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Mechanical Properties of Banana Fibre Reinforced Polymer Composites

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ABSTRACT

The Mechanical properties of banana fiber epoxy composites were investigated. The short fibers from pseudo stem part of the banana plant were used to prepare composites. The composite samples were prepared both from alkali treated and untreated banana fibers. Laminates were prepared from Vacuum molding technique. The fibre matrix weight ratio 30-70% resulted in optimum strength of the composites. The surface treatment improves the mechanical properties when compared with untreated composites. The alkali treated banana fibre are proved to be the most effective reinforcement for the improvement of mechanical properties.

Key words: Natural fiber, fracture toughness, tensile strength, mechanical testing, scanning electron microscope

I. INTRODUCTION

Growing environmental awareness worldwide has aroused an interest in the use of environmentally benign material in engineering [1]. Natural fiber itself contains natural polymers such as lignin, cellulose, hemicelluloses and wax. Many advantages of natural fibers compared to synthetic fibers. It is cheaply available and almost equal in strength in comparison with synthetic fibers.
Natural fibers readily absorb moisture from the environment which alters the strength and geometrical dimension. Hence natural fiber should be protected to avoid absorption of moisture [2].
Most of the structural components are fabricated using natural fiber reinforced polymer matrix composites because cost effective, reduces health hazard, and improves thermal stability and reducing tool wear during machining [3 & 4].
Banana fibre is a lingo-cellulosic fibre, which obtained from the pseudo-stem of banana plant. Banana fibre is having relatively good mechanical properties. The present study mainly focus on determination of physical and mechanical properties and model analysis of natural banana fibres of a composite laminate. Most of the literature available on natural fiber composites, in which fibers are reinforced in cement matrix [5,6,7,8,9] it was found that even a small amount of natural fiber as reinforcement improved impact and fracture toughness.
From the available literature it is understood that fracture toughness of polymer composites were evaluated as similar that of metals, hence ASTM D5045 standard procedure were adopted to determine critical stress intensity factor(K_{IC})and Critical energy release rate(G_{1c}) [10,11,12].
In the present study Mode-I fracture experiments was conducted on compact tension specimen to determine the fracture toughness of a short banana fiber reinforced epoxy polymer composite material. Since composite material was fabricated from brittle matrix.

II. Material and Method

The Banana fibers were extracted from pseudo stem of plant, water tank retting method used for the extraction of fibers.Some of the banana fibers are used without treating and some fibres were then treated with 10% NaOH solution for 6 hours. The fibres are then washed thoroughly with distilled water. Fibres are then put in an oven for 24 hours at 80^{o}c to remove any traces of moisture.Epoxy resin 3062 and hardener K6 grade were used to prepare the composites (Epoxy density 1.2g/cm^3). The natural short banana fibre composite laminate were prepared by 30% wt. fibres and remaining 70% wt. epoxy and a K6 hardener mixture with 10:1 ratio. Fibres are chopped to a length of 5-12mm. two laminates one from untreated short banana fibers and other from alkali treated short banana fibers were prepared using epoxy matrix. Vacuum bag process method was adopted to fabricate composite laminates. The weight fraction of fibers and epoxy matrix materials were determined by considering the density, specific gravity and mass. The short banana fibers and resin were stirred thoroughly. The required thickness of mixtures was poured in the mold and covered with polythene sheet. vacuum bagging is applied then to the mold at a vacuum pressure of 0.1 m bar. The composite is cured at room temperature and the post curing was done at 60 °C for 1 hour. The samples (ASTM D3039, ASTM D504 and ASTM D256) from the cured laminate were cut using diamond tip cutting tool

Tensile test

The tensile specimens of a short banana fibre epoxy composites were prepared as per the ASTM D-3039 The tensile specimens are having a dimensions are 250 x 25.4 x 4.5 mm. Tensile test were carried out using KIC-2-1000c machine at test speed of 1mm/min.

Low velocity impact test

The low velocity impact test specimens are prepared according to ASTM D 256 and dimensions are 63.5 x 12.7 x 4.5mm using Daho Meter (Model DH8215A) and the notch is created at the center of the specimen; the notch is created by notch cutter machine. The depth of the notch is 2.5mm and angle of notch is 45^o.The low velocity impact load was applied on the Izode test specimen using computerized pendulum.

