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Effect of Fiber Volume Fraction on the Mechanical Properties of Banana and Sisal Fibers with Polyester Composite

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Abstract

In this project by using a natural fibers of banana and sisal are combined in the same matrix (unsaturated polyester) to make banana/sisal fiber hybrid composites. The Tensile, Flexural, and Impact strength properties of hybrid reinforced composite were described as per ASTM standards. Fabricate the hybrid polyester composite with varying aspect ratio of fibers and Volume fraction (20%, 30% and 40%). The fibers were kept under alkali treatment to improve the mechanical properties of the fiber significantly as compared to untreated fibers. The fibers were extracted from banana and sisal by manual processes and fabrication processes were done by Hand layup method. In this work, water absorption pattern of these fabricated composite at room temperature was found. Compare the mechanical properties of hybrid reinforced composite with plastics materials, wood and other natural fibers etc.

Keywords:
Banana and sisal fibers, Volume fraction, mechanical properties, hand layup method, Water absorption.

1. Introduction

Fiber reinforced polymeric composites have been used for a variety of structural applications because of their high specific strength and modulus compared to metals [1]. Initially developed for the aerospace industry, high-performance or 'advanced' composites are now found in applications from automotive parts to circuit boards, and from building materials to specialty sporting goods [2, 3]. Most composites currently available on the market are designed with long-term durability in mind and are made using non degradable polymeric resins, such as epoxies and polyurethane, and high-strength fibers, such as graphite, aramids, and glass. Many of these polymers and fibers are derived from petroleum, a non-replenish able commodity [4, 5]. The push now is to use composites in place of common plastics in consumer products to improve performance and reduce weight and cost. With increasing numbers of applications and mass volume uses, in particular, recording double-digit growth worldwide, disposal of composites after their intended life is already becoming critical, as well as expensive [6]. Because composites are made using two dissimilar materials, they cannot be easily recycled or reused. Most composites end up in landfills, while some are incinerated after use, although there are some efforts to recycle and/or reuse them [7, 8, and 9]. Both these disposal alternatives are expensive and wasteful, and may contribute to pollution. With growing environmental awareness, this search has particularly focused on eco-friendly materials, with terms such as renewable, sustainable and triggered biodegradable becoming buzzwords [10].

2. Materials and methods

2.1 Matrix

Polymers generally act as a good binder for fibers. Their availability coupled with their lower cost has provoked the selection of polymer as the binder for these fibers. Isophthalic resins are higher grade resins than ortho resins in that the molecular structure is denser. It is a special raw material utilized in corrosion resistant and/or premium grade polyester resins. These resins will exhibit a higher heat distortion temperature, higher strength, and greater flexibility and are more waterproof than orthophthalic resins.

2.2 Banana fiber

Banana is one of the rhizomatous plants and currently grown in 129 countries around the word. It is the fourth most important global food crop. Different parts of banana trees serve different needs, leaves as food wrapping, and fiber and paper pulp. Banana fiber is a multiple celled structure. The lumens are large in relation to the wall thickness. Cross markings are rare and fiber tips pointed and flat, ribbon like individual fiber diameter range from14 to 50 microns and the length from 0.25 cm to 1.3 cm showing the large oval to round lumen. Banana fiber is a natural fiber with high strength, which can be blended easily with cotton fiber or other synthetic fibers to produce blended fabric & textiles.

2.3 Sisal fiber

Sisal fiber made from the large spear shaped tropical leaves of the Agave Sisalana plant. Fine fiber available as plaid, herringbone and twill. Sisal fiber is extracted by a process known as decortication, where leaves are crushed and beaten by a rotating wheel set with blunt knives, so that only fibers remain.

2.4 Fiber surface treatment

Washed and dried Banana fibers and Sisal fibers were taken in separate trays, to these trays 6% NaOH solution was added, and the fibers were soaked in the solution for 5 hours. The fibers were then washed thoroughly with water to remove the excess of NaOH sticking to the fibers. The fibers were chopped into short fiber length of 3 cm for molding the composites.

