Mode I Fracture Characterization of Banana Fibre Reinforced Polymer Composite

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Abstract: In this paper, fracture behavior and Mechanical properties of short banana fiber reinforced polymer composites is investigated. Fibers are extracted from banana plant,Further compositelaminates were prepared with randomly distributed fiberswith different weight fraction of banana ranging from 30%, 35% and 40%. Composites are prepared using hand layup technique.Tests were performed to determine fracture toughness(Mode I) and mechanical properties of these laminates.The tests were performed to examine the effect of weight fraction of fiber on the fracture toughness of the composite.As epoxy is a brittle material, stress intensity factor is utilized to evaluate the fracture toughness of the composites.From the experimental results were carried out on different weight fractions of banana. It is observed that the 40 % of banana fiber shows maximum fracture toughness,Composite plate of 30% shows the maximum tensile strength.

Keywords—Bannana fiber, Polymer Matrix Composites (PMCs*)*

1. INTRODUCTION

In recent decades, natural fibre composites are getting much attention in structural applications. However, due to a flaw-free material is extremely difficult to be produced and cracks may be introduced during service, understanding the crack resistance ability is thus essential. Good toughness and crack stopping capability are particularly important. It has been mentioned that toughness of a brittle thermosetting polymer such as polyester and epoxy can be improved through natural fibre reinforcement [1]. Fracture behavior characterization of polymers and composites are still at infant stage [2].

In principle, composites can be constructed of any combination of two or more materials, whether metallic, organic or inorganic. Advanced composites are a blend of two or more components, one of which is made up of stiff long fibers and the other, for polymeric composites, a resinous binder or matrix that holds the fibers in place. High performance fiber reinforced composite materials are comprised of high strength and modulus fibers, embedded in, or bonded to a matrix, with a distinct interface between them. In a composite, the fiber, as well as the matrix, retain their physical and chemical identities, but still provide a combination of properties that cannot be achieved with either of the constituents alone. In general the fibers play the role of load bearer. The matrix, while keeping the fibers in the desired location and orientation, act as a load transfer agent and protects the fibers from external conditions such as chemicals, heat and moisture [3]. Manmade fibers using glass, carbon, boron etc. are being used as reinforcingmaterials in the fiber reinforced plastics (FRP), which have been widely accepted as materials for structural and non-structural applications.Nowadays-natural fibers like banana, cotton, coir, sisal jute have attracted the attention of scientists and technologists for applications in packaging, low-cost housing and other structures. It has been found that these natural fiber composites possess better electrical resistance and high resistance to fracture [3].

Avci et al. [3]tested glass fibre reinforced polyester concrete using Linear Elastic Fracture Mechanics (LEFM) approach. Single edge notch (SEN) specimens were used and loaded by three-point bending test. Load–displacement curves showed that increasing both resin and fibre contents improved the load carrying capacity of the composites. Correspondingly, the fracture toughness was improved. By initial notch depth method, 10% of increment in fracture toughness was obtained with 1 wt.% of glass fibre reinforcement at 13 wt.% of polyester content. With additional 0.5 wt.% of glass fibre, another 18% of improvement was achieved Silva et al. [4]characterized short sisal and coconut fibres composites as well as sisal fabric composites using compact tension (CT) specimens. It was found that increasing fibre content increased fracture toughness of the composites. At comparative fibrecontent, sisal fabric composite demonstrated better fracture toughness compared to short sisal fibre composite. Besides, fracture toughness of jute and hemp laminates reinforced polyester composites were investigated by Hughes et al. [2]. It was found that hemp/polyester composite demonstrated better critical stress intensity factor and energy release rate. At 20% of fibre volume fraction, 313% and 870% improvement in fracture toughness and critical strain energy release rate were achieved for jute/polyester composite respectively, whereas for hemp/polyester composite, the improvement were 466% and 1740%.

