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Jute Fiber for Reinforced Composites and its Prospects

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This article consists of the two parts. In the first part the nature of jute fiber, productivity, advantages, disadvantages, its composition etc. have been described. The jute fiber is also compared with the glass fiber. Inspite of some advantages, this natural fiber possess some drawbacks and thus needs chemical modification. For modification of fiber-matrix interaction i.e.to reduce jute polymer interactions and to facilitate wetting, the use of compatibilisers is also mentioned.

In the second part different types jute composites have been described. The role of jute composite as wood substitute is explained. The different methods of jute composite manufacture with its potentials & prospects are also described in a nutshell.

Keywords: jute; natural fiber; composites; biocomposite; compatibiliser; chemical modification

JUTE FIBER

Background

Jute, the fiber of commerce, annual plant of tropical countries is obtained from the stem of cultivated varieties of the two species Corchorus Capillaries L.(white jute) and C. Olitorius L. (tosa jute). The major jute producing countries are India and Bangladesh. Others are China, Thailand, Nepal, Indonesia, Brazil, Nepal, Burma, Peru and Vietnam. In India, the total area

under cultivation is approximately 0.9 million hectare and yield is 2 MT/hectare. Jute ranks next to cotton as the most important natural fiber in the world. Jute, in India, provides livelihood to around 4 million farmers and 362 thousand workers.

The Nature of the Fiber

The major differences between cotton & jute fibers are :

1. Jute has 12 - 14 % lignin which is nil in cotton
2. Jute fiber units are multiple cells cemented with each other by lignin and hemicellulose where as cotton fiber units are single cells
3. The aspect ratio of jute cells is 98 to 118 and for cotton it is in order of 1000

Jute fiber, like other natural fibers, is hygroscopic. With water jute filament swells 23% in diameter, 40% in cross section and 0.06% in length [1]. Absorption of water vapor changes the dimensions of the filament as well as its mechanical and electrical properties. Mechanical properties of the fiber are the most favorable qualities for its load bearing applications.

The ignition temperature of dry jute is 193^0C and as this temperature is relatively low, frequent fires occur in jute warehouses [1].

Advantages of Jute

- *Annual renewable material*
- Inexpensive
- Plant matter is fully utilized
- Environment friendly
- Gives up a very low level of harmful substances and leaves no residues when incinerated
- High level of stability

- Resistance towards fracture
- Non-abrasive
- Low density
- High strength, low elongation .
- No health hazard
- Absorb atmospheric carbon dioxide to grow

One further aspect, which is of special relevance to processing, is the high degree of porosity usually found in vegetable fibers in general, which is chiefly a result of the empty lumens of the ultimate cells. This hollow nature of jute fiber may impart acoustic insulation properties.

Disadvantages of jute

- Affinity towards moisture
- Lignin degradation sets in around 200^0 C
- Low mildew resistance

Composition of Jute Fiber

Jute fiber contains (12-14%) lignin, (21-24%) hemi-cellulose and (58-63%) α-Cellulose besides some trace ingredients like nitrogenous matter, fats, waxes and ash. Like wood fiber, the chemical composition of jute is not uniform. Jute fiber can be considered as a polymer composite by itself. Jute, among natural fibers, contains highest proportion of stiff natural cellulose, approximately 65 wt.%[2]. The lignin and hemicelluloses are acting as a matrix in a cellulose backbone.

Jute is a harsh fiber due to presence of substantial amount of lignin and low wax content. Moreover, the presence of cellulose backbone in a lignin matrix makes it the stiffest among natural fibers and this is the basic reason for its technical non-viability as a textile fiber from spinning point of view. However, these limitations give an important design criteria for the development of fiber reinforced composites. The tensile strength, tensile

modulus and elongation at break are 442 MPa, 56 GPa and 1.3% respectively [3]. Due its lower specific gravity, its specific properties are favorable to the material scientist and comparable to glass. The specific tensile strength is 303 MPa, about 22.5% of glass and specific tensile modulus is 38.4 GPa which is about 35% more than glass. The choice of jute as a reinforcing fiber is mainly due to its good specific mechanical properties, low cost and good availability. The long fiber and its flexibility also confers very good impact strength. Its less abrasive nature augment the machinery life.

In spite of all these advantages, the fiber bears the draw back of non-resistance to high temperature, susceptible to moisture absorption and mildew attack. For this, chemical modification is required to develop performance driven composites.