2.5 Preparation of hybrid composite

Initially the percentages of resin, fibers, accelerator and catalyst are determined for optimum weight percentages so that strength of the composite is notable and worthy here we found that those percentages are 60% resin, 2% accelerator, 8% catalyst, and 30% of Sisal and banana fibers in equal proportions, first the chopped fibers as per the Aspect ratio is laid over the acrylic sheet where a ASTM rubber of 10mm thickness is placed over the sheet cut down to desired dimensions after laying of fibers are over, another sheet is placed over the rubber and the sides are sealed to protect any leakages using tape then clips are used to hold the sheets together at a definite pressure once these things are over the resin mixed with the above said % of components has to be poured between the space of two plates and after a curing time of about 5 to 7 hours the composite can be obtained.

2.6 Mechanical testing

Three important mechanical properties, tensile strength, flexural strength and impact strength were tested. All test specimen dimensions were according to the respective ASTM standards. All tests were performed at room temperature.

2.6.1 Tensile strength test

Tensile tests were conducted using universal testing machine with across head speed of 2.0 mm/min.Tensile test samples were cut as per ASTM D638 test procedure. Tests were carried out at room temperature and each test was performed until tensile failure occurred.

2.6.2 Flexural strength test

Flexural analysis was carried out at room temperature through three-point bend testing as specified in ASTM D 790, using universal testing machine. The speed of the crosshead was 2.0 mm/min. Each test was performed until failure occurred.

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2.6.3 Izod impact test

Izod impact test was performed on reinforced hybrid composite specimens as per ASTM-D256-90.

3. Result and discussion

Development of hybrid composites made from natural fibers with increased strength, stiffness and durability requires necessary understanding of mechanical behaviors. The mechanical properties of hybrid composites depend on the fiber strength, fiber modulus, fiber length, fiber orientation, and fiber–matrix interfacial bond strength. A strong fiber–matrix interface bond plays a vital role in establishing high mechanical properties of composites. A good interfacial bond is required for effective stress transfer from the matrix to the fiber by which maximum utilization of the fiber strength in the composite can be obtained. The analysis of mechanical properties of composites is important for understanding the behavior of composite materials. It is a well-known fact that the mechanical properties of fiber-reinforced composites depend on the nature of matrix material, the distribution and orientation of the reinforcing fibers and the nature of the fiber-matrix interfaces.

3.1 Tensile strength

Tensile strength of the hybrid composites before and after treatment NaOH treatment is shown in the figure: 1 as a function of fiber loading (weight percentage). The treated fibers, because of the removal of lignin, and modification of the fiber surface formed a good interface between fiber and matrix.

