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Preparation and Characterization of Banana Reinforced Phenol Formaldehyde Composite

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ABSTRACT

Fibre reinforced polymer composites has been used in a variety of application as class of structure material because of their many advantages such as relatively low cost of production, easy to fabricate and superior strength compare to neat polymer resins. A light weight composite material had prepared using banana fibre as reinforcement in phenol formaldehyde resin matrix by compression moulding (CM) techniques. The mechanical properties such as tensile and flexural behavior were studied for different fibre lengths.

Key words: Fibre Reinforced Composite (FRP), Polymer Matrix Composite (PMC), Phenol Formaldehyde (PF), Compression Moulding (CM), Ceramic Matrix Composite (CMC)

INTRODUCTION

Composites are materials consisting of two or more chemically distinct constituents, on a macro-scale, having a distinct interface separating them. One or more discontinuous phases therefore, are embedded in a continuous phase to form a composite. The discontinuous phase is usually harder and stronger than the continuous phase and is called the reinforcement, whereas, the continuous phase is termed the matrix. The matrix material can be metallic, polymeric or can even be ceramic. When the matrix is a polymer, the composite is called polymer matrix composite (PMC). The reinforcing phase can either be fibrous or non-fibrous (particulates) in nature and if the fibres are derived from plants or some other living species, they are called natural-fibres. The fibre reinforced polymers (FRP) consist of fibres of high strength and modulus embedded in or bonded to a matrix with distinct interface between them. In this form, both fibres and matrix retain their physical and chemical identities. In general, fibres are the principal load carrying members, while the matrix keeps them at the desired location and orientation, acts as a load transfer medium between them, and protects them from environmental damages.

NATURAL FIBRES

Natural fibres have recently attracted the attention of scientists and technologists because of the advantages that these fibres provide over conventional reinforcement materials, and the development of natural fibre composites has been a subject of interest for the past few years. These natural fibres are low-cost fibres with low density and high specific properties. These are bio-degradable and nonabrasive, unlike other reinforcing fibres. Also, they are readily available and their specific properties are comparable to those of other fibres used for reinforcements. However, certain drawbacks such as incompatibility with the hydrophobic polymer matrix, the tendency to form aggregates during processing, and poor resistance to moisture greatly reduce the potential of natural fibres to be used as reinforcement in polymers.

Types of Natural Fibres

Natural fibres are grouped into three types: seed hair, bast fibres, and leaf fibres, depending upon the source. Some examples are cotton (seed hairs), ramie, jute, and aflax (bast fibres), and sisal and abaca (leaf fibres). Of these fibres, jute, ramie, flax, and sisal are the most commonly used fibres for polymer composites. Natural fibres in the form of wood flour have also been often used for preparation of natural fibre composites.

On the basis of the source which they are derived from natural fibres can be grouped as:

- Fibres obtained from plant/vegetable - (cellulose: sisal, jute, abaca, and bagasse)
- Fibres derived from animal species - (sheep wool, goat –horse hair, rabbit hair, angora fibre)
- Fibres from bird / aqueous species - (bird feathers, fish scale)

EXTRACTION PROCESS

Extraction of Fibres from Pseudo-Banana Stem

Initially the Pseudo stem is abstracted form the fully grown trunk. The stem is kept under the sunlight for 15 – 20 days. Then the dried fibres were soaked in water for at least 24 hours. And again it is dried under the sunlight until all the moisture is taken out. And finally the stem is cut horizontally and then the fibres are extracted. Banana fibres were extracted by first cutting the banana stem into small pieces by a roller crusher. Then, the small pieces were extracted into coarse fibre by a pin-roller. Before the coarse fibres were put in a dehydrator, they were boiled at 90˚C for 10 h to remove their fat and later dried in the rotary dryer.

Fig.1 Fibre Extraction through Crushing

Phenol Formaldehyde Resin

Phenolic resin (PF), as the first synthetic resin, due to its good thermal stability, mechanical properties, and good solvent resistance, is still attracting a great deal of research interests, especially for such applications as thermal insulation, coatings, aeronautic high temperature resistant ablative-materials, electro-optical devices, sensors, and friction-materials. PF-based friction materials usually contain a large number of reinforcing and filler constituents, such as reinforcing fibres, abrasives, binders, fillers, and friction modifiers (solid lubricants). This accounts for the great dependence of their properties on the interactions and synergistic effects among the multiphase ingredients. In this sense, it is very important to correctly select and properly combine the different components so as to satisfy a number of requirements for the properties of the friction materials, such as good wear resistance, stable friction coefficient, and reliable strength.

