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Physical Performance of Sisal-PALF-Banana/Glass Fiber Reinforced Polyester Hybrid Composites

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The natural fibers are used as an alternate substitute for glass fiber reinforced polymer composite materials because of its availability and low cost. The present study investigates the mechanical properties of sisal-PALF-banana-glass fiber reinforced with polyester hybrid composites. The results indicated that there will be a vast increase in the superior properties like tensile strength, flexural strength and impact strength of sisal-PALF-banana fiber when it is reinforced with glass fiber in the polyester matrix composites. The interfacial properties are analyzed by scanning electron microscope.

Keywords: Hybrid Natural fiber composites, Polymer matrix composites, Sisal-PALF-banana fiber, Mechanical properties.

INTRODUCTION

The natural fiber replaces the synthetic fibers because of its low density, low cost and availability[1,2]. Usually the spiral angle of fibrils and the percentage of cellulose content present in the natural fiber influence the mechanical property, since the composition of cellulose content differ for each and every natural fiber, accordingly the mechanical properties are altered[3]. Saw pan[4] evaluated the flexural property of hemp fiber reinforced with unsaturated polyester composites in which it is found that flexural strength of the composites decreased with increase in fiber content. Thermal property of banana fiber is improved by reinforcing with polymer matrices[5]. Polarity parameters likes solvatochromy, zeta potential measurements and dynamic mechanical behaviour like storage modulus is found for chemically modified banana-fiber reinforced polyesters composites by Pothan *et al.*[6,7]. It is found that storage modulus value is highest for the silane A 151 fiber. They also reported activation energy values for chemically modified banana-fiber polyester composites using arrhenius plots. The interfacial electrical and mechanical properties of sisal-fiber composites and their hybrids have been evaluated by Li *et al.*[8]. Joseph *et al.*[9] reported the tensile properties for chemically treated short sisal-fiber reinforced polyethylene composites. Effect of chemical treatment on the tensile properties of sisal-FRP-LDPE has been investigated. Chemicals are used to enhance the bonding at the fiber polymer interface. Low concentration of permanganate in sisal-LDPE enhances mechanical properties. Peroxide treatment of fiber imparted maximum interfacial interactions. The tensile and impact properties of widely used sisal-fiber-reinforced thermo set matrices have been studied by Sanadi *et al.*[10]. Rong *et al.*[11,12] have studied the impact strength of pretreated fiber and they found the water absorption on the impact properties of sisal-fiber polyester and sisal-fiber epoxy matrices. They found better results on sisal-fiber epoxy matrices. Mechanical and physical properties of sisal-epoxy and sisal-phenol composites are evaluated by Bisanda and Ansell[13] and Yang *et al.*[14]. It is seen that sisal-epoxy composites possess better mechanical and physical performances.

Impact properties of different natural fiber reinforced composites including sisal, pineapple, banana and coir are investigated by Gordon and Jeronomidis[15]. They have shown good impact strength on sisal-fiber reinforced composites than the other fibers used. Tensile properties of sisal-fiber and surface modified sisal-fiber using alkali treatment and acid treatment are evaluated by Yang *et al.*[16]. Mechanical characterization is done with and without thermal treatment of natural fibers. Thermal characterization is done by using TGA. The results showed that sisal-phenolic composites possess good tensile and flexural strength with or without thermally treated sisal-fiber at 60 °C for 72 h by Yang *et al.*[16]. It is found that chemically treated polyester/natural fiber (banana/sisal) reduces the thermal contact resistance, but the hybridization of natural fiber with glass afford better heat transport ability of the composites. In the present study, the mechanical property evaluation of sisal-PALF-banana-glass fiber reinforced polyester composites is carried out and analysed in detail.

EXPERIMENTAL

In this present investigation, sisal-banana PALF and glass fibers are used for fabricating the composite specimen. The sisal and PALF fibers are procured from South India Textile Research Association, Coimbatore. Isophthalic polyester resin and the catalyst methyl ethyl ketone peroxide (MEKP) are procured from M/s. Sakthi Fiber Glass Ltd, Chennai, India.

