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Mechanical behavior of chemically treated Jute/Polymer composites

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Fiber which serves as a reinforcement in reinforced plastics may be synthetic or natural past studies show that only artificial fibers such as glass, carbon etc., have been used in fiber reinforced plastics. Although glass and other synthetic fiber reinforced plastics possess high specific strength, their fields of application are very limited because of their inherent higher cost of production. In this connection, an investigation has been carried out to make use of jute, a natural fiber abundantly available in India. Natural fibers are not only strong and lightweight but also relatively very cheap. In the present work, jute composites are developed and their mechanical properties are evaluated. Mechanical properties of jute/polymer and compared with glass fiber/epoxy. These results indicate that jute can be used as a potential reinforcing material for making low load bearing thermoplastic composites.

INTRODUCTION :

A typical composite material is a system of materials composing of two or more materials, mixed and bonded on a macroscopic scale. Generally, a composite material is composed of reinforcement (fibers, particles, flakes, and / or fillers) embedded in a matrix (polymers, metals, or ceramics). The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties. The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. The composite materials are supposed to carry the advantageous properties of all the constituents used to fabricate it. There are a few definitions proposed by various researchers. As defined by Javitz, “Composites are multifunctional material systems that provide characteristic not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and

characteristics and sometimes in form”. Composites are the materials which consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is called as “reinforcement” which is usually harder and stronger than the continuous phase, where as the continuous phase is termed as the “matrix”. The strength of the fibers and matrix interface is significant in determining the properties of the composites. The interfacial bond strength must be sufficient enough for the load to be transferred from the matrix to the fibers. The interface must not be so strong that it does not fail for improved toughness of the composites. Volume fractions of the composites play a significant role in determining properties. It is regarded as the most important parameter for determining the properties of the composites. Homogeneity is also an important characteristic that determines the extent to which a material may differ in physical and mechanical properties from the average properties of the material. The isotropy of the system is affected by the orientation of the reinforcement of the matrix in the composites.

Natural fiber has attracted the attention of researchers worldwide as a potential reinforcement for composites because of their easy availability, easy process ability, low density, light weight, non-abrasivity, and lower cost and eco-friendly characteristics like sequestration of carbon dioxide (reduction of greenhouse effect). The silk fiber produced by spiders, silkworms, scorpions, mites and flies may have different composition, structure and material properties depending upon the specific source. These flaws can be avoided by spinning under controlled conditions to produce uniform cross-sectional area of silk fiber. Replacement of fiberglass with natural fibers removes worries about the lung disease caused by the former which is a great step towards sustainable development. These fibers are animal or plant products; the latter are essentially micro-composites consisting of cellulose fibers in an amorphous matrix of lignin and hemi cellulose. Cotton, jute, silk, wool, flax, hemp, jute, Roselle, kenaf, pineapple, ramie, bamboo, banana, and sisal are some of the natural fiber composites.

MATERIAL AND METHODS

The raw materials used in this work are

1. Jute
2. Epoxy resin
3. Hardener

A. MANUFACTURING PROCESS

Alkaline Treatment : Alkaline treatment or mercerization is one of the most used chemical treatment of natural fibers when used to reinforce thermoplastics and thermosets. The important modification done by alkaline treatment is the disruption of hydrogen bonding in the network structure, thereby increasing surface roughness. This treatment removes a certain amount of lignin, wax and oils covering the external surface of the fiber cell wall, depolymerizes cellulose and exposes the short length crystallites. Addition of aqueous sodium hydroxide (NaOH) to natural fiber promotes the ionization of the hydroxyl group to the alkoxide. A glass beaker is taken and 5% NaOH is added and 80% of distilled water is added and a solution is made. After adequate drying of the fibers in normal shading for 2 to 3 hours, the fibers are taken and soaked in the prepared NaOH solution. Soaking is carried out

for different time intervals depending upon the strength of fiber required. In this study, the fibers are soaked in the solution for three hours. After the fibers are taken out and washed in running water, these are dried for another 2 hours. The fibers are then taken for the next fabrication process namely the Procasting process.

