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Article Title: Processing Of a Manufacturing Material Using Treated Bamboo

Processing Of a Manufacturing Material Using Treated Bamboo

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ABSTRACT

Natural plant fibers have unequivocally contributed economic prosperity and sustainability in our daily lives. Particularly, bamboo fibers have been used for industrial applications as diverse as textiles, paper, and construction. Recent renewed interest in bamboo fiber (BF) is primarily targeted for the replacement or reduction in use of glass fiber from nonrenewable resources. In this project, various mechanical, chemical, and biological approaches for the preparation and separation of bamboo fibers from raw bamboo are summarized. In this work the mechanical properties of Bamboo Fiber Reinforced Composite (BFRC) were studied. The bamboo fibers were prepared through chemical treatment by CUSO4, Borax and Boric acid followed by physical milling method. Compression, tensile, hardness were showed improvement in mechanical properties. Hence this composite material can be used as a manufacturing material for production, manufacturing industries.

Keywords: Bamboo Fiber Reinforced Composite coating, TGA/DSC test, Epoxy resins, polymer composite,

1 Introduction

1.1 According to type of matrix material they are classified as:

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

1.1.1 Metal Matrix Composites

Higher strength, fracture toughness and stiffness are offered by metal matrices. Metal matrix can withstand elevated temperature in corrosive environment than polymer composites. Titanium, aluminum and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft application. Because of this attributes Metal Matrix Composites are under consideration for wide range of applications. Combustion chamber nozzle (in rocket, space shuttle) housings, tubing, cables, heat exchangers, structural members, etc.

1.1.2 Ceramic Matrix Composites

One of the main objectives in producing ceramic Matrix Composites is to increase the toughness. Naturally it is hoped and indeed often found that there is a concomitant improvement in strength and stiffness of Ceramic Matrix Composites.

1.1.3 Polymer Matrix Composites

Most commonly used matrix materials are polymeric. In general the mechanical properties of polymers are inadequate for many structural purposes. In particular their strength and stiffness are low compared to metal and ceramics.

1.2 Bamboo Fiber

Bamboos are evergreen perennial flowering plants in the subfamily bambusoideae of the grass family. The word "bamboo" comes from the Dutch or Portuguese languages, which probably borrowed it from Malay.

Bamboo is one of the fastest growing plants in the world, due to a unique rhizome dependent system. Certain species of bamboo can grow 910 mm (36 in) within a 24-hour period, at a rate of almost 40 mm (1 1⁄2 in) an hour (a growth around 1 mm every 90 seconds, or 1 inch every 40 minutes).Giant bamboos are the largest members of the grass family.

As a fiber, bamboo is a natural cellulosic regenerated biodegradable environment friendly textile material. Not only a green fiber but it has also inherent property of anti-bacterial and UV protective property, which makes it a unique ecofriendly textile material in 21st century.

It is not only used in conventional textile but also it is very useful for high performance end uses as a composite material due to high tensile strength, durability, stability.

1.3 Morphological Structure of Bamboo

Bamboo is best fiber like jute, flax, ramie etc. Main components of bamboo are:

- Rhizomes
- Roots
- Culms
- Branches
- Leaves
- Flowers

1.4 Properties of Bamboo Fiber

Physical Property of bamboo fiber:

1. Dry tensile strength (cN/dtex) - 2.33
2. Wet tensile strength (cN/dtex) - 1.37

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3. Dry elongation at break (%) - 23.8
4. Linear density (% deviation) - 1.8
5. Percentage length deviation - 1.8
6. Over length staple fibers (%) - 0.2
7. Whiteness (%) - 69.6
8. Moisture region - 13.03
9. Oil content - 0.17

Figure 1: *Natural Bamboo Tree*

1.5 Character tics of Bamboo Fiber

There are approximately 1200 different species of bamboo and both the species and the growing conditions will affect the characteristics of each individual bamboo stalk.

In general bamboo is very durable. The outer layer of the stem is quite dense and strong. Bamboo is both flexible and elastic.

As a result items made from bamboo tend to be very resilient and resist breaking when placed under stress.

Bamboo does not have rays or knots the way wood does, this means that stress applied to the bamboo is evenly distributed over the surface.

1.6 Chemical Composition

Bamboo is a lingo-cellulosic bast fiber. Chemical composition and properties are similar to the other bast fibers like jute, flax. It contains cellulose (70-74%), hemicellulose (12-14%), lignin (10-12%), extractives like protein, pectin, wax (2-3%).

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1.7 Applications of Bamboo Fiber

After global warming and sustainability issues emerged, bamboo as building materials is widely discussed and reviewed. Some architects and builders nowadays tend to choose bamboo for building material. High-quality woods for construction are rarely found nowadays because of deforestation. Wood also takes a long time to regrow and is ready to use as construction materials. Meanwhile bamboo can be harvested in a short time, which is between 3-5 years.

Figure 2: *Application of Bamboo Material*

When planting, bamboo also releases oxygen into the air, the ability that cannot be performed by industrial materials like steel, plastic and concrete. For these reasons, bamboo has been widely known as sustainable building materials and is being used in architectural and construction works.

1.8 Bamboo Fiber Reinforced Composites

The Bamboo structure can be generally viewed as a Functionally Graded composite material constituted by long and aligned cellulose fibers embedded in a lignin matrix. Analyzing the transversal section of a Bamboo culm, one can observe that the fiber distribution is variable through its thickness.

