FLEXURAL BEHAVIOR OF NEEDLE PUNCH GLASS/JUTE HYBRID MAT COMPOSITES

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Abstract

In this research, creation of higher mechanical natural fiber mat composites was proposed. The hybrid mat with jute and glass mat was fabricated by needle punching system, in which jute mat was placed on glass mat. The ratio of jute and glass mat layers was set to be 1:0, 1:1, 1:2, and 2:1, respectively. The composites were fabricated by hand-lay up method with unsaturated polyester resin after needle punching process. Three-point bending test was carried out in order to obtain flexural behavior of different composites. The results show that flexural strength obtained for JF was approximately 37 MPa. Whereas similar flexural strength were achieved in JF/GF and JF/GF/GF, that exhibited about respective 61.7 % and 62.0 % higher than the values of JF. However, JF/JF/GF exhibited a lower value at around 38 MPa due to larger thickness of specimens than others. Finally, morphological analysis was carried out to observe fracture behavior using scanning electron microscope.

Key words: jute mat; glass mat; needle punch; laminates; flexural properties.

1. Introduction

Glass mat composites have been extensively exploited in the past few decades so that it can be said to be the basic materials of composites. Hand-lay up method is commonly employed to fabricate glass mat thermosetting resin composites, which possesses laminate structure. As a result, interlaminar fracture is one of the most common fracture forms for laminates and usually causes serious loss. Needle punch system can be introduced to prevent interlaminar fracture occurrence.

Natural fibers as an alternative reinforcement in polymer composites for making low cost engineering materials has attracted the attention of many researchers and scientists in recent decades due to their advantages such as economic viability, low density, comparable specific tensile properties, non-abrasive to the equipments, non-irritation to the skin, reduced energy consumption, less health risk, renewability, recyclability and good biodegradability. [1-3] These natural fibers include flax, hemp, jute, sisal, kenaf, coir, kapok, banana, henequen and many others. [4,5] In the case of natural fiber mat composites, random natural fiber mat configuration is very common as well as glass mat. However, the main drawback is low mechanical properties compared with glass mat composites. Therefore, natural fiber and synthetic fiber hybrid composites have been studied by many researchers and scientists.

Rafiquzzaman M et al. [6] conducted experiment on tensile, flexural and impact properties of glass-jute fiber reinforced polymer composite. Results showed that by incorporating the optimum amount of jute fibers, the overall strength of glass fiber reinforced composite can be increased and cost saving of more than 30% can be achieved. It can thus be inferred that jute fiber can be a very potential candidate in making...
of composites, especially for partial replacement of high-cost glass fibers for low load bearing applications. M. Ramesh et al. [7] investigated on the hybrid composites and the effect of various parameters on the performance of the hybrid composites are subjected to mechanical testing such as tensile, flexural and impact test. The results indicated that the jute composite material shows maximum tensile strength and the jute composite material shows incorporation of sisal-jute fiber with GFRP can improve the properties and used as an alternate material for glass fiber reinforced polymer composites. Khan et al. [8] studied on the mechanical properties of woven and non-woven jute fabric reinforced poly (L-lactic acid) based composites. Experiments show that woven structure exhibited excellent mechanical behavior like tensile, flexural and impact loadings compared to non-woven composite. Tensile, flexural and impact strengths of WJF/PLLA composite were found higher at warp direction than weft direction.

In this research, creation of higher mechanical natural fiber mat composites was proposed. The needle punching system is employed to fabricated hybrid mat using jute and glass mat. The composites were fabricated by hand-lay up method with unsaturated polyester resin after needle punching process. Polymer was mixed with the hardener MEKPO (PERMEK N; NOF Corporation) in a ratio of 100:0.7. Finally, the blocks of the composite pressed and naturally cured for 24 hours in ambient temperature, post cure was followed in an oven at a constant temperature and time of 100 °C and 2 hours, respectively. The total fiber volume fraction is consisted of jute fiber volume fraction and glass fiber volume fraction as shown below in Table 1.

<table>
<thead>
<tr>
<th>Composite</th>
<th>v_j(%)</th>
<th>v_g(%)</th>
<th>v(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JF</td>
<td>12.5</td>
<td>-</td>
<td>12.5</td>
</tr>
<tr>
<td>JF/GF</td>
<td>16.5</td>
<td>4.2</td>
<td>20.7</td>
</tr>
<tr>
<td>JF/GF/GF</td>
<td>12.9</td>
<td>6.6</td>
<td>19.4</td>
</tr>
<tr>
<td>JF/JF/GF</td>
<td>19.4</td>
<td>2.5</td>
<td>21.8</td>
</tr>
</tbody>
</table>

