Studies on the Mechanical Properties of Jute-Sisal Fabric Composites

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***Abstract*—Natural fibers are emerging as low cost, lightweight and apparently environmentally superior alternatives to glass fibers in composites. Natural fiber composites are likely to be environmentally superior to glass fiber composites in most cases. Due to these facts, they are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling panelling, partition boards), packaging, consumer products, etc. The present work aims at learning the mechanical properties of natural fiber reinforced polymer composites such as tensile strength, flexural strength, and impact strength and free vibration analysis. Sisal and Jute composites are fabricated using hand layup technique. Specimens were cut from the fabricated laminate according to the ASTM standards for different experiments. 4% NaOH treated samples gives better ultimate tensile strength and with stand higher load as compare to untreated and 6% treated fiber. 4% of NaOH treatment samples have very good results Flexural Young's modulus, secant modulus and impact strength. Fundamental frequency of 4% chemically treated jute-sisal composite is better as compare to untreated and 6% chemical treated hybrid PVA composite. Jute-sisal hybrid composite fractures morphology was studied using Scanning electron microscope.**

Keywords*—Hybrid Composite, Jute-Sisal composite, Polyvinyl alcohol

I. INTRODUCTION

Natural fibers like flax, hemp, jute and sisal have been well recognized as good potential reinforcements for engineering fiber composites. The advantageous features of these fibers are lightweight, high specific modulus, non-toxic and easy for processing and absorbing CO_2 during their growth. These benchmarking properties open the wide area of natural fibers in the composite sector and challenge the replacement of synthetic fibers. However, natural fibers are not a problem-free alterative and they possess certain shortfalls in properties. These sustainable and eco-efficient fibers have been applied as substitutions for glass fiber and other synthetic polymer fibers for diverse engineering applications. Their remarkable advantages compared with those conventional inorganic manmade fillers enhance their commercial and research potentials. Natural fibers normally are abundantly-renewable resource so that their cost is relatively low as compared with other synthetic fibers. With the consideration of environmental consciousness, natural fibers are biodegradable so as they can alleviate the problem of massive solid wastes produced and relief the pressure of landfills if they are used for replacing other non-degradable materials for product development. Besides, according to their inherent properties, natural fibers are flexible for processing due to their less susceptible to machine tool damage and health hazards during the manufacturing and etc. Moreover, natural fibers possess many advantageous characteristics such as desirable fiber aspect ratio, low density and relatively high tensile and flexural moduli. The effects of fibre diameter, test length and test speed on the tensile strength, modulus and percentage elongation at break of sisal fibers. They concluded that no significant variation of mechanical properties with change in fibre diameter is observed but the tensile strength and percentage elongation increases with fibre length. Young's modulus and tensile strength decrease with increase in speed of testing but elongation does not show any significant variation. Effect of chemical treatment of sisal fibers and in their work it is seen that alkali treated sisal composites show superior tensile properties than untreated sisal composites. This is due to the fact that alkali treatment improves fibre surface adhesive characteristics by removing impurities there by producing rough surface [2]. Tensile properties of eco friendly jute epoxy laminate and concluded that the tensile strengths in the longitudinal directions is more and it is due to higher degree of fibre pull out in this direction, which is caused relatively higher level of fracture surface [7]. Composite materials derived from biodegradable starch polymer and jute strands. In this work it has been seen that alkali treatment greatly improves the resin pick-up or wet ability of natural fibers during composite fabrication which is mainly due to the rough surface topography of fibers [8]. They prepared composites from uniformly distributed long jute fibre (200 mm) and randomly oriented short jute fibre (10 mm) using compression moulding technique. The tensile properties for uniformly distributed long jute fibre composites were found to be higher (tested along fibre length) compared with randomly oriented short jute fibre composites [9]. Review of green composites for automotive applications seen that fibers has to be processed at low temperature i.e below 200^0C, above this limit fibers starts to degrade and shrink which results in lower performance of composite [12]. Mechanical properties of sisal jute glass fibre reinforced polyester composites and concluded that jute and sisal composite sample is capable of having maximum flexural strength with 14.22mm displacement and 3.00 KN [13]. Mechanical properties, especially interfacial performances of the composites based on natural fibers due to the poor interfacial bonding between the hydrophilic natural fibers and the hydrophobic polymer matrices. Two types of fiber surface treatment methods, namely chemical bonding and oxidization were used to improve the interfacial bonding properties of natural fiber reinforced polymeric composites. Interfacial properties were evaluated and analyzed by single fiber pull-out test and the theoretical model. The interfacial shear strength (IFSS) was obtained by the statistical parameters. The results were compared with those obtained by traditional ways. Based on this study, an improved method which could more accurately evaluate the interfacial properties between natural fiber and polymeric matrices was proposed [15].