The non-uniform distribution of fibers prevents the direct application of equations used to model the behavior of Composite Materials, as the rule of mixtures equations for strength and modulus of elasticity. These equations assume, besides the perfect bonding between fiber and matrix, uniform distribution of the fibers in the matrix. In Bamboo, the fiber distribution follows an organized pattern with a higher concentration of fibers on the outer surface of the culm. Establishing how this variation occurs, the basic equations from the Composite Materials approach can be modified in order to model the mechanical behavior of Bamboo.

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1.9 Objectives

To Investigate and analyse the mechanical properties of a composite material using bamboo fiber. To explore the processing feasibility of bamboo fiber composites by different techniques and to study the resulting fiber and composite properties. To carry out a systematic study of the influence of processing parameters on the mechanical properties of bamboo fibers.

The long bamboo fiber was extracted using chemical digestion method. The fabrication of the composite was carried out using epoxy resin as the matrix and the bamboo fiber as reinforcement. Tests were carried out to determine the mechanical properties such as tensile, hardness and compressive strengths.

The results were studied and compared with the conventional materials and it process that the material developed can be used in structural applications with strong dependence on its mechanical properties.

The mechanical properties of bamboo such as stiffness, impact strength and flexibility are high and are comparable to the synthetic fibers such as glass fiber. The hardness of the column of bamboo depends on the number of fiber bundles and the manner of their scattering.

1.10 Methodology

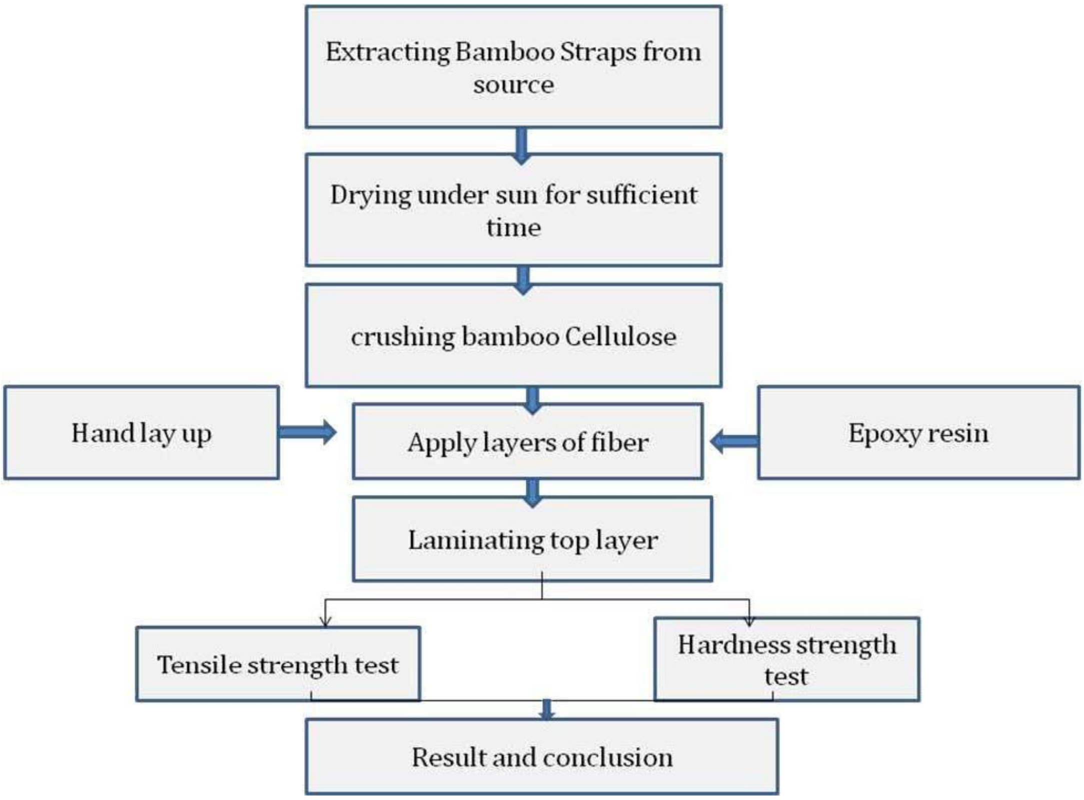

Figure3: *Experimental Investigations*

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2 Materials

2.1 Formula

2.1.1 Formula 1

- Boric Acid/Borax
- Ratio 1:1.5

2.1.2 Formula 2

- Boric Acid/Borax/Sodium Dichromate
- Ratio 2:2:0.5

2.1.3 Recommended Concentration

- 4-5% indoor use (not exposed to weather or ground contact)

2.2 Oric Acid Borax

Curing bamboo with borax and boric acid is the most popular bamboo preservation method (for indoor use) around the world because it is effective and more environmentally friendly than other wood preservatives.

The combination of boric acid and borax in a ratio of 1:1.5 is an alkaline salt called: Disodium octaborate tetrahydrate (Na2B8O13 × 4H2O) and disodium octaborate tetrahydrate is a white, odorless, powdered substance that is not flammable, cumbustible, or explosive and has acute low oral and dermal toxicity. The product itself is fire retardant and shows no hazardous decomposition.

