European Journal of Applied Sciences 7 (3): 138-144, 2015
ISSN 2079-2077

DOI: 10.5829/idosi.ejas.2015.7.3.22252

Experimental Investigation on the Mechanical Properties of Jute/Sisal/Glass and Jute/Banana/Glass Hybrid Composite Materials

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Abstract: This present work investigates the hybridization of glass fibers with natural fibers for the applications of structural, aerospace and automobile industry. Composites made of natural fibers are of low cost, light weight and user friendly but lower in strength when compared to synthetic fibers. Hence, the natural fiber and synthetic fiber composition need to be optimized for utilization as High Strength (HS) hybrid composite materials for many applications. In this research work two hybrid composites have been developed using Glass, Jute, Sisal and Banana fibers in the form of laminates, namely Jute-Sisal- Glass (JSG) and Jute- Banana-Glass (JBG) combinations. The fabricated test samples have been subjected to tensile, flexural and impact tests to evaluate their mechanical properties. The microstructures of the tested specimens have been performed through Scanning Electron Microscope (SEM) for fracture mode analysis. The comparison of the results shows that the high strength hybrid composite made of Jute-Banana-Glass (JBG) provides better mechanical properties and it could be used for a wide range of applications.

Key words: Glass fibers · Hybrid composites · JSG · JBG · Mechanical Properties · Scanning Electron Microscopy

INTRODUCTION

Natural fibers are derived from plants, animals and mineral sources. In modern days, the natural fibers from plants like sisal, banana and jute mixed with the glass fiber are used to get high strength (HS) hybrid composite materials which are widely used in many applications. HS composite materials are replacing the metallic materials when used in the aerospace, structural and automobile industries. The properties of natural fibers depend mainly on the nature of the plant, location where the plant grows, age of the plant and the extraction methods used. In general sisal fibers, banana fibers and jute fibers are easily available have good mechanical properties like low density, flexibility, high impact resistance (toughness), renewability and also biodegradability [1-9].

The glass fiber composites in recent years have moved towards developing materials with high physical and mechanical characteristics and the focus is to create heat-resistant composites. Glass fibers are made by silicon-di-oxide with the addition of other oxides in some small percentages. It is strong, stiff and temperature resistant and is used as reinforcing materials in many sectors like automotive industries, naval industries and sports equipments. They are produced by spinning process in which the glass fibers are pulled out through a nozzle from molten glass [10-14].

Soma Dalbehera and Acharya [15] experimentally investigated the effect of stacking sequence on tensile, flexural and inter laminar shear properties of untreated woven jute and glass fabric reinforced epoxy hybrid composite. The results showed the properties of Jute - E glass - epoxy and its composites to have considerably improved by the incorporation of glass fiber as extreme glass piles. Hemachandra reddy *et al.* [16] evaluated mechanical properties such as tensile and flexural properties of hybrid glass fiber–sisal/jute reinforced epoxy composites. It was observed that the incorporation of sisal fiber with Glass Fiber Reinforced Polymers (GFRP) exhibited superior performance rather than the jute fiber

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reinforced GFRP composites for tensile properties and in contrast jute fiber reinforced GFRP composites performed better for flexural properties.

Shokrieh and Omidi [17] examined the strain rate effects on transverse tensile and compressive properties of unidirectional glass fiber reinforced polymeric composites. The characteristic results for the transverse properties suggest that damage evaluation is strain-rate-dependent for the examined material. Also, a strain-rate-dependent empirical material model associated with different regression constants have been proposed from experimental results obtained which was used to characterize the rate dependent behaviour of Glass/Epoxy composite material.

In the present work, two types of hybrid composites with the combinations of Jute-Sisal-Glass and Jute-Banana-Glass fibers as reinforcements in the epoxy resin matrix were prepared through hand layup method. The fabricated HS composites were subjected to mechanical tests for evaluating their tensile strength, flexural and impact strength. The results of the mechanical tests for the above hybrid composites were compared and presented as a detailed report.

