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Experimental Evaluation of Tensile Strength and Young's Modulus of Woven Jute fiber and Polyurethane Composite

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Abstract: Natural fiber reinforced composites (NFRCs) are increasingly used in a variety of commercial applications, but there has been little theoretical, micromechanical modeling of structure/property relationships in these materials. These can't be met by conventional metal alloys. The scope of possible uses of natural fibers is enormous.Plenty of research work is done on natural fiber composites. But, woven jute fiber and bio based polyurethane resin matrix is not used extensively for research studies. Mostly mathematical model is used to investigate and predict the properties and fiber loads effect on mechanical properties. The combination of jute fiber with PU produced the material that is competitive to synthetic composites. Literature review shows that composite made of combination of these constituents is not studied mechanically in order to evaluate its properties. The present paper focus is on the experimental analysis and testing of untreated woven jute fiber and PUR composite. The tensile properties of natural fiber reinforced composites (NFRCs) are modeled experimental method.

Keywords— Jute Fiber, NFRCs, PUR, Tensile strength, Young's Modulus

I. Introduction

Biocomposite is the composite having natural fiber and bio based resin matrix as its constituents. One of the limitations of biocomposites is the difficulty to predict the mechanical behavior due to the interface conditions between the natural fibers and the polymeric matrices. Mechanical properties of natural fibers, especially flax, hemp, jute and sisal, are very good and may compete with glass fiber in tensile strength and modulus. A number of mechanical and experimental investigations have been conducted on several types of natural fibers such as kenaf, hemp, flax, bamboo, and jute to study the effect of these fibers on the mechanical properties of composite materials. The elastic and tensile properties of NFRC can be experimentally determined or derived from a variety of mathematical models [1].

In some cases, fiber aspect ratio, fiber volume fraction and fiber orientation are also included. The mechanical properties of a natural fiber-reinforced composite depend on many parameters, such as fiber strength, modulus, fiber content ,fiber length and orientation, in addition to the fiber-matrix interfacial bond strength. A strong fiber-matrix interface bond is critical for high mechanical properties of composites [2].

Avtar Singh et al. studied mechanical properties of Hybrid Natural Fiber Composite. Samples of several Jute-Bagasse-Epoxy & Jute-Lantana camara-Epoxy hybrids have been manufactured using hand layup method were kept at 40%-60%. With increase of fiber loading capacity by 20%, the flexural strength value increases to 155.5MPa for Jute-bagasse and 310.9MPa for jute-lantana camara. The tensile strength of epoxy is 62-72 MPa with 3-4 % elongation and with increase of fiber loading capacity by 20 % the tensile strength increases.

Vasanta V. Cholachagudda et al., have been chosen coir fiber as the major reinforcement and rice husk as an additional fiber to improve the mechanical property of polymer composite with vinyl ester as the base material prepared by hand layup process according to ASTM standards. Test specimens are prepared with different weight fractions of coir fiber at the optimization point of tensile test a small percentage of rice husks are added and tests are conducted and the improvement in mechanical properties.

M. Mohamed et al., presented stiffness load carrying capacity of composite with thermoset polyurethane resin system as a matrix.

This paper outlines some of the mechanical properties of natural fiber based polymer composites with special emphasis is on woven fiber reinforced bio- based polymer composites. This work is related to the experimental analysis and mechanical characterization of untreated woven jute fiber and polyurethane resin (PUR) composite.

Literature review shows that composite made of combination of jute fiber and bio based polyurethane resin matrix is often studied up to research extent. Presently, limited literature is available on the evaluation of mechanical properties of jute fiber and polyurethane composites. This paper outlines some of the mechanical properties of natural fiber based polymer composites with special emphasis is on woven fiber reinforced bio- based polymer composites.

The present paper focuses on the experimental analysis and testing of untreated woven jute fiber and PUR composite. In this article we have chosen jute fiber as the fiber material to improve the mechanical properties of polymer composite with polyurethane as the base material prepared by hand layup process according to ASTM standards. Test specimens are prepared with different weight fractions of fiber and the improvement in mechanical properties (tensile strength and tensile modulus) of the bio based composite material is observed.

This work is related to the experimental analysis and mechanical characterization of untreated woven jute fiber and polyurethane resin (PUR) composite.

II. Materials and Processing

A. Materials

The materials used in the present research work are tabulated in TABLE I with their properties.