This salt, is used as an insecticide and fungicide, and is also effective against fungi and algae. It has an infinite shelf life and is not affected by temperature. Diluted with water, bamboo can be impregnated, submerged or sprayed with this chemical.

Figure 4: *Processing of Bamboo Treatment Materials*

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2.3 Bamboo Fiber

Bamboo fiber is a cellulose fiber extracted or fabricated from natural bamboo. These are collected from local sources. Bamboo belongs to grass family Bambusoideae. It is a natural Lignocelluloses composite, in which cellulose fibers are embedded in the lignin matrix.

Figure 5: *Bamboo Fiber*

2.4 Epoxy Resin

Epoxy resins, also known as poly epoxies, are a class of reactive polymer high mechanical properties, temperature and chemical resistance. Epoxy has a wide range of applications, including metal coatings, use in electronics/ electrical components, high tension electrical insulators, fiber-reinforced plastic materials and structural adhesives.

Figure 6: *Epoxy material*

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Figure 7: *Testing Specimen*

3 Methods

3.1 Non-Fixing Type Preservatives

Non-fixing bamboo preservatives mainly consist of boron salts, which are effective against borers, termites and fungi (except soft rot fungi). These boron salts are dissolved in water. After treatment, the water evaporates leaving the salts inside the bamboo. They are not toxic and can be used for treating bamboo products like baskets, dry containers, etc. which come in contact with food products.

3.2 Fixing Type Preservatives

These chemical bamboo preservation formulations are proportionate mixtures of different salts which interact with each other in the presence of bamboo and become chemically fixed. In principle, the degree of fixation and efficacy depends upon the nature of the components and their combination and concentration.

For example: Chromium is responsible for fixation, copper is effective against decay fungi and soft rot and the third compound acts against insect and fungus. The process of fixation requires some weeks during which the material should be stored under cover. Slow fixation is preferred in case of bamboo as it allows diffusion and better distribution of preserving salts.

3.3 Mechanical Extraction Methods

There are many forms of mechanical extraction methods such as steam explosion method, crushing, grinding, rolling in a mill and retting. These methods are used for the extraction of bamboo fiber for application in various industries for making bamboo fiber reinforced composites.

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3.3.1 Crushing

In this procedure, raw bamboo is first cut into small pieces by a roller crusher. Then the coarse fibers were extracted from small pieces of bamboo by a pin- roller. Then the fibers were boiled at 90^{0}C for 10 hours to remove the fat and later dried in the rotary dryer and put in a dehydrator. The main problem with this process is that it yields only short fibers, and with mechanical over- processing, it becomes powdered.

3.3.2 Grinding

In this procedure, bamboo culm without any nodes was cut into strips and then soaked in water for 24 hours. Then those drenched strips were cut into smaller pieces with a knife. Wider strips were passed through an extruder and long
Bamboo strips were cut into small bamboo chips. These small bamboo chips were ground in a high speed blender for 30 minutes to acquire short bamboo fibers. Using several sieves with various apertures, the fibers were separated by size. The extracted fibers were finally dried in an oven at 105^{0}C for 72 hours. Long fibers are able to carry high tensile load due to the increase in transverse length and thus tensile modulus of the composite is increased. Some researchers used the same method for extracting bamboo fibers and the rheological and morphological behavior of the bamboofiber composite were studied. This method has also been used in studies, where particles from dry bamboo strands are used with nano clay.

3.3.3 Rolling Mill

In this procedure, bamboo culm was cut into small pieces from the nodes and these pieces were cut into strips with 1mm thickness. To facilitate the separation of fibers from the strips, the strips were soaked in water for 1 hour. They were then passed through the rolling mill under slight pressure and at low speed. The rolled strips were soaked for 30 minutes in water and then using a razor blade, the fibers were separated. The obtained fibers were dried in the sun for 2 weeks and their length ranged from 220 to 270mm. In another study, bamboo strips were cut from the bamboo culm and pressed between two pairs of steel cylinders and without soaking in water, fibers were extracted. In another study, sliced bamboo strips are steamed and soaked in water to soften the lignin content and the fibers are then passed through the roller. The length of fibers extracted ranged from 30 to 60 cm.

3.3.4 Retting

In this procedure, cylindrical part of the bamboo culm was peeled to obtain the strips. The bundles of strips were kept in water for three days. The wetted strips were beaten, then scraped with a sharp edged knife and combed. In this method the process of scraping had strong effect on the fiber quality and the fibers broke less. In another study, no scraping or combing is involved, but raw bamboo is simply cut into several longitudinal parts without the removal of bamboo node and epidermis. The bamboo strips were then cleaned with flowing

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water and were fermented in water at room temperature for 2 months. Two different retting types namely aerobic and anaerobic retting were used to separate the fiber bundles from the culm. The authors found that from every fiber bundle, single fiber can be extracted and the fiber length can be acquired in any length.

3.4 Chemical Extraction Methods

The chemical extraction methods such as chemical retting and alkali or acid retting are used to remove or reduce the lignin content from the fibers. These chemical extraction methods also have effects on other fiber components such as pectin and hemicelluloses.

