REINFORCEMENT EFFECT ON MECHANICAL PROPERTIES OF BIO-FIBER COMPOSITE

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ABSTRACT

Influence of reinforcement effect on mechanical properties of banana bio fiber polyester has been investigated. Three different type of weaving patterns such as plain, basket and twill banana fabric were used to analyze the mechanical properties of composites. Results revealed that composite with basket weaving style enhances the properties of composite material compared to other two patterns. Further, same weight percentage of banana fiber was reinforced in the polyester matrix with random orientation. Three different lengths (3 mm, 4 mm and 5 mm) have been employed to analyze the influence of random orientation of composites mechanical properties compared to woven reinforcement. Results depicted that composite with woven reinforcement enhances the properties of composites compared to short fiber with random orientation. Reason is woven fiber reinforcement enhances the young’s modulus of composite laminate which offers more resistance against deformation and transfer stress uniformly from reinforcement to matrix.

Key words: Composite; Mechanical properties; Weaving; Natural Fiber, Polyester.

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1. INTRODUCTION

Natural fibers have been recognized as a good replacement material to synthetic fibers for structural and automotive applications due to advantages associated with natural fibers such as potential environmental, health and end of life disposal [1-3]. Researchers analysed wide range of applications of natural fiber reinforced polymer composite for various application such as automobile, aerospace and structural applications. Holmberg et al. [4] and Joshi et al. [5] reported usage of light weight natural fiber reinforced composite in automobile reduces the weight of final product which in turn eco-friendly via less fuel consumption.

Exhaust research has been conducted on natural fiber composite for mechanical properties by reinforcing natural fiber in the polymer matrix as short form with random orientation. Banana, Jute, hemp, sisal, flax etc., Natural fibers are commonly used by various researchers with short and random orientation [6, 7]. Monteiro et al. [8] carried out experimental investigation of coir fiber reinforced polyester composites. Results revealed that composite with 50 wt% enhances the properties of composite. Boopalan et al. [9] compared the mechanical properties of banana-jute hybrid reinforced composites and compared the results with individual jute and banana fiber reinforced composites. They found hybrid composite enhances the mechanical properties of composite material by 17%, 4.5% and 35.5% respectively for tensile, flexural and impact strength. Jawaid et al. [10] investigated the mechanical properties of jute-oil palm hybrid composite and found that composite with higher amount of jute fiber enhances the mechanical properties of composites. Mayandi et al. [11] carried out experimental investigation of veldt grape bast fiber/ polyester composite on mechanical properties. Results revealed that fiber length and weight percentage influences much on properties of composites. Researchers found that natural fiber with short and random orientation in the polymer matrix not enhancing the mechanical properties of composite material due to fiber discontinuity and amorphous nature [12, 13].

In order to improve the load carry capacity of natural fiber composite, researchers suggested to use advantages of textile concept in the composite filed. John et al. [14] reviewed importance of different type of weaving pattern such as plain, basket, twill, and stain and proposed for natural fiber composite to enhance the strength of composites. Sapuan and Maleque [15] suggested woven banana fabric epoxy composites for household telephone stand. Sastra et al. [16] compared the reinforcement effect of drenga pinnata fiber. They used three different reinforcement type such as long random, short random and woven roving on mechanical properties of composites. They found that composite with woven rowing enhances the mechanical strength of composite laminates due to higher modulus associated with woven form.

Jawaid et al. [17] investigated the impact properties of woven jute-oil-palm fibers reinforced composite. Results revealed that composite with woven form reinforcement enhance the impact properties of composite material. Alavudeen et al. [18] compared the effect of reinforcement on mechanical properties of banana/kenaf fiber reinforce composite. They found that composite with woven form reinforcement increases the strength of composite material compared to natural fiber with short form random orientation. Rajesh and Pitchaimani [19] compared the mechanical properties of woven, braided and knitted fabric reinforced composite. They found that composite with braided reinforcement enhances the mechanical properties of composites compared to woven and knitted form. It is due to higher youngs modulus associated with braided yarn enhances the modulus of natural fiber braided fabric. Enhancement in the fabric influences much on loqad carry behaviour of composite material and transfer stress from fabric to matrix uniformly. Further, they made comparison with random oriented short natural fiber composite and found that composite with woven form enhances the mechanical properties of composite material compared to natural fiber with short form. In the case of short fiber reinforcement, composite fails early due to fiber discontinuity and poor stress transfer from
fiber to matrix. They extended the studies on mechanical properties of woven composite. They considered weaving architecture, intra-ply hybridization and stacking sequence of fabrics. They found that composite with four layer, basket weaving style enhances the properties of composites [20].

