A Study on Mechanical Properties of Natural Fiber Reinforced Laminates of Epoxy (Ly 556) Polymer Matrix Composites

V. Muthukumar¹, R. Venkatasamy², A. Sureshbabu³, D. Arunkumar⁴

¹,²,⁴ Department of Mechanical Engineering, Saveetha Engineering College, Chennai
³ Department of Manufacturing Engineering, CEG, Anna University, Chennai

Abstract: The growing need of eco-friendly product manufacturing led to the development of natural fiber composite to suit various applications in the field of Automobile interior parts, construction and manufacturing. Composite material is a material composed of two or more distinct phases (matrix phase and dispersed phase) and having bulk properties significantly different from those of any of the constituents. In this study, the composite materials are reinforced with natural fibers such as Jute, Sisal, Banana, and Palmyra in the Epoxy (LY 556) Matrix. The impressive mechanical properties led to the selection of these fibers for the study. Hand lay-up technique was used for the preparation of composites. Hybrid fiber mates were also prepared using all these fibers. The mechanical properties such as tensile strength, compressive strength, flexural strength and impact strength were determined and compared for the different combinations.

Keywords: Natural fiber composite, Epoxy (LY 556) resin, PMC, Hand lay-up technique Hybrid Fiber mates.

1. INTRODUCTION

Recent years, Materials scientists and engineers in all over the world have focussed their attention among Natural fibre-reinforced polymer composites due to their attractive features include light weight, low material cost, moderate strength, high specific modulus, lack of health hazards, renewable and environmentally friendly. Therefore, natural fibre-based composites have diverse and varied applications in ship and submarines, aircrafts and spacecrafts, trucks and rail vehicles, automobiles, robots, civil engineering structures, packaging and storage devices [1]. Although many studies have been conducted in which widely used conventional materials were substituted in engineering applications with natural fibre components [2-4].

India, endowed with an abundant availability of natural fibers such as jute, coir, sisal, pineapple, ramie, cotton, bamboo, banana etc., has focused on the development of natural fiber composites primarily to explore value-added application avenues. Such natural fiber composites are well suited as wood substitutes in the housing and construction sector [5-7]. Satyanarayana [8] has worked on the incorporation of the natural fibers in polymer matrix and characterization of their new composites, with and without subject on to environmental conditions. A comparative study between the moisture absorption behaviour of sisal and jute fiber composites in an epoxy matrix by Giridhar and Rao [9] reveals that sisal fiber, in spite of possessing a more compact structure than jute fiber, exhibits higher moisture absorption level in the composite form. Das et al. [10] have attempted to improve the mechanical performance of jute composites by using unidirectional oriented jute fiber as the reinforcement and general purpose polyester resin as the matrix. Kuruvilla Joseph et al. (1999) has reviewed on work published in the field of sisal fibre reinforced polymer composites with special reference to the structure and properties of sisal fibre, processing techniques and the physical and mechanical properties of composites.

Keeping this in view the present work has been undertaken to develop a polymer matrix composite (epoxy resin) using banana, sisal, jute and Palmyra fibers and to study its mechanical properties like Tensile strength, flexural strength and impact strength.

2. METHODOLOGY

The methodology depicted in Figure 1 has been adopted to accomplish the research work being reported in this thesis. As shown, fabrication and testing of composite material for mechanical properties in manufacturing has been selected as a broad field of research. A literature survey has been conducted to investigate the research studies already carried out in this field with the focus of mechanical properties of the composite materials. The lack of information in the previous research works in this domain were identified and used to define the research problem. The thrust activities in the development of composite materials influence the scope of the research were identified for the study and subsequently, methodology has been designed. Experiments have been conducted by applying the designed methodology. The results of the application of methodology were obtained and reviewed. Based on the review of the results, conclusions have been drawn.
3. MATERIAL SELECTION

The main objective is to select natural fibers which are available easily and eco-friendly. Hence we have selected the widely available fibers such as sisal, banana, palmyra, and jute. The most adopted epoxy resin (LY556) and industrial application hardner (HY951) are employed to fabricate the laminated sheets and hybrid combinations. The fibers vegetative origin used as reinforcement countries of origin are given in Table 1.

