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EFFECT OF VOLUME FRACTION OF PSEUDO-STEM BANANA FIBER ON THE PROPERTIES OF EPOXY COMPOSITE

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ABSTRACT

The aim of this study is to investigate the influence of the volume fraction of pseudo-stem banana fiber (woven fabric form) on the properties of epoxy composite. The banana woven fabric was prepared from waste banana stem or trunk, and hand lay-up technique was used to prepare the reinforced epoxy composite specimens. Tensile, flexural, and impact tests were conducted to investigate the mechanical behavior of pseudo-stem banana fiber into epoxy resin. After carrying out the experimental work, a great potential of using pseudo-stem banana fiber to reinforce in to epoxy matrix was observed. The experimental results showed the improved tensile, flexural and impact characteristics of epoxy resin in presence of banana fiber. The tensile properties increased with increasing the volume fraction of pseudo-stem banana fiber in the epoxy matrix. Since waste banana stem exist in abundance therefore, the feasibility of using this fiber in conjunction with an epoxy matrix to develop composite materials for household application is very promising. The thermal properties study after thermal conductivity test is also discussed in this paper.

Keywords: Banana fiber, epoxy, volume fraction, mechanical properties.

1. INTRODUCTION

Currently, polymeric based composite materials are being used for many life applications, such as, automotive, sporting goods, marine, electrical, industrial, construction, household appliances etc. because of their unique properties with high strength and stiffness, light weight, economical and corrosion resistance. In past decade, the research work on polymer based composite materials has been devoted as the use of these materials has been increased tremendously in many applications. As a reinforcement material, the natural fibers are free resource to reinforce into polymer matrix in order to develop a light and strong material.

Recently, natural fibers (such as, flax, jute, cotton, coconut etc.) are being used as a reinforce material into polymeric based matrix for enhancing the mechanical properties of the basic polymer [1-4]. Natural fiber composite is actually not a new technology found in human history. Egyptian should have been given the credit on introducing natural fiber composite to human civilization since the greatest known composite was found in Egypt. The pyramid in Egypt was built using a combination of straw, clay and sand. Derive from this evidence now researchers are pursuing to develop a natural fiber composite that can give comparable strength with existing material such as wood, steel, plastic and also synthetic fiber composite. Traditionally, natural fiber composites have been using for many household components/products such as basket, clothing, sacks, ropes and rug, kitchen cabinet, tray etc.

Natural fibers are basically obtained in the form of bast or stem, leaf fiber, core pith or stick fiber, seed hair fiber and other plant fiber [5]. Research works have been done on the mechanical properties of different natural fiber composites [6]. It was found that the maximum tensile, impact and flexural strength of the natural fiber reinforced plastic (NFRP) composite are 104.0 MN/m^2 for jute-epoxy composite, 22.0 kJ/m^2 for jute-polyester composite and 64.0 MN/m^2 for banana-polyester composite.

The main advantage of natural fiber composite is it's low impact to environment (eco-friendly). Another reasonable advantage of natural fiber is the better strength to weight ratio to replace glass-filled and some unfilled plastics in interior trim [6]. Another attraction is that the manufacturing cost of these materials is less especially when the fiber is taken from waste component of plant. Physically natural fiber is suitable for developing a composite because of the cellulosic which contain a strong hydroxyl bond. Earlier study on the fiber composition and morphology have found that cellulose content and microfibril angle tend to control the mechanical properties of cellulosic fiber [7]. Also higher cellulose content and lower microfibril angle result in higher work of fracture in impact testing.

Since volume fraction of the fiber is an important parameter in the development of composite which might play a big role in the mechanical properties of the development of natural fiber composite, the research study of this fiber content parameter on the mechanical properties of banana woven fabric epoxy composite is scared in literature. Therefore, the aim of this paper is to study the effect of the volume fraction of pseudo-stem banana fiber (woven fabric form) on the properties of epoxy composite made by hand lay- up technique and find the feasibility of using this fiber in conjunction with an epoxy matrix to develop composite materials for household application.