It is reported that alkaline treatment has two effects on the fiber: (1) it increases surface roughness resulting in better mechanical interlocking; and (2) it increases the amount of cellulose exposed on the fiber surface, thus increasing the number of possible reaction sites. Alkaline treatment also significantly improved the mechanical, impact fatigue and dynamic mechanical behaviors of fiber-reinforced composites.

Acrylonitrile Treatment : A solution was made of 3% acrylonitrile, 0.5 hydrogen peroxide, and 96.5% ethanol (all % weight) and stirred in a covered beaker for 3 hours. In Acrylonitrile Treatment, fibers are immersed in 5% aqueous NaOH solution for 1h at room temperature. The fibers were oriented in the mould, and the mold placed in the solution and allowed to soak for 15 minutes. The fibers were then drained and allowed to dry under the hood for 30 minutes.

Benzoylation Treatment : Benzoylation is an important transformation in organic synthesis. Benzoyl chloride is most often used in fiber treatment. Benzoyl chloride includes benzoyl which is attributed to the decreased hydrophilic nature of the treated fiber and improved interaction with the hydrophobic PS matrix. Benzoylation of fiber improves fiber matrix adhesion, thereby considerably increasing the strength of composite, decreasing its water absorption and improving its thermal stability. The isolated fibers were then soaked in ethanol for 1 hour to remove the benzoyl chloride and finally was washed with water and dried in the oven at 80°C for 24 h.

Sample preparation

The samples were prepared using the fibers and epoxy, which are handled differently in the processing. The moulds are cleaned and dried

before applying epoxy. Wax was used as the releasing agent. In the case of glass fiber/epoxy fabrication, the epoxy mixture is laid uniformly over the mould using a brush. Then a layer of the chopped strand mat is applied over the layer of epoxy. The same process was repeated until three such layers of epoxy and chopped strand mat are applied. Now the mould is closed and compressed for a curing time of 24 h. For JUTE/epoxy fabrication, the JUTE fibers were laid uniformly over the mould before applying any releasing agent or epoxy. Then the compressed form of JUTE is removed from the mould. This was followed by applying the releasing agent on the mould, after which a coat of epoxy was applied. The compressed fiber was laid over the coat of epoxy, ensuring uniform distribution of fibers. The epoxy mixture is then poured over the fiber uniformly and compressed for a curing time of 24 h. After the curing process, test samples were cut to the required sizes prescribed in the ASTM standards.

Short Fiber Reinforced Composite : In this the short fibers with length of (3, 5, 7 & 9) mm is taken. For different length of fibers, a calculated amount of epoxy resin and hardener HY951 of density 0.90 to 0.99g/cm³ is used (ratio of 10:1 by weight) was thoroughly mixed with gentle stirring to minimize air entrapment. For quick and easy removal of composite sheets, mould release sheet was put over and below the mould cavity and wax was applied at the inner surface of the mould. After keeping the mould on a glass sheet a thin layer (\approx 1 mm thickness) of and matrix were poured into the mould. The bundles of short fibers were arranged random directional into the mould. Then again the matrix was poured above the fibers and care was taken to avoid formation of air bubbles. After 24 hrs the samples were taken out of the mould, cut into different sizes as per the ASTM standards and kept in air tight container for further experimentation.

B. MECHANICAL TESTING

After fabrication the test specimens were subjected to various mechanical tests as per ASTM standards (Table1). The mechanical tests that we carried out are tensile test, impact test,

flexural test, wear test. The specimen size and shape for corresponding tests are as follows.

Table (1) : ASTM standard for specimen preparation

TEST	ASTM STANDARD	SPECIMEN SIZE (mm)
Tensile test	D 3039	250 x 25 x 2.5
Flexural test	D 790	154 x 13 x 3
Impact test	D 256	64 x 12.7 x 3.2

Tensile Test : After the fibers reinforced composite was dried, it was cut using a saw cutter to get the dimension of specimen for mechanical testing. The tensile test specimen was prepared according to ASTM D3039. The most common specimen for ASTM D3039 has a constant rectangular cross section, 25 mm (1 in) wide and 250 mm (10 in) long. The specimen was mounted in the grips with 50 mm gauge length. The stress strain curve was plotted during the test for the determination of ultimate tensile strength and elastic modulus. All the test results were taken from the average of three tests.

