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Prediction of Mechanical Properties and Morphological Characterization of the Reinforced Hybrid Natural Fiber Polymer Composites using the Bidirectional Sisal Fiber and Woven Jute

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Abstract — *The demands on material performance are so great and diverse that no one material can satisfy them, e.g., lightweight yet strong & stiff structure. Composite material offers the advantage of a flexible design that can be tailored to the design requirements. While comparing metals like steel & aluminum with composites, the composites show the better results such as comparison by weight composites are much lighter and have low thermal expansion than other two metals and similarly in case of stiffness &. Composite materials have picked up fame in superior products that should be lightweight yet sufficiently strong enough to take cruel stacking. Carbon composite is a basic material in today's dispatch vehicles and shuttle. Composite materials also manufacture many aerospace parts due to their relevant properties and cheaper than metals. It is generally used in solar board substrates, antenna reflectors, and burdens of the rocket.*

Different synthetic fibers like nylon, glass, polyester, and carbon are mainly utilized to reinforce plastics composites. Natural and bio-degradable products are a good replacement for the high-cost materials. The role of composite materials in the field of engineering is gradually increasing. The composite consists of mainly two phases, i.e., matrix and fiber.

This study evaluates mechanical properties such as impact strength of hybrid sisal/jute reinforced epoxy composites. The composite samples are prepared by hand lay-up and compression molding technique. The hybrid composites of sisal/jute are fabricated with various weight ratios (100/0, 70/30, 50/50, 30/70, and 0/100) at 20% and 30% overall fiber fraction. The results showed that the hybrid fiber composites performed better than non-hybrid fiber reinforced epoxy composites. Structural analysis was carried out to check fracture behavior and fiber pull out of the samples using a scanning electron microscope

Keywords — *Hybrid, Mechanical Properties, morphological characterization, and Compression Molding* Introduction.

I. INTRODUCTION

In recent years, the attraction of using plant fibers as support in plastic has expanded drastically in numerous applications due to their comparative good mechanical and chemical properties. Natural fibers are less expensive, bio-degradable, and have no health hazards. The tensile, flexural, and dielectric properties of fabricated composites manufacture by reinforcing vakka, sisal, bamboo, banana fibers into the polyester polymer. The composites of vakka were compared with other fiber composites for their properties [15]. All composites were fabricated for the different volume fraction of fibers, such as 37% for tensile and 39% for dielectric and flexural. The different length of banana fibers (5 to 20 mm) is used to prepare the composites and samples were prepared for different fiber weight fractions (8%, 12%, 16%, and 20%) [20]. Alfa fibers are subjected to alkali treatments with NaOH solution at 1%, 5%, and 10% for 0, 24, and 48 h at 28 °C. The fiber weighting fraction kept 40% constant for all composites. The results offered that al-kali treated fibers' flexural behavior improved compared to the untreated fiber composite. The flexural strength was improved from 23 MPa to 57MPa for 10% NaOH treated composite for 24hr [16]. It was noticed that the tensile behavior of fabricated samples was almost comparable to bamboo fiber composite but 1.89 times better than that of sisal fiber composite whereas, flexural con-duct of jowar fiber composite is 4%, 35% better than bamboo fiber and sisal fiber composites, respectively. The results demonstrated that the addition of glass fiber layers into natural fiber composites improved tensile behavior.

In contrast, the flexural properties were enhanced by two layers of glass fibers on a banana–sisal compo-site rather than three glass fiber layers. The impact strength was improved when sisal and three-layer glass fiber were used [1]. The jute fiber reinforced natural rubber green composite was prepared at fiber loading of 0, 10, 20, and 40 wt.%, and composites were fabricated with the help of two roll mills and after that by hot pressure molding technique [11]. The hybrid composites were prepared for 15, 20, 25, and 30 weight fraction. The viscoelastic properties and water absorption properties were studied for fabricated composites. The hybrid composite with the highest fiber fraction proved to be better than other composites [4]. It has been proved that the tensile property (TS), tensile modulus (TM), bending strength (FS), flexural modulus (FM), and impact strength (IS) of untreated jute composite were improved about 103%, 211%, 95.2%, 42.4%, and 85.9%, respectively. It was also found that woven jute FRP compo-sites in warp/weft conditions resulted in higher mechanical conduct than non-woven jute FRPC [5]. In recent years, Natural fibers based polymer composites had proved itself an alternative to plastic in numerous applications because of their comparative good mechanical and chemical attributes. Natural fibers are less expensive, bio-degradable, and have no wellbeing risk.

