Investigation on Mechanical Behaviour of Hybrid Jute/Sisal Fiber Reinforced Polyester Composites

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Abstract— Composite materials are being used in huge quantity in every walk of the life by almost every country throughout the world. By making use of conventional fibers such as carbon, glass and Kevlar, the cost of the products become very high and also the conventional fibers used towards these are not degradable. So attempts are being made to use natural fiber to develop composites, as natural fibers are environmental degradable, non-toxic in nature possess high specific strength, damping properties and better impact resistance. This work is carried out to develop and characterize the non-conventional composites prepared by using locally available jute and sisal fibers as reinforcement and polyester resin as matrix material and to investigate its mechanical properties. The hybrid jute-sisal laminate are prepared by hand lay-up technique and specimens are extracted from the laminates as per ASTM standards and subjected for different mechanical tests such as to obtain tensile strength, impact strength and hardness properties.
Key words: Jute, Sisal, Polyester Resin, Handlay Up

I. INTRODUCTION

The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable and biodegradable. Plants such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana etc., as well as wood used from time immemorial as a source of lignocelluloses fibers are more and more often applied as the reinforcement of composites. Their availability, renewability, low density and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites. The natural fiber containing composites are more environmentally friendly and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling, paneling, partition boards), packaging, consumer products etc.

II. SELECTION OF MATERIALS

A. Jute Fabric:

Jute is a bast fiber extracted from stem fiber plants, it is similar to flax and hemp. Due to its special firmness and stability, the jute fiber (approximately 1.5 m to 2.0 m long) is particularly suited for the manufacture of coarse fibrous, stable and durable yarns and fabrics.

In this work, a unidirectional type of fabric weave having count of 20 x 12 (for yarns of 245-302 tex) is investigated. 20x12 indicates 20 in number larger yarns in the warp direction and 12 in number smaller yarns in the weft direction per inch are used and shown in Fig.2.1

Fig. 2.1: Jute fabric

B. Sisal Fiber:

Sisal fibers are extracted from the leaves of the agave sisalana plant and are classified as hard fiber. The agave consists of fleshy leaves and is bluish green in colour with a prominent ash shade, usually long and narrow which grows from a central bud and measures 0.8 m to 1.5 m long, 10-15 cm wide and 5-6 mm thick at the centre. The fibers are removed by scraping away the pulpy matter, which is done manually or mechanically. In manual method, the fibers are extracted after immersion of the leaves over a required period of time (30-60 days) in water until pulpy material decays which facilitates easy removal of fibers from the leaves after dashing the leaves against hard surface and washing the fibers in water and then dried. In mechanical operation, the mechanical decorticator is used for extraction of fibers. In this, the leaves are fed between a rotating drum and adjustable shaft. The gap between the two can be adjusted according to the thickness of leaves; the leaves are manually inserted one by one. The first half of the leaf is decorticated for few seconds and then drawn back and reversed and the non-decorticated part undergoes the same treatment. During this operation the pith from leaves is separated and the fibers are then dried under sunlight. The sisal fibers are shown in Fig.2.2.

Fig. 2.2: Untreated sisal fiber

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1) Sisal fabric:

The dried and cleaned fibers (Fig. 2.2) were used for preparation of sisal fabric. Plain weave fabric was prepared in a simple handloom machine having fabric count of 37 x 47 (varied) that is 37 fibers in warp (longitudinal) direction and 47 fibers in weft (crosswise) direction per inch. Fibers in weft direction were uncontrollable due to variation in size of the fibers. In the present work plain weave fabric (mat) was used. Sisal fabric is shown in Fig. 2.3.

Fig. 2.3: Sisal fabric

C. *Constituents of Matrix Material:*

1) Polyester resin:

It is the commercially available cheapest general purpose polyester resin which is used as matrix material. Before applying the resin to the reinforcement a curing system is blended into the resin. On curing, it forms a matrix.

2) Curing system:

The selection of proper catalyst and the amount to be used for any application depend upon the resin, the temperature at which the resin is to be cured, the required working or pot life and the time of gelation. No catalyst is available which can meet all the requirements. Therefore, combination of catalyst and accelerators must be used to obtain the best results.

3) Accelerator or Promoter:

Cobalt napthenate is used as an accelerator to cure the resin without application of heat to it. Octoate or Cobalt napthenate is available as a solution containing 6% cobalt metal. It helps in starting gelation of the resin and propagation of complete cure at room temperature in conjunction with peroxide.

