Investigation on Mechanical Behavior of Hybrid Jute/Banana Natural Fiber Reinforced Polyester Composites

Gowtham M¹ Somashekar S M² Pradeep A N³ Naveen N⁴
¹Assistant Professor, ³ & ⁴ Department of Mechanical Engineering, C Byregowda Institute of Technology, Kolar
²Assistant Professor, Department of Mechanical Engineering, New Horizon College of Engineering, Bangalore

Abstract — Natural fibers are a type of renewable sources and a new generation of reinforcements and supplements for polyester based composite materials. Natural fibers are one such proficient material which replaces the synthetic materials and its related products for the less weight and energy conservation applications. Automotive and aircraft’s industries have been actively developing different kinds of natural fibers, like hemp, jute, sisal, banana, coir etc. for their interior components. The applications of natural fibers are growing in many sectors such as automobiles, furniture, packing and construction. This is mainly due to their advantages compared to synthetic fibers. This work is carried out to develop and characterize the non-conventional composites prepared by using locally available jute and banana fibers as reinforcement and polyester resin as matrix material and to investigate its mechanical properties. The hybrid jute-banana laminate are prepared by hand lay-up technique and specimens are extracted from the laminates as per ASTM standards and subjected for different mechanical tests such as to obtain tensile strength, impact strength and hardness properties.

Keywords: Jute, Banana, Polyester Resin, Hand lay-Up

I. INTRODUCTION
The interest in natural fiber reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable and biodegradable. Plants such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana etc., as well as wood used from time immemorial as a source of lignocelluloses fibers are more and more often applied as the reinforcement of composites. Their availability, renewability, low density and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites. The natural fiber containing composites are more environmentally friendly and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling, paneling, partition boards), packaging, consumer products etc.

II. SELECTION OF MATERIALS

A. Jute:
Jute is a long, soft, shiny plant fiber that can be spun into coarse, strong threads. Jute fibers are composed primarily of the plant materials cellulose and lignin. Jute is a rainy season crop, growing best in warm, humid climates. It is 100% bio-degradable & recyclable and thus environment friendly. Jute fiber and Jute fabric is shown in Fig. 2.1 and Fig. 2.2.
B. **Banana:**

Banana Fiber contains cellulose, hemicelluloses and lignin. Available at reasonable prices, our Banana Fiber is widely appreciated for its characteristics such as high strength, strong moisture absorption, good luster, lightweight, fast moisture absorption and release, small elongation, easy degradation and many more. Banana fiber and Banana fabric are shown in Fig. 2.3 and Fig. 2.4

C. **Constituents of Matrix Material:**

1) **Polyester resin:**

It is the commercially available cheapest general purpose polyester resin which is used as matrix material. Before applying the resin to the reinforcement a curing system is blended into the resin. On curing, it forms a matrix.

2) **Curing system:**

The selection of proper catalyst and the amount to be used for any application depend upon the resin, the temperature at which the resin is to be cured, the required working or pot life and the time of gelation. No catalyst is available which can meet all the requirements. Therefore, combination of catalyst and accelerators must be used to obtain the best results.

3) **Accelerator or Promoter:**

Cobalt napthenate is used as an accelerator to cure the resin without application of heat to it.

4) **Catalyst:**

Methyl Ethyl Ketone Peroxide (MEKP) is used as catalyst. The function of a catalyst is to act an initiator for the polymerization process. Curing time can be controlled by varying the catalyst.

### III. OBJECTIVES

The objective is to study the mechanical behaviour of natural fiber reinforced polyester composites. The objectives are as follows:

- Preparation of test specimens according to ASTM standards by Hand Lay-Up Technique.
- Evaluation of mechanical properties of hybrid jute-banana composite.
IV. EXPERIMENTATION

From the literature it shows that the jute and banana fibers were better reinforcing materials compared to other natural fibers. Jute and banana fibers are abundant in India and relatively inexpensive, possess higher tensile strength and modulus than plastics and can be a good substitute for conventional fibers in many situations. Literature reveals that no single group of researchers has completely determined the mechanical properties such as tensile, impact strength and hardness of hybrid jute-banana fabric reinforced polyester composites. Hence, the purpose of present work was to determine the various mechanical properties of hybrid jute-banana fabric reinforced polyester composites. The specimen was prepared using hand lay-up technique as per ASTM standards.

