the use of coir fibers as reinforcement in polymer–matrix composites are described in the literature. Coir is an abundant, versatile, renewable, cheap, and biodegradable lingo-cellulosic fiber used for making a wide variety of products [28]. Coir has also been tested as filler or reinforcement in different composite materials [29-32]. Furthermore, it represents an additional agro-industrial nonfood feedstock (agro industrial and food industry waste) that should be considered as feedstock for the formulation of Eco compatible composite materials. Due to lowest thermal conductivity and bulk density Coconut coir gives the most interesting products. The addition of coconut coir reduced the thermal conductivity of the composite specimens and produced a lightweight product. Development of composite materials for buildings using natural fiber as coconut coir with low thermal conductivity is an interesting alternative which would solve environment and energy concern [33, 34]. Geethamma et al. [35] have studied the dynamic mechanical behavior of natural rubber and its composites reinforced with short coir fibers. Coir fiber–polyester composites were tested as helmets, as roofing and post-boxes [36]. These composites, with coir loading ranging from 9 to 15 wt%, have a flexural strength of about 38 MPa. Coir polyester composites with untreated and treated coir fibers were studied for various mechanical properties [37]. The untreated fibers reports clear signs of the presence of weak interface long pulled-out fibers without any resin adhered to the fibers and low mechanical properties were observed. Alkali treatment is also reported for coir fibers [38, 39]. Treated fiber polyester composites, with volume fraction ranging for10% to 30%, show better properties than composites with untreated fibers, although the flexural strength of these composites was consistently lower than that of the bare matrix. A maximum value of 42.3MPa is reported against a value of 48.5MPa for the neat polyester. However, the fiber loading has to be fairly high, 45 wt. % or even higher, to attain a significant reinforcing effect when the composite is tested in tension. Moreover, even with high coir fiber loading fractions, there is no improvement in the flexural strength [40]. From these results, it is apparent that the usual fiber treatments reported so far did not significantly change the mechanical performance of coir-polyester composites. Although there are several reports in the literature which discuss the mechanical behavior of natural fiber reinforced polymer composites, however, the effect of fiber length on mechanical behavior of coir fiber reinforced polymer composites is hardly been reported. In this contrast, the present research work has been taken, with an objective to investigate the potential of coir fiber as a reinforcing material in polymer composites.

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 coir fiber reinforced fiber reinforced epoxy composites.
2. Evaluation of mechanical properties such as tensile strength, impact strength flexural strength, and micro-hardness etc of composites.
3. To study the influence of fiber length and loading on the mechanical behavior of composites.
4. To study the fracture surface morphology using SEM.

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CHAPTER 3

MATERIALS AND METHODS

This chapter deals with the details of processing of the composites and the experimental procedures followed for their mechanical characterization. The raw materials used are:

- Epoxy resin.
- Coconut coir fiber.
- Hardener

3.1. Specimen preparation

The coconut fiber (Figure 3.1) which has been taken as reinforcement in this study is collected from local sources. The epoxy resins and the hardener are supplied by Ciba Geigy India Ltd. The moulds have been prepared of dimensions of 180×180×40 mm^3. The coconut fiber of different length has been mixed with epoxy resins of their respective values by simple mechanical stirring and mixture are poured in various moulds, keeping the view on testing condition and characterization standards. The composites set of nine different compositions have been prepared with different length of coconut fiber. The details of composites and their compositions are shown in Table 3.1. A releasing agent has been use on mould sheet give easy removal of composites from the mould after curing. The air trapped is removed by sliding roller and the mould has been closed at temperature 30C for 24 hour. At a constant load of 50 kg. After curing, the specimen has been cut in suitable dimensions with help of diamond cutter for mechanical tests as per the ASTM standards.