METHODOLOGY

Preparation process adopted here is hand lay-up process followed by applying pressure using compression moulding. The fibre mats of uniform thickness were prepared from banana fibres of particular length. The composite consists of 2 layers. The mats were impregnated with epoxy resin. MEKP is the catalyst mixed with phenol formaldehyde (pf) resin to give effective binding. Initially the banana fibres are dried under the hot sun to remove the moisture for more than 24 hours. The fibre layers are washed in the acetone thinner before they are fabricated. This removes the impurities on them and makes them ready for binding with the resin. The banana fibres are mounted on the base plate which is placed on the table, and then it is completely filled with the pf resin.

The resin gets mixed with the fibre and may tend to dried up in the open atmosphere under hot sun for 48 hours. Before the resin gets dried up the second layer must be mounted on it. The process is repeated for another layer also. The pf resin applied is distributed to the entire surface by means of a roller and the air gaps formed between layers during fabrication are removed by gently squeezing. The specimen is then pressed at a temperature of 32°C, under the pressure of 6MPa, and the average relative humidity of 65%. Three such samples were prepared with different lengths and volume fractions, tested and the average values are used for detailed analysis.

Here Hand Laminating Moulding is used for fabricate the natural fibre composites. The base plate is fixed inside the frame for fabricate the natural fibre composites 70% of rein hardener mixture and remaining natural fibres are used. The mixed resin and hardener is filled in the pattern. The prepared natural fibres are randomly poured in the resin hardener mixture without any gap. The roller is rolled in the mould. Again the mould is filled in pattern by next layer and fibres poured randomly .This process is simultaneously done till the height of the mould 10mm.The lid is fixed on the top of the frame for distribute the load evenly on the mould. The setup is kept in the dry place for 24 hours. After 24hours the mould is taking away from the pattern.

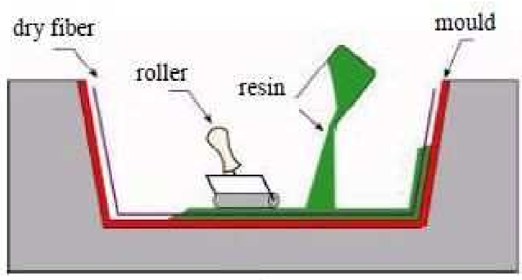

Fig. 2 Hand Laminating Method

Fig. 3 Fibre mixed with resin after curing

Preparation of Composites by Compression-Moulding Technique

The samples were prepared using Paul-Otto Weber Press Machine (compression moulding machine). In this moulding process, the die used has a ring of inside diameter 146 mm and outside diameter 158 mm and have two disc (or plates) on each side, each 3.56 mm in thickness. In compression, the polymeric materials and the fibre are subjected to heat and pressure in a single stroke. This is accomplished by using a hydraulic press with heated plates. Silicone mould release agent was used on the interior surfaces before pouring the fibre and matrix mixture into the moulding device. Sufficient pressure of 50 KN was applied to get the desired shape and possible homogeneity. The applied pressure was measured by using a pressure gauge, set in the device. Heating was done electrically and the temperature was set at 180^o C. The temperature reached to 180^o C after about 35 minutes. After reaching the temperature at 180^oC, it was kept for about 20 min. After completion of heating the initial pressure was set zero and an additional pressure of 50KN was applied to avoid voids and to have a thickness. Cooling was done by tap water through the outer area of the heating plates of the machine. Finally the prepared composite was de-moulded and the standard specimens were prepared by cutting them for mechanical testing.

Fig. 4 Compression moulding apparatus

Preparation of Test Specimens

In order to prepare the specimen, 10cm x 1cm dimension was cut out from the sample. The ASTM standard test recommends that the length of the test section should be 100 mm specimens with fibres parallel to the loading direction should be 10 mm wide. Tensile test specimen photo is also given. The specimen prepared is shaped into required dimension using an angle grinder and the edges are polished using a sand paper. It is prepared according to the ASTM D638 standard. The dimensions, gauge length and cross head speeds are chosen according to the ASTM D638 standard. The composites were ready for the tests. The operation was repeated with the other samples which were produced with the same amount and method.