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TABLE I Specifications of the Materials [4,5]

Materials	Specifications
Jute Fiber	Fiber density:1.46 g/cc Single fiber length:120-150 mm Tensile strength: 393-800 MPa
Polyurethane Resin (Urecast 70)	Density: 1.300 ± 0.500 g/cc Viscosity at 27°C : 5000 ± 500 mPa.s Curing time for Optimum properties : 6 hrs at RT and post cure at 80-90 ° C – 4 hrs or 4-5 days at RT Flexural strength: 360-370 kg/ cm^2 Modulus (E): 4500 N / mm^2 Impact strength notched : 2.6-3.0 kg/ cm^2 Deflection at Break: 4.0mm Adhesive Strength: 155 kg /cm^2
Hardener PU (from supplier)	Density: 1.220 ± 0.100 g/cc Viscosity: 300 ± 100 mPa.s

B.Processing of Woven jute/Polyurethane Composite

First make some sample preparation calculation before preparing the woven jute fiber and PUR composite. Firstly Mould releasing agent is applied on inner surface of both mould plates. A rectangular mould of size 600x150x3mm is used for manufacturing of composite laminate. The calculated amount of resin with thoroughly mixed promoters, accelerators and hardener (PU resin: PU Hardener, 100:25 % by weight) and after 5-10 minutes it is made ready for pouring into mould with fibers. Resin is applied by using brush on the lower plate of mould. Woven fiber layer is then kept over resin layer. As per thickness required, number of layers is evaluated and alternatively fiber layers and resin are arranged. At last upper mould plate is kept over lower one and pressure is applied by fixed using C-clamps and bolts. It is then heated in a furnace at 60^0 for an hour. The setup for 24 hours to complete cure the laminate and once the laminate is completely cured then it's ready for machining according to ASTM standard for testing, repeat the procedure by adding 32%, 44%, 50%, 55% wt of jute fiber to the resin[447,5].

Fig. 2 (a) Composite laminate

Fig. 2 (b) Tensile test specimen for tensile test

C. Sample Preparation

Composite laminates of 150 mm X 300 mm X 3 mm have been fabricated and specimens are prepared according to ASTM standards for mechanical testing. In this work following standards are used-

TABLE II ASTM Standards used for specimens

Sr. No.	Standards	Mechanical Property
1	ASTM D 638-03	Tensile strength
2	ASTM E 111 04	Young's Modulus

1) Density of PU (δ) = 1.35 g/cm^3

2) Volume of the mould (V) = 600x150x3mm
= 270000 mm^3= 270 cm^3

3) Mass of resin (m) =Volume of mould x Density of PUR
= 270 x1.35 = 364.5g ≈ 365g.

TABLE III Samples Preparation Calculation for Woven Jute/PUR Composite

Samples	% wt of Jute	% of PUR resin Matrix	Mass of jute fiber (g)	Mass of PUR resin (g)	Total Mass (g)
A	0	100	0	250	250
B	30	70	75	175	250
C	42	58	105	140	250
D	48	42	120	125	250
E	51	49	127.5	122.5	250
F	53	47	132.5	117.5	250
G	54	46	135	115	250

The above samples are tested for investigation of tensile strength and tensile modulus (modulus of elasticity or Young's Modulus) as per ASTM standards.

III. Mechanical Characterization

Tensile test is carried on Woven Jute fiber and Polyurethane composite to elastic constant using Universal Testing Machine (UTM). UTM is used for the measurement of loads and the associated test specimen deflections such as those encountered in tensile, compression or flexural modes. Load cells and extensometers are used to measure the key parameters of force and deformation. The universal testing machine is shown in Fig.3 (a)

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TABLE IV Universal Testing Machine Specifications

UTM specification	
Load Cell	9800N.
Temperature	25 ºC
Speed	10 mm/min
Pre Tension Load	0 N
Gauge Length	50mm

A.Ultimate Tensile Strength

Ultimate tensile strength, often referred to tensile strength is the maximum stress that a material can withstand while being stretched or pulled before fracture. The tensile tests have been carried out for the specimens.

The specimens of size 200 mm x19 mm x 3mm have been tested with a span length of 200 mm in tensile mode at a cross head speed of 10 mm / min. Instantaneous values for load, deflection, and stress and strain have been recorded.

