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A Review on Feasibility of Using Jute Fiber Composite for Industrial Pallets and Trays

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Abstract

Pallets and trays used in industry are widely made up of polypropylene plastic. These are used for material handling and for better storage efficiency. Once damaged or broken, it should be appropriately disposed or recycled, but this does not happen many times and they are just thrown carelessly out in the open or even burnt sometimes. This is harmful as polypropylene plastics are non-biodegradable and are harmful to nature in many ways. Many previous studies have suggested that jute fiber composite has mechanical properties almost equal to polypropylene plastic or more than it in some cases. Also jute fiber composites are not harmful to nature as they are biodegradable. Moreover, jute fiber composites have found many applications in recent years. This paper gives a literature survey on feasibility of using jute fiber composite instead of polypropylene plastics for pallets and trays used in industry.

Keywords— *jute fiber composite, industrial pallet, industrial tray, polypropylene plastic, natural fiber composite*

I. INTRODUCTION

Pallets are used for various purposes like stacking, storing or moving materials with the use of forklifts, pallet jacks, erect cranes, etc. It is a flat structure with stringers beneath it which provide jack openings to lift it. They are usually made up of plastics or woods and also metal in special cases. They come in various sizes recognized by International Organization for Standards (ISO) or can be customized. Various molding processes are used to manufacture pallets. Trays are a shallow, rectangular shaped structures used for storing, inspecting cleaning or finishing of smaller size and less weighing work pieces or products. Most commonly they are made up of plastics, but sometimes metals like aluminum and steel are used for specific purposes. They are manufactured by using different types of thermoforming processes.

Various types of plastics are used for manufacturing these but in small scale industries those made up of polypropylene are generally used because it is light in weight, has optimum strength and is economic. It has high melting point, around 160^{o}C. It is quiet durable and resistant to many chemicals. In spite of having many advantages the major disadvantage of using polypropylene plastic is that it is non-biodegradable. After the life of these products is over, i.e. when they are damaged or broken they are most of the time thrown out in open or burnt. On burning it releases harmful gases. When thrown in water bodies it adversely affects the aquatic bodies and also causes water pollution. It prevents water from seeping into the ground. It affects the fertility of the soil. Dumping the plastic in the ground affects the growth of plants in the area as they do not get water from the soil.

Jute fiber composite on other hand has similar advantages compared to that of polypropylene plastic. According to various studies, it has physical properties almost equal to polypropylene plastic and in some cases even more than it. Also jute fiber composite can be easily manufactured. And as it is a natural fiber composite, it is biodegradable. Hence it can be easily disposed and cause no harm to the environment. Its range of melting point can be more than that of polypropylene and is around

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185°C. And it has good chemical resistivity as well. It is almost as durable as polypropylene plastic. In recent years it has found a wide range of applications. It is used for making bio gas containers, suitcases, helmets, toys, interiors of railway coaches, furniture, false ceilings etc. It can be easily manufactured by using molding processes like hand laminating/contact molding, compression molding or resin transfer molding. Hence, the pallets and trays used for industrial purposes can be made of jute composite fiber instead of polypropylene plastic thus keeping the environment safe.

II. FIBER REINFORCED COMPOSITE AND JUTE

Composites can be classified on the basis of their matrix and reinforcement.

- Matrix based composites are

1. Polymer matrix composite
2. Metal matrix composites
3. Ceramic Matrix Composites.

- Reinforcement based composites are

1. Fiber reinforced composites
2. Particle reinforced composites

Jute fiber composite is a polymer matrix composite and fiber reinforced composite. It is manufactured by cross-linking jute fiber molecules with resins in the fiber reinforced composite material matrix through a proprietary molecular re-engineering process. This gives it exceptional structural properties.

Jute is one of the biggest sources of natural fiber. The cellulosic fibers i.e. jute is obtained from the stem of the jute plant. Jute constitutes majorly of Lingo-Cellulose, a polymer. The chemical formula of jute is $(C_6H_{10}O_5)_n$. The table given below gives the composition of jute.

