International Journal of Physical Sciences Vol. 3(2), pp. 017-021, December 2015
Available online at http://academeresearchjournals.org/journal/ijps
ISSN 2331-1827 ©2015 Academe Research Journals

Full Length Research Paper

Mechanical behaviour of chemically treated Jute/Polymer composites

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Accepted 11 February, 2014

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 was 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 were developed and their mechanical properties were evaluated. Mechanical properties of JUTE/POLYMER were 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.

Key words: Jute, polymer, glass fiber, epoxy, plastics.

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 (Mohanty et al., 2000).

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 “reinforcement” which is usually harder and stronger than the continuous phase, whereas 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) (Blazewicz et al; 1997). 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

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which is a great step towards sustainable development (Paul et al., 2003) . 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 (Joseph et al; 1999, Chandramohan and, Bharanichandar 2013).

MATERIALS AND METHODS

Here, the details of processing of the composites and the experimental procedures followed for their mechanical characterization, are described. The raw materials used in this work are: 1) jute, 2) epoxy resin, and 3) hardener.

Alkaline treatment

Alkaline treatment or mercerization is one of the most used chemical treatments 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 (Clemons and Caulfield 1994). Addition of aqueous sodium hydroxide (NaOH) to natural fiber promotes the ionization of the hydroxyl group to the alkoxide. In alkaline treatment, fibers are immersed in 5% aqueous NaOH solution for 1 h at room temperature. It is reported that alkaline treatment has two effects on the fiber:

(1) It increases surface roughness resulting in better mechanical interlocking;
(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 h. The fibers were oriented in the mould, and the mould placed in the solution and allowed to soak for 15 min. The fibers were then drained and allowed to dry under the hood for 30 min.

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 fiber was initially alkaline pre-treated in order to activate the hydroxyl groups of the cellulose and lignin in the fiber; then the fiber was suspended in 10% NaOH and benzoyl chloride solution for 15 min. The isolated fibers were then soaked in ethanol for 1 h 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 were cleaned and dried before applying epoxy. Wax was used as the releasing agent. In the case of glass fiber/epoxy fabrication, the epoxy mixture was laid uniformly over the mould using a brush. Then a layer of the chopped strand mat was applied over the layer of epoxy. The same process was repeated until three such layers of epoxy and chopped strand mat were applied. At this time, the mould was 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 (Khashaba et al. 2006). Then the compressed form of JUTE was 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 was 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

For this composite, the short fibers with length of 3, 5, 7 and 9 mm were taken. For different lengths of fibers, a calculated amount of epoxy resin and hardener (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 (≈ 1 mm thickness) and matrix were poured into the mould. The bundles of short fibers were arranged in a random direction into the mould. Then again the matrix was poured above the fibers and care was taken to avoid formation of air bubbles. Pressure was then applied from the top and the mould was allowed to cure at room temperature for 24 h. After 24 h, 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.

Mechanical testing

After fabrication, the test specimens were subjected to various mechanical tests as per ASTM standards (Table

Table 1. ASTM standard for specimen preparation.

Test	ASTM standard	Specimen size (mm)
Tensile test	D 3039	250 × 25 × 2.5
Flexural test	D 790	154 × 13 × 3
Impact test	D 256	64 × 12.7 × 3.2

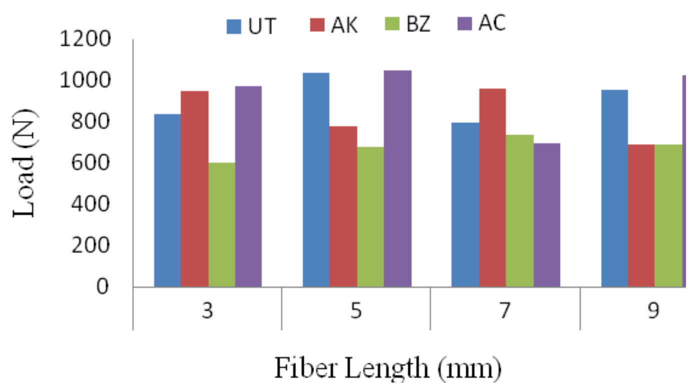

Figure 1. Load versus fiber length.

1). The mechanical tests that were carried out are tensile test, impact test, flexural test and wear test. The specimen size and shape for corresponding tests are as follows:

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 used the 3-point bending method according to ASTM D790. The specimen dimensions were 157 mm (L) × 13 mm (W) and it 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 totally broke. 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 material's 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 64 × 12.7 × 3 mm (2½ × ½ × 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.

