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Investigation of Mechanical Behaviour of Sisal Epoxy Hybrid Composites

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Abstract

Objectives: The recent development in materials replaces automotive and aerospace components with composites. Among composites, natural fiber composites play a vital role due to their properties like bio-degradability, low strength to weight ratio and ease of manufacturing. **Method:** In this work, sisal epoxy hybrid composite was fabricated by hand layout process. Initially, releasing agent is applied on the top surface of the mould over which Glass Fiber Reinforced Plastic (GFRP) is placed. On GFRP, apply resin hardener mixer over which sisal is placed. Again GFRP layer is kept on sisal. **Findings:** The result shows that, breaking load of double shear test is increased from 1.02 to 1.43 kN. Hardness value increased from 76.2 to 88.2. The results of inter de lamination test also increased from s 7.96 to 8.52 kN. Above results proved that composite with equal fibre ratio of glass and sisal (50:50) has improved the mechanical properties than composite with minimum percentage of sisal fiber. **Applications:** The material developed is suitable for automotive bumper application. Also, it may be used as partition and load carrying medium in railway and marine application.

Keywords: Glass Fibre, Hybrid Composites, Mechanical Properties, Sisal Fibre

1. Introduction

Nowadays natural fibres are widely used instead of synthetic fibres due to their environmental advantages such as bio degradability, high strength to weight ratio, good mechanical properties, low weight and economical advantages. Natural fibres can be obtained from plants such as banana, sisal, bamboo, kenaf, jute, bamboo and sugarcane. Many researchers have reported that the mechanical properties of reinforced fibres depend on the fibre-matrix interface[1] have shown that the lifetime of flax/Poly (L-Lactic) Acid bio composites has a strong influence on their global environmental impact. Understanding the aging mechanisms of these materials is therefore of primary importance. Aging in a humid environment affects the matrix, the fibres and the fibre/matrix interface of composite materials. The latter may control the long term durability[2] showed that the diffusion of water at a polymer/substrate interfaces may be much faster than that in the polymer alone. Cognard[3] proposed that water condensing at interfaces could result in osmotic pressure and lead to interface debonding. These interactions control the load transfer between fibre and matrix and hence the global composite properties. Gaur[4] also observed during immersion a 21% increase in post-debonding frictional stress due to the pressure exerted by matrix swelling[5] observed that improved adherence between Sisal fibres and polypropylene via chemical treatments reduced their Weight gain due to water absorption, by reducing capillary water in gress.

In[6] have studied the effects of chemical treatments on reinforcements and matrix modification of Uni-Directional (UD) sisal fibres impregnated with epoxy and polyester matrix. In[7] have investigated the influence of reinforcement (jute, hemp and flax, glass), stacking sequence and fibre content on the fatigue response

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of composites. Results have highlighted that the stiffer composite, i.e. UD glass fibre laminate with the highest fibre content loaded along fibre direction, exhibited the best fatigue resistance. In[8] have compared the fatigue response of hemp fibre mat and ±45 glass fibre reinforced composites. In[9] studied the deformation under an active loading of a short misaligned fiber composite is modelled by the orientation averaging approach, employing an analytical description of the behaviour of a Unit Cell (UC), the parameters of which are determined using a Finite Element Method (FEM) analysis of UC response under selected loading modes. The model is applied to the prediction of stress–strain diagrams in tension of flax/polypropylene composites with different fibre volume fractions. In[10] studied the effect of fibre volume fraction on Young's modulus, maximum tensile strength and impact strength of untreated jute fibres in unsaturated polyester resin, made by a leaky mould technique. In[11] made unidirectional hemp fibre reinforced epoxy composites, with a fibre volume fraction of 0.2, a tensile strength of 90 MPa and Young's modulus of 8 GPa, by pinning-decortication and hand combing. In[12] determined the fracture energies for sisal, pineapple, banana, and coconut fibre reinforced polyester composites using Charpy impact tests They found that, except for the coconut fibre, increasing fibre toughness was accompanied by increasing fracture energy of the composites. In[13] examined the influence of fibre content and fibre length in banana fibre Reinforced epoxy composites, and found that impact strength increased with higher fibre content and lower fibre length. In[14] are very encouraging and point towards the possibilities of structural applications. In[15] show that the high temperatures (170–180 _C), to which fibre bundles are probably subjected during fibre processing and composite manufacturing, do not induce significant effects on their tensile properties if such temperatures are maintained for less than 1 h.

