Study on Mechanical Characteristics of Unidirectional Sisal/Glass Fiber Reinforced Polyester Hybrid Composites

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Abstract: ***This paper presents the mechanical behavior of sisal/glass fiber reinforced polyester hybrid composites. Sisal fiber has been hybridized with glass fiber reinforced polyester using hand lay-up process to improve the mechanical properties. Test specimens were prepared using glass fiber(GF)/sisal fiber of 30/70, 50/50 and 70/30 weight fraction ratios as per ASTM standards and mechanical properties like tensile, impact and flexural strength of sisal /glass fiber reinforced polyester are evaluated and compared. The results shows that tensile strength of 30%GF-70%sisal composition and flexural strength of 70%GF-30%sisal composition and impact Strength of 50%GF-50%sisal composition is found to be better than the remaining two compositions.***

Keywords: Sisal fiber, glass fiber (GF), Hand Lay-up, Polyester

1. Introduction

The development of composite materials and their related design and manufacturing technologies is one of the most important advances in the history of materials. Environmental awareness among all over the world focused the attention towards the use of natural fiber as reinforcement in polymer matrix. The natural fiber reinforced composites are high specific strength, low weight, low cost, fairly good mechanical properties, non-abrasive, eco-friendly and bio-degradability characteristics. Among various natural plant fibers, sisal fiber has a great potential to be used as reinforcement in polymer composites. Over hundreds of years sisal has been used in the applications of ropes, beds, bags etc. Sisal is abundantly available in India, East Africa, China, etc. Glass fiber reinforced polyester (GFRP) composites are largely used mainly due to a combination of low cost and good mechanical properties. The tensile strength and elastic modulus increased upon glass fiber incorporation and for higher % volume fraction (Vf). This behavior is mainly due to the higher strength and stiffness of the glass fiber in relation to curaua and the better adhesion of the former with the polyester resin [1]. Use of eco friendly composites gains attraction due to its lightweight and moderate strength in the recent years. The mechanical properties of the composites are improved due to the addition of glass fiber along with palmyra fiber in the matrix [2]. Mechanical and water absorption behaviour of banana/sisal reinforced hybrid composites were studied by Venkateshwaran.et.al. [3]. they observed that the addition of sisal fiber in the composite increase in tensile strength, flexural strength and increase in impact strength. The mechanical behaviors of unidirectional flax and glass fiber reinforced hybrid composites with the aim of investigation on the hybrid effects of the composites made by natural and synthetic fibers. The tensile properties of the flax/glass fiber reinforced hybrid Composites were improved with the increasing of glass fiber content [4]. The incorporation of sisal–jute fiber with GFRP can improve the properties and used as an alternate material for glass fiber reinforced polymer composites [5]. Hybridization of natural fiber composite by another natural fiber does not yield superior mechanical properties as hybridization by glass fiber [6,7] and hence this kind of hybrid composite are suitable for low cost applications and this kind of materials very popular in engineering market such as automotive and construction industries [8].

In this work, unidirectional sisal fibers and glass fibers were selected to make the hybrid composite laminates. The mechanical properties, such as tensile, flexural and impact properties of the hybrid composite laminates were studied.

2. Materials and Experimental Details

2.1. Materials

The unidirectional Glass-Fiber Reinforced Polymers (GFRPs) of 300gsm were supplied by Suntech Fibre Private Limited, Bangalore. The unidirectional sisal fibers were supplied by Chandra Prakash & Co, Jaipur. Isophthalic polyester resin and the catalyst Methyl Ethyl Ketone Peroxide (MEKP), Cobalt Napthanate accelerator is added as 10:1 with the resin and the catalyst are purchased from Chemicote Engineers., Bangalore, India.

2.1.1. Sisal fibers

Sisal fiber with the botanical name *Agave sisalana* is derived from the leaves of the plant. Sisal fiber is fairly coarse and inflexible. It is valued for cordage use because of its strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in saltwater. Sisal is used various purpose making of ropes, baler and binders twine. Ropes and twines are widely employed for marine, agricultural, and general industrial use. The properties of sisal fibers are given in Table 1 [5].

Table 1 Physical properties of sisal fiber.