MATERIALS AND METHODS

Materials: The materials used in fabricating the hybrid composite specimens were Sisal (Agave sisalana), Banana (Musa Sapientum), Jute (Corchorus oliotorus), Glass fibers and epoxy resin. The raw sisal, Banana and jute fibers were collected in the form of residues from Salem District of Tamil Nadu State in India. The Glass-Fiber of bi-directional woven mat was used in the fabrication. The matrix used was epoxy resin AW106 of density 1.2 g/cm^3, mixed with hardener HV953 of density 0.98 g/cm^3. The weight ratio of mixing epoxy and hardener was 10:1. The physical properties of the natural fibers are presented in Table 1.

Method of Preparation: The composite samples were prepared by the hand layup process. Raw sisal, banana and jute fibers of 30cm length were used in specimen preparation. The first type of composite consists of jute and banana layers kept between two layers of glass fibres. For good adhesion of layers the laminate was gently squeezed using a roller. Finally the laminate was kept in the weight press, for over 24 hours to get the perfect shape and thickness. The thickness of the laminate was limited to 8mm and the size to 300mm x 210mm. After solidification in dry condition, the edges of the specimen were neatly cut by using a cutting tool (saw) as per the required dimensions. The same processes were carried out on the second laminate in which layers of sisal and jute were kept between glass fibres.

The steps involved in the fabrication process of composite specimens are shown in Figure 1.

Step 1: Setup the mould, frame and the die used for the preparation of the samples.

Step 2: The processes of making the samples where the fibres and the matrix material are being mixed.

Step 3: The process of pressing the sample with weight press to get the desired shape. Step 4: The final specimen can be obtained after removing the weight and mould plate.

Mechanical Testing

Tensile Test: The rough edges of the specimens were smoothly finished by using emery paper before subjected to tensile testing. The specimens were prepared as per the ASTM D638 standard size of 300 mm long, 35 mm wide and 8 mm thick. The tensile tests on hybrid composite samples were carried out using Universal Testing Machine (UTM).

A tensile test specimen was placed in the testing machine and load was applied until it fractures. The elongation of the specimen during the test was recorded. The experiments were repeated for three times for each specimen and the average values were used for presentation.

Flexural Test: The specimens were prepared for the flexural tests as per the ASTM D5943 standards and the flexural properties were obtained by using Instron universal testing machine. The flexural strength was recorded for all the test samples.

Impact Test: Izod impact test specimens were prepared in accordance with ASTM D 2240 to find the impact strength. The sizes of the specimens were 75 mm length, 35 mm width, 8 mm depth. A sharp file with included angle of 45° was drawn across the centre of the saw cut at 90° to the sample axis to obtain a consistent starter crack. The sample tests were performed by impact testing machine and the impact strength was calculated.

Table 1: Physical Properties of natural fibers (Sisal, Banana and Jute)

Sln0	Physical Property	Sisal	Banana	Jute
1	Density (g/cm^3)	1.34	1.35	1.48
2	Tensile Strength (KN/mm^2)	610-720	529-914	410-780
3	Elongation at break (%)	2-3	1 - 4	1.9
4	Moisture Absorption (%)	11	10-11	12
5	Price of raw fiber (Rs./kg)	60-70	20-30	40-50

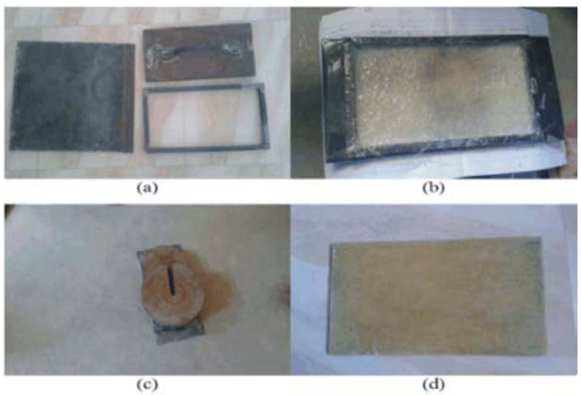


Fig. 1: Fabrication Steps (a) Mould plate, Frame and Die (b) Sample on the mould (c) Weight on Mould (d) Hybrid Composite Material Specimen

RESULTS AND DISCUSSION

Mechanical Properties: This study attempts to analyse the effect of hybridization of natural fibers with glass fibers on the mechanical behaviour of the composites by conducting tests to evaluate their tensile, hardness and impact strengths and compare them. The results for the tensile, flexural and impact testing of the hybrid composite samples are given in Table 2.