2. Experimental procedures

2.1 Materials and fabrication

Unsaturated polyester resin (supplied by Showa High Polymer Co., Ltd., with a density of 1.25 and Young’s modulus of 3.2 GPa; Tensile strength 42 MPa; elongation at break 2.18%) was used for matrix. Jute mat and glass mat were employed as reinforcement. Jute fiber mat (punched mat from YANOSEIKEI Company, with an average density of 1.163 g/cm² and unit area weight of 820 g/cm²) is selected, as depicted in Fig.1. Glass mat (Nitto Glass tex Co., Ltd.) with gram weight of 485 g/m² was made of cut glass fibers with a length of 50 mm. The chopped glass bundles are distributed in random directions, as depicted in Fig.2. Here, the hybrid composite laminates were fabricated following the flowchart shown in Fig. 3. The hybrid mat with jute and glass mat was fabricated by needle punching system, in which jute mat was placed on glass mat. The ratio of jute and glass mat layers was set to be 1:0,1:1,1:2 and 2:1, respectively. The composites were fabricated by hand-lay up method with unsaturated polyester resin after needle punching process. Finally, the blocks of the composite pressed and naturally cured for 24 hours in ambient temperature, post cure was followed in an oven at a constant temperature and time of 100 °C and 2 hours, respectively.

Table 1 The fiber volume fraction of four types of composites.
Fig. 1 Photo of jute mat.

Fig. 2 Photo of glass mat.

Fig. 3 Process flow chart used in the fabrication of different composites using hand lay-up method.

2.2 Measurements and characterization

Flexural tests were carried out according to ASTM D790-07 using a three-point bending test measuring at least three specimens for each composite. The tests were performed in a universal testing machine (INSTRON, 55R4206) at a span-to-depth ratio of 16 and at a constant crosshead speed of 1mm/min in ambient atmosphere at room temperature. The ending test specimens had rectangular dimensions of 15mm in width and 20 times of the thickness in length according to Japanese Industrial Standards (JIS K7017). The fracture surface of each hybrid composite specimens as inspected and analyzed using a scanning electron microscope (SEM, JSM-5200) after the flexural test. Microscopic analyses were performed aiming to identify the failure mode occurrence in the specimens tested.

3. Results and discussions

3.1 Flexural properties

The flexural properties of different composites are displayed in Fig. 4. It is observed that the flexural strength reached a minimum value of 36.5 MPa for JF with the lowest flexural deflection. In the case of JF/GF and JF/GF/GF, both composites showed similar maximum flexural strength. Additionally, it can be observed that JF/GF/GF resulted into the maximum flexural deflection.

![Flexural stress-deflection curves of different composites](image_url)

Furthermore, the results presented in Fig. 4 are summarized in Fig. 5 showing the average values of the flexural strength and flexural modulus. As depicted in Fig. 5, the minimum flexural strength obtained for JF was approximately 37 MPa. While similar maximum flexural strength were achieved in JF/GF and JF/GF/GF due to similar total fiber volume fraction, that exhibited about respective 61.7 % and 62.0 % higher than the values of JF. However, JF/JF/GF exhibited lower value at around 38 MPa due to larger thickness of specimens than others. Observations on different composites showed that flexural modulus was noticed similar.
Fig. 5 Comparison of flexural modulus and flexural strength.

In summary, JF showed a rapid and steep flexural stress rise, showing the lowest flexural strength among the tested samples, but it also showed a low deflection, indicating a brittle property. It seems that JF/GF and JF/GF/GF exhibited similar flexural properties. Especially, the JF/GF/GF showed a slightly slow flexural stress rise, obtaining the largest yield deflection and the lowest maximum flexural stress from among all tested samples, suggesting that JF/GF/GF has good ductility primarily due to higher elongation property of glass fiber compared with that of jute fiber.

3.2 Scanning electron microscopy (SEM) analysis

The SEM micrographs of the flexural fracture surfaces of different composites are manifested in Fig. 6. Jute fiber pull-outs, split, breakage, cracking of the matrix and debonding were the common occurrences for JF. Both JF/GF and JF/GF/GF showed similar values for flexural strength and modulus (Fig. 5), the latter (JF/GF/GF) showed better ductility, especially (Fig. 4), which could be attributed to higher elongation property of glass fiber compared with that of jute fiber. The scanning electron micrograph (Fig. 6(d)) reveals that relative less glass fiber can be found than that of JF/GF and JF/GF/GF, which led to lower flexural properties.

Fig. 6 SEM micrographs showing the tensile fracture surfaces for different composites specimens; (a) JF, (b) JF/GF, (c) JF/GF/GF, (d) JF/JF/GF.

4. Conclusions

This study explored the possibility of incorporating jute fibers into glass fiber reinforced composite by needle punch system and investigated the hybrid effect on the flexural properties of different laminates. The results obtained can be summarized as follows:

1. Flexural modulus of different composites showed no much variation in the three-point flexural test.
2. It is noteworthy that JF manifested the lowest
flexural strength among the tested samples of different laminates, but it also showed a low deflection, indicating a brittle property.

3. It seems that JF/GF and JF/GF/GF exhibited similar flexural properties. Especially, JF/GF/GF showed better ductility, which could be attributed to higher elongation property of glass fiber compared with that of jute fiber. Whereas, lower flexural strength is achieved in JF/JF/GF due to lager thickness of specimens than other two hybrid composites.

References