A STUDY ON MECHANICAL BEHAVIOR OF SURFACE MODIFIED 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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DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA 769008

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CERTIFICATE

This is to certify that the thesis entitled ***"A Study on Mechanical Behavior of Surface Modified Jute Fiber Reinforced Epoxy Composites"***submitted by Ritlal Kumar Yadav ***(Roll Number: 109ME0430)*** 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

Composites are materials consisting of two or more chemically distinct constituents on a macro scale having a distinct interface separating them and having bulk behavior which is considerably different from any of the constituents. In current age natural fiber is more delightful material because of its many advantages such as low density, nontoxic, nonabrasive, radially available in nature and is cost effective. A lot of work has been done in this particular area all over the world over the use of natural fibers as reinforcement for preparing different varieties of composites. Due to incompatibility between polymer and fiber it is more to likely form unwanted substances during processing and the poor resistance to moisture, reduce the use of the natural fibers as reinforcements in polymer. To this end, an attempt has been made to study the effects of chemical treatment on mechanical behavior of jute fiber reinforced epoxy composites. Composites are fabricated using simple hand lay-up technique. It has been observed that there is a significant effect of surface treatment of fiber on the mechanical behavior of composites. Finally, the morphology of fractured surfaces is examined using scanning electron microscopy (SEM).

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CHAPTER 1

INTRODUCTION

1.1 Introduction and Background

Engineering materials establish the foundation of technology whether the technology is applied in structural, thermal, electronic, electrochemical, biomedical or other applications. The history of human civilization is characterized by different ages and the age is marked by certain materials. The iron age brought tools, the steel age brought rails, and the space age brought the even more advanced materials i.e. composite materials that are both strong and lightweight. The composite materials are successfully replacing the traditional materials due to lightweight, high tensile strength at elevated temperature and high toughness when the strength requirement is more. The definition of composite is: "Composite materials are multi-phase materials obtained by artificial combination of different materials, so as to attain properties that the individual components by themselves cannot attain" [1]. The primary phase of composite having continuous nature is called matrix and the discontinuous phase are called reinforcement. The matrix is less hard and more ductile but the reinforcement is tougher than matrix and it gives the strengths of composites so that the overall mechanical behavior increases. In general the composites are classified into following categories according to their matrix material [2].

- Metal-Matrix composites
- Ceramic-Matrix composites
- Polymer-Matrix composites

Metal Matrix Composites (MMCs):

The basic elements of metal reinforced with hard ceramic particles or fibers are better-quality stiffness, high hardness, wear and abrasive resistance, good strength, combined with the possibility of higher operating temperatures than for the unreinforced metal. The main application of MMCs are aerospace, automobile (piston crowns), electrical (superconductor, electrodes) etc.

Ceramic-Matrix Composites (CMCs):

Under the heading of "ceramics", are technical ceramics such as alumina and silicon nitride, carbon, glass-ceramics and glasses. The CMCs have high strength and stiffness but were brittle in nature. Thus the main objective is to increase the toughness. The processing is more complicated, therefore the improvement in toughness is associated with an extra cost burden. CMCs development has lagged behind other composites such as polymer matrix composites and metal matrix composites for main two reasons; firstly it required high temperature for processing. It follows that it was not until fibers and whiskers of high temperature ceramics, such as silicon carbide. And the second problem is that monolithic ceramic is that they maintain their properties of high temperature and this characteristic is only retained in CMCs. The main applications of CMCs are Aerospace (after burners, brakes, heat shields, rocket nozzle), automobile brakes, medical (prostheses, fixation plates), manufacturing (thermal insulation, cutting tools, wire drawing die).

Polymer matrix composites (PMCs):

The more commonly used composite is polymer matrix composite. Polymer matrix composites are more commonly used due to following reasons: polymer matrix composites are much easier to fabricate than metal matrix and ceramic matrix composites. This is because of the relative low processing temperature and pressure required for fabricating polymer matrix composites. For above two reasons the polymer matrix composites are developing faster and are soon becoming popular in many structural applications. The two main categories of polymer matrix are the thermoset and thermoplastic. The thermosets are epoxy, phenolic and furfuryl resin. They are the materials which undergo a curing process during fabrication after they are rigid and cannot be re-formed. The processing temperature ranges from room temperature to 200° C. For thermoplastics such as polyimide (PI), polythersulfone (PES), polytherimede (PEI), and polyphenyl sulfide (PPS) that can be repeatedly softened and re-formed by application of heat. The processing temperature ranges from 300°C to 400°C. Thermosets resin hardens gradually owing to the completion of polymerization and the associated cross-links of the polymer molecules. Among them, thermosets, especially epoxies are the most widely used matrix due to many advantages such as good mechanical properties, good electrical insulating, good adhesive in nature etc. Thermoplastic have recently become important because of their greater ductility and processing speed compared to thermosets, and recent availability of thermoplastics that can be withstand high temperature.