TABLE I
COMPOSITION OF JUTE

Cellulose	58% - 63%
Hemi-cellulose	21% - 24%
Lignin	12% - 14%
Protein	0.8% - 2.5%
Mineral Matter	0.6% - 1.2%
Wax	0.4% - 0.8%
Pectin	0.2% - 0.5%

As observed in the table above, there is about 58%-63% of cellulose in jute. Hence on combustion it does not produce any kind of toxic gases. It is carbon dioxide neutral and biodegradable. Also it has good chemical resistance, low thermal conductivity and is less abrasive. Besides as it is grown abundantly around the globe, it is cheap. Jute fiber also has some drawbacks which are inherent, some of them being stiffness and harshness. It is difficult to produce fine yarns because of presence of lignin in it. Because of lignin there is branching and fiber length also varies. But as it has coarse and hard fiber it is possible to improve its mechanical properties by removing the non-cellulosic components to some extent. Hence, in spite of having some disadvantages, those can be overcome by various means. This makes composites of jute fiber useful in various fields of science and engineering technology.

The table below gives a comparison of mechanical properties of jute epoxy composite and polypropylene plastic.

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TABLE III
COMPARISON OF MECHANICAL PROPERTIES OF JUTE EPOXY COMPOSITE AND POLYPROPYLENE PLASTIC

Property	Jute Epoxy Composite	Polypropylene Plastic
Tensile Strength	42.54 MPa	40.7 MPa
Flexural Strength	45 MPa	40 MPa
Young's modulus	1250 MPa	1265 MPa
Flexural modulus	1850 MPa	1400 MPa

Jute fiber composite is usually made by using Hand Laminating Molding or also called as contact molding. In this first the chopped fibers and resins are sprayed with hand or a special gun on the mould and trimmed. Then it is allowed to cure. And after curing it is removed from the mould. Other methods include Compression Molding and Resin transfer molding which are rarely used.

III. LITERATURE REVIEW

[1.] **P. J. Roe** *et al*. calculated fiber strength of jute reinforced polyester composite to be 442 MNm^{-2} and Young's modulus was calculated as and 55.5 GNm^{-2}. They are tough at $V_f > 0.3$ and have work of fracture 20 kJm^{-2}. If the application does not require high strength jute has many advantages as a composite. On comparing the properties of jute and glass fiber on the basis of cost and weight they concluded that jute fiber was superior to glass fiber in many aspects. Jute fiber forms strong bond with the polyester resin. The jute composite is aesthetically better. Superior quality composites with specific properties can be produced with jute and polyester resin. And hence there is much scope for increasing the use of jute fiber.

[2.] **Hua Wang** *et al*. showed that by modifying the jute fiber in jute fiber composites can increase the tensile strength more than 43 MPa and as high as about 83 MPa than the pure epoxy. The tensile strength, elongation at break void fraction and interfacial adhesion of treated jute fiber composites was observed to be better than the corresponding raw jute fiber composites. Chemically treating the jute fiber makes the matrix-fiber adhesion stronger. These findings were supported by SEM images of fractured surface of composites. Also after treating chemically there was no change chemical composition of the jute fiber.

[3**.] Vivek Mishra** *et al*. mentioned natural fibers are not only strong and less weighing but are also comparatively cheap. The study's result showed considerable effect of fiber loading on the mechanical properties of the composites. The hardness, impact test and tensile properties of jute-epoxy composites increase as fiber loading increases. Also the flexural strength and inter-laminar shear strength was affected by void content of composites and improved with void content from 12 wt.% to 48 wt.%. As void content decreases fiber loading increases. The tensile strength was found to vary from 43 MPa to 110 MPa when fibers varies from 0 wt.% to 48 wt.%. 4.875 J was the maximum impact strength in case of composite with 48 wt.% of fiber loading.

[4**.] Md. Rashnal Hossain** *et al*. tested jute fiber composites having jute fiber pre-form staking sequences (0/0/0/0), 0/+45°/-45°/0 and 0/90°/90°/0. It was found out that the tensile strength and stiffness of 0-0 laminate composite was more than that of 0-45 and 0-90 in longitudinal direction. This was because there was higher degree of fiber pull in that direction. But the scenario was opposite in case of bending strength in the same direction. In traverse direction the tensile strength and bending strength of 0-0 was lower than 0-45 and 0-90 laminate composites. In the same direction of 0/0/0/0 composites the jute fiber that was reinforced underwent drastic slicing and fibrillation. This was the reason for poor traverse mechanical properties.

