Mechanical Performance Of Natural Fiber-Reinforced Epoxy-Hybrid Composites

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ABSTRACT:

Presently polymer matrix composites reinforced with fibers such as glass, carbon, aramid, etc. are being used more because of their favorable mechanical properties in spite of they being more expensive materials. Nowadays natural fibers such as sisal, flax, hemp, jute, coir, bamboo, banana, etc. are widely used for environmental concern on synthetic fibers (such as glass, carbon, ceramic fibers, aramid etc.). Engineered bio-composites are needed to meet the needs of users for construction and commodity products which will simultaneously maximize the sustainability of natural resources. This coming generation of engineered bio-composites must provide construction materials and building products that exceed current expectations, such as lower cost, greater adaptability and reliability and lower maintenance. These engineered bio-composites are opening new markets in the field of commercial construction, automotive, aerospace and also reducing effects on the environment such as energy, air, water, and waste. In this investigation, arecanut fruit husk fibers and tamarind fruit fibers are reinforced with Epoxy matrix and composites have been developed by manual hand layup technique. These fibers were treated with NaOH (Alkali treatment) for better fiber matrix adhesion. The fiber percentages (10%, 20%, 30%, 40% and 50% by weight) were used for the preparation of hybrid composites. These natural fiber reinforced hybrid composites were then characterized by mechanical tests. The results showed increase in the tensile strength as the fiber percentage increased; however, after a certain percentage of fiber reinforcement, the tensile strength decreased. Compared to untreated fiber a significant change in tensile strength and flexural strength has been observed for surface treated fiber composites. Flexural also followed the tensile behavior and the maximum flexural strength was obtained for 40% of the treated fiber reinforced. Maximum impact energy absorbed was for the composites reinforced with 50% of treated fiber.

Keywords: *Natural fiber reinforced hybrid composites, Arecanut husk fibers, Tamarind fruit fibers, Alkali treatment, Mechanical properties.*

I. INTRODUCTION:

The excess use of petroleum products has lead to depletion of petroleum resources and entrapment of plastics in the environment. The increasing pollution caused by the use of plastics is affecting the food, water and air used by the human beings. The exhaustive use of petroleum based resources is insisting to develop bio-degradable plastics. The production of bio-based materials as replacement for petroleum based products is ultimately not the solution. The reasonable remedy would be to combine petroleum and bio-based materials to develop an effective product having many applications. Biopolymers or synthetic polymers reinforced with natural fibers are an alternative solution to glass fiber composites. Researchers, academicians and scientists are looking at the various opportunities of combining bio-fibers such as sisal, flax, hemp, jute, banana, wood and various grasses with polymer matrices from non-renewable and renewable resources to form composite materials.

The use of composites filled with particles in epoxy system has gained significant importance in the development of thermosetting composites. One of the most important focuses in achieving this goal is to develop a new material, which possesses a strength-to-weight ratio that far exceeds any of the present materials. Epoxy resin is the most important matrix used in the high-performance transportation systems. When epoxy combines with glass/carbon fibers, it results in advanced composites, which have sound-specific properties such as impact, hardness, tensile, strength, modulus, and tri-bological properties. The new found properties make this material very attractive for use in aerospace applications. A rough estimation has it that for every unit of weight reproduction in an aircraft, there is a considerably less consumption of fuel or higher load capacity, and hence materials offer load saving [1-4]. Hybrid composites are materials are made by combining two or more different types of fibers in a common matrix. Hybridization of two types of short fibers having different lengths and diameters offers some advantages over the use of either of the fibers alone in a single polymer matrix. The combination of bio-fibers like oil palm, kenaf, industrial hemp, flax, jute, henequen, pineapple leaf fiber, sisal, wood and various grasses with polymer matrices from both non-renewable (petroleum based) and renewable resources to produce composite materials that are competitive with synthetic composites such as glass–polypropylene, glass epoxies, etc., is gaining attention over the last decade. Available data in literature usually covers hybrid composites made of natural fibers/synthetic fibers and remembering that plant-based fibers have been selected as suitable reinforcements for composites due to their good mechanical performances and environmental advantages. Hybrid composites reinforced with natural fibers, very often combined with synthetic fibers such as glass fibers, can also demonstrate good mechanical performance [5–7]. Polymer composites with hybrid reinforcement solely constituted of natural fibers are less common, but these are also potentially useful materials with respect to environmental concerns [8]. Investigations of lingo-cellulosic fibers have shown that the properties of fibers can be better used in hybrid composites [9]. The main parameters which affect the mechanical properties of the composites are fiber length, weight ratio, fiber orientation and interfacial adhesion between fiber and matrix.