According to reinforcement composites materials are synthetic and natural. Synthetic fiber is made by human beings. Synthetics are also known as man-made fibers such as glass, carbon, aramid etc. Recently, natural fibers as reinforcement in polymer composites have drew the attention of researchers because of their many advantages. These fibers are low-cost fibers with low density and high specific properties which are comparable to those of man-made fibers used as reinforcements. Unlike other synthetic fibers, natural fibers are readily available, nonabrasive in nature and biodegradable. Natural fibers are also non-uniform with irregular cross sections, which making their structures much different and quite unique from synthetic fibers.

These fibers can be divided into three groups based on their origin, i.e. vegetable/plant fibers (hemp, flax, sisal etc.), animal/protein fibers (wool, hair, silk etc.) and mineral fibres (asbestos). Plant fibers are renewable with good mechanical properties, which justify their use as reinforcement for polymers. Plant fibers are composites consisting of cellulose fibers in an amorphous matrix of hemicellulose and lignin. The compositions of some commonly used natural fibers are shown in Table 1.1.

Table 1.1 The chemical composition of natural fibers [3]

Fiber	Cellulose (Wt%)	Hemicelluloses (Wt%)	Lignin (Wt%)	Pectin (Wt%)	Moisture content (Wt%)	Waxes (Wt%)
Banana	63-64	10	5	-	10-12	-
Bamboo	60.8	0.5	32	-	-	-
Coir	32-43	0.15-0.25	40-45	3-4	8	-
Cotton	85-90	5.7	-	0-1	7.85-8.5	0.6
Fax	71	18.6-20.6	2.2	2.3	8-12	1.7
Hemp	70-74	17.9-22.4	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
Sisal	66-78	10-14	10-14	10	10-22	2

Among various natural fibers, jute is considered as one of the most potential reinforcement for polymer composites due to many advantages such as its easy availability, its production cost is very low and its satisfactory mechanical properties as compared to others fibers. Due to incompatibility between polymer and fiber it is more to likely form unwanted substances during processing and the poor resistance to moisture, reduce the use of the natural fibers as reinforcements in polymer. Attempts have been made in this research work to study the effect of surface treatment on the mechanical behavior of jute fiber reinforced epoxy composites.

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CHAPTER 2

LITERATURE SURVEY

The composite materials are successfully replacing the traditional materials due to lightweight, easy handle, renewable resources, nontoxic, high tensile strength. The study on natural fiber has already been reported by many researchers. It has been reported from some investigation the difference in coconut coir ages that lead to different chemical characteristics in the fiber and water content [4]. So many investigations have been done to the natural fiber as reinforcement for composites. The variation in experimental data has been found due to different processing condition [5]. The main reason for this is due to irregular characteristics of natural fibers. On the other side natural fibers are hydrophilic and many thermoplastics are hydrophobic in nature. Most of the drawbacks can be compensated by the use of surface modification [6]. Mechanical properties of composites depend on the fiber loading, fiber orientation, fiber-matrix adhesion and fiber length. Therefore it needs to improve fiber properties as well as matrix properties so that mechanical properties of composites increase [7]. A number of investigations have been performed on different types of natural fibers such as jute, flax, hemp, bamboo, and kenaf to study the effect of these fibers on the mechanical properties of composite materials [8]. It has been reported from the some study that the mechanical properties of the composites get better with increment interfacial strength. Surface structures of jute with treated and untreated fiber in SEM micrographs shows that untreated fiber composites are smoother due to cementing made up of fats, lignin, and wax. Treated fiber composites show groovy surface due to the removal of cementing [6]. It has been investigated on date palm fiber (DPF) that treated fiber reinforced composite has higher tensile strength and Young's modulus as compared to untreated date palm fiber [9]. Optimum NaoH concentration was 1% which increases the tensile strength by 300% compared to untreated date palm fiber and when NaoH concentration was high, it has been found that the solution attacks the main components of the fiber and so the strength decreases [9]. It has also been reported that natural fiber composite absorbs more water compared to glass fiber composites [10]. It has also been reported that the natural fibers such as jute, hemp, bamboo, etc. their composition varies depending on the harvesting area and agricultural situation [11]. It has also reported that treated jute fibers with up to 28% NaOH , resulted an increase in tensile strength of 120% [12]. Experimental investigation has been done on the banana fiber and it is found that 1% NaOH treated fiber reinforced composites behaves superiorly than other treated and untreated fiber composite [13]. It was also reported that after 2% alkali treatment, the coir fiber polyester composites showed 15% increment in tensile strength [14]. The experimental results shows that, on Alfa fiber when it was treated with 10% NaOH for 10 hr., the flexural strength and flexural modulus increased from 23 Mpa to 57 Mpa and from 1.16 to 3.04 GPa. One the same time when Alfa fiber was treated with 5% NaoH for 48 hr. the flexural properties of composites decreased [15]. Other studies have also shown how various methods such as alkali, silane and peroxide treatments affect the properties of natural fibers. Out of these above methods, it has been observed that one of the simplest, most efficient forms of treatments with least environmental effect is an alkali treatment, particularly mercerization using NaOH [16].