Chemical Modification of Jute Fiber

Lignocellulosic fibers are hygroscopic in nature, flammable and biodegradable. To develop composite materials with long service life one has to prevent these drawbacks by treating the jute fiber with specific chemicals. These chemicals are often corrosive, toxic and can cause environmental pollution. Other approach is to perform a chemical reaction between the reactive part of the fiber cell wall and a reagent with or without a catalyst to form a covalent bond between the two. In order of stability, the types of covalent chemical bonds that may be formed are : ethers > acetals > esters [4.5].

Dimensional Stability

Changes in dimensions, especially thickness in presence of water is a measure of Dimensional Stability. Water being a polar liquid possesses the affinity to penetrate into lignocellulosic composites, wood and swell the cell walls by breaking inter hydroxyl hydrogen bonding [6]. In case of wood this swelling is reversible i.e. upon release of water the wood cell wall reverse back to the

original dimensions. On the contrary in case of lignocellulosic composites or reconstituted wood like flake board, particle board, etc., in other words, the composites made under pressure, undergo swelling caused by the release of residual compressive stresses and is known as irreversible swelling. Water sorption causes both reversible and irreversible swelling, with some of the reversible shrinkage occurring when the board dries. Dimensional instability of lignocellulosic composites has been the major reason for their restricted use. The mechanism of enhancing dimensional stability is based on bonding chemicals to the cell wall hydroxyl groups by the polymer resulting in bulking, simultaneously rendering the wood more hydrophobic [7].

Modification of Fiber - Matrix Interaction

Addition of filler / fiber to a polymer usually has a positive effect on composites mechanical properties such as stiffness, but negative effect on the elongation at break and impact strength. It is possible to improve these properties through modification of fiber / matrix interfaces. The basic role of such modifications is to reduce particle - particle interactions and to facilitate wetting [8].

JUTE COMPOSITES

Background

The use of straw in the mud huts from ancient times probably the pre-cursor of the modern man made composites. The use of bio-based composites has rapidly expanded in recent years and there is tremendous potential for future growth in this area. The reason for this is mainly two fold. One is to resist deforestation and the other, there is demand of new materials due to growth of world population. The uses range from automotive interior components to geotextiles. A broad range of agro-based fibers is utilized as the main

structural components or as fillers / reinforcing agents in these composite materials.

A composite can be defined as a material having two or more chemically distinct phases which, at the microscopic scale, are separated by a distinct interface (boundary). A composite can also be defined as a more simpler way - it is a combination of properties of two or more resources held together by some type of mastic or matrix. The continuous phase is known as matrix and the other components as fillers or reinforcements. In general, fibers are principal load carrying members while the surrounding matrix keeps them in the desired position, acts as a load transfer medium between them. So from theoretical point of view fibers having very good strength and modulus having very good bonding with the matrix is supposed to give birth of quality composite materials [9-11].

Some of the most common composites, are decorative laminate and helmet. Decorative laminate is composed of phenolic resin impregnated kraft paper in the base and melamine resin coated design paper on the top. The wood fibers present in the kraft paper play the role of reinforcement and resin as binder. In the helmet, Chopped Strand Mat (CSM) made of fiber glass and unsaturated polyester resin are the main constituents. Fiber orientation stacking sequence, press cycle etc. are some of the important parameters to generate a wide range of physical and chemical properties for the composite materials.

The most common form of nature made composite is wood. Continuous use of wood for different applications like furniture, packaging, pulps, fuel, construction materials etc. a drastic deforestation took place in wood poor countries. To resist pollution there is a dire need to develop wood substitute using fast renewable resources.

Natural Fiber Composites as Wood Substitute

Between 1952 and 1988, in 36 years, the forest cover has gone down from 22 to 12% of the total area i.e. @ 0.4% per annum. The Food and Agricultural Organization of the United Nations has estimated that India lost 3.4 million hectares of tree cover between 1951 and 1972, which means 1,55,000 hectares are lost per annum [12]. These rapid depletion of forest, causing environment pollution, forced Supreme Court of India to ban forest cutting. So in one hand there is a great demand of wood substitute and on the other hand jute fiber due to its stiff competition in the traditional field with synthetic needs diversification. These two counter facts make enough sense to develop jute composite as wood substitute.