Figure 3.1 Coconut coir fibers

Table 3.1 Designation of Composites

Composites	Compositions
C1	Epoxy (90wt%)+ Coir fiber (fiber length 5mm) (10wt%)
C3	Epoxy (80wt%)+ Coir fiber (fiber length 5mm) (20wt%)
C4	Epoxy (70wt%)+ Coir fiber (fiber length 5mm) (30wt%)
C5	Epoxy (90wt%)+ Coir fiber (fiber length 15mm) (10wt%)
C6	Epoxy (80wt%)+ Coir fiber (fiber length 15mm) (20wt%)
C7	Epoxy (70wt%)+ Coir fiber (fiber length 15mm) (30wt%)
C8	Epoxy (90wt%)+ Coir fiber (fiber length 25mm) (10wt%)
C9	Epoxy (80wt%)+ Coir fiber (fiber length 25mm) (20wt%)
C9	Epoxy (70wt%)+ Coir fiber (fiber length 25mm) (30wt%)

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 cross head speed was taken as 10 mm/min and a span of 30 mm was maintained. 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. Figure 3.2 shows the experimental set up and loading arrangement for the specimens for tensile test and three points bend test Leitz micro-hardness tester is used for micro-hardness measurement on composite samples

Figure 3.2 Experimental set up and loading arrangement for the specimens for tensile test and three points bend test

3.4 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 3.3 SEM Set up

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CHAPTER 4

MECHANICAL CHRACTERISTICS OF COMPOSITES: RESULTS & DISCUSSION

This chapter deal with the mechanical properties of the coir fibre reinforced epoxy composites.

4.1 Mechanical characteristics of composites

The mechanical properties of composite are highly depending on many factors like fiber length and fiber loading. The mechanical properties of the coir fiber reinforced epoxy composites with different fiber length and loading are presented in Table 4.1.

Table 4.1 Mechanical properties of the composites

Composites	Hardness (Hv)	Tensile strength (MPa)	Tensile modulus (GPa)	Flexural strength (MPa)
C1	9.4	12.31	1.523	35.12
C2	18.2	17.71	1.433	28.44
C3	6.2	3.208	1.331	24.34
C4	10.6	14.32	1.913	38.32
C5	18.1	9.11	1.743	32.17
C6	16.8	6.73	1.401	30.23
C7	25.4	15.67	2.428	41.08
C8	26.4	11.09	2.023	35.77
C9	18.7	10.57	1.727	33.15

4.1.1 Effect of Fiber length on Tensile Properties

The effect of fiber length and loading on tensile properties of coir fiber reinforced epoxy composites are shown in Figures 4.1 and 4.2, respectively. It has been seen that the tensile strength and tensile modulus of the composite increases with increase in fiber length. There may be due to the chemical reaction at the interface between the fiber and the matrix may be too strong to transfer the tensile strength. From Figure 4.1 it is clear that the both tensile strength and tensile modulus is maximum for 25 mm fiber length. Further, it is evident from Figure 4.2 that the increase in fiber loading the tensile strength decrease it is due to mainly improper bonding with epoxy resin due increase in fiber loading.