Tensile Strength: The tensile strength of the composite is based on the fibers strength, length and matrix interaction. The samples were tested in the Universal Testing Machine (UTM) and the stress-strain curve was plotted. The Stress –Strain curve was generated directly from the Universal Testing Machine. From the results it can be seen that the Jute/Sisal/Glass fiber composite has got the maximum tensile strength of 23.29MPa with the ultimate load of 6.41KN. But the Jute/Banana/Glass fiber composite shows the maximum tensile strength of 42.24MPa obtained from the ultimate load of 11.12KN. The Jute/Banana/Glass fiber composite has reached the high tensile strength compared to the Jute/Sisal/Glass fiber composite. The stress-strain curves for Jute/Sisal/Glass composites and Jute/Banana/Glass composites are presented in Figures 2 and 3 respectively.

The Ultimate Tensile Strength (UTS) values of the three samples of each type of composite were tested and presented in Figure 4. The results indicate that the ultimate tensile strength of the Jute/Banana/Glass composite is higher than the Jute/Sisal/Glass composite.

Flexural Strength: The flexural strength of the composite samples was tested in the UTM. The strength values for Jute/Banana/Glass.

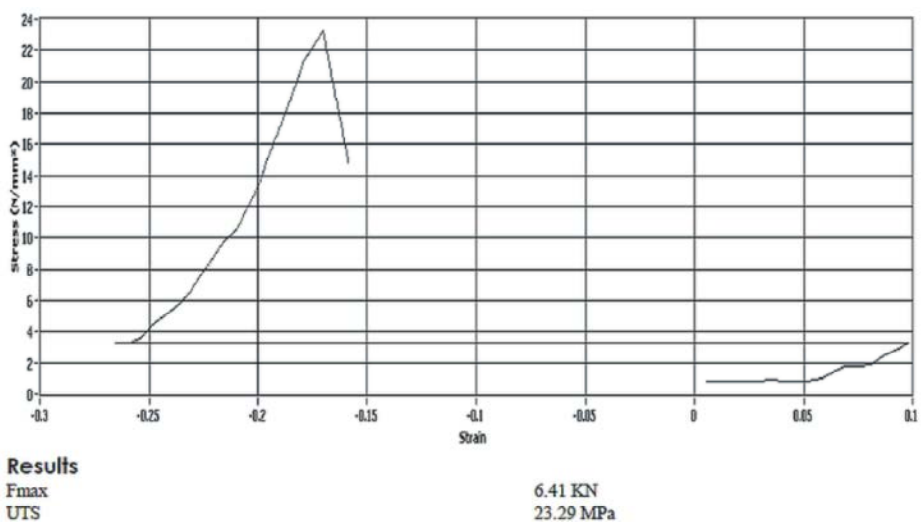