In the present investigation, the Tensile Strength, Flexural strength and impact strength of hybrid-biological fiber reinforced composite material was found out experimentally. The natural fibers used are fibers from the husk of arecanut and fibers from the fruit of tamarind.

I. MATERIALS AND METHODS

Matrix:

Epoxy is a thermosetting polymer that cures (polymerizes and cross links) when mixed with a hardener. Epoxy resin of the grade LM-556 with a density of 1.1–1.5 g/cm3 was used. The hardener used was HY-951. The matrix material was prepared with a mixture of epoxy and hardener HY-951 at a ratio of 10:1.

Fibers:

Arecanut husk fibers:

Arecanut is also known as Betel nut. The arecanut husk fibers are predominantly composed of cellulose and varying proportions of hemicellulose, lignin, pectin and protopectin. The husk is about 15–30% of the weight of the raw nut. The fibers adjoining the inner layers are irregularly lignified group of cells called hard fibers, and the portions of the middle layer below the outermost layer are soft fibers [10]. India dominates the world in area (57%), production (53%) and productivity of arecanut (0.679 million tonnes in 2010). The husk constitutes about 60–80% of the total weight and volume of the fresh fruit. The husk fiber is composed of cellulose with varying proportions of hemicellulose (35–64.8%), lignin (13.0–26.0%), pectin and protopectin [11]. The average fiber length of the areca husk fiber is 4 cm. The arecanut husk fibers are extracted by soaking in water for 3 weeks and then beating with a mallet.

Tamarind fruit fibers:

The Tamarind (Tamarindus indica) is in the family Fabaceae. In India there are extensive tamarind orchards producing 275,500 tons (250,000 MT) annually. The ripe fruit comprises of about 55% tamarind pulp, 33% seeds and about 12% fiber; Tamarind trees are very common in South India, particularly in Tamil Nadu and Andhra Pradesh. Fibers from the tamarind fruit were collected after removing the pulp and the seeds.

Fiber surface treatment:

Washed and dried Tamarind fruit fibers and arecanut husk fibers were taken in separate trays, to these trays 10% NaOH solution was added, and the fibers were soaked in the solution for 10 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.

Preparation of Hybrid Composite:

A GI Sheet mould with required dimensions was used for making the sample as per ASTM standards. The mould was coated with a mould releasing agent for the easy removal of the sample. The resin and hardener were taken in the ratio of 10: 1 parts by weight, respectively. Then, a pre-calculated amount of hardener was mixed with the epoxy resin and stirred for 20 minutes before pouring into the mold. The hand lay-up technique was used to impregnate the composite structures. In this technique, the tamarind fruit fibers and the arecanut husk fibers were wetted by a thin layer of epoxy suspension in a mold. A stack of hybrid fibers were carefully arranged in a unidirectional manner after pouring some amount of resin in to the mold. The remaining mixture was poured over the hybrid fibers. Brush and roller were used to impregnate fiber. The closed mold was kept under pressure for 24 h at room temperature. Test specimens of required size were cut out composite manufactured after curing. The percentages of fibers used are 10%, 20%, 30%, 40% and 50% by weight. The ratios of fibers used for tamarind fruit fibers and the arecanut husk fiber was 1:1.

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. Five specimens of each type were tested and five replicate values were taken as an average of tested specimens.

Tensile strength test:

Tensile tests were conducted using universal testing machine with across head speed of 5mm/min. In each case, five samples were tested and average value tabulated. 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.

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 5 mm/min. five composites specimens were tested for each sample and each test was performed until failure occurred.

Flexural strength was calculated from the Equation.

$\boldsymbol{\sigma}_f = (3PL) / (2bd^2)$, where,

P = Load at a given point on the load deflection curve in Newton (Peak load)

L = support span in mm

b =width of the samples in mm

d = thickness of the samples in mm

Izod impact test:

Izod impact test was performed on arecanut husk fibers and tamarind fruit fibers reinforced hybrid epoxy composite specimens as per ASTM-D256-90. Five samples were tested at ambient conditions and the average of impact strength was calculated.

