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Manufacturing and Properties Analysis of Fibre Reinforced Polymer Composites

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ABSTRACT

The developments of new materials are growing progressively, due to increase demand of low price and high quality–light weight material, there is need of developing such material which fulfils all the required needs. So concentration is on composite material because of its superior property such as high strength to weight ratio. Fiber reinforced composites such as a sisal polymer composite becomes more attractive due to their lightweight, high specific strength, and biodegradability. Natural fiber like sisal fibre is mixed with glass fibre and carbon fiber which resulted in sisal – glass–carbon fiber reinforced epoxy composites. Then their mechanical properties such as tensile strength and flexural strength are tested. The interfacial properties such as internal cracks and internal structure of the fractured surfaces are evaluated by using Scanning Electron Microscope.

Keywords : Composites, Fibre, Specific Strength, Reinforcement.

I. INTRODUCTION

The term composite can be defined as a material composed of two or more different materials, with the properties of the resultant material being superior to the properties of the individual materials being superior to the properties of individual material that make up the composite.

Composites consist of one or more discontinuous phases (reinforcement) embedded in a continuous phase (matrix) Examples: Cemented carbides (WC with Co binder),rubber mixed with carbon black, wood (a natural composite as distinguished from a synthesized composite).

Some examples of composite materials: (a) plywood is a laminar composite of layers of wood veneer, (b) fiber glass is a fiber-reinforced composite containing stiff, strong glass fibers in a softer polymer matrix (× 175), and (c) concrete is a particulate composite containing coarse sand or gravel in a cement matrix (reduced 50%). Sisal, Carbon, Glass Fiber Reinforced Polymers is a fiber reinforced polymer made of a plastic matrix reinforced by fine fibers of Sisal, Carbon, Glass. Fiber glass is a lightweight, strong, and robust material used in different industries due to their excellent properties. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are very favorable when compared to metals, and it can be easily formed using molding processes.

Now a day's natural fiber such as sisal and jute fiber composite materials are replacing the glass and carbon fibers owing to their easy availability and cost. The use of natural fibers is improved remarkably due to the fact that the field of application is improved day by day especially in automotive industries. Several researches have been taken place in this direction.

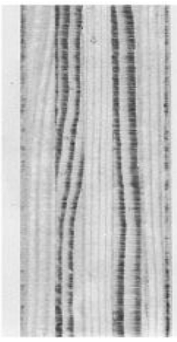

Figure 1a

Figure 1b

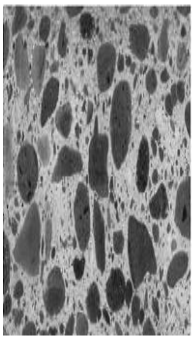

Figure 1c

Most of the studies on natural fibers are concerned with single reinforcement. The addition of natural fiber to the glass fiber can make the composite hybrid which is comparatively cheaper and easy to use.

II. Composite Material Used

The materials used in the present research work are tabulated in TABLE I with their properties and suppliers.

Sisal fiber is obtained from the leaves of the plant Agavsisalana, which was originated from Mexico and is now main, cultivated in East Africa, Brazil, Haiti, India and Indonesia (Nilsson, 1975; Mattoso et al., 1997). It is grouped under the broad heading of the “hard fibers” among which sisal is placed second to manila in durability and strength (Weindling, 1947).The name “sisal” comes from a harbor town in Yucatan, Maya, Mexico (Nilsson, 1975). It means cold-water.