Fig. 2: Stress strain curve for tensile test with Jute/Sisal/ Glass composites

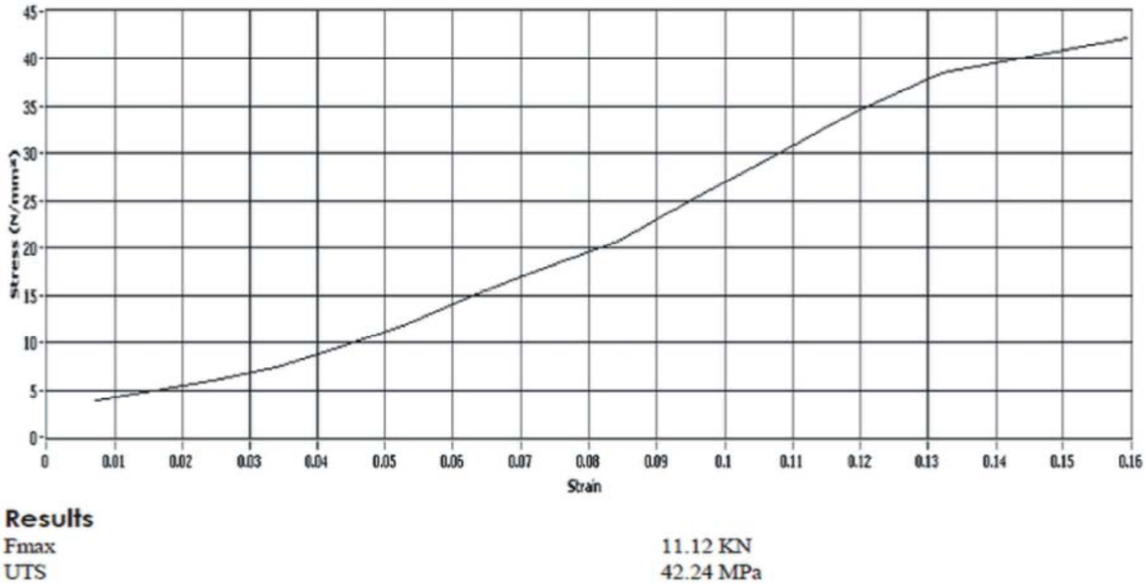


Fig. 3: Stress strain curve for tensile test with Jute/ Banana/Glass composites

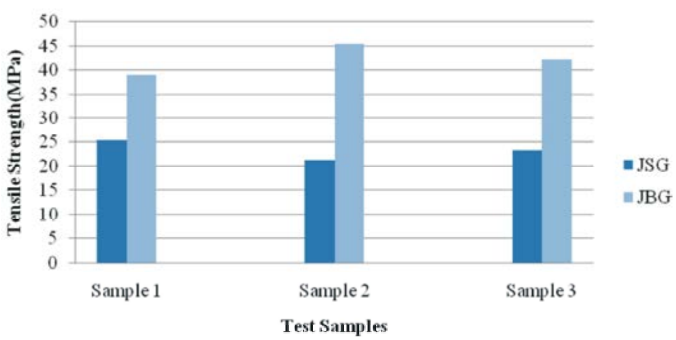


Fig. 4: Tensile Strength of Jute/Sisal/ Glass and Jute/ Banana/Glass composite samples

Table 2: Mechanical properties of JSG and JBG composite samples (Average of three samples)

Sample	Tensile Modulus (Mpa)	Tensile Modulus (GPa)	Flexural Strength (MPa)	Flexural Modulus (GPa)	Impact Strength (KJ/m^2)
Jute/Sisal/Glass (JSG) composites	23.29	2.08	59.80	3.14	15.01
Jute/Banana/Glass (JBG) composites	42.24	2.65	72.93	4.70	26.35

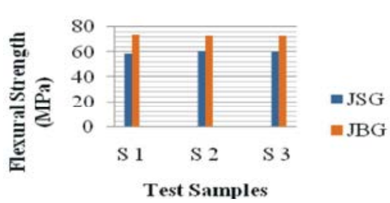


Fig. 5: Flexural strength for Jute/Sisal/ Glass composite and Jute/ Banana/Glass composite samples

Composite and Jute/Sisal/Glass composite samples are presented in Figure 5. The results show that Jute/Banana/Glass composites possess more flexural strength when compared to Jute/ Sisal /Glass composite.

Impact Strength: The Impact strength of the composite samples is tested in the Izod method for Jute/Banana/Glass composite and Jute/Sisal/Glass composite samples and the values are presented in Figure 6.

It can be observed that the impact strength of Jute/Banana/Glass composite is very high when compared to the Jute/Sisal/Glass composite.

