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Fabrication Of Bamboo Fibre Reinforced Polymer Matrix Composites

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ABSTRACT
In this work bamboo fibres are used as reinforcement material in polymer matrix to create a bio fibre reinforced polymer composite. This paper details the methods followed to fabricate the composite. Bamboo fibre is extracted from bamboo, and is subjected to various chemical treatment process to obtain these required properties and fibres are reinforced in a polymer matrix and a laminate is created. The fibres are arranged in various angles to obtain isotropic properties throughout. The method used for fabricating this composite is hand layup process.

KEYWORDS: Bamboo fibre, Polymer matrix composite, hand layup process, bio composite

INTRODUCTION

A. Bamboo:

Bamboo is peffrennial plant having its origin in Indiansub-continent, its scientific name and its classification is given below in table 1. There are about 75 genres of bamboo and 1500 species of bamboo. The structure of a bamboo visualised as below by Liese [24] is shown below in Figure 1.

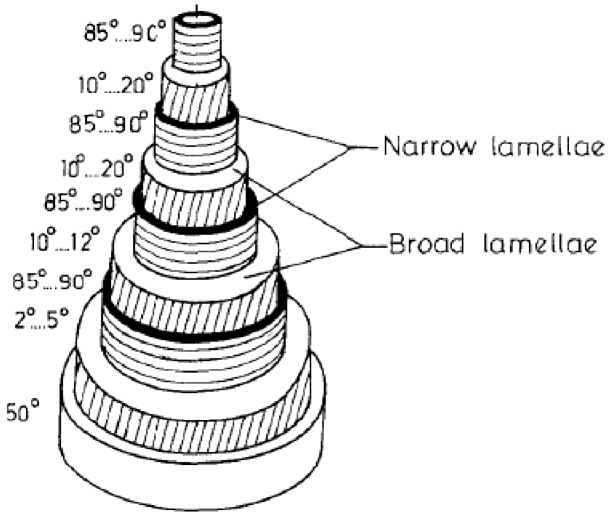

Fig. 1: Structure of Bamboo

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Table 1: Bamboo Nomenclature

Group	Angiosperm
Order	Monocotyledon
Family	Poaceae
Subfamilies	(i) Arundinoideae, (ii) Pooideae, (iii) Chloridodeae, Panicoideae, and (iv) Bambusoideae.

A. Material:

Composite materials can be classified based on the matrix material used and the type of reinforcement used. Based on the matrix material used, composite can be broadly classified into Ceramic matrix composites, metal matrix composites and polymer matrix composites. Each type of composites have their own advantages and applications. Based on the type of reinforcement used, a composite material is classified into fibre reinforced composites in which the fibre used for reinforcement may be unidirectionally aligned or it may be dispersed in whisker form in the matrix, and particle reinforced composites in which a metal or oxide or nitride or carbide material is dispersed in the matrix medium to improve certain properties as shown in figure 2. [1] Some commonly used fibres are glass fibres, carbon fibres, and metallic fibres also can be used.A fibre reinforced polymer (FRP) is a composite material in which the matrix is a polymer which is reinforced with high-strength fibres like glass, aramid and carbon. Common thermoplastic resin matrix materials are polypropylene, polyethylene, and poly vinyl chloride

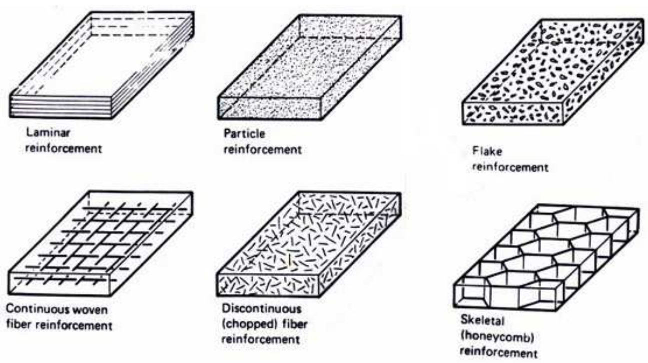


Fig. 2: illustration of composite reinforcement common thermosetting resin matrix materials are phenolic, epoxy and polyester resins.

