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FTIR Spectroscopy & Mechanical Behaviour Study on Jute Fiber Polymer Composite

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ABSTRACT

Influence of surface treatment and weaving pattern of a natural jute fiber in woven form on mechanical properties and free vibration behavior of surface treated woven fabric polymer composite has been investigated. Effect of number of layers and sequence of layers of different types of fabric also analyzed. It is found that the basket type fabric reinforced composite has consist of better dynamic and mechanical properties and its due to the uniformity in stress distribution in both directions i.e. warp and weft directions of the fabric for four layered composites. In the case of other number of layers, herringbone type fabric gives better result due to less gap between fiber yarn and tight initial physical bonding between them. After surface treatment of jute fibers with NaOH the dynamic and mechanical properties are getting enhanced. Results also reveals that the properties getting enhanced with increasing in the number of layers of natural fiber composite. FTIR results indicate that there is no triple bond functional group is available in the composite.

Keywords - Natural Fiber, Surface Treatment, FTIR Spectroscopy.

1. INTRODUCTION

From the past few years, researchers are interesting in the development of different natural fiber composites like banana fiber composite, sisal fiber composite, jute fiber composite, oil palm fiber composite, lotus fiber composite, wood reinforced composite, sugarcane fiber reinforced composite bamboo fiber composite, pineapple fiber composite, straw fiber composite etc. and researchers are also doing great work on natural fiber hybrid polymer composite as nanoclay filled hybrid composite, natural fiber PLA hybrid composite, natural glass fiber reinforced hybrid composite, etc. researchers and engineers has turned over the utilization of natural fiber composites (plant and animal fiber) as economically and effectively as possible for the production of a good quality of natural polymer composite for different uses like building, aircraft, and other needs. It is due to the high availability, environment friendly (biodegradability) and less cost of natural fiber. People have great interest on natural fiber composite because their advantages over synthetic polymer composites. As the use of natural fiber composite there is a problem of disposal of synthetic polymer composite so they increase environment bourdon as well as synthetic polymer composite has more cost then natural fiber composite. Natural fiber composite has light weight then synthetic fiber composite that due to light weight that increases the mechanical properties of composite like strength, stiffness, etc. it is beneficial in case of parts design for bending stiffness. Natural fibers are biodegradable so there is no problem of decomposition. Natural fiber composite is a renewable source and require less energy for the development of natural fiber composite so it causes less production of carbon dioxide. It makes the materials in low wages countries. In most cases natural fiber composites are better than glass fiber composites. The Natural fibers are processing friendly, no tool wear occur, no irritation to skin, thermal cycling is possible whereas glass fiber causes problem in combustion process. Natural fiber has good thermal and acoustic properties over synthetic fiber. Sometimes composites made of natural fibers are superior then synthetic fiber composites. Researchers has done some great work to identify the comparative life cycle assessment studies of glass fiber and natural fiber composites, and investigated the key drivers for relative environmental performance among them. The application of hybrid natural fiber composite for the application of car bumper made up of glass/kenaf fiber reinforced composite and focused on the mechanical behaviour of hybrid glass/kenaf epoxy composite to use as bumper in a passenger car. In case of hybrid composites, the mechanical properties get enhanced if they are fabricated using modified SMC method because the applied pressure causes strong bonds between fibers. With water absorption in glass fiber composites or unsaturated polymer composites, it has been seen that the increase in energy dissipation while decrease in storage modulus with extended storage time. It's because the matrix material and the fiber interface deteriorated by water molecules and glass transition temperature increases after immersion for matrices and it happens because soluble products would get extracted. In glassy state, bentonite help in retention of mechanical properties due to the presence of water molecules in both composites and matrices.

