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Characterization and Comparison of Natural and Synthetic Fiber Composite laminates

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Abstract:

Composites are engineered materials made from two or more constituents with different physical or chemical properties, which remain separate and distinct within the finished structure. A fiber is a material, which is made into a long filament with diameter generally in the order of 10 microns. The aspect ratio of length to diameter can be ranging from thousands to infinity in continuous fibers. Increasing worldwide environmental awareness is encouraging scientific research into the development of cheaper, more environmentally friendly and more sustainable construction and packing materials. For environment concern on synthetic fiber (such as glass, carbon, ceramic gibers etc) natural fibers (such as flax, hemp, jute, kenai) etc are widely used. Industrial hemp fiber is one of the strongest of the natural fibers available and possesses benefits such as low cost and low production energy requirements. The primary objective of this research is to fabricate the natural fiber composites with suitable processing/manufacturing methods and to examine the mechanical properties when subjected to Tension, Bending and to compare & contrast the results with the available literature. In this research work, hemp fiber reinforced Epoxy matrix composites have been developed by hand layup method with varying process parameters, such as coupling agent(with and without compatibilizers) and different fiber percentages (10%,20% and 30% by weight). The developed composites were then characterized by tensile test and flexural testing. Results show that the tensile strength and flexural properties increases with the increase in fiber percentage. However after a certain percentage the tensile strength decreases again. Compared to untreated hemp fiber, no significant changes in the tensile strength have been observed for treated hemp fiber reinforcement. The flexural strength / modulus of the composite were higher compared to pure epoxy for all filler/fiber loadings.

Keywords—***Composite material , Hemp fiber, E-glass fiber***

I. INTRODUCTION

Composite materials are new generation materials developed to meet the demands of rapid growth of technological changes of the industry. The composite materials are well known by their combination of low weight and high structural stiffness. Their inherent anisotropy allows the designer in order to achieve the desired performance requirements. Composite material system consists of two or more phases, whose mechanical performance and properties are designed to be superior to those of the constituent material acting independently. One of the phases is usually stiffer and stronger is discontinuous and is called reinforcement, whereas less stiff and weaker phase is continuous and is called matrix. The composite are classified based on the matrix materials as polymer and metal based composites. The idea of composite materials is not a recent one. Nature is full of example where in the idea of composite materials used. Since early 1960s,an increasing the demand for materials that are stiffer and stronger yet lighter in fields as aerospace, energy and civil construction. By selecting an appropriate combination of reinforcement and matrix material, manufactures can produce properties that fit the requirement for a particular structure for a particular purpose. Composite material results in a performance unattainable by the individual constituents and they offer the great advantages of flexible design. Most of efficient design an aerospace structure, an automobile, a boat or an electric motor; we can make a composite material that meets the need. Glass fiber reinforced resins have been using since 1940s. Glass fiber reinforced resins are strong and very light materials their stiffness is not very high. Composite materials are made from two or more constituents that remain distinct and separate on a macroscopic level while forming a single component. It consists of a matrix and reinforcement; matrix is a material holding the reinforcement together in position and helps in transferring the loads. Matrix materials support and surround the reinforcement materials by maintaining relative positions. Most composites had been created to improve combinations of mechanical characteristics such as strength, wear resistance, stiffness, toughness, ambient and high temperature and aesthetic properties. Reinforcement is the load bearing material and provides additional properties like impact strength, wear resistance, corrosion resistance, lubricating property damping properties to the composite. The reinforcements impart their mechanical and physical properties to enhance the matrix properties. Most commercially produced composites commonly use a polymer matrix material called a resin solution. Polymer matrix materials often called a resin solution. Polymers are polyester, vinyl ester, epoxy, phenolic, polyimide, polyamide, polypropylene, peek and others. Mud bricks one of the examples for composite materials. A cake of dried mud is easy to break by bending, which puts a tension force on edge, but makes a good strong wall. Concrete is the best example for composite for composite. Concrete, it has good strength under compression and it can be made stronger under tension by adding metal rods, wires, mesh or cables to the composite.