2. MATERIALS AND METHODOLOGY

2.1 Preparation of banana Fiber and Matrix Materials

The fabrication method of pseudo-stem banana woven fabric reinforced epoxy composite was the hand lay-up method since the fibers are extracted from banana stems by hand, and it was dried by sunlight. Then, the dried fibers are made in the configuration of woven fabric as shown in Fig. 1.

Fig 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 becomes uniform. The matrix material was poured into the mould slowly in order to avoid air trap. 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 and another layer of matrix covers it by pouring the mixture slowly onto the surface of the fibers woven fabric. The banana woven fabric (with different volume fraction) composites are cured at room temperature until it was dried as shown in figure 2. The same steps were used to make an unreinforced epoxy material.

2.2 Thermal Conductivity Testing

Thermal conductivity test was conducted in finding the developed composite thermal conductivity in terms of coefficient of thermal conductivity by using WL376 Thermal Conductivity Unit. Thermal conductivity coefficient is a constant value of material ability in conducting heat. High thermal conductivity coefficient gives an impression that the heat can transfer through the material efficiently. While, low thermal conductivity coefficient shows that the material will resist heat transfer through it, which is suitable for heat insulation. Along with the thermal conductivity coefficient, it is also possible to measure the thermal resistance coefficient in heat flow through the material.

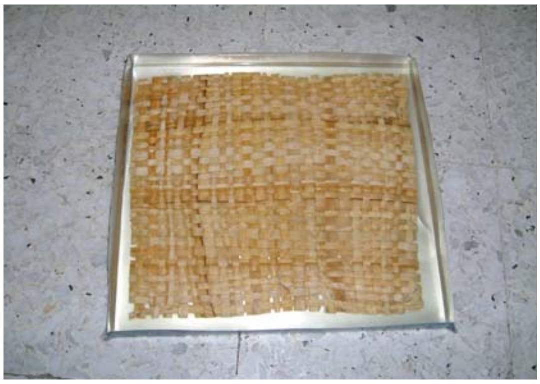


Fig 2. Pseudo-stem banana fibers reinforced epoxy composite during curing process

Test specimen was put into the furnace of the test unit. A heater was used to supply heat to the specimen. Heat flows through the specimen to cooling plate (lower plate). The lower plate was set as the ambient temperature. The heat conductivity was calculated using thermal conduction principle through wall.

The flow of heat due to thermal conduction is calculated using equation:

$$Q = - \lambda.A.t\ (dt/dx) \qquad (1)$$

Where, λ = thermal conductivity, A= area, t= temperature, (dt/dx) = temperature gradient

At a constant cross-section A and dx=s (thickness of specimen) the following is obtained:

$$Q = (\lambda/s).A.\ (t_1-t_2) \quad \text{in} \quad W/m^2 \qquad (2)$$

2.3 Tensile Testing

After the unreinforced epoxy resin and fibers reinforced composite are dried, it was cut using saw cutter to get the dimension of specimen for mechanical testing. Tensile test specimen was prepared and tested according to ASTM D638 [8]. 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.

2.4 Flexural Testing

Flexural test was conducted to study the behavior and ability of material under bending load. The load was applied to the specimen until it is totally break. The flexural test was conducted for three different types of fibers volume fractions of composite.

The flexural test specimen dimension was 15 mm x 100 mm x 5 mm and three point bend method was used for flexural testing (as shown in Fig. 3) according to BS EN ISO 14125:1998 [9].

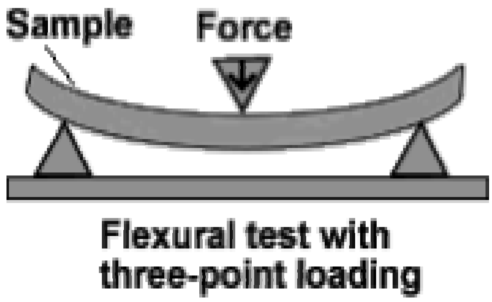


Fig 3. Flexural test with 3-point loading.

