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Review Article

Comparison of Jute and Banana Fiber Composites: A Review

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Abstract

Last few decades have seen composite materials being used predominantly in various applications.Many types of natural fibers have been investigated for their use in plastics including Flax, hemp, jute, straw, wood fiber, rice husks, wheat, barley, oats, cane (sugar and bamboo), grass reeds, kenaf, ramie, oil palm empty fruit bunch, sisal, coir, water pennywort, kapok, paper-mulberry, raphia, banana fiber, pineapple leaf fiber and papyrus. Their volume and number of applications have grown steadily. Natural fibers offer both cost savings and reduction in density when compared to glass fibers. Natural fibers are an alternative resource to synthetic fibers,as reinforcement for polymeric materials for the manufacture is cheap, renewable and environment friendly. This paper discusses in detail about the uses & applications of jute and banana fiber composites.

Keywords*: Jute fibers, Banana fibers, Properties of fibers, Application of fibers, uses of fibers*

1. Introduction

Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker materials (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position, orientation of the reinforcement and transfers the external load to the reinforcement. Significantly, constituentsof the composites retain their individual, physicaland chemical properties. Historical examples of composites are abundant in literature.Jute has been used since ancient times in Africa and Asia to provide cordage and weaving fiber from the stem and food from the leaves. In several historical documents (Ain-e-Akbari by AbulFazal, 1590) during the era of the great Mughal Emperor Akbar (1542 –1605) states that the poor villagers of India used to wear clothes made of jute.Chinese papermakers from very ancient times have selected almost all the kinds of plants as hemp, silk, jute, cotton etc. for papermaking.The East India Company which was the first Jute traderin India,was the planet's biggest producer of bananas and Alexander the Great found them growing there in 327 BC, when he conquered India. Infantrymen of Alexander the Great returned to Greece and Persia with bulbs from banana plants, 'Musa accuminata, ' where they were distributed and planted. Antonius Musa, the private surgeon of Augustus Caesar, imported the first banana trees, 'Musa accuminata, ' to Rome from Africa in 63 BC. Later, slaves from Portugal brought bananas to Europe from Africa in the early 1400's. Although the banana is said to have originated in India, (Eastern East Asia), it was established in Africa and Europe as a basic food product many centuries back and came into North America through Spanish missionaries. The leaves of banana trees are used as wrappers for steaming other foods within, and the banana flower is also eatable.

1.1 Types of Composites:

Composites can be grouped into categories based on the nature of the matrix each type possesses. They are
a) Metal Matrix Composites (MMC)
b) Ceramic Matrix Composites (CMC)
c) Polymer Matrix Composites (PMC)

a) Metal Matrix Composites (MMCs)

Examples of matrices in such composites include aluminum, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient ofthermal expansion, thermal and electrical conductivities of metals can be reduced by theaddition of fibers such as silicon carbide.

b) Ceramic Matrix Composites (CMCs)

Examples of matrices such as alumina, calcium, aluminosilicate reinforced by silicon carbide. The advantagesof CMC include high strength, hardness,high service temperature limits for ceramics,chemical inertness

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and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture. Composites successfully made with ceramic matrices are reinforced withSilicon carbide fibers. These composites offer the same high temperature tolerance of super alloys but without such a high density. The brittle nature of ceramics makes composite fabrication difficult. Usually most CMC production procedures involve starting materials in powder form. There are four classes of ceramics matrices: glass (easy to fabricate because of low softening temperatures, include borosilicate and alumino silicates), conventional ceramics (silicon carbide, silicon nitride, aluminum oxide and zirconium oxide are fully crystalline), cementand concreted carbon components.

