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Tensile and Flexural Properties of Sisal/Jute Hybrid Natural Fiber Composites

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Abstract: *During the last two decades using natural fiber as reinforcement in polymers has increased drastically. The present research work has been carried out to make use of sisal/jute natural fibers. The aim of this paper is to describe the development and characterization of new set of hybrid natural fiber composites. It is made by reinforcing sisal/ jute fibers with epoxy resin in matrix by using hand layup technique. The natural fibers were extracted by retting and combing process manually. Hybrid composites were prepared using sisal/jute fibers of 0/40, 10/30, 20/20, 30/10, 40/0 weight fraction ratios while overall fiber weight fraction was fixed as 0.4 weight fraction. The tensile and flexural properties were carried out using hybrid composite samples. The results indicated that addition of sisal fiber in jute/epoxy composites up to 50% weight fraction results increasing the mechanical properties.*

Keywords: *Sisal & jute fibers, Hybrid composites, tensile properties and flexural properties.*

I. Introduction

Composite materials are consisting of two or more chemically distinct constituents, on a macro-scale, having a distinct interface separating them. One or more discontinuous phases therefore, are embedded in a continuous phase to form a composite. The discontinuous phase is usually harder and stronger than the continuous phase and is called the reinforcement, whereas, the continuous phase is termed the matrix [1–3]. The matrix material can be metallic, polymeric or ceramic. A metal matrix composite consist of a matrix of metals or alloys reinforced with metal fibers such as boron and carbon. When the matrix is a polymer, the composite is called polymer matrix composite (PMC). The reinforcing phase can either be fibrous or non-fibrous (particulates) in nature and if the fibers are derived from plants or some other living species, they are called natural-fibers. The fiber reinforced polymers (FRPs) consist of fibers of high strength and modulus embedded in or bonded to a matrix with a distinct interface between them. In this form, both fibers and matrix retain their physical and chemical identities. In general, fibers are the principal load carrying members, while the matrix keeps them at the desired location and orientation, act as a load transfer medium between them, and protect them from environmental damage [4–8].

Hybrid composite materials are which are made by combining two or more different types of fibers in a common matrix. Hybrid of short fibers having same length and different diameter offer some advantage over the use of one type of fibers alone in a polymer matrix. The natural fibers like jute, sisal, hemp, kenaf, and banana are renewable, non-abrasive and can be incinerated for energy recovery. They possess a good calorific value and cause little concern in terms of health and safety during handling. In addition, they exhibit excellent mechanical properties, have low density and are inexpensive.

Pervaiz and Sain [9] examined the energy consumption of glass and natural fibers, and they found that by using vegetal fibers in place of glass fibers, energy could be saved at a rate of 60% per ton of product. Jute, a natural fiber in polymer composites would be suitable for the primary structural applications, such as indoor elements in housing, temporary outdoor applications like low-cost housing for defense and rehabilitation and transportation. The insulating characteristics of jute may find applications in automotive door/ceiling panels and panel separating the engine and passenger compartments [10].The use of natural fiber like jute not only help us in ecological balance but can also provide employment to the rural people in countries like India and Bangladesh where jute is abundantly available. S.M. Sapuan et al [11] investigated the tensile and flexural properties of banana fiber reinforced with epoxy. The statistical analysis carried out, showed an increase in mechanical properties. Maries Idicula et al [12] Dynamic studies on mechanical properties of randomly mixed sisal and banana fibers were carried out and it is observed that the flexural and tensile modulus shows improvement in results. The damping behavior also improved for sisal polyester composites. M. Ramesh et al[13]in their paper hybrid glass/sisal fiber reinforced epoxy composites. The performance of these natural fiber composites is lower than that of the GFRP it has been used in many application which requires medium strength. In this present investigation is to the potential utilization of sisal/jute fiber as reinforcement in polymer matrix composites. Fabricate and evaluate their mechanical properties.

II. Materials and Methods

1. Natural fiber:

Natural fibers such as fiber extraction from sisal, jute, coir, flax, hemp, pineapple and banana for making a new environment friendly and biodegradable composite materials (somehow these composites are called ‘Green Composites’’). Recent studies in natural fiber composites offer significant improvement in materials from renewable sources with enhanced support for global sustainability. These natural fiber composites possess high/moderate strength, thermal stability when they are recyclable, but the problems of using pure biodegradable polymers are their low strength and transition temperature.