III. RESULTS 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. A better understanding of the effect of surface treatment of the fibers and fiber loading will help to develop productive uses for tamarind fruit fibers and arecanut husk fibers. This leads to developing an alternative material to wood. 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. A change in the physical and chemical structure of the fiber for a given matrix will result in drastic changes in the overall mechanical properties of composites.

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 Maximum stress gradually increased as fiber loading increases from 10% to 40%, but decreased in further increase of reinforcement (50%). The treated fibers, because of the removal of lignin, and modification of the fiber surface formed a good interface between fiber and matrix. The overall increase in the tensile strength was 31.3% when compared with untreated fiber reinforced composites. The overall increase in comparison with pure epoxy was 78%.

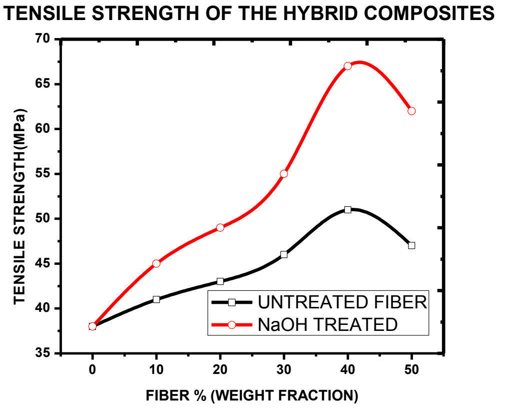

Figure: 1; *Variation of Tensile strength with fiber loading (weight fraction) [NaOH treated and untreated fibers]*

NaOH treatment removes the cementing material present in the fibers namely lignin and hemicellulose 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. The unidirectional fiber orientation leads to less overlapping of fibers and thus reducing fiber pull outs, fiber agglomerations. Due to unidirectional fiber orientation there are less chances of air entrapment. The entrapment of air leads to crack tip formations, which leads to poor stress transfer between the fiber and the matrix.

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 10% to 40%, but decreased in further increase of reinforcement (50%). The overall increase in the flexural strength was 18% when compared with untreated fiber reinforced composites. The overall increase in comparison with pure epoxy was 48%.

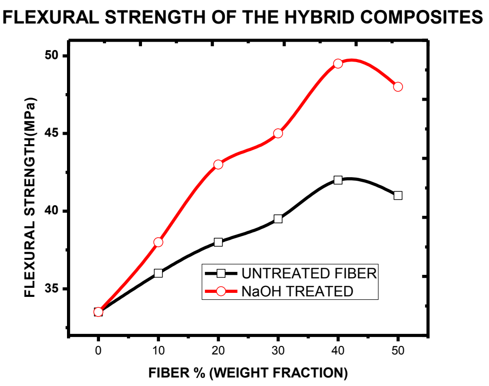

Figure: 2; *Variation of Flexural strength with fiber loading (weight fraction) [NaOH treated and untreated fibers]*

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.

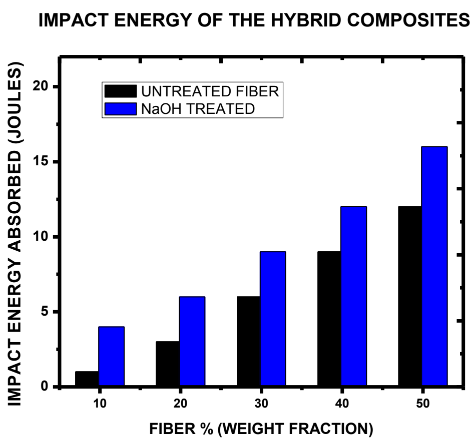

Figure: 3; *Variation of Impact energy absorbed with fiber loading (weight fraction) [NaOH treated and untreated fibers]*

The maximum impact energy absorbed was for treated fiber and for a fiber loading (weight fraction) of 50%, there is an increase of 30% in the energy absorbed when compared with untreated fibers reinforced hybrid composites.

VI. CONCLUSIONS:

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 from husk of arecanut and fibers from the fruit of tamarind 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 40-50% of the fiber reinforcements. The hybridization has also increased the mechanical properties. The fiber extracted from tamarind fruit is a byproduct (waste) in tamarind extraction plants. Availability of these fibers is in bulk and needs a processing technology for making industrial level usage. Fibers from tamarind fruit is hard and tough, which is similar to coir fibers and its porous surface morphology is useful for better mechanical interlocking with matrix resin for composite fabrication. The enormous availability (arecanut husk fibers and tamarind fruit fibers) 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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