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A Review of Bamboo/Jute/PLA Biodegradable Composite

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***Abstract*- Biodegradable polymers can potentially be combined with natural fibers to produce biodegradable compositematerials. In this work, PLA (Polylactide) was used in combination with Jute fabric to generate bio-composite by compression molding technique. Various mechanical characterizations like tensile, flexural and impact properties of bio-composite were determined. The result from mechanical testing showed that use of Jute fabric with PLA, increases the tensile strength and tensile modulus, why the flexural modulus is reduced. Scanning electron microscopy (SEM) investigation also showed good bonding between the Jute fabric and PLA as there were no air voids. Water absorption results reported increase in weight of the bio-composite for 24 hrs conditioned time. The findings of this work create the scope of use of the Jute fiber/ fabric for making fully biodegradable composites for potential application as architectural interiors in building construction sector. The developed composites were also used as the replacement for mica sheets for the table top, chairs, door panels and many more.**

***Keywords*- PLA, JUTE FIBERS, Glass Fiber,SEM**

I. INTRODUCTION

The term Composite may be defined as a mixture of two or more distinct constituents or phases. However this definition is not sufficient, there are some conditions which have to be satisfied before a material is to be said as a composite. First, both constituents have to be present in reasonable proportions, say greater than 5%. Secondly, it is only when the constituent phases have different properties, and hence the composite properties are noticeably different from the properties of the constituents, that we have come to recognize these material as composites. We know that composite have two or more phases on a macroscopic scale, separated by a distinct interface.

The constituent that is continuous and is often but not always, present in greater quantity in the composite is termed as „Matrix□. A composite have ceramic, metallic or a polymeric matrix. Reinforcement is the part of the composite that provides strength, stiffness, and the ability to carry a load. In many cases the reinforcement is harder, stronger and stiffer than the matrix. Wood is an interesting example of a natural fiber composite comprising of cellulose fibers in a matrix of lignin with varying spiral angle.

In manufacturing, fibers are the most commonly used reinforcement that defers Fiber Reinforced Composite (FRC). The reinforcement is embedded into the matrix. Common matrixes include mud (wattle and daub), cement (concrete), polymers (fiber reinforced plastics), metals and ceramics. The most common polymer-based composite materials include fiberglass, carbon fiber and synthetic fibre. Fiberglass is probably one of the most familiar reinforcing composite materials that were introduced in 1940, consisting of glass fiber reinforcement of unsaturated polyester matrix [1].

This glass fiber had numerous problems that led to search for alternate substitute as reinforcement. Fiber as reinforcement to the composite had outstanding physical, chemical, thermal and mechanical performance, durability and biodegradable nature that highlighted and promoted its scope. The starting of composite materials may have been the bricks formed by the ancient Egyptians from mud and straw.

The ancient brick-making method can still be seen on Egyptian tomb paintings in the Metropolitan Museum of Art.

Commercialization of the composites could be traced to early century when the cellulose fibers were used to reinforce phenolics, urea and melamine resins. Composites in the world of today have wide range of applications, wherever high strength-to-weight ratio remains and important consideration for use. Its principal use is found

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in automotive, aerospace, marine and construction industries.

In majority of cases, requiring high performance in the automotive and aerospace industries, the discontinuous phase or filler is in the form of a fiber. In most cases, composite matrix is the thermosets having carbon and ceramics for high temperature applications.

Thermosets (epoxy,polyester, phenolics etc.) and thermoplastics (polyetherether ketone, polypropylene,PLA etc.) due to high strength and performance are found to be for research and industrial applications.[2]

The use of natural fiber as reinforcement in composite was a challenging job. Ferreria et al. [3] enhanced the fatigue strength by using hybrid fiber composites with a polypropylene hemp layer next to the bond interface which was expected to produce more uniform stress in temporary regions.

A major drawback of natural (plant) fibers compared to synthetic fibers is their non-uniformity, variety of dimensions, and their mechanical properties (even between individual natural (plant) fibers in the same cultivation). Due to their high specific strength andmodulus, natural fibre reinforced polymer composites are receiving widespread attention. Keeping these things in mind, this paper is focused on microwave processing of partially and fully bio-degradable composites.

The advantage of microwave processing is that, it leads to significantly faster curing times compared to thermal processing. Natural fibres like coir, rattan and bamboo are experimented as reinforcement applied flow visualization experiments using resin transfer molding for developing a better understanding of the mold filling process for hemp mat reinforced phenolic composites.

Eucalyptus urograndis pulp used as the reinforcement for thermoplastic starch showed an increase of 100% in tensile strength and more than 50% in modulus with respect to non-reinforced thermoplastic starch [4].