3.4.1 Chemical Retting

Chemical Assisted Natural (CAN) retting procedure was used by researchers to reduce lignin and water content in the fibers. Bamboo culm was cut in longitudinal direction with a slicer into thin slabs. The fibers separated manually were immersed in Zn(NO3)2 solution with 1%, 2% and 3% (owf) concentrations at 1:20 material to liquor ratio. These fibers were immersed at 40^0C for 116 hours in neutral pH and kept in BOD incubator and then for 1hr They are boiled in water. This procedure was able to remove more lignin than alkali and acid retting, but the treated fibers had high moisture content. In another study, bamboo culm is slit into 2cm chips and the chips are roasted at 150^0C for 30 minutes. The chips were then immersed in water for 24 hours at 60^0C and air dried prior to removing further impurity. Further, the fiber bundles were cooked with 2% sodium silicate, 2% sodium sulphite, 2% sodium polyphosphate and 0.5% NaOH (w/v) solutions at 100^0C for 60 minutes at 20: Liquor to bamboo ratio. The fibers were then washed with hot water and treated with 0.04% xylanase and 0.5% diethylene triamine pentacetic acid at 70^0C with pH 6.5 for 60 minutes. The fibers obtained were again cooked at 100^0C for 60 minutes with the same procedure, but with 0.7% NaOH. The fibers were then put in a polyethylene bag and bleached with 0.5% sodium silicate, 4% H2O2 and 0.2% sodium hydroxide for 50 minutes. The liquor ratio was maintained at 20 and the pH was kept at 10.5. Finally the fibers are treated with 0.5% sulphuric acid for 10 minutes and after emulsification for 5 days, refined bamboo fibers were obtained. The study found that bamboo fibers had smaller orientation angle for exterior macro fibrils, and in comparison with flax, ramie and cotton fibers, bamboo fiber is suitable for fiber reinforcement composites.

3.4.2 Alkali or Acid Retting

In the alkali retting procedure, bamboo strips were heated with 1.5N NaOH solution in a stainless steel container at 70^0C for 5 hours. Then the alkali treated bamboo strips were pressed using a press machine and by using steel nail, fibers were separated. Finally, water was used

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to wash these extracted fibers and the extracted fibers were dried in an oven. Fiber damage caused in this extraction method is less. In another study, to influence the cellulosic and non-cellulosic parts of bamboo fibers, bamboo strips in size of chips were soaked in NaOH with 4% mass per volume for 2 hours. To extract the fiber in pulp form, this procedure was repeated several times at a certain pressure. Problem with this extraction procedure is that it produced large fiber bundles. In another research, small bamboo strips were soaked in 1N sodium hydroxide solution for 72 hours to facilitate extraction of fibers. Trifluoroacetic acid (TFA) and alkaline solutions were used to extract the fibers as lignin content is soluble in acidic and alkaline conditions. Amount of lignin in the middle lamellae was also considered by the researchers. Results showed that lignin remained in the middle lamellae, in the alkali procedure, but a large portion was removed in the TFA process. The interfacial bonding and surface adhesion of composites with alkali treatment is improved as compared to other method.

3.5 Combined Chemical and Mechanical Extraction

Usually after alkali treatment and chemical treatment, compression moulding technique (CMT) and roller mill technique (RMT) are used to extract fibers. In a research study, a bed of alkaline treated bamboo strips between two flat platens were pressurized under a load of 10 tons using CMT. To separate high quality fibers, starting bed thickness and compression time are important factors to be considered. In the RMT, two rollers with one fixed and other rotated were used and the treated bamboo strips were forced between two rollers. In both compression moulding technique and roller mill technique, bamboo strips are flattened and the combination of alkaline and mechanical extraction enabled the easy separation of fibers from bamboo strips. The mechanical and physical properties of bamboo fibers, influenced by mechanical methods, chemical methods, combined chemical and mechanical methods of fiber extraction.

3.6 Universal Testing Machine (UTM)

Figure 8: *Universal Testing Machine (UTM)*

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A universal testing machine is used to test the tensile stress and compressive strength of materials. Universal testing machines (UTMs) that test mechanical properties such as tensile, flexural, and compressive and shear. The UTM is a great multi-purpose instrument for an R&D lab or quality control department.

Operation of the machine is by hydraulic transmission of load from the test specimen to a separately housed load indicator. The system is ideal since it replaces transmission of load through levers and knife edges, which are prone to wear and damage due to shock on rupture of test pieces. Load is applied by a hydrostatically lubricated ram. Main cylinder pressure is transmitted to the cylinder of the pendulum dynamometer system housed in the control panel. The cylinder of the dynamometer is also of self - lubricating design. The deflection of the pendulum represents the absolute load applied on the test specimen. Return movement of the pendulum is effectively damped to absorb energy in the event of sudden breakage of the specimen.

3.7 Rockwell Hardness Machine

Figure 9: *Rockwell Hardness Machine*

In a Rockwell hardness test, initially a minor load of 10 N is applied and the zero datum position is established. The major load (60, 100, or 150 N) is then applied for a specific period (a few seconds) and removed, leaving the minor load applied. The resulting Rockwell hardness number (as seen on the dial or as a digital output), is inversely related to the additional depth to which the indenter was forced by the major load, beyond the depth resulting from the previously applied minor load.

3.8 Micro Hardness Test Machine

Though hardness is not an inherent mechanical quality, it is - as mentioned - intrinsically linked to various key physical properties and functionalities. Studies have uncovered a correlation between hardness and grain size in various materials. In ceramics and metal alloys, the

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orientation and phase composition have also proven to be a critical factor underlying surface hardness.