II. MATERIALS AND METHODS

A. *Extraction of fibre*

Sisal leaves are cut from the plant manually using machetes. Cut leaves are submerged inside the water for 15-18 days where microbial decomposition of sisal leaves occurs which separates the fibre from pith. This process is called retting of fibre. The retting time must be properly chosen, under-retting makes separation difficult, and over-retting weakens the fibre. The sisal leaves are taken out from the water and they are subjected to beating action where the fibers are separated from the outer skin. The separated fibers are washed thoroughly with water to remove impurity and the surplus wastes such as chlorophyll, leaf juices and adhesive solids then the fibers are sundried to remove moisture content present in it. The fibre quality depends upon moisture content so proper drying is important. If moisture content still remains in the fibre layer it weakens the strength of the fibre. The figure 1 shows the procedure of fibre extraction where sisal leaves are cut and they are processed in the water. Then sisal leaves are passed through the machine which separates the outer covering and the fibre. The extracted fibre is dried and used for further processes.

Figure 1 Sisal leaves, Extraction Machine, Dried, Sisal fiber.

B. *Chemical Treatment of Jute-Sisal wovens.*

Sisal and Jute woven are chemically treated using 4% and 6% of NaoH solution for after 4 hours the pieces are taken out of the NaoH solution and washed thoroughly. Then the mats are sun dried for 24 hours. Figure 2 shows (a) Sisal mat treatment (b) jute mat treatment (c) Dried sisal mat (d) Dried Jute mat.

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C. *Pripration of Composite*

Hand layup technique is used to prepare laminated composite. A mould plate of 300x300 mm dimensions is used in this process and cut in to 250 x 250 mm to get better properties.

III. TESTING THE COMPOSITE

A. *Tensile Test*

Tensile test was conducted in Universal Testing Machine, R.V. College of Engineering, Bangalore, according to the ASTM standards by varying the thickness of the samples. The tensile specimens were prepared with dimensions of 100mm x 15 x 3 mm, 100mm x 15 x 5 mm and 100 mm x 15 x 7 mm for a constant feed rate of 5 mm/min and gauge of 50 mm.

B. *Flexural Test*

Flexural test was conducted in universal testing machine, Brakes India Private Limited, Nanjanagudu, Mysore according to the ASTM standards. The specimens are prepared with dimensions of 127 mm x 12.7 mm x 3 mm, 127 mm x 12.7 mm x 5 mm, and 127 mm x 12.7mm x 7 mm, 2 mm/min and maintained span of 50mm.

C. *Imapct Test*

Izod impact test is conducted on the specimens using Izod impact tester. The dimensions of the specimens were 50mm x 10 mm x 3 mm, 50mm x 10 mm x 5mm and 50mm x 10mm x 7mm. The capacity of the impact tester is up to 25 joules and release angle of the pendulum is 150^0. The specimen was placed in a vertical position. When the impact hammer is released, it strikes the specimen and the corresponding impact strength and angle is displayed digitally.

D. *Free viration*

The experimental setup used to carry out the modal analysis of sisal/jute hybrid composite laminates using impact hammer. The accelerometer is attached at the end of rectangular composite laminate with wax. The modally tuned impact hammer with sharp hardened tip is chosen for getting higher frequencies. The displacement signal from accelerometer has been recorded in personal computer through data acquisition system and ICP conditioner. Two separate adaptors are used for capturing the output signal, one for receiving accelerometer signal and the other for measuring the magnitude of the response by the hammer from laminates. The response is displayed in the monitor.