Figure 2: Sisal plant

Figure 3: Fibers removed from Sesal plant

Figure 4: Sisal fibers

TABLE I
SPECIFICATIONS OF THE MATERIALS
SISAL FIBER

Materials	Specification
Unsaturated polyester resin **ECMOLAN 4413**	Density: 1.13 g/cm^3; UTS: 50MPa Flexural Strength:85 MPa Heat distortion temperature:70 ^{0} C
Sisal fiber	Bulk density : 1.450 g/cm^3 ; Chopped length: 50–80 mm Diameter:100–300 µm
Carbon fiber	Bulk density :70- 80 g/cm^3 ; length : 3- 6 mm
Cobalt (Accelerator)	Density:0.98 g/cm^3
Methyl Ethyl Ketone peroxide (MEKP) Catalyst.	Density:1.17 g/cm^3
Glass fiber Sheet	Thickness:100µm

A. Preparation of Composite Specimen

The composite materials used for the present investigation is fabricated by hand layup process. Chopped sisal fibers of 50 mm length were used to prepare the specimen. The composite specimen consists of total five layers in which glass fiber layers are fixed in top middle and bottom of the specimen. Second and fourth layers are filled by natural fibers such as sisal fiber. The layers of fibers are fabricated by adding the required amount of epoxy resin. Initially the glass fibers polymer, sisal fiber are dried in sun light to remove the moisture.

The cutter glass fiber is placed on the Mylar sheet for 1.2mm thick and then the resin is coated on the glass fiber using roller brush. Further the compressed sisal is placed on the glass fiber and then coated the resin in natural fiber. Then another glass fiber is placed above the sisal again the resin coated then the fourth layer sisal is placed. Resin coated further evenly distributed in the fiber using roller, the fifth layer is placed glass. After five layers laminated sheet is placed in the compression molding machine with 10bar pressure and 80°C.

B. **Processing of Sisal fiber, Glass fibre combined Carbon fibre&Unsaturated polyester resin Composite**

Composite is prepared first to know at what percentage of weight fraction the composite gives the Ultimate Tensile Strength from that percentage some percentage of Rice Husk is added to enhance its tensile property.First make some sample preparation calculation before preparing the composite as given below and start the fabrication by preparing the temporary mould using beadings arranged on the granite base representing a rectangular mould of 250 mm x 25 mm x 10 mm is shown in figure 1. Pour the calculated amount of resin with thoroughly mixed Promoters, Accelerators & Catalyst of 1% to the UPS and wait for ten minutes so that it starts pre hardening then put a Glass fiber sheet on to it and then apply pressure by placing a concrete block over the setup for 24 hours to complete cure the laminate and once the laminate is completely cured then it‟s ready for machining according to ASTM standard for testing, repeat the procedure by adding 0,5, 10, 15, 20 % wt of sisal fiber to the resin. At optimum percentage then add 1, 3, and 5% of Rice Husk and repeat the same procedure to get the Hybrid composite and is tested for mechanical properties. Composite with % wt fiber prepared using Hand layup procedure.

Size oflaminate

Initially we take the alkaline treatment of sisal fiber and it's chopped into 50mm. Then the chopped sisal fiber is compressed in the compression molding machine into the form of sheet 1.2mm.

The dimension of compressed sisal fiber is,Width= 290mm, Length = 290mm, Thick = 1.2mm

Figure 5: Polymer matrix composite.

Then the glass fiber (Woven Roving Mat) is cutting into the required shape, Length = 290mm, width = 290mm

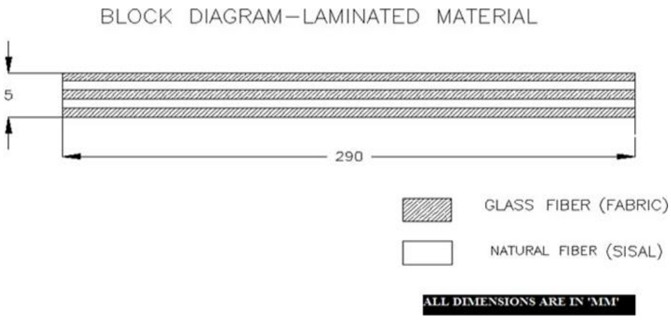

Figure 6:. Block diagram of laminated material

TABLE 2

: % WT OF SISAL FIBER AND UPS

Samples	**% Wt of Sisal Fiber, g**	**% of Unsaturated polyester resin, g**	**Mass of sisal Fiber, g**	**Mass of Unsaturated polyester resin**	**Total Mass, g**
A	0	100	0	70.62	70.62
B	5	95	3.53	67.09	70.62
C	10	90	7.06	63.56	70.62
D	15	85	10.59	60.03	70.62
E	20	80	14.12	56.50	70.62