A. Fabrication method and preparation of hybrid jute-sisal fiber reinforced polyester composite specimen:

Each layer of fabric was pre-impregnated with matrix material which is prepared by mixing general purpose polyester resin, accelerator and catalyst. And these layers were placed one over the other in the mould with care to maintain practically achieved tolerance on fabric alignment. Casting was cured under light pressure for 2 hours before removal from the mould.

Hand lay-up technique is used to prepare specimen as shown in Fig. 4.1. The working surface was cleaned with thinner to remove dirt and a thin coat of wax is applied on the surface to get smooth finish. Then a thin coat of poly vinyl alcohol (PVA) is applied for easy removal of mould. Jute and banana fabrics are cut to the required dimensions for specimen pre-impregnated with matrix material and placed one over the other in the mould. Casting was cured under light pressure for at least 8 hours before removal of mould.

V. MECHANICAL TESTING ON COMPOSITE SPECIMEN

Mechanical tests on laminates expect impact tests were carried out on MST-810 machine, having maximum capacity of 10 metric ton. For the tests 1 metric ton range is used. All specimens were tested as per ASTM-D standard. Minimum of five samples were tested to account for statistical scatter and arrived at mean values. All the tests were carried out at room temperature

A. Tensile test:

Tensile tests on composite specimens were carried out according to ASTM–D 3039 standard to determine tensile strength and modulus of elasticity for jute-sisal FRP to observe the behavior of FRP under load. The test specimen is showed in Fig.5.1.
B. Impact test:
Impact test is carried out according to ASTM-D 256 standard to measure material ability to withstand shock loading. It is a dynamic test in which a selected specimen is struck and broken by a single blow on a specially designed machine and the energy absorbed in breaking the specimen is measured and gives a quality of the material, particularly its brittleness. Highly brittle materials have low impact strength. Impact test specimen is shown in Fig.5.2

C. Hardness test:
The hardness of the composite is determined by use of a Rockwell hardness tester. The indicating dial has 100 divisions.

VI. RESULTS AND DISCUSSION
A. Determination of fiber volume fraction
Fiber volume fraction is a percentage of fiber reinforced in the matrix material. The volume of matrix material was obtained by using rule of mixture. It is calculated as follows:

\[
\text{Mass of Jute Fiber (MJ)} = 101.9 \text{ gm.} \\
\text{Mass of Banana Fiber (MB)} = 64.95 \text{ gm.} \\
\text{Density of Jute Fiber (DJ)} = 1.14 \text{ gm.} \\
\text{Density of Banana Fiber (DB)} = 1.2 \text{ gm.} \\
\]

Therefore, Volume of Fiber = \[
\frac{\text{MJ}}{\text{DJ}} + \frac{\text{MB}}{\text{DB}}\]
\[
= \frac{101.9}{1.14} + \frac{64.95}{1.2}
\]
\[
= 143.51 \text{ cm}^3.
\]

Volume of composite = \(30 \times 30 \times 0.45\) = 405 cm³.

Volume of fiber fraction = \[
\frac{\text{Volume of fiber}}{\text{Volume of composite}}
\]
\[
= \frac{143.51}{405}
\]
\[
= 35.43 \%
\]
Law of mixture:
Weight of fibers (MJ + MB), $W_f = 166.85$ gm.
Weight of composite, $WC = 510$ gm.
Weight of fiber fraction $= \frac{W_f}{WC} = \frac{166.85}{510} = 0.3271 = 32.71\%$

$W_f + W_m = 1$

$W_m = \text{Weight of matrix}$

$W_m = WC - W_f$

$= 510 - 166.85$

$= 343.15$ gm.

Weight of matrix fraction $= \frac{W_m}{WC} = \frac{343.15}{510} = 0.6728$

$= 67.28\%$

Therefore law of mixture satisfied, $32.71\% + 67.28\% = 99.99\% \approx 100\%$

B. Tensile properties

Fig. 6.1: Stress strain curve for specimen 1

Fig. 6.2: Stress strain curve for specimen 2
Table 6.1: Tensile test results of Hybrid Jute-Banana FRP composites

<table>
<thead>
<tr>
<th>Type of Composite</th>
<th>Strength (MPa)</th>
<th>Modulus (GPa)</th>
<th>Volume Fiber Fraction %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid Jute/Banana FRP</td>
<td>32.90</td>
<td>2.26</td>
<td>35.43</td>
</tr>
</tbody>
</table>