IV. RESULT AND DISCUSSION

A. Tensile Test

For 3mm thickness:

Untreated specimen having young's modules of 2060.3 N/mm^2, ultimate tensile strength 86.74 N/mm^2 and peak load 2602.21 N. Whereas for 4% treated specimen having 1223.8 N/mm^2, 99.49 N/mm^2 and 2984.8 N and 6% treated specimen have 1238.6 N/mm^2, 47.06 N/mm^2 and 1412 N.

Table 1 Tensile Test results of 3, 5 and 7 mm thickness

Specimen Thickness	NaoH treatment	Young's Modulus in N/mm^2	Ultimate tensile strength	Peak Load in N
3mm	Untreated	2060.3	86.74	2602.21
	4% treated	1223.8	99.49	2984.8
	6% treated	1238.6	47.06	1412
5mm	Untreated	2306.38	129.38	3881.6
	4% treated	1347.76	98.78	2963.7
	6% treated	1022.23	96.08	2280.70
7mm	Untreated	4472.91	220.06	6602
	4% treated	388.24	134.36	4031
	6% treated	3266.24	48.66	1460

For 5mm thickness:

Untreated specimen having young's modules of 2306.38N/mm2, ultimate tensile strength 129.38N/mm2 and peak load 3881.6N. Whereas for 4% treated specimen having 1347.76N/mm2, 98.78N/mm2 and 2963.7N and 6% treated specimen have 1022.23N/mm2, 96.08N/mm2 and 2280.70N.

For 7mm thickness:

Untreated specimen having young's modules of 4472.91N/mm^2, ultimate tensile strength 220.06N/mm^2 and peak load 6602N. Whereas for 4% treated specimen having 388.24 N/mm^2, 134.6N/mm^2 and 4031N and 6% treated specimen have 3266.24N/ mm^2, 48.66N /mm^2 and 1460N.

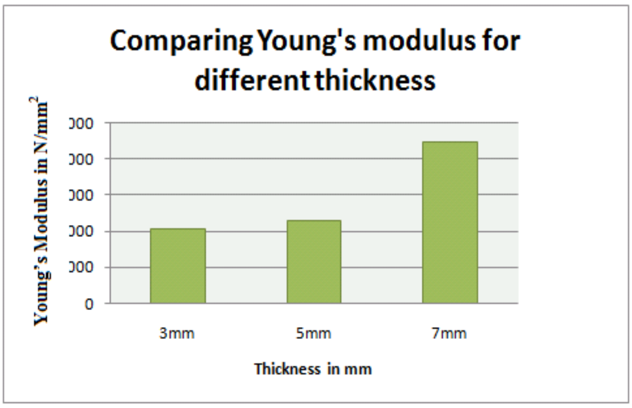

Fig 3 Tensile test graph of untreated specimens

From the graph 3 it can be concluded that young's modulus increases with increase in thickness in case of untreated specimens.

B.Flexural Test

Flexutral test was conducted for five identical samples and average of five samples results was tabulated.

Table 2 Flexural test results of 3, 5 and 7mm thickness

Specimen Thickness	NaoH treatment	Maximum Load KN	Maximum Deflection mm	Maximum Bending stress MPa	Maximum Bendin g strain
3mm	0%	0.232	8.003	82.51	0.060
	4%	0.535	8.002	82.51	0.060
	6%	0.355	8.0025	55.88	0.0960
5mm	0%	0.46	8.0037	91.53	0.068
	4%	0.77	8.0035	347.29	0.0422
	6%	0.23	8.003	9.71	0.177
7mm	0%	1.845	8.0035	100.7	0.0575
	4%	1.91	8.003	110.21	0.041
	6%	1.44	8.002	37.65	0.10

For 3mm thickness:

4% chemically treated shows better results as compare to the untreated and 6% chemically treated samples. 4% treated specimen having Maximum Load 0.535 kN, Maximum Deflection 8.002 mm and Maximum Bending tress of 82.51 MPa for sample thickness of 3mm.

