MECHANICAL PROPERTIES STUDY OF PSEUDO-STEM BANANA FIBER REINFORCED EPOXY COMPOSITE

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1. INTRODUCTION

Composite materials were known to mankind in the Paleolithic age (also known as Old Stone age). The 300 ft high *ziggurat* or temple tower built in the city center of Babylon was made with clay mixed with finely chopped straw [1, 2]. In recent years, polymeric based composite materials are being used in many applications, such as automotive, sporting goods, marine, electrical, industrial, construction, household appliances, *etc*. Polymeric composites have high strength and stiffness, light weight, and high corrosion resistance.

In the past decade, extensive research work has been carried out on the natural fiber reinforced composite materials in many applications. Natural fibers are available in abundance in nature and can be used to reinforce polymers to obtain light and strong materials. Natural fibers from plants are beginning to find their way into commercial applications such as automotive industries, household applications, *etc*. [3].

A number of investigations have been conducted on several types of natural fibers such as kenaf, hemp, flax, bamboo, and jute to study the effect of these fibers on the mechanical properties of composite materials [4–7]. Mansur and Aziz [6] studied bamboo-mesh reinforced cement composites, and found that this reinforcing material could enhance the ductility and toughness of the cement matrix, and increase significantly its tensile, flexural, and impact strengths.

On the other hand, jute fabric-reinforced polyester composites were tested for the evaluation of mechanical properties and compared with wood composite [7], and it was found that the jute fiber composite has better strengths than wood composites. A pulp fiber reinforced thermoplastic composite was investigated and found to have a combination of stiffness increased by a factor of 5.2 and strength increased by a factor of 2.3 relative to the virgin polymer [8].

Information on the usage of banana fibers in reinforcing polymers is limited in the literature. In dynamic mechanical analysis, Laly *et al*. [9] have investigated banana fiber reinforced polyester composites and found that the optimum content of banana fiber is 40%. Mechanical properties of banana–fiber–cement composites were investigated physically and mechanically by Corbiere-Nicollier *et al*. [10]. It was reported that kraft pulped banana fiber composite has good flexural strength. In addition, short banana fiber reinforced polyester composite was studied by Pothan *et al*. [11]; the study concentrated on the effect of fiber length and fiber content. The maximum tensile strength was observed at 30 mm fiber length while maximum impact strength was observed at 40 mm fiber length. Incorporation of 40% untreated fibers provides a 20% increase in the tensile strength and a 34% increase in impact strength. Joseph *et al*. [12] tested banana fiber and glass fiber with varying fiber length and fiber content as well. The analysis of tensile, flexural, and impact properties

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Key Words: Pseudo-stem banana fiber, epoxy, mechanical properties, SEM

Paper Received 15 October 2005; Revised 28 July 2006; Accepted 8 November 2006

of these composites revealed that composites with good strength could be successfully developed using banana fiber as the reinforcing agent. The source of banana fiber is the waste banana trunks or stems which are abundant in many places in the world. Therefore, composites of high–strength pseudo-stem banana woven fabric reinforcement polymer can be used in a broad range of applications. The objective of this paper is to study the tensile, flexural, and impact properties of pseudo-stem banana fiber reinforced epoxy composites.

2. EXPERIMENTAL DETAILS

1.1. Preparation of Banana Fibers and Matrix Materials

The pseudo-stem banana woven fabric reinforced epoxy composite was prepared by the hand lay-up method. The fibers are extracted from banana stems by hand and dried in sunlight for 12 hours until all the moisture is removed from the fiber. The dried fibers are made in the configuration of woven fabric as shown in Figure 1.