TABLE 3
% WT OF SISAL FIBER, UPS AND CARBON &GLASS FIBER

Samples	% Wt of Sisal Fiber	% of Unsaturated polyester resin	%Wt of Carbon &Glass Fiber	Mass of Unsaturated polyester resin, g	Total Mass, g
F	19	80	1	56.49	70.62
G	17	80	3	56.49	70.62
H	15	80	5	56.49	70.62

The above samples are tested for mechanical properties that are tensile and flexural strength according ASTMstandards.

III. MECHANICAL CHARACTERIZATION

Composite materials were subjected to various mechanical tests to measure strength, elastic constants, and othermaterial properties. The results of such tests were used for two primary purposes: 1) engineering design (for example, failure theories based on strength, or deflections based on elastic constants and component geometry) and 2) quality control either by the materials producer to verify the process or by the end user to confirm the material specifications. A Universal Testing Machine (UTM) is an instrument used for the measurement of loads and the associated test specimen deflections such as those encountered in tensile, compression or flexural modes. It is used to test the tensile, flexural properties of materials. Load cells and extensometers measure the key parameters of force and deformation as the sample was tested [3].

Ultimate Tensile Strength

Ultimate tensile strength, often referred to tensile strength is the maximum stress that a material can withstand while being stretched or pulled before fracture. The tensile test for the specimens was conducted according to ASTM .The specimens of size 250 mm x 25 mm x 10 mm were tested with a span length of 250 mm in tensile mode at a cross head speed of 1 mm / min.

Figure 7: Universal tensile testing machine

Ultimate tensile strength ={ Maximum load in N in MPs} /{ c/s area in mm^2}

Young's modulus (E) = {stress} /{ strain} in Gpa

Stress(σ) ={ load(P)} / { Area(bxd)} in N/mm^2

Strain ={Change in length} /{ Original length}

P = maximum load in N, b = width of the specimen in mm, d = thickness of the specimen in mm

IV. RESULT AND DISCUSSIONS

A. Tensile Test

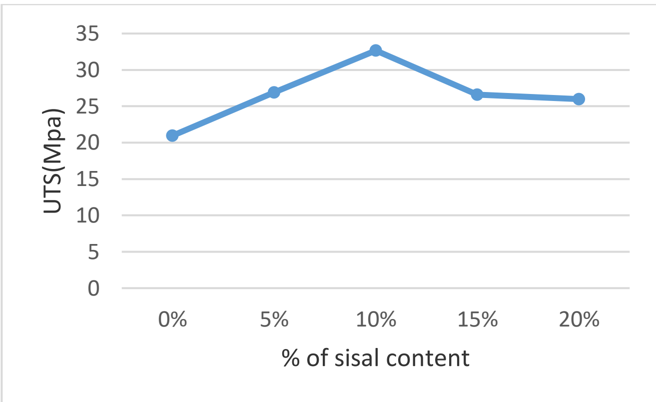

Figure 8: Wt% of sisal Ve UTS

TABLE 4

ULTIMATE TENSILE STRENGTH OF SISAL FIBER AND UNSATURATED POLYESTER RESINS.

Samples	% wt of sisal fiber	UTS, MPA	UTS, MPA	UTS, MPA	Average UTS, MPA
A	0	20.40	19.79	22.71	20.96
B	5	24.92	31.84	23.91	26.89
C	10	27.75	31.33	38.91	32.66
D	15	24.45	27.27	28.08	26.60
E	20	31.94	24.76	21.30	26.00

TABLE 5

ULTIMATE TENSILE STRENGTH

Samples	%wt of Carbon and glass	%wt of sisal	UTS, MPA	UTS, MPA	UTS, MPA	Average UTS, MPA
E	1	19	15.45	18.56	20.64	18.21
F	3	17	19.90	15.32	18.56	17.92
G	5	15	20.25	15.55	17.16	17.65