MECHANICAL CHARACTERISATION

Tensile Testing

The tension test was performed on all the four samples as per ASTM D3039-76 test standards. The tension test is generally performed on flat specimens. A uniaxial load is applied through the ends. The ASTM standard test recommends that the length of the test section should be 100 mm specimens with fibres parallel to the loading direction should be 10 mm wide. Tensile test specimen photo is also given.

The specimen prepared is shaped into required dimension using an angle grinder and the edges are polished using a sand paper. It is prepared according to the ASTM D638 standard. The dimensions, gauge length and cross head speeds are chosen according to the ASTM D638 standard. The tensile test is performed on the Universal Testing Machine (UTM) Make FIE (Model: UTN 40, S. No. 11/98-2450).

The process involves placing the test sample in the UTM and applying tension to it until the fracture of the material. Then the force is recorded as a function of the increase in gauge length. During the application of tension, the elongation of the gauge section is recorded against the applied force. Four different of samples of bamboo fibre based composites were tested. Ultimate tensile strength is the force required to fracture a material. The tensile strength can be experimentally determined. Using the obtained data stress versus strain curves were drawn and tensile modulus were determined from the initial slope of the stress-strain curves.

Flexural Testing

Flexural strength and stiffness is the combined effects of a materials basic tensile, compressive and shear properties. When a flexural loading is applied to a specimen, *all three* of the material's basic stress states are induced. To simplify the stress state in the specimen, it is customary to minimize the shear stress component. This is done by making the specimen support span (ℓ) long relative to the specimen thickness (t), because shear stress is independent of specimen length while the bending moment (and thus the tensile and compressive stress) is directly proportional to specimen length.

Normally, the specimen is loaded while in a horizontal position, and in such a way that the compressive stress occurs in the upper portion and the tensile stress occurs in the lower portion of the cross section. Three-point loading consists of a support point near each end of the beam and one load point at the mid-span. The flexural specimens are prepared as per the ASTM D790 standards and the test has been carried out using the same UTM. The 3-point flexural test is the most common flexural test and used in this experiment for checking the bending strength of the composite materials. Four specimens of each composition were tested and the average values were reported. The testing process involves placing the test specimen in the UTM and applying force to it until it fractures and breaks.

Water Absorption Behavior

Water absorption tests of the composites were conducted according to ASTM D570-99 (2002). The samples were dried in an oven at 100°C for about 2 hrs, then cooled and immediately weighed to the variation of 0.001 g using an electronic balance. The dried and weighed samples were immersed in water for about 2 hrs as described in ASTM D570-99 (2002). Excess water on the surface of the samples was removed and the weights of the samples were taken.

The percentage of water absorption in the composites was calculated by weight difference between the samples immersed in water and the dry samples using the following equation:

$$\Delta M(t) = \frac{m_t - m_0}{m_0} \times 100$$

Where, $\Delta M(t)$ is moisture uptake, M_o and M_t are the mass of the specimen before and after aging, respectively.

RESULTS AND DISCUSSION

Tensile Test Result

Table 1 shows the tensile properties of the banana fibre reinforced phenol formaldehyde composite of varying lengths. The fibre lengths of the samples taken for testing are of varying lengths 1mm, 2mm, 3mm and 4mm respectively.

Table - 1 Tensile Test Result

Specimen No.	Break Load (N)	Width (mm)	Thickness (mm)	Ultimate Stress (MPa)	Break Stress (MPa)	Young's Modulus (MPa)	Yield Stress (MPa)	Percentage of elongation (%)
B 1	68.5	10.180	2.206	3.98	0.622	2824	1.98	1.72
B 2	70.32	10.450	2.213	4.24	1.461	3375	4.02	1.81
B 3	78.1	10.200	2.208	4.58	0.828	9390	4.58	2.31
B 4	66	10.310	2.206	4.19	0.598	2012	2.59	2.65

