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Analysis of Moisture Absorption Effect on The Longitudinal Three Point Bend Properties of Jute Epoxy Composite Processed Under Modified Compression Molding Process

Md. Rashnal Hossain[1, 2,] Md. Aminul Islam[1,] Ayasha Akter[1,] Aart Van Vuure[2] and Ignaas Verpoest[2]

[1] Department of Materials & Metallurgical Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh,

[2] Department of Metallurgy and Materials Engineering, Katholieke Universiteit Leuven, Kasteelpark Arenberg 44 bus 2450, 3001 Heverlee, Belgium

E-mail: hrashnal@gmail.com

Abstract

Commercialized use of natural fiber based polymer composite is of concern since the last two. Along with this the use of jute as reinforcement with polymeric materials has shown considerable interest globally. In this research two types of jute reinforcement namely Bangla White grade B and Bangla Tosha (BT) jute were used. The unidirectional jute preform was clamped while making jute epoxy composite. Longitudinal and transverse tensile and three point bend properties were studied according to ASTM D 3039 and ASTM D 790. Moisture sensitivity of the longitudinal three point bend property was also analyzed at 65%, 85% and 95% (RH) relative humidity. It was observed that the jute epoxy composite shows degradation of longitudinal three point bend strength and stiffness and this degrading affect increases with the increase in the RH value. The microbial growth was also observed. The fractographs of the composites were also analyzed under FEG SEM.

Keywords: *Jute epoxy, BT, BWB, Relative humidity, Moisture gain*

1. Introduction

Jute polymer composites have occupied the field of materials science due to the environmental awareness and to bring some modification of some existing everyday usable items. Continual research in this field has let scientist gather knowledge about this fiber and the matrix that can bring some social changes regarding materials science. But the basic problem to deal is its hygroscopicity for which cases modification of fiber is required [1, 2].

During composite fabrication if jute fiber inside matrix is inappropriately covered with the matrix, and if humidity is changed, then the equilibrium moisture content also changes. This change in moisture content either expands or shrinks the jute fiber thereby probing the fiber polymer interface and due to this reason jute polymer composite property degrades in presence of moist environment [3].

Jute as a natural fiber is hygroscopic in nature and while processing with polymer to make a composite involves pressure, temperature. At this condition although composite is formed, but the natural tendency of jute is to revert to its original shape like shape memory alloy via moisture gain. This implies in presence of moisture jute fiber within the composite body gains water and tries to get back to its early size and shape [4].

However, non-polar materials interact very poorly because of the hydrophilic nature of jute fiber. When a fiber composite fails by an interfacial or adhesive type failure it is presumed that part of failure arise from lack of sufficient chemical bonding between the fiber and matrix. But it is also likely that the part of failure arise from the inability to achieve ultimate molecular contact. Strength can be improved for the fiber reinforced polymer composite if the surface energies of both the fiber and the matrix are compatible. The adhesion between the plastic and polar lingo cellulosic fiber is critical in determining the properties of composite. Transcrystallinity around the fiber surface complicates the understanding of interfacial phenomenon since crystallite can act like cross links by many molecules together, although for jute thermoset composites this is quite different [5, 6].

Research on the moisture diffusion experiments of short jute reinforced PP composite showed dependence of fibre volume content, matrix molecular weight, and matrix modification which was validated according to the Fickian model [6, 7].

The water absorption behavior of pultruded jute polyester composite shows that the water absorption increases with increase in the immersion time. The water absorption process also showed geometry dependence. The decrease in mechanical properties with increasing in moisture content was attributed to the formation of hydrogen bonding between the water molecules and cellulose fibre thereby reducing the rigidity of the cellulose structure and interfering with interface properties [8].

The study of adhesive tensile and moisture absorption properties of randomly distributed areca fibre and maize powder reinforced urea formaldehyde composite showed decreased moisture absorption with decrease in the fibre to maize powder ratio and moisture content increases with the increase in the time duration and attains saturation [9].

The effect of fibrous reinforcement and solvent content on moisture uptake in composite laminate clearly show the contribution of the fiber reinforcement as well as solvent content on the water absorption rate and mechanical property changes [10].

The study of hemp fibre reinforced unsaturated polyester composites were subjected to water immersion. The study indicated that the percentage of moisture uptake increased as the fibre volume fraction increased due to the high cellulose content. Moisture induced degradation of composite samples was significant at elevated temperature [11].