For 5mm thickness:

4% treated specimen shows better result as compared to the untreated and 6% treated Maximum Load 0.77 kN, Maximum Deflection 8.0035 mm and Maximum Bending tress of 347.29 MPa for sample thickness of 5mm.

For 7mm thickness:

4% treated specimen shows better result as compared to the untreated and 6% treated Maximum Load 0.91 kN, Maximum Deflection 8.003 mm and Maximum Bending tress of 110.21 MPa for sample thickness of 7mm.

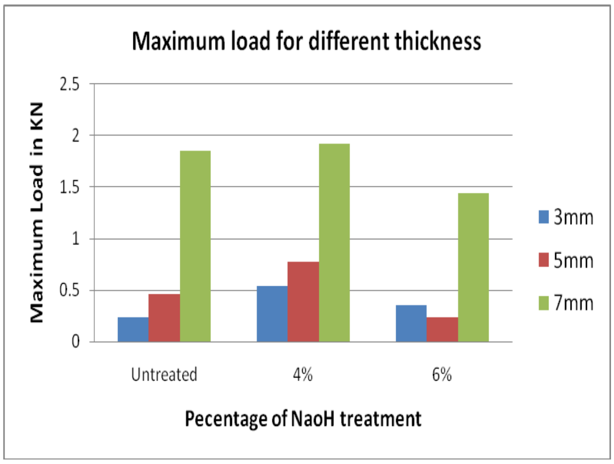

Fig 4 Maximum load capacity in bending test

From the graph 4 it can be seen that maximum load taking capacity increases with increase in thickness. Up to 4% of NaoH treatment value increases and after that maximum load decreases which is due to the removal of secondary outer and inner wall of the fibre during treatment.

C. Impact Energy

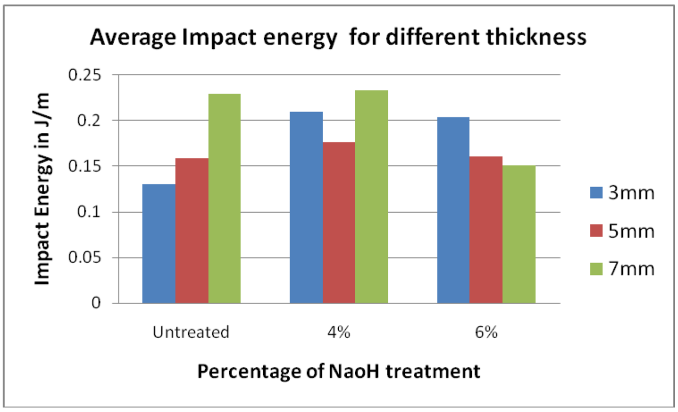

Figure 5 Impact Energy

Figure 3 it can be concluded that the impact strength of 4% treated specimens is more compared to remaining percentages of NaoH treatment. The impact strength increases with increase in percentage of NaoH treatment up to 4%. Above 4% treatment the impact strength gradually decreases. This might be due to the breaking of outer layer of fibre which is having rough structures and exhibits inner layer which is having more strength than outer rough layer.

B. Free Vibration

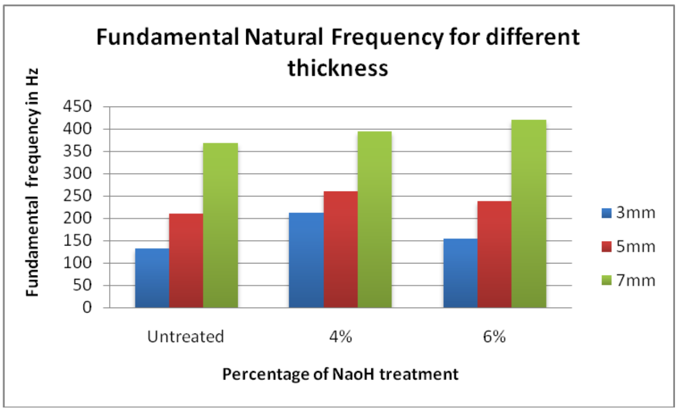

Figure 6 Fundamental Frequncy of Composite

Fundamental frequency of sisal-jute hybrid composite was tested by dividing samples in to ten divisions. From the figure 4 it was clearly observed that fundamental frequency increases with increases in thickness of the composite out of this 4% NaoH treated have better fundamental frequency then the untreated and 6% treated samples.