Figure 10: *Micro Hardness Test Machine*

We can usually characterize micro hardness testing as either an exploration of material characteristics or functionality. This means that micro hardness tests are typically used to either test material hardenability; to confirm process
parameters or ability; or to predict other mechanical properties such as wear resistance, toughness, resistance to impact, and tensile strength.

The range of materials that can be accessed via micro hardness testing is always expanding, with advanced indentation systems opening up new avenues into biological hardness testing for tissues and organic polymers.

3.9 FTIR Test Machine

FTIR, which stands for Fourier Transform Infrared Spectroscopy, is a powerful analytical technique used to identify and characterize chemical compounds based on their absorption of infrared light. It provides information about the functional groups present in a sample and is widely used in various fields, including chemistry, pharmaceuticals, materials science, and environmental analysis.

XRD Test Machine

XRD, which stands for X-ray Diffraction, is a widely used technique for analysing the crystal structure, composition, and phase identification of solid materials. It is based on the principle of X-ray diffraction, where X-rays interact with the atoms in a crystal lattice and produce a unique diffraction pattern.

TGA/DSC Test Machine

TGA/DSC, also known as Thermogravimetric Analysis/Differential Scanning Calorimeters, is a combined analytical technique used to study the thermal behaviour of materials. It provides information about the changes in mass and heat flow associated with physical and chemical processes occurring in a sample as a function of temperature or time.

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4 Process

4.1 Chemical Bamboo Preservation

Chemical preservation (with or without the help of special equipment) ensures long term protection. Depending upon the method of bamboo treatment, chemical preservatives can impart short term or long term protection.

With a few exceptions, chemical preservatives to protect bamboo against biological attacks and degradation are toxic. Selection and application has to be done with great care to meet performance, environment requirements and safety.

Depending upon the carrier solvents, bamboo preservatives are divided into 2 different categories: Non-fixing and fixing type preservatives. Non-fixing preservatives will leach out the bamboo when exposed to rain. In other words non-fixing type preservatives are not suited for outdoor use.

4.2 Process of Bamboo Treatment

Curing bamboo with borax and boric acid is the most popular bamboo preservation method (for indoor use) around the world because it is effective and more environmentally friendly than other wood preservatives.

The combination of boric acid and borax in a ratio of 1:1.5 is an alkaline salt called: Disodium octaborate tetra hydrate ($Na_2B_8O_{13}$ x $4H_2O$). Disodium octaborate tetra hydrate is a white, odorless, powdered substance that is not flammable, combustible or explosive and has acute low oral and dermal toxicity. The product itself is fire retardant and shows no hazardous decomposition.

This salt, is used as an insecticide and fungicide, and is also effective against fungi and algae. It has an infinite shelf life and is not affected by temperature. Diluted with water, bamboo can be impregnated, submerged or sprayed with this chemical.

4.3 Processing of Bamboo Fiber

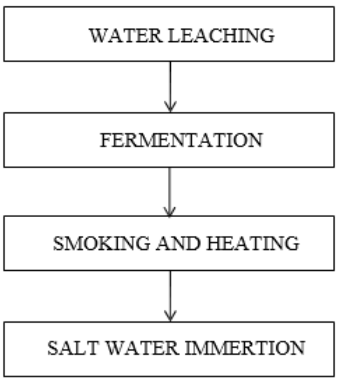

Figure 11: *Processing of Bamboo Fiber*

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Figure 12: *Bamboo treated in boric acid*

Figure 13: *Bamboo immersed in borax boric acid*

4.4 Process of the hand layup technique for preparing polymer composite

The polymer used is Kemapoxy 150 JM, supplied by CMB Egypt. Two sizes of ceramic silicon carbide particles were used in the investigation: medium size, which is a particle size less than 25 µm, and fine size, which is a particle size less than 90 nm. Both sides were supplied by Sigma Aldrich, Germany.

Silicon carbide powder was selected because it is a hard ceramic commonly used to protect surfaces against friction and wear. Recycled paper bags made from kraft paper were used in the experiments. Paper bags were cut into circular pieces to produce paper lamina with a diameter equal to 900 mm.

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Ceramic particles were cleaned with deionized water to remove any impurities. The epoxy resin composite mixture was produced using a combination of epoxy resin, hardener, and specified wt.% of silicon carbide powder, which was mixed by using mechanical stirring for 4 min with a speed of 500 rpm and heated by an electrical heater (900C) for 1 min to remove air bubbles generated during mixing and to reduce the cure time. The preparation process was carried out at room temperature inside a circular wood mould with a radius of 1400 mm and 40 mm depth. All obtained composite samples were left under a hydraulic press for 8 h until they were completely dried. The final thickness for all obtained samples was 2 mm to meet the requirements of DIN EN ISO 527-4.The schematic view of the experimental setup is presented.