Scanning Electron Microscope Analysis: The micro images of each three samples of JSG and JBG are obtained by using Scanning Electron Microscope (SEM). Figure 7 shows that the tensile failure of the JSG test specimens

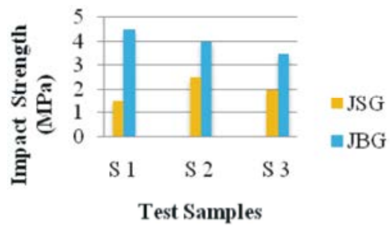
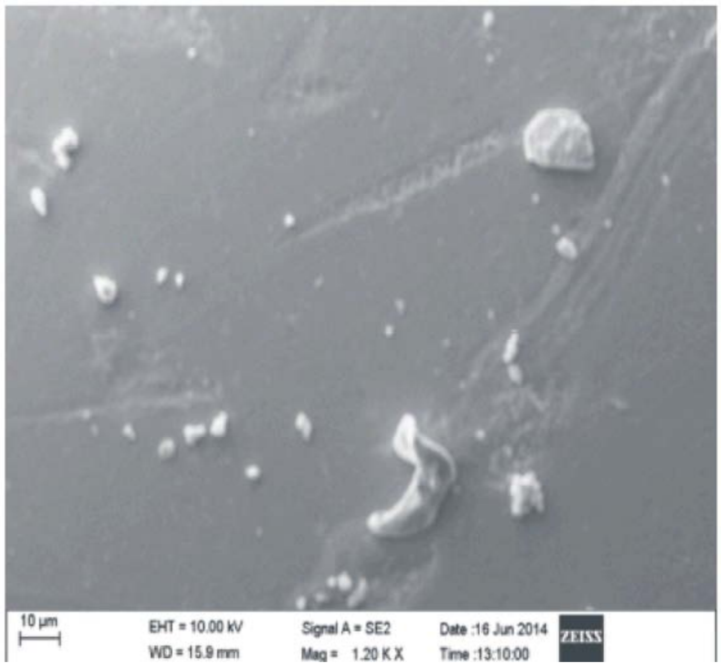


Fig. 6: Impact Strength value for Jute/Sisal/ Glass composite and Jute/ Banana/Glass composite samples