[5.] **K. Deepak** *et al*. studied the effect of addition of nano clay and water absorption on jute fiber. It was found that the tensile strength of jute composite with nano clay was 43MPa which was higher

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than jute fiber without nano clay with the value of 33 MPa. The impact test showed that the energy absorbed increased from 0.5 J to 0.7 J after using nano clay. Compressive strength was increased by use of nano clay. Adding nano clay also increased the viscosity of the resin mix due to increased clay-resin interaction. To ascertain its suitability for more applications more tests should be performed to evolve hygro-thermal and wether resistance properties.

[6**.] M. Jawaid** *et al*. concluded that epoxy based three layer Jute fiber reinforced hybrid composites are strongly resistant to all chemicals. The void content was observed to decrease with hybridization of oil palm EFB composite with jute fibers. The tensile modulus of hybrid composites was higher than pure EFB composites. Tensile strength of pure EFB composites is lower than all other composites. The low tensile strength of pure composites was enhanced with addition of jute fibers. It was concluded that hybrid composite show better adhesion to matrix than pure EFB fiber polymers. This was proved with the help of SEM micrograph of tensile fracture surface samples.

[7.] **Dipa Ray** *et al*. treated jute fibers with 5% alkali (NaOH) solution for 0, 2, 4, 6 and 8 hours at 30°C. As a result the mechanical properties of the composites reinforced with these alkali treated jute fibers improved. The composites treated with 4h treated fibers at 35% fiber loading showed maximum improvements. The flexural strength and the modulus increased by 20% from 199.1 MPa to 238.9 MPa and 23% from 11.89 GPa to 14.69 GPa respectively. After 6h treatment is was found that the jute fibers were more crystallized which led to increase in modulus. The SEM investigations of fracture surfaces supported these observations.

[8.] **Ajith Gopinath** *et al*. prepared, tested and analyzed jute epoxy and jute polyester composites and then compared them. The tensile strength for jute-epoxy was found to be 12.46 N/mm^2 and of jute-polyester composites was 9.23N/mm^2. Tensile strength of 10% NaOH treated jute epoxy composite was 18.67% more than 5% NaOH treated same composite. In jute polyester composite the 10% NaOH treated specimen showed 16.67% more tensile strength than 5% NaOH treated specimen. Jute polyester composite took less time for processing than jute epoxy composite. The results indicated that jute epoxy composite has better properties and thus it is more suitable for automotive applications over jute polyester composite.

[9.] **Prabhakar Kaushik** et al. found that jute epoxy resin composite had lower erosion wear rate than jute polyester composite. Taguchi experimental design was used to analyze erosion behavior of the composites. It was observed that impact velocity is highly affecting control factor for erosion rate. Maximum impact strength of jute epoxy composite was found to be 110.74 J/m^2 while that of jute polyester composite was 148.58 J/m^2. Impact strength was maximum at 44% volume fraction. Till then impact strength increases with increase in volume fraction. The same trend was seen in flexural strength in both jute epoxy composites and jute polyester composites.

[10.] **Priya Singhal** *et al.* experimented and evaluated the effects of chemical pre-treatments of jute fiber composite on damping properties of jute epoxy/polyester composite. Treating with alkali, permanganate pretreatments, benzoyl chloride, malic anhydride and silane improve interfacial bonding leading to better damping properties. The DMA test result concluded that if jute fiber reinforced in polymer composite is silanized and benzoyl chloride treated, then it improves storage modulus and the thermal stability in comparison to untreated fiber reinforced composite. These composites show better strength than untreated composites of corresponding concentrations. Hence treated jute epoxy/polyester composites are suitable for using as insulating or damping materials or as fillers.

IV. CONCLUSIONS

Jute fiber composite can successfully replace polypropylene for manufacturing industrial pallets and trays. Based upon the research available, we can conclude that jute fiber composite has similar mechanical properties to that of polypropylene plastic which makes it durable, reliable and chemical resistant. Adding to this it is also eco-friendly as it is carbon dioxide neutral and biodegradable; it is

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cheap and easily available in nature. With more research on improving its strength and other properties, jute fiber reinforced composites can surely find many more applications in engineering and technology replacing other materials thus keeping the environment safe.

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