Fracture toughness

The compact tension specimens of natural short banana fibre composite were prepared as per to ASTM D-5045.the figure 1.shows the image of the compact test specimen and dimensions.

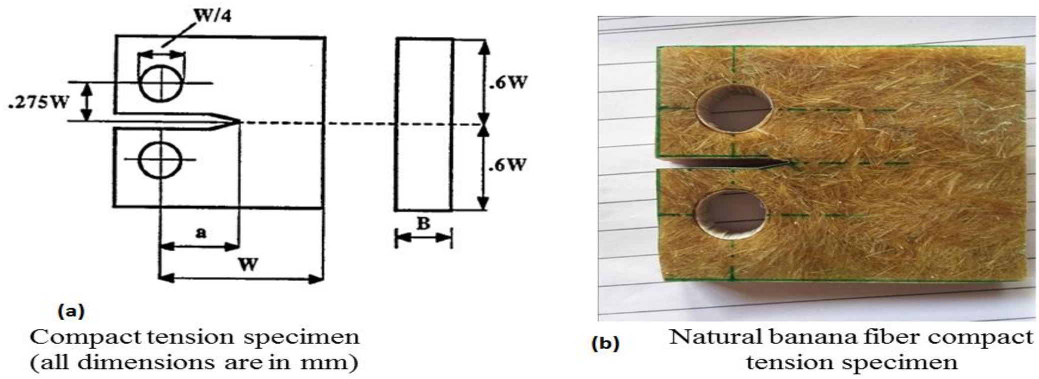

Figure.1 Compact tension specimen (a) standard compact tension specimen dimensions, (b) Banana fiber composites compact tension specimen

Scanning electron microscopy

The fractured surface of the specimen was absorbed in scanning electron microscopy (make TESCAN VEGA3) to study the surface morphology, before that the composite specimen were cut as per test requirement and cleaned, air-dried and are coated with a gold coater (make QUORUM).

III. Results and Discussion

A. Tensile test

Parameters like volume fraction of the fibers, fiber aspect ratio, fiber– matrix adhesion, stress transfer at the interface, and orientation of fibers are the important factors that decide properties of the composites especially natural fiber polymer composites [13,14 and15].

Both the matrix and fiber properties are important in improving mechanical properties of the composites. To improve the tensile strength of a composite, a good fiber matrix bonding is important. In this study banana fibers are treated with alkali solution (10% NaOH) to improve the fiber matrix bonding. The tensile

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test for a natural banana fiber reinforced polymer composite ware conducted to determine the tensile strength, young s modulus and elongation of a natural banana fibre composite material.

Table 1.Tensile and impact strength of banana fiber epoxy composites.

Parameters	Treated banana fiber	Un treated banana fiber
Tensile strength in (MPa)	18.25	15.74
% elongation	0.78	0.83
Young's modulus(MPa)	2337 .7	2311.5
Impact strength (J/m)	0.14	0.11

From the above tensile results (Table.1) it is observed that tensile and impact strength of alkali treated fiber composites increased in comparison to untreated fiber reinforced composites. The tensile strength is increased significantly for alkali treated fiber by 15.8%.The most interesting is that the percentage elongation is improved in case of untreated fiber composites due presence of wax and other substance which are present in the fiber, which acts as ductile material. Also from Fig 2(a) & 2(b) it can be seen that treated sample has good fiber matrix adhesion compared to untreated sample.
The impact tests of natural banana composite laminate were conducted as per ASTM –D 256.The test was conducted for both treated and untreated specimens having 30 % fibre and 70 % matrix.
The izod impact strength of treated and untreated composites is shown in Table. 1. The impact strength of treated banana composite specimen was 0.14 J/m, which is 27.28% higher than that of untreated banana composites. The reduction of impact strength of untreated banana fiber reinforced composites is due to the poor interfacial adhesion between the fiber and matrix as shown in SEM micrograph in Figs2(c)&2(d).

B. The Fracture toughness test

The fracture toughness test for a compact tension test specimen was conducted as per ASTM –D 5045, to determine the critical stress intensity factor and critical energy release rate of a natural banana composite. The notched specimen was loaded in a computerized universal testing machine in tension mode that has been pre cracked.
Compact tension test was performed to calculate the Mode I fracture toughness. This test method was used to define the toughness of plastics in terms of critical stress intensity factor. This test method involves loading a specimen that has already cracked by creating a notch. In the compact tension test load is applied on the specimen, to propagate the already created crack. Load is applied and the cross head speed is set as 10 mm/min. The load at which the crack propagates is noted from the computer attached to the UTM. This load is used for the fracture toughness calculation using equation (1), (2) and (3).

