EXPLORATION OF FLEXURAL, IMPACT AND MORPHOLOGY TEST OF SISAL GLASS FIBER REINFORCED EPOXY COMPOSITE INCORPORATED WITH MOLYBDIC ACID

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ABSTRACT- The assimilation of natural fibers such as sisal with glass fiber composites has engorged increasing applications both in many areas of Engineering and Technology. The purpose of this work is to assess mechanical properties such as Flexural and impact properties of hybrid glass fiber-sisal reinforced epoxy composites in addition with molybdic acid. Natural fiber composites such as sisal polymer composites became more attractive due to their high specific strength, lightweight and biodegradability. Microscopic examinations are carried out to analyze the interfacial characteristics of materials, internal structure of the fractured surfaces and material failure morphology by using Scanning Electron Microscope (SEM). The percentage of Fiber and Matrix content is varied and the properties are evaluated. The results indicated that 40% Fiber with 60% Matrix exhibited superior properties when compared to other composition.

Keywords: Sisal fiber, Glass fiber, Molybdic acid, Mechanical properties, Scanning Electron Microscope

1. INTRODUCTION

The term composite can be defined as a material composed of two or more different materials, with the properties of the resultant material being superior to the properties of the individual materials that make up the composite. Composites are heterogeneous in nature, created by the assembly of two or more components with fillers or reinforcing fibers and a compactable matrix. The property of natural fiber composite depends upon fibers, matrix and interaction between them. Natural fiber mainly consists of cellulose, hemicelluloses and lignin. The various advantages of natural fibers over manmade synthetic fiber are cheap, renewable, completely or partially recyclable, and bio degradable. The natural fiber composites include flax, hemp, jute, sisal, kenaf, coir, kapok, banana, henequen and many others. Natural fibers have been used in strings, cords, cables, ropes, mats, brushes, hats, baskets, fancy articles like bags.

2. PROBLEM IDENTIFICATION

A. Problem Definition

- Synthetic polymer cannot be decomposed by bacteria or other micro-organisms which leads to disposal problems
- Natural polymer composites are more environmental friendly compared to polymer composites with synthetic fiber reinforced.
The overall performance of these sisal reinforced polymer composites is low when compared to other composites.

Storage modulus of epoxy and sisal composite is found to decrease at higher temperature due to loss in stiffness.

**B. Objectives**

- To develop sisal-glass fiber reinforced composites incorporated with molybdic acid and to study their mechanical properties such as flexural strength and impact strength.
- To analyze the interfacial characteristics of materials, internal structure of the fractured surfaces and material failure morphology by using Scanning Electron Microscope (SEM).

**3. LITERATURE SURVEY**

Manjunath G. Prasada et al [1] had found that increase in fiber loading enhances the hardness values of the sisal fiber reinforced epoxy composites. Also impact energy of the composite was found to be constant irrespective of fiber loading. K M V Ravi Teja et al [2] had said that by adding Molybdic acid up to 2% we can increase the strength and modulus. Also the tensile molybdic acid filled composites are 20 to 30% more than that of composites without molybdic acid.

Easwara Prasad GL et al [3] had found that treated sisal polyester composite has shown highest impact strength of 1.962 N-m at its 30% fiber volume fraction. Also impact strength of both untreated and 5% NaOH treated sisal fiber embedded polyester matrix composites increases with increase in their thickness and fiber volume fraction. MK Gupta et al [4] had addressed that the addition of sisal fibers in epoxy matrix up to 30wt% increases the mechanical, thermal, and water absorption properties. The values of storage modulus increase with the increase in fiber content up to 25 wt% and then decrease.

Chand Badshah SBVJ et al [5] had addressed that Natural fiber composites such as sisal polymer composites become more attractive due to their high specific strength, light weight and biodegradability. The maximum tensile force of the Sisal-Epoxy resin composite is in the range of 24KN. MK Gupta et al [6] had observed that the tensile and flexural properties of sisal fiber epoxy composite both in unidirectional and mat form are found to be maximum at 30 wt%.

R. Badrinath et al [7] had observed that sisal fiber/epoxy has better tensile strength than banana fiber. He also states that the morphological study reveals that fibers pull out are occurred on unidirectional fibers than bidirectional fibers. M. Ramesh et al [8] had found that the incorporation of sisal fiber with GFRP exhibited superior properties than the jute fiber reinforced GFRP composites in tensile properties and jute fiber reinforced GFRP composites performed better in flexural properties.

M. Boopalan et al [9] had found that the mechanical properties such as tensile strength, flexural strength and impact strength are found to be maximum for 50/50 weight ratio of jute and banana fiber reinforced epoxy hybrid composites. Yan Li et al [10] had observed that Fiber-surface treatment can improve the adhesion properties between sisal fiber and matrix and simultaneously reduce water absorption. Also Sisal and glass fibers can be combined to produce hybrid composites which take full advantage of the best properties of the constituents.