In this study, fracture behavior of banana fibre reinforced polyester composites is characterized through LEFM approach. Banana fibre is selected due to its relatively excellent physical and mechanical properties in terms of density, strength, stiffness and strain at break [5]. Composites at fibre contents of 30, 35 and 40 vol.% (at increments of 10 vol.%) for fibres at 4, 6 and 8 mm lengths respectively are studied. In accordance to ASTM D638 requirements, the composite samples were made for tensile examining to find the material qualities. Each and every test sample of 100 mm gauge length, thickness 5mm and 15 mm wide were made. It had also been discussed that fracture toughness of brittle thermosetting matrix composites is usually characterized by critical stress intensity factor, K_{IC}[6].

2. MATERIALS

2.1 Banana Fiber

Bananas fibers acquired through the banana crop. Bananas fibers at current are the spend item of a banana farming as well as often not appropriately used and also mostly carried out as such. A removal fibers through pseudo stem won't be a typical exercise as well as a great part of stalk won't be utilized for generation of fabric. The customers for bananas materials are irregular as well as there may be no methodical technique to draw out materials frequently. Valuable utilizations of these kinds of fibers might make regular interest that may be shown drop in the costs.

2.2 Epoxy resin

Epoxy resin (L-12) is polyether material including more than one epoxy team able of being turned into

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thermoset type. This resin, on treating, does not make volatile products despite of the existence of volatile solution. The epoxies might be known as oxides, for example, ethylene oxides (Epoxy ethane) or 1, 2-epoxide. This resin is chosen mainly because it gives higher bonding strength.

2.3 Hardener

Curing operators assume a vital part in the curing procedure of epoxy resin since they identify with the curing energy, response rate, gel time, level of time, level of cure, thickness, curing cycle, and the last properties of the cured items. Epoxy resin has great bond to hardener (epoxy L-12 has powerful adhesion with k-6 hardener) which provides excellent resilience, toughness and strength. Excellent potential to deal with chemical attack and wetness, excellent electrical insulation properties.

3. EXPERIMENTAL DETAILS

3.1 Preparation of laminates (Hand lay-up)

Fibers were air dry for twenty four hours at lab temperature and dried fibers were cut into 4,6 and 8mm in length and mixed for 15min. Afterwards these fibers and epoxy resin were mixed together. The composite readiness procedure was conducted in the following sequence using arbitrary mixing technique by hand lay-up. Initially, the Epoxy L-12 resin and the K6 hardener were mixed in the rate of 10:1 by weight as suggested. One 50 percent of resin was kept within the mixing area and fibers were included over a time period of two min. Then, the next 50 percent of the epoxy resin was included in to the mixing chamber and then mixed for an intervalof fifteen min. Proper care and interest was taken to make sure a uniform sample since contaminants are more likely to pile and tangle together when combined. The causing content was pressure molded in a mold box of sizing 300mm X 300mm X 5mm. The constant load was applied on the mould box for one day at room temperature (32^{o} C) with respect to several compositions of fibers.Composite plate A is prepared by uniform mixing of 30% by weight banana fiber with 70% by weight epoxy resin. Composite plate B is prepared by uniform mixing of 35% by weight banana fiber with 65% by weight epoxy resin. Composite plate C is separated by uniform mixing of 40% by weight banana fiber with 60%by weight epoxy resin.Compact tension analyze was carried out to calculate the mode I fracture toughness. This analyze technique is utilized to determine the strength of plastic materials relating to critical stress intensity factor. This analyze technique includes loading a sample which has previously cracked by producing a notch. In this compact tension analyze load is put on the sample, to grow the previously established crack. This analyze was conducted in accordance to ASTM 5045 standard utilizing universal testing machine (UTM). For CT specimen, a razor blade with thickness of 0.1 ± 0.005 mm is inserted at themiddle to initiate 3 mm pre-crack.Unique tensile testing fixtures are designed for the analysis and two 10 mm bolts are introduced in the little holes to hold the specimen to these kinds of fixtures. Load is introduced into the specimen and head speed is maintained at 5mm/min. The crack propagates at which load is noted from the system connected to the UTM. This load is utilized for computation of fracture toughness. Stress intensity factor could be defined as an estimation of fracture toughness. For the mode I critical stress intensity factor is provided by the equation.