Figure 1. Pseudo-stem banana fibers in the woven fabric configuration

Matrix material (epoxy resin, grade 3554A and hardener grade 3554B) were prepared in a portion of 4 parts of epoxy resin and 1 part of hardener by volume. These two materials were thoroughly mixed and stirred at low speed until it become uniform. The matrix material was poured into the mould slowly in order to avoid air trapping. The mixture was left for 2 hours so that it becomes a little tacky. After that, the banana fiber woven fabric was laid on the matrix layer, which was covered by another layer of matrix by pouring the mixture slowly onto the surface of the fiber woven fabric. The three-layered composite was cured at room temperature until it was dry, as shown in Figure 2. The same steps were used to make an unreinforced epoxy material.

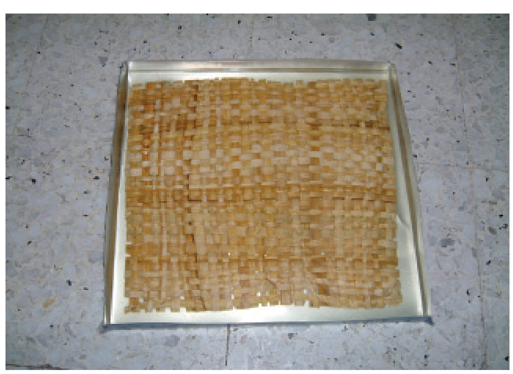

Figure 2. Pseudo-stem banana fibers reinforced epoxy composite during curing process

1.2. Tensile Test

After the unreinforced epoxy resin and fibers reinforced composite was dried, it was cut using a saw cutter to get the dimension of specimen for mechanical testing. The tensile test specimen was prepared (Figure 3) according to ASTM D638; the details dimension, gauge length and cross-head speed can be found at ASTM D638 [13]. The specimen was mounted in the grips of the Instron universal tester with 10 mm gauge length. The stress strain curve was plotted during the test for the determination of ultimate tensile strength and elastic modulus. From the stress-strain curve, a straight line was drawn and from the slope of the line the Young's modulus or elastic modulus was determined. All the test results were taken from the average of two tests.

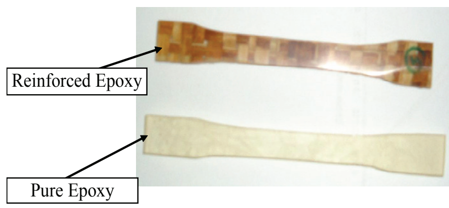

Figure 3. Tensile test specimen of banana fabric reinforced epoxy composite and virgin epoxy material

1.3. Flexural Test

The flexural test specimen dimension was 15mm ×100mm×5mm and three point bend method was used for flexural test according to BS EN ISO 14125:1998 [14].

1.4. Impact Test

By using a notch milling machine, the standard specimens were prepared for impact testing and Jalling weight impact test was performed as per BS 2782 [15]. The specimen was clamped into the pendulum impact test fixture with the notched side facing the striking edge of the pendulum. The energy loss was obtained from reading at scale plate.

3. RESULT AND DISCUSSION

1.1. Tensile Properties

Figure 4 shows the ultimate tensile strength (UTS) of virgin epoxy and pseudo-stem banana reinforced epoxy composite. The tensile test results depict that UTS of virgin epoxy resin was in the range of 22–26 MPa, and the mean is 23.98 MPa. The UTS of banana fibers reinforced epoxy resin was in the range of 44–50 MPa, and the mean was 45.57 MPa. The UTS of banana fiber reinforced epoxy composite increased by 90% as compared to the unreinforced epoxy. The epoxy matrix transmits and distributes the applied stress to the banana fiber resulting in higher strength. Therefore, the composite can sustain higher load before failure compared to the unreinforced epoxy. In addition, higher ultimate tensile strength and higher elongation leads to higher toughness of the material. Figure 5 shows the result of the Young's modulus of the virgin

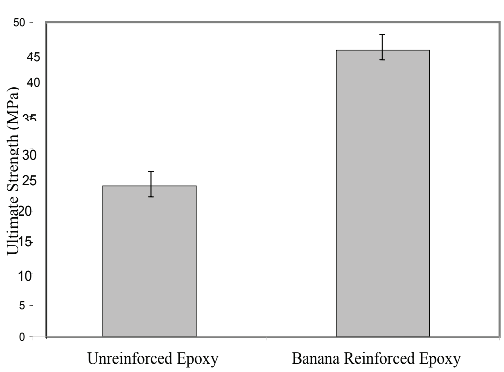

Figure 4. Ultimate Tensile Strength of virgin epoxy and pseudo-stem banana reinforced epoxy composite