2. Sisal fiber:

Sisal fibers are extracted from the leaves of sisal plant. The fibers are extracted through hand extraction machine composed of either serrated or non serrated knives. The peel is clamped between the wood plank and knife and hand-pulled through, removing the resinous material. The extracted fibers are sun-dried which whitens the fiber. Once dried, the fibers are ready for knotting. A bunch of fibers are mounted or clamped on a stick to facilitate segregation. Each fiber is separated according to fiber sizes and grouped accordingly. To knot the fiber, each fiber is separated and knotted to the end of another fiber manually. The separation and knotting is repeated until bunches of unknotted fibers are finished to form a long continuous strand. This Sisal fiber can be used for making variety of products.

3. Jute fiber:

Jute take nearly 3 months, to grow to a height of 12–15 ft, during season and then cut & bundled and kept immersed in water for ‘‘Retting’’ process, where the inner stem and outer, gets separated and the outer plant gets ‘individualized’, to form a Fiber. Then the plant get separated and washed to remove dust from the plant. The fiber after drying is taken to Jute mills, for getting converted to Jute yarn and Hessian. From the Jute, various lifestyle products are being produced and diversified into various forms, due to R&D support and also due the support by Government Organizations.

4. Weight fraction of the fiber:

The weight of the matrix was calculated by multiplying density of the matrix and the volume (volume in the mould). Corresponding to the weight of the matrix the specified weight percentage of fibers is taken. For hybrid combination the corresponding weight of fiber obtained is shared by two fibers.

Fig. 1 - Sisal and Jute fibers

5. Preparation of epoxy and hardener:

Epoxy LY556 of density 1.15–1.20 g/cm^3, mixed with hardener HY951 of density 0.97–0.99 g/cm^3 is used to prepare the composite plate. The weight ratio of mixing epoxy and hardener is 10:1.This has a viscosity of 10-20 poise at 250^{0}C. Hardeners include anhydrides (acids), amines, polyamides, dicyandiamide etc.

6. Mould Preparation:

Mould used in this work is made of well-seasoned teak wood of 200 mm X 200 mm X 3 mm dimension with five beadings. The fabrication of the composite material was carried out through the hand lay-up technique. The top, bottom surfaces of the mould and the walls are coated with remover and allowed to dry. The functions of top and bottom plates are to cover, compress the fiber after the epoxy is applied, and also to avoid the debris from entering into the composite parts during the curing time.

7. Composite fabrication:

The moulds are cleaned and dried before applying epoxy. The fibers were laid uniformly over the mould before applying any releasing agent or epoxy. After arranging the fibers uniformly, they were compressed for a few minutes in the mould. Then the compressed form of fibers (sisal/jute) is removed from the mould. This was followed by applying the releasing agent on the mould, after which a coat of epoxy was applied. The compressed fiber was laid over the coat of epoxy, ensuring uniform distribution of fibers. The epoxy mixture is then poured over the fiber uniformly and compressed for a curing time of 24 h, with load of 5kg. Composites are prepared by changing the weight fractions of both sisal and jute fibers. Individual composites with sisal and jute as reinforcement are also prepared under similar processing conditions for comparison purpose. Laid over the coat of epoxy, ensuring uniform distribution of fibers. The epoxy mixture is then poured over the fiber uniformly and compressed for a curing time of 24 h, with load of 5kg. Composites are prepared by changing the weight fractions of both sisal and jute fibers. Individual composites with sisal and jute as reinforcement are also prepared under similar processing conditions for comparison purpose [14].

III. Testing Of Composites

1. Tensile Test:

The hybrid composite material fabricated is cut into required dimension using a jig saw cutter and the edges finished by using emery paper for mechanical testing. The tensile test specimen is prepared according to the ASTM D638 standard. The dimensions, gauge length and cross-head speeds are chosen according to the ASTM D638 standard. [15] A tensile test involves mounting the specimen in a machine and subjected to the tension. The testing process involves placing the test specimen in the testing machine and applying tension to it until it fractures. The tensile force is recorded as a function of the increase in gauge length. During the application of tension, the elongation of the gauge section is recorded against the applied force. The tensile test is performed on the Universal Testing Machine (UTM).There are five different kinds of specimens are prepared according to the fibers used. The first specimen consists of (0/40) pure sisal. The second specimen consists of (10/30) jute/sisal. The third specimen consists of (20/20) jute/sisal. Fourth specimen consists of (30/10) jute/sisal and fifth specimen is consists of (0/40) pure jute. The fabricated specimen for tensile test is presented in Fig. 2. The experiments are repeated for several times and the average values are used for discussion.

Fig: 2 Tensile test specimens

2. Flexural Test:

The flexural specimens are prepared as per the ASTM D790 standards [16]. The 3-point flexure test is the most common flexural test for composite materials. Specimen deflection is measured by the crosshead position. Test results include flexural strength and displacement. The testing process involves placing the test specimen in the universal testing machine and applying force to it until it fractures and breaks. The specimen used for conducting the flexural test is presented in Fig. 3.