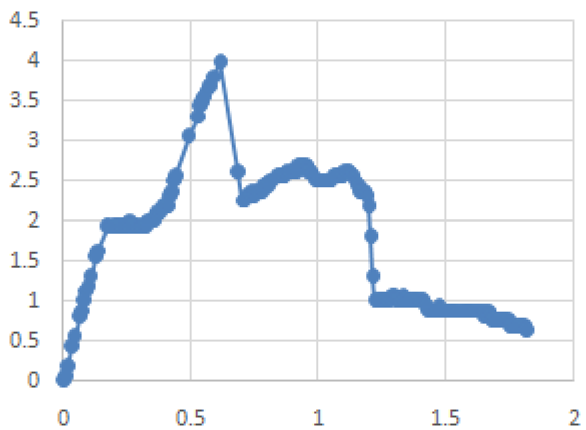

Fig. 5 Stress Strain graph of 1mm fibre length

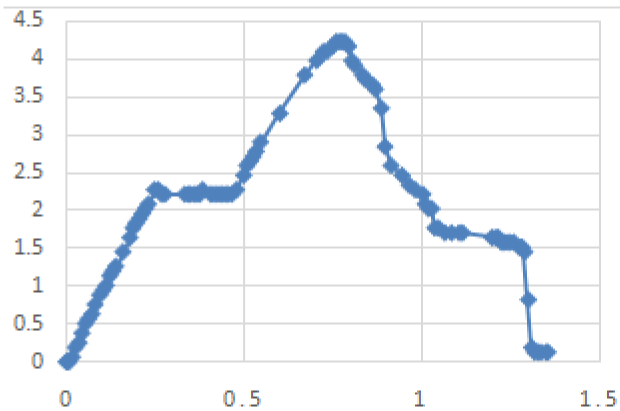

Fig. 6 Stress Strain graph of 2mm fibre length

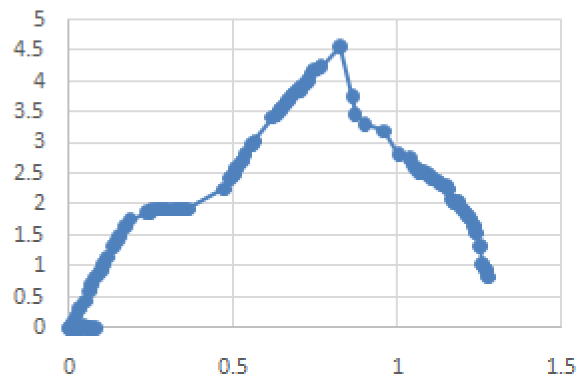

Fig. 7 Stress Strain graph of 3mm fibre length

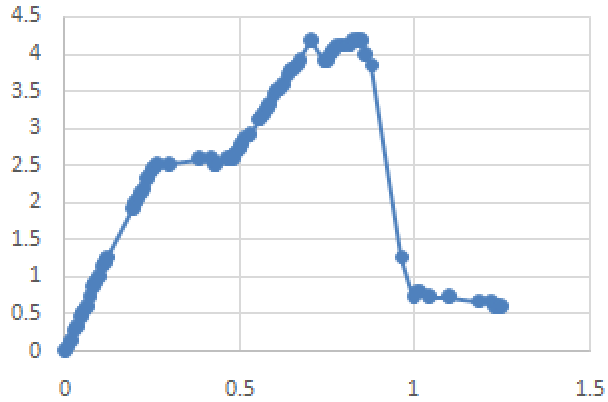

Fig. 8 Stress Strain graph of 4mm fibre length

The properties of the composite are strongly influenced by the fibre length. The fibre length plays an important role in the fracture of short fibre composites. To gain maximum level of stress in the fibre, the fibre length must be at least equal to the critical fibre length. Figs 5, 6, 7 and 8 show the stress-strain behaviour of the composites fabricated by CM techniques respectively, at different fibre lengths. The tensile strength or maximum stress at break expresses the load the material can bear before it ruptures. The plasticizing effect increases in fibre-filled composites due to the presence of cellulosic fibre. At high fibre lengths (30 and 40 mm), a stable network structure can occur throughout the composite, which hinders easy deformation within the composite upon application of an external stress. The composites show a linear behaviour at low strains followed by a significant change in slope showing a nonlinear behaviour which is maintained up to the complete failure of the composite. Tensile strength gets increased with fibre length, and the maximum value is for 30 mm fibre and thereafter decreased. In the case of fibres shorter than this optimum length (lower than critical fibre length), the fibres will debone from the matrix resulting in failure of composite under low strain. Similarly, lowering of stress value at higher fibre length (greater than critical fibre length) was observed, because the effective stress transfer is not possible due to fibre curling and fibre bending. Thus, it can be concluded that the fibre-having length of 30 mm was found to be the optimum for effective reinforcement in PF.

Stress strain cure for plywood of 2mm thickness is shown below (Fig. 9). The variation of stress for plywood is in the range of 0-5 MPa, which is similar to banana of 3mm fibre length. For 3mm fibre length banana composite the ultimate stress obtained is 4.58MPa resulting in a strain of 0.83. From the following graph we can see that ultimate stress value is 4.41MPa for a strain of 3.75. Load carrying capacity of banana reinforced phenol formaldehyde composite is more than that of plywood and also the composite is more flexible than plywood for the same thickness.

