Moisture Absorption and Its Effect on Tensile and Flexural Properties of Luffa Fibre Reinforced Epoxy Composite

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ABSTRACT

The present work aims to study the moisture uptake behaviour and its effect on tensile and flexural properties of Luffa cylindrica epoxy composite. Composites were casted with Single (SL), double (DL) and triple layer (TL) of Luffa Cylindrica fibre reinforced with epoxy resin by general hand lay-up technique. Moisture uptake tests of composites were conducted by subjecting the composites samples in three different environments such as distilled water, saltwater (5% NaCl solution) and sub-zero temperature(-5°C). The equilibrium moisture content (EMC) was found out. As the fibre layer increases the percentage of moisture uptake increased due to the high cellulose content. The mechanical properties of the composites were decreased with moisture absorption .Scanning electron microscope (SEM) studies were carried out to study the fracture behaviour of tested samples.

Keywords: *Luffa cylindrica fiber, water absorption, tensile strength, flexural strength.*

NOMENCLATURE

Density	g/cm^3
Temperature	°C
Load	g/f
Length	mm
Time	hours
Speed	mm/min

Greek Symbols

W_0	Initial weight
W_t	Final weight after time 't'

Subscripts

SL	Single
DL	Double
TL	Triple
LC	Luffa cylindrica
wt.%	Weight percentage
EMC	Equilibrium Moisture Content
K_{SR}	Swelling rate parameter

1. INTRODUCTION

Natural fibre composites have emerged as the realistic alternatives to synthetic fibre in many applications due to their easy availability, light weight, low cost, high specific modulus, nontoxicity and pollution-free production. Interestingly several types of natural fibres that are abundantly available, such as jute, bagasse, areca, bananas [1-4] have proved to be useful and efficient reinforcement in polymer matrix composites. However, the significant problems associated with the use of natural fibres in the composite industry are the poor compatibility with the polymer matrix, high moisture absorption and very sensitive to environmental condition [5]. In these composites, delamination due to moisture absorption reduces the interfacial strength and causes degradation in the mechanical properties of the composites.

Luffa cylindrica (LC) a tropical plant belonging to the family of Cucurbitaceous, is one such natural fibre which is abundantly available. Its potential as natural fibre reinforcement in polymer composite can be ascertain from the fact that like other natural fibre, it contains 62.0% cellulose, 20% hemicelluloses, 11.2% lignin, 0.40% ash and 3.1% extracts [6]. The literature on water absorption behaviour and effect of water absorption on mechanical properties of Luffa cylindrical fibre reinforced polymer composite are scare. Ghali et al. [7-8] studied the flexural properties as well as hygrothermal behaviour of alkali treated luffa polyester composite (single layer). They have the opinion that fibre modification decreases the diffusion coefficient and the maximum amount of water absorbed by the fibre. Boyand et al. [9] have also studied the flexural properties of the Luffa cylindrical fibre polyester composite by treating the fibre with alkali. In their work they have taken volume fraction of fibre is limited to 30%.They also have the opinion that the treatments promote a precise removal of outer surface layer with exposition of the inner fibrillary structure and the consequent increase in the fibre surface area, only a secondary increase on the mechanical properties was obtained.

Hence, the present work an attempt has been made to develop Luffa cylindrical reinforced epoxy composite. Composites were prepared with single

(SL), double (DL) and triple (TL) layers of Luffa cylindrical fibre using hand layup technique. The mechanical properties and water absorption behaviour of these composites were tested by subjecting the samples in different environments distil water, saltwater (NaCl 5%), and sub-zero temperature (-5°C).SEM studies were carried out and reported for both dry as well as environmental treated samples to know the fracture mechanism.

2. EXPERIMENTAL DETAILS

2.1. Materials details

Epoxy LY 556 (bisphenol-A-diglycidyl-ether) is used as matrix material. Hardener HY-951 9NN0 (2-amineethylethane-1, 2- diamin) is used as a curing agent. Luffa fibers were collected locally. The details of fiber preparation are given in [10].

2.2. Composite fabrication

Composites were fabricated by hand lay-up technique by a wooden mould of dimension 140×100×6 mm. The composites were casted with single, double and triple layer of Luffa cylindrical 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 in the ratio of 10:1 was thoroughly mixed with gentle stirring to minimize air entrapment. For easy removal of the composite from the mold before using, a releasing agent (silicon spray) is used. Each ply of the LC fibre is of dimension 140x100 mm. The cast of each composite is cured under a load of 25 kg for 72 hours. Specimens of required sizes were cut using a diamond cutter for physical characterization and mechanical testing. The schematic views of layered composites are presented in figure 1.

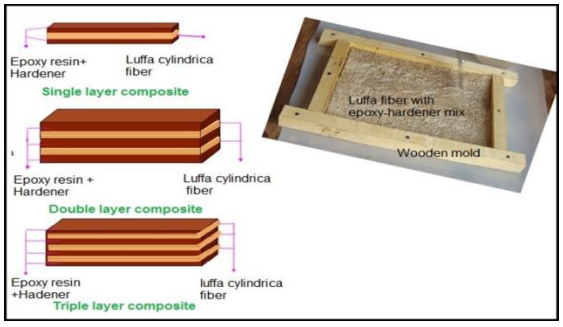

Fig.1: Schematic view of layered composite.

