Manufacturing & Applications of Jute Fiber Composites

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Abstract

Now-a-days, newer polymer matrix composites reinforced with fibers such as glass, carbon, aramid, etc. are getting a steady expansion in uses because of their favorable mechanical properties. Despite these advantages, the widespread use of synthetic fibre-reinforced polymer composite has a tendency to decline because of their high-initial costs, their use in non-efficient structural forms and most importantly their adverse environmental impact. On the other hand, the increase interest in using natural fibres as reinforcement in plastics to substitute conventional synthetic fibres in some structural applications has become one of the main concerns to study the potential of using natural fibres as reinforcement for polymers. In the light of this, researchers have focused their attention on natural fiber composite (i.e. bio-composites) which are composed of natural or synthetic resins, reinforced with natural fibers. The use of natural fibers, derived from annually renewable resources, as reinforcing fibers in both thermoplastic and thermo set matrix composites provide positive environmental benefits with respect to ultimate disposability and raw material utilization.

Key words: Bio composites, Reinforcement, Matrix, Thermoplastic composites

1. Introduction

1.1. Overview of composites

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective.

1.2. Merits of Composites

Advantages of composites over their conventional counterparts are the ability to meet diverse design requirements with significant weight savings as well as strength-to-weight ratio.

Some advantages of composite materials over conventional ones are as follows:

- Tensile strength of composites is four to six times greater than that of steel or aluminum (depending on the reinforcements).
- Improved torsional stiffness and impact properties.
- Higher fatigue endurance limit (up to 60% of ultimate tensile strength).
- 30% - 40% lighter for example any particular aluminum structures designed to the same functional requirements.
- Lower embedded energy compared to other structural metallic materials like steel, aluminium etc.
- Composites are less noisy while in operation and provide lower vibration transmission than metals.
- Composites are more versatile than metals and can be tailored to meet performance needs and complex design requirements.
- Long life offer excellent fatigue, impact, environmental resistance and reduce maintenance.
- Composites enjoy reduced life cycle cost compared to metals.
- Composites exhibit excellent corrosion resistance and fire retardancy.
- Improved appearance with smooth surfaces and readily incorporable integral decorative melamine are other characteristics of composites.
- Composite parts can eliminate joints / fasteners, providing part simplification and integrated design compared to conventional metallic parts.

2. Classification of Composites

2.1 Matrix Based

- Polymer Matrix Composites (PMC)
- Metal Matrix Composites (MMC)
- Ceramic Matrix Composites (CMC)

2.2 Reinforcement Based

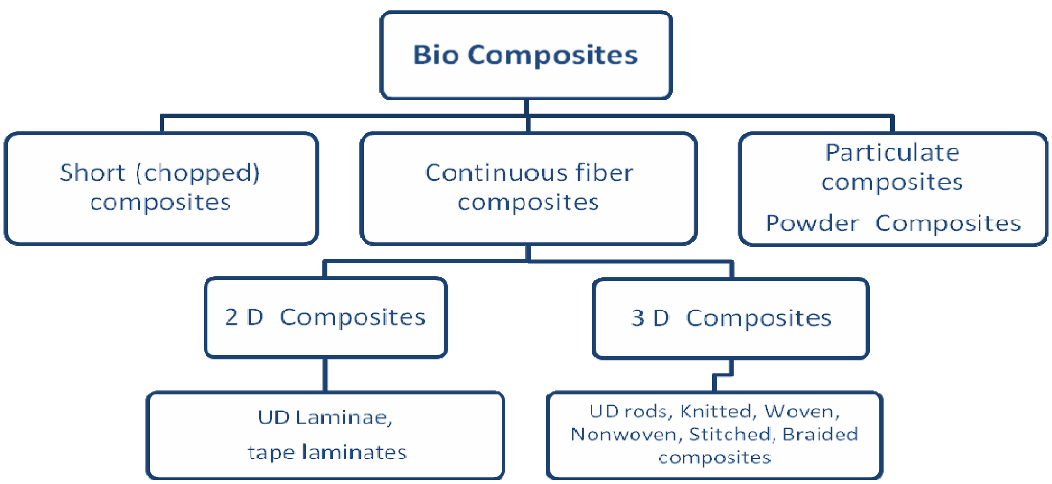
- Fiber Reinforced Composites (FRC)
- Particle Reinforced Composites (PRC)

3. Natural Fiber Reinforced 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. The natural fiber-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products, etc.