II. EXPERIMENTAL PROCEDURE

A. Materials and Specimen Fabrication

Two different types of laminates were fabricated by hand lay-up technique; (i) hemp fiber epoxy matrix laminates and (ii) E-Glass fiber epoxy matrix laminates. Hand lay-up technique reinforced manufacture low volume with minimum tooling cost. Fabrication process involves each layer of fabric was pre-impregnated with matrix material which is prepared by mixing general purpose LY556 resin and HY951 hardener in the weight ratio of 10:1 respectively and these layers were placed one over the other in the mould with care to maintain practically achieved tolerance on fabric alignment. Casting was cured under light pressure for 2 hours before removal from the mould [3]

III. Mechanical Test

A. Tensile Test

According to ASTM–D 3039 standard tensile test on composite specimens were carried out to determine tensile strength and modulus of elasticity for hemp FRP to observe the behavior of FRP under load. Table 3.1 the dimensions are showed and Fig.3.1 shows the test specimen in Tensile testing or tension testing, is a fundamental materials science test in which a test specimen is subjected to uniaxial tension until specimen failure. The results from the test are commonly used to select a material for quality control, and for an application, and to predict how a material will react under other types of forces. Properties that are measured in a tensile test are ultimate tensile strength, maximum elongation and reduction in area. The following properties can also be determined from these measurements: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics.

Fig.3.1 Hemp/Epoxy FRP tensile test specimen

Fig 3.2 tensile test

B. flexural test

3-Point bend flexural test is one of the simple bending tests used to determine flexural strength of a material. The basic procedure involved in conduction of 3 point bend flexural test is that sample for testing is placed on the supporting rollers of diameter 10mm; the selection of roller diameter depends upon the thickness of the test sample. Rollers of diameter 15mm, 20mm and 25mm are also available. The advantage of this test is the ease of the specimen preparation and testing. However, the disadvantages of this method: the results of the testing method are sensitive to specimen and loading geometry and strain rate. The specimens are prepared according to ASTM D790.

Fig.3.3: 3-Point Bending test

C. Free Vibration Characteristics of Hemp/Epoxy

Free vibration takes place under the action of forces a system oscillates inherent in the system itself due to initial disturbance and when the absence of externally applied forces. Free vibration system will vibrate at one or more of its natural frequencies which the dynamical system established by its mass and stiffness distribution. In this work a cantilevered rectangular symmetric plate of hemp/Epoxy fabric reinforced composite with dimension 300x300x3.05 with 11 layers of fabric for hemp/epoxy laminate with fibre direction orientation at [0/90] 11 hemp/epoxy laminate is prepared. The hemp/epoxy laminate is shown in Fig.3.4.

The experimental set up of Fast Fourier Transform (FFT) is as shown in Fig.3.5. A grid of 7x6 (42 points) measurement points were marked over the surface of the test specimen. The test specimen is clamped to test fixture and an impulse technique is used to excite the structure by impact hammer with force transducer built in to tip to get the force input. The excitation signal was feed to the analyzer through amplifier unit. A piezoelectric accelerometer stuck on the specimen senses the resulting vibration response. In the charge amplifier, the accelerometer signals were conditioned and fed to the analyzer. The analyzer in conjunction with Fast Fourier Transform (FFT) gives mathematical relation between Frequency Response Spectrum (FRS) and time and coherence functions are taken in the required frequency range. Five measurements were made at each grid point and their average was obtained. The output data of all 42 measurements was used for LABVIEW-2009 package to identify frequencies response as an input data. From the response frequencies damping factor, natural frequencies and mode shapes were obtained and animated.

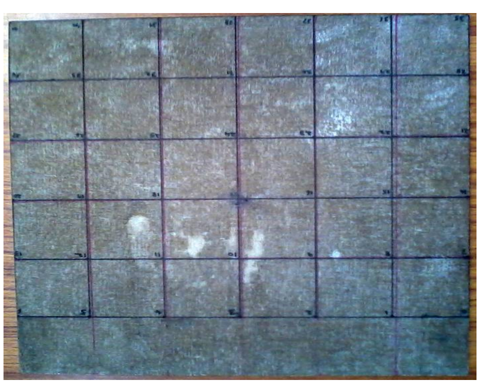
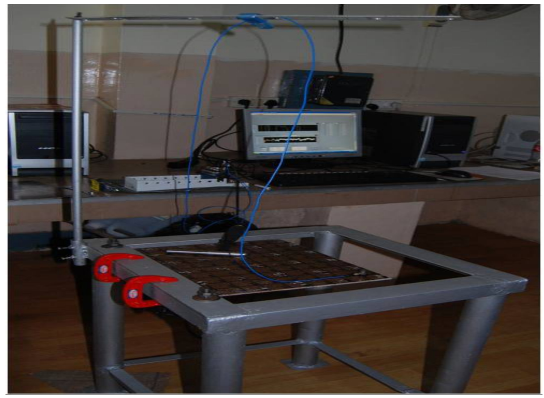