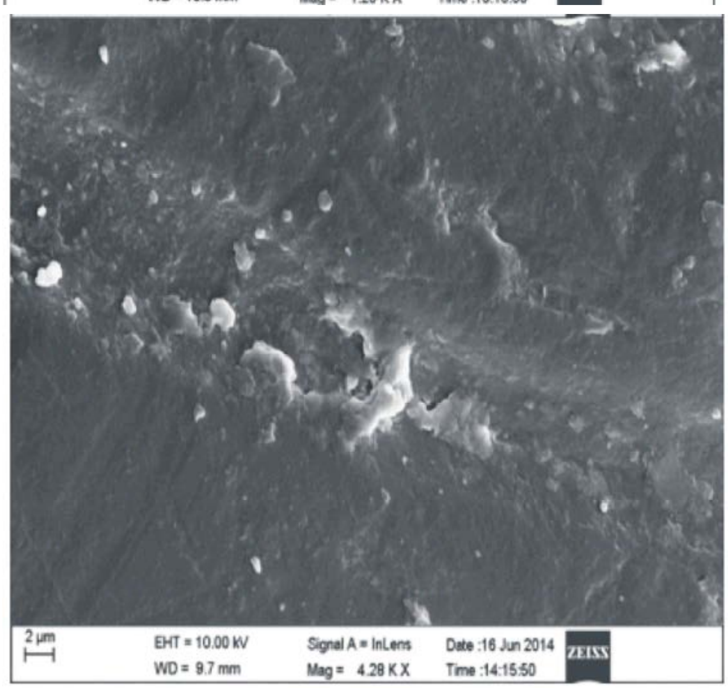


Fig. 7: SEM images of Jute/Sisal/ Glass specimens after tensile fracture

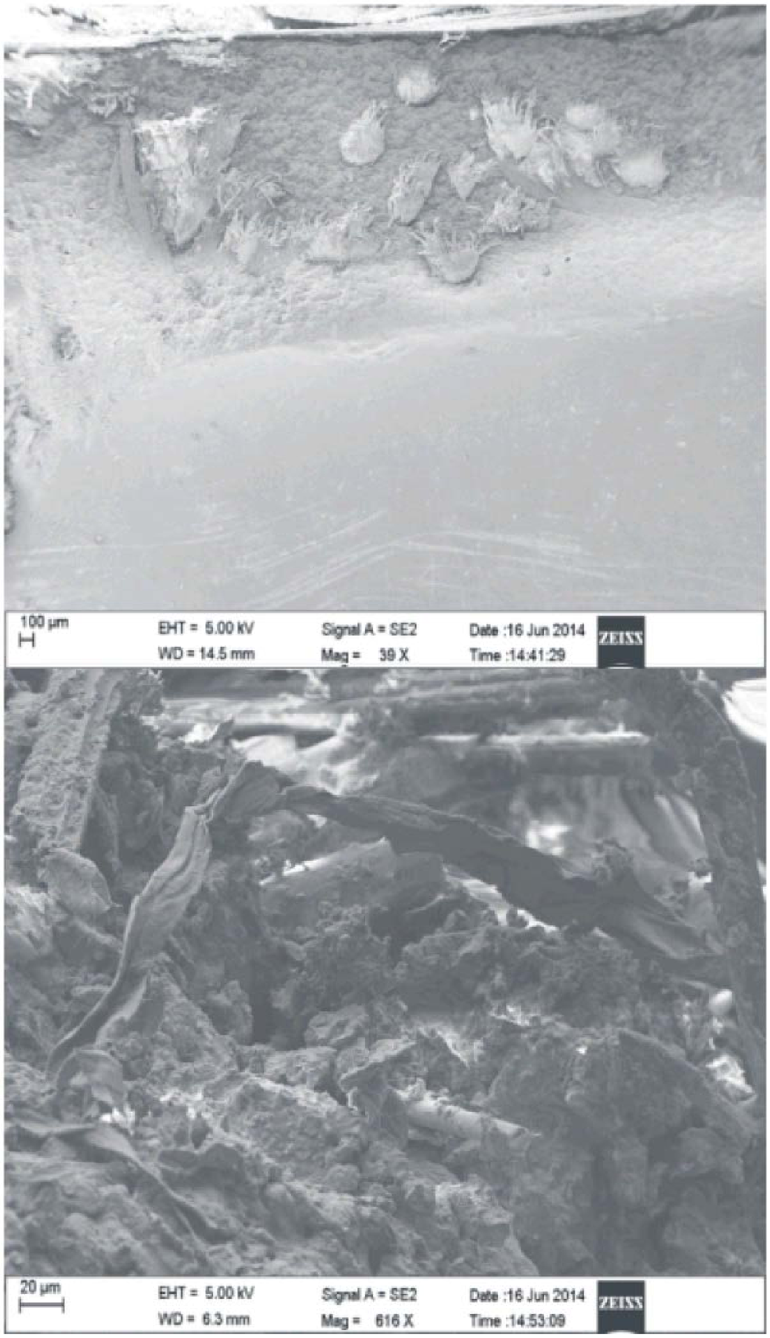


Fig. 8: SEM images of Jute/ Banana/Glass specimens after tensile fracture

with hackles and fiber fracture is caused by pull out under uniaxial tension which is due to low interfacial bonding strength. Figure 8 show that the JBG specimens possess good bonding strength when compared with JSG. It can also be observed that there is no significant elongation of the fiber and sudden brittle mode of failure occurs. A good fiber matrix interface and the fracture surface with resin rich regions can also be observed.

CONCLUSION

The Jute/ Sisal/ Glass and Jute/ Banana/ Glass hybrid laminate composite specimens are prepared and subjected to tensile, flexural and impact testing.

From the experimental results, the following conclusions are derived.

- The Jute/Banana/Glass composite samples possess high tensile strength and more flexural strength when compared to Jute/Sisal/Glass composite specimen.
- The Jute/Banana/Glass composite specimen shows the maximum impact strength of 26.35KJ/m^2 when compared to Jute/Sisal/Glass composite specimen.
- The failure micro graphs of the tested samples are examined by using Scanning Electron Microscope.
- From the results, it can be concluded that Jute/Banana/Glass hybrid composites would performed as a high strength material and it can best suited for the applications in structural, aerospace and automobile industries.

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