Fig: 3 Flexural test specimens

IV. Results and Discussion

1. Tensile Strength:

Table1. Tensile Properties of Different Composite Samples.

Composites	% Weight fraction	Tensile Strength (MPa)	Tensile Modulus (MPa)
Pure sisal	0/40	38.93	1585.2
Jute/sisal	10/30	37.61	1468.25
Jute/sisal	20/20	39.93	1597.28
Jute/sisal	30/10	31.31	1246.89
Pure jute	40/0	36.93	1457.2

The load with respect to the displacement for different combination of composite specimen is presented in Fig. 4. The results indicated that (20/20) 39.93 MPa, (jute/sisal) specimen gives better tensile strength then the other four types of composites. The ultimate tensile strength of the pure sisal and pure jute composites are 38.93 MPa and 36.93 MPa respectively. Hybrid combination of fibers jute/sisal (10/30) and (30/10) composite values were observed to be low as compared to pure composites. The effect of hybridization is found to be negligible for the above two composites. This behavior can be correlated to hybridization effect as both fibers contributed higher tensile strength to the composite.

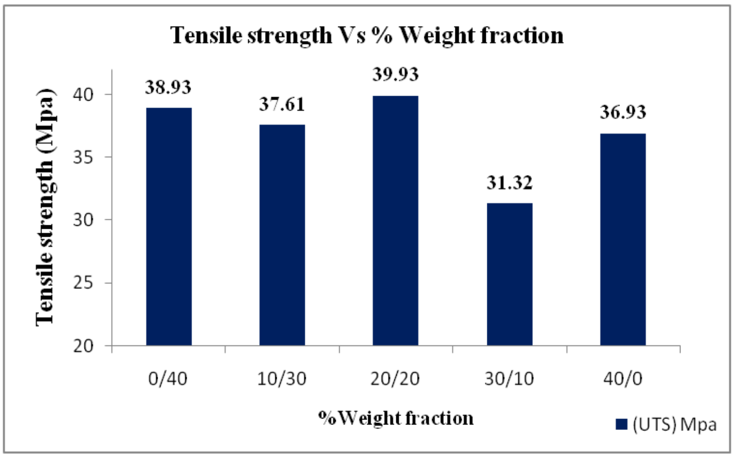

Fig: 4 Tensile Strength Vs Weight Fraction

The tensile modulus of sisal/jute fiber hybrid composites values presented in table 1. Fig 5, the results indicated that the (jute/sisal) (20/20) hybrid composite exhibits higher tensile modulus, than the other fiber reinforced composites. The jute/sisal hybrid composite tensile modulus values for w/f (10/30) and (30/10) are 1468.25 MPa and 1246.25 MPa respectively. But it is lower than the pure composites**.**

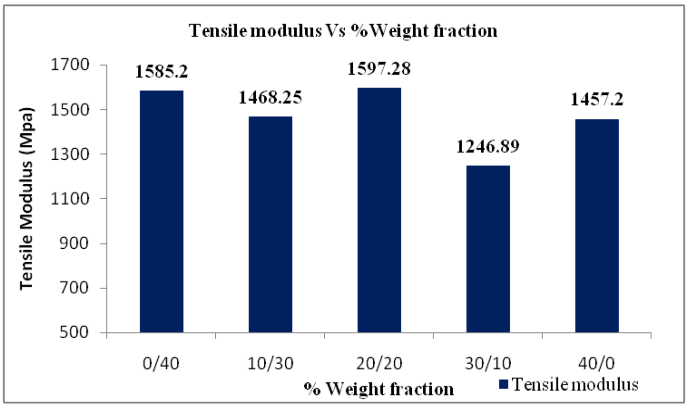

Fig: 5 Tensile Modulus Vs Weight Fraction

Flexural strength:

Table 2. Flexural Properties of Different Composite Samples

Composites	% Weight fraction	Flexural strength (MPa)	Flexural modulus (MPa)	Elongation
Pure sisal	0/40	87.15	3486	4.25
Jute/sisal	10/30	84.35	3374	3.86
Jute/sisal	20/20	88.33	3533	4.72
Jute/sisal	30/10	82.26	3482	1.72
Pure jute	40/0	87.05	3330	2.74

