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Review on mechanical properties of natural fiber composites.

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Abstract

The present experimental study aims at learning the mechanical behavior of natural fiber composites. Natural fibers have an attracting the interest to engineers, researchers, professionals and scientists all over the world as an alternative reinforcement, because of its superior properties such as high specific strength, low weight, low cost, fairly good mechanical properties, non-abrasive, eco-friendly and bio-degradable characteristics. A brief review has been carried out to make use of natural fibers (such as abaca, jute, sisal, banana, cotton, coir, hemp, etc) abundantly available in India. This paper presents a review on the mechanical properties of Abaca, Jute, Sisal.

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Keywords: Composite materials, Hybrid composites, Silicon carbide, Jute fiber, Sisal fiber, Natural rubber, Glass fibers, Epoxy.

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1. Introduction

A composite is combination of two materials in which one of the materials, called the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other materials called the matrix phase[2]. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites typically have a fiber or particle phase that is stiffer and stronger than the continuous matrix phase and serve as the principal load carrying members[4] [12]. The matrix acts as a load transfer medium between fibers, and in less ideal cases where the loads are complex, the matrix may even have to bear loads transverse to the fiber axis. The matrix is more ductile than the fibers and thus acts as a source of composite toughness. The matrix also serves to protect the fibers from environmental damage before, during and after composite processing. When designed properly, the new combined material exhibits better strength than would each individual material. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications. “Composites are multifunctional material systems that provide characteristics 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” [1] . The composites should not be regarded simple as a combination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them. “The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings”, in order to obtain improved materials. Composite materials as heterogeneous materials consisting of two or more solid phases, which are in intimate contact with each other on a microscopic scale. They can be also considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property.

2. Study on Natural fiber composites

The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lingo cellulosic fibers, are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites[1]

2.1Fibers used

Fig1: Abaca,jute. Fig2: Sisal

3. Study on Abaca, Jute, Sisal

Abaca (i.e., Manila hemp) fiber is a kind of strong natural fibers produced mainly in Philippine, which is from the leaf of Musa species plant similar to banana tree but with inedible fruit. It has been reported that abaca fiber has a high tensile strength, is resistant to rotting and has a specific flexural strength comparable to that of glass fiber [4]. Thus it has been widely used as raw material for ropes, bags, and paper. In recent years, the application of abaca fiber has been extended to the automotive industry like Mercedes-Benz manufacturer Daimler Chrysler. It is also reported that the abaca fiber is the first natural fiber to meet stringent quality requirements for the exterior components of road vehicles with a good resistance to the stone strike, exposure to the elements, and dampness [5]. Therefore, to obtain high quality abaca fiber is essential for the industrial application of this tropical fiber. It is well known that the microstructure of materials influences its properties. Researchers often improve the mechanical properties through changing the microstructure. There are many works regarding the mechanical properties of natural fibers as well as their composites with high strength derived from chemical or physical treatment of fiber itself and/or matrix [6–9]. However, to our best knowledge, there is few work reporting the effect of FHFS on the original structure of natural fibers and in turn on their properties [10,11]. Due to the dependence of structure of natural fiber on the fiber growing condition [10], it is possible to obtain natural fibers with desired properties by selecting fibers from different positions of plant. To achieve this objective, the tensile properties and the physicochemical properties of abaca fiber as well as its composites will be piecewise studied in this paper by cutting fibers into sequent fragments.

Jute fibre was collected from J. Schilgen GmbH & Co., Emsdetten, Germany. It was wrapped in cone with twist number Nm 3.6/1. The fibre chopped into 25 mm length to ensure easy blending with polymer matrix. The single fibre diameter was 60–110 μm and original fibre length was 3 to 3.5 m long. On the other hand jute is one of the most common agricultural fibres which exhibit moderately higher mechanical properties and are cultivated almost exclusively in Bangladesh, India, Thailand and in some parts of Latin America. The total annual world production of jute is about 2500 thousand tones [18]. In addition, flax is the most important and demandable bast fibres in Europe. About 80% of the total world flax crop is grown in France, Belgium, Spain, UK and Holland. Flax fibre is relatively stronger, crisper and stiffer to handle [19]. During the last decade jute and flax fibre gained remarkable attention as reinforcing materials of composites.

