INFLUENCE OF NANO CLAY ON MECHANICAL AND MORPHOLOGICAL PROPERTIES OF SISAL/BANANA FIBER REINFORCED COMPOSITES

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Abstract

This paper mainly focuses on the Nano clay effect in mechanical properties of sisal/banana hybrid FRP composites. The composites with and without the addition of Nano clay have been made by fusing sisal/banana fiber up to maximum volume of 30% as support in polymer matrix and mechanical properties are investigated.

The composite material prepared was tested for tensile, flexural, impact strength with aid of respective apparatus. Fiber length and % of weight were calculated initially for preparation of specimens. Banana fiber was hybridized with sisal fiber to examine the changes in mechanical properties of the samples. Mechanical properties (Tensile strength, Flexural strength along with their modulus) of the composites with nano clay are found to be 0.8, 1, 1.5 and 2.3 times greater than that of composites without nano clay. 50% better results in the impact test were achieved. SEM analysis was carried out on the samples after conducting the test to find out the fracture pattern and the fiber pull out.

The experimental outcomes illustrate that under testing the mechanical properties shows an increase with adding up of Nano clay at higher volume fraction. Tensile & flexural properties show an affirmative hybrid effect.

Keywords: Polymer- Matrix composites, Mechanical properties, scanning Electron Microscope analysis, Hybridization of sisal/banana

I. Introduction

Utilization of natural fiber as reinforcement in composites has grown its importance in recent years. Natural fiber composites (NFC) make use of plant-derived fibers with plastic as matrix. Some of the natural fibers are coconut, cotton, kenaf, flax, jute, banana shoot fibers, wood bamboo, maddar, wheat straw and other fibrous material. The benefits of those materials compared to others such as synthetick fiber composites, inclusive of low environmental effect and low cost, support their potential across a extensive range of applications. Maximum research work has gone in increasing the mechanical overall performance to extend the applications of this group of materials.
Many studies are made on the usage of natural fibers as reinforcements for composites and in numerous cases the end result have proven that the natural fiber composites own good stiffness but the composites do not reach the same level of strength as of glass fiber composite.

Natural fiber reinforced polyester composites were tested for strength and cost and proved to be a competitor for glass fiber / polyester composites. The hybridization of two different fibers has been shown to be an effective method of developing materials designed to different requirements [I]. Earlier studies by Thomas and his colleagues [II, III] have shown that both banana and sisal fibers can be used in the polyester matrix as efficient reinforcement.

Sisal and banana fibers have been hybridized in this work; their mechanical and thermal properties are studied. Venkateshwaran. N, Elaya Perumal showed that adding sisal fiber to banana / epoxy composites up to 50 percent by weight improves the mechanical properties and decreases the absorption properties of moisture. [IV]. A truck model "Manaca" was built by Al-Qureshi, H. A using banana fiber and epoxy resin. The vehicle has passed road performance tests for many years and has delivered excellent results. [V]

TP Mohan and K Kanny suggested that when Nanoclay induced fibers were compared with untreated and treated alkaline fibers. The results suggests that Nano clay in fusion has a positive effect on the tensile, interfacial and thermal properties of fibers [VI]. Kulkarni et al. studied the mechanical properties of banana fiber [VII]. We found that the banana fiber intension failure was due to the removal of microfibrils followed by the breaking of cell walls.

A.V Ratna Prasad et al. [IX] prepared a lightweight composite material using banana fruit bunch fiber (banana – EFB) as a reinforcement of the polyester resin matrix and studied its mechanical properties. The use of the banana-EFB in the polyester matrix shows a slight increase in the composites’ tensile properties. AV Ratna prasad, K. B. Rao, KM Rao [X] investigated the incorporation of Nano clay into polyester resin, mechanical properties for a maximum volume of 40% of fiber and found that the mean tensile strength and tensile module of Nano clay filled wild cane grass fiber composites is 6.3% and 18.3% higher than those of non-Nano clay filled fiber composite. A. Yasmin, J.L. Luo, J.L Abort & I.M. Daniel used a servo-hydraulic testing machine and a dynamic mechanical analyzer to study the mechanical and visco-elastic velocity of Nano composites its concentrations of 1-10% of clay particles. Results indicated that the application of clay particles significantly improved both the elastic modulus and the pure epoxy storage modulus [XI].