II. BANANA, HEMP, WOOD DUST, AND JUTE FIBERS

Other selective natural fibers where some researchers used in determining its mechanical properties as in Table 2 are banana, hemp, wood dust, and jute. Gosh et al. [24] treated its banana fibers with 5% of NaOH and dried the banana fiber mat in 80ºC for 24 hours, the same method used by Meon. The matrix material used for his experiment is Bisphenol Epoxy based and Vinyl Ester, fabricated using hand lay-up technique and the tensile properties is 122 MPa. used hemp fibers in their study of tensile and flexural which gives a result of 17.39 MPa and 16.39 MPa for both tensile and flexural test respectively. The hemp fibers were mixed with 90% High Density Polyethylene (HDPE) and fabricated with injection molding machine after gone through mercerization process of 5% NaOH in 24 hours.

III. OVERVIEW OF NATURAL FIBERS AND ITS CLASSIFICATIONS

Natural fibers originated in Southeast Asia then spread to China .Reports of the spinning of cotton in India date back to 3000 BC. Natural fibers have great antistatic properties, low thermal conductivity, moisture regain properties is good enough (about 13.75%) and 100% biodegradable. Hence they can be widely used in agriculture sector, textile sector, woven sector and non-woven sector.

On burning the natural fibers we don't get poisonous gas. Natural fiber, any hair like raw material directly obtainable from an animal, vegetable or mineral source and convertible into non-woven fabrics such as felt or paper or ,after spinning into yarns ,into woven cloth. A natural fiber may be further defined as an agglomeration of cells in which the diameter is negligible in comparison with the length [4]. Although nature abounds in fibrous materials, especially cellulosic types such as cotton, wood, grains and straw. Only a small number can be used for textile products or other industrial purposes.

Apart from economic considerations, the usefulness of a fiber for commercial purposes is determined by such properties as length, strength, pliability, elasticity, abrasion resistance, absorbency and various surface properties. Most textile fibers are slender, flexible and relatively strong. They are elastic in that they stretch when put under tension and then partially or completely return to their original length when the tension is removed .Some of the factors that differentiate between natural and synthetic fibers as shown in Table 1.

Table 1. Comparison between Natural and synthetic fiber.

Aspects	Property	Natural fibers	Synthetic fiber
Technical	Mechanical property	Moderate	High
	Moisture sensitivity	High	Low
	Thermal sensitivity	High	Low
Environmental	Resource	Infinite	Limited
	Production	Low	High
	Recyclability	Good	Moderate

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Based on their origins natural fibers can be classified as plant, animal and mineral fibers. Animal fibers such as hair and silk and mineral fibers have not been widely used as a reinforcement fiber.
The detailed classification of natural fibers shown in Figure 1.But several plants fibers have been used widely in biocomposites field for the applications in the area of automotive, marine and construction [5]. Some of the available plant fibers are seed, bast, leaf, stalk, cane, grass and reed fibers. Available mineral fibers are Asbestos, Fibrous and brucite fibers.

Compared to glass fibers, commonly used in composites, natural fibers have lower tensile strength. However, when the specific tensile strength (tensile strength/density) is considered, some natural fibers have comparable values to that of glass fibers because of their lower density.

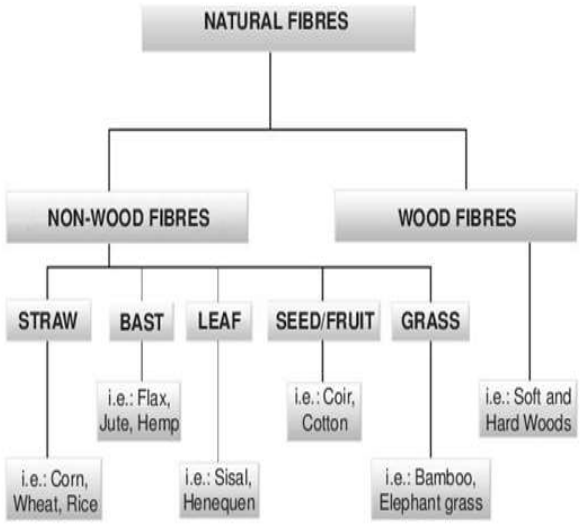

Fig 1. Classification of Natural Fibers.

The properties of natural fibers not only vary depending on origin, quality of the plant, location, weather, age, and pre-conditioning or processing but are also highly influenced by their chemical structure in-terms of degree of polymerization, cellulose content, orientation and crystallinity. The thermal properties of natural fibers are very important since the fibers are likely to be exposed to high curing temperatures used during composite fabrications with thermoset resins. Since natural cellulose fibers are mixture of organic components leads to a variety of chemical and physical changes [6].

IV. RELATED WORK

Porras et al. [5] made an attempt to develop fully biodegradable green composite by using bamboo woven as a reinforcement and poly lactic acid (PLA) as a resin by using single screw extruder in which extruder temperatures were set at different values as 51% fiber volume fraction composite prepared and tested .As results on the basis of mechanical properties the laminated in transverse direction as compared to axial direction shows the best energy taking capabilities and also good in other engineering applications.