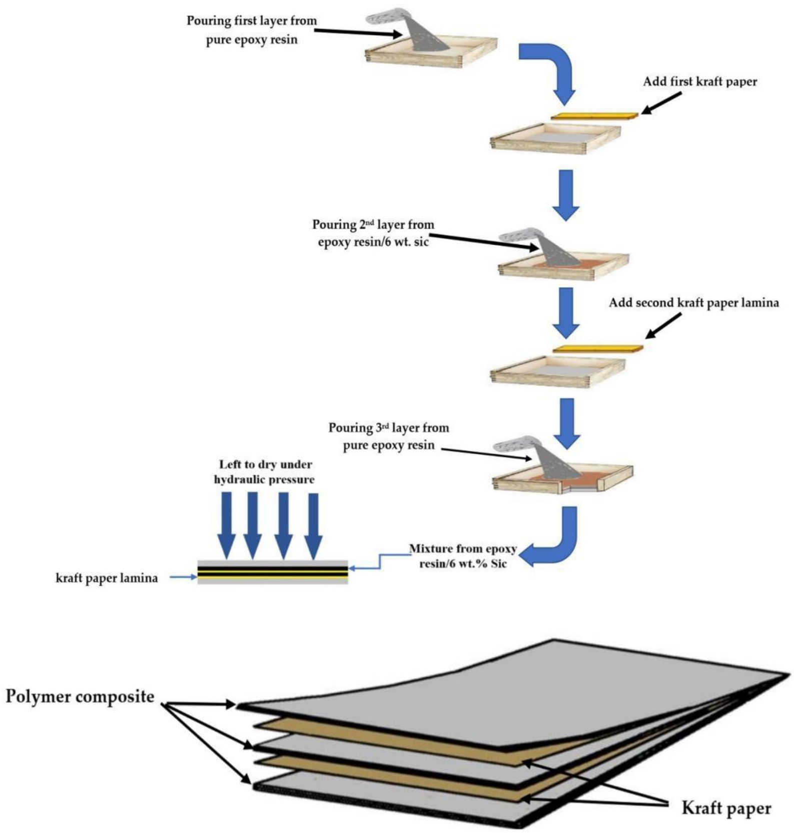

Figure 14: *Flowchart representing the steps of the hand layup technique for preparing polymer composite sample*

The amount of ceramic content varied in each location (layer), but the total wt. % ceramic contents for samples were as follows:

- Samples no. 1, 2, 3, and 11 were reinforced with 6 wt% SiC.
- Samples no. 4, 5, and 6 were reinforced with 12 wt% SiC.
- Sample no. 7 was reinforced with 18 wt% SiC.
- Sample no. 8 was reinforced with 15 wt% SiC.
- Samples no. 9 and 10 were reinforced with 9 wt% SiC.

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- Sample no. 12 was reinforced with 3 wt % SiC.

Figure 15: *Bamboo Fiber Composite*

4.5 Compression Test

During a compression test, properties of the material including sample stress and strain are measured and various calculations made. Data is plotted as a stress-strain diagram. Data is used to determine qualities such as compressive strength, elastic limit, proportional limit, yield point, yield strength, and modulus of elasticity.

Many samples are placed between two plates or platens that distribute the applied load across the entire surface area of two opposite faces of the test sample. The plates are compressed together by a compression-capable test machine, causing the sample to flatten. The sample's deflection or strain is measured by the machine or by a deflectomer or extensometer.

4.7 Tensile Test

Tensile testing and material characterization are crucial for manufacturers and researchers in all industries. In order for a material to be selected for a new product or use, researchers must ensure that it can withstand the mechanical forces that it will encounter in its end-use application. For example, tire rubber must be elastic enough to absorb inconsistencies in road surfaces, while surgical sutures must be strong enough to hold living tissue together. Furthermore, materials and products might be exposed to mechanical forces for short or long periods of time, through cyclical or repeated use, and in a wide variety of different temperature and environmental conditions. Automotive tires are expected to last for a certain number of miles under a variety of weather conditions, while surgical sutures, though only used once, must maintain a consistent tensile strength for long enough for the body to heal.

In addition to its importance to the R&D process, tensile testing is also used by quality assurance departments to ensure that batches of finished product are meeting the required specifications for tensile properties. This is important from both a safety and a business perspective, as defective products can be dangerous to the end user and can also cause significant harm to manufacturers in the form of product delays, lost revenue, and damaged reputations.

4.8 Hardness Test

Hardness is the resistance of a body to the indentation by another (harder) body. This simple but precise definition has taken its place in technical circles, and is just as valid today as it was then. Technical hardness is a mechanical characteristic used to describe a material or the state of a material.

Hardness cannot be measured directly, but is derived from primary measured variables (for example test load, indentation depth, indentation area) Depending on the test method.

4.9 FTIR Test

1. Sample Preparation: The sample is typically prepared in a suitable form for analysis, such as a solid pellet, liquid film, or gas cell. The sample should be thin and transparent to infrared radiation.

2. Instrument Setup: The FTIR instrument consists of a high-energy infrared light source, an interferometer, a sample holder, a detector, and a computer system for data acquisition and analysis. The instrument should be properly calibrated and set up according to the manufacturer's instructions.

3. Background Measurement: Before analysing the sample, a background measurement is performed. The interferometer measures the background spectrum by analysing an empty sample holder or a reference material. This background spectrum is later subtracted from the sample spectrum to remove any instrument-related noise.

4. Sample Measurement: The prepared sample is placed in the sample holder, and the instrument measures the spectrum by passing an infrared beam through the sample. The interferometer splits the beam into two paths, one passing through the sample and the other through the reference path.