4) Catalyst:

Methyl Ethyl Ketone Peroxide (MEKP) is used as catalyst. The degree and the rate of curing are controlled by catalysts. The function of a catalyst is to act an initiator for the polymerization process. Curing time can be controlled by varying the catalyst. It does not lead to a full cure by itself at ambient temperature. However, with addition of an accelerator the catalyst will cause gelation and almost completely cure within short period of time depending upon the percentage of each constituents used within the resin.

III. OBJECTIVES

The objective is to study the dynamic characteristics of natural fiber reinforced polyester composites. The objective is achieved by executing the following steps.

- Preparation of test specimens by hand lay-up technique
- Evaluation of mechanical properties of hybrid jute-sisal composite

IV. EXPERIMENTATION

From the literature it shows that the jute and sisal fibers were better reinforcing materials compared to other natural fibers. Jute and sisal fibers are abundant in India and relatively inexpensive, possess higher tensile strength and modulus than plastics and can be a good substitute for conventional fibers in many situations. Literature reveals that no single group of researchers has completely determined the mechanical properties such as tensile, impact strength and hardness of hybrid jute-sisal fabric reinforced polyester composites. Hence, the purpose of present work was to determine the various mechanical properties of hybrid jute-sisal fabric reinforced polyester composites. The specimen was prepared using hand lay-up technique as per ASTM standard at atmospheric condition. In this work tensile strength, impact strength and hardness properties of composites were obtained.

A. *Fabrication method and preparation of hybrid jute-sisal fiber reinforced polyester composite specimen:*

Each layer of fabric was pre-impregnated with matrix material which is prepared by mixing general purpose polyester resin, accelerator and catalyst in the weight ratio of 1:0.02:0.026 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.

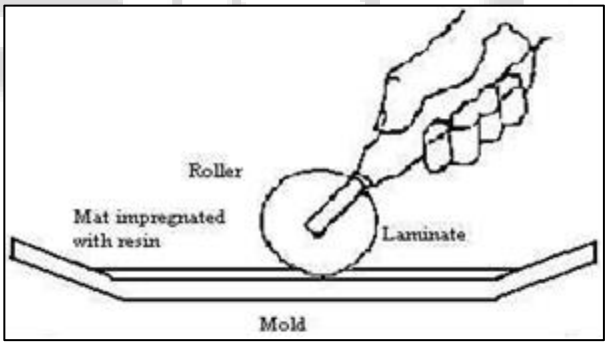

Fig. 4.1: Hand lay-up

Hand lay-up technique is used to prepare specimen as shown in Fig. 4.1. The working surface was cleaned with thinner to remove dirt and a thin coat of wax is applied on the surface to get smooth finish. Then a thin coat of poly vinyl alcohol (PVA) is applied for easy removal of mould. Jute and sisal fabrics are cut to the required dimensions for test specimen pre-impregnated with matrix material and placed one over the other in the mould. Casting was cured under light pressure for 2 hours before removal of mould. All test specimens were moulded and prepared according to ASTM-D standard to avoid edge and cutting effect, thereby minimizing stress concentration effect.

V. MECHANICAL TESTING ON COMPOSITE SPECIMEN

Mechanical tests on laminates expect impact tests were carried out on MST-810 machine, having maximum capacity of 10 metric ton. For the tests 1 metric ton range is used. All

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specimens were tested as per ASTM-D standard. Minimum of five samples were tested to account for statistical scatter and arrived at mean values. All the tests were carried out at room temperature.

A. Tensile test:

Tensile tests on composite specimens were carried out according to ASTM–D 3039 standard to determine tensile strength and modulus of elasticity for jute-sisal FRP to observe the behavior of FRP under load. The test specimen is showed in Fig.5.1.

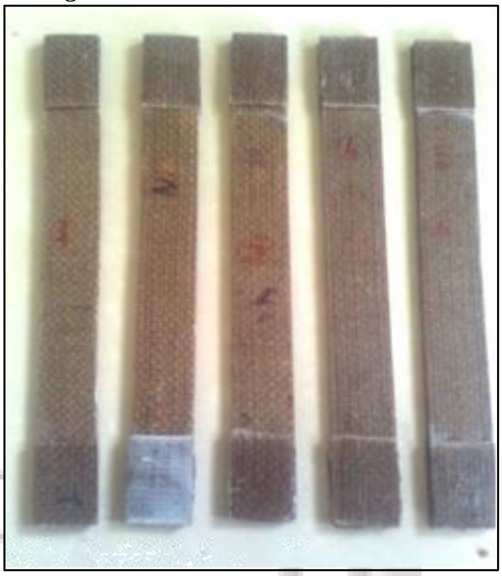

Fig. 5.1: Hybrid jute-sisal FRP tensile test specimen

B. Impact test:

Impact test is carried out according to ASTM-D 256 standard to measure material ability to withstand shock loading. It is a dynamic test in which a selected specimen is struck and broken by a single blow on a specially designed machine and the energy absorbed in breaking the specimen is measured and gives a quality of the material, particularly its brittleness. Highly brittle materials have low impact strength. Impact test specimen is shown in Fig.5.2