<table>
<thead>
<tr>
<th>Fibers</th>
<th>Origin</th>
<th>Type of Vegetative Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jute</td>
<td>India, Egypt, Guyana, Jamaica, Ghana</td>
<td>Bast</td>
</tr>
<tr>
<td>Palmyra</td>
<td>Iraq, Tanzania, Jamaica, South Africa</td>
<td>Leaf</td>
</tr>
<tr>
<td>Sisal</td>
<td>East Africa, Bahamas, Antiqua, Kenya, India</td>
<td>Leaf</td>
</tr>
<tr>
<td>Banana</td>
<td>India, Sri Lanka, Philippines, Malaysia</td>
<td>Stem</td>
</tr>
</tbody>
</table>

The chemical nature of the natural fibers include cellulose content, lignin content were presented in Table 2.

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Cellulose content (%)</th>
<th>Lignin content (%)</th>
<th>Diameter (micrometer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana</td>
<td>64</td>
<td>5</td>
<td>50-250</td>
</tr>
<tr>
<td>Sisal</td>
<td>70</td>
<td>12</td>
<td>50-200</td>
</tr>
<tr>
<td>Palmyra</td>
<td>85</td>
<td>12</td>
<td>20-80</td>
</tr>
<tr>
<td>Jute</td>
<td>37</td>
<td>42</td>
<td>100-450</td>
</tr>
</tbody>
</table>

4. SELECTION OF RESIN (EPOXY)

Softener (Araldite LY 556) made by CIBA GUGYE limited having the following outstanding properties has been used as the matrix material.

- Excellent adhesion to different materials.
- High resistance to chemical and atmospheric attack.
- High dimensional stability.
- Free from internal stresses.
- Excellent mechanical and electrical properties.
- Odourless, tasteless and completely nontoxic.
- Negligible shrinkage.

5. SELECTION OF HARDNER (HY951)

Epoxy hardeners are not catalysts and they react with the epoxy resins, greatly contributing to the ultimate properties of the cured epoxy resin system. Epoxy hardeners provide: Gel time; mixed viscosity; remold time of the epoxy resin system. Physical properties of the epoxy resin system such as tensile ability, compression, flexural properties, etc., are also influenced by epoxy hardeners. The performance of epoxy hardeners in the epoxy resin system depend on the chemical characteristics of the epoxy resins and the physical characteristics while applying the epoxy resin system. The chemical characteristics of the epoxy resins that influence epoxy hardeners are: viscosity; amount and kind of diluents and fillers in epoxy resins. The physical characteristics of the epoxy resins system influencing the behavior of epoxy hardeners in the epoxy resins system are: temperature of the work area, temperature of the resins system (i.e. the heated resins), and moisture (dampness).

6. FABRICATION OF COMPOSITE MATERIALS

This chapter deals with the fabrication stages carried out to obtain the composite material. The materials used in our fabrication process are

- Epoxy resin-LY556
- Hardner-HY951
- Polythene Sheets
- ASTM Rubber
- Polythene Sheets
- Banana, sisal, Palmyra, jute fibers.

6.1 HAND LAY-UP TECHNIQUE

Hand lay-up is the simplest and oldest open molding method of the composite fabrication processes. It is a low volume, labor intensive method suited especially for large components. Glass or other reinforcing mat or woven fabric or roving is positioned manually in the open mold, and resin is poured, brushed, or sprayed over and into the glass plies. Entrapped air is removed manually with squeegees or rollers to complete the laminates structure. Room temperature curing polyesters and epoxies are the
most commonly used matrix resins. Curing is initiated by a catalyst in the resin system, which hardens the fiber reinforced resin composite without external heat. For a high quality part surface, a pigmented gel coat is first applied to the mold surface. The hand layup technique is the simplest way of processing UP-resins into final products. It does not require extensive investment in equipment takes place at room temperature and is used for a wide variety of products. It is an open mould process. Also called contact moulding. It is a production technique suitable for prototypes and low volume production of fiber composite material parts. The composite part will have a nice smooth surface on one side and a very rough one on the other. The fibers are manually placed into a one-sided gel coated male or female mould. A matrix of thermosetting resin is rolled onto the fiber using a hand roller. More layers can be added and, after drying, the composite part can be removed from the mould. Easy to control fibers orientation. Furthermore, the process is very flexible as it can produce from very small, up to very large part of different kinds of geometry. The cycle time per part is very long, and only small series can be produced.