RESULTS AND DISCUSSION

The fabricated JUTE fiber reinforced composites were alsubjected 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) was conducted and their properties were evaluated (Shah and Lakkad 1981).

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 that acrylonitrile treatment (5 mm) had a small improvement. The increase in tensile strength came from the pre-impregnation process which resulted in an enhancement of the mechanical interlocking; however, when the acrylonitrile treatment was used, an increase in the tensile strength was observed.

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 was observed in this study, that the different fiber surface techniques with respect to the untreated fibers were different from the ratio of material property values obtained from the composites using treated fibers and the untreated fibers.

Flexural property

The flexural strength of the JUTE/epoxy fiber composites

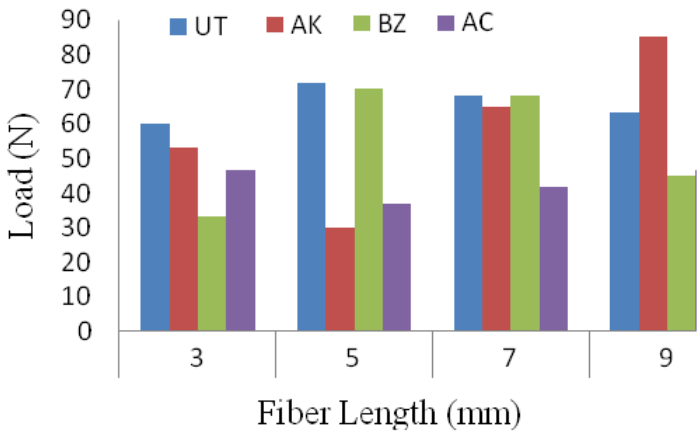

Figure 2. Load versus fiber length.

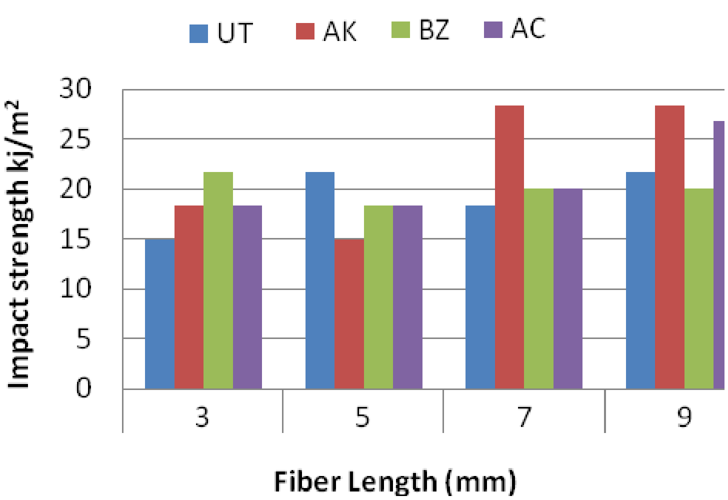

Figure 3. Impact strength versus fiber length.

plotted again as a function of the different fiber surface treatments are shown in Figure 2.

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 was loaded in either a three-point bending mode or a four point bending mode. In either mode, a large span thickness (L/h) ratio was recommended. The three-point flexural test only was considered for our discussion. The maximum fiber stress at failure on the tension side of a flexural specimen was considered as the flexural strength of the material. Thus, using a homogeneous beam theory:

- The flexural strength in a three-flexural test is given by the formula:

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

Where, P_{max} = maximum load of a failure, b = specimen width, h = specimen thickness, and L = specimen length between the two support points.

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

$E_F = mL^3/4bh^3$--------------------------- (2)

Where, m is the initial slope of the load versus 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 was treated with the alkaline, a larger increase in the flexural strength was also observed. When the chemical and mechanical components of the adhesion were combined, a larger increase of strength was observed (20%). The failure modes are discussed to further clarify the relationship between the fiber-matrix adhesion and the flexural strength.

Impact property

Impact is a single point test that measures a material's 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 (13×66×3) mm and specimen were prepared. As shown in Figure 3, this result shows that alkaline treated (7, 9 mm) fibers 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 obtained good result due to better mechanical interlocking between the fiber and matrix. Flexural strength of the alkaline treated 9 mm fiber length obtained good result due to better mechanical interlocking also between the fiber and matrix. Impact strength of the alkaline treated (7, 9 mm) fiber length obtained same results due to better mechanical interlocking between the fiber and matrix. Lastly, the alkaline treated (7, 9 mm) fiber had the overall best result in that it obtained good result due to better mechanical interlocking between the 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.

ACKNOWLEDGEMENT

The authors wish to thankfully acknowledge the Management of Vel Tech, Avadi, Chennai for their constant encouragement and support.

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