Several researchers analysed influence of layering sequence on mechanical properties of composite material. Jawaid et al. [21] investigated experimental analysis on mechanical properties of tri-layer oil-palm jute woven composite. They found that stiff jute fiber as facing layer enhances the properties of oil-palm-jute woven sandwich composite. Reason is, stiff jute fiber increases the rigidity of composite material and provide more resistance against bending load. Bennet et al. [22] carried out experimental investigation on coconut sheath/sansevieria cylindrica polyester composite. Results revealed coconut sheath/sansevieria cylindrica/coconut sheath composite enhances stiffness of composites. Santulli et al. [23] compared mechanical behaviour of intercalated and sandwich method of jute cloth/wool felts composite and found that sandwich composite enhances the properties of composites. Ramesh et al. [24] investigated the mechanical properties of sisal-jute-glass fiber composites. They found that composite with glass fiber enhances the mechanical properties of composite material drastically compared with individual sisal and jute fiber layered composite. However, detailed investigation of influence of weaving style, layer sequence and number of layer on mechanical properties has to be carried out.

Main aim of the present work is to enhance the mechanical properties of poor strength associated with banana natural fiber composite, three different style such as plain, basket and twill has been employed. Further, woven banana composites are compared with random oriented short fiber composite.

2. EXPERIMENTAL DETAILS

2.1. Material used

In this study banana fiber is used as reinforced material whereas polyester resin is used as matrix material. Initially, loose banana natural fiber is converted into continuous fiber yarn. For that, 100 to 150 loose natural fiber is spurned into yarn. Further, continuous yarns are used to fabricate three different weaving styles such as plain, basket and twill. In addition, banana natural fibers are prepared with 3 mm, 4 mm and 5 mm length for random orientation.

2.2. Matrix Material Preparation

Unsaturated polyester resin, catalyst (Methyl Ethyl Ketone Peroxide) and an accelerator (cobalt naphthenate) is used to prepare the matrix mixture. In this study 100:1:1 weight ratio has been used to prepare the matrix mixture using unsaturated polyester resin, catalyst and an accelerator.

2.3. Fabrication of composites

Hand lay-up technique is employed to fabricate the composite laminate. Mould has been prepared with a dimension of 300 mm×300 mm×3 mm. Initially, matrix mixture is poured in the mould cavity. Followed by this, woven banana fabric is placed and remaining amount of matrix mixture is poured. To achieve better adhesion between two layer, woven fabric has been dipped in the matrix material and removed slurry over the fabric. Later, stiff parallel plate made of stainless steel has been placed over the mould cavity and placed around 50 kg weight to achieve uniform composite plate. After allowing 4 hours curing, composite laminates are removed from mould cavity and sized for tensile, flexural and impact test respectively.
2.4. Testing Standard
Tensile and flexural test of banana reinforced composite are conducted in the universal testing machine while impact test has been carried out using Izod impact test machine. ASTM D-638 is followed to conduct the tensile test on composite specimen with speed of 2 mm/min [25]. Specimen Dog bone shape with a dimension of 57 mm in length and 13 mm in width is used to carried out tensile test. ASTM D-790 is employed to perfume the flexural test of composite material [26]. ASTM D-256 is used to conduct the Izod test with the dimension of 63.7 mm×12.7 mm×3 mm.

3. RESULTS AND DISCUSSION
Tensile properties of different woven composites are presented in the Table 1. Results revealed that composite with basket weaving pattern enhances the mechanical properties of composite material compared to composite with plain and twill woven composite. It is due to enhancement in the young’s modulus of composite material increases the load carry capacity of composite material. Advantage associated with basket style is fiber yarn movement, tightness between two yarns in the warp and weft direction reduces the gap between two successive fiber yarns which reduces stress concentration under loading. From the Table 1, it is observed that composite with plain, basket and twill woven reinforcement enhances the tensile strength 100%, 152% and 91%, flexural strength 68%, 915 and 56% and impact strength of composites 58%, 1135 and 47% respectively compared to neat polyester resin.

It reveals that addition of fiber in the polymer matrix enhances the properties of composite material while neat polyester resin composite fails early under loading.

