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Mode I Fracture Toughness of Banana Fiber and Glass Fiber Reinforced Composites

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Abstract. Although fiber-reinforced polymers (FRP) have until now been largely applied to various fields of engineering, these materials have also been used in many technical applications, especially where high strength and stiffness are required, but with low component weight. Among various natural fibers, banana fiber is of particular interest in that its composites have high tensile strength, high tensile modulus, and low elongation at break beside its low cost and eases of availability. In this study, banana fiber and glass fiber reinforced polyester Resin composites were prepared using hand lay up technique . Experiments are conducted to compare and to find the effect of fiber volume fraction on mode I fracture toughness of both composites.

Introduction

The modern composite materials have had a significant impact on the technology of design and construction. The commercial and industrial applications of fiber composites are varied and widespread. Natural fiber-reinforced composite materials also have found wide use in the automotive industry. Great emphasis is being placed on the development of light weight automobiles, fuel economy, and cost-effectiveness issues. Furthermore natural fiber reinforced fibers are seen to have good potential in the future as a substitute[1]. It is interesting to note that natural fibers such as jute, coir, banana, sisal, etc., are abundantly Available in developing countries like India, SriLanka and some of the African countries but are not optimally utilized.

All most all the plant fibers are of hydrophilic in nature with a moisture content of 8-13% due to the presence of cellulose in cell structure[2]. In addition to cellulose, plant fibers contain different natural substances. The most important one is lignin. The lignin content of plant fibers influences its structure, properties and morphology. Another important characteristic of plant fiber is the degree of polymerization. Bast/Stem fibers (Flax, jute, Hemp, Kenaf and Ramie) have highest degree of polymerization (approx 1000) .

Fiber properties. Banana is one of the earliest cultivated plants in the world. The word “banana” comes form Arabic and means” finger”. It belongs to the Musaceae family and there are approximately 300 species, but only 20 varieties are used for consumption. Approximately 70 million metric tons of bananas are produced every year[3] by the tropical and subtropical regions of the world. The nutritional facts of banana are the following(100g pulp): Carbohydrates 18.8g;protein 1.15g; fat 0.18g; water 73.9g; vitamins C1 B1 B2 B6 E ,other minerals 0.83g and 81kcal. Banana-trees produce generally 30 large leaves (almost 2m long and 30–60 cm wide)

Banana fiber processing. The extraction of the natural fiber from the plant required certain care to avoid damage. In the present experiments, initially the banana plant sections were cut from the main stem of the plant and then rolled lightly to remove the excess moisture. Impurities in the rolled fibers such as pigments, Broken fibers, coating of cellulose etc. were removed manually by means of a comb, and then the fibers were cleaned and dried. This mechanical and manual extraction of banana fibers was tedious, time consuming, and caused damage to the fiber. Consequently, this type of technique cannot be recommended for industrial application. This was followed by cleaning and drying of the fibers in a chamber at 20˚C for three hours. The fibers were then labeled and ready for lamination process. The mechanical properties of these fibers were also tested and found to be greatly influenced by the condition of the fiber, whether the fiber was fresh or dried, and upon the part of the plant from which the fiber had been removed.

Materials and Methods

Raw materials. Raw materials used for this experimental work are:
1. **Natural fiber** (Banana fiber) 2. **Glass Fiber** (E Glass) 3.**Matrix** - Polyester Resin (As per volume fraction) 4.**Accelerator**-Methyl ethyl ketone (2%) 5.**Catalyst** - Cobalt (1%) 6.**Separator** - Polyvinyl (2%)

Polyester resin. Polyesters are one of the least expensive resin. Polyester has the advantage of being extremely inexpensive when compared with other thermoset resins i.e. vinylesters and epoxies. If the upside is cheap pricing, the down side includes poor adhesions, high water absorption, and high shrinkage. Polyester resins are only compatible with fiberglass fibers. Polyester is best suited for applications insensitive to weight and do not require high adhesion or fracture toughness.

Fabrication of composites. The following procedure has been adopted for the preparation of the specimen.

Banana fiber preparation. The banana fiber used in the study is 10 mm long chopped banana fiber. The banana stalk was supplied from ROPE Internationals, Chennai. Banana fibers were obtained from the pseudo stem of the banana plant. The extraction of the fiber from the stripped leaf sheath (cleaned well) was done by hand scraping using a soft wooden plank. The pith was then removed continuously until the fibers appeared clean. Due to the low moisture content of the banana fiber samples, no fungi grew during the storage.

Glass Fiber. The glass fiber used in this study is circular cross-section E-glass obtained from Sakthi glass fiber, Chennai. Longer Chopped fiber glass strands are mixed with a resinous binder (a polyester powder) and spread in a random two-dimensional fashion to form chopped strand mats. These mats are typically used for hand lay-up molding and provide equal properties in all of the in-plane directions of the structure.

Polyester Resin. The resin used in this work was general purpose polyester resin from obtained from Sakthi glass fiber, Chennai. It is one of the commercial thermoset polymers which contain a number of carbon, C=C double bonds. Unsaturated means that the resin is capable of being cured from a liquid to a solid state.

Experimental Procedure

Composite preparation. A wooden mold of dimension (100x100x3) mm was used for casting the composite sheet. The first group of samples was manufactured with 13%, 17% and 20% volume fraction of fibers. For different volume fraction of fibers, a calculated amount of polyester resin, accelerator(2%) and catalyst (1%) was thoroughly mixed with gentle stirring to minimize air entrapment. For quick and easy removal of composite sheets, separator was applied at the inner surface of the mold. After keeping the mold on a glass sheet a thin layer (≈ 3 mm thickness) of the mixture was poured. Then the required amount of fibers was distributed on the mixture. The remainder of the mixture was then poured into the mold. Care was taken to avoid formation of air bubbles. Pressure was then applied from the top and the mold was allowed to cure at room temperature for 48 hrs. This procedure was adopted for preparation of 13%, 17% and 20% fiber volume fractions of composites shown in Fig 1 & Fig2. After 48 hrs the samples were taken out of the mold and cut into different sizes mm.