2.5 Impact Testing

By using a notch milling machine, the standard specimens were prepared for impact testing and test was performed according to the BS 2782 Part 3 [10]. 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. RESULTS AND DISCUSSION

3.1 Physical Properties

The fabrication of the woven banana fiber composite was developed by hand lay-up technique. The developed epoxy resin composite showed transparent and crystallized appearance. Since the resin is transparent, the color of woven banana fiber was also obtained golden yellow color. The density of woven banana fiber reinforced epoxy composite with respect to volume fraction of fiber is shown in Table-1.

Table 1: Density of woven banana fiber reinforced epoxy composite with respect to volume fraction of fiber.

Volume Fraction of Fiber (%)	Density (g/cm^3)
2	1.46
4	1.48
6	1.51

3.2 Thermal Properties of Pseudo Stem Banana Woven Fabric Composite

The thermal conductivity (TC) provides the thermal properties of developed composite. The test was performed at different process temperature for different volume fraction of fiber reinforced epoxy composite.

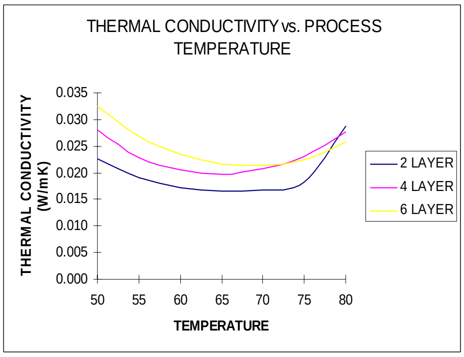


Fig 4. Effect of volume fraction of the pseudo stem fiber on the thermal conductivity of the developed composite.

Fig. 4 showed the effect of volume fraction of fiber on thermal properties of psedo-stem banana fiber reinforced composite. It can be seen that 2% volume fraction of fiber exhibited higher TC followed by 4 and 6 volume fraction of fiber in the matrix material.

The explanation is that as more fiber reinforced into the matrix, the heat conductivity of the material reduced which in tern provide the integrated fiber orientation in the matrix. The minimum and maximum value of the TC for all the specimens was 0.029 W/m-K and 0.026 W/m-K respectively. Up to 65 ^{0}C, the TC for 2% volume fraction of fiber was lower but after that it increases gradually until steady state condition. In contrast, the TC for 6% volume fraction of fiber, initially was higher but decreases again up to 65 ^{0}C with the value of 0.022 W/m-K and then start increasing until steady state condition reached.

Fig. 5 showed the **e**ffect of volume fraction of the pseudo stem fiber on the thermal resistance of the developed composite. From Fig. it can be seen that the normal trend of the graph is in quadratic form for all tested specimens.

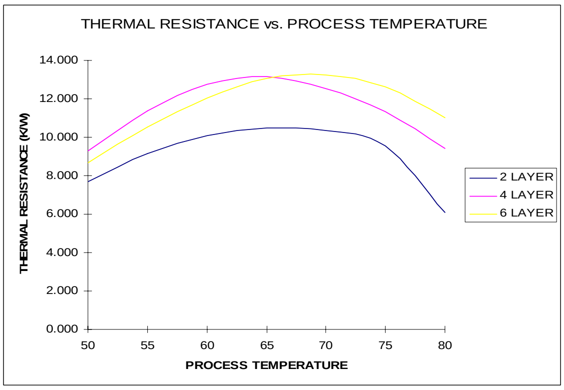
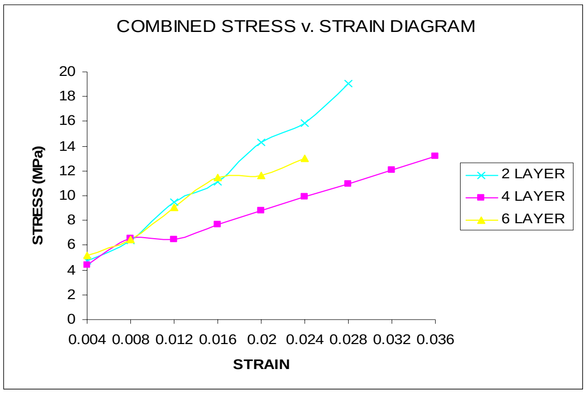


Fig 5. Effect of volume fraction of the pseudo stem fiber on the thermal resistance of the developed composite.