$K_{IC} = (P/B\sqrt{W})\, f(x)$
$f(x) = (2+x)(0.886+4.64x-13.32x2+14.72x3-5.6x4)$

where:
P = Load at which crack propagates in N
B = Specimen thickness in mm
W = Specimen width in mm

a = Crack length in mm
x = a/W

Fig. 1 illustrate the dimensions of fracture tests used in this study. The dimensions are determined according to ASTM D638 [7]and ASTM D5045 [8]respectively.

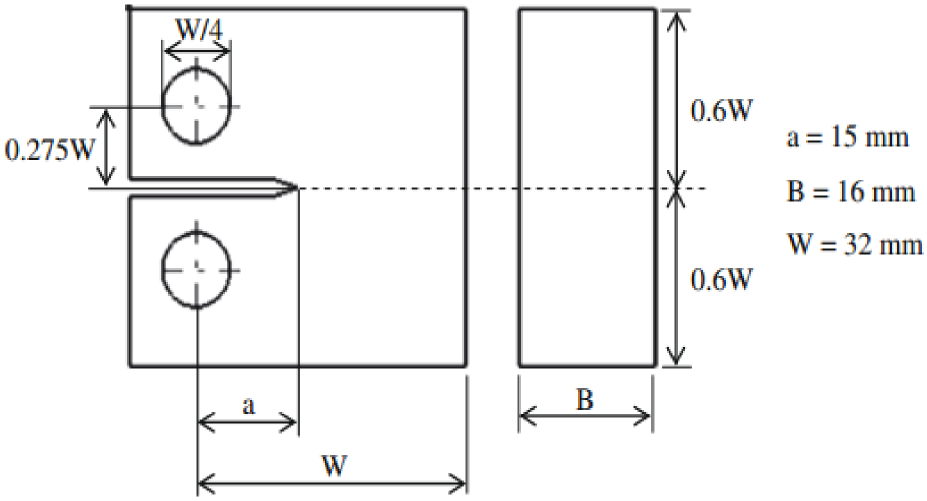

Fig .1.Dimensions of a compact tension specimen.

3.2 TENSILE STRENGTH

According to ASTM standard D638the composite specimens were prepared for tensile testing to determine the Young's modulus of the material [1].

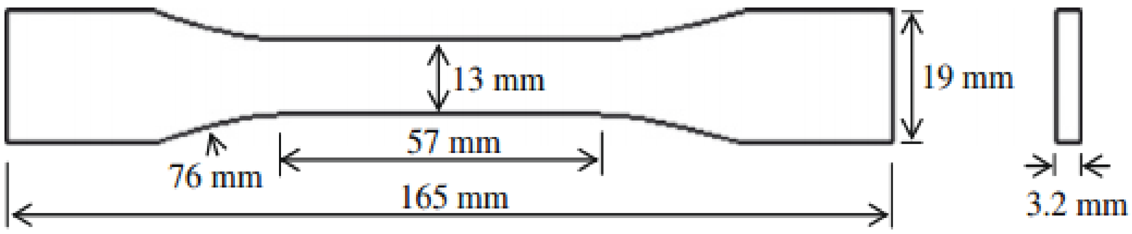

Fig.2.Dimensions of a tensile specimen.

Each test specimen of 57 mm gauge length, 13 mm wide and thickness 3.2 mm were prepared as shown in Fig.2.The specimens were subjected to tensile test in the UTM of capacity 50 kN interfaced with the computer and the stress, strain and young's modulus were determined.

4. RESULTS AND DISCUSSION

4.1 Compact test

Compact tension test was conducted on banana laminates, each specimen with different weight fractions of banana fiber. The experimental results are shown in Table.

Table: 1. Experimental results of the Compact tension test.

Specimen	**Load (N)**	**Displacement (mm)**	**Fracture toughness (Stress Intensity Factor) (MPa.√m)**
30% Banana	175.40	1.2	1.692
35% Banana	268.66	1.8	2.592
40% Banana	301.68	2.0	2.911

The experimental results and stress intensity factor were calculated and are tabulated in table from the results, it is clear that 40% of banana has highest Fracture toughness value of 2.911MPa.√m. But as the percentage of banana fracture toughness value also increases. Now by comparing with 30,35,40 % weight fraction of banana, it is observed that laminates 40% of banana fiber has highest fracture toughness close observation of the composite has shown that the increase in fracture toughness is due to the increase in percentage of fibers. Hence it may be concluded that increasing the percentage of fiber increases fracture toughness.Fig. 3illustrates the load–displacement curves for 40% Banana composite plate.