c) Polymer Matrix Composites

Most commonly used matrix materials are polymeric. The reason for this is twofold. In general the mechanical properties of polymers are inadequate for many structural purposes. In particular their strength and stiffness are low compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers. Secondly the processing of polymer matrix composites need not involve high pressure and doesn't require high temperature. Also equipments required for manufacturing polymer matrix composites are simpler. For this reason polymer matrix composites developed rapidly and soon became popular for structural applications. Composites are used because overall properties of the composites are superior to those of the individual components for example polymer/ceramic. Composites have a greater modulus than the polymer component but aren't as brittle as ceramics. Two types of polymer composites are:
• Fiber reinforced polymer (FRP)
• Particle reinforced polymer (PRP)

1.2 Fiber Reinforced Polymer

Common fiber reinforced composites are composed of fibers and a matrix. Fibers are the reinforcement and the main source of strength while matrix glues all the fibers together in shape and transfers stresses between the reinforcing fibers. The fibers carry the loads along their longitudinal directions. Sometimes, filler might be added to smooth the manufacturing process, impact special properties to the composites, and / or reduce the product cost. Common fiber reinforcing agents include asbestos, carbon / graphite fibers, beryllium, beryllium carbide, beryllium oxide, molybdenum, aluminum oxide, glass fibers, polyamide, natural fibers etc. Similarly common matrix materials include epoxy, phenolic, polyester, polyurethane, polyetherethrketone (PEEK), vinyl ester etc. Among these resin materials, PEEK is most widely used. Epoxy, which has higher adhesion and less shrinkage than PEEK, stands second for its high cost.

1.3 Particle Reinforced Polymer

Particles used for reinforcing include ceramics and glasses such as small mineral particles, metal particles such as aluminum and amorphous materials, including polymers and carbon black. Particles are used to increase the modules of the matrix and to decrease the ductility of the matrix. Particles are also used to reduce the cost of the composites. Reinforcements and matrices can be common, inexpensive materials and are easily processed. Some of the useful properties of ceramics and glasses include high melting temp., low density, high strength, stiffness; wear resistance, and corrosion resistance. Many ceramics are good electricaland thermal insulators. Some have specialproperties; some are magnetic materials; some are piezoelectric materials; and a few special ceramics are even superconductors at very low temperatures. Ceramics and glasses have one major drawback: they are brittle. An example of particle reinforced composites is an automobile tire, which has carbon black particles in a matrix of poly-isobutylene elastomeric polymer. Polymercomposite materials have generated wide interest in various engineering fields, particularly inaerospace applications.Research is underway worldwide to develop newer

Composites with varied combinations of fibers and fillers, so as to make them useable under different operational conditions. Against this backdrop, the present work has been taken up to develop a series of PEEK based composites with glass fiber reinforcement and with ceramic fillers and to study their response to solid particle erosion done either after the fruits have just developed or when they have ripened ready for food purposes. Table1 shows the classification of the selected plant fibers. In this it knows that jute fiber is the most abundant followed by banana. These fibers could easily be used in the composite manufacture.

Table 1: Production details of fibers, origin

Fiber Type	Botanical Name	Plant Origin	Production (10^3 Ton)	Source
Jute	Corchoruscapsularies, Corchorusolitorius	Stem	2850	1
Banana	Musa ulugurensis warb	Leaf	200	2,3,4

2. Fiber Types

Fibers have been classified into three main groups arranged according to their morphological structure namely a) Bast fibers b) leaf fibers c) Seed fibers

2.1 Jute Fiber Type

It is a Bast stem fiber obtained from the stems of various dicotyledonous plants. It is a fast growing annual plant which stands thesecond most important fiber apart from cotton.In hot and humid climatejute plants reach about 2.5 - 3 m in height within 4-6months. *Corchoruscapsularis*has a globular shaped podwhereas *Corchorusolitorius*is cylindrical. Most of the jute is harvested when about 50 %

of the plants arein pod because it is during this stage of growth that highquality jute fiber bundles can be obtained. The fiber bundles are separated from the woody stem by the rettingprocess. About 10,000 to 14,000kgs of green plant yieldfrom 4. 5 - 8 % of their green weights in dry fiber. The fiber lies along the length of the plant's stem in the form of anannular meshwork composed of more than one fiber layer.Jute is the most widely produced of the bastfibers followedby flax and hemp fibers. It has a higher lignin content,which distinguishes it from flax and hemp fibers.