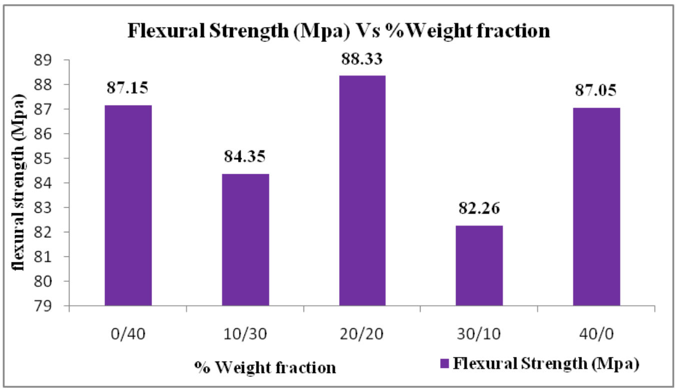

Fig: 6 Flexural Strength vs Weight Fraction

Fig: 6 show that jute/sisal (20/20) hybrid composite exhibits better results among the others. It has been observed that pure sisal and pure jute composite values are 87.15 MPa and 87.05 MPa, these composites performing well when compared to other hybrid composites. The hybrid composites of jute/sisal (10/30) and (30/10) values are compared to low as pure composites. The increase of flexural strength is due to the increased area of bonding at the interfacial region of the matrix and fiber.

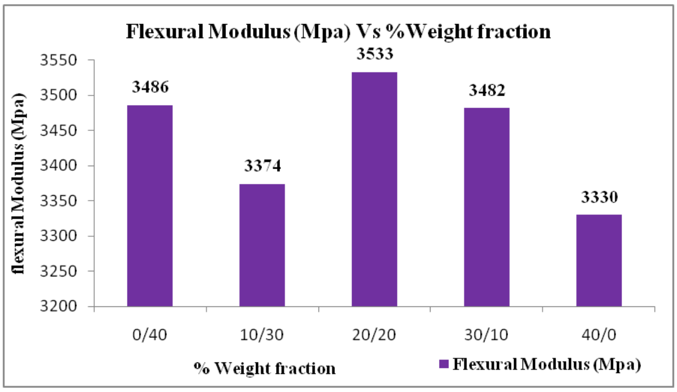

Fig: 7 Flexural Modulus vs Weight Fraction

Sisal/jute hybrid composites is considerable increase of flexural modulus as the percentage adds jute/sisal fiber increases to maximum value of (20/20) 3533 MPa as shown in Fig 7.The flexural modulus were observed pure sisal and pure jute values are 3486 MPa and 3330MPa respectively. The hybrid combination of jute/sisal (10/30) and (30/10) flexural modulus values are very low, when compared to pure composites.

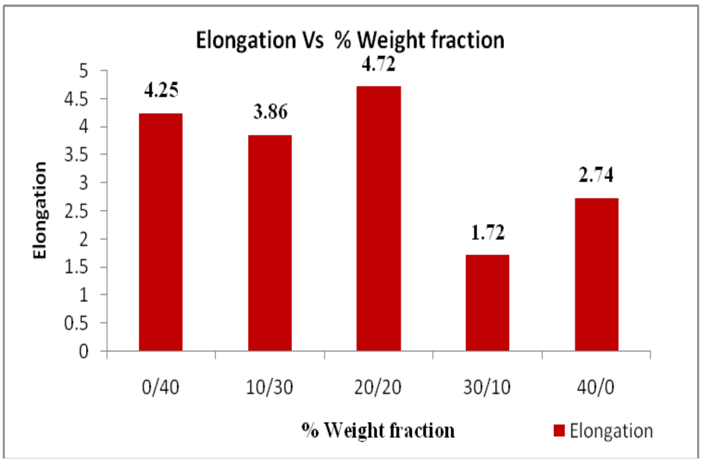

Fig: 8 Elongation vs % Weight fraction

Fig8, the results indicated that elongation of sisal/jute hybrid composite (20/20) value is 4.72MPa. It is evident that the highest tensile strength and highest elongation was found. This can be attributed that hybridization effect as both fibers contributed higher strength and elongation of the hybrid composite.

V. Conclusions

After determining the material properties of natural fiber reinforced epoxy hybrid composites with five different weight fractions of the materials, the following conclusions can be made.

1. Successful fabrication of the hybrid composite using sisal/jute fiber reinforced epoxy has been done by the hand layup technique.
2. It can be observed that jute /sisal (20/20) weight fraction hybrid composite samples possess good tensile strength and can with stand the strength up to 39.93 MPa.
3. The jute /sisal (20/20) weight fraction hybrid composite samples maximum flexural strength 88.33MPa.
4. Now a day's most of automobile manufacture company's try to replace synthetic fibers with natural fibers but it is not comparable in properties. While fabricating hybrid composite by the combination of two natural fibers given them advantage to replace synthetic fibers.
5. This work also demonstrates the potential of the hybrid natural fiber composites can be regarded as a useful material in light weight applications.

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