Flexural Test : Flexural test were using the 3-point bending method according to ASTM D790. The specimen dimensions were 157 mm (L) x 13 mm (W) and had 3 mm thickness. Flexural test was conducted to study the behavior and ability of material under bending load. The load was applied to the specimen until it is totally break. The flexural test was conducted for three different types of surface treatments of fiber composites.

Impact Test (Izod Method) : Impact is a single point test that measures a materials resistance to impact from a swinging pendulum. Impact is defined as the kinetic energy needed to initiate fracture and continue the fracture until the specimen is broken. This test can be used as a quick and easy quality control check to determine if a material meets specific impact properties or to compare materials for general toughness. The standard specimen for ASTM D256 is 64x12.7x 3

mm ($2\frac{1}{2} \times \frac{1}{2} \times \frac{1}{8}$ inch). The most common specimen thickness is 3 mm (0.125 inch), but the preferred thickness is 6.4 mm (0.25 inch) because it is not as likely to bend or crush.

RESULT AND DISSUSSION :

The fabricated JUTE fiber reinforced composites was subjected to various tests to evaluate their mechanical properties. All specimens were prepared under the specifications of ASTM standard. Mechanical testing of composites (tensile strength, flexural, impact strength) were conducted and their properties were evaluated.

Tensile Property : Tensile strength of the composite was calculated by maximum load to which the material can withstand. It is usually a universal testing machine loaded with a sample between 2 grips that are either adjusted manually or automatically to apply force to the specimen. Material to be tested must be cut to a specific shape so as to fit the grips, most usually in the form of a dog-bone shape when flat sheet is being tested. The sheet is cut or machined to shape, and great care is needed to create a smooth edge. The tensile strength of the JUTE/epoxy composites is shown in Figure (1). When the fiber surface was modified with an aqueous NaOH solution or benzoylation or acrylonitrile with the pre-impregnation process, the tensile strength of the composite did seem to improve noticeably. With the pre-impregnation process, the tensile properties of the composite showed acrylonitrile treatment 5 mm a small improvement. The tensile strength increases resulting from the pre-impregnation process resulted in an enhancement of the mechanical interlocking however, when the acrylonitrile treatment is used, an increase in the tensile strength was observed.

From the above result shows that acrylonitrile treated 5 mm fiber length obtained good result. This increment is attributed to chemical interactions and mechanical interlocking. It is believed that this acrylonitrile treatment results in an improvement in the interfacial bonding by giving rise to additional sites of mechanical interlocking, hence promoting more resin/fibre interpenetration at the interface. It is observed in this study, that the different fiber surface

techniques with respect to the untreated fibers is different from the ratio of material property values obtained from the composites using treated fibers and the untreated fibers.

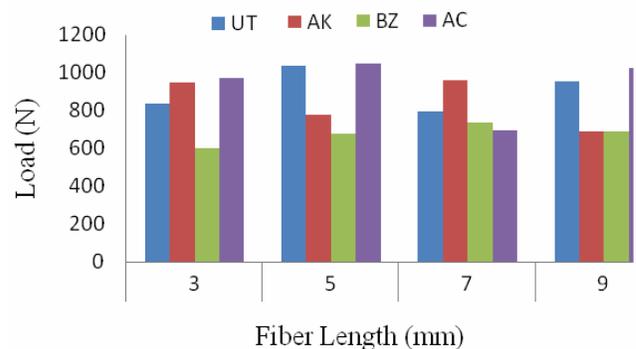


Figure (1) : Load vs. fiber length.

Flexural Property : The flexural strength of the JUTE/epoxy fiber composites plotted again as a function of the different fiber surface treatments are shown in Figure (2).