The resistance of injection molded bamboo fiber reinforced polypropylene composite to hygrothermal aging and their fatigue behavior has shown moderate reduction of tensile property after aging. Moisture absorption and tensile strength degradation are suppressed by using maleic anhydride [12].

2. Experimental

BWB and BT Jute were procured from the Bangladesh Jute Research Institute (BJRI). Next to that the procured jute were washed and sun dried for further work. After that the jute fibers were cut up to 350mm length and washed with demonized distilled water and dried over night at 60°C temperature. Dry preforming technique (taking bunch of jute fiber of 350mm length from jute fiber stock and put under tension with adhesive tape on a 400/400 size 3mm aluminum plate) was followed for unidirectional preform preparation.

However jute polymer composite was prepared with modified compression molding technique. As resin material Epikot 828 LVEL (bisphenol A and epichlorehydrine type) epoxy resin was used and the curing agent was diaminocychlohexene. 35% and 60% volume containing BWB jute and 40% and 50% volume containing BT jute epoxy composites were fabricated with this technique.

The fabricated composites were tested for longitudinal and transverse tensile and three point bend properties according to ASTM D 3039 and ASTM D 790. Moisture sensitivity of the longitudinal three point bend property (ASTM D 790) was also analyzed at 65%, 85% and 95% (RH) relative humidity in a humidity chamber under 50°C temperature.

The percentage moisture gain was plotted against the square root of time (hour). Gradual moisture absorption behavior of the composites was also analyzed for all the composites. Only the longitudinal three point bending properties are discussed, due to the limited scope of the paper. At the final stage of moisture saturation the composite specimens were tested under three point bending according to ASTM D 790 and a plot of strength variation to that of % moisture gain was obtained. Microbial activity was also observed under SEM.

As additional work the BWB jute and BT jute single fiber tensile test was carried out in different set of experiment and the result is used here in this paper but discussion opted out due to paper limitation.

3. Results and discussion

The tensile property of BWB jute was found; strength 844.72MPa, stiffness 55.44 GPa and strain to failure is 1.64%. The tensile property of BT jute was found; strength 671.73 MPa, stiffness 34.63 GPa, and strain to failure 1.93%. The tensile strength of epoxy resin was found; strength 87.2 MPa, stiffness 3.89 GPa and strain to failure 2.14%.

3.1. Three point bending property of jute epoxy composites

Table 1 shows the three point bending behavior of BWB and BT jute epoxy composites in the longitudinal direction. The effect of volume fraction and the fiber wet ability with matrix is clearly observed in this table. And it can be said from the above table that the optimum jute fiber volume fraction for any kind of jute polymer composite must never exceed 50% volume to that of the whole composite.

If we consider Table 1 then we must notice that the experimentally obtained strength value rests within the theoretical strength value of jute epoxy composites. But the stiffness value is much higher than the theoretical value, which is attributed to the betterment of fiber matrix interaction inside composite due to modification in the composite processing technique. But due to wet ability problem this phenomenon does not go well with 60% volume containing BWB jute epoxy composite.

Table 1. Longitudinal three point bending property of BWB and BT jute reinforced composite

Name	Strength Mpa	SD	Stiffness Gpa	SD	Strain to Failure %	SD
35%BWB	205.93	17.89	17.24	2.24	1.99%	0.10%
60%BWB	233.66	22.54	19.77	2.27	2.01%	0.21%
40%BT	245.22	15.86	22.03	1.43	1.67%	0.18%
50%BT	349.12	20.28	36.44	3.25	1.43%	0.09%

When jute composite is failed under longitudinal three point bend loading the fracture surface would look like the following as shown in Figure 1a to d.