2. EXPERIMENTAL DETAILS

In this study, jute fiber fabrics are considered for natural fiber fabric in three different forms i.e. plane, basket and herringbone with fabric thickness between 0.8mm to 0.9mm while glass fiber fabric is considered for synthetic fiber fabric. In this work, methyl ethyl ketone peroxide (MEKP) used as a catalyst and cobalt naphthenate used as an accelerator while the matrix material taken is unsaturated isophthalic polyester resin respectively. Initially, one weight percentage of cobalt naphthenate and methyl ethyl ketone peroxide are taken and mixed uniformly with the unsaturated polyester resin in the ratio of 1:1:10 by weight ratio. In this work, the dimension of composite laminates were prepared was 300 mm ×300 mm ×3 mm with the use of a mild steel plate mould and compression moulding machine. The preparation of composites laminates and cutting has been done at atmospheric conditions. Initially it was the known calculated weight ratio of all three catalysts, accelerator and resin mixture was poured into the mould and then, the natural fiber woven mat was placed over the poured resin, then the remaining amount of resin was also poured with the help of flask over the natural fiber mat. A roller is used for uniform distribution of resin in fabric mats as well as to remove the voids present in woven fabrics. After completion of this process, 150 Kgf/cm^2 pressure has been applied at 80^{0}c temperature at a rate of 2 ^{0}c has been applied using compression moulding machine to obtain the uniform composite laminates. Single, double, three and four layered jute plain, basket and herringbone composite laminates are prepared. Tensile, Flexural and impact properties have been obtained to analyze the mechanical properties while free vibration test carried out to analyze natural frequencies and loss factors. FTIR stands for Fourier Transformation Infrared Spectroscopy and it is used to analyze the functional group in a composite material with infrared wave's absorption at particular wavelength. It is used to analyze the qualitative analysis and quantitative analysis of organic compounds both. The chemical bonds in compounds absorb the infrared (IR) energy at given specific wavelengths (frequencies). With the help of FTIR the basic structure of any compound can be obtained with the help of spectral locations of their infrared absorption frequencies. The plot between compound's infrared transmissions via frequency graph is known as its "fingerprint," which comparing to reference spectrum graph, it identifies the material. The major advantage of using FTIR spectrometer for providing better sensitivity and speed while testing with better accuracy that many times is not possible to achieve with earlier wavelength-dispersive instruments and other techniques available. This capability of FTIR spectroscopy allows rapid analysis of even micro samples to the Nano gram (Nano) level in some cases; it makes the FTIR technique unmatched for problem-solving tool in organic compound analysis.

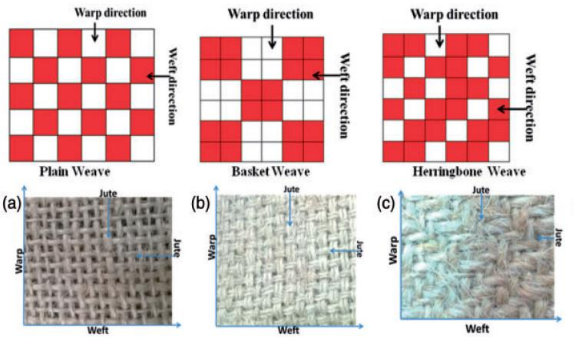

Fig. 1 a) Jute plane fabric b) Jute basket fabric c) Jute herringbone fabric

In FTIR spectroscopy technique one can generate spectra from a few Nano grams of material quickly with better accuracy and with little sample preparation because it requires samples in powder form or in the form of palates in very few quantity and produce the result in more data at lower cost. Because FTIR is an analytical technique, it requires few sample constraints for analysis. In FTIR Technique, solids, liquids and gases (three phases of matter) can be accommodated. In addition of that these are many contaminants that are present on reflective surfaces like solder pads or printed circuitry, can be readily analyzed using the FTIR microscope in reflectance mode.

3. TESTING STANDARDS

Testing standards used in this study are as per ASTM standards.

Table 1 Standards used for composite preparation

Test	Standard	Specimen Size	Testing Speed
Tensile	ASTM D-638	30cm×3cm	5mm/min
Flexural	ASTM D-790	125mm×12.7 mm	1.7 mm/min
Impact	ASTM D-256	63.5mm×12.7 mm	-
Free Vibration Test	-	170mm×17mm	-
FTIR Analysis	-	Powder form	-

4. EXPERIMENTAL RESULT AND DISCUSSIONS

Investigation carried out on tensile & flexural behavior of natural fiber woven fabric and its composite, flexural and impact properties of natural fiber fabric composite, free vibration behavior of natural fiber fabric composites are presented first. Then influence of stacking sequence of natural fiber and synthetic fiber fabrics on mechanical and free vibration properties are presented next. In between, results on influence of pre-surface treatment of natural fiber fabric also presented.