2.1 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 jute fiber reinforced epoxy composites.
2. Evaluation of mechanical properties such as tensile strength, flexural strength, inter-laminar shear strength and micro-hardness of composites.
3. To study the influence of chemical treatments (alkali treatment) on mechanical behavior of composites.
4. To study the fracture surface morphology using SEM.

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CHAPTER 3

MATERIALS AND METHODS

3.1Composite 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. Jute fibers were cleaned and dipped in 1 and 2% NaOH solution for 3, 6 and 9 hours at room temperature. After this, the fibers were filtered and thoroughly washed with distilled water and subsequently neutralized with acetic acid. Finally the NaOH treated fibers were dried in an oven at 80°C for 3 hours. The epoxy resin (LY556) and corresponding hardener (HY951) is mixed in a ratio of 10:1 by weight percentage. 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. Three sets of composites were fabricated using simple hand lay-up technique such as:

- Composites with treated fibers (treatment with 1% sodium hydroxide (NaoH) solution for different hours i.e. 3hr, 6hr and 9hr respectively)
- Composites with treated fibers (treatment with 2% sodium hydroxide (NaoH) solution for different hours i.e. 3hr, 6hr and 9hr respectively)
- Untreated composites

3.2 Mechanical testing of composites

The tensile test was performed on all the three samples as per ASTM D3039-76 test standards. Generally the tensile test is performed on flat specimens. A uni-axial load is applied through the ends. 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 3.1) 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 surface of the composites after tensile test was 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 NaOH concentration (1% and 2%) and different treatment time (3, 6, 9 hours) under this investigation are presented in Table 4.1

Table 4.1 Mechanical properties of the composites

Concentration % of NaOH	Time in hours	Tensile strength(Mpa)	Tensile modulus(Gpa)	Flexural strength(Mpa)	Inter-laminar strength(Mpa)	Micro-Hardness (H_v)
untreated	0	29.76	2.722	66.21	1.83	15.3
1% concentration	3	32.78	3.065	70.4	2.93	18.6
	6	35.56	3.729	80.42	3.15	18.8
	9	34.76	3.298	73.01	3.05	19.2
2% concentration	3	31.6	2.946	69.1	2.239	18.9
	6	34.77	3.375	79.34	2.83	21.4
	9	34.26	3.13	68.53	2.73	20.5

4.1.1 Effect of % concentration of NaOH and time on hardness of composites

Figure 4.1 shows the effect of surface treatment on hardness of composites. It is found that the composite reinforced with treated fiber has better hardness value compared to untreated fiber reinforced composites. Optimum value is obtained for composites with treated fibers at 2% NaOH for 6 hour may be due to the fact that when treatment is done on the fibers, cementing material is removed so that adhesiveness properties increases which leads to the increase in hardness value