In this work, tests have been prepared for composite specimens by varying the fraction of volume (10, 15, 25 and 30). Sisal fibers were introduced at different ratios (10/90, 20/80, 30/70..., 90/10) to improve the mechanical properties of the banana /sisal polyester composites. Hybridization by sisal fibers produces significant changes in mechanical properties.

Study on mechanical properties (Tensile strength, Flexural strength, and Impact strength) of hybrid sisal/banana composite for different stacking sequences.
For each five samples are prepared and the mean values are taken into consideration. SEM analysis on fiber - matrix adhesion and fiber pull out.

II. Experimental Details

A. Materials

A type of bast fiber, banana fiber (Musaceae family) is extracted from the banana tree bark. Sisal is a natural Agavaceae (Agave) family fiber that produces a stiff fiber that is traditionally used to make twine and rope. All fibers are bought from the local resource. Table 1 [VIII] shows the properties of banana and sisal fibers.

| Properties            | banana fiber | sisal fiber |
|-----------------------|--------------|-------------|
| Cellulose%            | 63.5-65      | 67          |
| Hemicelluloses%       | 21           | 14          |
| Lignin%               | 6            | 10          |
| Moisture content%     | 11           | 10          |
| Density(kg/m$^3$)     | 1450         | 1550        |
| Flexural modulus(GPa) | 2-5          | 12.5-17.5   |
| Micro fibrillar angle | 11           | 20          |

B. Preparation of Polyester and Hardener

PUTECH005 is an unsaturated polyester resin with clear colorless pale yellow color. Its viscosity is 82sec on ford cup B-4 and specific gravity 1.06gms/cc. The gel time is 15min at 25°C is used to prepare the composite samples.

C. Mould Preparation

The mould used in this work consists of banvar sheets for tensile, flexural and impact specimens with different standard ASTM dimensions. The composite material is produced by means of the hand lay-up technique. The walls are covered and allowed to dry with remover. After applying polyester, the sheets are covered with top and bottom plates to compress the fibre and also to prevent debris from entering the composite parts during the healing period.

D. Fabrications of Composites

For the initial preparation of composites, fibres of different lengths for various specimens (tensile, flexural and impact) and volume fractions (10, 15, 25 and 30) were mixed with polyester. Until adding polyester, the moulds are cleaned and dried. Before any releasing agent or polyester was added, the fibres were spread uniformly over the mould. After arranging the fibers uniformly, they were compressed in the mould for a few minutes after uniform arrangement of the fibres. The compressed fibres (banana
and banana / sisal) are then separated from the mould. Subsequently, the releasing agent was added to the mould, after which a polyester coat was applied. The compressed fibre was placed over the polyester coat to ensure consistent fibre distribution. The polyester mixture is then evenly poured and squeezed over the fibre for 24 h healing time. Test samples were obtained in the appropriate sizes as specified in the ASTM standards after the curing process.

E. Testing Standards

The test specimens were subjected to various mechanical tests in compliance with ASTM requirements after manufacturing. The following requirements are ASTM D638-89[14] for tensile testing. The flexural strength was determined according to the standard D790M-86 [XV]. Tensometer was used for both tensile and three-point bending tests. The impact strength of the composite specimens has been determined using a D256-097 Standard Izod impact tester [XVI]. Five specimens were tested for the average value in each case.

F. Scanning Electron Microscopy Study

Interfacial properties such as fibre-matrix interaction, fracture behavior and sample fibre pullout after mechanical testing using Joel-scanning electron microscope were observed. The sample fractured portions were cut and gold coated uniformly over the surface to be examined. The voltage of acceleration used in this work is 10 kV.

G. Mechanical Testing

Tensile testing was carried out for several reasons. Tensile test results are used in the selection of materials for engineering applications. To ensure quality, tensile properties are often included in material specifications. During the development of new materials and processes, tensile properties are often calculated in order to compare various materials and processes. Finally, tensile properties are often used to predict a material's behavior under non-uniaxial loading forms. Mechanical testing (Tensile, Flexural) was carried out in Tensometer (Microtech, Pune) with load capacity ranging from 0 to 2000kgs and elongation 0 to 200mm. it is having an accuracy of 0.001.

For impact testing Izod and charpy testing machine (International equipment, Mumbai) is used which is having a maximum energy of 22J. Sonicator with a frequency of 30 kHz is used to mix Nano and polyester.