**4. MATERIAL SELECTION**

**A. Glass Fibers:**

Glass Fiber Reinforced Polymers (GFRPs) is a fiber reinforced polymer made of a plastic matrix reinforced by fine fibers of glass. The layer sequence has greater effect on flexural and inter laminar shear properties and placing the GFRP layers at the ends possess good mechanical strength.

**B. Sisal Fibers:**

Sisal fiber is a hard fiber extracted from the leaves of the sisal plant (Agave sisalana). Sisal fiber is a promising reinforcement for use in composites on account of its low cost, low density, high specific
strength and modulus, no health risk, easy availability in some countries and renewability. The composition of Sisal fiber is basically of cellulose, lignin and hemicelluloses.

C. Epoxy Resin and Hardener:
Epoxy is a thermosetting polymer and hence requires a hardener for curing. HY951 hardener is used. Density and dynamic viscosity of epoxy resin are 1.108 g/cm³ and 11.789 Pa.s respectively. The matrix material was prepared by using epoxy and hardener in the ratio 10:1, as recommended. Araldite LY556 and hardener HY951 (Tri Ethylene Tetra Amine) as the matrix because it has good bonding strength and it is mainly used for application of composite parts.

D. Sodium Hydroxide:
To remove the cellulose content of sisal fiber Sodium Hydroxide is used. Alkali treatment is done using 10% NaOH in order to enhance the adhesion property of the fiber with epoxy resin. Sisal fibers conditioned in a sodium hydroxide solution retained respectively 72.7% and 60.9% of their initial strength after 420 days.

E. Molybdic Acid
Molybdic acid refers to hydrated forms of molybdenum trioxide and related species. Mixing of molybdic acid in polyester resin is performed by using sonicator instrument. To improve the strength and the modulus, Molybdic acid is added. The Molar mass and density of Molybdic acid is 161.95 g/mol and 3.1 g/cm³ respectively.

5. CALCULATION
A. Properties calculations:
Density of composite-  \[ \rho_c = (\rho_f \times V_f) + (\rho_m \times V_m) \]  ; Young’s modulus of composite  \[ E_x = (E_f \times V_f) + (E_m \times V_m) \]
Young’s modulus of composite  \[ 1/E_y = (V_f/E_f) + (V_m/E_m) \]  ; Poisson's ratio
\[ P_{12} = P_{11} \times V_f + P_{22} \times V_m \]
Where  \( \rho_f \) = Density of fiber,  \( \rho_m \) =Density of Matrix,  \( V_f \) =Volume fraction of Fiber,  \( V_m \) =Volume fraction of Matrix
\( E_f \) = Young’s Modulus of Fiber,  \( E_m \) = Young’s Modulus of Matrix,  \( E_x \) = Young’s Modulus of Composite in x direction
\( E_y \) = Young’s Modulus of Composite in y direction

B. Selection of combination of the composite

| Table 5.1 Material Properties |
|-------------------------------|-----------------|-----------------|-------------------------------|-----------------|-----------------|
| Young’s modulus of Fibers (Pa) Ef | Young’s modulus of Matrix (Pa) Em | Vol. Fract. of Fiber Vf | Vol. Fract. of Matrix Vm | Young’s modulus of composite in X Direction (Pa) Ex | Young’s modulus of composite in Y Direction (Pa) Ey |
| 6.1E+10 | 4.00E+09 | 0.3333 | 0.6666 | 2.30E+10 | 5.81E+09 |
| 6.1E+10 | 4.00E+09 | 0.4 | 0.6 | 2.68E+10 | 6.39E+09 |
| 6.1E+10 | 4.00E+09 | 0.3 | 0.7 | 2.11E+10 | 5.56E+09 |
6. MODELLING OF DIE

7. Preparation of composite specimen
The long length fibers were first cleaned to remove the dust and other particles so as to use the fibers for further treatments. The fibers were cut to a length of 200 mm to make the further treatments easy. Alkali treatment is done using 10% NaOH in order to enhance the adhesion property of the fiber with epoxy resin. First the fibers are soaked in NaOH solution for 48hrs and then the fibers are washed in distilled water to remove the traces of NaOH. This treatment improves adhesion by removing the lignin and cellulose content. The composite materials used for the present investigation is fabricated by hand layup process. Treated sisal of 25 mm length and chopped glass fiber mat were used to prepare the specimen.