Another interesting observation has been observed form Table 1 is, basket style reinforcement enhances the young’s modulus of composite material drastically compared to other composite which allows composite to carry more load. Banana fiber with basket style reduces the stress concentration between two yarns. This helps to carry more load and transfer stress uniformly from reinforcement to matrix. Next to basket weaving pattern, plain style enhance the properties of composite material. This reveal fiber yarn orientation in the warp and weft directions influences much on properties of composites. In the case of basket and plain weave is, fiber yarn movement in the warp and weft direction is straight and uniform and also less gap compared to twill style. In the case of twill style, fiber yarn movement in the warp and weft directions are not uniform and move diagonally which transfers stress non-uniformly. To understand the modulus of woven fabric, tensile test has been carried out on woven fabric. Table 2 shows tensile properties of different woven fabric used in the study. Results revealed that basket woven fabric has higher modulus compared to plain and twill weave. Similar observation has been observed for flexural and impact strength of composites.

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Tensile properties</th>
<th>Flexural properties</th>
<th>Impact properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tensile strength (MPa)</td>
<td>Tensile modulus (GPa)</td>
<td>Flexural strength (MPa)</td>
</tr>
<tr>
<td>Neat resin</td>
<td>11.9</td>
<td>0.69</td>
<td>21.0</td>
</tr>
<tr>
<td>Plain</td>
<td>24.1</td>
<td>1.40</td>
<td>35.4</td>
</tr>
<tr>
<td>Basket</td>
<td>30.1</td>
<td>1.52</td>
<td>40.2</td>
</tr>
<tr>
<td>Twill</td>
<td>22.8</td>
<td>1.36</td>
<td>32.9</td>
</tr>
</tbody>
</table>
Table 2 Tensile properties of different types of woven fabrics

<table>
<thead>
<tr>
<th>Type of pattern</th>
<th>Tensile Strength (MPa)</th>
<th>Tensile modulus (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain</td>
<td>10.1</td>
<td>110</td>
</tr>
<tr>
<td>Basket</td>
<td>12.4</td>
<td>125</td>
</tr>
<tr>
<td>Twill</td>
<td>9.8</td>
<td>101</td>
</tr>
</tbody>
</table>

Table 3 Mechanical properties of randomly oriented short fiber banana composites

<table>
<thead>
<tr>
<th>Fiber length</th>
<th>Tensile properties</th>
<th>Flexural properties</th>
<th>Impact properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tensile strength</td>
<td>Tensile modulus</td>
<td>Flexural strength</td>
</tr>
<tr>
<td></td>
<td>(MPa)</td>
<td>(GPa)</td>
<td>(MPa)</td>
</tr>
<tr>
<td>3 mm</td>
<td>13</td>
<td>0.92</td>
<td>21.0</td>
</tr>
<tr>
<td>4 mm</td>
<td>16</td>
<td>1.01</td>
<td>26.3</td>
</tr>
<tr>
<td>5 mm</td>
<td>15</td>
<td>0.99</td>
<td>24.0</td>
</tr>
</tbody>
</table>

Further, reinforcement studies has been carried out on mechanical properties of composite laminate. Three different length has been taken to compared the short fiber reinforcement with basket woven reinforcement. Results revealed that composite with composite with 4 mm fiber length enhances the properties of composite material compared to 3mm and 5 mm fiber length. It is due to uniform distribution of short fiber in the matrix influences on their properties. However, compared to short fiber composite woven composite enhances the properties of composite material. Youngs modulus plays important role on mechanical properties of composite material. From Table 1 and 3, it is found that composite with woven reinforcement has higher young’s modules for irrespective of weaving pattern whereas random oriented fiber composite has less youngs modulus. Another main reason is short fibers in the polymer matrix are not capable to transfer stress uniformly. Fiber ends act as stress concentration in the matrix and creates more number of crack and allows them in the matrix rapidly. Similar observation has been observed for flexural and impact strength. Hence, it is concluded that composite with woven reinforcement enhances the properties of composite material and improves the properties of poor strength natural fiber composite.

4. CONCLUSION

Effect of natural fiber reinforcement such as weaving and random orientation have been investigated on mechanical properties of composite material. Results revealed that composite with woven reinforcement enhances the mechanical properties of composite material compared to random oriented short fiber composite. Basket weave composite enhances the mechanical properties of composite material compared to plain and twill woven composite due to fiber yarn arrangement in the warp and weft directions reduces the stress concentration in the matrix while random oriented short fiber composite decreases the properties of composite. It is due to poor stress transfer from fiber to matrix lead to fails composite early under loading. Hence, it is concluded that poor strength natural fiber composite can be used for low and medium load applications and weight sensitive application with woven reinforcement.
REFERENCE