2.2 Banana Fiber Type

It is a leaf fiber. Banana fiber*Musa paradiisiaca*L.var*Sapientum*or *Musaulugurensis.* Warb is the most cultivated banana plant. The word banana comes from Arabic and it means 'finger'. There are about 300 species of banana and about 20are used for consumption. In order to obtain the best fiber, the plants are cut when they are almost at the Flowering stage, before any fruit has formed. The separation process is done manually and it involves cutting pieces of banana from the stem and passing them through a mangle to remove excess moisture (water), and then combined and dried at ambient temperatures. The fiber obtained is usually of low quality because the separation of the fiber bundles is

Table 2 shows the chemical composition of jute and banana plant fibers, and their physical properties. It is noted that cellulose is the main constituent of plant fibers followed by hemi-celluloses and lignin interchangeably and pectin respectively. Cellulose is also the reinforcement for lignin, hemi cellulose and Pectin. This makes plant fibers exhibit characteristics of a composite material.

Table 2: Chemical composition of Jute and Banana fibers

Fiber Type	Cellulose	Hemi cellulose	Lignin	Pectin	Source
Jute	51-84	12-20	5-13	0.2	5
Banana	60-65	6-19	5-10	3-5	6

Table 3 is those of the single cell fibers i.e., the physical properties of jute and banana fibers. Fibers with the highest aspect ratio will exhibit highest tensile properties provide high surface area which are advantageous for reinforcement purposes.

Table 3: Physical properties of the plant fibers

Fiber Type	Dia (μm)	Length (mm)	Aspect Ratio (l/d)	Bulk Density (kg/m^3)	Moisture regain (%)	Source
Jute	15.9-20.7	1.9-3.2	157	1300-1500	17	5
Banana	----	2-3.8	----	1300-1350	60	4

Table 4 shows mechanical properties of jute and banana fibers

Table 4: Mechanical properties of jute and banana fibers

Fiber Type	Tensile Strength (Mpa)	Specific Tensile Strength (Mpa)	Young's Modulus (Gpa)	Specific Young's Modulus (Gpa)	Failure Strain (%)	Source
Jute	200-450	140-320	20-55	14-39	2-3	7
Banana	529-914	392-677	27-32	20-24	1-3	3

3. Chemical modification of natural fibers

One of the major problems associated with the use of natural fibers in composites is their high moisture sensitivity leading to severe reduction of mechanical properties and delamination.The reduction in mechanical properties may be due to poor interfacial bonding between resin matrices and fibers. It is therefore necessary to modify the fiber surface to render it more hydrophobic and also more compatible with resin matrices. An effective method of chemical modification of natural fibers is graft copolymerization. The resulting co-polymer displays the characteristic properties of both fibrous cellulose and grafted polymer. One of themost explored chemical modifications is the acetylation-esterification of cellulose-OH, by reaction with aceticanhydride. This reaction reduces hydrophilicity and Swelling of lignocellulosics and their composites.