The accelerator used for fabricating the composite is cobalt naphthenate and is added as 1 % with the resin as the catalyst. The Glass fiber reinforced polymers (GFRP) used for the fabrication is of a unidirectional mat having 1000 gsm.

Natural fiber: Natural fibers such as hemp, sisal, jute, flax, coir, coconut, pineapple and sugarcane are readily available and renewable. These materials have been used as reinforcement material for composites, since it possess low specific mass, easy handling, eco-friendly and bio-degradable.

Sisal fiber: It is a hard fiber extracted from the sisal leaves. It is one of the widely used natural fibers and grows in field hedges. Usually it produces 25 leaves and each one consists of 900-1000 fiber bundles. It is extracted through retting process followed by scraping. Mechanically created sisal plant give 3.5 % fiber with good quality than the retting process. Recently it is used in marine applications, fisheries and in many engineering fields.

Banana fiber: Banana fiber is prepared from the leaves of pseudostem of the plant and it contains less percentage of fiber (10 %) and the remaining is moisture. The fiber is extracted manually from the pseudostem of the plant. Usually fibers have been extracted from the leaves both inside and outside of pseudostem.

Pineapple leaf fiber: PALF presents in the spiky leaves of pineapples. The waste pineapple leaves were collected from sedenak or penak nanas, jahore during the harvest process. They were pressed using rapic two-roll mill to remove 90 % of water content. Fibers are extracted manually from these semi-dried leaves by sharp edge tool. The physical properties of sisal, pineapple leaf and banana fiber are presented in Table-1.

TABLE-1
PHYSICAL PROPERTIES OF SISAL, PINEAPPLE LEAF BANANA AND GLASS FIBER

Properties	Sisal	PALF	Banana	Glass
Density (g/cm^3)	1.45	1.44	1.35	2.54
Diameter (μm)	50-200	20-80	120 ± 5.8	5-25
Tensile Strength (MPa)	468-640	413-1627	550 ± 6.7	2000-3500
Young's Modulus (GPa)	9.4-22.0	34.5-82.51	20	70
Elongation at break (%)	3-7	1.6	5-6	2.5

Preparation of composite specimen: Composites are prepared by hand lay-up process. Chopped natural fibers such as sisal-PALF banana are used to prepare the composite. It consists of six layers in which glass fiber is placed in top, middle and bottom of the composite. The remaining layers are arranged by using sisal-PALF-banana. Sufficient quantity of polyester resin is added to complete the fabrication.

The resin gets distributed uniformly on the entire surface by pressing the surface using roller during which air voids formed are removed completely. The processed composite is pressed to improve the hardness and then it is dried. During pressing, excess of air present in between fiber and resin is removed and then it is dried for several hours to get equally sized samples.

Mechanical testing

Tensile test: The fabricated hybrid composite is subjected to the tensile test. The specimens are prepared using a diamond saw cutter and edges are smoothened by using an emery paper. The specimens are prepared and the test is carried out as per ASTM D638 standard. The tensile test is carried out by mounting the specimen in the chuck of the machine and is subjected to tension. The tensile force obtained during the tensile test is recorded as a function of increase in gauge length (elongation of gauge length). The tests are performed on Universal testing machine make FIE (Model: UTN 40, S.No.11/98-2450). Five different specimens are prepared *Viz*: (i) Sisal-banana-PALF-GFRP (ii) Sisal-PALF-GFRP (iii) Banana-PALF-GFRP (iv) Sisal-GFRP (v) Banana-GFRP. There are three experiments conducted on each fiber combination and average values are used.