In[16-18] investigated flexural behaviour of pine apple fiber hybrid composite. Also, they investigated mechanical properties of Jute-flax composites and concluded that hybrid composite has better mechanical strength. In[8] studied the impact and tension–tension fatigue behaviour of a mathemp/ polyester composite and compared it with a ±45_ glass fibre cloth/polyester. In[19] did a complete initial characterisation, analysing the influence of several parameters on the fatigue behaviour, such as: type of fibre (UD-flax/epoxy versus UDjute/epoxy), textile architecture (UD-jute/epoxy versus wovenjute/epoxy), fibre–matrix adhesion (treated and non-treated jute as reinforcement of epoxy, polyester and polypropylene resins) and fibre volume fraction. In[20] have evaluated the effect of two treatments of diss fibres on the mechanical properties of a mortar incorporating these fiber. In[21] have assessed the effect of the horrification of the vegetable fibres on the mechanical performance and durability of softwood kraft pulp and cotton linters cement mortar composites. In[22] have modified the chemical composition and the surface properties of jute fibers for their homogeneous distribution into the cement matrix by the combination of NaOH and polymer emulsion treatment. In[23] studied the tensile and flexural properties of the green composites with different pineapple fibre content and compared with the virgin resin. Sisal fibre is fairly coarse and inflexible. It has good strength, durability, ability to stretch, affinity for certain dyestuffs and resistance to deterioration in seawater. In[24] carried out research work on filament wound cotton fibre reinforced for reinforcing High-Density PolyEthylene (HDPE) resin. In[25] investigated the new type wood based filler derived from Oil Palm Wood Flour (OPWF) for bio-based thermoplastics composites by thermo gravimetric analysis and the results are very promising. In[26,27] determined mechanical and thermal behaviour of banana hybrid composite and concluded that increase in strength result in increase of fiber content. They also found tensile property of kenaf flax hybrid composite and suggested that increases in kenaf content result in high strength. In[28] have studied the effects of chemical treatments on reinforcements and matrix modification of unidirectional (UD) sisal fibres impregnated with epoxy and polyester matrix. Results have shown that the NaOH treatment improved slightly the fatigue resistance. In[29] have investigated the influence of reinforcement (jute, hemp and flax, glass), stacking sequence and fibre content on the fatigue response of composites. Results have highlighted that the stiffer composite, i.e. UD glass fibre laminate with the highest fibre content loaded along fibre direction, exhibited the best fatigue resistance. In[30] as reported fabrication of composites consisting of loose natural fibres using conventional compression moulding methods typically results in a non-uniform fibre distribution.

In[31] reported that a tensile modulus as high as7.2 GPa can be achieved, although details on the fibre sizes have not been described. Non-woven kenaf mat/PP composites have been reported to have flexural strengths up to 118 MPa and flexural moduli of 9.6 GPa at 50 wt% fibre content. In[32] studied the effect of three different stir casting routes on the structure and properties of fine fly ash particles in reinforced aluminium silicon alloy composite and found that the separation of fly ash particles and its dispersion are more effective in compo casting method than in liquid metal stir casting due to the shearing of fly ash particles. In[33] worked on processing of advanced Al/SiC particulate metal matrix composites under intensive shearing and found that the distribution of the SiC particles in the metal matrix was improved significantly when the composites were produced using the Reprocess. In[34], who experimentally tested aluminium matrix composites with various particle reinforcements, to evaluate their fracture toughness and compare the experimental results with the fracture toughness estimates using the Hahn–Rosen field model and found that there was a close agreement between the experimental results and the predicted toughness using the modified fracture model. In[35] carried out dynamic mechanical investigations of chemically modified jute fibre and polyester composites. The data obtained from their study suggest that storage modulus and thermal transition temperature of the composites improved enormously due to chemical treatment of the fibre.