2.3. Moisture absorption and Thickness swelling test

The Moisture uptake and thickness swelling tests were carried out according to ASTM D570-98.Composite were cut to a dimension of 140 x 15mm (length x width) and the experiment was performed for each composite (SL, DL, TL) of five specimens. Before doing the test, samples were dried in an oven at 80° C and kept in a desiccator containing silica gel. The initial weight and thickness of the samples were taken by0.001 accuracies weighing machine and a digital calliper and then subjected to the different environments (distil water, saltwater (5% NaCl) and sub-zero temperature). The samples were taken up from the environmental chamber at regular time interval of 12 hours and the moisture content on the surface of composites were removed by a tissue paper. Then the weight and thickness of the wet samples were measured and subjected to respective environmental chamber. This procedure was repeated till the equilibrium state of moisture content in composite was assumed to be reached. Equilibrium Moisture Content (EMC) of the sample was the moisture content when the periodic weight change of the sample was less than 0.1%, and thus the equilibrium state was assumed to be reached.The percentage moisture uptake of the samples was calculated by (1):

$$M_t(\%) = \frac{(W_t - W_0)}{W_0} \times 100 (1)$$

Where 'W_0' is the initial weight of the composite and 'W_t' is weight of the composite aftertime't 'during aging.

2.4. Mechanical Testing

The tensile and flexural test (three point bend test) of the dry and environmentally treated composites were done by using a Computerized Universal Testing Machine (UTM; H10KS, Hounsfield Test Equipment Ltd, England).The tensile test was done according to standard ASTM D 3039-76. Flexural tests were performed according to the ASTM D790-03 standard. The span lengths of the flexural specimen were 70 mm. Both the tensile and flexural tests were performed at a crosshead speed of 2mm/min.

3. RESULTS AND DISCUSSION

3.1. Moisture absorption behaviour

The EMC of different composites at different environmental conditions are presented in figure 2. It is clearly seen that as the LC fibre layer increases the EMC value increases. It is also observed that moisture absorption rate in distil water environment is more than the salt water. This might have happened because, in case of composite immersed in salt water, NaCl ions are get deposited on the surface of fibre that increases with immersion time and slows down subsequent water diffusion . Again the absorption rate of moisture in distil water and

salt water environment are much higher compared to Sub-zero treatment. Less intermolecular hydrogen bonding in sub-zero treatment is responsible for this type of behaviour.

3.2. Moisture absorption behaviour

3.2. 1 Tensile strength

Figure 3 shows the tensile properties of both dry composite and moisture absorbed samples in different environmental conditions. From the figures, it is clearly observed that the tensile strength increases as the fiber content increases up to the double layer for the dry composites. However, there is a decrease in strength achieved for triple layer dry composites. It might have happened due to poor fibre wetting with matrix materials. The tensile strength obtained for environmentally treated composites also follows the same trend as dry composites. It is also clearly observed that the tensile strength decreases due to moisture absorption as compared to dry composites for all three environments. This reduction in strength is about 12.04-20%, 17.64-26.66% and 10-15% for saltwater, distil water and Subzero temp environment respectively.

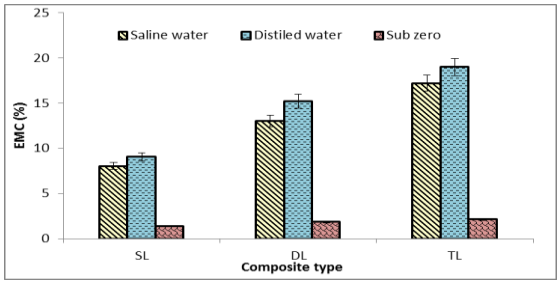

Fig. 2: Equilibrium moisture content (EMC) for single, double and triple layer of LCF epoxy composite at different environmental condition.

Minimum reduction in tensile property for subzero environment is achieved which might be due to less moisture absorption as discussed in the previous section. This reduction of mechanical properties may be attributable to the reduction of bonding strength of fibre and matrix those results in effective stress transfer between fibre and matrix.

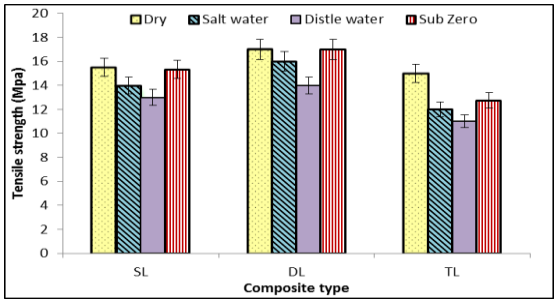

Fig. 3: Tensile strength of dry and environmentally treated composites.