The hand layup technique is the simplest way of processing UP-resins into final products. It does not require extensive investment in equipment takes place at room temperature and is used for a wide variety of products. It is an open mould process. Also called contact moulding. It is a production technique suitable for prototypes and low volume production of fiber composite material parts. After curing composite was separated from the mould and the specimens were cut according to the ASTM and ISO standards.

### 6.2 Material Characterization

Tensile test was performed on a computer controlled universal testing machine according to the guidelines of ASTM D638 standard. The flexural tests were performed using the 3-point bending method according to ASTM D790 standard. The standard specimens were prepared for both compression and shear tests and tests were performed in a UTM. Six sample specimens were tested for each test and their average values are used to determine tensile strength, Compression strength, flexural strength, and shear strength.

### 7. RESULTS AND DISCUSSION

The mechanical properties such as tensile strength, compressive strength, flexural strength and impact strength for different aspect ratios such as .5 cm, 1cm, 2cm, and 3cm are determined. The results obtained from the various tests are presented and possible reasons for the mechanical behavior of the composite are discussed.

#### 7.1 Tensile Test

Tensile test was performed on a computer controlled universal testing machine according to the guidelines of ASTM D638 standard with a specimen having dimensions of 20cm length, 3cm width and 0.3cm thickness. Various mechanical properties such as ultimate breaking load, displacement at maximum force and ultimate stress were determined and tabulated in Table 3.

### Table 3

Comparison of Tensile Test Results Under Different Aspect Ratio

<table>
<thead>
<tr>
<th>Fiber Test</th>
<th>Palmyra</th>
<th>Jute</th>
<th>Banana</th>
<th>Sisal</th>
<th>Banana+ Palmyra+ Sisal</th>
<th>Jute+ Palmyra+ Sisal</th>
<th>Banana+ Sisal+ Jute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate Break Load (KN)</td>
<td>0.965</td>
<td>2.66</td>
<td>0.86</td>
<td>3.60</td>
<td>2.360</td>
<td>2.170</td>
<td>2.853</td>
</tr>
<tr>
<td>Displacement (mm)</td>
<td>3.800</td>
<td>0.900</td>
<td>4.0</td>
<td>5.300</td>
<td>4.800</td>
<td>5.200</td>
<td>4.3</td>
</tr>
<tr>
<td>Ultimate Stress (KN/mm²)</td>
<td>0.23</td>
<td>0.065</td>
<td>0.030</td>
<td>0.093</td>
<td>0.054</td>
<td>0.043</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Figure 3 shows a comparison of the ultimate tensile stress of various fibres tested under tensile test. By Fig. 3, it becomes clear that palmyra fibre exhibits the highest tensile strength of among seven kinds of fibres tested.

7.2 Compression Test

Compressive load was applied on the composite using UTM Machine and the following parameters were determined. The mechanical properties such as ultimate breaking load, displacement at maximum force and ultimate stress were determined and tabulated in Table 4.

Under compression test of fibres tested, the ultimate tensile strength of banana is higher as compared with all other combinations and shown in Figure 4.

7.3 Shear Test

Shear test was carried out using UTM for a specimen having dimension of 20cm length, 3cm width and 0.3cm thickness and the mechanical properties such as ultimate breaking load, displacement at maximum force and ultimate stress were determined and tabulated in Table 5.

A comparison of the ultimate tensile stress of various fibre materials tested under shear test is represented in Figure 5. From Figure 5, it becomes clear that sisal parent fibre exhibits the highest tensile strength of among seven kinds of fibres tested.

7.4 Flexural Test

The flexural tests were performed using the 3-point bending method according to ASTM D790 standard specimen size of 24cm × 3cm × 0.3 cm. The important mechanical properties such as ultimate breaking load, displacement at maximum force and ultimate stress were determined and tabulated in Table 6.

Figure 6 shows a comparison of the ultimate tensile stress of various fibre materials tested under flexural and also clear that Palmyra parent fibre have higher tensile strength of among seven kinds of fibres tested.

Thus the experimental results reveal that Palmyra individual fiber is better choice than other seven different composites studied because it shows highest ultimate tensile stress under various tests performed.