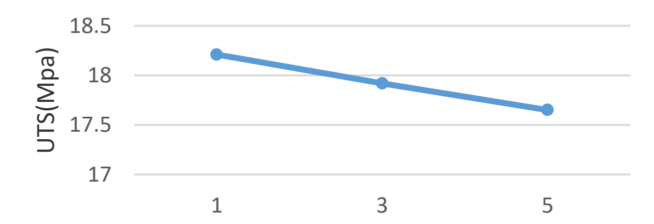

Fig. 9. % wt. of Sisal, Carbon and Glass fiber and resin Vs UTS

Figure 9 : % wt. of Sisal, Carbon and Glass fiber and resin Vs UTS

B. **Bending Test**

TABLE 6

ULTIMATE FLEXURAL STRENGTH OF SISAL FIBER WITH UNSATURATED POLYESTER RESIN

Samples	%wt of Sisal	UTS in Mpa	UTS in Mpa	UTS in Mpa	Avg UFS in Mpa
A	0	35.2	31.77	28.18	31.71
B	5	58.95	58.31	56.73	57.99
C	10	35.6	40.51	50.68	42.26
D	15	32.38	38.47	46.01	38.95
E	20	43.32	20.27	26.88	30.15

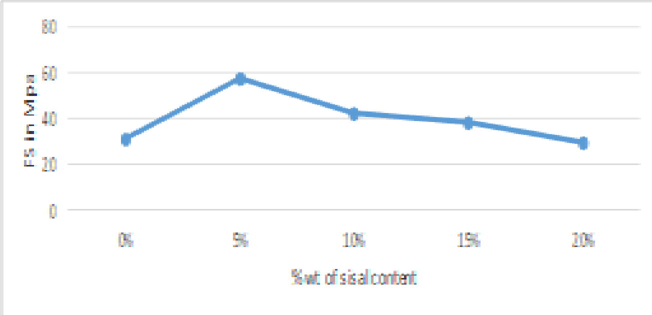

Figure 10: Graph 3: % wt of sisal vs Flexural strength

Flexural Strength = (3PL) / ($2BD^2$) ….in MPa

Flexural Modulus = $\frac{PL^3}{4BD^3\delta}$ ………. GPa

P – Peak Load in N, δ – Deflection at load P in mm

Size of the specimen for flexural test is the 200 mm x 15 mm x 5 mm

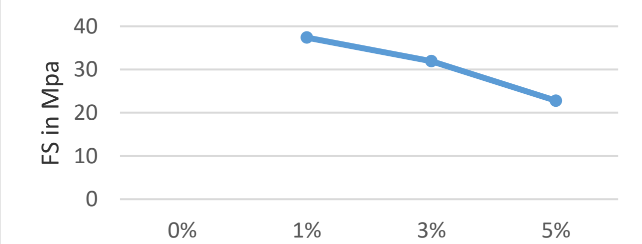

Figure 11: % wt of sisal Vs flecural strength

TABLE 7
ULTIMATE FLEXURAL STRENGTH OF SISAL FIBER, CARBONAND GLASS FIBER WITH UNSATURATED POLYESTER RESIN

Samples	%wt of Carbon and glass fiber	%wt of sisal	UTS in MPA	UTS in MPA	UTS in MPA	Average UTS, MPA
E	1	19	62.64	19.92	29.59	37.38
F	3	17	41.23	40.36	17.31	31.96
G	5	15	26.43	17.75	24.23	22.80

C. **Hardness Test**

TABLE 8
HARDNESS OF THE NATURAL FIBER REINFORCED POLYMER COMPOSITE

SL.No	Sample Description	Shore 'D' Hardness
1	A	85, 85, 84
2	B	86, 86, 85
3	C	87, 86, 87
4	D	87, 87, 86
5	E	86, 86, 84
6	F	84,85,84
7	G	85, 85, 86
8	H	84,85,84

Shore hardness tester is used to determine the hardness of the fiber reinforced polymer composite is shown in table 7. Up to 15 % wt of sisal fiber, the hardness of composite is increased. And 17% sisal fiber, 3% Carbon &Glass fiber and 80% of resin for this combination, the hardness is increased.