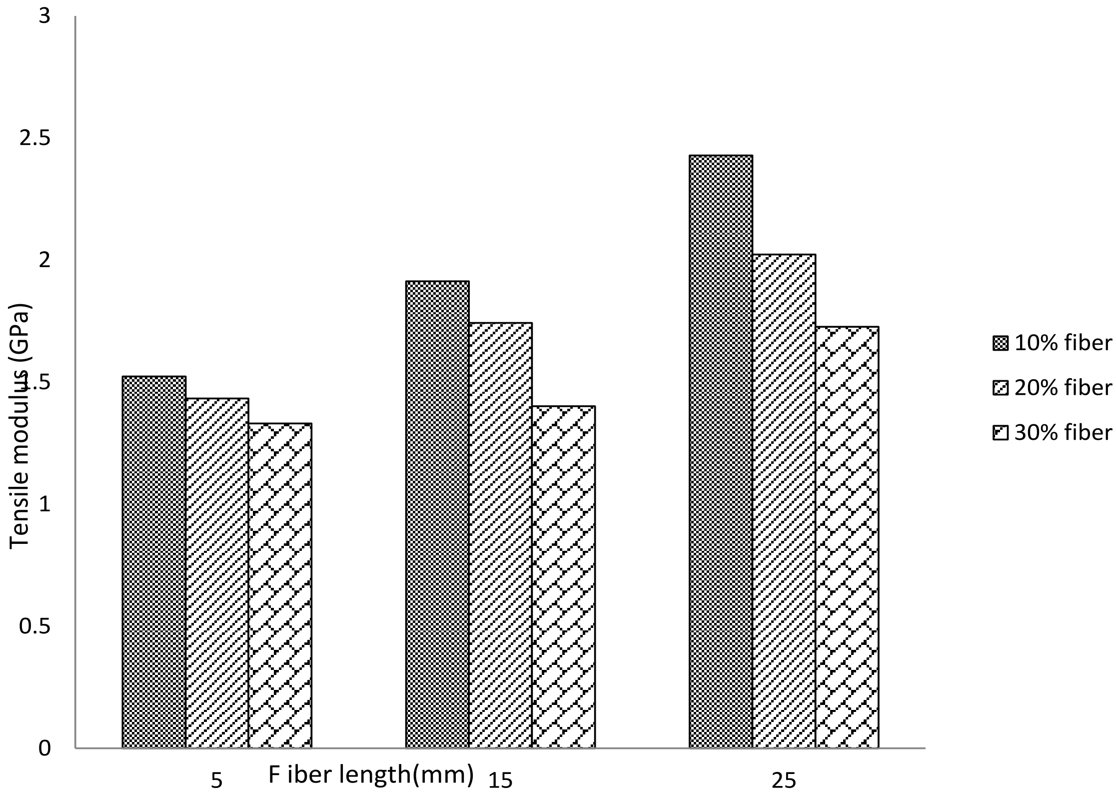

Figure 4.1 Effect of fiber length on tensile modulus of composites

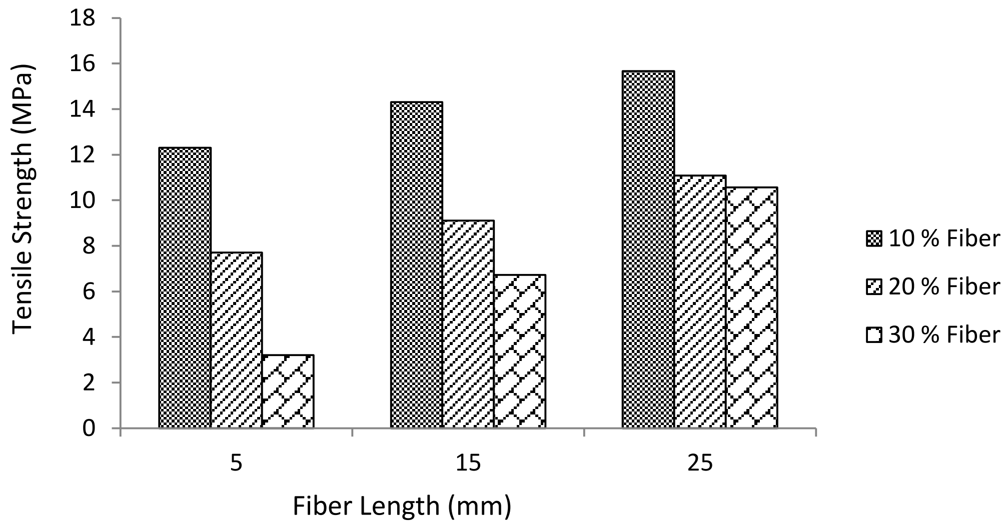

Figure 4.2 Effect of fiber length on tensile strength of composites

4.1.2 Effect of Fiber length on Flexural Strength

Figure 4.3 shows the effect of fiber length and loading on the flexural strength of composites. From the figure it is clear that with increase in fiber length the flexural strength increase and with increase in fiber loading the flexural strength decrease. The maximum flexural strength is observed for composite reinforced with 10wt% fiber loading with 25mm of fiber length.