The processed composite is pressed hard and the excess resin is removed and dried. Finally these specimens are taken to the hydraulic press to force the air gap to remove any excess air present in between the fibers and resin, and then kept for several hours to get the perfect samples. After the composite material get hardened completely, the composite material is taken out from the hydraulic press and rough edges are neatly cut and removed as per the required dimensions.

A. Composite samples

B. Weight of the composite

Table 7.1 Composition of composite material

| Fiber & Matrix Percentage | Composite weight(g) | Weight of Sisal fiber (g) | Weight of Glass fiber (g) | Weight of Matrix(g) |
|--------------------------|---------------------|--------------------------|--------------------------|---------------------|
| 40% Fiber + 60% Matrix   | 185                 | 22.5                     | 67                       | 95                  |
| 35% Fiber + 65% Matrix   | 182                 | 20                       | 60                       | 102                 |
| 30% Fiber + 70% Matrix   | 183                 | 18                       | 55                       | 110                 |

8. TESTING AND RESULTS
A. Flexural Test:
The flexural specimens are prepared as per the ASTM D790 standards. The 3-point flexure test is the most common flexural test for composite materials. Specimen deflection is measured by the crosshead position. Test results include flexural strength and displacement. The testing process involves placing the test specimen in three point bending machine which is shown in Fig.8.1 and applying force to it until it fractures and breaks. The specimen of dimension (100*12.7*5) used for conducting the flexural test is presented in Fig.8.2. The results are tabulated and shown in Table 8.1 and Table 8.2 respectively.

**Table 8.1 Flexural Test Result**

| S.no | Volume Fraction of the Fiber | Load Applied (kN) | Displacement (mm) |
|------|-------------------------------|-------------------|-------------------|
| 1    | 40% Fiber and 60% Matrix      | 0.165             | 3.70              |
| 2    | 35% Fiber and 65% Matrix      | 0.115             | 2.90              |
| 3    | 30% Fiber and 70% Matrix      | 0.090             | 4.60              |

The Load vs Displacement curve for the Flexural test for the three samples is shown below in Fig.8.3, Fig.8.4, Fig.8.5 respectively.

**Table 8.2 Flexural Strength Result**

| S.no | Volume Fraction of Fiber | Flexural Strength (MPa) |
|------|--------------------------|-------------------------|
| 1    | 40% Fiber and 60% Matrix | 119                     |
| 2    | 35% Fiber and 65% Matrix | 83                      |
| 3    | 30% Fiber and 70% Matrix | 65                      |
Fig 8.6 Comparison Chart

From this we can conclude that 40% Fiber and 60% Matrix has higher Flexural strength when compared to other composition.

**B. Impact Test:**

According to ASTM D256, ISO 180 standards for composites, the specimens were prepared for Izod impact test. The impact properties of the composites are studied by applying indentation load normal to fibers diameter and normal to fiber length for various specimen types. The results are tabulated and shown in Table 8.3. The Izod test specimen as per ASTM standard and Test machine are show in Fig.8.7, Fig.8.8 respectively.

| S.no | Volume Fraction of the Fiber         | Energy Absorbed (J) |
|------|--------------------------------------|---------------------|
| 1    | 40% Fiber and 60% Matrix             | 2.4                 |
| 2    | 35% Fiber and 65% Matrix             | 1.9                 |
| 3    | 30% Fiber and 70% Matrix             | 1.6                 |

From this we can conclude that 40% Fiber and 60% Matrix has higher Impact strength when compared to other composition.

**C. Scanning Electron Microscopy (SEM) analysis:**
The surface characteristics of the composite material used for the investigation is studied through scanning electron microscopy. The Scanning Electron Microscope (SEM) images are taken to observe the interfacial properties, internal cracks and internal structure of the fractured surfaces of the composite materials. All the specimens are coated with conducting material before observing the surfaces through SEM. SEM image of the Sisal fiber and glass fiber are shown in Fig 8.10 and Fig 8.11.

The SEM image for the Sisal-GFRP composite material under Flexural test is presented in Fig. 8.12 and it shows the fracture in the fiber bundle and incomplete distribution of the fiber and matrix in the composite material.

The SEM image for the sisal-GFRP composite material which subjected to impact test is shown in figure.

9. CONCLUSIONS

It has been observed from this work that the Flexural strength for 30% Fiber is 65MPA which is lesser when compared to other samples. The maximum Flexural Strength is 119MPa for 40% Fiber. During the Impact test, it is found that the energy absorbed for 40% Fiber sample is 2.4 J, which is more than 30% Fiber sample, i.e., 1.6J

By analyzing all the results we inferred that 40% Fiber was good in Flexural Strength, Impact Strengths. So from these two samples 40% Fiber was good and it can be applied to both load and non-load bearing members. With the results obtained, the properties of the specimen tested suits for various applications like automobile components.

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