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FABRICATION AND TESTING OF BABASSU FIBER (Attalea Speciosa) REINFORCED COMPOSITES FOR AEROSPACE APPLICATIONS

Sanatan Ratna[1], Prem Narayan Vishwakarma[1] and Manish Kumar Ojha[2]
[1]Department of Mechanical Engineering, ASET, Amity University Uttar Pradesh, Noida, India
[2]Department of Aviation, Logistics and Tourism Management, Galgotias University, Greater Noida, India
E-Mail: sanatan_ratna@yahoo.co.in

ABSTRACT

The tensile and flexural properties of composite materials containing Babassu fiber (Attalea Speciosa) as a novel natural fiber in a polyester resin matrix have been thoroughly investigated. These composite materials were created using fibers that were removed using retting and hand techniques. In order to evaluate their tensile and flexural qualities, these composites have undergone extensive testing. They have also been compared to well-known composites including vakka, sisal, bamboo, and banana, all of which were produced under uniform laboratory circumstances. The composites have been produced with a maximum fiber volume fraction of 0.30 for tensile and flexural evaluations. It has been noted that the tensile attributes enhance in correlation with the volume fraction of Babassu fiber present within the composite and exceed those exhibited by sisal and banana composites. Additionally, the flexural strength of the Babassu fiber composite has been determined to surpass that of vakka, sisal, bamboo, and banana composites. Furthermore, the density of Babassu fiber has been quantified at 587.85 kg/m^3, which is significantly lower than that of sisal (1450 kg/m^3), bamboo (910 kg/m^3), and banana fibers (1350 kg/m^3); following chemical treatment, the density of Babassu fibers is noted to decrease to 454.88 kg/m^3. This characteristic is crucial as it facilitates the development of low-density natural composites suitable for lightweight applications.

Keywords: tensile and flexural properties, natural fibre, low density natural composites, retting.

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1. INTRODUCTION

The contemporary utilization of natural fibers, which have been employed for centuries to fulfil human needs such as apparel and shelter, has been adversely affected by the increasing reliance on synthetic fibers towards the conclusion of the twentieth century. Concerns regarding environmental sustainability and the exhaustion of petroleum resources have rekindled interest in natural fibers, prompting both researchers and industry professionals to favor sustainable fibers over conventional synthetic alternatives [1-4]. In addition to their mechanical and physical attributes, including favourable specific modulus values, low density, and exceptional toughness characteristics, natural fibres possess advantages such as cost- effectiveness, recyclability, nontoxicity, and widespread availability, which facilitate the integration of natural fibre-reinforced composite materials across various sectors including automotive, aerospace, and defence. Composites that use Vakka as a novel natural fiber in a polyester resin matrix have had their tensile, bending, and dielectric properties thoroughly investigated. The composite material was synthesized from fibers obtained through traditional roasting and manual techniques. These composites are evaluated in comparison to established composites such as sisal, bamboo, and banana fibers produced under identical laboratory conditions with respect to their tensile, bending, and dielectric properties [6]. The Babassu palm, native to the Amazon Rainforest in Brazil, is often referred to as the "Tree of Life," and its kernel is recognized as one of the most resilient to breakage globally. Babassu oil, alternatively known as babassu wax or babassu butter, is extracted from the body of literature that has emerged regarding various natural fibers and their composites; the current study endeavours to present a novel natural fiber, specifically Babassu fiber (Attalea Speciosa), as a reinforcing agent in the formulation of innovative composite materials intended for lightweight structural applications. This cost- effective resource, in comparison to alternative natural materials, remains significantly underexploited. The main objective of this study is to remove the fibers using mechanical and retting methods, then incorporate them into a polyester resin matrix to create composites with varying fiber volume percentages. To determine their tensile and flexural properties, the resulting composites underwent extensive testing and characterization.