In[36] carried out dynamic thermo mechanical and tensile properties of chain extended polyethylene terephthalate after chemical modification. The Tg values determined were found to be in good agreement with those obtained by differential scanning calorimetric. In[37] reported on the recent analytical and experimental results regarding the improvement and optimization of damping in composites. They reported on using dynamic modulus and damping values to quantify fibre–matrix adhesion. In[38] have analyzed the heat transfer in unidirectional fibrous composites with a periodic hexagonal microstructure primarily in the fiber direction using a binary mixture theory. In[39] measured the thermal conductivity and thermal diffusivity of oil–palm–fiber reinforced untreated and differently treated composites with the transient plane source technique at room temperature and under atmosphere pressure. In[40] investigated the thermal conductivity, diffusivity and specific heat of polyester/natural fiber (banana/sisal) composites as function of filler concentration and for several fiber surface treatments. The thermo physical behaviour of hybrid PineApple Leaf Fiber (PALF) and glass fiber reinforced polyester composites has been also evaluated for a constant total fiber loading of 0.40 Vf by varying the ratio of PALF and glass. In[41-43] investigated mechanical behaviour of natural fiber composite and found that hybrid composite has good property than mono fiber composite.

Huang[44] carried out a micromechanical approach for examining the dynamic response of laminated composite plates composed of randomly oriented fibres in each layer. Valeria and Marie Dynamic[45] mechanical analysis of unsaturated polyester resin modified with poly-organo siloxanes and they concluded that 1,3-Amino Propyl Triethoxy Silane (APTS) was incorporated to the resin by reaction of its amino group with Glycidyl MethAcrylate (GMA), generating a graft copolymer, which has its flexibility improved by the addition of a chain extender. In[46] the effect of compatibiliser on the structure–property relationships of kenaf-fibre/polypropylene composites and have investigated. In[47] studied the shear strength of kenaf fibre by adding with carbon fibre in different ratios for the concrete structure. They obtained the results carbon addition improve the concrete strength. In[48] also investigated the tensile strength of treated and untreated kenaf, jute fibre and jute rope. Tensile strength of kenaf and jute fibre is higher than jute rope and water absorption properties of treated fibre have higher resistance than untreated fibres was studied.

2. Materials Used

Sisal fibres are natural and biodegradable fibres and they are affordable too. Glass fibres are artificial fibres and expensive compared to natural fibres. In this work, Hybrid composites can be made by combining sisal and glass fibres. Sisal fibres and glass fibres were collected from local sources. For the reinforcement, hardeners and epoxy resins were collected from Covai Seenu Company. Alkali treatment is generally done to improve the properties of natural fibres, for this alkali tablets were purchased from scientific company. Epoxy resin [LY556] and hardener [HY951] mixed in a ratio of 10:1. The properties of fibres are given in Table 1.

Table 1. Properties of fibres

Fibre type	Density g/cc	Tensile strength (MPa)	Youngs Modulus (GPa)	Elongation at break %
E-Glass	2.55	3500	73	3.7
Sisal	1.42	700	35	2.9

3. Methods and Processing of Fibres

Extraction of fibres comprises two times of bleaching. Here, the sisal fibres are chopped up to 5 mm and it is subjected to two hours of alkali treatment. After the treatment the fibre is washed in water and allowed to dry in atmospheric temperature up to 39˚C. Glass fibres were obtained in the desired size.

4. Fabrication of Composite

Different combinations of composites such as (**50:50 45:55 40:60 30:70**) were selected to do hybrid composites of sisal/glass/epoxy laminates in the form of chopped fibres. Hand layup method is used for the preparation of composite. GFRP acts as the top and bottom layer of the composite while glass and sisal fibres are used as intermediate layers. Here we are fabricating three categories of composites. In first category the fibres in the second layer are placed orthogonal to the top and bottom layers. In the second category the fibres are placed parallel to each other and in third category the fibres in the middle layer are placed at 45 degree to the end layers. First the polyvinyl alcohol is spread over the table which helps in faster removal of the final fabricated composite. A thin layer of resin [ARALDITE LY556] is applied on the bottom layer and now 3 layers of GFRP is spread over this and a weight of 7 kg is placed over this for eliminating air bubbles between the layers and this entire setup is kept undisturbed for 5-8 hours. Now the bottom layer of the composite is ready. Now the alkali treated and dried natural sisal fibre and glass fibres are placed over this glass fibre layer. Several layers of these sisal-glass fibres are placed over this. Between each layer a mixture of hardener and epoxy resin is applied and allowed to dry. Now the finishing process is done by placing the final layer of composite which is again the GFRP layer. Now a load of 20-23 kg is placed over this composite for 8-12 hours. This gives the intra- layer hybrid composite. Now the composite is machined to the required dimensions. This is actually composite of equal proportion of glass and sisal fibres 50:50. Now the process is repeated for 45:55 40:60 30:70 ratios of glass-sisal fibres.