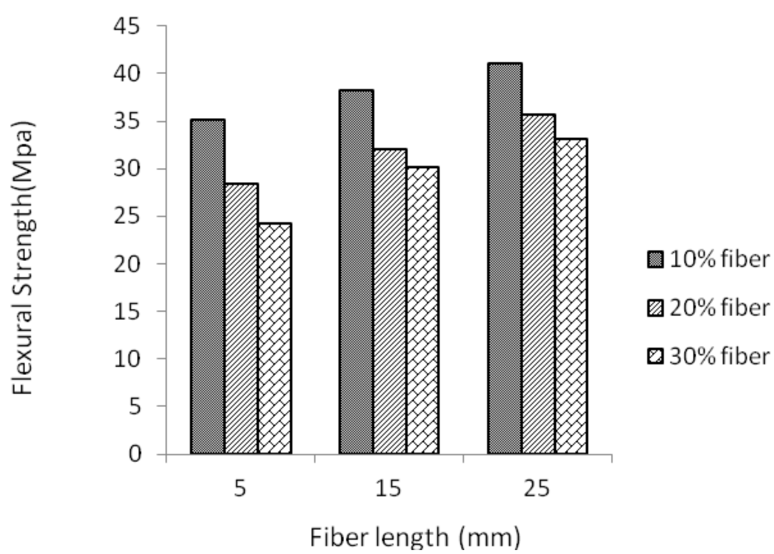

Figure 4.3 Effect of fiber length on flexural strength of composites

4.1.3 Effect of Fiber length on Micro-hardness

The effect of fiber length and loading micro-hardness of composites is shown in Figure 4.4. It is clear from the figure that the micro-hardness value increases with increase in fiber length and it is maximum at 25mm fiber length. However, with increase of fiber loading hardness value increases up to 20 wt% fiber loading then the value decreases.

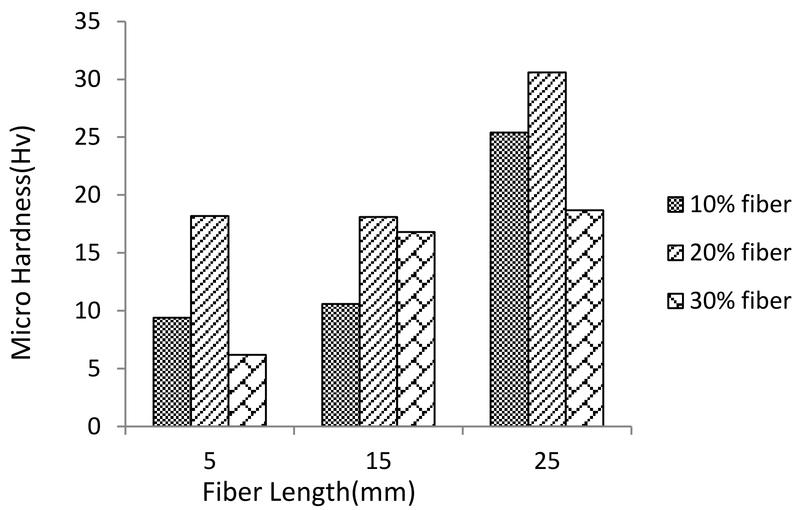

Figure 4.4 Effect of fiber length on micro-hardness of the co

4.3 Surface morphology of the composites

Figure 4.5 a-b shows the fracture surfaces of coir fiber reinforced epoxy composite after the tensile test with different fiber lengths. Figure 4.5a shows the tensile fracture of composite specimen reinforced with 10wt% fiber loading at 5mm fiber length. It can be clearly seen from the figure that the fibers pull out from the resin surface due to poor interfacial bonding. However, fracture surface of composites reinforced with 10wt% fiber loading at 25mm length shows no pull out of fiber leads to the better compatibility between fibers and epoxy matrices as shown in Figure 4.5b.