3.1 Classification of Bio Composites

This classification is based on reinforcement form i.e. on the type of fibers such as short, continuous or powder used in manufacturing of natural fiber composites.



3.2 Manufacturing of Bio Composites

<u>3.2.1 Hand Laminating/contact moulding</u>

Chiefly used for polyester resin and practiced where very large article is to be made.

Sequence of operation:

- Chopped fiber/ sliver/woven fabric and resin are sprayed on to the mould with a special gun or by hand.
- Trim and allow to cure
- After curing article is released from the mould.

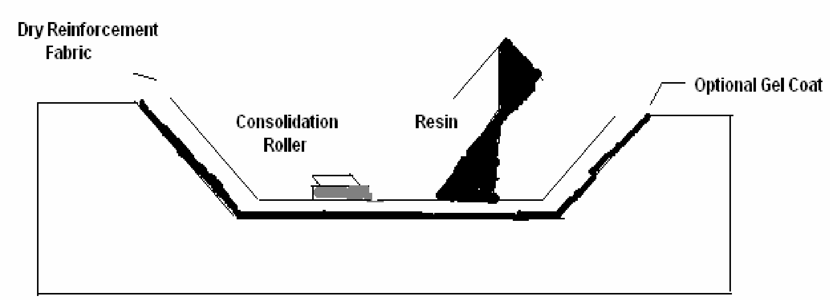


Fig 1: Wet Hand lay up

Advantages:

- No size limitation
- Adaptable production method since metals or extra fabric can be added.
- Low pressure process and does not require power to mould
- Curing can be done at room temperature and it varies from room temperature to 80°c.
- It is suitable for small production run.

3.2.2 Compression moulding

It is high temp, high pressure process. Widely used for all thermosetting polymer (polyester, epoxy etc.). It is cost effective for high runs.

Sequence of operation:

- Lubrication of both top and bottom mould is done by petroleum jelly/silicon emulsion.
- As the mould is closed, the charge is heated rapidly a little flash ensures complete mould filling. Then heat from the mould cures the resin matrix thus producing solid parts.
- After curing the solid moulded parts are ejected by ejector pin.
- Compression moulding is relatively slow and labour intensive and therefore quite expensive method.

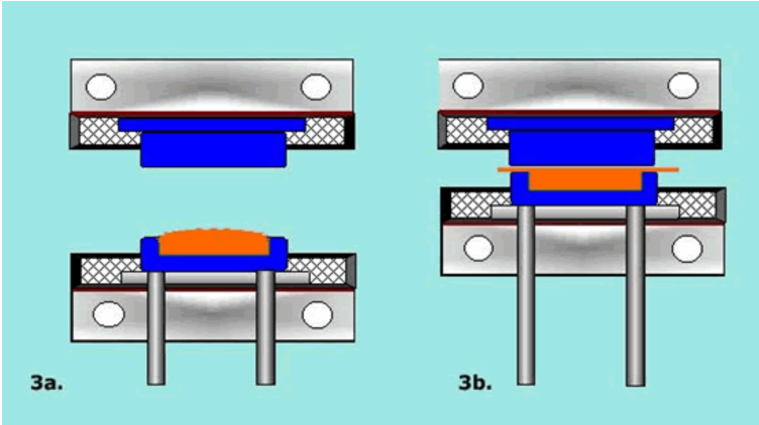


Fig 2: **Compression moulding**

3.2.3 Resin transfer moulding

RTM is a process where resin is injected into a closed cavity mould that is filled with fiber reinforcement. It is a relatively low pressure vaccum (100psi) process that moulds near complete shapes in 30 – 60 min.

Sequence of operation:

- Reinforcing jute, in fiber/fabric/non woven form is laid on the mould.
- A matching mould half is mated to the other half containing jute and clamped tightly.
- A pressurized resin system mixed with catalyst is punched from one or more tanks into the mould.
- Resin and fibre stays in the mould for efficient curing, after which solid part is taken out.