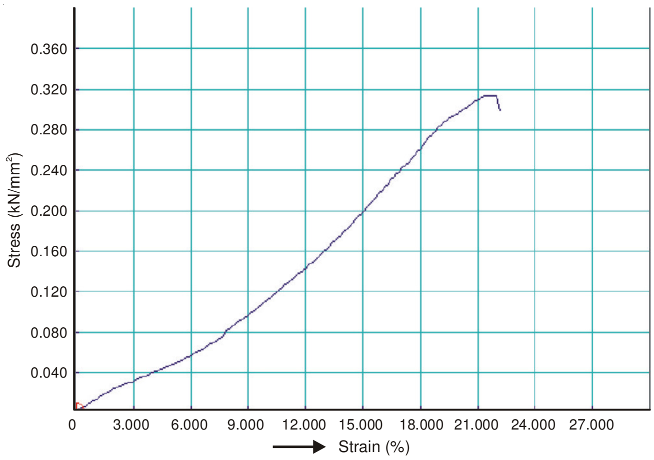

Fig. 1. Stress-strain sample graph generated from the machine for sisal-PALF-banana GFRP composite

Tensile test is carried out using universal testing machine. The stress-strain graph generated from the machine for sisal-PALF-banana-GFRP composite is presented in the Fig. 1. This curve is plotted to observe the elastic modulus and tensile strength of the sample. The stress-strain curve for different combination of composites is represented in the Fig. 2. The results indicated that the stress increases proportionally up to 22 mm strain and try to fall after the limit. The hybrid natural fiber with different combination shows variation in stress by varying the strain.

The results indicated that sisal-PALF-GFRP specimen gives composite gives better tensile strength than the other types of composites tested. Banana-GFRP hybrid composite possess low tensile strength than the other types considered. The comparative results of different composite specimen tested

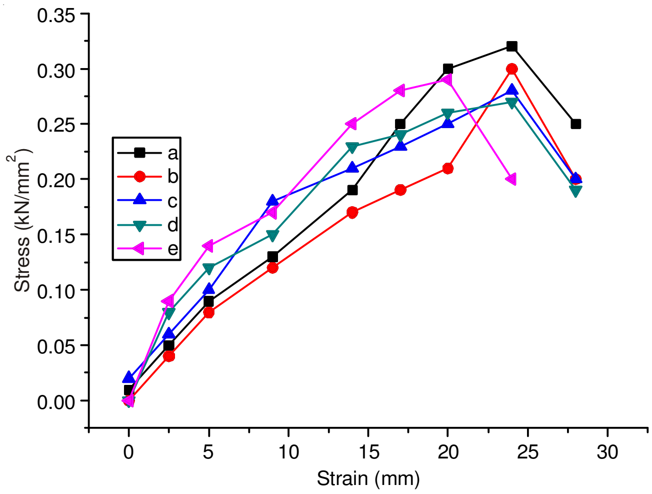

Fig. 2. Stress *vs.* Strain curve for different composites

are presented in Fig. 3. The ultimate tensile strength (UTS) of sisal-banana-PALF composite, sisal-PALF composite, banana-PALF composite, sisal-GFRP and banana-GFRP are in the range of 0.33 kN/mm^2, 0.27 kN/mm^2, 0.25 kN/mm^2, 0.23 kN/mm^2 and 0.07 kN/mm^2 respectively. The results indicated that the sisal-banana-PALF-GFRP composites outperformed the other types of composites tested followed by sisal-PALF-GFRP hybrid composites.

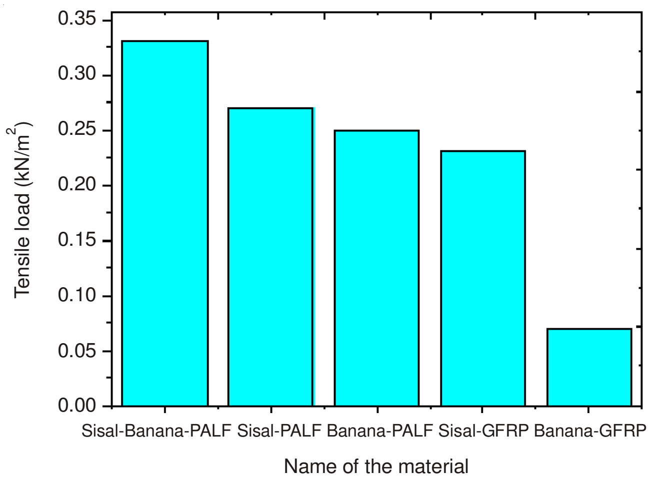

Fig. 3. Tensile load comparison of different composite materials

Flexural test: The flexural test is carried out using universal testing machine according to the ASTM standard D970. In the flexural test the specimen is placed under a compressive load until the composite specimen undergoes breaks or cracks. The tests are carried out at the room temperature having proper humidity. The flexural deflection of the specimen is measured. The experiments are repeated for 3 times and the average values are taken.