As discussed previously, many studies have been carried out for developing green composites at different process parameters such as type of natural fibers, fiber fractions, polymers, and many more. Still, little work has been done on the hybridization of two natural fibers at different fiber fractions to identify the effect of hybridization on composites' mechanical properties.

II. EXPERIMENTATION

In this research work, the two types of natural fiber (i.e., Sisal and Jute fiber) and epoxy resin were selected. The samples are prepared at different fiber fractions to evaluate their mechanical properties, such as impact strength. Morphological characterization is studied to analyze the fractured surfaces' internal structure and material failure morphology by using SEM.

TABLE I

Properties	Jute	Sisal
Density(g/cm3)	1.34	1.48
Tensile Strength (KN/mm^2)	610-720	410-780
Stiffness(KN/mm)	30-38	10-30
Elongation at break (%)	2-3	1.9
Moist Absorption	11	12

The epoxy C-51 and Hardener K-59 is used. Vaseline is used as a releasing agent in this work.

Jute mate and bidirectional sisal hybrid and non-hybrid composites are fabricated by reinforcing the sisal and jute fibers in the epoxy matrix by hand lay-up procedure. The epoxy resin C-51 and related hardener K-59 are mixed in a proportion of 2:1 by weight as prescribed. The composite specimens are fabricated at 20% and 30% fiber weighting fraction. Further, the fiber fraction of hybrid composites are divided into three sub-parts 15:5, 10:10, and 5:15 (means 15% fiber fraction are given by jute and 5% by sisal and vice versa) for 20% fiber loading hybrid specimens and 10:20, 15:15, and 20:10 in case of 30% fiber loading hybrid composites. Raw sisal and jute mate fibers of 320mm length and 90mm width are used for specimen preparation. The lamina consisted of layers of jute mate and bidirectional sisal fibers, and the number of mute jute layers depends upon the weight of fiber used, and each layer was 4g. At first, the fibers were dried under sunlight for 1 to 2 hours. Before preparing the resin and hardener solution, both are kept under sunlight for half an hour for homogeneous mixing. The mixture is stirred physically to diffuse the resin and the hardener in the framework. Vaseline is utilized to facilitate the easy evacuation of the composite from the mold after curing. Every composite is cast under a load of 400 KN for 24 hours to get the perfect shape and thickness.

For Jute mate composites, first of all, Vaseline layers are applied over both surfaces of the die. The resin mixture layer is applied over Vaseline's layer, and then the first layer of jute mate fiber is filled with a matrix solution. The second layer of jute mate fiber is then placed over the matrix solution before it gets dried, and the next layers are filled. The air void formed between the layers amid fabrication is delicately squeezed out by utilizing a steel plate. Then, close the mold with their other half and kept under load for 24 hours at room temperature. Similarly, bidirectional sisal composites are prepared by changing the orientation of sisal fiber, and also, hybrid composites are prepared by a similar method

TABLE II

Sr. No.	Samples	Weight of fiber (g)			Weight of composite (g)	%Age of fiber used		Total %age of fiber in composite
		Jute	Sisal	Total		Jute	Sisal	
1.	S01	0	26	26	134	0	100	20
2.	S02	28	0	28	140	100	0	20
3.	S03	18	8	26	124	70	30	20
4.	S04	13	13	26	121	50	50	20
5.	S05	8	18	26	130	30	70	20
6.	S06	0	44	44	148	0	100	30

7.	S07	45	0	45	152	100	0	30
8.	S08	32	14	46	150	70	30	30
9.	S09	22	22	44	150	50	50	30
10.	S10	14	32	46	153	30	70	30

Table II shows the detail of the fabricated hybrid and non--hybrid composites. From the above table, it is clear that 26-28 grams of fiber and 130-135 gram of resin give a fiber fraction of 20% whereas 44-46-gram fiber and 160 gram of resin give a fiber fraction of 30% at 400 KN load. Samples S01, S02, S06, and S07, are non-hybrid composites, whereas the remaining samples S03, S04, S05, S08, S09, and S10 are a hybrid composite of sisal/jute epoxy composites at different percentages of sisal and jute fiber.

$$\%W\_f = w\_f/w\_c \times 100 \qquad (1)$$

$$\%W\_r = w\_r/w\_c \times 100 \qquad (2)$$

Fiber loading percentage in the composite can be calculated either by volume or by weight percentage. Jute/sisal fiber reinforced epoxy composite specimens weight fraction ratios were calculated using the following formulas [10].