4. Literature Review

A report from the National Institute of Research on Jute and Allied Fiber Technology (NIRJAFT), Calcutta reveals that, usually for moulded jute composites with polyester resin, the resin intake can be maximum up to 40%. Both hot press molding and hand lay-up technique can be used for its fabrication. The effect of chemical treatment of natural fibers with sodium alginate and sodium Hydroxide has also been reported for coir, banana and sisal fibers. This modification results in an increase in adhesive bonding and thus improves ultimate tensile strengthup to 30%.Mitraet al. have reported that treatment of jute with polycondensates such asphenol-Formaldehyde, melamine-formaldehyde and cashew nut shell with liquid-formaldehyde improves the wet ability of jute fibers and reduces water regain properties. Gassanet al. have improved the tensile, flexural strength and stiffness of jute-epoxy composites by treating the fibers with silane. The delignification by bleaching produces better interfacial bond between the jute fiber and the polyester matrix, and hence results inbetter mechanical properties of the composites. The absorption of steam by banana fiber/novalac resin composites has been found to reduce after esterification of the –OH groups with the maleic anhydride. The tensile strength of maleic anhydride treated fiber composites is higher than that of the untreated fiber composites. Wambuaetal bridged the gap and investigated the responseof flax, hemp, and jute fabric reinforcedpolypropylene composites to ballistic impact byfragment simulating projectiles.The effect of alkali (5% NaOH for 2hrs) and silane (1% oligomericsiloxane with 96% alcohol solution for 1 hr) treatment on the flexural properties of jute epoxy and jute polyester composites. For jute epoxy composites alkali over silane treatment resulted in about 12% and 7% higher strength and modulus properties compared to the alkali treatment alone. Similar treatment led to around 20% and 8% improvement for jute polyester composites. Dipa et al. have reported 4h alkali treated jute- vinyl ester composites accounted 20% and 19% increased in flexural strength and inter laminar shear strength properties. Treated jute fibers with NaOH solution of concentration 1 and 8%for 48 h and observed130% improvement in the tensile strength of the fibers in boththe cases. Similarly, jute fibers were treated with 2%NaOH solution for 1 h and 13% improvement in the tenacity of the fibers was reported. Lina Herrera-Estrade, Selvumpillay and udayvaidy aproved that 6% NaoH treated banana fiber/ epoxy composites environmental resistance is higher than banana fiber/polyester composites without any treatment. This is due to improvement in fiber/ matrix interaction with the fiber chemical pre treatment in epoxy composites and to deterioration of the inter phase in polyester composites.the tensile testing of untreated jute fabric-reinforced polyester composites was studied and the average values of UTS, initial tangent modulus for these composites are 60MPa, 7GPa. Researchers investigating thermal properties of jute/bagasse hybrid composites observed that thermal stability of hybrid composites increased by increasing residual char left at 600oC.Kamaker et al. reported that using 3wt% MAHgPP (type G-3002, with an average molecular weight of 40,000 and containing 6 wt% of maleic anhydride, as coupling agent in Jute/PP composite increases composite mechanical properties. The tensile strength is doubled from 29.82 MPa to 59.13 MPa and the bending strength increases from 49.97 MPa to 87.66 MPa in composite with 50 wt% fiber content.Gassan et al. showed that the tensile, flexural and dynamic strength increase up to 50% but impact energy decreases due to the lower energy absorption in the interface of jute/PP composite when jute fibers are treated by 0.1wt% MAHgPP solution in toluene for 5min at 100°C. Ray et al. used a solution of NaOH 5% to treat the jute fibre for 0, 2, 4, 6 and 8 hours at 30°C. For the vinyester resin composites reinforced by 35 wt% jute fibre treated for 4 h, an improvement of 20% for the flexural strength, of 23% for the flexural modulus and of 19% for the laminar shear strength was observed. The acetylation of jute fiber was investigated by Rana et al. and showed animprovement in thermal resistance compared to untreated fiber.Treatment of the jute fiber with PF and CNSL-PF carried out by Mitra et al. showed a reduction of the thermal stability of the treated fiber.Kita et al. reported that the degradation of lignin in cellulose fiber sets in at around 200°C, and other polysaccharides, mainly cellulose, are oxidized and degraded at higherTemperature.The influence of the injection molded processing on the final fiber length of the polypropylene composites based on abaca, jute and flax fibers investigated by Biagotti et al.showed the minor effect with the higher fiber content and a more significant size reduction of theflax fibre due to its more rigid behavior.The swelling of the jute fibre in the polypropylene composite was found by Karmaker et al. to have positive effects on the mechanical properties .The influence of fibre surface treatment by MAHgPP on the dynamic mechanical properties of jute reinforced polypropylene was investigated by Gassan and Bledzki. It was shown that maleic anhydride polypropylene co-polymer increases the level of adhesion between polypropylene and jute fibre. Roe, P et al. reported that the reinforcement of polyesters with jute fibers..Due to presence of hydroxy and other polar groups in various constituents of jute fibre, the moisture uptake is high (approx. 12.5% at 65% relative humidity & 20o C) by dry fiber. Polymeric coating of jute fiber with phenol-formaldehyde or resorcinol formaldehyde resins by different approaches is highly effective in enhancing the reinforcing character of jute fiber, giving as high as 20-40% improvements in flexural strength and 40-60% improvements in flexural modulus. These modifications improve the fiber-matrix resin wet ability and lead to improved bonding.

