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Original Article

Tensile, flexural and interlaminar shear properties of Luffa Cylindrica fibre reinforced epoxy composites

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Abstract
The present investigation is aimed at processing a composite using single, double and triple layer luffa cylindrica fibre mats. The tensile, flexural and interlaminar shear stresses of the composites were studied. The fracture surface of the composite were studied using SEM. From this study it appears that networking structure of fibre increases the tensile and flexural strength for double layer composite. However there is a decrease in strength for triple layer composite which seem to be due to poor wetting of fibre with the matrix material.

Keywords -luffa cylindrica fibre (LCF), tensile strength, flexural strength, interlaminar shear stress, SEM.

Introduction
Increasing environmental awareness throughout the world is motivating the researchers to design material that are compatible with the environment. Synthetic fibre such as glass, carbon and aramid are being widely used in polymer composites because of their high stiffness and strength properties[1,2]. Natural fibre such as jute, bagasse, pineapple, sisal. Banana [3-10] etc based polymer composite form a new class of materials which have good potential to be used in polymer composite and have established themselves as potential fillers materials for numerous applications. The attractive features of these fibres are light weight, high specific modulus, non toxicity, friendly processing and absorbed CO$_2$ during their growth [11, 12]. These outstanding properties of the natural fibres open up areas for these fibres to be used as filler materials replacing synthetic fibers. There is still growing need to find out new fibres as a source of filler material for composite manufacturing. In these categories luffa cylindrica is one such tropical plant which originates from America [13] belongs to cucumber and marrow family. This fruit is popular in China and Southeast Asia and eaten as a vegetable. It is interesting to note that these fibre contains cellulose 63.0%, hemicelluloses 14.4%, lignin 1.6%, ash 0.9% and others 20.1%, which makes it suitable for reinforcing material in polymer matrix [14].

In the pursuit of visualising the importance of this fibre Lassaad Ghali etal [15] studied effects of fibre weight ratio, structure and fibre modification on the Flexural Properties of Luffa-Polyester composites. They observed that the chemical modification of luffa fiber enhanced the flexural strength and the flexural modulus. Boyand etal [16] studied the effect of alkali treated fibre on the flexural properties of the composite. They observed that an increase of 14% improvement in flexural properties with the treated fibre.

Available literatures on luffa cylindrical fiber reinforced polymer composite are scare. Hence the present work has been undertaken to develop luffa cylindrica fibre reinforced epoxy composite. The composites were prepared with single, double and triple layers. The tensile, flexural and interlaminar shear strength (ILSS) of the composite have been studied and reported in this work.

Experimental details
Matrix Material
Epoxy LY 556 is the resin which is used as matrix material. Its common name is bisphenol-A-diglycidyl-ether and it chemically belongs to the epoxide family. The epoxy resin and the hardener are supplied by Ciba Geigy Ltd.

Fiber Material
Luffa cylindrica (LC) is a tropical plant belonging to the family of Cucurbitaceae, with a fruit possessing netting like fibrous vascular system. The LC strut are characterized by a micro cellular architecture with continuous hollow microchannels which forms a vascular bundles and yield a multimodal hierarchical pore system[17]. Figure1(a) shows the sponge guard and the hollow micro channels. This specific morphology makes it possible to imagine a specific composition on crystallinity cellulose. In this work LC fibers were cut to rectangular mat like after opening the
outer core and the micro channel portion as shown in figure 1(b) and (c) from the sponge guard neglecting the end portion to keep the thickness same for the mat and have been used for manufacturing the layered composite.

**Composite fabrication**

A wooden mould of dimension 140×100×6 mm was used for casting the composite slab. The composites were manufactured with single, double and triple layer of luffa cylindrica fibre in three different weight proportions (8 wt%, 13 wt%, and 19 wt%). For different wt% of fibres, a calculated amount of epoxy resin and hardener (ratio of 10:1 by weight) was thoroughly mixed with gentle stirring to minimize air entrapment. For easy removal of the composite from the mold after curing, a releasing agent (silicon spray) is used. Each ply of the LC fibre is of dimension 140×100 mm. The layered composites were made by conventional hand lay-up technique. The cast of each composite is cured under a load of 25 kg for 72 hours before they are removed from the mold. Specimen of required dimensions were cut using a diamond cutter for physical characterisation and mechanical testing. Almost care has been taken to maintain uniformity of the composites. The schematic view of the layered composites is shown in figure 2.

**Experiment**

**Tensile Strength**

The tension test is generally performed on flat specimens. The most commonly used specimen geometries are of dog-bone type and the straight side type with end tabs. The specimen used for the present case is shown in fig 3. The tensile tests were conducted according to the ASTM D 3039-76 standard on a Computerized Universal Testing Machine INSTRON H10KS. The span length of the test specimen used was 42 mm. The tests were performed with a constant strain rate of 2 mm/min.

**Flexural and interlaminar shear strength**

Flexural test were performed using 3-point bending method according to ASTM D790-03 standard procedure. Specimen of 140 mm length and 15 mm wide were cut and were loaded in three point bending with recommended span to depth ratio of 16:1. The same Instron machine is used for this test. The specimens were tested at a crosshead speed of 2 mm/min. The specimen in loading position is shown in fig 4. The flexural strength was found out by using equation 1

\[ \sigma = \frac{3FL}{2bt^2} \]  

Where F is the maximum load (N), L is the distance between the supports (mm), b and t are the width and thickness (mm) respectively.