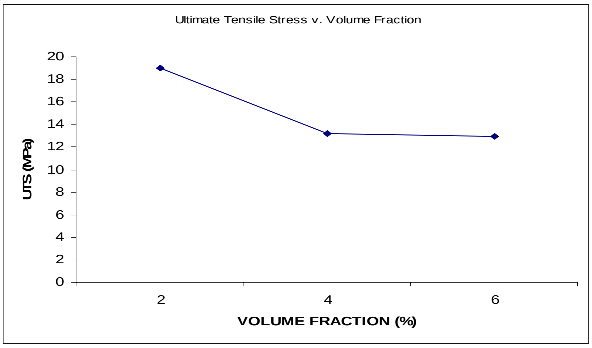
Based on the present data, it can be concluded that the developed composite with different volume fraction of banana fiber showed better insulation than heat conduction. This feature can be taken into consideration in designing the house-hold products/components which are subjected to heat and temperature.

3.3 Tensile Properties of Pseudo Stem Banana Woven Fabric Composite

The stress-strain diagram has been plotted in Figure 6 (a) whereas; corresponding ultimate tensile stress (UTS) of the specimens is in Fig. 6 (b). From Fig. 6 (a), it can be seen that different volume fraction of fiber will have a different characteristics feature. The differences are in fact in terms of materials' brittleness, ductility, high strain nature and ultimate tensile stress (UTS). In terms of UTS, 2% woven banana fiber composite provided higher value of tensile strength with 19.04 MPa and in terms of rigidity this specimen also gives the higher tensile modulus. In terms of strain, 4% woven banana fiber composite gave the longer elongation compared to other volume fractions. The 6% woven banana fiber composite showed the higher yield strength (YS), which means that higher force needed to deform the material plastically. Generally, 4% volume fraction banana fiber showed better tensile characteristics features even though it gives a moderate tensile strength.



(a)



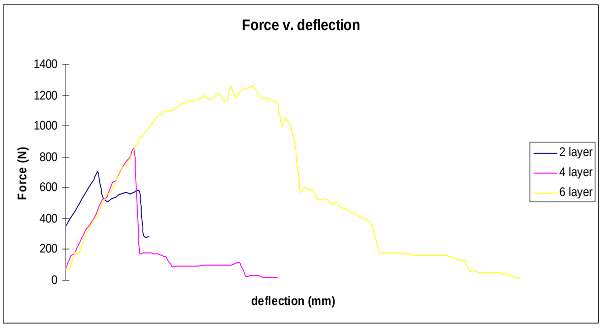
(b)

Fig 6(a). stress strain diagram of banana fiber reinforced epoxy composite with respect to volume fraction of fiber; (b) showing the corresponding UTS of the composite material.

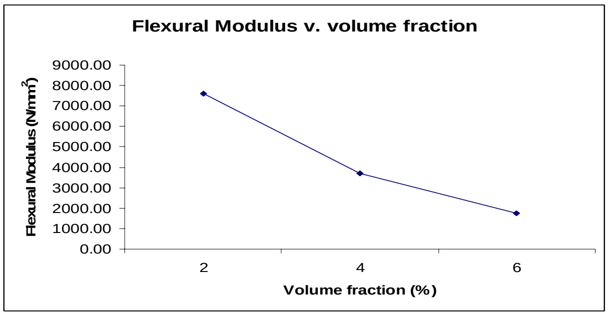
3.4 Flexural Properties of Pseudo Stem Banana Woven Fabric Composite

Figure 7 showed flexural modulus properties of banana fiber reinforced epoxy composite with respect to volume fraction of fiber.