Fig.3.4 Hybrid hemp-E-glass laminate



III **RESULTS AND DISCUSSION**

Fig.3.5 Fast Fourier Transform

IV. Tensile Properties of Hemp Fabric Reinforced Epoxy Composites

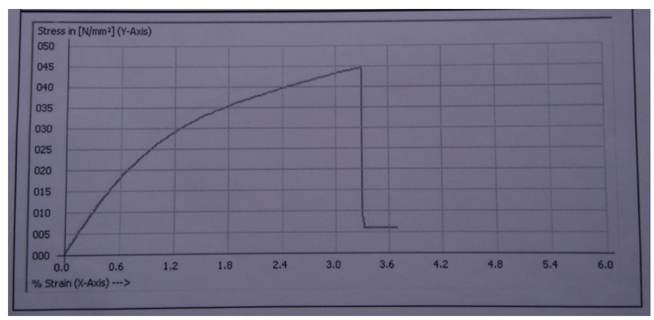
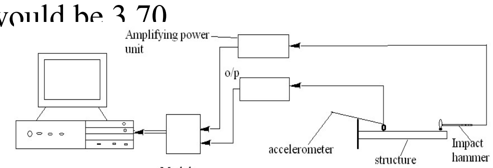


Fig.4.1 Tensile stress v/s Strain response of specimen 1

Stress-Strain curve for specimen 1 is shown in fig 4.1. The curve is linear up to certain load and the specimen will break at 44.54N/mm2 with ultimate stress of 44.54 N/mm2 and the percentage of elongation would be 3.70



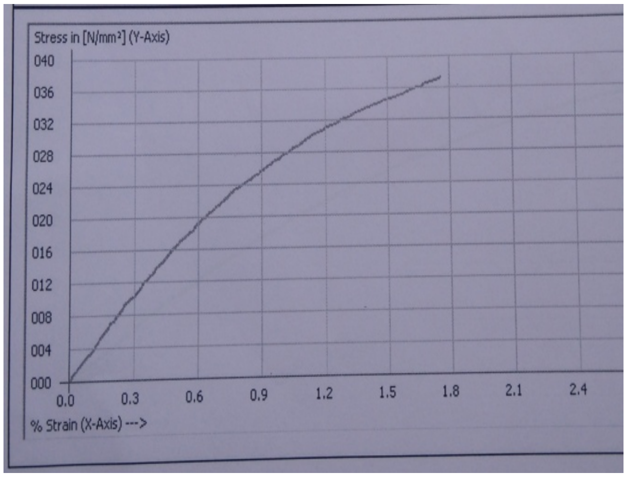


Fig.4.2 Tensile stress v/s Strain response of specimen 2

Stress-Strain curve for specimen 2 is shown in fig 4.2. The curve is linear up to certain load and takes load continuously and the specimen will break at 37.14N/mm2 with ultimate stress of 37.17N/mm2 and the percentage of elongation would be 1.77.

A. Free Vibration Characteristics of Hemp/Epoxy Fabric Reinforced Composites

A cantilever test plates of Hemp/Epoxy fabric reinforced composite having dimensions of 300x300x3.05 mm were tested to obtain modal properties for input frequency of 250 Hz. The frequency response function (FRF) method is used for structural testing, analysis and reporting software to identify the modal parameters of a structure is used. In this method, FRF measurements with FFT analyzer and transferred to the lab view system for processing and curve fitting. The modal frequency shows in table 4.1 and the damping factor of Hemp/Epoxy laminate. To obtain the response at various points, fixed excitation is used on the specimen and results are also obtained at all points. Fig.4.3 shows each peak from left to right and it relates to corresponding mode shapes 1, 2 and 3 of Hemp/Epoxy laminate. The first three experimental mode shapes obtained for Hemp/Epoxy laminate plates are given in Fig.4.4 and Fig.4.5. The mode shapes give the information of dynamic behavior of plates under various natural frequencies. The fundamental mode is mode-1 is called bending, mode-2 is called twisting and the rest of the modes are under combination of bending and twisting.