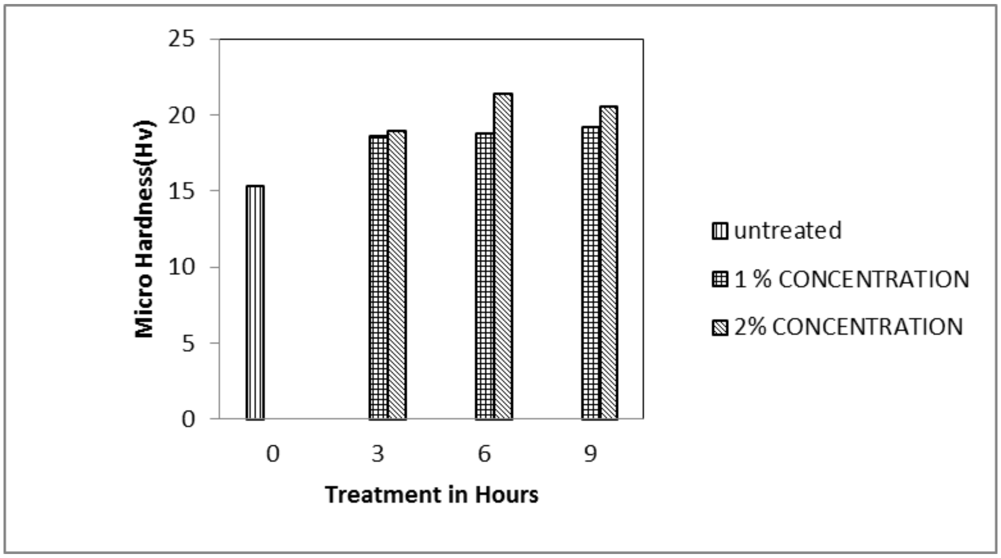

Figure 4.1 Effect of % concentration of NaOH and time on hardness of composites

4.1.2 Effect of % concentration of NaOH and time on tensile properties of composites

Tensile strength and tensile modulus are the most important properties of any material. The effect of surface treatment on the tensile strength and tensile modulus of compotes are shown in Figure 4.2 and 4.3 respectively. From the figures, it is evident that the both tensile strength and tensile modulus of composites with treated fibers is increasing as compared to untreated one. As far as effect of time is concerned, the value increases up to 6hours, however further increase in time the value decreases. The maximum tensile strength and tensile modulus is observed in case of composites with 1% NaOH treated fiber. The increase in tensile properties in case of treated fiber is may be due to the structural transformation of fiber from cellulose-I to cellulose-II. Therefore at 1% NaOH gives the better compatibility and adhesiveness. Further increase in the NaOH concentration decreases the tensile properties, may be due to the fiber surface gets damaged by NaOH [13].

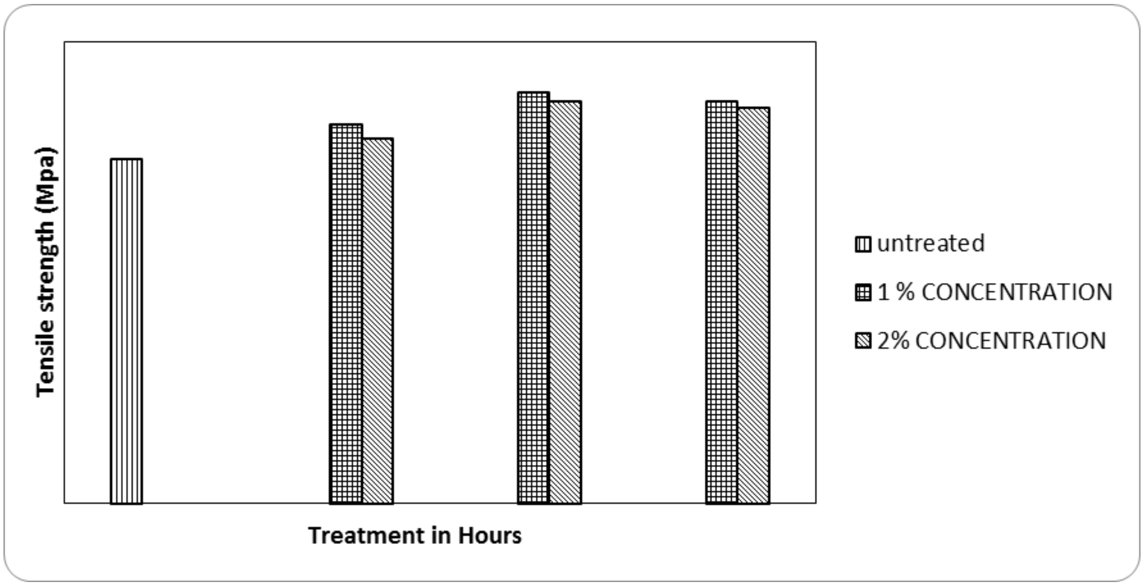

Figure 4.2 Effect of % concentration of NaOH and time on tensile strength of composites