Banana fibre Musa paradiisiacaL. varSapientumor MusaulugurensisWarb is the most cultivated banana plant.The word banana comes from Arabic and it means 'finger'. Satyanarayana et al.reported that the reinforcement of polyesters with banana-cotton fibers. Sreekumar et al., 2008 [19] investigated thatBanana FRPcomposites having fiber length of 30 mm and a fibercontent of 40vol% showed the maximum tensile strength.The highest tensile strength values has obtained for an intimate mixture of banana and glass fibers has been obtained for composite samples prepared from interleaving layers of banana fiberand glass fiber. Composites with good strength could be successfully developed using banana fiber asthe reinforcing agent in phenolic resins. Where the interfacial shear strengthwas higher in banana fiber embedded in phenolic resins than for glass fiber indicating a strong adhesion between the lignocellulosic banana fiber and phenolic resins.El-Abden S. Z et al [20]Asbestos free friction composites reinforced by natural fibers was developed. Asbestos was replaced by natural fibers such as flax linen, kenaf, casuarina, date palm luffa,willow, banana core, bamboo, coconut coir, camphor and human hair. The proposed composites contained iron, sand and phenolic resin. Bilba et al. examined four fibers from banana-trees (leaf, trunk) and coconut-tree (husk, fabric) before their incorporation in cementitious matrices, in order to prepare insulating material for construction. Thermal degradation of these fibers was studied between 200 and 700 °C under nitrogen gas flow. The researchers have reported the mechanical aspects of banana and sisal hybrid fiber reinforced polyester composites. Agarwal et al.analyzed the variation of thermal conductivity and thermal diffusivity of banana-fiber reinforced polyester composites caused by the addition of glass fiber. They observed that the thermal conductivity of composites increased as compared to the matrix. However, the thermal conductivity of the composites with increased percentage of glass fiber decreases when compared to composite of pure banana fiber. The composites made up of glass fiber reinforced with nanochitosan has more crystallinity in terms of better strength compared to banana composites reinforced nanochitosan.

5. Conclusions

- The present review explores the potentiality of jute & banana fiber composites, emphasizes both mechanical and physical properties and their chemical composition.
- The utilization and application of the cheaper goods in high performance appliance is possible with the help of this composite technology.
- Combining the useful properties of two different materials, cheaper manufacturing cost, versatility etc., makes them useful in various fields of engineering, high performance applications such as leisure and sporting goods, shipping industries, Aerospace etc. Hence, with thisback ground, it is concluded that, the composites stand the most wanted technology in the fast growing current trend

5.1 Advantages of jute fiber composites

The composites reinforced with natural fibers like jute are abundant, cheaper and of low density, biodegradable and carbon dioxide-neutral Jute fiber has the potential to compete with glass fiber, as reinforcing agents in plastics. Jute composites are true substitute of wood. A range of products that are presently being produced from jute composites are sheet/board, door, window, furniture, corrugated sheet, etc

- Unbreakable, maintenance free, durable
- Fire retardant and water resistant
- UV, acid and alkali resistant
- Less abrasive
- Less costly
- Low thermal conductivity
- Biodegradable
- Renewable
- Eco-friendly