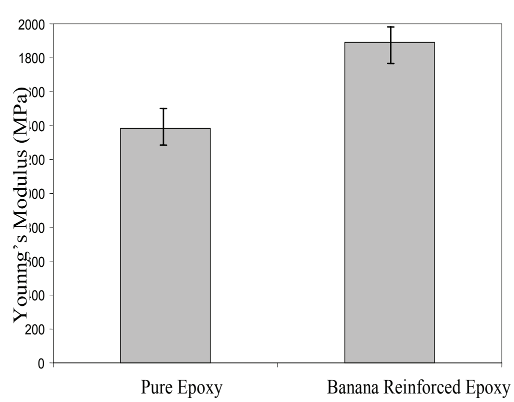

Figure 5. Tensile Young's modulus of virgin epoxy and pseudo-stem banana reinforced epoxy composite

and reinforced epoxy composite. It can be seen that the Young's modulus of the banana fiber reinforced epoxy composite was greater than the virgin epoxy. The average values of Young's modulus of the virgin and reinforced epoxy was 1390 MPa and 1890 MPa respectively, which indicated that the Young's modulus increased by 36% in banana fiber reinforced composite.

1.2. Flexural Properties

Figure 6 shows the flexural strength of the virgin epoxy resin and pseudo-stem banana woven fabric reinforced epoxy composite. From the figure, it can be seen that the flexural strength increased from 53.38 MPa to 73.58 MPa when banana woven fabric was used with epoxy material. The flexural modulus which is used as an indication of a material's stiffness in static bending condition shows an increase from 1563.2 MPa to 1834.6 MPa for the banana fiber reinforced composite as shown in Figure 7.

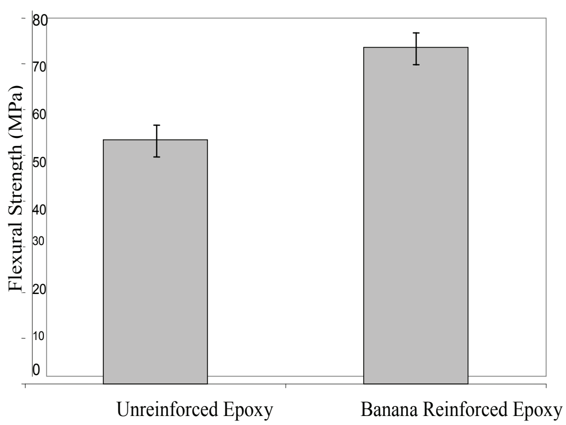

Figure 4. Ultimate Tensile Strength of virgin epoxy and pseudo-stem banana reinforced epoxy composite

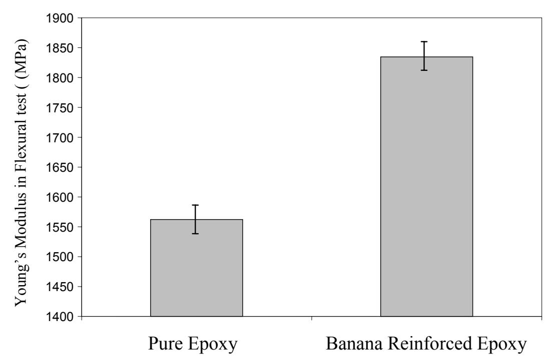

Figure 5. Tensile Young's modulus of virgin epoxy and pseudo-stem banana reinforced epoxy composite

1.3. Impact Properties

The impact response in pseudo-stem banana fiber reinforced epoxy composites reflects a failure process involving crack initiation and growth in the resin matrix, fiber breakage and pullout, delaminating and disbanding. Figure 8 shows the impact strength values for virgin and pseudo-stem banana reinforced epoxy, which are 4.92 kJ/m^2 and 6.95 kJ/m^2 respectively. The result of impact test showed that the banana fiber improved the impact strength properties of the virgin epoxy material approximately 40%. Higher impact strength value leads to the higher toughness properties of the material.