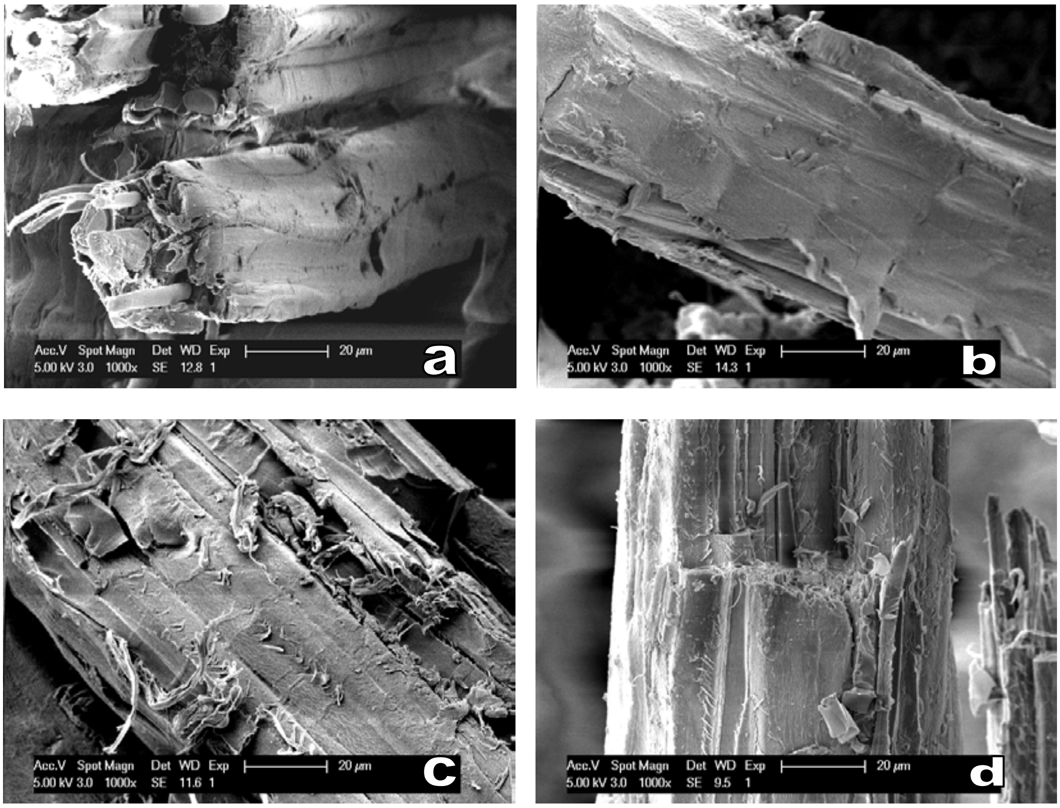

Fig 1: Fracture surface observation of unidirectional composite under longitudinal three point bend load; a) 35% BWB, b) 40% BT, c) 50% BT and d) 60% BWB

The messages from the figures are very clear that the BT jute contains the most resin debris (Fig 1b & c). But the wet ability is severely affected by higher volume of BWB jute as shown in Figure 1d, where as moderate amount of resin is adhered with BWB jute at 35% fiber volume fraction as shown in Figure 1a. Therefore BT jute showed better adhesion with epoxy compared to the BWB jute.

3.2. Effect of humidity on property of jute epoxy composite

There are two kinds of impact of moisture absorption on the properties of jute epoxy composites. First, as the relative humidity value increases the percentage moisture absorption increases and reaches a certain steady value at that condition we say that the moisture absorption of composites reaches saturation. There is also a time constraints that is under low RH value if longer time of moisture absorption is allowed then that also assists the jute fiber reinforced composite to reach a certain saturation value. This is since, with increasing RH there is particular percentage of moisture that remains in equilibrium with the jute fiber and the equilibrium moisture gain also varies with the variety of jute. Therefore it can be said that the jute variety, relative humidity, time, temperature and equilibrium moisture content, all plays their role cumulatively during moisture absorption test.

Experiments have also revealed that as the jute volume fraction is increased the tendency of higher moisture absorption is also increased [6, 13]. For jute like natural fiber it is very hard to achieve proper wetting at the higher volume fraction composite, which means that this makes the composite more vulnerable to moisture attack.