5. Interferogram Formation: The interferometer generates an interferogram, which is a time-domain signal representing the interference between the sample and reference beams. This signal contains information about the sample' absorption of different infrared frequencies.

6. Fourier Transform: The interferogram is subjected to Fourier transform to convert it from the time domain to the frequency domain. This transformation separates the different frequencies and generates a spectrum known as the Fourier transform infrared (FTIR) spectrum.

7. Spectrum Analysis: The FTIR spectrum is analysed to identify the functional groups and chemical bonds present in the sample. It is compared with reference spectra from databases to determine the chemical composition and structure. Various software programs are available to assist in spectral analysis.

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8. Data Interpretation: The identified peaks in the FTIR spectrum correspond to specific vibrational modes of atoms or groups in the sample. By comparing the positions and intensities of these peaks with known standards, qualitative and quantitative analysis can be performed.
9. Result Reporting: The results of the FTIR analysis, including the identified functional groups and any quantitative data, are compiled and reported. These results can be used for quality control, research purposes, or to address specific analytical questions.

4.10 XRD Test

1. Sample Preparation: The sample for XRD analysis should be in a powdered form. If the sample is not naturally powdered, it may need to be ground or crushed to achieve a fine powder. The sample should be homogeneous and representative of the material being studied.
2. Instrument Setup: The XRD instrument consists of an X-ray source, a sample holder, a detector, and a computer system for data acquisition and analysis. The
X-ray source emits X-rays of a specific wavelength, usually copper (Cu) or cobalt (Co), which are commonly used in XRD instruments.
3. Sample Mounting: The powdered sample is evenly spread onto a sample holder, which is typically a flat plate or a glass slide. The sample should be uniformly distributed and should not be too thick or too thin to ensure accurate diffraction data.
4. Calibration: The XRD instrument needs to be calibrated before analysis. Calibration involves measuring the diffraction pattern of a standard material with a known crystal structure and lattice spacing. This step ensures accurate measurement and interpretation of the diffraction data.
5. Measurement: The X-ray beam is directed onto the sample, and the detector measures the intensity of diffracted X-rays at different angles. The sample holder is rotated or the detector is moved to obtain a full range of diffraction angles. The XRD instrument records the intensity of diffracted X-rays as a function of the diffraction angle.
6. Data Analysis: The obtained diffraction pattern, known as the XRD pattern or diffractogram, is analysed to determine the crystal structure, lattice parameters, and phase composition of the sample. The diffraction peaks in the pattern correspond to the constructive interference of X-rays by the crystal lattice planes.
7. Peak Identification: The positions and intensities of the diffraction peaks are compared to reference databases, such as the International Centre for Diffraction Data (ICDD) database, to identify the phases present in the sample. The phase identification is based on the unique pattern of diffraction peaks for each crystal structure.
8. Quantitative Analysis: The intensities of the diffraction peaks can be used for quantitative analysis, such as determining the relative abundances of different
phases in a sample. This analysis requires calibrations and reference standards for accurate quantification.

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9. Result Reporting: The results of XRD analysis are compiled and reported. This includes the diffractogram, phase identification, lattice parameters, and any quantitative data obtained. The results are used for material characterization, quality control, phase identification, and research purposes.

4.11 TGA/DSC Test

1. Sample Preparation: The sample is typically prepared in a small, well-defined form. It can be a solid, liquid, or gas, depending on the capabilities of the instrument. The sample should be representative and accurately weighed or measured.
2. Instrument Setup: The TGA/DSC instrument consists of a balance (for mass measurement), a furnace (for temperature control), a sample holder, a reference material, and appropriate sensors. The instrument should be calibrated and set up according to the manufacturer's instructions.
3. TGA Measurement: Thermogravimetric analysis (TGA) measures the change in mass of the sample as a function of temperature or time. The sample is placed in the sample holder, and the instrument heats the sample at a programmed rate while continuously recording the mass changes. Any weight loss or gain can be attributed to processes such as evaporation, decomposition, oxidation, or reaction.
4. DSC Measurement: Differential scanning calorimetry (DSC) measures the heat flow (enthalpy) associated with physical and chemical processes in the sample. The sample and a reference material (usually an inert material with known properties) are simultaneously heated or cooled at a constant rate. The instrument measures the temperature difference between the sample and reference, providing information about endothermic (heat-absorbing) or exothermic (heat-releasing) processes.
5. Data Analysis: The TGA/DSC instrument generates data curves representing the changes in mass (TGA) and heat flow (DSC) as a function of temperature or time. These curves can be analysed to determine various properties, such as decomposition temperature, thermal stability, phase transitions, heat capacity, and reaction kinetics. Software programs are available to assist in data interpretation and analysis.
6. Result Interpretation: The interpretation of TGA/DSC data involves correlating the observed mass loss or gain and heat flow with the underlying processes occurring in the sample. This can include identifying decomposition temperatures, determining reaction kinetics, assessing sample purity, evaluating thermal stability, and understanding phase transitions.
7. Result Reporting: The results obtained from TGA/DSC analysis are compiled and reported. This includes presenting the data curves, identifying key features and transitions, and providing interpretations and conclusions based on the analysis. The results can be used for quality control, material characterization, research, and other applications.