<table>
<thead>
<tr>
<th>Fiber Test</th>
<th>Palmyra</th>
<th>Jute</th>
<th>Banana</th>
<th>Sisal</th>
<th>Banana+Palmyra+Sisal</th>
<th>Jute+Palmyra+Banana</th>
<th>Banana+Sisal+Jute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate Break Load (KN)</td>
<td>0.870</td>
<td>3.265</td>
<td>0.130</td>
<td>2.950</td>
<td>5.070</td>
<td>4.751</td>
<td>2.610</td>
</tr>
<tr>
<td>Displacement (mm)</td>
<td>1.1</td>
<td>0.72</td>
<td>1.0</td>
<td>0.7</td>
<td>1.100</td>
<td>0.75</td>
<td>0.7</td>
</tr>
<tr>
<td>Ultimate Stress (KN/mm²)</td>
<td>0.005</td>
<td>0.069</td>
<td>0.13</td>
<td>0.063</td>
<td>0.069</td>
<td>0.101</td>
<td>0.050</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fiber Test</th>
<th>Palmyra</th>
<th>Jute</th>
<th>Banana</th>
<th>Sisal</th>
<th>Banana+Palmyra+Sisal</th>
<th>Jute+Palmyra+Banana</th>
<th>Banana+Sisal+Jute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate Break Load (KN)</td>
<td>0.855</td>
<td>1.240</td>
<td>0.865</td>
<td>1.3</td>
<td>0.99</td>
<td>1.15</td>
<td>1.17</td>
</tr>
<tr>
<td>Displacement (mm)</td>
<td>0.80</td>
<td>0.80</td>
<td>0.90</td>
<td>1.00</td>
<td>1.80</td>
<td>1.30</td>
<td>1.0</td>
</tr>
<tr>
<td>Ultimate Stress (KN/mm²)</td>
<td>0.017</td>
<td>0.025</td>
<td>0.023</td>
<td>0.026</td>
<td>0.020</td>
<td>0.023</td>
<td>0.023</td>
</tr>
</tbody>
</table>
Table 6
Comparison of Flexural Test Results Under Different Aspect Ratio

<table>
<thead>
<tr>
<th>Fiber Test</th>
<th>Palmyra</th>
<th>Jute</th>
<th>Banana</th>
<th>Sisal</th>
<th>Banana+ Palmyra+</th>
<th>Sisal+</th>
<th>Jute+ Palmyra+</th>
<th>Sisal+</th>
<th>Banana+ Sisal+</th>
<th>Jute+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate Break Load (KN)</td>
<td>6.655</td>
<td>1.610</td>
<td>3.215</td>
<td>0.460</td>
<td>0.595</td>
<td>1.060</td>
<td>0.655</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Displacement (mm)</td>
<td>0.60</td>
<td>1.50</td>
<td>0.70</td>
<td>2.00</td>
<td>1.00</td>
<td>1.80</td>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultimate Stress (KN/mm²)</td>
<td>0.098</td>
<td>0.009</td>
<td>0.072</td>
<td>0.008</td>
<td>0.008</td>
<td>0.072</td>
<td>0.010</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 4: Comparison of the Ultimate Tensile Stress Under Compression Test

Fig. 5: Comparison of the Ultimate Tensile Stress Under Shear Test

Fig. 6: Comparison of the Ultimate Tensile Stress Under Flexural Test
8. CONCLUSIONS

Natural Fibers are renewable raw materials, environmentally friendly material and they are recyclable. Extensive uses of this material will save wood resources and thus protect forests. In this study, the composite materials are reinforced with natural fibers such as Jute, Sisal, Banana, and Palmyra in the Epoxy (LY 556) Matrix. The developed natural fiber composite used in various applications in the field of Automobile interior parts, construction and manufacturing and being adopted in aircraft interior decoration, designing body parts.

1. Based on experimental investigations, micro mechanics assessment and statistical analysis the strength determining factors such as ultimate breaking load, ultimate stress, displacement at maximum force and impact strength are being determined for the parent fibers banana, Palmyra, sisal, jute and hybrid combinations.

2. The comprehensive mechanical properties are increased to different extents compared with those of parent fibers and hybrid composites; for instance, ultimate breaking strength, Ultimate stress, displacement and Impact strength.

3. Hand lay-up technique can be used for the preparation of composite specimens successfully.

4. Palmyra individual fiber is better choice than other seven different composites studied because it shows highest ultimate tensile stress under various tests performed.

5. In future, there is tremendous investments on natural fibers, to bring an great impact on manufacturing sectors.

REFERENCES