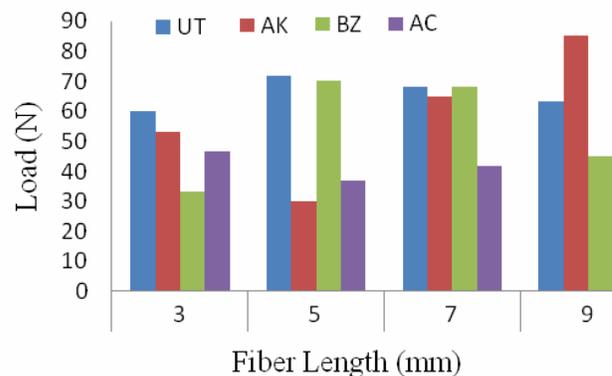


Figure (2) : Load Vs Fiber length.

Flexural properties such as flexural strength and modulus are determined by ASTM test method D790. In this test, a composite beam specimen of rectangular cross section is loaded in either a three-point bending mode or a four point bending mode. In either mode, a large span thickness (L/h) ratio is recommended. We will consider only the three-point flexural test for our discussion. The maximum fiber stress at failure on the tension side of a flexural specimen is considered the flexural strength of the material.

Using a homogeneous beam theory, The flexural strength in a three-flexural test is given by the formula

$$\sigma_{UF} = 3P_{max}L/2bh^2 \text{ ----- (1)}$$

where,

P_{max} = maximum load a failure

b = specimen width

h = specimen thickness

L = specimen length between the two support points

Flexural modulus is calculated from the initial slope of the load deflection-curve

$$E_F = mL^3/4bh^3 \text{ ----- (2)}$$

where, m is the initial slope of the load vs. deflection curve.

Also, the observations made earlier for the tensile strength on the effect of fiber–matrix adhesion are also seen clearly here. The fiber surface treatments had a marginal effect on the flexural modulus, similarly to the observations made for the tensile properties. This indicates that a better contact and the increase in area of contact between the fiber and the matrix are improving the level of adhesion, probably by the incorporation of a mechanical component of adhesion for the matrix–fiber interfacial strength. From the above result alkaline treated 9 mm fiber length obtained good result. When the fiber is treated with the alkaline a larger increase in the flexural strength is also observed. When the chemical and the mechanical components of the adhesion are combined, a larger increase of strength is observed (20%). The failure modes are discussed to further clarify the relationship between fiber–matrix adhesion and the flexural strength.

Impact Property : Impact is a single point test that measures a materials resistance to impact from a swinging pendulum. Impact is defined as the kinetic energy needed to initiate fracture and continue the fracture until the specimen is broken.

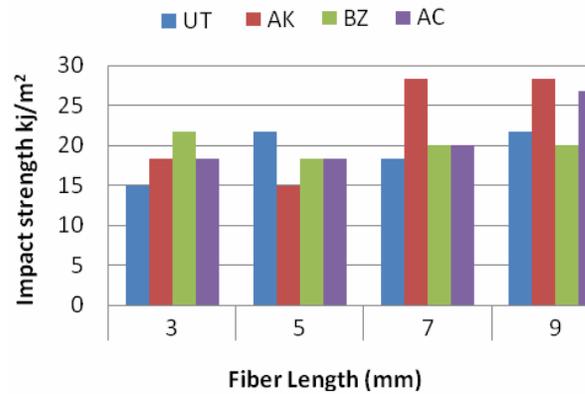


Figure (3) : Impact strength vs fiber length.

This test can be used as a quick and easy quality control check to determine if a material meets specific impact properties or to compare materials for general toughness. The standard specimen for ASTM D256 (13×66×3) mm and specimen prepared. Shown in Figure (3) in this result show that alkaline treated (7, 9 mm) fibers were obtained same and good results.

CONCLUSION :

Experiments were conducted to characterize the surfaces of treated and untreated fibers and to investigate tensile property, flexural property and impact property in natural fiber composites. Tensile strength of the acrylonitrile treated 5 mm fiber length was obtained good result due to better mechanical interlocking between fiber and matrix. Flexural strength of the alkaline treated 9 mm fiber length was obtained good result due to better mechanical interlocking between fiber and matrix. Impact strength of the alkaline treated (7, 9 mm) fiber length was obtained same results due to better mechanical interlocking between fiber and matrix. The alkaline treated 7, 9 mm is the overall best result obtained good result due to better mechanical interlocking between fiber and matrix. From the above result it can be concluded that the 3 mm fiber were not suitable for short fiber (JUTE) epoxy composite.

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