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ANALYTICAL AND EXPERIMENTAL INVESTIGATION ON SISAL FIBERS REINFORCED POLYMER COMPOSITES IN AVIATION

Sridhar K
Department of Aeronauical Engineering
Nitte Meenakshi Institute of Technology, Bangalore

Suthan R
Department of Aeronauical Engineering
Nitte Meenakshi Institute of Technology, Bangalore

Suresh P
Department of Aeronauical Engineering
Dayananda Sagar College of Engineering, Bangalore.

Sivakumar P
Department of Aeronauical Engineering
Sri Ramakrishna Engineering College,Coimbatore

Abstract. The present work aims to analyze the mechanical characteristics of sisal fiber over other natural fibers and non-natural fibers. Over the past decades, natural fibers are established as promising raw material for development of major components in the field of automobile and aviation industry. Sisal fibers are extracted from Agave sisal Ana plant and fibers sheets have been prepared in bidirectional method and reinforced with epoxy, followed up angle ply laminate using hand layup technique. After curing, laminate was cut by CNC machine as per ASTM standards. The mechanical properties were determined and observed that the strength properties were found lower than the glass fiber reinforced composites. However these natural fiber composites have enough strength and stiffness and could be used in various non- structural critical components in aviation and automobile industries for the problem of weight penalty.

Index Terms: Composite materials, Epoxy, Hand layup, Natural fibers, Sisal fiber

I. INTRODUCTION

Composite materials, ceramics and plastics have been widespread prominent materials over last three decades. Because of these good mechanical properties, recyclability eco friendly- sustainable production and its wide range of application, so that natural-based reinforced composites are leading a major role within the structural community. The sisal fiber to enact as an excellent reinforcement materials and high machinability leads low cost for extraction from plants [12]. Amongst different natural fibers, the sisal fibers have excellent impact strength, good tensile and flexural strength compared to other lignocelluloses fibers [8]. These materials have very less density, enough specific properties, and biodegradable and non abrasive; due to this uniqueness of these materials it has a great connotation in the automobile and transportation industry. When compared to conventional fiber composites these natural fiber composites producing equal amount of properties [3]. Natural polymer fibers has a considerable demerits such as liquid absorption, less resistance to the fire and due its lesser amount of mechanical properties, it has a limited application. [9].Some following factors such as chemical treatment, load on the fibers, hybridization, dimension and size of fibers are affecting the mechanical properties of its polymer composites. By adding different fibers and fillers, the specific properties would be elevated according to purpose and requirement of strength [10]. These properties of the natural fibers inspired to explore the possible use of natural fibers as a substitute for synthetic fibers. This work intention is to meet the required mechanical properties of composite material by using natural fibers which is impregnated with suitable polymer.

II. METHODOLOGY AND MATERIALS USED

2.1 Fabrication of composite

In fabrication process the conventional hand layup has been adopted. The Harder HY917 and epoxy were mixed in the ratio of 1:10 and sisal fibers were applied as reinforcement. Sisal fiber properties are shown in below Table 1. After reinforcement of the fiber then it will be rolled by using roller to remove the air inside to avoid the voids. Then it is kept in mould for one day under the load of 5000 grams to make the laminate.

TABLE 1. Sisal Fibers Properties

Property	sisal fiber
Diameter (μm)	100-300
Density (g/cm3)	1.45
Cellulose	65-78
Hemicelluloses (%)	10-14
Pectin (%)	10
Lignin (%)	9.9
Wax (%)	2.0
Elongation at break (%)	4-9

2.2 Specimen testing

Tensile test

To find the load required to break a natural fiber polymer composites specimen, ASTM D638 tensile testing has been used and it ill elongated to its breaking point. The figure shows the test specimen with standard size for testing.

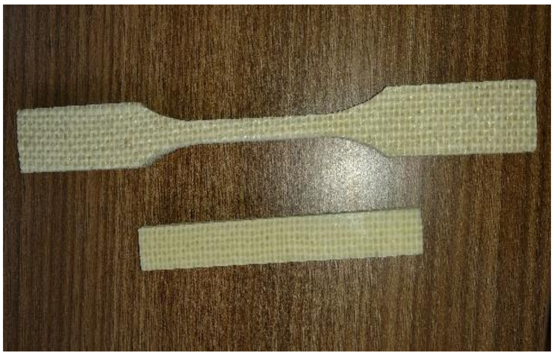

FIGURE 1. Test specimen.