D. SEM Analysis

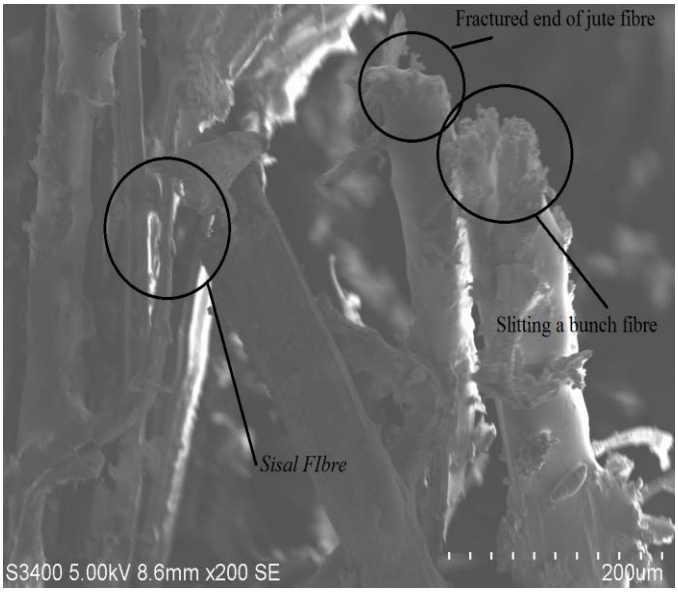

Figure 5 SEM image of Tensile Failure Untreated 3mm Sample

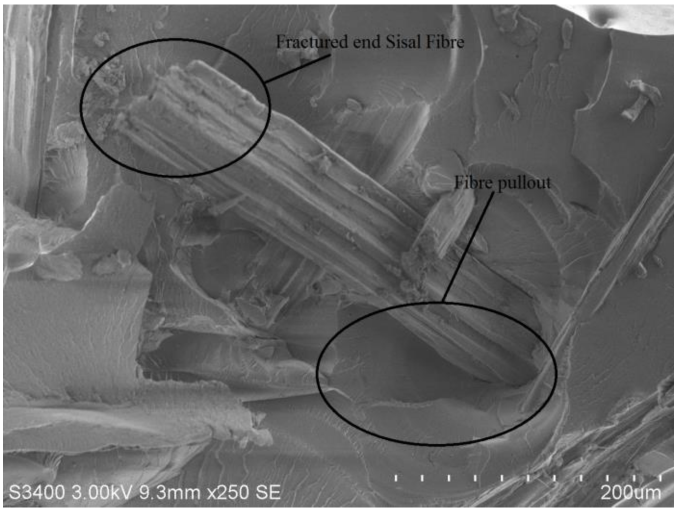

Figure 6 SEM image of Tensile Failure 6% treated 5 mm Sample

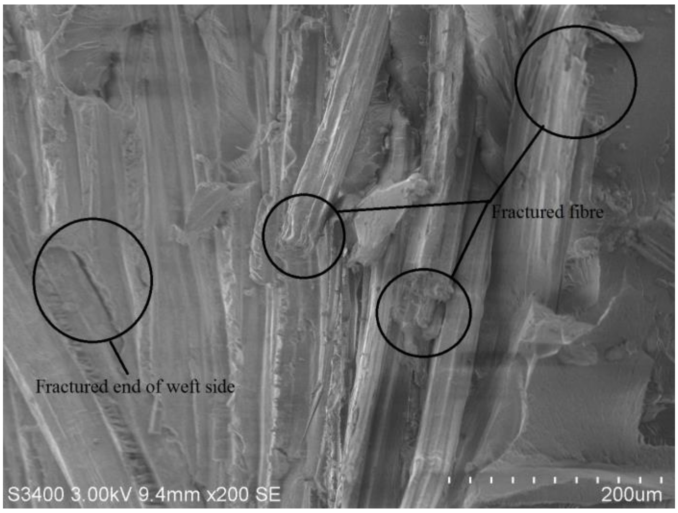

Figure 7 SEM image of Flexural Failure 6% treated 3mm Sample

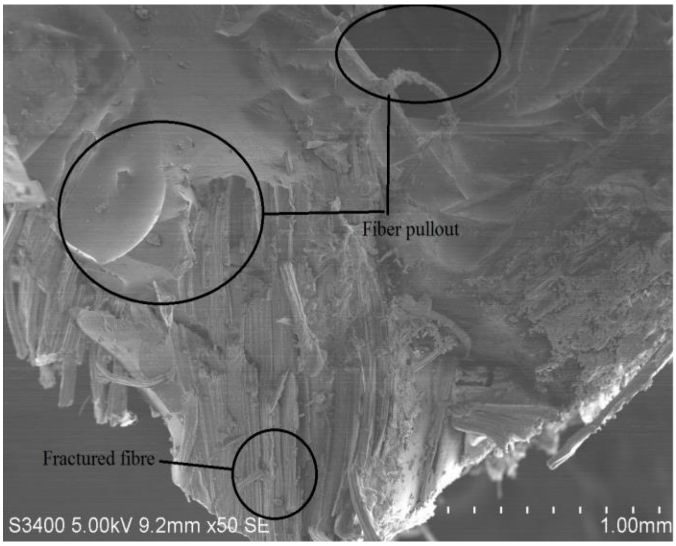

Figure 8 SEM image of Tensile Failure 4% treated 3mm Sample

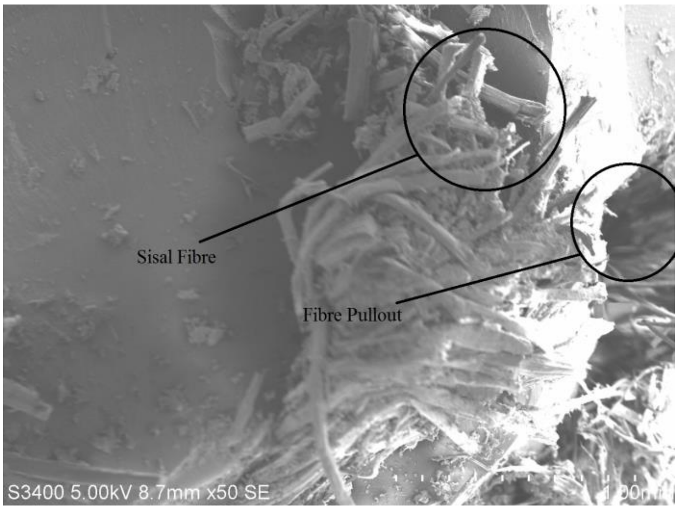

Figure 9 SEM image of Tensile Failure Untreated 7 mm Sample

Scanning electron microscopy provides an excellent technique for examining the surface morphology of composite specimens. It is expected that the surface morphology of the tensile, flexural and impact at 0%, 4% and 6% for 3, 5, 7mm samples. The small pores can act as stress concentration points, and lead to premature failure of the composites during loading. Therefore, studies of the composite surface topography provide vital information on the level of interfacial adhesion that exists between the fiber and the matrix and leads to failure because of fiber pullout.

CONCLUSION

Chemically treated Hybrid (Sisal/Jute) biodegradable composites are prepared by using hand layup technique and their mechanical properties are evaluated experimentally. From the results the following conclusions are drawn.

(a) The tensile strength increases with increase in thickness.

(b) The Young's modulus, flexural strength, elastic strength and secant modulus increases from untreated specimen to 4% treated specimen and decreases for 6% treated specimen. The 4% treated specimen exhibits excellent bending properties.

(c) The impact strength increases with the thickness of the specimen. In 3mm, 5mm and 7mm thickness specimen, 4% treated specimen has more impact strength.

(d) The natural frequency is increasing with increase in thickness of the specimen. The specimens treated with 4% NaoH of 3mm, 5mm and 7mm is having higher frequency values.

(e) Hybrid sisal-jute composites possess good damping factor.

(f) The NaoH treated specimens shows good mechanical properties up to 4% and decreases after that.

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