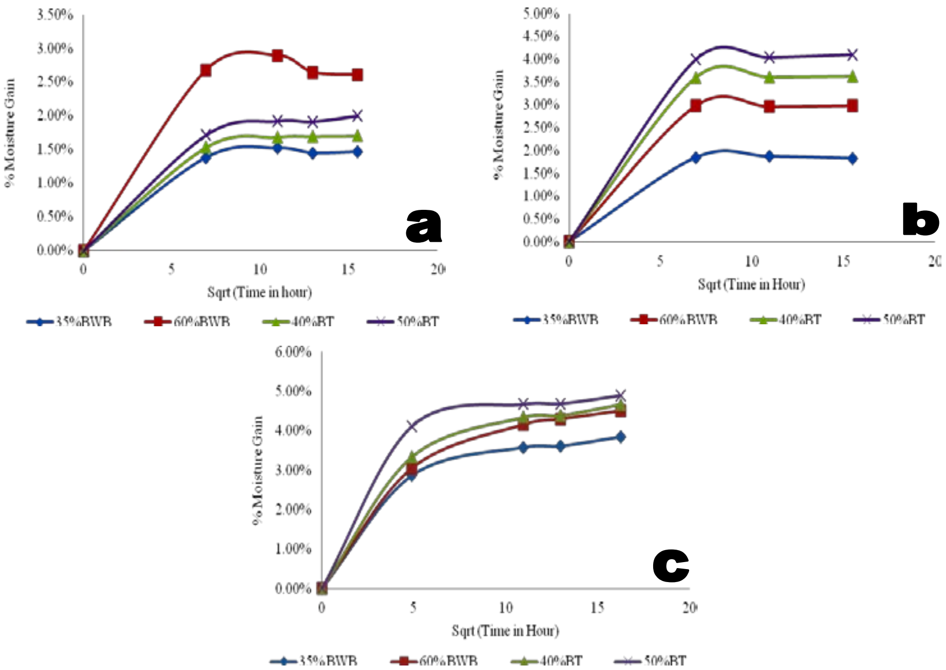

Fig 2: Moisture absorption behavior of jute epoxy composites at different relative humidity; a) 65%RH, b) 85%RH and c) 95%RH

Figure 2 a, b and c shows the moisture absorption characteristics of jute epoxy composites at two different fiber volume fractions. At 65% RH value the 40% and 50% BT jute reinforced composite showed intermediate moisture gain between the 35%BWB and 60% BWB jute reinforced epoxy composite (Fig 2a). Successively at 85% RH value both BWB and BT jute showed reinforcement volume fraction dependent moisture absorption behavior and BT jute showed higher moisture absorption compared to BWB jute (Fig 2b). But at 95%RH the initial moisture uptake rate is similar for both the 35% and 60% volume fraction BWB jute containing epoxy composites but BT jute reinforced composite clearly showed higher degree of moisture absorption (Fig 2c) . However, as the equilibrium moisture content is higher for the higher volume fraction jute containing epoxy composite so if we virtually combine the three charts we definitely notice that both the BWB and BT jute at different fiber volume fraction showed different moisture absorption at different RH value.

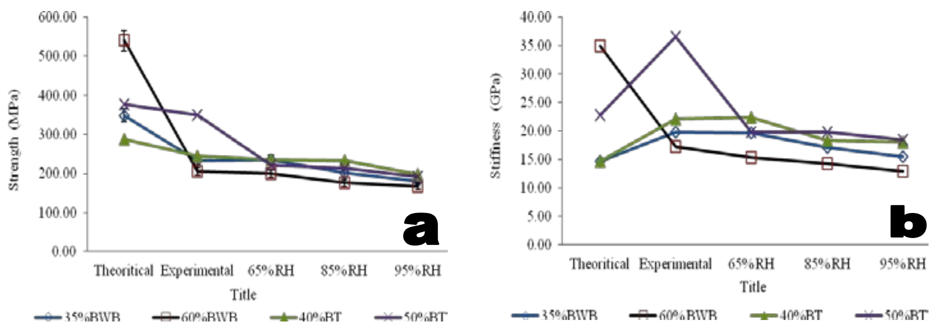

Fig 3: Effect of moisture absorption on the longitudinal three point bending property of jute epoxy composites; a) Strength and b) stiffness

Figure 3a shows the longitudinal three point bending strength degradation behavior of BWB jute epoxy composites at different relative humidity value. Before augmenting further a little reminder could be made, that is both 35% and 60% volume fraction jute containing epoxy composite showed lower strength than the theoretical value. Additionally as moisture at different RH begins to penetrate the unidirectional jute epoxy composites, it showed strength degradation. Although not drastic but continual degradation of strength value is noticeable. Figure 3b shows the stiffness degradation trend of jute epoxy composites. Similar kind of behavior of BT jute reinforced composite was also observed. However, in this case the degradation is noticeable [6, 7, and 14].

Lignin is water repellent but susceptible to microbial action, but cellulose on the other hand is hygroscopic. However, during moisture gain the jute fiber bulges since the cellulose –OH group forms hydrogen bonding with the absorbed and adsorbed moisture. Consecutively as the fiber becomes dry it returns to its earlier shape. Therefore, in some sense jute fiber acts like shape memory alloy [14, 15].