Both jute and wood are lignocellulosics and so far as chemical composition is concerned they are very close to each other. The main difference between them is one is flexible and the other is rigid. The very flexible nature of jute fiber allows the scientist to develop molded composites at the same time to eliminate the fabrication cost. The various jute composites developed by IJIRA including the hybrid with glass using different thermosetting and thermoplastic resins are described by Mitra et. al. [13], Ranganathan et. al.[14], Rana et. al. [15-18] and Biswas et. al.[19].

Glass fiber, asbestos and cotton are the most frequently used reinforcing fiber by most of the composite industries. The high cost and very good mechanical properties of glass fiber composites are not often justified as substitute of wood. The use of asbestos has been restricted due to its carcinogenic effect and cotton is also a costly proposition for its use as a reinforcing fiber for the development of wood substitute. Considering these facts jute fiber has a future in playing its role as a low cost reinforcing fiber for the development of jute composites in the field of wood substitute.

Potentials and Prospects

Jute Board

Commercial Production of Jute Board from Jute Fabric, Jute non woven using water soluble thermosetting resins has already been started by two companies in India. More companies are coming up to cater the needs of Indian Railways for coach building purposes and other domestic needs for the replacement of wood and plywood. The method of production includes the simple route of impregnation, drying and pressing in the multidaylight hydraulic press following the compression molding technology under heat and pressure.

Autotrim

For automotive interior applications jute non woven polyester system is already introduced commercially. However, an effort is being done by IJIRA to introduce jute polypropylene calandered sheet similar to wood fiber polypropylene available in the advanced countries. Though jute fiber is very costly as compared to wood fiber, the use of waste jute from the jute mill may be considered for the cost reduction purposes. The major drawback for the implementation of this technology is the very high cost of imported machinery.

Board from Total Jute Plant

MDF board from total jute plant has been developed at the BioComposite Centre, UK. Till now in India all the fibers are being used for wovens or nonwoven purposes. Efforts are being done to develop similar boards using jute stick and indigenous machinery.

Pultruded Profiles

The traditional pultrusion process is simple continuous fiber reinforcement in which fiber is pulled through a bath of thermosetting resin and then through a hot die where consolidation and curing occur. After curing the composite profile is cut to the required length. Use of jute fabric, yarn, nonwoven with

phenolic/polyester matrix were successfully done for the production of different profiles including door frame, U-channel etc.

Resin Transfer Molding

This process is very popular using glass substrate. For applications, where very high cost and strength is not justified, there, either in the core or total glass may be replaced by the jute substrate. Due to very low bulk density of jute as compared to glass little modification is required in mold making. This jute-RTM technology has bright future for items like door, automotive component, instrument panel, truck hood, bonnet, etc.

Jute Thermoplastic Granules

The art of making composites is mainly restricted to synthetic polymer and synthetic reinforcing fibers like glass, carbon, nylon, etc. The potentiality of natural fiber based composites using cellulose, wood, jute, kenaf, hemp, sisal, pineapple, coir, etc. as reinforcing fiber in thermosetting resin matrix, has received considerable attention among scientists all over the world for its excellent specific properties. Composites, based on thermoplastic resins, are now becoming popular due to their processing advantages. IJIRA in collaboration with Forest Products Laboratory, USA have developed jute fiber reinforced polypropylene granules suitable for injection molding purposes. There is immense scope to replace a part of virgin polymer by jute fiber resulting high mechanical property and low material cost. Spools and bobbins, base plate for white goods, pellets, other packaging auxiliaries, etc. are some of the items of techno-economic interest.

Jute Thermoplastic Board

Jute thermoplastic board of thickness 20 mm and above using plastic waste and jute waste is a recent introduction in India to check environment pollution and to utilise waste for value added application. The board is now

commercially available for application like garden fencing, mobile homes, shower cabins, kiosk, waste disposal bins, etc.

Jute Glass Hybrid Contact Molding

Probably the first commercial approach to develop jute composite has started long back around 1980 with the part replacement of glass by jute for suitable applications like low cost housing, silos, boat, etc. At IJIRA such hybrid boat has been lying for the last 15 years. This clearly reflects that judicious use of jute glass may produce low cost items with appropriate longevity.

CONCLUSION

Emerging enormous possibilities of jute composites utilising jute fiber, fabric, nonwoven, tape, caddies, and even jute stick with thermoplastic and thermosetting matrix may give birth a new dimension to jute industry. This jute composite in one hand will help us to protect the environment and on the other hand help jute industry to find non traditional applications of jute web.

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