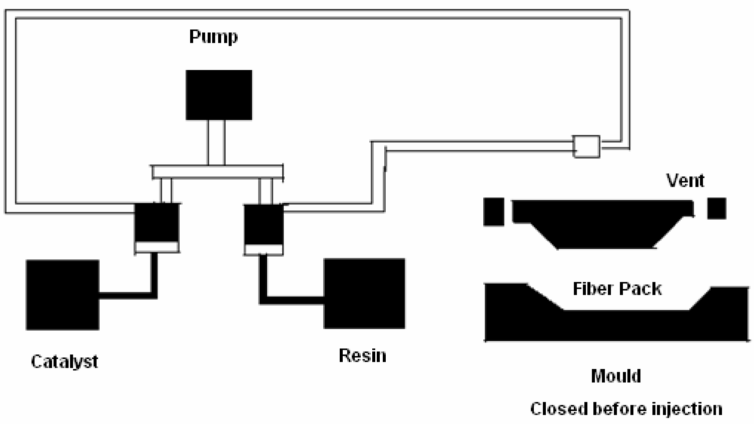


Fig 3: **Resin transfer moulding**

4. Jute Fiber Composites

Why Jute fiber?

Jute, sisal, banana, and coir the major souce of natural fibers, are grown in many parts of the world. Some of them have aspect ratios (ratio of length to diameter) > 1000 and can be woven easily. These fibers are extensively used for cordage, sacks, fishnets, matting and rope, and as filling for mattresses and cushions (e.g.rubberised coir). Cellulosic fibers are obtained from different parts of the plants. E.g. Jute is obtained from stem.

The biodegradable and low priced jute products merge with the soil after using providing nourishment to the soil. Being made of cellulose, on combustion, jute does not generate toxic gases. Due to jute's low density combined with relatively stiff and strong behavior, the specific properties of jute fibre can compare to those of glass and some other fibres.

Recent reports indicate that plant based natural fibers can very well be used as reinforcement in polymer composites, replacing to some extent more expensive and non renewable synthetic fibers such as Glass. The maximum tensile, impact and flexural strengths for natural fiber reinforced plastic (NFRP) composites reported so far are 104.0 MN/m^2 (Jute - Epoxy), 22.0 kJ/m^2 (Jute - Polyester) and 64.0 MN/m^2 (Banana – Polyester) respectively.

Different geometries of these fibers, both singly and in combination with glass have been employed for fabrication of uni – axial, bi – axial and randomly oriented composites. Amongst these various lingo cellulosic fibers, jute contains a fairly high proportion of stiff natural cellulose.

Several studies of fiber composition and morphology have found that cellulose content and micro fibril angle tend to control the mechanical properties of cellulosic fibers. Higher cellulose content and lower micro fibril angle results in higher work of fracture in impact testing.

Fibre	Density (g/cm^3)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation At break (%)	Specific Tensile Strength (MPa/ g.cm^{-3})	Specific Young's Modulus (GPa/g.cm^{-3})
Jute	1.3-1.45	393-773	13-26.5	1.16-1.5	286-562	9-19
Flax	1.5	345-1100	27.6	2.7-3.2	230-773	18
Ramie	1.5	400-938	61.4-128	1.2-3.8	267-625	41-85
Sisal	1.45	468-640	9.4-22.0	3-7	323-441	6-15
Coir	1.15	131-175	4-6	15-40	114-152	3-5
E-glass	2.5	2000-3500	70	2.5	800-1400	28
S-glass	2.5	4570	86	2.8	1828	34

Table 1: Comparison of Properties of Jute Fiber with other fibers

4.2 Types of Jute reinforced composites

4.2.1 Thermoset composites

It is a natural fiber reinforcement impregnated by cross linking resins to produce semi permanent mouldings which is an irreversible process. The resins used may be Saturated polyester, epoxy, vinyl ester and phenolic resin.

4.2.2 Thermoplastic composites

It is a moulding incorporating synthetic polymer fibers or resins as binders/matrices, which can be modified by the application of heat. The most commonly used polymers are PP, polyamide and polyester.