Because of environmental concern and health hazards, instead of metallic and non-organic fibres, bio degradable organic bio fibres are used to a large extent in composite materials that are used for various industrial applicationslike automobile parts (doors and body panels) and in sound damping applications.

For our work the resin selected was thermosetting Epoxy resin. The properties of this resin are shown in table 1. On comparing these properties as well as the cost among various resins including Polyester resin and Vinyl ester resin, epoxy resins have lower density, higher elastic modulus and tensile strengthbut the major disadvantage is thatthe impact strength which is less than other polymer material.

Similarly the reinforcement material was selected as bamboo fibre. In the table 2, based on literature survey conducted the physical properties of various fibre materials are listed along with references.Among the materials considered for making the reinforcement, the concentration was on bio fibres so E glass and S glass fibres were not eligible. Of all other materials, bamboo has least density and the young'smodulus of 36 GPa was the highest compared to Cotton (12.6 GPa), Jute (26.5 Gpa), flax (27.6 GPa), Sisal (22 GPa) and Coir (6 MPa). It also exhibits considerable tensile strength of 441 MPa. Also the bamboo fibres are often referred as natural glass fibres because of its high specific strength (strength to weight ratio) but they are brittle in nature. So the fibres are to be drawn carefully.

Table 2: Properties of Epoxy Resin (Matrix)

Density g/cm^3	Elastic modulus GPa	Tensile strength MPa	Compressive strength MPa	Elongation %	Cure shrinkage %	Water absorption 24h@20°C	Impact strength J/m
1.1 - 1.4	3 – 6	35 – 100	100 – 200	1-6	1-2	0.1 – 0.4	0.3

Table 3: Properties of fibre materials.

Fibre	Density g/cm^3	Elongation %	Tensile strength MPa	Elastic Modulus GPa	Reference
Cotton	1.5 – 1.6	7.0 – 8.0	400	5.5 – 12.6	2,3
Flax	1.5	2.7-3.2	500-1500	27.6	4
Hemp	1.47	2 – 4	690	70	4
Kenaf	1.45	1.6	930	53	4
Sisal	1.5	2.0 – 2.5	511 – 635	9.4 – 22	5
Coir	1.2	30	593	4 – 6	6
E – glass	2.5	0.5	2000 – 3500	70	6
S – glass	2.5	2.8	4570	86	6
Bamboo	0.8	1.3	441	36	7

Literature Survey:

A. Material:

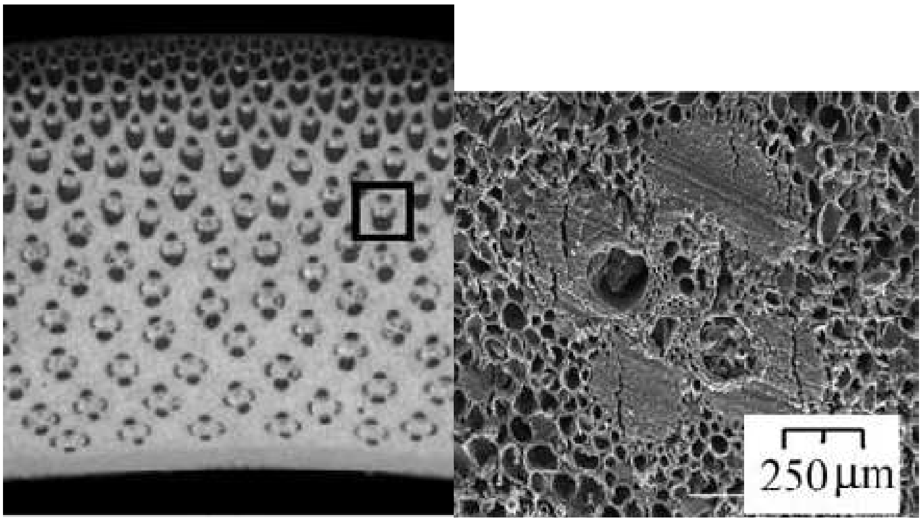
a) Bamboo fibre:

Bamboo can be effectively used as a reinforcement material because, the cellulose fibres are arranged in such a way that they are along the length of bamboo. This arrangement provides maximum tensile strength and rigidity along the direction.