Singh et al. [6] studied the importance of biodegradable composites or green composites with various types of composite making by using different fibers as a reinforcement and resin as a matrix .in which it is got to know about the highest production of natural fibers as taking jute so the India and Bangladesh is largest producer, with this various different chemical composition and physical as well as mechanical properties of composites have studied. In which the processing of Bamboo flour with poly lactic acid by injection molding shows the tensile strength of 50MPa, whereas jute/PLA by film stacking reviews the 100.5 MPa also adding the problems regarding with natural fibers because of its hydrophilic and hygroscopic classification.

Verma et al. [7] conducted an experimental work on bamboo as a fiber and PLA as a resin by adding the little amount LDI (lysine based di isocyanate) through kneading process and shows the effect at various percentages. In SEM it is shown that the bond between the interfaces is becoming stronger than without using LDI content. Also when NCO content mixed upto extent 33% tensile strength increased directly from 29 MPa to 42 MPa and after the amount of 30 percent it declined also with increasing tensile modulus from 2666 to 2964 MPa. In further experiments shows LDI amount also make composite hard after mixing. The main drawback of bamboo is hydrophilic nature and PLA is hydrophobic but after LDI amount in composite makes absorption truly resistant.

Hebel et al. [8] performed an experiment by taking natural fiber as bamboo and resin material epoxy to develop a composite with hot press method with altering various parameters like temperature, pressure and press or hold time so the link between tensile strength and these varying parameters can be analyzed,

so the study reveals that the tensile strength gives better results at specified temperature and pressure with due respect to press or hold time, in less temperature and high pressure the inter face bond is not at its best level ,and in high temperature with moderate pressure good interface bond is revealed, but also by continuously enhancing the temperature with holding time shows carbonization in composite. Moreover, it is shown by altering these parameters not affects only tensile strength but other effective properties in composite.

Perriman's et al. [9] experimentation done to notice the effect of directionality of fibers in composite. Taking

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bamboo as a natural fiber with epoxy 828 LVEL with hardener DYTEK DCH 99, various numbers of fiber configuration taken in bamboo for composite making., so as getting results it is got to know in between continuously arranged and discontinuously pattern in fibers, former has more tensile strength than latter, but also if taking randomization arranged pattern it has only 15% less tensile strength than continuously fiber arranged pattern.

Khalil et al. [10] studied the usage of green fiber or biodegradable fiber bamboo with various types of polymers to evolve composite and its effective use in different kinds of areas, also reveals the importance of silane treatment in bamboo/epoxy reinforced composite enhanced the mechanical properties (tensile and flexural strength as well as elastic modulus) it also achieves the better interfacial bonding with reducing the water absorption capability, treated with amino propyltriethoxy silane possess best results.

Jiang et al. [11] conducted an experiment to develop the effect of hydrothermal ageing or water absorption experiment on composite so to evolve the consequences of water absorption with various kinds of properties. In first case that is ageing for 7 days shows a absorption at faster rate but with slight change in tensile strength (less than 12%) because of water molecules have effect of plasticize. In another case i.e. up to 28 days weakening of interface bond is shown with swelling in composite which lessen the tensile strength also with increasing the porous effect. After 28 days or up to 42 days hydrolysis process starts due to which cracking in microstructure is shown which drastically decreases the tensile strength and slight change in ductility.

Huang et al. [12] experimentation done on the basis of 3 samples prepared i.e.(Bamboo fiber Bamboo/epoxy, Bamboo/epoxy/alkaline), after that the tensile and flexural test performed which shows bamboo fiber has 717.53Mpa which reduces to 473.05Mpa after treating with alkaline solution and for another sample i.e. bamboo/epoxy/ALK gives better results or comparable with respect to theoretical value given and for flexural it is reveals that for bamboo/epoxy has 141.39Mpa which increases upto 1820.29Mpa, also fiber pull out test performed which shows the shear strength between interfaces has increased. At last hydrothermal ageing test shows BF/EP/AKL increases the moisture immersed increases and also reached to its threshold in 4 hours that is 19% which affects the mechanical properties.

V. CONCLUSION

This study has been concerned with how the properties of the neat PLA differ with the application of the Jute fabric. The use of the Jute fabric with PLA resulted in the increase of the mechanical properties of the bio-composite only the flexural modulus of the bio-composite showed reduction and further research is in progress to authenticate the reason, why the flexural modulus is reduced.

The use of natural fibre fabric-biopolymer composites in industrial application provides challenges for researchers around the world to access the performance and quality of natural fibre fabric-biopolymer composites for use as materials in many applications, especially in packaging applications. Natural fibre fabric-biopolymer composites are biodegradable, renewable, and recyclable; they may replace or reduce the use of man-made fibres in various applications.

Thus, it is crucial to recognize the functional properties required for natural fibre fabric-biopolymer composites to be used as material for packaging.

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