Tensile and bending properties of jute fiber mat reinforced unsaturated polyester matrix composites produced by a modified hand lay-up method

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Abstract
Jute fiber mat reinforced unsaturated polyester matrix composites having different fiber weight contents (11, 22, 32 wt%) were fabricated by modifying the hand lay-up technique with resin pre-impregnation into the jute mats in the vacuum. Tension and three-point bending tests were carried out to evaluate the effect of fiber contents on these mechanical properties of above-mentioned composites. The results show that as the fiber weight content increases, Tensile and flexural properties (strength and modulus) increase. Fiber pull out mechanism is the predominant failure mode revealed at the fracture surfaces under tensile load as well as at tension side of composites under bending load.

1. Introduction
Natural fibers reinforced composite materials have been subject of many intensive studies due to the considerable characteristics of the natural fibers, such as biodegradability, abundance, renewability, etc. However certain drawbacks, such as incompatibility with the hydrophobic polymer matrices, the tendency to form aggregates during processing, and poor resistance to moisture absorption, reduce significantly the mechanical properties of the natural fibers reinforced composite materials [1-3].

Amongst the natural fibers used as composite reinforcements, jute fiber constitutes large area of investigation. This is because the good mechanical properties of jute fibers when compared with other natural fiber, such as sisal, coir, and ramie [1]. Several authors have studied the continuous jute fiber composites from different aspects, e.g., mechanical properties [4-6] dynamic mechanical properties [7], and physical properties [5].

In this research, a modified hand lay-up technique was introduced to fabricate jute fiber mat reinforced unsaturated polyester matrix composites. The same fabrication procedure of the conventional hand lay-up technique was used after primary resin impregnation into the jute mats in vacuum conditions. The effect of jute fiber weight contents on the tensile properties, bending properties and fracture behavior of the composites was examined for determining the required fiber weight content for high performance composites.

2. Experimental procedure

2.1 Preparation of the composites
Jute fiber mats consisting of 50% jute slivers and 50% recycled jute were prepared by Yano Co.LTD, Japan. Unsaturated polyester, Rigorac™ was obtained from Showa Denko K.K., Japan and the curing agent is Methyl ethyl ketone peroxide (PERMEK® N) obtained from NOF Corporation, Japan.

The jute mats were dried for 6 h at 100°C and were completely submerged in unsaturated polyester resin. The next step is that the jute mats were degassed in a vacuum for 20 minutes at room temperature to remove the entrapped air bubbles. Then, the jute mats were cured under a pressure of about 15 kg/cm² at room temperature
for 24 h with the presence of a 6 mm spacer to produce the composite on the same thickness for different fiber contents. The composite was then post-cured at 100°C for 2 h and finally it was allowed to cool naturally to room temperature for about 30 minutes.

2.2 Mechanical characterization

Tensile properties were determined according to ASTM D 3093/ D3039 M standard with sample dimensions of 250x25x6 mm. The measurements were done using a universal Instron testing machine (Model 55 R 4206, Japan) at a crosshead speed of 1mm/min. at room temperature. Three-point bending test was also done using the same machine according to ASTM D 790-03 at a crosshead speed of 1mm/min with sample dimensions of 140x18x6 mm and the span to depth ratio was 16:1. The fracture behavior of the composites for the different mechanical tests was studied using scanning electron microscope (SEM).

3. Results and discussions

3.1 Tensile properties of the composites

The tensile strength and young’s modulus of neat resin and jute mat composites at different fiber weight contents are indicated in Fig. 1. It can be seen that the tensile strength and young’s modulus increase as the fiber weight content increases. The tensile strength was decreased by 16% at 11 wt% fiber weight content compared to the value of neat resin, while the young’s modulus was decreased by 18% compared to that of the neat resin. The dispersion of the fiber is very poor so that the stress transfer will not work properly and according to [4], when the volume fraction of the reinforcing fiber is lower than the critical quantity, the fiber acted as flaws in the matrix. The improvement had occurred at 22 wt% fiber weight content, which by increasing the fiber weight content to 22 wt%, the tensile strength and young’s modulus were improved by 16% and 67% compared to those of the neat resin respectively. Increasing the fiber weight content to 32 wt%, an additional upgrading of tensile strength and young’s modulus had occurred by 48% and 96%, respectively with respect to those of the neat resin.

The fracture surface of the composites for different fiber contents under tensile loading is emphasized in Fig. 2, fiber pull out is the predominant failure mode during the fracture behavior. As the fiber content increases, the retention of the resin with the broken fiber ends increases as shown in Fig. 2a, b and c, so the stress transfer characteristics from the matrix to the fibers were improved and so the tensile strength and modulus increase.

![Figure 1](image1.png)

**Fig. 1.** Effect of fiber content on (a) the tensile strength and (b) young’s modulus of the composites.
3.2 Flexural properties of the composites

The effect of fiber weight content on the flexural strength and modulus is displayed in Fig. 3a and b respectively. It can be observed that as the fiber content increases, the flexural strength and modulus increase. The flexural strength was decreased by 28% at the lower fiber content 11wt% compared to the value of neat
resin whereas the enhancement for the flexural modulus had occurred at the same fiber weight content which was enhanced by 33% compared to that of the neat resin. By increasing the fiber content to 22 wt%, the improvement of the flexural modulus is 49%, while the flexural strength was decreased 10% regarding to that of neat resin. The flexural strength and modulus was improved 15% and 83%, respectively by increasing the fiber weight content to 32 wt% with respect to the value of neat resin.

The fracture surface of the composites after three-point bending test for tension side for different fiber contents is shown in Fig. 4, fiber pullout is the predominant failure mode for different fiber contents. At 11 and 22 wt% fiber contents, holes result from deboning and complete pull out occurring along the fiber as shown in Fig. 4a and b. It can be seen from the fiber ends in the fracture surface that most of the fibers are unbroken due to the lack of interaction at the interface which will lead to a poor stress transfer between the matrix and the fiber. On the other hand, the fewest holes and broken fibers were found on the fracture surface at 32 wt% fiber content as shown in Fig. 4c indicating that pull out occurring along the fiber due to better stress transfer characteristics between the matrix and the fiber. Moreover, it can also be observed that as the fiber content increases, the retention of the resin with the broken fiber ends increases as shown in Fig. 4a, b and c indicating that the increase of the fiber weight content enhances the load transfer characteristics from the matrix to the fibers, so the flexural strength and modulus increase.

4. Conclusion

Jute fiber mat reinforced unsaturated polyester matrix composites were fabricated by modifying the hand lay-up technique. As the fiber weight content increases, Tensile and flexural properties (strength and modulus) increase. Specifically, the improvement of tensile strength and modules had occurred at 22 wt%, while the improvement had occurred for the flexural strength and modulus at 32 and 11 wt% respectively. Fiber pull out mechanism is the predominant failure mode revealed at the fracture surfaces under tensile loading as well as at tension side of composites under bending load.

References