Table 4 .1: Modal properties of Hemp/Epoxy laminate
Dimension: 300x300x3.05 mm
Aspect ratio: 0.83

Mode No.	Frequency (f) (Hz)	Damping Factor (ξ) %
1	24.109	0.856
2	40.76	0.851
3	130.67	1.122

The Table 4.1 gives the modal properties of Hemp/Epoxy laminate. However, the damping factors of Hemp/Epoxy reinforced composites are higher than that of conventional composites and monolithic materials (given in the Table 4.2)

Table 4.2 Damping factors of various materials

Sl. No.	Material	Damping factors (ξ)

1	Mild steel	0.17
2	6061 Al alloy	0.09
3	E-Glass epoxy	0.70
4	Boron-epoxy	0.67
5	E-Glass polyester	1.30
6	Graphite epoxy	0.35
7	Wood	0.30

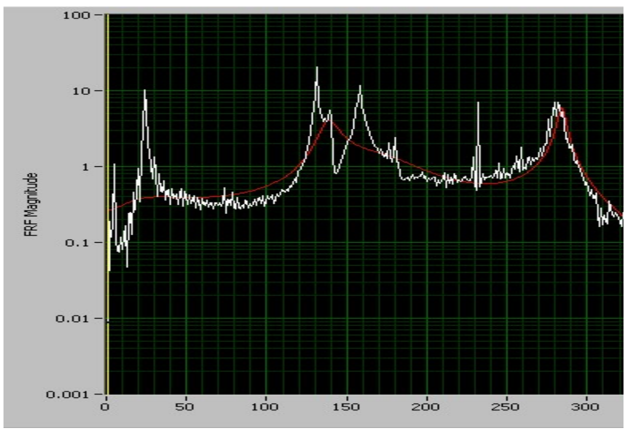
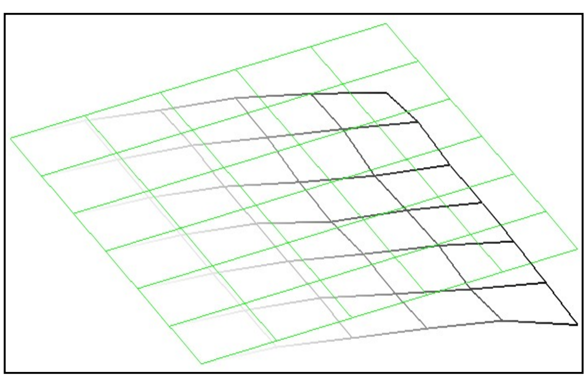
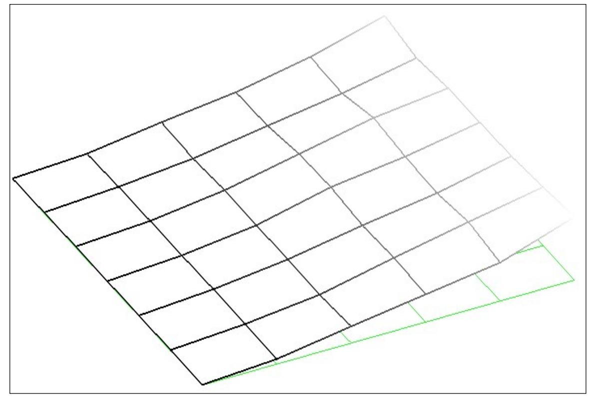
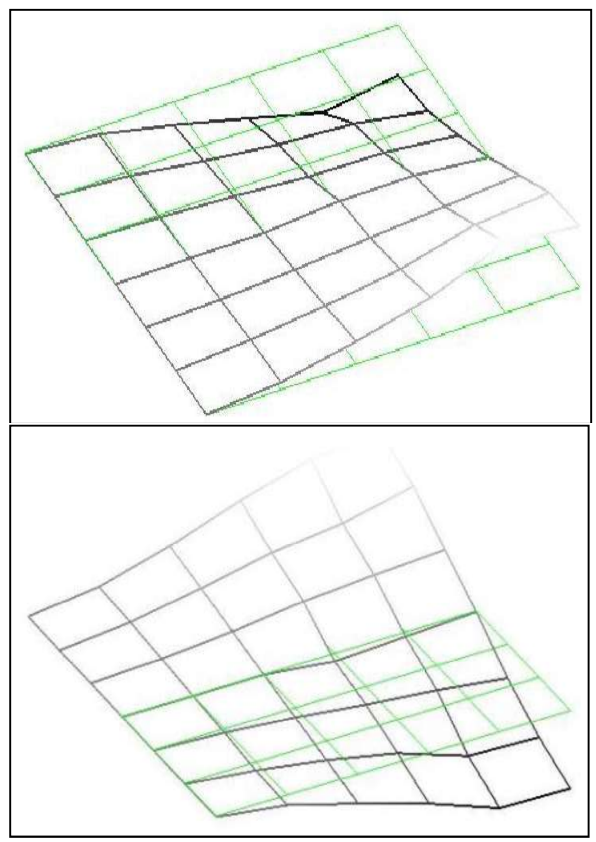