2. MATERIALS AND METHODS

2.1 Matrix

ECMALON 4411 is an unsaturated polyester resin that has a specific gravity of 1258 kg/m3 at 250°C and a viscosity of 500-600 cps (Brookfield viscometer). It has a monomer content of 35%, an acid number of 22 (mg KOH/g), a Young's modulus of 440 MPa, a tensile strength of 15.1 MPa, and an elongation at break of 3.4%. Two distinct techniques were used to extract fibres: (1) retting and manual extraction, and (2) chemical and manual extraction.

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2.2 Extraction of Fibres

The babassu fibre was collected from the tree's waste dry stem, and the leaves at the nodes and ends were cut. The stem was cut into small pieces after trimming. Cutting was used to remove the node parts, and the stem was cut into 180 mm pieces. The single fibre was extracted in the longitudinal direction using the hollow cylindrical part. These stem strips were steeped in water for two to three weeks. After that, the stem went through a mechanical procedure to separate the fibres. After soaking, the dry stem of babassu fiber start removing of fibers from, it manually by use of thumbs and knifes as shown in pictures. Initially removing very thin fiber as in 1-2 weeks of fiber not fully soaked properly; then, after 4-5 weeks, fibers are removed in ideal length and dried in the sun to remove moisture [7].

2.3 Fiber Surface Treatment

The extracted mechanical fibres (M), weighing 20 gm each, were separated and soaked in 11 parts $KMnO_4$ in acetone medium at a concentration of

0.055 percent before being air dried. Mechanical fibre (M) and chemical fibre (C) were denoted by mechanical fibre (M) and chemical fibre (C), respectively, after surface treatment. So, collecting fibres manually needs chemical treatment on half of the fibers as $KMnO_4$ and Acetone medium would change some of the properties of fibers such as density, specific flexural strength, etc. Then, chemical treatment is performed on the fibers and then further dried in air for 24 hours.

3. COMPOSITE PREPARATION

To test the reinforcing potential of babassu fibres, unidirectional composites were made with a polyester matrix. At room temperature, one percent by volume of resin is added to each of the accelerator and catalyst for curing. The prepared mould was filled with a proper amount of resin mixture and unidirectional babassu fibres using the hand lay-up method, starting and finishing with layers of resin. To produce high-quality unidirectional fibre composites, fibre deformation and movement should be avoided. Consequently, the composite specimens were cured for 24 to 48 hours while the mold was subjected to a compression pressure of 0.05 MPa. The specimens were post-cured at room temperature following their removal from the mold.

Two of the most critical parameters that determine the composite's qualities are fibre configuration and volume percentage. The configuration in this work is only unidirectional, continuous babassu. Fibres of the same length as the specimen, i.e., 160 mm, and five different percentage volumes of babassu fibres were used to make the composite samples: 0.06,0.12,0.18,0.24,0.30. To validate the requisite dimensions, the specimens were made by hand lay-up in the form of a rectangular strip. A smooth surface, such as a wooden table, was prepared for the mould by placing a rubber sheet mould on it. Babassu fibres of the requisite length (160mm for tensile testing, 75mm for impact testing, and 100mm for flexural testing) were precisely weighed and moulded through an unsaturated polyester resin, catalyst, and accelerator mixer (1.0 percent each by volume of resin). The manner of fibre orientation in the mould, the pressure applied to it, and the curing period were all allowed to dry.

4. TESTING OF COMPOSITES

4.1 Tensile and Flexural Testing

Tensile test specimens were built in accordance with the ASTM D 638 M standard to measure the tensile characteristics [8-11]. Five identical specimens measuring 160 mm in length, 12.5 mm in width, and 3 mm in thickness were used to assess each composition. In order to prevent the sample from being compressed at the grip, the homogeneous material was affixed to the ends of the specimen, filling the space between the tab overlaps. The samples were examined at a crosshead speed of 0.5 mm/min using an extensometer to measure strain. Three-point bend tests were conducted in compliance with the ASTM D 790 M test procedure to ascertain flexural properties. The samples measured 100 mm in length, 25 mm in width, and 3 mm in thickness.