Sisal with the botanical name ***Agave sisalana***, is a species of ***Agave*** native to southern Mexico but widely cultivated and naturalized in many other countries. It yields a stiff fiber used in making various products[1] . The term sisal may refer either to the plant's common name or the fiber, depending on the context. It is sometimes referred to as "sisal hemp", because for centuries **hemp** was a major source for fibre, and other fibre sources were named after it.

The sisal fibre is traditionally used for **rope** and **twine,** and has many other uses, including **paper, cloth, footwear, hats, bags, carpets,** and **dartboards.**

4. Mechanical Properties of Abaca

The material was wiped up using a piece of soft cloth and the final weights of the specimens Tensile, flexural, impact strength, hardness and water absorption tests of the specimens were carried out. For each test and type of the composite, ten specimens were tested and the average values are reported. [1]

4.1 Tensile properties

Tensile tests were carried out according to ASTM D 638-01 [19] using a Universal Testing Machine (Model: MSC-5/500, Agawn Seiki Company Limited, Japan) at a crosshead speed of 10 mm/min.

4.2 Flexural properties

Static flexural tests were carried out according to ASTM D 790- 00 [20] using the same Testing Machine mentioned above at the same crosshead speed.

4.3 Impact strength

Dynamic impact tests were conducted on notched composite specimens according to ASTM D 6110-97 [21] using a Universal Impact Testing Machine.

4.4 Hardness

The hardness of the composites was measured using a Rockwell Hardness Testing Machine according to ASTM D785-98 [22].

5 Mechanical properties of sisal

The fiber breakage analysis was carried out by dissolving 1 g of the uncured composite in toluene, followed by the separation of fibers from the solution.The distribution of fiber length was determined using a travelling microscope. Curing properties were measured in a Monsanto R-100 rheometer, at a temperature of 150 _C.

Stress–strain measurements were carried out at a crosshead speed of 500 mm per minute. Tensile strength and tear strength was measured according to ASTM methods D412-68 and D624-54, respectively. The tensile tests were done using dumbbell samples cut at different angles with respect to the orientation of fibers. Green strength measurements were carried out at a stretching rate of 500% min_1 using dumb-bell shaped samples obtained from unvulcanized composites.

Scanning electron microscopic studies were conducted to analyse the fracture behaviour of the composites. The fracture ends of the tensile and tear specimens were mounted on aluminium stubs and gold coated to avoid electrical charging during examination. Equilibrium swelling measurements of the vulcanizates
was performed in toluene at room temperature.

6 Mechanical properties of Jute

The fiber breakage analysis was carried out by dissolving 1 g of the uncured composite in toluene, followed by the separation of fibers from the solution. The distribution of fiber length was determined using a travelling microscope. Curing properties were measured in a Monsanto R-100 rheometer, at a temperature of 150 _C.

Stress–strain measurements were carried out at a crosshead \speed of 500 mm per minute. Tensile strength and tear strength was measured according to ASTM methods D412-68 and D624-54, respectively. The tensile tests were done using dumbbell samples cut at different angles with respect to the orientation of fibers. Green strength measurements were carried out at a stretching rate of 500% min_1 using dumb-bell shaped samples obtained from unvulcanized composites. Scanning electron microscopic studies were conducted to analyse the fracture behaviour of the composites. The fracture ends of the tensile and tear specimens were mounted on aluminium stubs and gold coated to avoid electrical charging during examination. Equilibrium swelling measurements of the vulcanizates was performed in toluene at room temperature. [1]

Among various natural fibers, both coir and jute fibers are widely available and cheap in context to the economic condition of Bangladesh. Coir and jute are lignocellulosic fibers mainly consisted of cellulose, lignin and hemicelluloses. High content of lignin in coir than jute fiber has made it high weather resistant. The coir fiber is relatively water-proof and is one of the few natural fibers resistant to damage by salt water. They absorb water to a lesser extent compared to all the other natural fibers including jute due to its less cellulose content.