Chemical composition of Jute

Jute is made up of a polymer known as Ligno-cellulose as the major constituent is cellulose, the chemical structure of jute is represented by that of cellulose, viz $(C_6H_{10}O_5)_n$

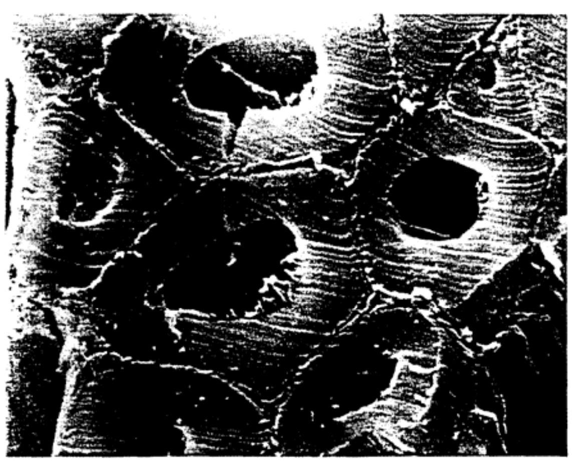
Cellulose – 64.4%

Hemi cellulose – 12%

Lignin – 11.6%

Moisture – 10%

Fats, waxes & Pectins – 11.8%



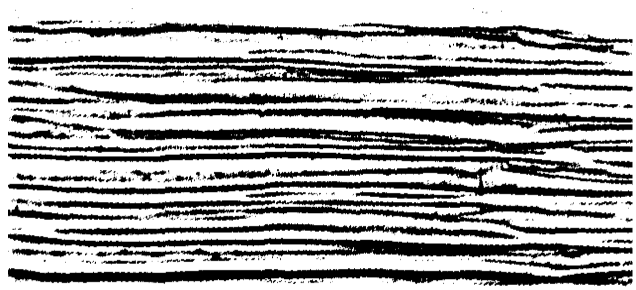


Fig 4: Part of a Jute Fiber bundle in traverse fiber View under SEM

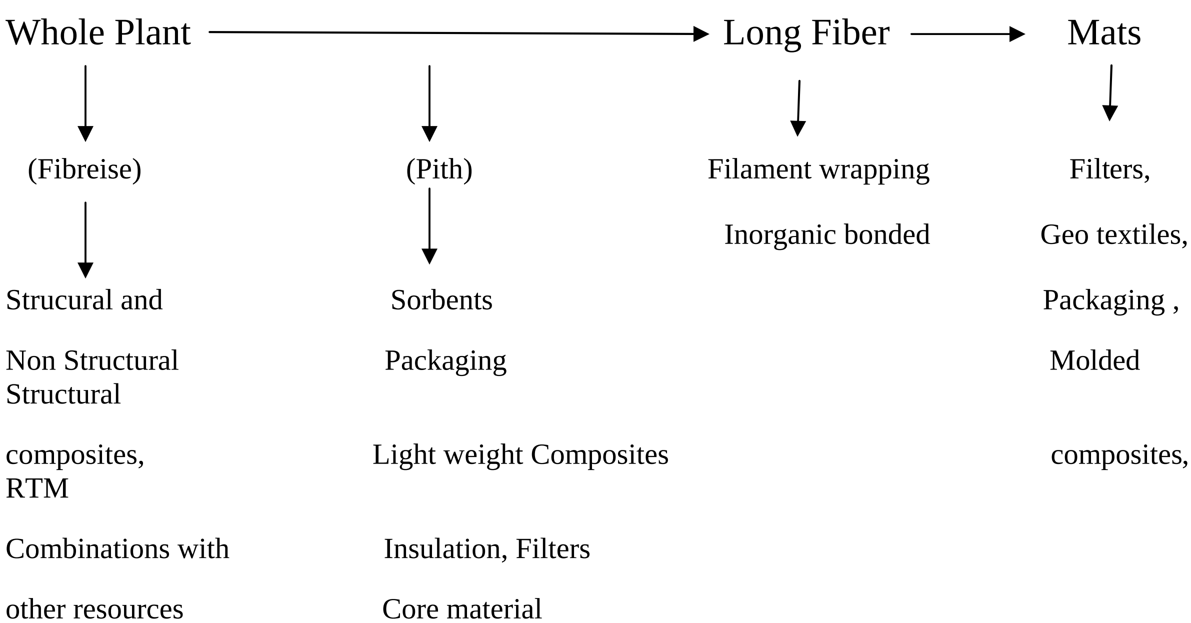
Fig 5: Longitudinal view of single strand of Jute Fibers