3.2. Flexural strength

Figure 4 shows the flexural strength of both dry and moisture absorbed composite samples that undergone treatments in different environments. The flexural strength found to increase with the fiber content up to double layer then decreases for TL composite. The maximum flexural strength is observed for the composite prepared with double layer reinforcement. It clearly indicates that inclusion of LC fiber improves the load bearing capacity and ability to withstand the bending of the composite up to certain weight fraction of fiber. The flexural strength of environmentally treated composites also decreases due to moisture absorption and follows the same trend as tensile strength. However, it is interesting to note that for TL composite subjected to the subzero environment, the flexural strength increases to about 5%. This type of behavior that occurs might be due to the swelling of fibers, which fill the gaps between the fiber and the polymer matrix and eventually lead to an increase in flexural properties of the composite .

3.3. SEM Morphology of composite sample

Figure 5 (a-d) shows the fractured surface of the composite tested under tensile load under gone treatment in distilled water, saltwater and sub-zero temperature environment. Figure 5(a) shows the micrographs of sample subjected to distilled water, where micro cracking due to swelling of fibre is clearly visible. The occurrence of swelling of fibre is the main cause for developments of cracks in the brittle matrix (epoxy).Figure 5(b) the same micrographs with high magnification where in addition to breaking of fibre, fibre matrix debonding are also visible. Figure 5(c) shows the micrographs subjected to saltwater environment. Here in addition to fibre matrix debonding, matrix cracking as happened for distilled water. Some cavities are also formed due to pull out of fibre. Fibre matrix debonding (gap) in case of sub-zero environment is seems to be less(Figure 5(d)). This might have happened due to less absorption of water because of less intermolecular hydrogen bonding .Therefore the strength of the composite subjected to sub-zero treatment under tensile load is higher. This also supplements to the result shown in figure 3.

Figure 6(a-d) shows the morphology of fractured surface under the flexural load of moisture aged sample in distilled water, saline water and the sub-zero environment. For distilled water exposed samples Figure 6(a), matrix cracking, fibre breakages are clearly visible due to flexural load. Also, fibre-matrix debonding are noticed in higher magnification of same distilled water treated composite under flexural load (Figure (6 (b)) which may be due to water penetrated into

the fibre matrix interface region through the micro cracks developed due to swelling of fibre. For composites exposed Saltwater (Figure 6 (c)), matrix cracking, breakage and Bending of luffa fibres are noticed due to flexural load. Figure 6(d), for composite subjected to sub-zero environment, fibre-matrix debonding are not at all visible and fibres are intact in the matrix may due to less moisture absorption. However, the breaking down of network structure into bundles of small fibres is noticed due to flexural load.

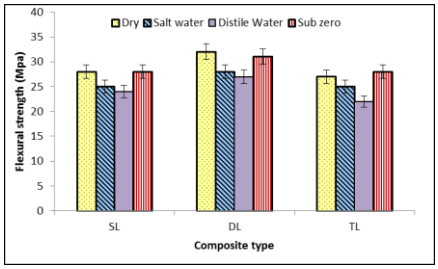

Fig. 4: Flexural strength of dry and environmentally treated composites

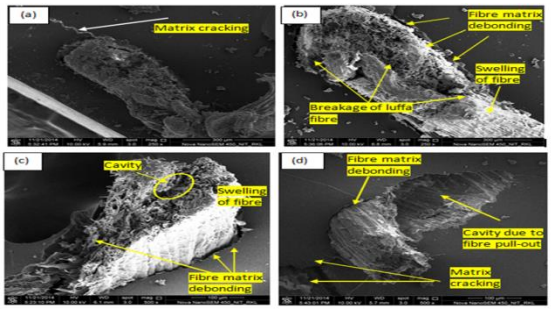

Fig. 5: SEM micrographs of facture surface of composite under tensile load for different environmental condition (a, b) distilled water (c) saline water (d) Sub-zero temperature.

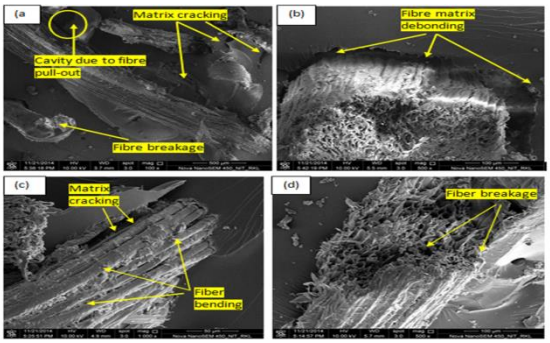

Fig. 6: SEM micrographs of fractured surface under flexural load for different environmental condition (a, b) distilled water (c) saline water (d) sub-zero environment.

4. CONCLUSIONS

The following conclusions have been drawn from this study

1. As the luffa fibre loading increases in the composite, the moisture uptake increases due to a rise of cellulose content for all the environments. The composites subjected to sub-zero environment absorbed less moisture than the salt water and distil water environment.
2. The swelling rate parameter (KSR) of the composites increases with increase in fiber layer. The values of KSR are higher in subzero environment followed by Saltwater and distil water environments. U
3. Under all environmental condition the tensile and flexural properties are decreases as compare to the dry composite samples. The maximum degradation of properties occurs in case of distil water environment followed by salt water and sub-zero environment.

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