Where %Wf and %Wr are the weight fraction percentage ratios of fiber and resin respectively in the composite; wf and wr are the weight of fiber and resin mixture used (g), and wc is the weight of composite (g).

%Wf = the weight fraction percentage ratios of fiber.

%W_r= the weight fraction percentage ratios of resin

III. RESULTS AND DISCUSSION

This part deal with the mechanical behavior of the hybrid and non-hybrid sisal/jute reinforced epoxy composites. Mechanical attributes of composites, such as impact strength and morphological characterization, have been studied and discussed.

A. Impact Strength

The graphs represent the resistance offered by composites to impact energy. As discussed above, the impact strength of non-hybrid bidirectional sisal composites (S01 and S06) is also more than jute mate composites (S02 and S07).

TABLE III

Total %age of Reinforcement In Composite (Weight Fraction)	Composites type	Nomenclature of Samples	Impact Energy (Joules)
20%	Non-hybrid	S01	1.5
	Non-hybrid	S02	1.0
	Hybrid	S03	1.5
	Hybrid	S04	1.5
	Hybrid	S05	2.0
30%	Non-hybrid	S06	2.0
	Non-hybrid	S07	1.5
	Hybrid	S08	2.0
	Hybrid	S09	2.0
	Hybrid	S10	2.5

Table III impact strength of jute/sisal hybrid and non-hybrid composites.

When sisal fiber is added to jute fiber composite, it improves the jute composite's impact strength (hybrid samples S03, S04, S05, S08, S09, and S10). The maximum impact strength is 2 J and 2.5 J obtained by samples S05 and S10 respectively for 20% and 30% fiber fraction. Further, it is concluded that the flexural strength of composites is increased by increasing fiber fraction.

The hybridization of sisal and jute fiber at 20% weighting fraction results in an increase in the impact strength of hybrid composites by amount of 33.33%thansisal fiber composite and 100% than jute composites.

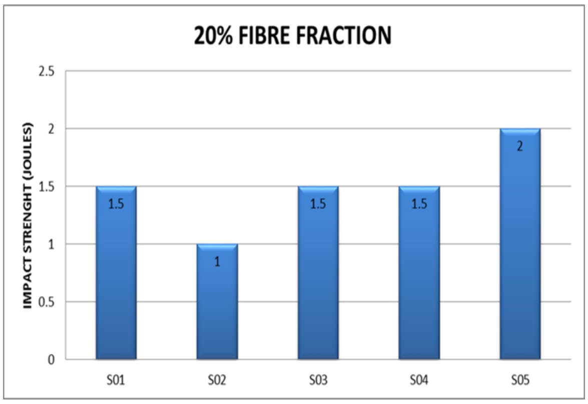

Fig. 1 Graphical representation of Impact strength for 20% fiber fraction composites

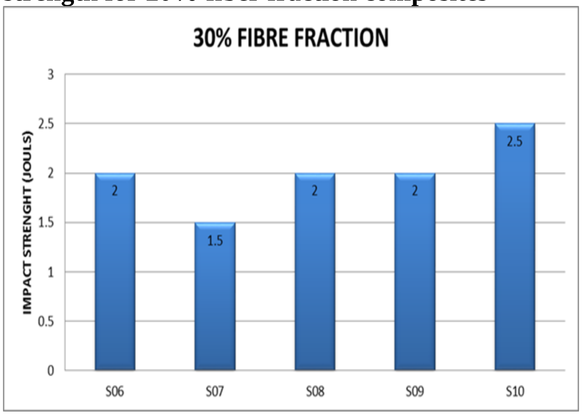

Fig. 2 Graphical representation of Impact strength for 30% fiber fraction composites

In the case of 30% wt. Fraction, bending strength of hybrid composites is improved by 25% than SFREC and 66.66% than JFREC. The maximum flexural strength is obtained when 70% sisal fiber and 30%

jute fiber are used for fabricating composites at both fiber fraction.