Both fibers are biodegradable and recyclable. They are renewable resources and. these materials are CO2 neutral [10]. Furthermore, these fibers are typically less abrasive than glass or carbon fibers. Jute fiber has low density and high mechanical strength. Among different thermoplastics polypropylene possesses outstanding properties such as low density, good flex life, sterilizability, good surface hardness, abrasion resistance and excellent electric properties [4] [1] . Although natural fibers lag behind from the impressive property of synthetic fiber, their eco-friendly nature has made them attractive. The objective of present research is to develop hybrid composite by using two lignocelllosic fibers which are abundant, inexpensive and eco-friendly and improving the new era of green composite. The same trend was also observed by other researchers [15][18].

6.1 Tensile properties

The tensile test is done by cutting the composite specimen as per ASTM: D638 standard (sample dimension is 216 × 19 × 3 mm3). A universal testing machine (UTM) (Model: KIC-2-1000-C) is used for testing with a maximum load rating of 100 KN. Composite specimens with different fiber combinations are tested In each case, three samples are tested and the average is determined and noted. The specimen is held in the grip and load is applied and the corresponding deflections are noted. The load is applied until the specimen breaks and break load, ultimate tensile strengths are noted. Tensile stress and strain are recorded and load vs length graphs are generated

The composites specimens L1, L2, L3, and L4 are tested for tensile properties in UTM and obtained tensile properties . The load vs Length curves are shown in. The mechanical properties like break load, tensile modulus and ultimate tensile strength (UTS) are shown in. The Laminate L1 which consists of pure glass layers shows a high tensile strength of 280.25 N/mm2 and L3 which consists of pure jute layers shows a lower tensile strength of 50.641 N/mm2, but the mixture of jute/glass
layers laminates L2 & L4 shows better results than the L3.

6.2 Flexural Properties

Flexural properties (Flexural strength and flexural modulus) were measured for samples of each fiber content (5, 10, 15 and 20 wt %) with the help of flexural stress/strain curves and respective equations. The flexural strength of raw coir and jute fiber reinforced hybrid polypropylene composites at different fiber loading.The flexural strength increased with an increase in fiber loading which was in agreement with the findings by other researchers [8, 9, 16]. This may be due to the favourable entanglement of the polymer chain with the filler which has overcome the weak filler matrix adhesion with increasing filler content [18]. Variation of flexural strength at different fiber content.

The flexural modulus values of raw coir and jute fiber reinforced hybrid polypropylene composites at different fiber loading ,the flexural modulus increased with an increase in fiber loading [6]-[8],[16]. Since both coir and jute are high modulus material, higher fiber concentration demands higher stress for the same deformation [18]. So the incorporation of the filler (rigid coir and jute) into the soft polypropylene matrix results into the increase in the modulus.

6.3 Impact Strength

Variation of the Charpy impact strength with fiber loading for coir and jute fiber reinforced hybrid composite .Impact strength increased with fiber loading [10] [15] [17] [19]. Impact strength of a material provides information regarding the energy required to break a specimen of given dimension, the magnitude of which reflects the materials ability to resist a sudden impact. The impact strength of the fiber reinforced polymeric composites depends on the nature of the fiber, polymer and fiber–matrix interfacial bonding [20]. Strength of all composites increased with fiber loading. This result suggests that the fiber was capable of absorbing energy because of favourable entanglement of fiber and matrix.

7. Applications

The natural fiber composites can be very cost effective material for following applications:
Building and construction industry: panels for partition and false ceiling, partition boards, wall, floor, window and door frames, roof tiles, mobile or pre-fabricated buildings which can be used in times of natural calamities such as floods, cyclones, earthquakes, etc.

- Storage devices: post-boxes, grain storage silos, bio-gas containers, etc.
- Furniture: chair, table, shower, bath units, etc.
- Electric devices: electrical appliances, pipes, etc.
- Everyday applications: lampshades, suitcases, helmets, etc.
- Transportation: automobile and railway coach interior, boat, etc

8.Conclusion

The mechanical and physical properties of natural fibers varies from fiber to fiber. Natural composites like abaca, jute, sisal are used in many engineering applications, because of its superior properties such as specific strength, low weight, low cost, fairly good mechanical properties, non abrasive, eco friendly and bio degradable characteristics..The mechanical property among these material is good for abaca.The flextural property among these material is good for jute.The hardness is good for cisel

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