Physical property	Sisal fiber
Density (g/cm3)	1.41
Elongation at break (%)	6-7
Cellulose content (%)	60-65
Lignin content (%)	10-14
Tensile strength (MPa)	350-370
Young’s modulus (GPa)	12.8
Diameter (lm)	205-230
Lumen size (lm)	11

2.1.2. Glass-fiber reinforced polyester

Fiberglass is the common name for glass-fiber reinforced plastic (GFRP). Fiberglass is a fiber reinforced polymer made of plastic reinforced by glass fiber. The plastic may be a thermosetting plastic- most often epoxy, polyester, vinylester. Fiberglass is a strong lightweight material and is used in aircraft, boats, automobiles, telecommunication, bath tubs and enclosures, hot tubs, thermal and electrical insulation, septic tanks, water tanks, roofing, pipes, cladding, casts, surfboards, and external door skins. Although it's not as strong and stiff as carbon fiber it is less brittle, and its raw materials are much cheaper. Its bulk strength and weight are also better than many metals, and it can be more readily molded into complex shapes.

2.2 Mould preparation

Mould used in this work is made of stainless steel of 260 x140 x10mm^3 dimensions with four beadings as shown in fig.1-4. 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 Wax and allowed to dry. The function of top plate is to cover, compress the fiber after the polyester resin is applied.

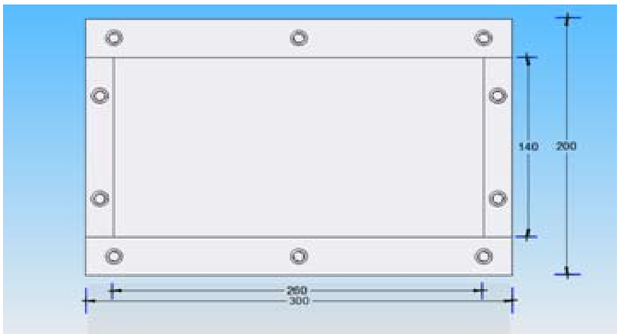

Figure 1: Top view of the base plate

Figure 2: Front view of the base plate

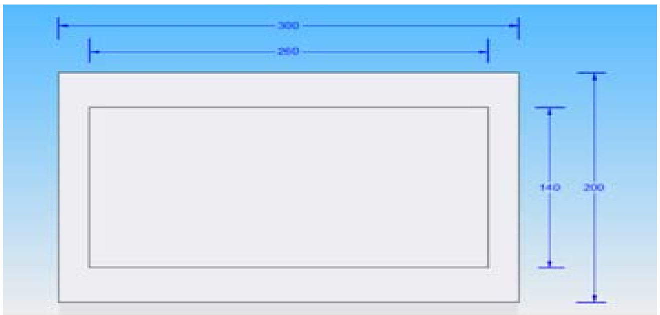

Figure 3: Top view of the top plate

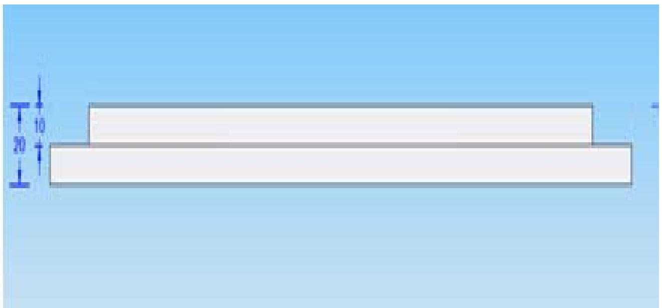

Figure 4: Front view of the top plate

2.3 Fabrication of Composite Specimen

Unidirectional sisal fibers of 260 mm length were used to prepare the specimen. The composite specimen consists of number of layers in which glass fiber layers and sisal fiber layers are placed alternatively until we obtain required thickness. The layers of fibers are fabricated by adding the required amount of polyester resin. The glass fiber is mounted on the mould. The glass fiber reinforced polymer is then completely filled with polyester resin. The resin got mixed with glass fiber reinforced polymer, which may tend to dry up within15–20 min. Before the resin gets dried, the second layer of sisal fiber is mounted over the glass fiber reinforced polymer. The polyester resin applied is distributed to the entire surface by means of a roller. The air gaps formed between the layers during the processing are gently squeezed out. The processed composite which is placed in the base plate of mould is then closed by the top plate of mould, and pressure is applied over the mould and kept for several hours to get the perfect samples. After the composite material gets hardened completely, then is taken out from the mould. In this study, the test specimens were prepared using GF/sisal fiber of 30/70, 50/50 and 70/30 weight fraction ratios and test samples were cut to the required sizes prescribed in the ASTM standards.