A sample graph of flexural strength observed for sisal-banana PALF composites was drawn. The flexure test gives the tensile stress in the convex side and compression stress in the concave side. It is the maximum stress in the outermost fiber. The result indicated that the displacement increases with the increase in applied load up to 6.2 kN and then it tends to decrease, *i.e.* breaking takes place. The maximum displacement observed is 3.2 mm. Fig. 4 shows load *vs.* displacement graph for different composites tested. The results indicated that the displacement increases with the increase of load. After the 3.2 mm breaking exists. The results indicated that sisal-banana-PALF-GFRP composite shows good flexural strength than the other composites tested.

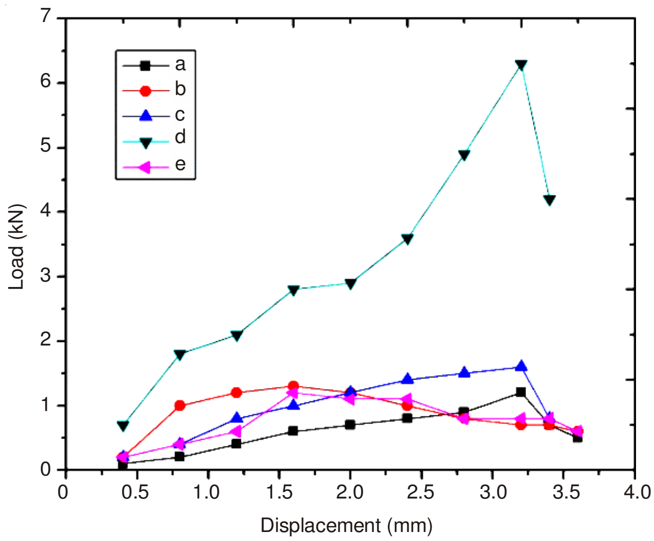

Fig. 4. Load *vs.* displacement curve for flexural test

The comparative results of different composites specimen tested are presented in Fig. 5. The ultimate flexural strength (UTS) of sisal-banana-PALF composite, sisal-PALF composite, banana-PALF Composite, sisal-GFRP, banana-GFRP are in the range of 6.5kN, 1.5kN, 1.4kN, 1.2kN and 0.09 kN respectively. The results indicated that the sisal-PALF-banana composite outperformed the other types of composites tested.

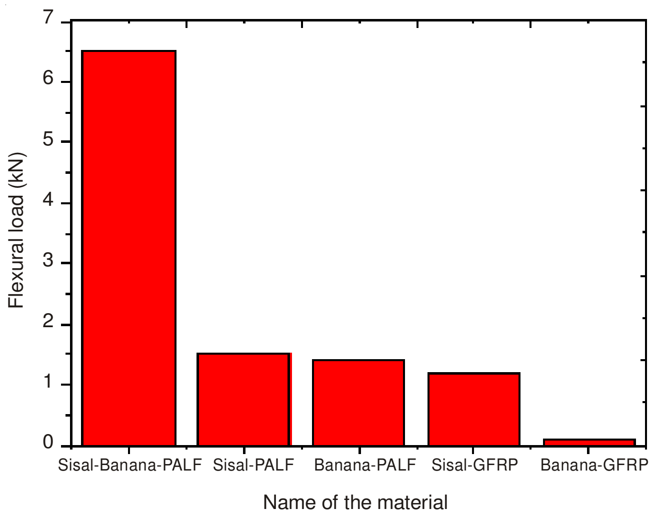

Fig. 5. Flexural load comparison of different composite materials

Impact test: The impact test of the specimen is carried out using impact testing machine. The samples are prepared according to the ASTM D6110 Standard. The tests are carried out at room temperature. The experiments are repeated for 3 times and average values are used for the analysis.

For finding the impact capability of the different specimen the impact test is carried out. The impact test is carried by charpy impact testing machine. The maximum impact strength is found for sisal-PALF-banana composite. The results are shown in Fig. 6.