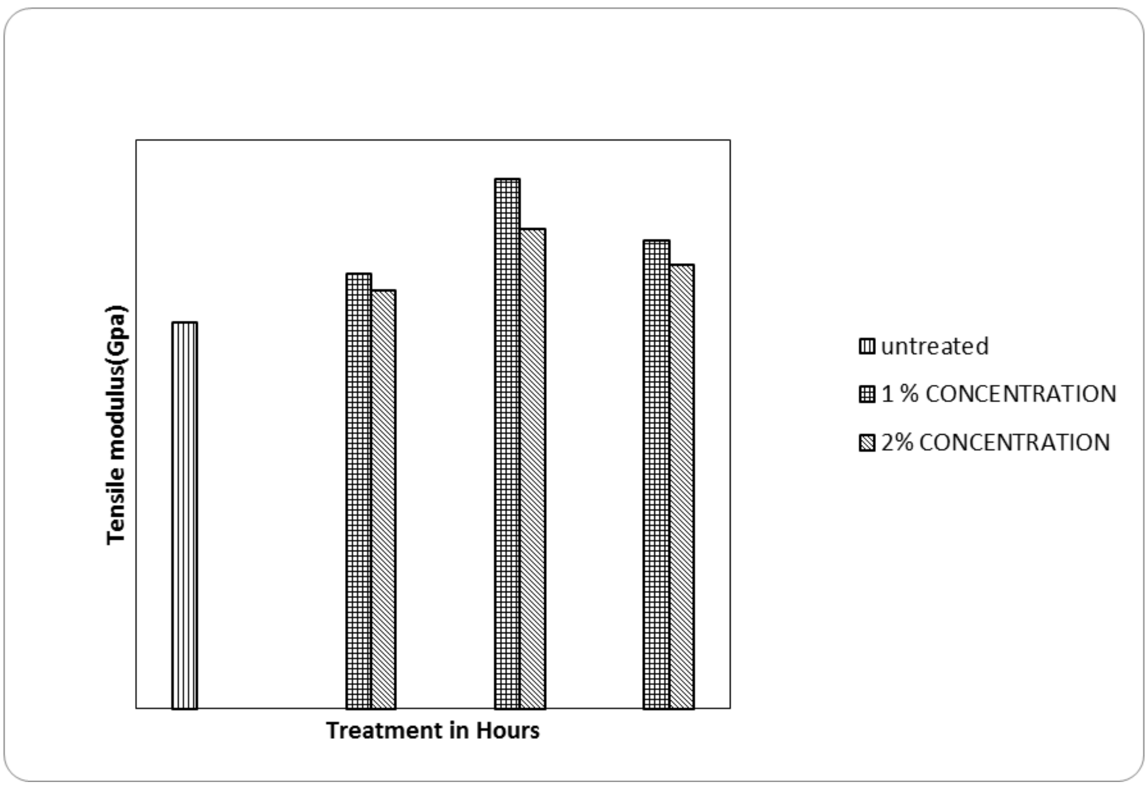

Figure 4.3 Effect of % concentration of NaOH and time on tensile modulus of composites

4.1.3 Effect of % concentration of NaOH and time on flexural strength of composites

Flexural strength is one of the most important properties of materials. The effect of surface treatment on the flexural strength of composites is shown in Figure 4.4. It is clearly seen in the figure that the flexural strength is increasing from the untreated fiber composite to the treated fiber composite. Untreated fiber composite having flexural strength 66.21Mpa, treated with 1% and 2% NaOH for 3 and 6hr is increasing and then decreasing. Optimum value is obtained at 1% NaOH concentration for 6 hours and it is found 80.42 Mpa. It is found that when the NaOH concentration is higher, NaOH direct attacks the main components of the fiber so the fiber get damaged due to that reason the flexural strength of the fiber decreases [9]. Fiber breakage is due to higher brittleness; so that it could not be able to transfer the effective stress resulted in lower strength of composite [17].