5. Testing of Composites

In this work, double shear test, de-lamination test and hardness test were performed.

5.1 Double Shear Test

Double shear test is conducted in accordance with American Society for Testing and Materials (ASTM) standards. A schematic sketch shown below describes the double shear test. When the beam has been loaded, normally the shear stress is considered negligible when compared with bending stress. But shear stress gains importance in certain design calculations. Hence a test for shear stress is made by universal testing machine with a special fixture for double shearing test. The test is performed by placing the specimen between the grippers.

5.2 Inter De-Lamination Test

De lamination is an internal mode of failure which results in the separation of the various reinforced layers. This results in a loss of strength of the composite. A test called the de-lamination test is made to determine this level of failure in the hybrid composites of different ratios and the best combination ratio of glass-sisal composite is found. The samples are prepared according to the ASTM: D5528 standard for this test. Application of load is done till the failure point or until the specimen fractures. Finally the breaking load as a result of this test is determined.

5.3 Hardness Test

Hardness of a material is the measure of its resistance to indentation due to compressive force caused by sharp tools. It is observed that the hardness increases with increase in the ratio of glass-sisal fibre content in the glass-sisal hybrid composite. The results of the hardness test are shown in the Table 2.

6. Results and Discussion

In the following session the result of double shear, hardness and delamination properties are discussed.

6.1 Double Shear Test

Table 2. Result of double shear test

Sample	Ratio of Glass : Sisal	Breaking Load (KN)	Displacement (mm)
1	50:50	1.43	1.06
2	45:55	1.24	1.22
3	40:60	1.11	1.41
4	30:70	1.02	1.68

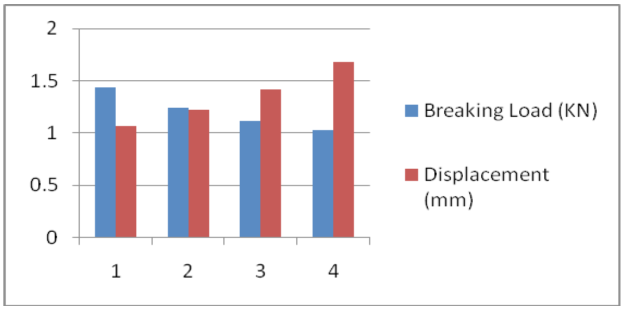

Figure 1. Comparison of double shear test result

From Figure 1 and 2 it is clear that, breaking load of composite increases with increase in glass fiber content. Composite 1 withstand maximum load with minimum displacement.

6.2 Inter De-Lamination Test

Table 3. Result of inter de-lamination test

Sample	Ratio of Glass : Sisal	Breaking Load (KN)	Displacement (mm)
1	50:50	8.52	4.2
2	45:55	8.41	3.8
3	40:60	8.13	3.2
4	30:70	7.96	2.9

From Figure 2 and Table 3 it is clear that, breaking load of composite increases with increase in glass fiber content. Result of inter de-lamination test shows that Composite 1 withstand maximum braking load with minimum displacement.

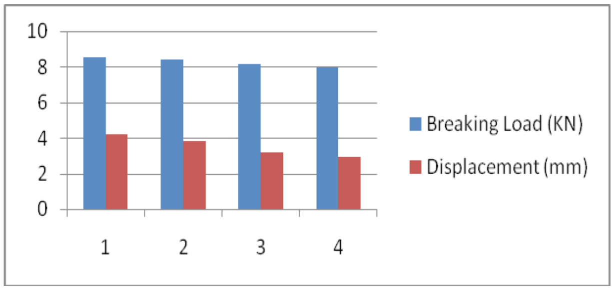

Figure 2. Comparison of inter de-lamination test

6.3 Hardness Test

Table 4. Result of hardness test

Sample	Ratio of Glass : Sisal	Hardness (HRC)
1	50:50	88.2
2	45:55	86.4
3	40:60	81.3
4	30:70	76.2

From Table 4 it is clear that compote 4 has maximum hardness since, it contains equal amount of glass and sisal fibre.

7. Conclusion

In this work glass-sisal composite was fabricated by hand layup process and their shear, de lamination and hardness are found. The result shows that composite with 50:50 E-glass and sisal has good mechanical properties than other combination.

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