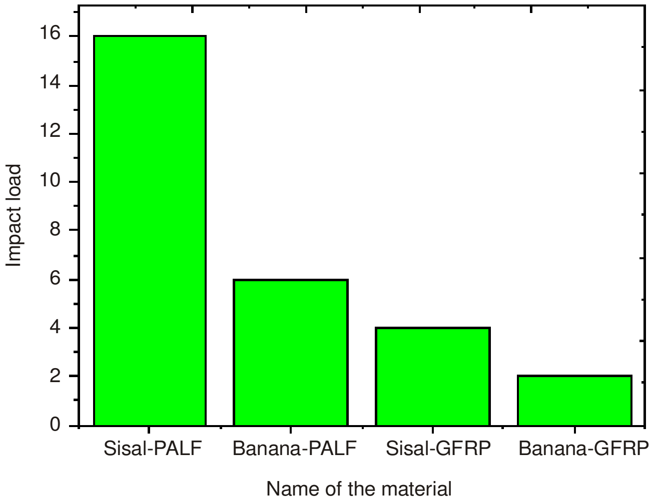

Fig. 6. Impact load comparison of different composite materials

Scanning electron microscope (SEM): External surface morphologies and different fiber loading is studied by scanning electron microscope. The fiber damage, various fiber-length distribution, Internal structures and cracks can be determined from the cross-sectional view of composite material. The fractured surface obtained from the tensile, flexural and impact specimen for the sisal-banana-PALF composite is presented in Figs. 7-10. The analysis are carried out in the cross-section of the material using scanning electron microscope.

The SEM image of the fractured tensile specimen of sisal-banana-PALF is presented in Fig. 7. The figure indicated that the fibers are separated from the matrix materials due to the application of load. There is a cavity observed in between the distributed fibers in the matrix. So the crack initiated at the breaking region of the specimen when we go to the middle to the end. There is a smooth surfaces observed which shows that bonding takes place in the composite material produced when the force is applied the fibers are separated and form as like in Fig. 7. Fig. 8 shows the magnified image of the sisal-banana-PALF composite material. Fig. 9 shows the flexural

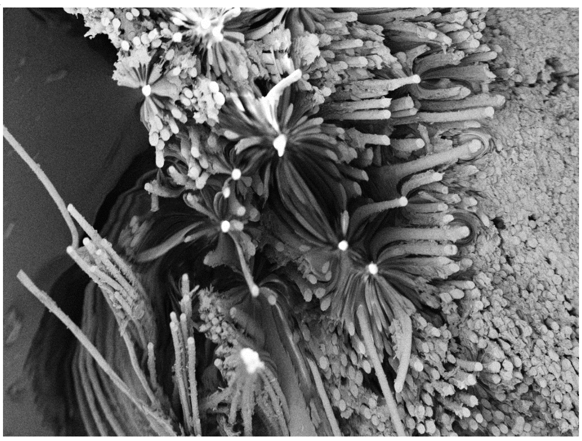

Fig. 7. Fractured tensile specimen observed through SEM for sisal-banana-PALF-GFRP composites subjected to tensile test