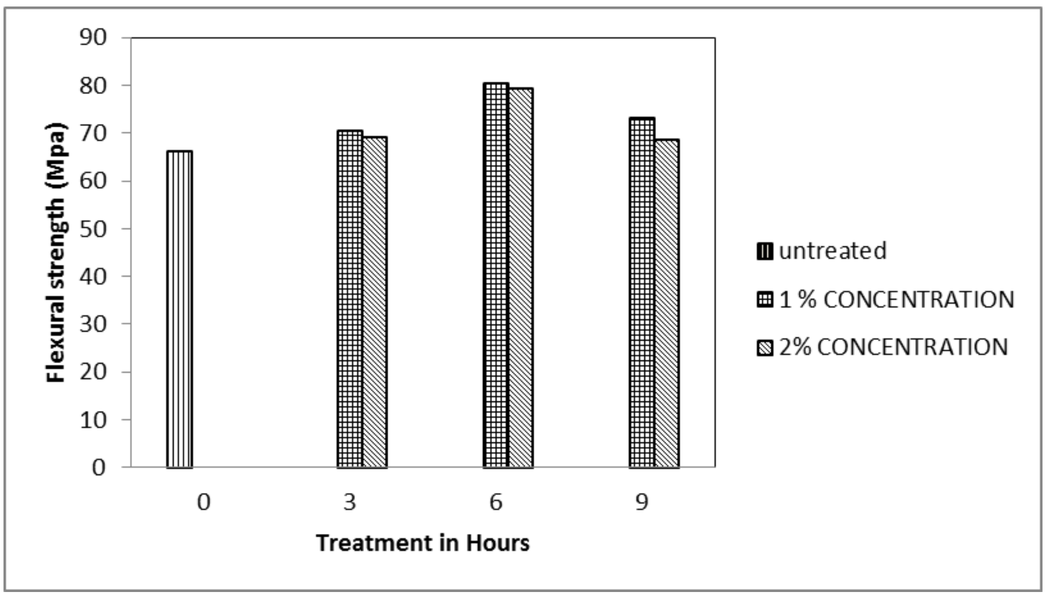

Figure 4.4 Effect of % concentration of NaOH and time on flexural strength of composites

4.1.4 Effect of % concentration of NaOH and time on inter-laminar shear strength of composites

Figure 4.5 shows the effect of surface treatment on inter-laminar shear strength of composites. The result shows that the treated fiber is having better inter-laminar shear strength compared to the untreated jute fiber composite. Untreated jute fiber composite having inter-laminar shear strength value of 1.83 Mpa. The optimum inter-laminar shear strength value is obtained as 3.15 Mpa for 1% NaOH for 6 hours.

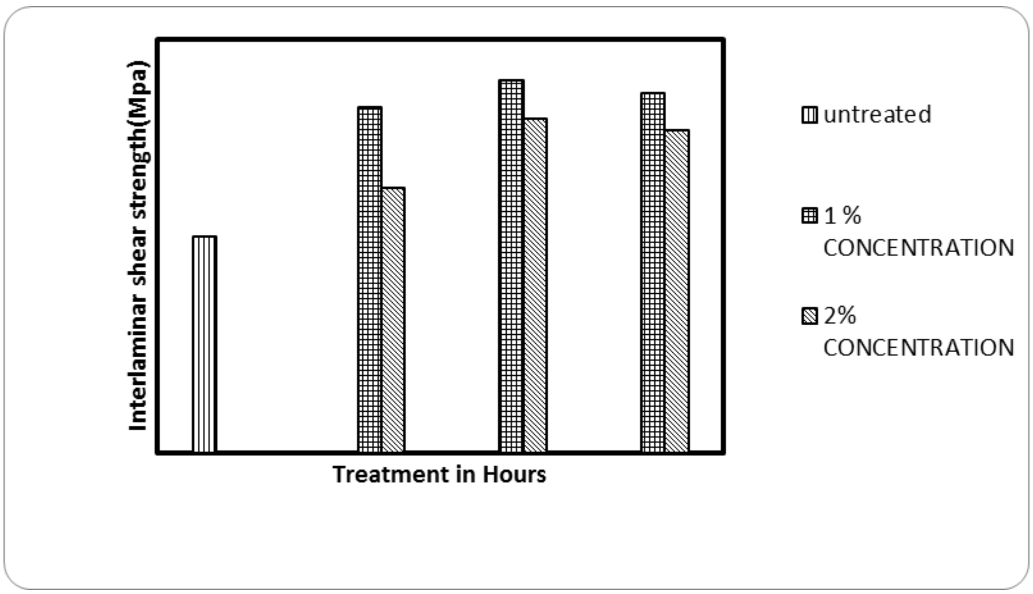

Figure 4.5 Effect of % concentration of NaOH and time on inter-laminar shear strength of composites

4.2 Surface morphology of the composites

Figure 4.6 a-b shows the fracture surfaces of jute fiber reinforced epoxy composite after the tensile test with treated and untreated fibers. Figure 4.6a shows the tensile fracture of composite specimen at 20wt% fiber loading and without treatment of fibers. 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 with alkali treatment of fibers shows the smooth surface indicating that the better compatibility between fibers and epoxy matrices as shown in Figure 4.6b.