The flexural modulus (Fig. 7b) of 2% fiber volume fraction was higher than other fiber volume fractions. For 4% fiber volume fraction, the fiber addition was efficient since the deflection is higher with higher stress (as can be seen in Fig. 7a) thus, giving the ductility effect on the material. After the first crack formed, the crack grows when force increases to deflect the specimen. The crack in fact formed after the specimen reach it's flexural strength. The flexural strength for 4% woven banana layer was 0.975 N/mm^2 at 1.7 mm deflection after 850 N of applied force. After reaching the flexural strength, there was a sudden drop of stress acted in the mid span of specimen. The drop of stress is due to crack formation subsequent reaching the flexural strength. The difference of the drop of stress was higher since the fiber did not hold the matrix well. As compared to 6 volume fraction of fiber, even after the crack initiation, the bonding between fiber and matrix was high which showed that fiber holds the composite and protect from sudden fractured.



(a)



(b)

Fig 7. Flexural test results of banana fiber reinforced epoxy composite with respect to volume fraction of fiber. (a) Flexural force vs deflection diagram; (b) Flexural modulus diagram.

3.5 Impact Properties of Pseudo Stem Banana Woven Fabric Composite

Impact test results showed that the the volume fraction of woven banana fiber reinforced epoxy composite influenced the toughness of the developed composite. The higher the percentage of banana fiber in the composite, the higher the absorption of energy (as can be seen in Fig. 8). Hence, increase the composite toughness.

The 6% woven banana fiber volume fraction exhibits more toughness compared to other tested specimens. The specimen fractured at 4.9 J. The absorption of energy was 23.53 kJ/m^2. In woven banana fiber composite, the energy is absorbed by the fiber impregnate in to it. During the impact, woven banana fiber will absorb the impact energy by fracturing it continuous fiber or by fiber pull-out from the matrix which is fracturing the bond between the fiber and the matrix. This mechanism causes higher energy to fracture of 6% woven banana fiber.

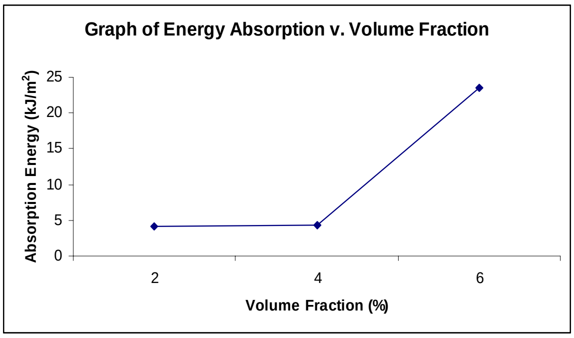


Fig 8. Graph of energy absorption versus volume fraction of fiber.

4. CONCLUSIONS

The following conclusions can be drawn from the present study:

1. Better thermal conductivity (heat conduction) was obtained from 2% volume fraction of banana fiber composite whereas, better thermal insulation properties was obtained from 6% volume fraction of fiber composite.
2. The ultimate tensile strength of the 2% volume fraction of pseudo-stem banana woven fabric reinforced epoxy composite was higher compared to other volume fractions. It can be said that the pseudo-stem banana fibre was pronounced in epoxy matrix material in this investigation.
3. In flexural stress test, flexural modulus decreased with the increasing of volume fraction of pseudo-stem banana fibre in the matrix.
4. The results of impact strength test showed that the pseudo-stem banana fiber improved the impact strength properties of the epoxy material . Higher impact strength value leads to the higher toughness properties of the material.
5. A great potential of using pseudo-stem banana fiber to reinforce in to epoxy matrix was observed. The stem banana fiber is abundant and therefore, the feasibility of using this fiber in conjunction with an epoxy matrix to develop composite materials for household application is very promising.

5. ACKNOWLEDGEMENT

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