Jute as a fiber contains 8% equilibrium moisture. The natural procedure is sun drying. But after oven drying if the jute fiber is taken in normal environment it again regains moisture [1 – 6, and16].

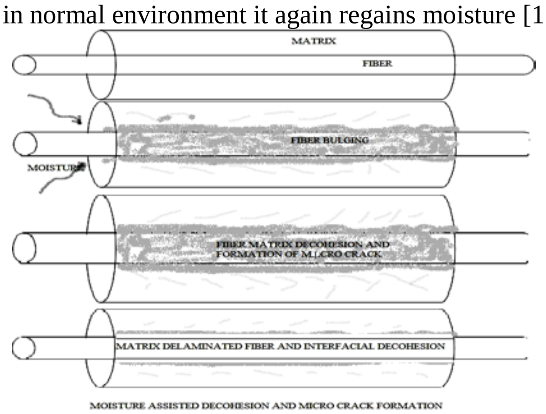

Fig 4: Schematic view of moisture absorption and effect at the interface of jute epoxy composite.

In the moist condition the jute fiber uptakes moisture and becomes bulged and it creates pressure at the jute polymer interface and as this moisture gain continues the jute fiber forces itself to regain its earlier shape. However, as the relative humidity of the environment differs so the moisture gain and discharge from the jute fiber also changes so as to ensure equilibrium. So this changing condition affects the cohesion and adhesion of jute fiber and polymer, which damages the fiber matrix interface and degrades the overall composite mechanical property and this is schematically shown in Figure 4.

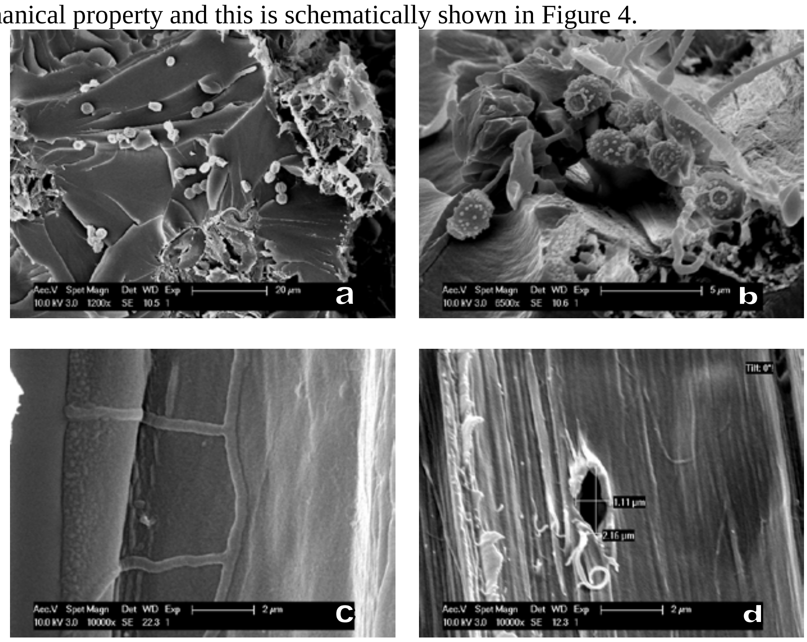

Fig 5: Bacterial growth on the a) epoxy matrix and b) jute fiber and bacterial action on ac epoxy matrix and d) jute fiber

The moisture absorption not only affects the fiber but also assists the microorganism to penetrate the composite body and synergize degrading affect, which is shown in Figure 5 a & b. So, during useful life the fiber should be effectively isolated from the environment to resist microbial action. From Figure 5 c & d it is observed that the bacterial action has perforated the fiber at some localized position and also created channel like entity on epoxy resin. This action degrades the fiber property by decreasing the fiber strength, which intern influences the composite property.

4. Conclusion

Based on the above study the following conclusions could be made
1. Modified compression molding showed higher stiffness value of composites then theoretical and the actual reason is yet unknown.
2. The percentage moisture absorption is diffusion controlled and an equilibrium process and as the saturation level is attained the moisture absorption and desorption remains steady.
3. Moisture absorption assists in formation of microbial growth which degrades composite property. which is dependent on the time, temperature, relative humidity.

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