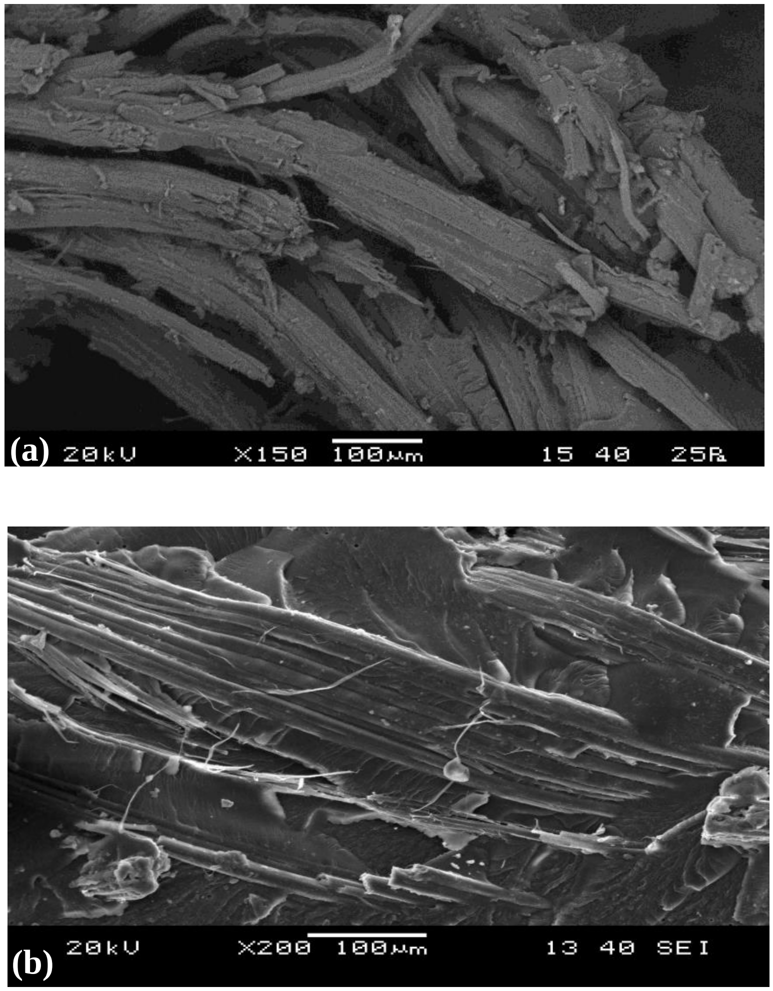

Figure 4.6 Scanning electron micrographs of jute fiber reinforced epoxy composite specimens after tensile testing with treated and untreated fibers

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CHAPTER 5

CONCLUSIONS

The experimental investigation on the effect of surface treatment on mechanical of jute fiber reinforced epoxy composites leads to the following conclusions obtained from this study are as follows:

1. Successfully untreated and treated types of composites were prepared with different NaOH concentration.
2. From the results it has been concluded that the surface treatment has significant effect on the mechanical behavior of composites. The tensile strength, tensile modulus, inter-laminar shear strength, flexural strength and micro-hardness value is maximum in composites with treated fibers for 6 hours irrespective of NaOH concentration. Similarly, composites reinforced with treated fibers at 1% concentration of NaOH shows better mechanical properties as compared to composites with treated fibers at 2% concentration of NaOH irrespective of time. The mechanical properties of treated fiber based composites are good as compared to untreated one.
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 for untreated composites the poor interfacial bonding is responsible for low mechanical properties and increase in mechanical properties of composites at 1% concentration of NaOH is due to the better interfacial bonding between fiber and matrix.

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 treatments on fibers and evaluation of their various properties and the experimental results can be similarly analyzed.

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