The CT specimen dimensions along with fracture test results were listed in Table 2.

$$K_{1c} = \left[\frac{P}{(BW)^{1/2}}\right] f(x) \text{---------------Equation (1)}$$

$$f(x) = \frac{(2+x)(0.866+4.64)x-13.32x^2+14.72x^3-5.64x^4}{1-x^{\frac{3}{2}}} \quad \text{--------Equation (2)}$$

$$G_{1c} = \frac{(1-v^2)(K_{1c}{}^2)}{E} \quad \text{----------------Equation (3)}$$

The critical stress factor and the energy release rate of a treated and untreated banana fiber composite was calculated using above equations. K_{1c} value of a treated and the untreated banana fiber composites are 318.22MPa$\sqrt{m}$ and 201.70 MPa$\sqrt{m}$ respectively. Interestingly the treated fiber exhibited more stress intensity than untreated sample, due to good fiber matrix bonding which generally require more effort for

Parameters	Treated sample	Untreated sample
Load P(N)	2220	1839
Thickness(B) mm	12.7	12.7
Width(W) mm	50	50
Crack length (a) mm	28.5	25
X=a/W	0.58	0.50
Poisons ratio(υ)	0.31	0.31
Young's modulus(E) MPa	2337.7	2337.7
Critical stress intensity factor K_{1c}	318.22	201.70
Energy release rate G_{1c}	39.15	15.73

crack propagation, whereas in untreated sample poor fiber matrix adhesion resulted lesser value. Similarly energy release (G_{1c}) rate for treated and untreated samples follows same trend, treated sample exhibits more energy release rate of 39.15 KJ/m^2 and least value of 15.73KJ/m^2 was obtained from untreated sample. Fiber matrix interface in composites plays important role in achieving high toughness value,.In this study treated sample exhibits high value when compared to untreated, also SEM images of treated sample fracture sample reveals that crack propagated along the fiber matrix interface, which as explained earlier by Hull and Clyne [16]

C. SEM analysis of natural short banana composite

The SEM micrographs study of natural short banana fibres composite after tensile test as shown in the Fig 2(a) & (b). The SEM analysis is conducted for both treated and untreated fibers. It is observed from the below image surfaces is looks breaking of a fibre and a matrix body. Also rough surface of banana fibers were seen in treated sample because of alkali treatment. Whereas in untreated sample voids and fiber deboning can be seen, this is due to poor fiber matrix adhesion.

The impact strength of untreated banana fiber epoxy composites and treated banana fiber epoxy composites was shown in table 1.

It can be seen that (table.1) the effects of alkali treatment of banana fibers on the impact strength improvement.

As the epoxy resin covered over the surfaces of banana fiber and no voids were observed. It means the effective interfacial adhesion between fiber and matrix were the important factors for impact strength improvement.

In Fig 2(c) & 2(d) the untreated banana fiber composites SEM micrograph indicates that fibers are pulled out and no resins were attached over the surface of the banana fiber due to smooth surface. Hence effective adhesion between fiber and matrix not achieved. These poor interphase resulted in low impact strength. Similar trend of variation in impact strength due to alkali treatment were studied by In the samples of fracture toughness test, treated fiber SEM image Figs 2(e)&2(f) reveals that the crack propagated by rupture of fibers and matrix. Crack developed along the boundaries of short fibers; due to the tensile load fibers are fractured. It can be seen from fig voids are formed long the path of crack, and poor fiber matrix adhesion because of smooth fiber surface which are untreated.