According to K Okubo et. Al, bamboo tree has large number of vascular bundles and xylem. Each vascular bundle contains four sheaths of fibres of diameter 20 µm, two vessels and some sieve tubes and they are surrounded by Xylem. [7].

Bamboo is basically made up of cellulose which accounts for 60%, hemi cellulose and lignin which accounts for about 32%. [8] Figure 2 shows the cross section of bamboo fibre and the enlarged SEM view of a single bundle is shown in figure 2 (b) where the sheaths of fibres and vessels and tubes are clearly visible.

b) Matrix material:



(a) (b)

Fig. 3: SEM image of Bamboo tree's section

B. Chemical Treatments:

a) Mercerisation:

Bio fibres which are used to reinforce thermosetting as well as thermoplastic materials are subjected to chemical treatment to obtain various required characteristics which are desirable in many ways. One of the most commonly used chemical treatment process is mercerisation which is also known as alkaline treatment. This process disturbs the hydrogen bond in network structure which increases the surface roughness which will result in better mechanical interlocking between the fibre and matrix material. This process also removes a little amount of lignin, wax and oils that cover the external surface of the fibre cell wall and also depolymerizes cellulose which exposes the crystallites. [9] Also this process increases the amorphous cellulose by decreasing the crystalline cellulose as showed by studies done by Morrisionet. Al.,[11] Garcia et. Al., [12]. Another major effect of this process is the increase in amount of cellulose being exposed. As per the work of Valdez et al., this increase in amount of cellulose increases the number of sites where reaction between the matrix and fibre can occur. [13]

$[FIBER] - OH + NaOH \rightarrow [FIBER] - O - Na + H_2O$

From the above equation put forward by Agarwal et. Al., it is clear that on adding aqueous sodium hydroxide to the natural fibre, the ionisation of hydroxyl group found in fibre to alkoxide group is achieved. [10]

Another major effect of this process is improvement of mechanical strength (both fibre strength and stiffness). As per the studies of Van de Weyenberg et al. [14] improvement of tensile properties to a level of 30% was observed.

Jaco et al., [15] and Mishra et al., studies show that maximum tensile strength is achieved at room temperature when the NaOH solution concentration is 4 – 5% as more amount of alkali will damage the bamboo fibre and result in excess removal of lignin.

b) Acetylation of Natural Fibres:

Acetylation process involves plasticization of cellulosic natural fibre by esterification process. In this process acetyl functional group (CH_3COO-) is introduced into an organic compound. On doing this process acetic acid (CH_3COOH) is produced as a by-product and this product must be removed.

This chemical treatment process involves the substitution of polymer hydroxyl groups with acetic anhydride (CH3-C(=O)-O-C(=O)-CH3) which makes the fibres hydrophobic or inactive to water. The reaction involved in this process according to Hill ASC et al., [17] is as follows

$$Fiber - OH + CH_3 - C\,(=O) - O - C(=O) - CH_3 \rightarrow Fiber - OCOCH_3 + CH_3COO$$

This process increases the dimensional stability and reduces the water affinity of the natural fibre. [17,18,19,20].

As observed by Nair et al. [21] Another major improvement because of this process on the fibre with respect to bonding betweenthe fibre and matrix is that the surface roughness increases many levels andbecomes very rough thereby providing better mechanical interlocking with the matrix material and also further increase in mechanical properties of natural bio fibres were observed because of better thermal stability and improved fibre matrix interactions.

c) Benzoylation Treatment:

As per the research work of Joseph et al., [22] this treatment process involves the treatment of fibre withBenzoyl chlorideand NaOH solution which results in increase of hydrophobic nature of the fibre. The reaction of this treatment is shown in this equation as

Fibre – OH + Na OH ->Fibre – 0^- Na^+ + H_2O

Based on previous works carried out this process results in improved thermal stability of composites compared to untreated fibres.