Fig.4.3 Magnitude – frequency response of Hemp/epoxy laminate



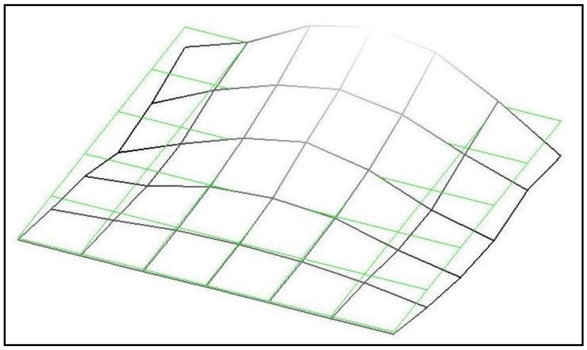


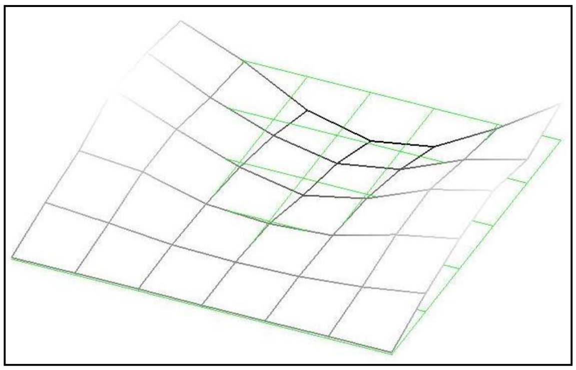
Frequency: 24.109Hz (Bending)
Damping ratio: 0.856%
Fig.4.4 Mode shape 1 for Hemp/epoxy laminate



Frequency: 40.760Hz (Twisting)
Damping ratio: 0.851%

Fig.4.5Mode shape 2 for Hemp/epoxy laminate





Frequency: 130.675Hz (Bending & Twisting)
Damping ratio: 1.122%

Fig.4.6 Mode shape 3 for Hemp/epoxy laminate

6.1 CONCLUSION

The natural fibers like jute, sisal, hemp, coir, banana, palm etc are the fibres of choice. Among all the fibres the literature survey reveals that hemp and Epoxy have been found to be the strong and better reinforcing materials.

- From the tensile test it is found that the tensile strength and modulus of Hemp/Epoxy fabric reinforced composite is 37.17MPa and 44.54MPa, these shows that the prepared hybrid epoxy composite is more stronger and strengthen than the other fibers.
- Experimentally determined the natural frequency and mode shapes for Hemp/Epoxy laminate by using Fast Fourier Technique (FFT) analyzer. And the results obtained by Finite Element Analysis shows that results are all most matching with the experimental values with maximum error percentage of 11.34 for the 1st mode.

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