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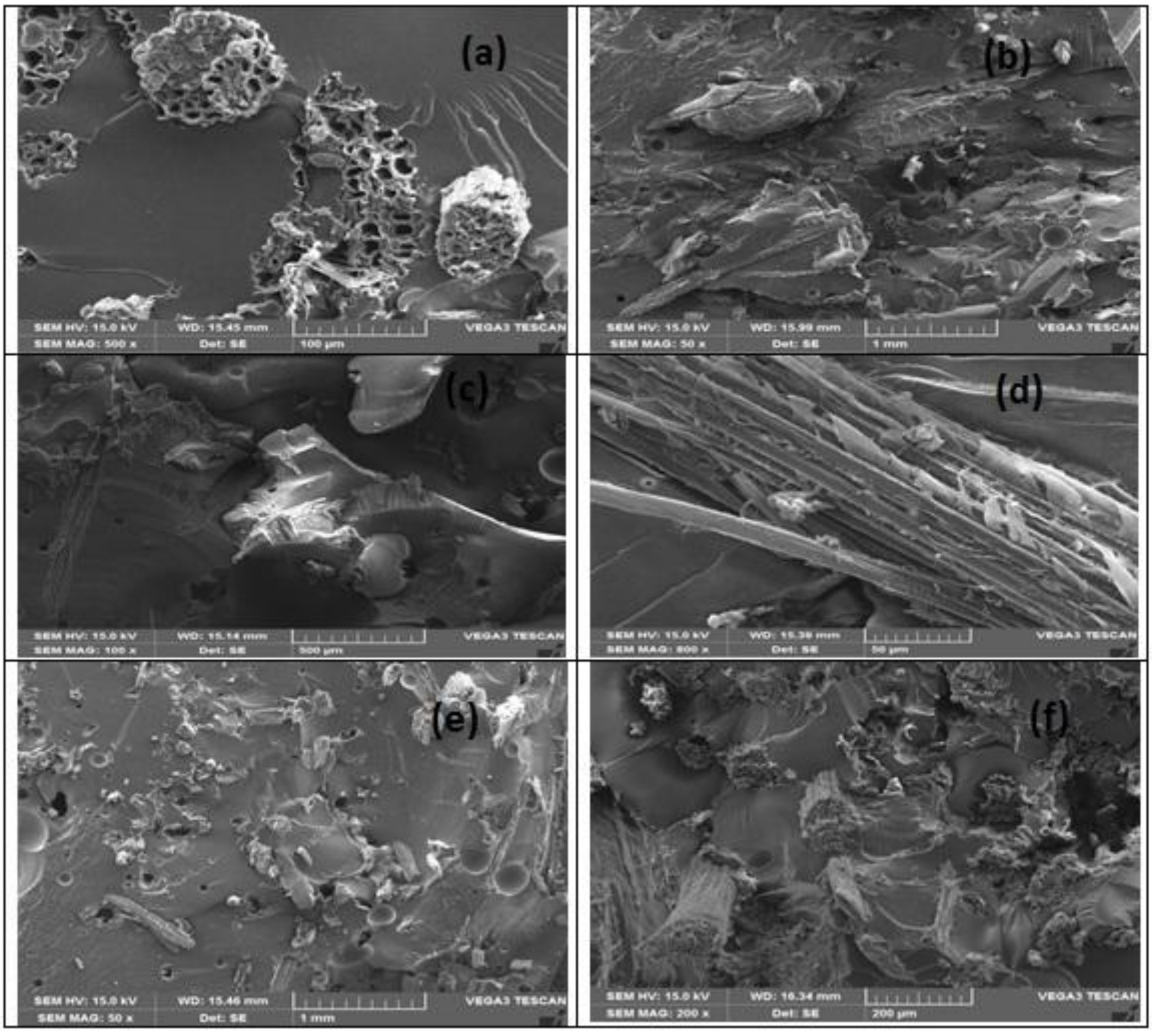

Figure 2.scanning electron micrographs of short banana fiber composites.(a) Tensile test fracture surface of treated composites(b) tensile fracture surface untreated composites(c) impact test fracture surface treated composites(d) impact test fracture surface untreated composites(e) fracture toughness test crack surface treated composites(f) fracture toughness test crack surface untreated composites

IV.CONCLUSION

The epoxy based composites reinforced with short banana fiber are prepared by vacuum molding process. The fiber matrix weight ratio 30-70% resulted in optimum strength of the composites. The poor interfacial bonding resulted in decrease of tensile, impact and the fracture toughness values. The effects of alkali treatment on banana fiber surface on tensile, the impact strength and the fracture toughness of banana fiber epoxy composites were evaluated. The surface treatment improved the mechanical properties when compared with untreated composites. In this study, the alkali treated banana fiber proved to be the most effective reinforcement for the improvement of tensile, impact strength improvement of natural fiber reinforced epoxy composite.

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