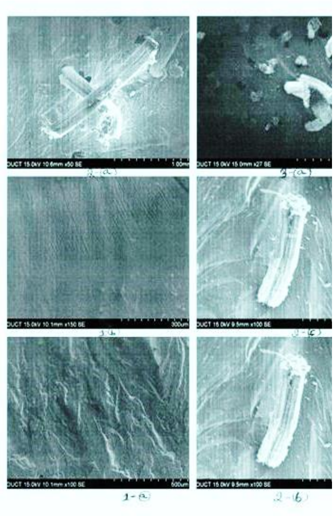

Figure 12:. SEM image of composite: (a) and (b) are the microstructure of 100% resin;(c),(d) and 2(e) are the 5% of sisal fiber and 95% of resin; (f), (g) and (h) are the 10% of sisal +90% of resin; (i) is the 15% of sisal + 90% resin.

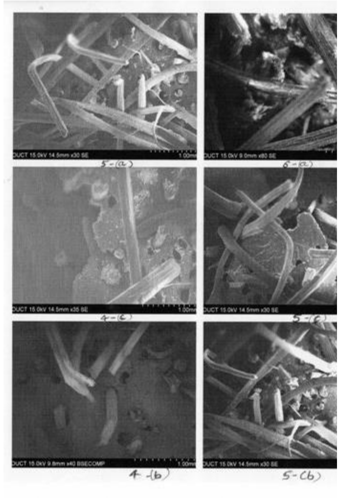

Figure 13: SEM image of composite: (a, b) are the 15% of sisal + 90% resin; (c, d, e) are the 20% sisal + 85% of resin; (f, g, h) are the 1% of Carbon and glass fiber + 19% of sisal fiber + 80% of resin; (i) the 3% of Carbon and glass fiber + 17% of sisal fiber + 80% of resin.

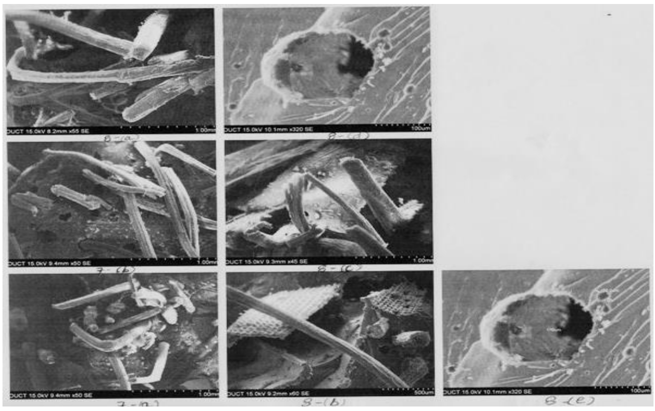

Fig. 14. SEM images of (a, b) are the 3% of Carbon and glass fiber + 17% of sisal fiber + 80% of resin; (c, d, e, f, g): are the 5% of Carbon and glass fiber + 15% of sisal + 80% of resin.

V. CONCLUSION

- In this research, ultimate tensile strength and flexural strength of the natural fiber reinforced polymer composite is increased.

- Ultimate tensile strength of the C specimen (sisal fiber 10% + resin 80%) is 32.66 Mpa is maximum.
- Ultimate tensile strength of (19% sisal, 1% Carbon &Glass fiber and 80% unsaturated polyester resin) E specimen is 18.21 MPA.
- Ultimate Flexural strength of sisal fiber, with unsaturated polyester resin B & C (5% & 10% of sisal with resin 95% & 90%) is 57.99 MPA and 42.26 MPA.
- Ultimate Flexural strength of E specimen (sisal fiber, carbon and glass fiber with unsaturated polyester resin) is 37.38 MPA.

Hardness test:

Specimen D (15 % wt of sisal fiber), the hardness of composite is 87; and G (17% sisal fiber, 3% Carbon &Glass fiber and 80% resin), the hardness is 86.

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