Test specimen prepared as per ASTM 638 – I & II standard size and dimensions are shown below.

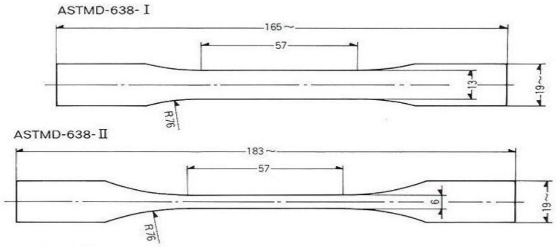

FIGURE 2. ASTM 638 - I & II standard size.

Compression testing and three points bend test

ASTM D790 standard size has been considered for preparing test specimen.

TABLE 2. ASTM D790 standard size

Compression test – specimen size	Three point bend test – specimen size
Width-25mm	Width – 12.5 mm
Length-100mm	Length – 100 mm

The specimen is subjected to compressive load to the unsupported center 12 to 25 mm gauge length of specimen in compression test. The wedges are inserted into the compression fixture, and extensometer is used to find the stain on specimen. He test results were affected based on specimen preparation, environmental conditions and method of conduction of test. The specimen is kept on the two supports and load has been applied at the third point (at center) in constant rate until specimen fails.

The above mentioned tests were conducted at the ADVANCED METALLURGICAL LABORATORY-BANGALORE based on the ASTM standards.

Laminate stiffness analysis

To obtain the required stiffeners and strength in the required directions, the plies and bonded and stacked one over the other to act as single laminate and by changing the orientation of the fibers in each ply relative to common laminate reference axes.

TABLE 3. Sisal- epoxy - Material properties

Sisal-epoxy - material properties				
E_1 (kN/mm^2)	E_2 (kN/mm^2)	G_{12} (kN/mm^2)	υ_{12}	υ_{21}
45.9	45.9	17.65385	0.3	0.3

Laminate equivalent constant

To determine the elastic constants in the membrane and bending mode by considering 7.2 mm thickness of laminate having membrane and bending compliance and shown below.

TABLE 4. Material property

Material property	Membrane mode	Bending mode
E_1 (kN/mm^2)	45.9	45.9
E_2 (kN/mm^2)	45.9	45.89999
G_{12} (kN/mm^2)	17.65385	17.65384
υ_{xy}	0.3	0.3
υ_{yx}	0.3	0.3
M_x	-0.00029	0.000169
M_y	-0.00029	-0.00056

III. RESULT AND DISCUSSION

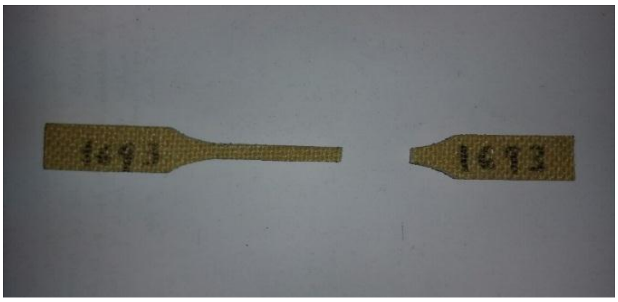

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FIGURE 3a. Tested specimen in tension test