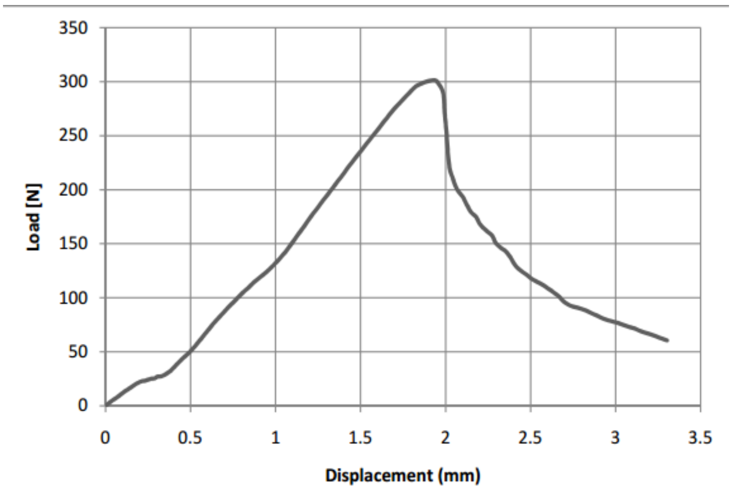

Fig .3. Load displacement curve of 40% banana composite.

4.2 Tensile test

From the load-deflection curves for various specimens, the composite plate with 30% banana (30% banana with 70% of epoxy resin) is found to have maximum tensile strength. The maximum tensile strength is for 30% composite plate is as shown in Fig. 4.

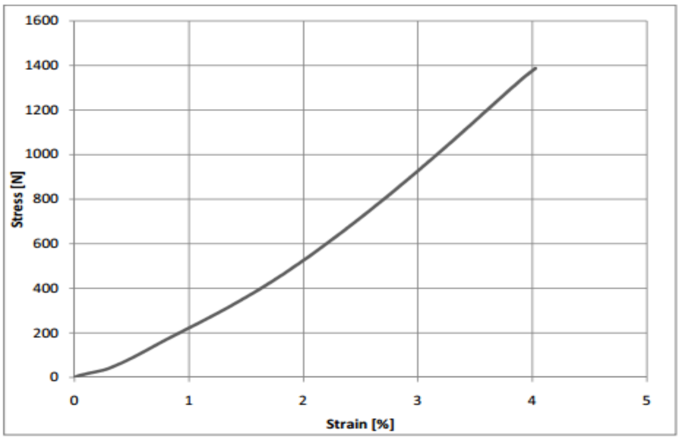

Fig.4.Stress- Strain curves for 30 % Composite plates.

The values of Young's modulus for different specimens are as shown in table2, and the maximum value of 17.1MPa is found for 30% banana laminates.

Table: 2. Yield stress for various composite plates

Composite plate	Yield stress in MPa
30% Banana	17.1

35% Banana	13.1
40% Banana	8.30

5. Conclusions

In this study, the influence of fiber weight fraction on the mode I fracture toughness different weight fraction of banana was investigated experimentally using compact tension specimen. The fracture characterization of fiber reinforced of composite materials using 4,6 and 8mm fibers had been studied. Within this research, the influence of chopped banana composites were examined on fracture toughness. Analysis were carried out on composites with the weight percentage of fiber 30%, 35%, 40% respectively. Fracture toughness test was performed on laminates with different weight fractions of banana. It is observed that 40% banana shows better fracture toughness values close to fracture toughness with 30% banana fibers Maximum fracture toughness. Hence it may be concluded that increasing the percentage of fiber increases fracture toughness.

Also all the prepared composite were tested for tensile strength. The tensile strength for composite plate of 30 % banana is 17.1 Mpa which is greater than other specimens. As the resin content increases, the composite plate becomes brittle therefore the strength of the composite plate decreases at higher epoxy contents. Hence may be concluded that increase in percentage of fiber increases the tensile strength of the material.

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