2.4 Testing Standards

After fabrication, the test specimens were subjected to various mechanical tests as per ASTM standards. The standards followed are ASTM D 638 for tensile test of specimen dimension is 246x29x10 mm^3. The flexural strength was determined as per ASTM D 790 of specimens having rectangular shape dimension of 150x12.7x10 mm^3. Both tensile and flexural strength were carried out using Instron Universal Testing Machine (UTM) 3382. The impact strength of the composite specimens was determined using a Charpy impact tester (Tinius Olsen 504) as per ASTM A370 Standard.

3. Results and Discussions

The test results for the Tensile, Flexural and Impact testing for the three varieties of the hybrid composite samples are presented.

3.1 Tensile Characteristics

The different composite specimen samples are tested in the UTM and the samples are left to break till the ultimate tensile strength occurs. Stress–strain curve as shown in fig.5 is plotted for the determination of ultimate tensile strength and elastic modulus. The Tensile Strength comparison for different combinations of specimens is presented as in the fig.6.The tensile results are shown in Table 2.

Table 2: Experimental Results for tensile Specimens

Composition	Yield Load (N)			Tensile Strain at break (%)		
Specimen	S1	S2	S3	S1	S2	S3
30%GF-70%Sisal	6467.2	6392.4	6285.7	2.6	2.6	2.4
50%GF-50%Sisal	3518.4	3492.6	3507.1	7.0	6.9	6.9
70%GF-30%Sisal	1064.2	1047.9	1028.3	6.9	7.0	6.8

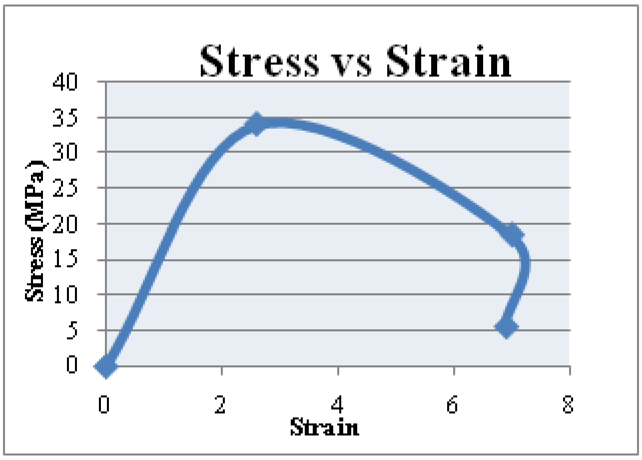

Figure 5: Stress – Strain diagram of tensile composite specimens

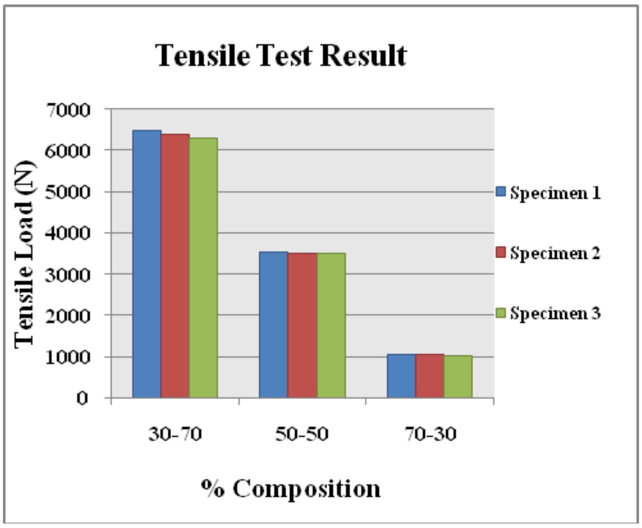

Figure 6: Tensile characteristics comparison of different compositions

3.2 Flexural Characteristics

Three point bend test was carried out in an UTM machine to measure the flexural strength of the composites. The flexural Strength comparison for different combinations of specimens is presented as in the fig.7.and results are tabulated in Table 3.