C. Preparation Of Composites:

There are several methods used for the preparation of composites. Some of them are as follows:

1. Hand Lay Up Process
2. Spray Up Process
3. Vaccum bagging Process
4. Pre Preg Process and others

Here by we are using Hand Lay Up process.

a) Hand Lay Up Technique:

The fiber plies are cut to size from the bamboo fiber. The appropriate numbers of fibre plies are taken (two for each) and weighed. The epoxy resin and hardeners are weighed and mixed using glass rod in a bowl Carefully without air bubbles as they may cause failure in matrix material.

The subsequent fabrication process consist of first putting a releasing film on the mould surface. Next a polymer coating is applied on the sheets. Then fiber ply of one ply is put and proper rolling has to be done. Then resin is again applied, next to it fiber ply of another fiber ply is put and rolled. The Rolling is done using cylindrical mild steel rod. This procedure is repeated until required alternating fiber layer has been laid. On the top of the last ply a polymer coating is done which serves to ensure a good surface finish. Finally a releasing sheet is put on the top; a light rolling is carried out. Then a 20 kgf weight is to be applied on the composite [25]. It has to be left for 72 hrs to allow sufficient time for curing and subsequent hardening

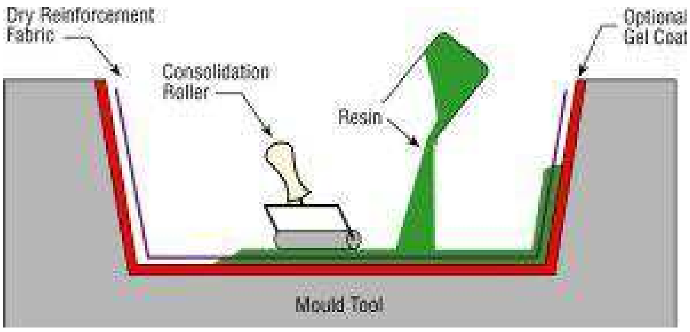


Fig. 4: Hand Lay Up Method

Preparation Of Frp:

To prepare the bio FRC, first the bamboo fibres were extracted from bamboo plant.

B. Mercerisation:

The process involves immersing the fibres in 2% NaOH solution for a period of 24 hours at 200^0C which degummed and defibrillated the bamboo fibres. This resulted in increase of tensile strength upto 25% ofuntreated bamboo fibres using prescribed test method [26].

C. Acetylation:

The fibres after mercerization aresubjected to acetylation process, in which they are treated with glacial acetic acid and acetic anhydride containing two drops of sulphuric acid which are obtained form M/S Royal Scientific for a period of 2 hours. The bamboo fibres surface roughness increased which results in better mechanical interlocking between the araldite matrix and fibre.

D. Benzoylation:

Next the fibres arepre-treated with alkaline to activate the hydroxyl group of cellulose and lignin in fibre and then it is suspended in 10% NaOH and benzoyl chloride solution for 20 minutes. After this treatment it was soaked in C_2H_5OH for an hour to remove the benzoyl chloride and then washed with water and dried for 48 Hours at room temperature. This removed the lignin.

E. Fabrication Of Frp Composite Laminate:

Initially any moisture content in bamboo fiber were removed by heating it in furnace at 125^0C for an hour. The araldite AW106 resin are mixed with 10% by weight of hardener HV 953 IN which are obtained from M/s Royal Scientific, Trichy, Tamilnadu, after removal of air bubbles. The fibres were soaked in this mixture and left for drying for 24 hours which resulted in formation of a composite lamina which had a dimension of 15cm x 1 cm x 1cm (LXBXW) shown in fig 5. The formed lamina is checked by non-destructive testing methods for internal defects at M/s G.B. Engg. Enterprises, Pudukudi, Trichy and they are found to be free of major defects (voids more than 1mm). As bamboo has minimum strength across the fibres, multi-layered composites of different fibre orientations, with a view to improving strength in all directions, have been developed. The composite laminate is constructed by cutting the plate and arranging the unidirectional fibre plate in required direction and applying the resin hardener mixture between individual laminas.

Fig. 5: Laminates

Scope For Future Work:

1. Hardness of the composite lamina is to be tested using brinell and Rockwell hardness.

2. Tensile test is to be done on the lamina to determined the tensile properties.

3. Drilling is to be done as different laminae can be joined together using holes drill and various defects that may occur during drilling process.

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