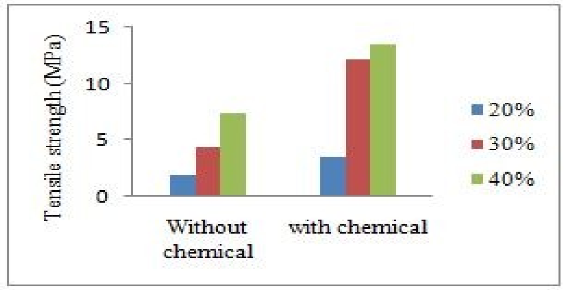

Figure 1 Tensile strength Vs volume fraction

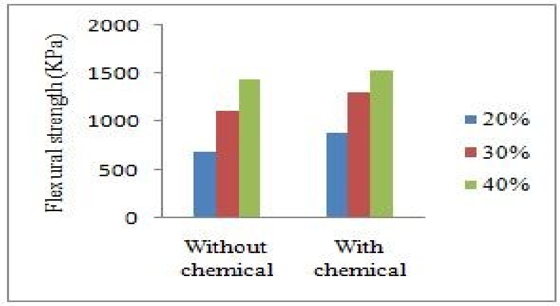

Figure 2 Flexural strength Vs volume fraction

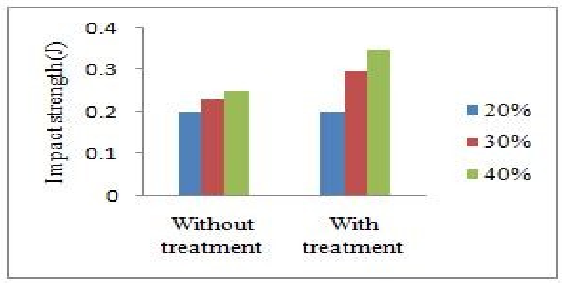

Figure 3 Impact strength Vs volume fraction

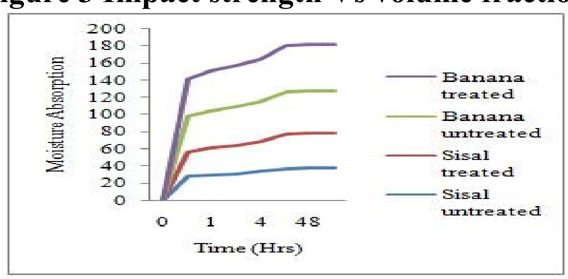

Figure 4 Moisture absorption for different fiber volume fractions

NaOH treatment removes the cementing material present in the fibers namely lignin and hemicelluloses thus increasing the surface area of the fiber. This increased surface area of the fiber leads to better adhesion of the fiber and matrix thus increasing the tensile strength. One more reason for the increased tensile strength can be due to the improvement of crystallinity of the treated fibers because of the removal of cementing materials. This leads to better packing of cellulose chains.

3.2 Flexural strength

Flexural strength of the hybrid composites before and after treatment NaOH treatment is shown in the figure: 2 as a function of fiber loading (weight percentage). The stresses induced due to the flexural load are a combination of compressive and tensile stresses. The Maximum Flexural strength gradually increased as fiber loading increases from 20% to 40%. Volume fraction of 40% fiber having the maximum flexural strength on both treated and untreated fibers. As compared to untreated fibers, the treated fibers have higher flexural strength as shown in below figure: 2.

3.3 Impact strength

Impact strength is the ability of a material to absorb energy under a shock load or the ability to resist the fracture under load applied at high speed. Impact behavior is one of the most widely specified mechanical properties of the Engineering materials. The variations of impact strength with respect to fiber loading (weight fraction) is as shown in Figure: 3 for Izod method of impact test. The maximum impact energy absorbed was for treated fiber and for a fiber loading (weight fraction) of 40%.

3.4 Water absorption

Moisture absorption was determined by the weight gain relative to the dry weight of the samples. The moisture content of a sample was computed as follows

$$Mt = (wt-w_0/w_0)*100\%$$

Where

W_0 = dry weight of sample

Wt = weight after specific time.

The effect of fiber content on the moisture absorption of different volume of fraction specimens are given as below tabulation and graph. Table shows us that increasing in weight of specimen initial up to 24 hrs and get constant further there is no increase or decrease in the weight of the specimens. Moisture absorption is less in chemical treated fibers specimen when comparing the moisture absorption with non Chemical treated fibers specimen. Figure shows deviation in curve % of moisture absorption to time in hrs.

4. Summary

The results in the investigation indicate that, it is possible to enhance the properties of fiber reinforced composites through fiber surface modification. The mechanical properties of composites of chemically treated fibers show better results when compared to untreated fibers. It is also noticed that the strength of the hybrid composites increases with increase in volume fraction of fiber in the hybrid composites. It is found that all the hybrid natural fiber composites show maximum mechanical properties for 40% of the fiber reinforcements. The enormous availability, cheaper and good strength of the composites leads way for the fabrication of lightweight materials that can be used in automobile body building, office furniture packaging industry, partition panels, and others compared to wood based plywood or particle boards.

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