1) Discussion:
Tensile stress-strain diagram of specimens tested for fabric reinforced polyester composites is shown in Fig.5.1. Strength and modulus of fiber as well as bonding strength between fibers and matrix are the prime factors, which accounts for the tensile strength of composite materials. The curve is linear up to 10 MPa and then follows a non-linear path. A significant change in the slope of the stress–strain curve indicates shear failure. Failure of matrix fiber usually starts after a stress level of 10 MPa. The ultimate point in the curve represents the complete fracture of the fiber. Failure mode exhibits little pull out of fibers and progressive failure of fibers. The first fiber failure occurs at the stress level of 10 MPa. The rest of the drops in the curves are indications of progressive failure of fibers as the applied load increases and the end of the curve represents the ultimate stress which is due to fiber fracture and may be fiber pull out. However, the failure mode exhibits breakage and little pull out of fibers. The average values of ultimate tensile strength and initial tangent modules for these composites are 32.90 MPa and 2.26 GPa. The ultimate point in the graph represents complete fracture of fibers. The mode of failure was due to matrix failure and fracture occurred due to the lamination with little pull out of fibers. Determination of other effects such as detachment of fiber from the matrix, exact beginning of matrix and fiber failure is difficult to analyze with the test setup used for testing the laminate.

C. Impact Properties of Hybrid Jute-Sisal Fabric Reinforced Polyester Composites:

Table 6.2: Impact test results of Hybrid Jute-Banana FRP composites

<table>
<thead>
<tr>
<th>Composites</th>
<th>Test</th>
<th>Impact Strength KJ/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid Jute-Banana</td>
<td>Charpy</td>
<td>31.66</td>
</tr>
<tr>
<td></td>
<td>Izod</td>
<td>21.66</td>
</tr>
</tbody>
</table>

1) Discussion:
Impact tests were conducted on hybrid jute-banana fabric reinforced polyester composites having volume fiber fraction (35-40%) with number of layers 11 and polyester resin using pendulum type impact tester. Impact strengths were obtained for both charpy and izod specimens. Charpy test were performed on hybrid jute-banana composite. The mode of fracture shows little pull out of fibers. The reason for this is poor bonding at the fiber matrix interfaces. The average impact strength values for hybrid jute-banana composite specimens are 31.66 KJ/m² for charpy, 21.66 KJ/m² for izod. Hybrid jute-banana fabric reinforced polyester composite impact strength results were compared with jute and banana fabric reinforced polyester composites.

D. Rockwell Hardness Properties of Hybrid Jute-Sisal Fabric Reinforced Polyester Laminate:

Table 6.3: Rockwell Hardness test results of Hybrid Jute Sisal FRP composite

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Type of Composite</th>
<th>Rockwell Hardness Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hybrid Jute Banana Composite</td>
<td>77</td>
</tr>
</tbody>
</table>
I) Discussion:
The variation in the hardness reading is caused by the difference in the hardness between resin and filler materials. Addition of fibers in the matrix reduces the hardness of binding material.

VII. CONCLUSION
Among all the natural fibers jute and banana have been found to be the better reinforcing materials for primary and secondary structural materials.  
The main emphasis of the work was on development, testing and characterization of these composites to know their suitability and adaptability for various structural and nonstructural applications
- From the tensile test it was found that the tensile strength and modules of hybrid jute-banana fabric reinforced polyester composite is 32.90Mpa, this value is 1.67 times more than those of banana fabric reinforced polyester composites which exhibits tensile strength of 19.61 Mpa. It indicates that the hybrid jute-banana fabric reinforced polyester composites has better tensile properties than the banana fabric reinforced polyester composites.
- Impact energy per unit area of hybrid jute-banana fabric reinforced polyester composite is 31.66 KJ/m² and it is 2 times more than the impact energy of the banana fabric reinforced polyester composite(15.6 KJ/m²).
- Rockwell hardness of hybrid jute-banana fabric reinforced polyester composite is 77 and it is 2.25 times greater than the banana fabric reinforced polyester composite and 1.14 times greater than the jute fabric reinforced polyester composite.

REFERENCES
III. Girisha K G, Anil K C; Mechanical properties of jute and hemp reinforced polyester composites. IJRET vol.2 issue 4, april 2014.