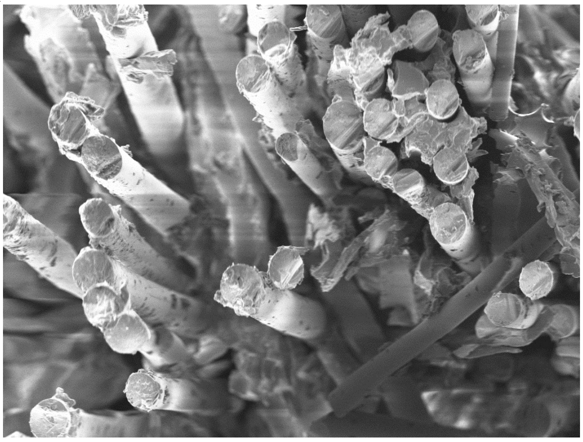

Fig. 8. Magnified SEM image for the sisal-PALF-banana subjected to tensile test

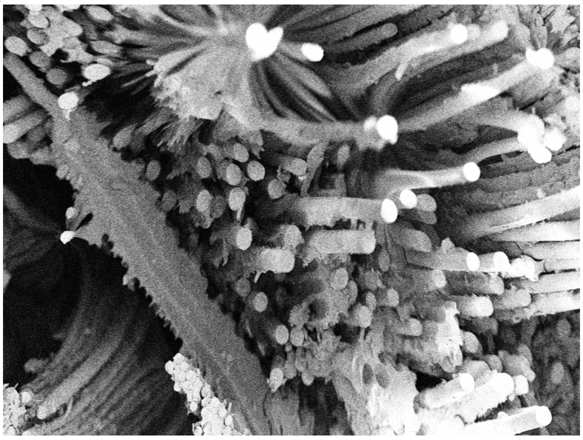

Fig. 9. SEM image for the cross-sectional view of sisal-PALF-banana subjected to flexural test

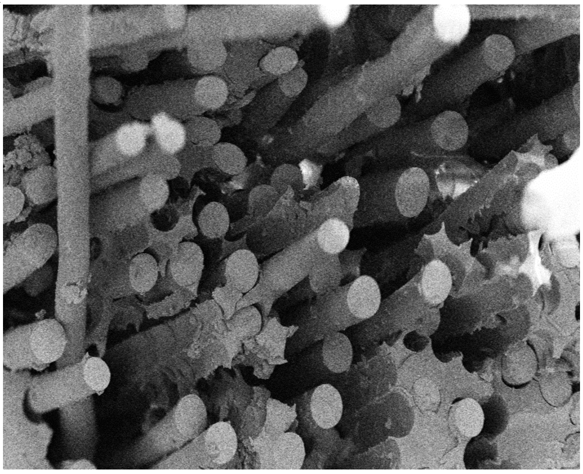

Fig. 10. SEM image for the cross-sectional view of sisal-PALF-banana subjected to impact test

specimen observed under the scanning electron microscope. Fig. 9 indicate that there is a protruding fibers and separated fibers in the region of applied load where the breaking occurs. Fig. 9 shows the three different fiber particles which are separated due to the application of pressure in flexural load. Fig. 10 shows the fractured surface of the impact specimen. The impact also shows that the fibers are cut in the longitudinal direction, due to the application of the load. From the observation, these SEM specimen indicated that fiber fractured, protruding fibers, formation of cavities are some of the forms of surfaces observed in sisal-banana-PALF.

RESULTS AND DISCUSSION

The natural fibers like sisal, PALF, banana, coir, hemp, flax and coconut fiber have been used as reinforcement in thermo plastic composites for applications in consumer goods, furniture, civil structures and low cost housing. This study is used to investigate the mechanical properties like tensile strength, flexural strength and impact strength for natural fiber reinforced glass fiber reinforced plastics. The test results for all the five composite samples are presented in the Table-2.

TABLE-2
MECHANICAL PROPERTIES OF TESTED SPECIMEN

Sample	Tensile strength (kN/mm^2)	Flexural load (KN)	Impact strength (Joules)
Sisal-banana-PALF composite	0.33	6.5	16
Sisal-PALF composite	0.27	1.5	6
Banana-PALF composite	0.25	1.4	4
Sisal-GFRP composite	0.23	1.2	2
Banana-GFRP composite	0.07	0.09	1

Conclusions

Sisal-banana-PALF composite sisal-PALF composite, banana-PALF composite, sisal-GFRP, banana-GFRP samples are fabricated. The hybrid composites are subjected to mechanical testing such as tensile, flexural, impact test. Based on the results, the following conclusions are drawn

• In this research, alternate layer of natural fibers are considered to reduce the environmental impact of synthetic fibers.

• The results indicated that sisal-banana-PALF composite shows maximum tensile strength, flexural and impact strength.

• The results also indicated that sisal-PALF-GFRP performs better than the other 3 samples considered.

• The internal structure and breaks are observed for the broken surfaces of the tested composite samples using SEM

• For the usage of natural fibers replacing the synthetic fibers further research is required.

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