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5 Results and Discussion

5.1 Result 1

5.1.1 Compression Test

Compressive strength = 140 MP

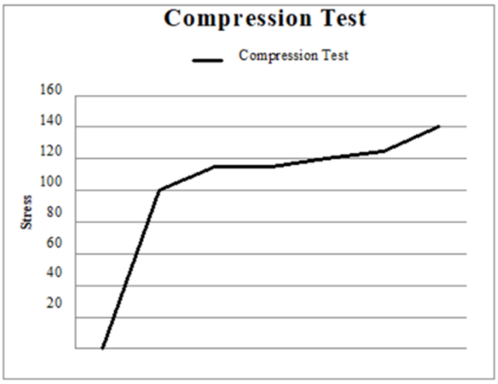

Figure 16: *Compression Test*

5.1.2 Tensile Test

Tensile Strength = 1.69 GPa
Ultimate Strength = 34.6 GPa

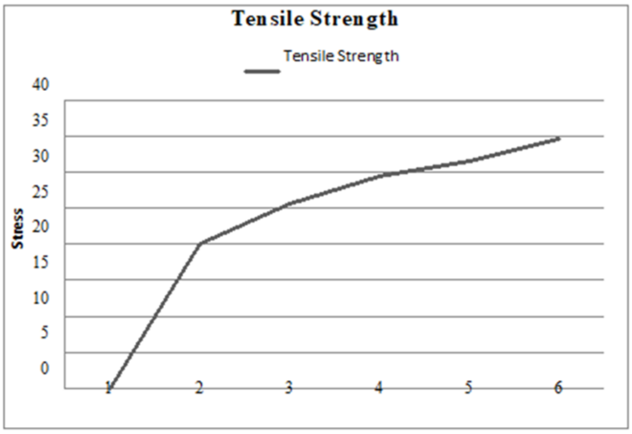

Figure 17: *Tensile Test*

5.2 Result 2

5.2.1 Rockwell Hardness Test

Hardness is a measure of how resistant rock-solid substance is to different kinds of permanent form change when a compressive force is applied. Rockwell hardness testing is an indentation testing method. It measures the permanent depth of a groove produced by a force/load on an indenter. The Rockwell Hardness Number (RHN) is calculated from the depth of

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permanent deformation of the indenter into the sample. The indenter is either a conical diamond or a hard steel ball. Although Rockwell Hardness test does not give a straight measurement of any performance properties; hardness of a material correlates directly with its strength, wear resistance and other properties. As per the above results, bamboo-linen epoxy resin composite has the highest Rockwell Hardness Number (RHN) of 40 while bamboo epoxy resin composite has the lowest Rockwell hardness test value of 20 RHN.

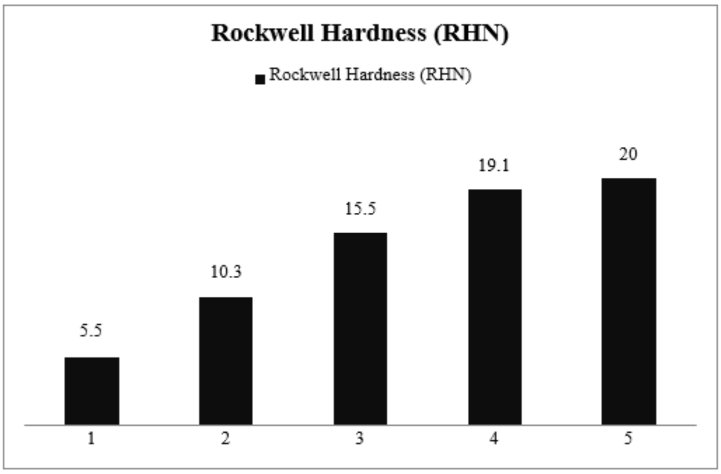

Figure 18: *Rockwell Hardness Test*

Specimen: Bamboo Epoxy Resin Composite
Hardness: 20 RHN

5.3 RESULT 3

5.3.1 Micro Hardness Test

Maximum value micro hardness = 30 MH

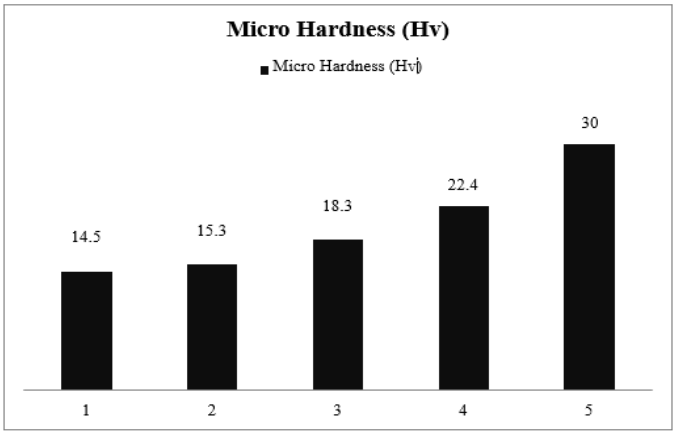

Figure 18: *Micro Hardness Test*

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6 Conclusion

Processed Bamboo fiber reinforced composites were fabricated successfully using hand by up method. It was focused that the composite of bamboo & epoxy us harder than bamboo alone. The treated bamboo encores there is no structural weakness due to decomposition. Hence the fabricated composite material may be used as a substituted for other manufacturing materials.

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