4.1. Effect of NaOH Treatment

Influence of chemical treatment time and concentration of NaOH on tensile behavior of four layered basket type woven jute fabric composite has been given below.

Table 2 Influence of chemical treatment on tensile behaviour

Treatment Time	Concentration of NaOH (%)	Tensile strength (MPa)	Tensile modulus (GPa)
30 minute	1	48±0.62	1.9±0.11
1 hour	1	49±0.6	1.9 ±0.10
30 minute	4	48.8±2.6	1.91±0.18
1 hour	4	50±1.17	1.174±0.23

From Table 2, it is evident that surface treatment with NaOH increases the value of tensile strength and tensile modulus. It is also evident that that after treatment the variation in values is not much, although the value of tensile strength is maximum for 1% with one-hour treatment but it is not much. So it can be concluded that, increase in percentage of NaOH or time does not affect the values much.

Table 3 Influence of chemical treatment on flexural behavior

Treatment Time	NaOH Concentration (%)	Flexural strength (MPa)	Flexural modulus (GPa)
30 minute	1	70.6±0.2	2.6±0.11
1 hour	1	71.7±0.6	3.2 ±0.10
30 minute	4	70±0.60	2.8±0.18
1 hour	4	95±1.17	3.99±0.23

From Table 3, it can be conclude that surface treatment improves the properties of composite materials and the maximum value has been seen in case of basket four-layer surface treatment with 4 % NaOH for one hour and that is considerably high as comparison with other ones. The value of mechanical properties is not varying much in remaining three cases namely 30 minute 1%, 30 minute 4% and 1 hour 1%. The exceptional high values come in case of 1 hour 1% concentration of NaOH is may be due to the maximum adhesion force between fiber and matrix due to increase in cellulose concentration.

In free vibration test, natural frequency of composite beam and their corresponding damping factor have analyzed. Results of Table 4 reveals that the effect of surface treatment increased the value of vibrational property of composite. The results also reveal that the effect of NaOH concentration and time duration for treatment doesn't affect the much variation in values however the basket type 4% NaOH and time duration 1 hour shows the better vibrational properties but as compare to others the variation is within 3%. The results are as follows:

4.2. FTIR Analysis for Surface Treated Basket Woven Natural Fibre Composite

From the above graphs we see that presence of peaks in the range of 650 – 2000 cm^{-1} shows the presence of single bonds of C-O, C-N and C-C in the range of 650-1500 cm^{-1} and peak present between 1500-2000 cm^{-1} shows the presence of double bonds of C=C, C=O, C=N. the presence of peak in the range of 3000 cm^{-1}

shows the presence of O-H functional group in composite. Because there is no linear slope in graph between 2500-3000 cm^{-1} , it shows that there is no triple bond functional group is available in the composite. From above figures it can be seen that for less number of layers, herringbone woven pattern has better mechanical properties and its due to its initial tightening force between woven fibres but in case of more number of layers basket woven pattern has better result and its due to the uniform load distribution in WARP and WAFT directions.

Table 4 Free vibration behaviour of treated jute woven fabric composite

Sl. No.	Time Duration	NaOH Concentration (%)	Free – Free Condition (Natural Frequency (Hertz) and Corresponding Damping Factor		
1	30 minutes	1	75.49	422.72	1387.0
			0.062	0.0548	0.04418
2	30 minutes	4	75.81	427.06	909.0
			0.0568	0.0500	0.04479
3	1 hour	1	76.55	484.78	1200
			0.068	0.066	0.0506
4	1 hour	4	77.837	494.30	806
			0.055	0.0380	0.0377