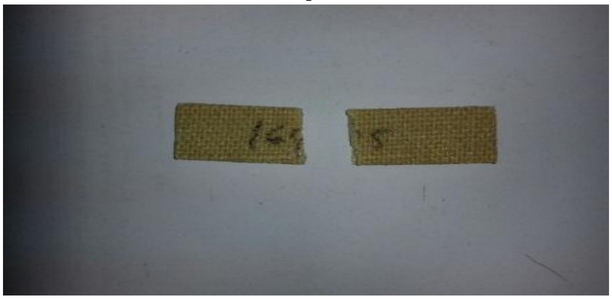

FIGURE 3b Tested specimen in compression test

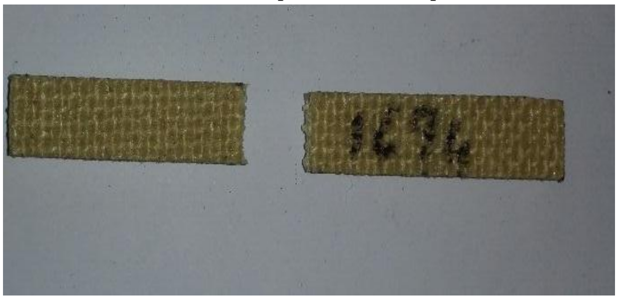

FIGURE 3c Tested specimen in bending test

Results of tension test

The maximum peak load absorbed was about 1600 N and corresponding tensile strength was found to be 37.08 GPa. The yield strength of the composite was found to be 30.57 GPa and the total percentage elongation was 0.08%.

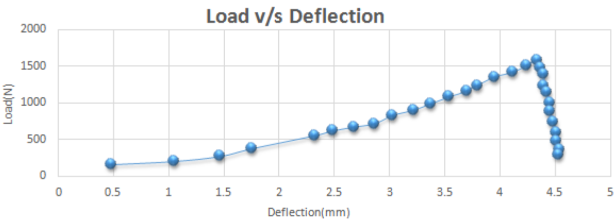

FIGURE 4. Load v/s deflection plot

A plot of load versus corresponding deflection for the tension test is given above this clearly indicates that the maximum load that the natural composite could withstand is about 1591 N (163.15 Kg). The plot has a steep slope indicating that the rate of deformation is low, indicating the sample holds it dimensions at the peak load condition.

Results of compression test

Similarly the compression test was performed on the specimen using UTM as per ASTM standards.

The peak load was absorbed was about 8400 N with the corresponding compression strength of 46 GPa.

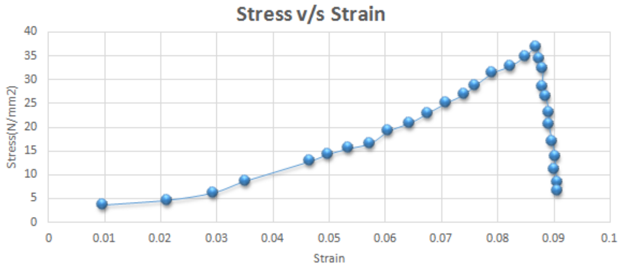

FIGURE 4. stress v/s strain plot

plot represents the stress versus strain plot for the tension test, the stress strain curve is one of the major parameter to access the mechanical properties of a materials also the slope of the curve gives the axial young's modulus of the natural composite. Plot 6.2 represents a typical behavior of a composite material, and the steep curve indicates a higher stiffness value. A best fit curve slope is plotted and the value of the young's modules is found to be E1= 46.31 GPa which is in accordance with the predicted value of 45.9 GPa using analytical calculations.

Results of bending test

Similar to the above test the three point bending test was carried out on the bending test machine as per ASTM standards. The maximum bending deflection absorbed was 3.62mm. The obtained are convincing, modulus of elasticity of the material is determined by finding the slope of stress vs strain plot. The load vs deflection plot for the tension test shown in the following results is digitalized and stress vs strain graph was developed. The slope of this plot gives young's modulus in primary direction.

IV. CONCLUSION

From the experimental and analytical assessment the following conclusion has been made for sisal fibers reinforced polymer composites.

- A multi layered composite by reinforcing with eco friendly, light weight and low cost natural sisal fibers using an epoxy resin matrix.
- The maximum of tensile strength and flexural load 37.08MPa and 260MPa respectively was noticed by the composite.
- The maximum stresses 30.6 N/mm^2, $46N/mm^2$, $2.776N/mm^2$, has been absorbed by the composite during tensile testing, compressive loading and flexural loading respectively.
- The strength properties has been found not good as those of the glass fiber reinforced composites. However these natural sisal fiber composite have enough strength and stiffness to be used in various non structurally critical components.

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