5.2 Advantages of jute

Advantages include good insulating and antistatic Properties, moderate moisture regain andmanufacture with no skin irritations. Jute has the ability to be blended with other fibers, both synthetic and natural, and accepts cellulosic dye classes such as natural, basic, vat, sulfur, reactive, and pigment dyes, while jute is being replaced by relatively cheapsynthetic materials in many uses, but jute’s bio degradable nature is suitable for the storage offood materials, where synthetics would be unsuitable. Good thermal properties, low embodied energy, reduced tool wear in the molding process and also have better acoustic properties thereby reducing cabin noise.

5.3 Applications of jute fiber composites

- In 1996 jute was being utilized in the door panels of the Mercedes Benz E- class vehicles.
- Some of the Car door panels from India and Asia contain jute.
- For the Eco-1 racing car the brake pads are made from jute.
- Numerous researchers have exploited the Reinforcement potential of jute for developing thermoplastic and thermo set composites using several different techniques, these composite materials have been successful in the semi structural as well as structural applications.
- jutefiber composite for fabrication of structural components such as rails, sills, tracks, stops and non-structural members such as grid, cove, bead etc. for residential & commercial architecture.
- The process of fabricating a low density insulating board made from jute fibers. The jute fibers are opened up into single fibers which are then wetted with a natural (starch, protein etc.) or synthetic thermo set resin and further compressed by rollers & cured in oven into desired shape with a density of 30-100 Kg/m3.
- The method for fabricating wet-laid non-woven webs using jute fiber as reinforcement. Composites of the unpulpedfiber webs with cellulosic and spun bonded sheets find applications as thermoformed trim products for vehicle interiors.
- The Mead Corporation Dayton, Ohio, USA described the use of jute mesh as the intermediate reinforcing material for a corrugated container such as bulk storage bins. The reinforcing material may be placed in between the outer & inner lines of two-faced corrugated board construction.
- M/s. De Groot Automotives BV of Netherlands describes the process of fabricating a sheet material. The sheet comprises polyurethane resin reinforced with binder free natural fibers such as jutepossibly combined with polypropylene, polyethylene and/or glass fiber.
- In the application dating back to 1974, double-wall reinforced & insulating building panel with a combination of glass & jute composites. The panels comprise of an inner skin of woven jute layers saturated in polyester resin and an outer skin of woven jute with an exterior coating of chopped glass fiber both impregnated with polyester resin.
- CGCRI-Calcutta has worked on jute-glass hybrid components for cost reduction without sacrificing the mechanical properties. An excellent example for commercial exploitation of jute composites has been the fabrication of automobile interiors (door panels) by Birla Jute Industries Ltd. CBRI's research activities provided new insight into the contribution of the interface to the properties of the composites.
- The project on “Jute-based Composites - An Alternative to Wood Products” has been launched in collaboration with M/s Duroflex Limited, Bangalore. The project activities involve the production of coir-ply boards with oriented jute as face veneer and coir plus waste rubber wood inside.
- A very thin layer of jute fibers impregnated with phenolic resin is used as the face veneer for improved aesthetics and to give a wood like finish. The orientation & uniformity of jute fiber improve with carding and this also helps in better penetration of resin into the fiber.

• The products made of jute-glass composites can be used as a replacement of high-cost sheet molding compound & low-strength dough molding compound based glass-fiber composites. The technology for the fabrication of hybrid composites incorporating jute felt and glass fiber using polyester resin as a matrix has been developed successfully by CGCRI.

5.4 Advantages of Banana fiber composites

• Banana fiber possesses good specific strength properties comparable to those of conventional materials like glass fibers.
• Banana Material has lower density than glass fiber.
• Alkali treatments have been proven effective in removing impurities from the fiber, decreasing moisture sorption and enabling mechanical bonding and thereby improving matrix reinforcement interaction.

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