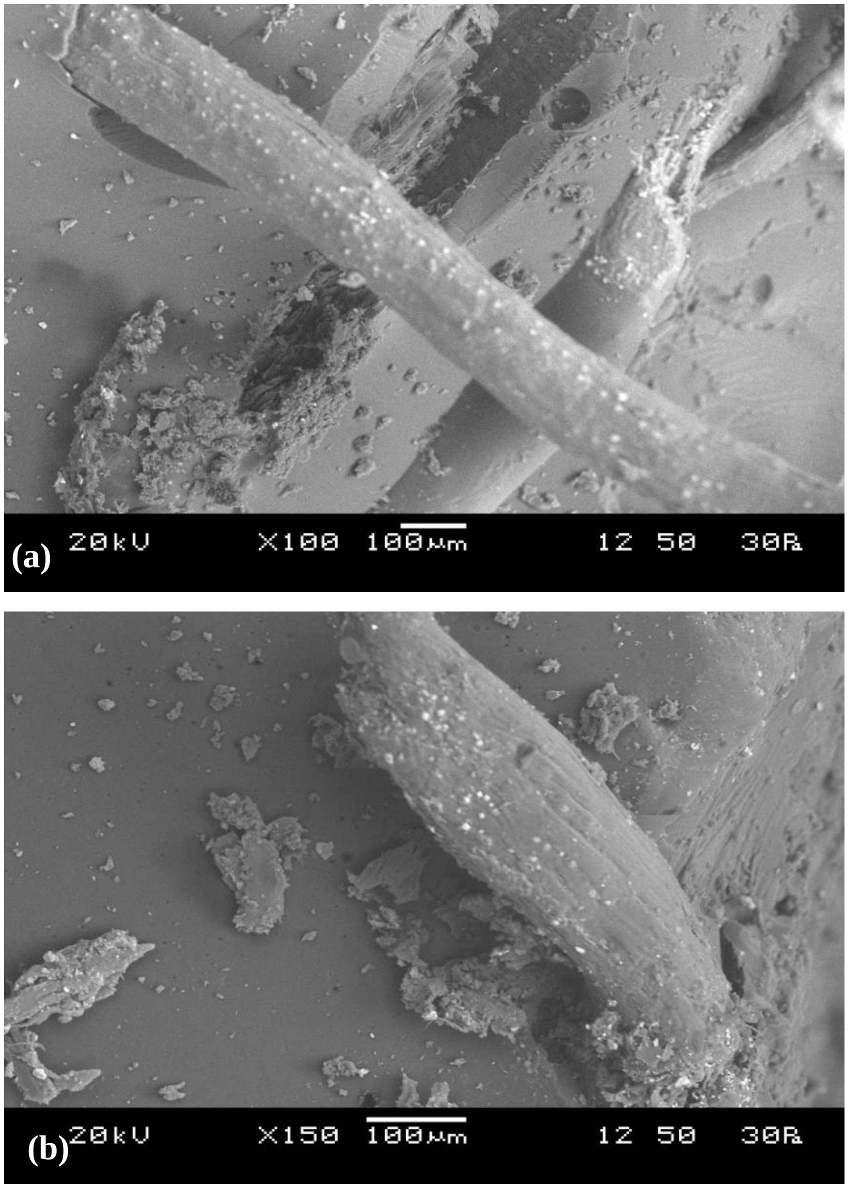

Figure 4.5 Scanning electron micrographs of jute fiber reinforced epoxy composite specimens after tensile testing with treated and untreated fibers

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CHAPTER 5

CONCLUSIONS

This experimental investigation of mechanical behavior of coconut coir reinforced epoxy composites leads to the following conclusions:

- In this work the successful fabrication of a coir fiber reinforces epoxy composites with different fiber lengths and loading is possible by simple hand lay-up technique.
- It has been noticed that the fiber loading and length has significant effect on the mechanical properties of the composites such as micro-hardness, tensile strength, tensile modulus and flexural strength.
- The mechanical properties of coir fiber reinforced composites increases with increase in fiber length and decrease with fiber loading. The mechanical is found better for composites reinforced with 10wt% fiber loading with 25mm fiber length.
- After tensile test, the fracture surface of composite reveals that the good interfacial bonding is responsible for better mechanical properties.

5.1. Scope for Future Work

For future scholar there is a very good opportunity to explore the preset area of research. The present work can be extended to investigate the other aspects such as fiber orientation; fiber treatment on mechanical behavior of coconut coir based polymer composite and the experimental values can be similarly analyzed.

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