The ILSS value values are calculated as follows

\[ ILSS = \frac{3F}{4bt} \]

Where ILSS is the interlaminar shear strength (N/mm²), F is the breaking load (N), b and t is the width and thickness of the specimen (mm) respectively.

**Result and discussion**

It is well known that fiber content and fiber strength are mainly responsible for strength properties of the composite. Therefore variation in strength properties of the composite with various fibers loading is obvious. This variation in tensile and flexural strength of the composites, single double and triple layer are presented in table 1 and are shown in fig 5 and 6. These figures clearly indicates the gradual increase in both tensile strength and flexural strength for single and double layer composite. However there is a decrease in both tensile and flexural strength for triple layer composite. It clearly indicates that inclusion of LC fiber improves the load bearing capacity and ability to withstand the bending of the composite. Similar observations are reported by Harsha et al [18] and Acharya et al [19] while they worked for fiber reinforced composite.
Table 1. Mechanical properties of LCF Epoxy Composites

<table>
<thead>
<tr>
<th>Luffa fibre layer</th>
<th>Fibres wt%</th>
<th>Tensile Strength (MPa)</th>
<th>Flexural Strength (MPa)</th>
<th>ILSS (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>neat epoxy</td>
<td>13.50</td>
<td>17.16</td>
<td>0.600</td>
</tr>
<tr>
<td>SL</td>
<td>7</td>
<td>16.29</td>
<td>22.677</td>
<td>0.644</td>
</tr>
<tr>
<td>DL</td>
<td>13</td>
<td>16.76</td>
<td>24.825</td>
<td>1.010</td>
</tr>
<tr>
<td>TL</td>
<td>19</td>
<td>15.78</td>
<td>22.415</td>
<td>1.38</td>
</tr>
</tbody>
</table>

thermoplastic such as poly-ether-ketone composite and jute fiber composites. It may be mentioned here that for recommending any composite as a candidate for structural applications both tensile and flexural strength are of immense important.

Figure 4: Three Point Bending Test with the specimen in loading position

Figure 5: Tensile strength of LCF epoxy composite

The stresses acting on the interface of the two adjacent laminae in a layered composite are called interlaminar shear stress. These stresses cause relative deformation between the consecutive laminae and if these are sufficiently high they may cause failure along the mid plane between two adjacent laminae. It is therefore almost important to evaluate ILSS through test in which failure of the laminates of the composite initiates in a shear (delamination mode). In the present case the ILSS value are measured and found to be appreciable increase for single, double and triple layer composites in comparisons to neat epoxy as shown in fig 7.

Figure 6: Flexural strength of LCF epoxy composite.

Figure 7: Interlaminar shear strength of LCF epoxy composite

Surface morphology of composite samples

The surfaces of the specimens are examined directly by scanning electron microscope JEOL JSM-6480 LV. The composite samples are mounted on the stubs with silver paste. To enhance the conductivity of the samples a thin film of platinum is vacuum evaporated on to them before the photomicrographs are taken. Tensile failure of double layer composites is shown in fig 9(a). Tearing of fiber along loading direction is clearly visible. Tearing/breaking of fiber along transverse direction is not visible. The networking of structure probably restricts the breaking/tearing of fiber along the transverse direction, which mainly responsible for higher tensile strength.
The matrix (fig 8(a)). These voids are small in numbers and hence does not create more problem on the composite properties. For 19 wt% of fiber, debonding between fibers and matrix due to insufficient wetting is clearly visible. This revels that for triple layer composite, poor fiber wetting occurs due to insufficient matrix material which results in lower flexural strength of the composite.

Fig 8(b) shows the tensile failure of triple layer composite. The fiber breakage and pull out of fiber from the matrix is clearly visible. This indicates a poor fiber matrix adhesion which results in lower tensile strength as discussed earlier.

Fig 9(a) and (b) shows the SEM micrograph of the fracture surface of 13 wt% and 19 wt% of LC fiber reinforced composite during bending test. For 13 wt% debonding of fibers at some place which creates voids are visible but most of the fibers are intact with the matrix (fig 8(a)). These voids are small in numbers and hence does not create more problem on the composite properties. For 19 wt% of fiber, debonding between fibers and matrix due to insufficient wetting is clearly visible. This revels that for triple layer composite, poor fiber wetting occurs due to insufficient matrix material which results in lower flexural strength of the composite.

Figure 9(a): SEM image of flexural fractured surface of LCF epoxy composite (a) Double layer (13 wt %)
Figure 9(b): SEM image of flexural fractured surface of LCF epoxy composite (b) triple layer (19 wt %) under flexural load.

Conclusion

The following conclusions are drawn from this study.

• A new set of composites with Luffa cylindrica fiber as reinforcement with epoxy resin are successfully fabricated.

• The maximum tensile and flexural strength is obtained for the composite prepared with the double layer Luffa cylindrica fiber.

• The maximum ILSS is obtained for the composite prepared with triple layer Luffa cylindrica fiber.

• The morphology of fractured surface observed by SEM suggests that the networking of structure restricts the breaking/tearing of fibre which is responsible for higher tensile and flexural strength for double layer composite. The decrease in strength for triple layer composite due to insufficient wetting of fibre with the matrix.

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