The samples were evaluated at a strain rate of 0.5 mm/min in the three-point bending test, with the outer rollers spaced 64 mm apart. The three-point bend test was selected because it uses less material per test and does not require test equipment to accurately estimate center point deflections.

5. RESULTS AND DISCUSSIONS

5.1 Density of Babassu Fiber (Attalea Speciosa)

It was discovered that the Babassu fiber's density was 578.85 kg/m^3. Babassu fiber's density was significantly lower than that of well-known fibers like sisal (1155 kg/m^3), coir (1288 kg/m^3), and banana (1101 kg/m^3), which was a desirable feature when creating lightweight materials.

5.2 Tensile Graphs

Tensile testing is a type of fracture mechanics and materials science test where a specimen is put under controlled tension until it breaks completely. For the tensile test, we use a universal testing machine, clamp a single specimen piece on both ends, and pull it apart until it breaks. This gauges its strength (tensile strength), elongation (stiffness), and tensile modulus (stiffness).

The tensile strength of Babassu fiber is calculated at various volume fractions, i.e., 0.06, 0.12, 0.18, 0.24 & 0.30. The Tensile modulus of the Babassu fiber is also determined to compare the stiffness of fibers at the five volume fractions. The values obtained from the tensile test graphs are used to calculate tensile strength and tensile modulus for the different volume fractions of the composites fabricated.

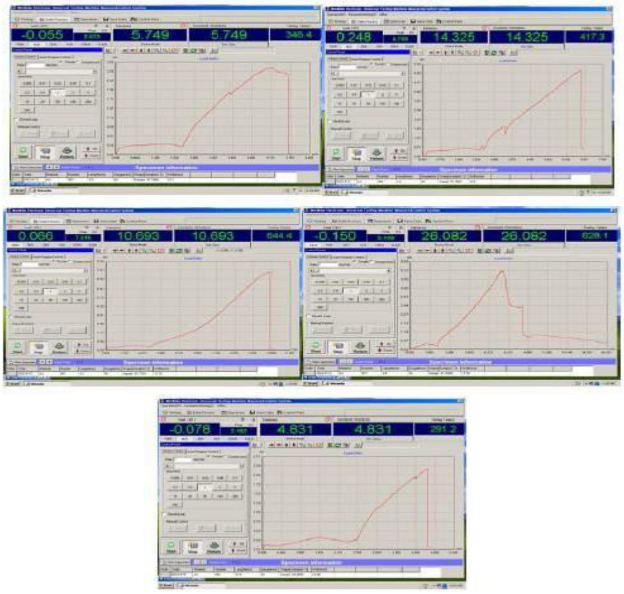

Figure-1. Tensile test graphs obtained for volume fractions of 0.06 M, 0.12 M, 0.18 M, 0.24 M and 0.3 M.

As per testing, the graphs are obtained, and there is a need to calculate the load and change in length as shown below:

- Mean ultimate tensile strength (σ): Load /

cross-sectional area (MPa) where,
Load = calculated from graphs
cross sectional area = (width * thickness) = (12.5 * 3)

- Tensile modulus or Young's modulus (E): tensile strength/strain, or proportional deformation (MPa)

where,
length $\varepsilon = \Delta\ell/\ell_0$, change at length /original length (160mm)

So, as per the formula given above, the tensile strength and tensile modulus are calculated.

The tensile strength values and the tensile modulus values are listed in the Table-1 and Table-2 below for the various volume fractions of the natural fibre composite samples when examined in a UTM.

Table-1. Tensile strength values.

Volume fraction	Tensile strength (MPa)
0.06	65
0.12	90.75
0.18	130
0.24	167
0.30	186

Table-2. Tensile modulus values.