Fig. 5.2: Hybrid jute-sisal FRP impact test specimen

C. Hardness test:

The hardness of the composite is determined by use of a Rockwell hardness tester. The indicating dial has 100 divisions. The dimensions of the specimens are 150 x 150 x 3.6 mm. The test specimen is shown in Fig. 5.3.

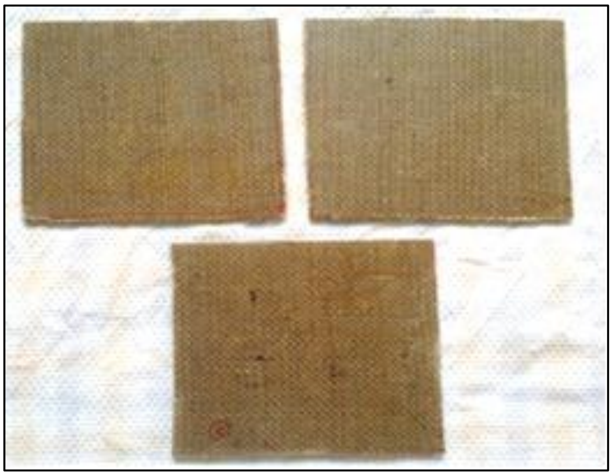

Fig. 5.3: Hybrid jute-sisal FRP hardness test specimen

VI. RESULTS & DISCUSSIONS

A. Determination of fiber volume fraction:

Fiber volume fraction is a percentage of fiber reinforced in the matrix material. The volume of matrix material was obtained by using rule of mixture. It is calculated as follows:

- Mass of Jute Fiber (MJ) = 142.57 gm.
- Mass of Sisal Fiber (MS) = 1.66 gm.
- Density of Jute Fiber (DJ) = 1.1268 gm.
- Density of Sisal Fiber (DS) = 0.973 gm.
- Therefore, Volume of Fiber = $\frac{MJ}{DJ} + \frac{MS}{DS}$

$$= \frac{142.57}{1.1268} + \frac{10.66}{0.973}$$

- Volume of composite = 30x30x0.38

  = 342 cm³.
- Volume of fiber fraction = $\frac{\text{Volume of fibre}}{\text{Volume of composite}}$

  = 40.19 %

1) Law of mixture:

- Weight of fibers (MJ + MS), Wf = 153.03 gm.
- Weight of composite, WC = 471.70 gm.
- Weight of fiber fraction = $\frac{Wf}{WC}$

$$= \frac{153.03}{471.70}$$

= 0.3244

= 32.44 %

- Wf +Wm = WC Wm = Weight of matrix

  Wm = WC - Wf

  = 471.70 – 153.03

  = 318.67 gm.

Weight of matrix fraction = $\frac{Wm}{WC}$

$$= \frac{318.67}{471.70}$$

= 0.6755

= 67.55 %

Therefore law of mixture satisfied, 32.44% + 67.55 % = 99.99% ≈ 100%

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B. Tensile Properties of Hybrid Jute-Sisal Fabric Reinforced Polyester Composites:

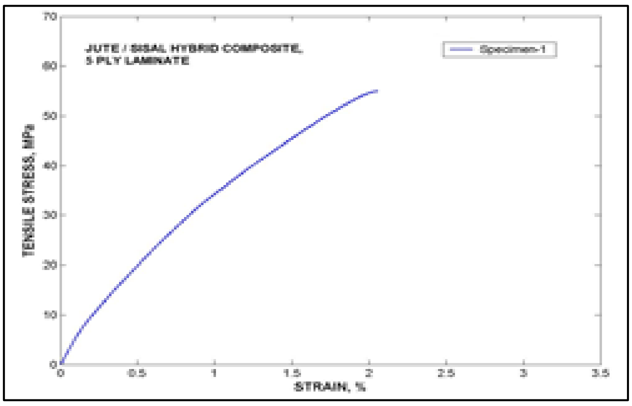

Fig. 6.1: Tensile stress-strain response of specimen-1

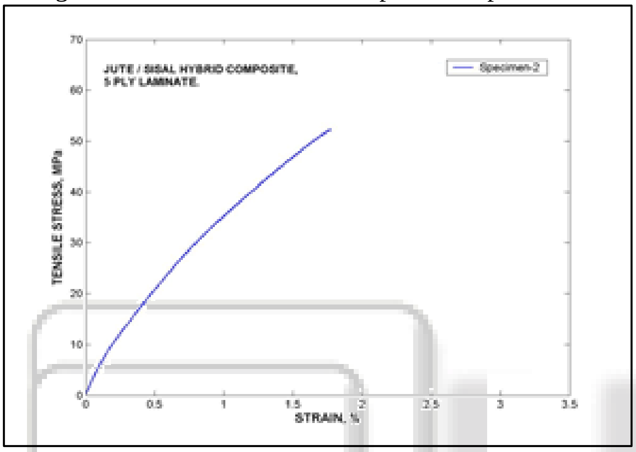

Fig. 6.2: Tensile stress-strain response of specimen-2

Type of Composite	Strength (MPa)	Modulus (GPa)	Volume Fiber Fraction %
Hybrid Jute-Sisal FRP	53.65	3.72	40.19

Table 6.1: Tensile test results of Hybrid Jute-Sisal FRP composites

1) Discussion:

- Tensile stress-strain diagram of specimens tested for fabric reinforced polyester composites in warp direction shown in Figs. 6.1 and 6.2. Strength and modulus of fiber as well as bonding strength between fibers and matrix are the prime factors, which accounts for the tensile strength of composite materials.
- The curve is linear up to 12 MPa (approximately) and then follows a non-linear path. A significant change in the slope of the stress–strain curve indicates shear failure. Failure of matrix / fiber usually starts after a stress level of 12 MPa.
- The ultimate point in the curve (Figs.6.1 and 6.2) represents the complete fracture of the fiber. Failure mode exhibits little pull out of fibers and progressive failure of fibers. The first fiber failure occurs at the stress level of 12 MPa (approximately). The rest of the drops in the curves are indications of progressive failure of fibers as the applied load increases and the end of the curve represents the ultimate stress which is due to fiber fracture and may be fiber pull out.

C. Impact Properties of Hybrid Jute-Sisal Fabric Reinforced Polyester Composites:

Composites	Test	Impact Strength KJ/M²
Hybrid Jute-Sisal	Charpy	23.178
	Izod	12.417

Table 6.2: Impact test results of Hybrid Jute-Sisal FRP composites

1) Discussion:

- Impact tests were conducted on hybrid jute-sisal fabric reinforced polyester composites having volume fiber fraction (40-43 %) with number of layers 12 and polyester resin using pendulum type impact tester. Impact strengths were obtained for both charpy and izod specimens (Table 5.1).
- Charpy test were performed on hybrid jute-sisal composite. The mode of fracture shows little pull out of fibers. The reason for this is poor bonding at the fiber matrix interfaces. The average impact strength values for hybrid jute-sisal composite specimens are 23.17 KJ/m² for charpy, 12.41 KJ/m² for izod.
- Failure mode shows that specimen is broken in to two pieces with little pull out of fibers on tension side.

D. Rockwell Hardness Properties of Hybrid Jute-Sisal Fabric Reinforced Polyester Laminate:

Type Of Composite	Rockwell Hardness Number
Hybrid Jute-Sisal Composite	79

Table 6.3: Impact test results of Hybrid Jute-Sisal FRP composites

1) Discussion:

The variation in the hardness reading is caused by the difference in the hardness between resin and filler materials. Addition of fibers in the matrix reduces the hardness of binding material.

VII. CONCLUSIONS

The main emphasis of the present work was on development, testing and characterization of hybrid jute-sisal fabric reinforced polyester composites to know their suitability and adaptability for various structural applications. Based on the experimentation the following are the salient feature of this hybrid composite material.

- From the tensile test it was found that the tensile strength and modulus of hybrid jute-sisal fabric reinforced polyester composite is 53.65 Mpa and 3.72 Gpa, these values are 2.56 and 1.1 times more than those of sisal fabric reinforced polyester composites and exhibits tensile strength of 21.1 MPa and modulus of 3.4 Gpa. [4,5]
- Impact energy per unit area of hybrid jute-sisal fabric reinforced polyester composite is 23.17 KJ/m² and it is 1.3 times more than the impact energy of the sisal fabric reinforced polyester composite (18.2 KJ/m²) and it is 1.37 times less than the jute composite (31.85 KJ/m²). [4,5]
- Rockwell hardness value of hybrid jute-sisal fabric reinforced polyester composite is 79 and it is 2.26 times greater than the sisal fabric reinforced polyester

composite and 1.18 times greater than the jute fabric reinforced polyester composite. [4,5]

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