B. Morphological characterization

The morphological characterization is done by scanning electron microscope (SEM) to analyze the fractured cross-section of samples under tensile, bending, and impact loading. The specimens which exhibit high elastic strength (S09), bending strength (S10), and impact strength (S10) are studied to analyze their microscopic structure. From all SEM images, it concluded that the failure of samples (or matrix and fiber) is due to tensile, bending, and impact loading, respectively. The SEM image of the tensile sample is shown in Fig. 3. In Fig. 3 large amount of fibers is pullout under tensile loading, and the pulling of fibers from the matrix offered high resistance and decreased the brittle nature of composite. Also, the combination of two nature fiber increases the tensile strength of composite

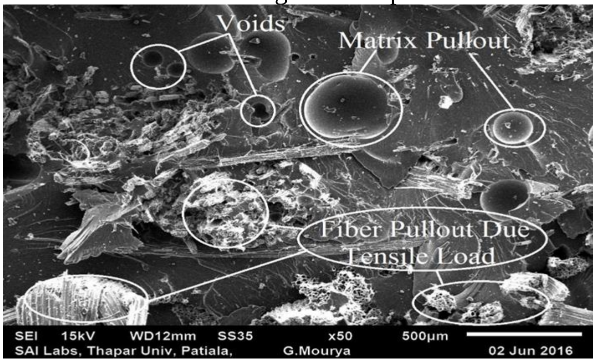

Fig. 3 SEM image of the sample subjected under tensile loading

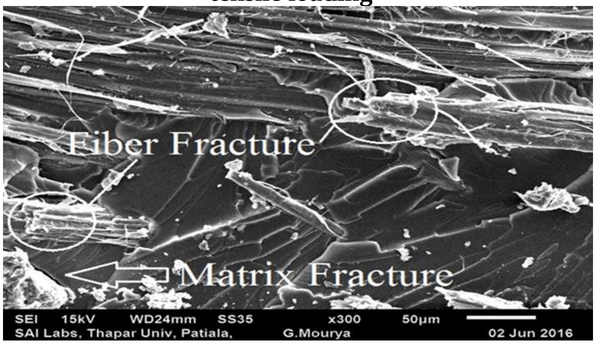

Fig. 4 SEM image of the sample subjected under flexural loading

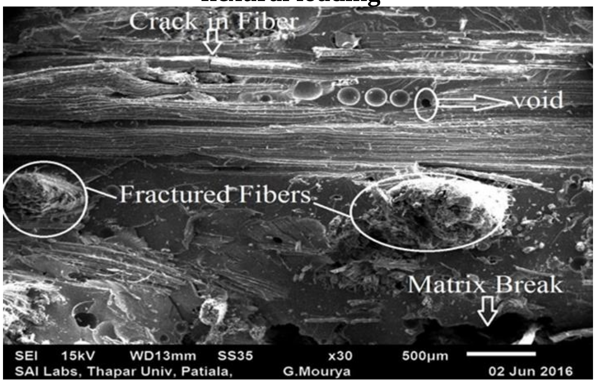

Fig. 5 SEM image of the sample subjected under impact loading

Fig. 4 shows the failure of the manufactured composite under flexural loading. It is clear from the SEM image that many fibers are pulling out from the matrix due to the bending load applied on the specimen, and pulling fibers offered high resistance against the bending load. The amount of resistance offered by fibers depends upon the number of fibers in composite (the large the amount of fiber, the larger will be the resistance or strength against the external force applied). Fig. 5 tested sample subjected under impact load. The samples are fabricated using bidirectional sisal and jute fiber. It is clear from Fig. 5 that only fibers along the composite's length are fractured due to impact load whereas, the fibers in other directions remain solid and offer low resistance against impact load.

IV. CONCLUSIONS

The woven jute and bidirectional sisal fiber reinforced hybrid and non-hybrid epoxy composites were fabricated in the present study. These composites were subjected to mechanical characterization as well as morphological characterization. The following conclusion has been derived out of this thesis work:

•Successfully developed the hybrid natural fiber reinforced polymer composites with hand lay-up and compression molding technique.

•The maximum impact strength is 2 and 2.5 joules for 20% and 30% fiber fraction composites, respectively, and achieved by composite having 30% jute and 70% sisal fiber.

•SEM showed many fibers are pulling out and subjected to large resistance and have no porous structure, which results in high mechanical properties.

•Mechanical characterization and morphological characterization are completely relevant to each other.

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