Volume fraction	Tensile modulus (GPa)
0.06	3.78126
0.12	4.87084
0.18	3.118777
0.24	4.02118
0.30	4.93997

5.3 Flexural Test

Flexure (Bend) tests are frequently used to evaluate the flexural modulus or strength of a material. The results of a flexure test are slightly different from those of a tensile test; however, the former is less costly. A force is applied to the top of the material (upper loading span) until the sample fails after the material is laid horizontally over two points of contact (lower support span). The maximum force recorded indicates the sample's flexural strength. Figure-2 below displays the graphs that were produced for the flexural tests.

Flexural strength and flexural modulus are most commonly determined via a flexure test. Flexural strength is defined as the maximum stress at the outermost fiber on either the compression or tension side of the specimen. The flexural modulus is calculated using the slope of the stress vs. strain deflection curve. The ability of a sample to withstand bending or flexure forces can be evaluated using these two figures.

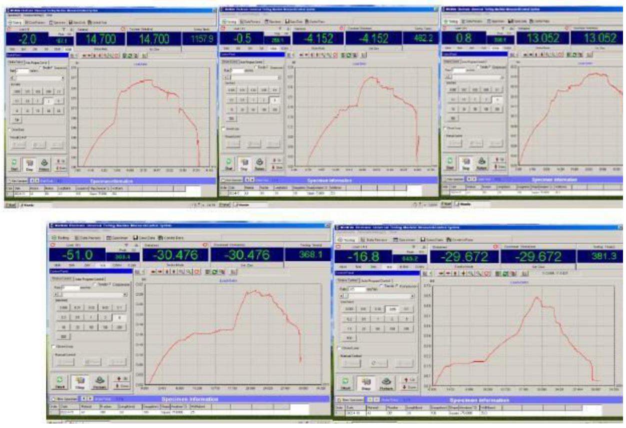

Figure-2. Graphs of flexural test (0.06 M, 0.12 M, 0.18 M, 0.24 M and 0.30 M).

The following formulas are used to calculate flexural strength:
Flexural strength (σ) = 3 P L / 2bt^2 (MPa) Flexural modulus (E) = P t^3 / 4bt^3 * d Where,
P = max. load (N)
L= span length (64mm)
l = original length (100mm)
b = width of specimen (25mm) t = thickness (3mm)
d = deflection (mm)

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The flexural strength values and the flexural modulus values for the different volume fractions are listed in the Table-3 and Table-4 respectively.

Table-3. Flexural strength values.

Volume Fraction	Flexural Strength (MPa)
0.06	82.0565
0.12	115.9082
0.18	147.2938
0.24	167.07
0.30	203.451

Table-4. Flexural modulus values.

Volume fraction	Flexural Modulus (MPa)
0.06	545.811
0.12	650.5178
0.18	1078.49
0.24	1092.521
0.30	1462.0739

CONCLUSIONS

The removal of babassu fibre is done by hand, and the fibre is of outstanding quality, quantity, and length, making it ideal for fabricating large composite components. When compared to other fibres addressed in this study and research, the lower density of babassu fibre is also a significant parameter in constructing lightweight materials. Compared to sisal and banana composites, the mean tensile strength of the fiber composite at the peak volume fraction of fiber in the current study is much greater and comparable to bamboo composites reported in other studies. The mean tensile modulus of the fiber composite is comparable to that of bamboo composite and greater than that of banana and sisal fiber composites at the highest volume fraction of fiber.

In this study, the flexural strength of babassu fibre composites is higher than that of sisal and banana composites as the volume proportion of fibre in the composite increases. The flexural modulus of the babassu fiber composite is significantly greater than that of the banana and sisal fiber composites with different flexural strengths, as the volume fraction of fiber in the composite increases to 0.30. It is also quite similar to that of the bamboo composite.

As a result of the light weight and low density of babassu fibre composites explored in this study, the composite can be evaluated for aerospace applications due to its availability, lower cost, and good impact strength, in addition to the manufacturing of lightweight materials used in vehicle body building, packaging, barrier panels, and other applications.

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