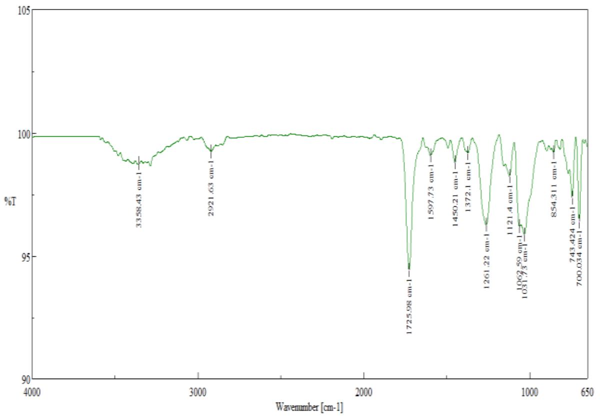

Fig. 2 basket type 1% NaOH with one-hour time duration

4.3. *Mechanical Properties*

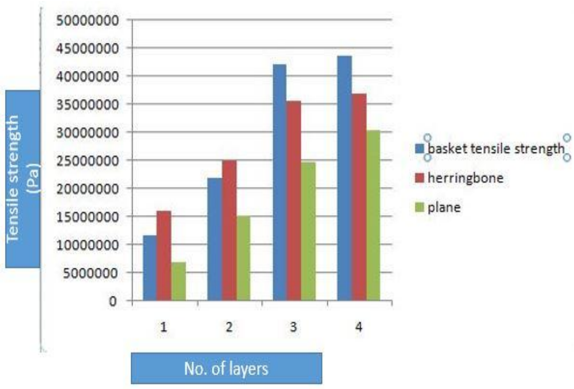

Fig. 3 Influence of number of layer on tensile strength

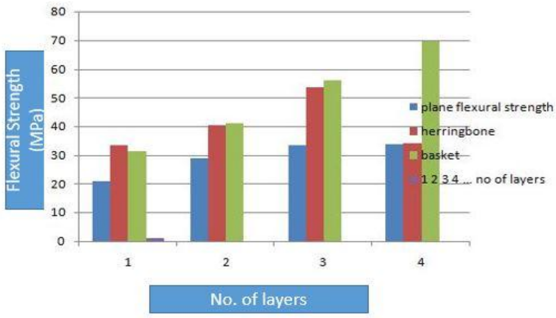

Fig. 4 Influence of number of layer on flexural strength

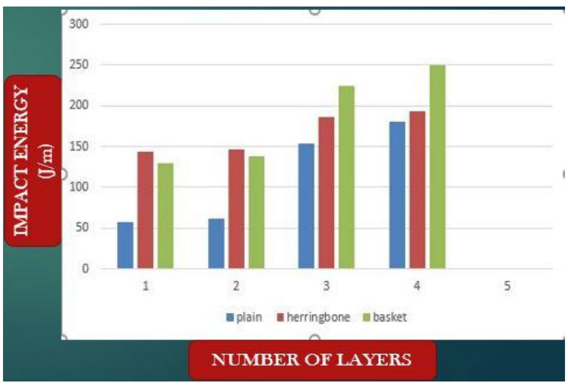

Fig. 5 Influence of number of layer on impact strength

5. CONCLUSION

From the above study it can be concluded that basket type weaving pattern can withstand more stress as compare to others due to the more uniform weaving pattern. Results for free vibration characteristics reveal that four-layer basket type showing the best result of vibration properties (natural frequency and damping factor). Herringbone type weaving pattern showing better result after basket and plain weave pattern is showing least properties. It can be concluded that on increasing the number of layers, the value of mechanical properties and vibration properties getting increased. After the surface treatment, the mechanical and vibrational properties of composite have increased but the curing time and percentage concentration doesn't affect much on these values. Plain woven fabric composite has better damping factor.

FTIR results reveal that the jute fabric composite has single bonds of C-O, C-N and C-C along with double bonds of C=C, C=O, C=N, O-H functional group in composite and there is no triple bond functional group is available in the composite. O-H functional group present in jute fiber shows the moisture absorbing characteristics of jute fiber composite.

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