Fig.3 (a) Universal Testing Machine

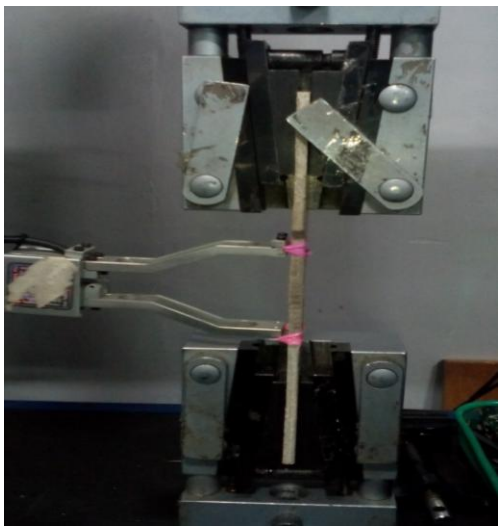

Fig.3 (b) Strain gauge mounted on specimen

IV. **Results and Discussion**

All the test results are tabulated in TABLE V. From these results, it has been observed that tensile properties of composite laminates rise with increase in the fiber volume fraction.

TABLE V Ultimate Tensile Strength of Woven Jute / Polyurethane Composite

Samples	**% volume fraction of Jute fiber**	**Ultimate Tensile Strength (MPa)**
A	30	19.964
B	42	33.1575
C	48	35.115
D	51	60.0525
E	53	73.885
F	54	84.605

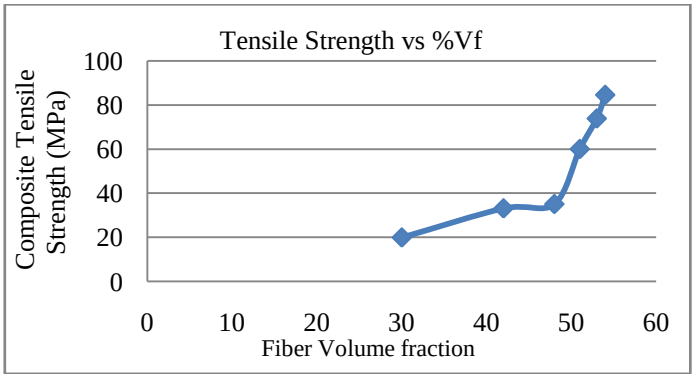

Fig.4 (b) Variation of UTS with jute fiber loading

TABLE V Young's Modulus of Woven Jute / Polyurethane Composite

Samples	**% volume fraction of jute fiber**	**Modulus of elasticity (MPa)**
A	30	1895.05
B	42	3216.095
C	48	3837.00
D	51	4200.38
E	53	4741.083
F	54	5779.685

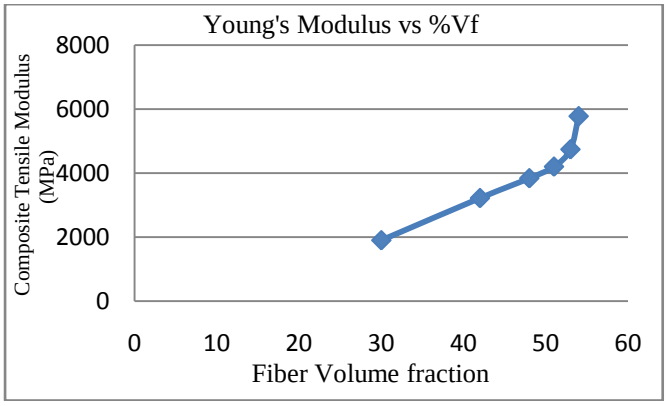

Fig.4 (c) Modulus vs Fiber volume fraction

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V. Conclusion

The experimental evaluation of mechanical properties of bio-based polymer composite laminate has been presented. Effects of change of fiber volume fraction on the behavior of laminates have been investigated. It has been observed Jute fibers and polyurethane resin matrix are having good compatibility. Jute fiber contributes for tensile strength of composite while polyurethane resin provides good elasticity to composite.

Based on the findings, the following conclusions can be made.
1. With the addition of woven jute fiber in matrix, the tensile strength increases from 19.964 MPa to 33.1575 MPa.
2. There is a gradual rise in tensile strength Up to 50% of fiber loading however there is a sudden rise in tensile strength for 53% fiber volume fraction.
3. There is a gradual rise in Young's modulus up to 48% of fiber volume fraction and there is a sudden rise observed for the fiber volume fraction ranging from 51%-54%.

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