Table 3: Experimental Results for flexural Specimens

Composition	Flexural Load (N)			Flexural Stress (MPa)		
Specimen	S1	S2	S3	S1	S2	S3
30%GF-70%Sisal	177.23	176.42	175.91	31.41	31.255	31.165
50%GF-50%Sisal	218.67	214.58	220.71	38.741	39.102	31.016
70%GF-30%Sisal	222.23	220.12	218.51	39.371	39.6667	38.997

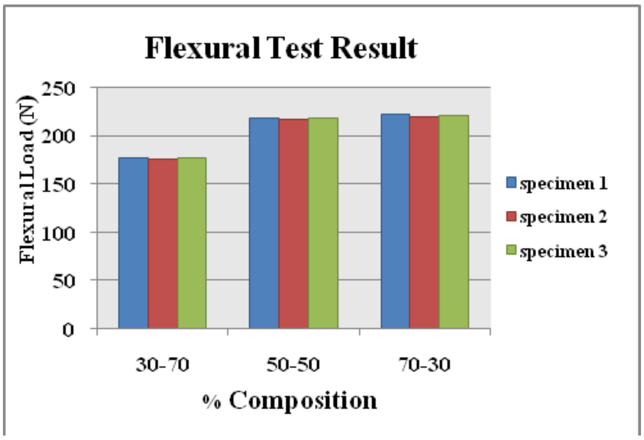

Figure 7: Flexural characteristics comparison of different compositions

3.3 Impact Characteristics

Charpy Impact Test was used to determine the impact properties of the material. The fig.8 shows the Impact Strength comparison of different compositions and test results shown in Table 4.

Table 4 Experimental Results for impact Specimens

Composition	Impact Energy (J)		
Specimen	S1	S2	S3
30%GF-70%Sisal	3.361	3.3143	3.2751
50%GF-50%Sisal	4.8585	4.6731	4.6297
70%GF-30%Sisal	2.6658	2.6612	2.6203

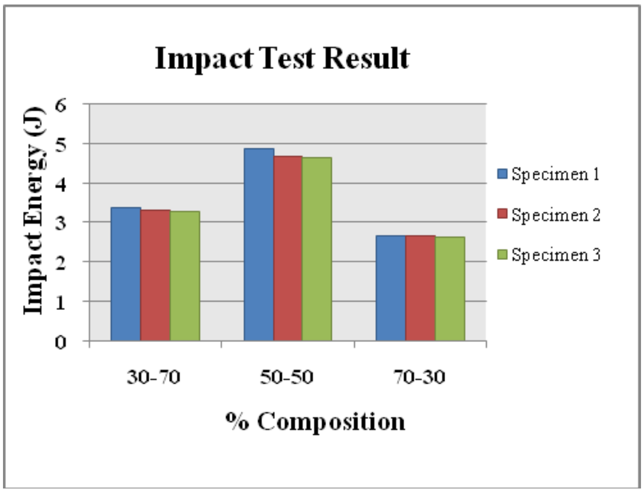

Figure 8: Impact characteristics comparison of different compositions

4. Conclusion

This experimental study on mechanical behavior of sisal/glass fiber reinforced polyester composites leads to the following conclusions:

- This work shows that successful fabrication of composites with different fiber composition is possible by hand lay-up process.
- In tensile test, 30%GF-70%Sisal composition of specimen S1 shows highest tensile strength of 6467.2N.
- In flexural test, 70%GF-30%Sisal composition of specimen S1 shows highest flexural strength of 222.23N.
- In charpy impact test, 50%GF-50%Sisal composition of specimen S1 shows highest impact strength of 4.8585J.
- Above results obtained on testing of unidirectional sisal/glass fiber reinforced polyester composites are not of significant value as compared to bi-directional polymers of sisal and hence further tests on sisal unidirectional polymers are not recommended.

5. Future Scope of this Study

This study leaves wide scope for future investigations. It can be extended to newer composites using other reinforcing phases and the resulting experimental findings can be similarly analyzed.

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