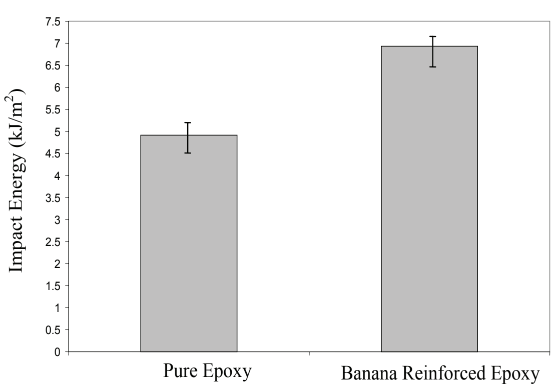

Figure 6. Flexural strength of virgin epoxy and pseudo-stem banana fiber reinforced epoxy composite material

3.4. Fracture Surface Study by SEM

The fracture surface study of pseudo-stem banana woven fabric epoxy composite is shown in Figures 9, 10. From the SEM micrograph of the fracture surface after the tensile test, it can be seen that the banana fiber composite exhibits a ductile appearance with minimum plastic deformation. Afracture profile in the form of a ridge appears on the surface, with the presence of continuous banana fibers. Higher magnification (Figure 10) also showed the continuous banana fibers with a fractured epoxy matrix, which again depicts the ductile characteristics and high strength carrying capacity of the fibers.

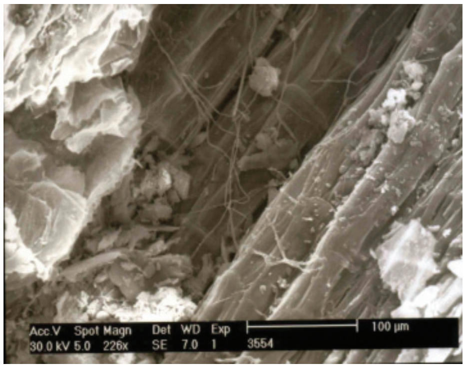

Figure 9. Scanning electron micrograph of banana woven fabric epoxy composite after tensile test at 226×magnification

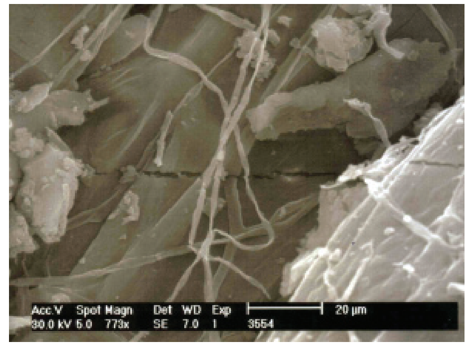

Figure 10. Scanning electron micrograph of banana woven fabric epoxy composite after tensile test at 773×magnification

4. CONCLUSIONS

The following conclusions can be drawn from the present study

1. The tensile strength on the pseudo-stem banana woven fabric reinforced epoxy composite is increased by 90% compared to virgin epoxy.
2. The flexural strength increased when banana woven fabric was used with epoxy material.
3. The results of the impact strength test showed that the pseudo-stem banana fiber improved the impact strength properties of the virgin epoxy material by approximately 40%. Higher impact strength value leads to higher toughness properties of the material.
4. The banana fiber composite exhibits a ductile appearance with minimum plastic deformation.

5. ACKNOWEDGEMENTS

The authors of this paper would like to express their gratitude and sincere appreciation to the Faculty of Engineering & Technology, Multimedia University and Department of Mechanical Engineering, University of Malaya for the supports that made this study possible.

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