Scanning Electron Microscope (Joel make) with dual vacuum modes (High vacuum mode and low vacuum mode) and magnification ranging from x5 to x100,000 is used.

III. Results and Discussion

III.i. Mechanical Properties of Banana and Sisal Composites

From Fig 1(a), by increasing the fiber volume ratio up to 30% the mean tensile strength of sisal fiber reinforced composites is 81.91 MPa. The maximum mechanical
properties, tensile strength, flexural strength, and impact strength are found as 81.91 MPa, 292.52 MPa, and 21.2 MPa respectively.

Fig. 1: Variation of (a) tensile strength (b) tensile modulus of composite with volume fraction of fiber
Fig. 2: Variation of (a) flexural strength (b) flexural modulus of composite with volume fraction of fiber

Fig. 3: Variation of (a) Impact strength

Fig. 4: Effect of Nano clay on (a) tensile Strength of S/B Hybrid composite
Fig. 4: Effect of Nano clay on (b) tensile modulus of S/B Hybrid composite

Fig. 5: Effect of Nano clay on (a) flexural Strength of S/B Hybrid composite

Fig. 6: Effect of Nano clay on (a) impact Strength of S/B Hybrid composite
Fig. 7: (a) SEM micrograph of fractured surface of 50/50 hybrid composite with voids

Fig. 7: (b) SEM micrograph of fractured surface with Initial cracks

III.ii. Mechanical Properties of Sisal/Banana Hybrid Reinforced Composites

In order to improve the mechanical properties of banana and sisal are hybridized to bring the hybrid effect.

1. The Mean Tensile strength of Nano clay filled sisal fiber polyester composites is increased to 93.69 MPa at volume fraction of 44% which is 21.2% higher that of composite without Nano clay.

2. The Mean Tensile modulus of Nano clay filled sisal reinforced composite is increased to 1725.36 MPa at volume of fiber 43% which is higher than that of composite without Nano clay.

3. The maximum Flexural strength of banana/sisal hybrid composite with Nano clay is at the 30/70 combination with 304.4 MPa and 216.66 MPa

4. The maximum Flexural modulus with sisal/banana hybrid composite is found to decrease with the addition of one fiber to the other fiber.

5. The Impact strength for sisal/banana reinforced fiber composite is maximum at 50/50 combination with a fiber volume ratio of 47%.

6. From the following it is clear that hybridization of fibers with the addition of Nano clay yield better than with composites without Nano clay and hence this kind of hybrid composite is suitable for low cost applications.
III.iii. Fractography Study

Figs. 7a-7b is the micrographs of fractured specimen after tensile, flexural and impact test. From the Fig. 7 (a) SEM micrographs indicate the voids due to fiber pull-out. Further, due to the presence of cracks there exists a weakness during the mechanical testing’s.

Conclusion

In this examination, the impact of hybridization of sisal fiber on the mechanical properties was considered. Ends from this investigation are as per the following:

1. The Mean Tensile strength of the sisal reinforced polyester composite increased to 81.91 MPa at volume fraction of fiber 30%. With the increase of fiber volume ratio the Tensile strength of banana reinforced polyester composite decreases.

2. The Mean Tensile modulus of sisal fiber increases from 1.081 GPa to 1.69GPa which is 59% more and the Tensile modulus of banana fiber reinforced composite decreased to 87% on the increase of fiber volume ratio by 30%

3. The Mean Flexural strength of sisal reinforced composite is found to be more in the composite with highest fiber volume ratio i.e.; 30% and the Mean Flexural strength of banana composite is more at 15% of total fiber volume ratio.

4. The Mean Flexural modulus of sisal reinforced polyester composite is 18.03 GPa and for banana reinforced composite is 17.48 GPa.

5. The addition of sisal Fiber in the composite brings about 16% increment in Tensile strength, 4% increment in Flexural strength and 35% increment in Impact strength.

6. Minor increments in mechanical properties are because of poor interfacial bonding among matrix and the fiber, which is clear from SEM examination.

7. Interfacial bonding among fiber and matrix will be improved by chemical treatment / treatment with coupling agent [XII].

8. Hybridization of natural fiber composite by another natural fiber doesn't yield predominant mechanical properties as hybridization by glass fiber and carbon fiber [XIII]

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