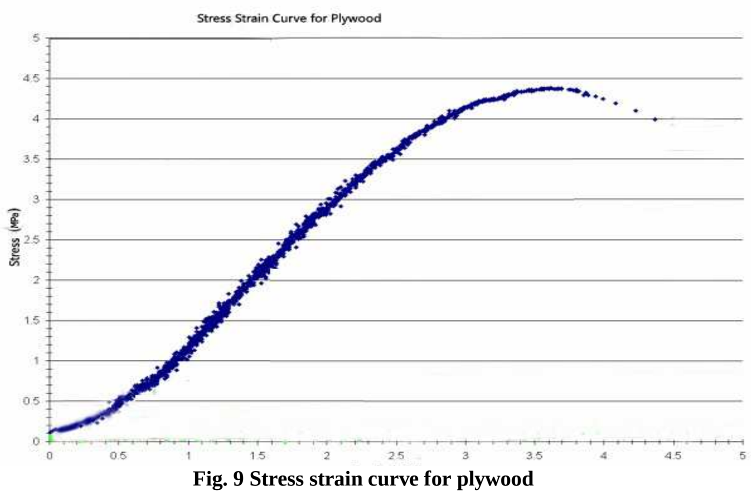

Fig. 9 Stress strain curve for plywood

Flexural Test Result

Table 2 shows the flexural strength of the banana fibre reinforced phenol formaldehyde composite of varying lengths. The fibre lengths of the samples taken for testing are of varying lengths 1mm, 2mm, 3mm and 4mm respectively. In flexural testing, stress is localized in the region of the applied load and hence, it will provide information about the fibre/matrix interaction. It is reasonable to assume that enhanced fibre matrix interaction will lead to an improved transfer of stress from the matrix to the fibre and thus, the flexural strength will increase. Data in Table 2 show that the strength of the banana fibre/PF of length 30mm are higher in comparison to the other samples, which means when length of the fibre increased flexural strength increases up to 30mm and then decreases.

Water Absorption Test

The effect of water absorption on banana fibre reinforced phenol formaldehyde composites was investigated by immersed in a water bath at room temperature. After immersion for 6h, the specimens were taken out of the water and all the surface water was removed by blotting with a clean dry cloth.

Table - 2 Flexural Test Result

Specimen No.	Fibre Length (mm)	Flexural Strength (mm)
B 1	10	25.31
B 2	20	33.67
B 3	30	49.90
B 4	40	36.05

Table - 3 Water Absorption Test Result

Specimen No.	Weight of dry sample (g)	Weight of wet Sample (g)	Water absorption
B 1	10.141	10.150	0.089
B 2	7.531	7.535	0.053
B 3	13.520	13.541	0.15
B 4	2.815	2.823	0.20

CONCLUSION

The mechanical properties of banana fibre, PF resin composites fabricated by CM techniques were analyzed as a function of fibre length and reached on the following conclusions.

- At higher fibre lengths, the stress value was lowered due the entanglements and fibre curling. The optimized fibre length was 30 mm.
- Up to 30mm fibre length stress value of the composite increases and after that stress value decreases.
- As fibre length increases percentage of elongation also increases. The plasticizing effect increases in fibre-filled composites due to the presence of cellulosic fibre.
- Load carrying capacity of banana reinforced phenol formaldehyde composite is more than that of plywood and also the composite is more flexible than plywood for the same thickness.
- It is found that the water absorption of the composite is only in the range of 0.01 to 0.02.The percentage of water absorption also increases with increase in fibre length.
- The fabricated composite has the relatively lower density and hence can be used for light weight applications.

SCOPE FOR THE FUTURE WORK

For the given tensile strength of the banana reinforced phenol formaldehyde composite several products may be fabricated in the field of aerospace, automotive, Sports, Leisure household equipment etc. Further from chemical treatments we may enhance the strength of the composites and product and attracts many researchers for the improvement of this composite. Scanning electron microscope was used for the morphological characterization of the composite surface which will help to analyzing the interfacial bonding between the fibre and resin. SEM also be used to examine whether the fibres are pulled out from the resin surface. In compression moulding, composite may have the chance of formation of voids which may lead to crack formation. Therefore RTM technique is advisable for voids free sample preparation.

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