4.3 Advantages of Jute Composites

The composites reinforced with natural fibers like Jute are abundant, cheap and low density, biodegradable and carbon dioxide neutral. Jute fiber has the potential to compete with glass fibre, 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
- Stronger than wood



<u>Fig 6:</u> Use of Jute plant in composites

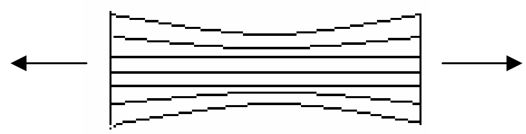
5. Factors the Composite Has To Withstand For Better Performance

A composite material is formed at the same time as the structure is itself being fabricated. This means that the person who is making the structure is creating the properties of the resultant composite material and so the manufacturing process they use have an unusually critical part to play in determining the performance of the resultant structure.

Loading: There are 4 main direct loads that any material has to withstand tension, compression, shear and flexure.

5.1 Tension

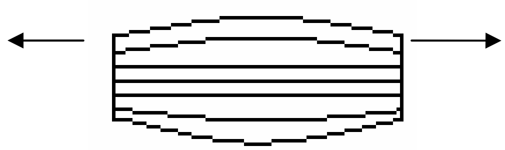
The response of a composite to tensile loads is very dependent on the tensile stiffness and strength properties of the reinforcement fibers, since these are far higher than the resin system on its own.



<u>Fig 7:</u> Composite under tensile load

5.2 Compression

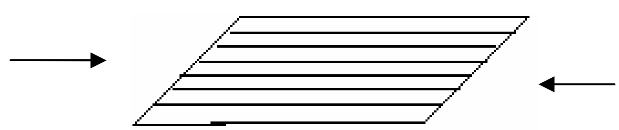
Here, the adhesive and stiffness properties of the resin system are crucial as it is the role of, the resin to maintain the fibers as straight columns and to prevent them from bulking.



<u>Fig 8:</u> A Compressive load applied to a composite

5.3 Shear

This load is trying to slide adjacent layers of fibers over each other. Under shear loads the resin plays the major role, transferring the stresses across the composites. For the composite to perform well under shear loads the resin element must not only exhibit good mechanical properties but must also have high adhesion to the reinforcement fiber. The interlaminar shear strength (ILSS) of a composite is often used to indicate this property in a multi layer composite.



<u>Fig 9:</u> Composite experiencing a shear loads

Two types of shear

In plane shear: The measure of fiber matrix bond within each lamina (or layer)

Inter laminar shear: The measure of bond strength between layers.

5.4 Flexure

Flexure load is involves the ability of the material to bend. Flexure loads are really a combination of tensile, compression and shear loads. When load is applied the upper surface is put into compression, the lower face is in tension, and the central portion of the partition experiences shear.

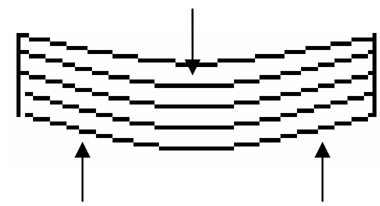


Fig 10: Composite experiencing a Flexure loads

6. Applications of Natural Fiber Composites

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.
- **Toys**
- **Sound proof materials**

7. Conclusion

Composites are there by, occupies a major role in the high performance applications such as leisure and sporting goods, shipping industries, aerospace etc. The utilization of the cheaper goods and applying it in a high performance application is possible with the help of this composite technology. Even though the composites have some disadvantages, advantages such as combination of the useful properties of the two different materials, cheaper manufacturing cost, versatility, etc. makes it useful in various fields of engineering and technology. With this background, it is sure that the composite is the most wanted technology in the fast growing current trend.

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