Fig 1 Banana fiber composite of (100×100×3) mm, each provides 13, 17, 20% of fiber respectively and having 10mm fiber length.

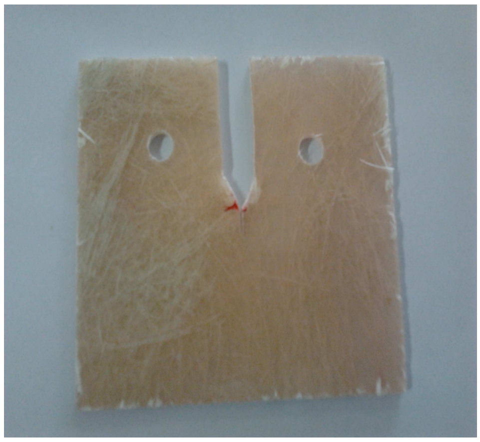


Fig 2 Glass fiber composite of (100×100×3) mm, each provides 13, 17, 20% of fiber respectively and having 10mm fiber length.

Testing Standards. The fracture toughness was determined using Instron type universal Testing machine as per ASTM D 638 method Fig 3 & Fig 4. The testing of the specimen is done with the help of *Instron 4204 Universal Testing Machine*(Fig 5)**.**The 2 bolts is inserted in the 8mm diameter hole.That 2 bolts are fixed in the testing machine.Thus the specimen will be fixed in the testing machine for conducting CT test.The testing machine will be connected with the computer to find out the required results digitally

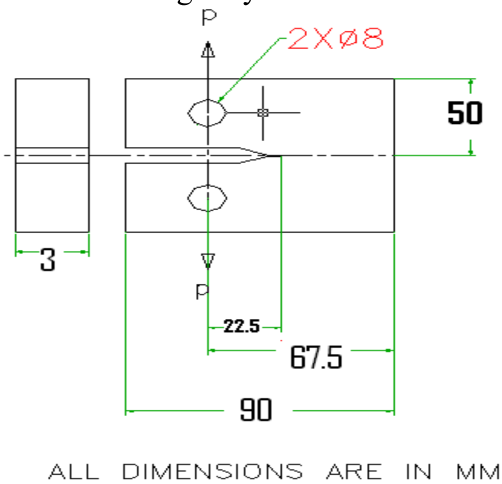


Fig. 3 Test Specimen as per ASTM Standards

Fig. 4 Banana Fiber Test Specimen as per ASTM Standards

Fig.5 Test Specimen fitted in Instron 4204 Universal Testing Machine

Results. Three specimens of same volume fraction were used to test the fracture toughness of the banana fiber and glass fiber reinforced composite. The variations in load for the same banana fiber composite were tabulated. The average load is used for calculating fracture toughness value of composite. The average loads are tabulated in table 4.1 & 4.2 and plots are shown in Fig 6 & Fig 7.

Calculation & Tabulation

Stress intensity factor. Stress intensity factor K can be considered as a estimate of fracture toughness. It depends on Load, Flow depth and geometry. Critical stress intensity factor for mode 1 is given by,

$$K_{ic} = \frac{P}{B\sqrt{W}}\left\{F\left(\frac{A}{W}\right)\right\}$$

Where P- load at which crack propagate, B- Thickness of the test specimen, w- Length of the specimen a - crack length , $F\left(\frac{A}{W}\right)$-geometry factor

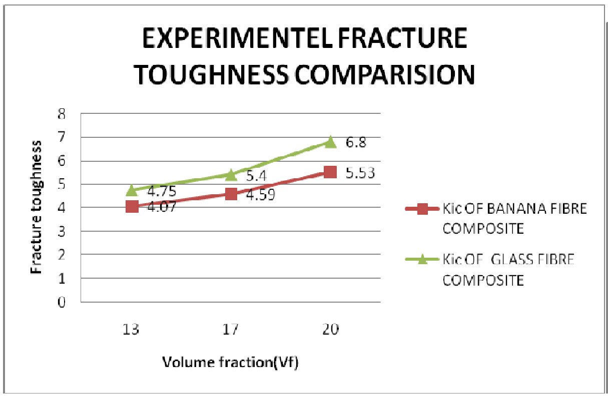
$$\left\{F\left(\frac{A}{W}\right)\right\} = \frac{2+\left(\frac{A}{W}\right)}{\left(1-\frac{A}{W}\right)^{1.5}}\left\{0.866 + 4.66\left(\frac{A}{W}\right) - 13.32\left(\frac{A}{W}\right)^{2} + 14.72\left(\frac{A}{W}\right)^{3} - 5.6\left(\frac{A}{W}\right)^{4}\right\}$$

Table 4.1(a) Results obtained from testing machine for banana fiber composite

BANANA FIBER COMPOSITE				
VOLUME FRACTION OF FIBER	LOAD (N)			AVERAGE LOAD (N)
	SPECIMEN			
	1	2	3	
13/100	16.53	18.66	22.4	16.56
17/100	18.4	18.6	18.8	18.66
20/100	22.2	22.7	22.5	22.46

Table 4.1(b) Results obtained from testing machine for glass fiber composite

GLASS FIBER COMPOSITE				
VOLUME FRACTION OF FIBER	LOAD (N)			AVERAGE LOAD (N)
	SPECIMEN			
	1	2	3	
13/100	19.8	19.2	19.5	19.3
17/100	22.2	21.9	22.4	22.15
20/100	25.3	25.6	25.7	25.5



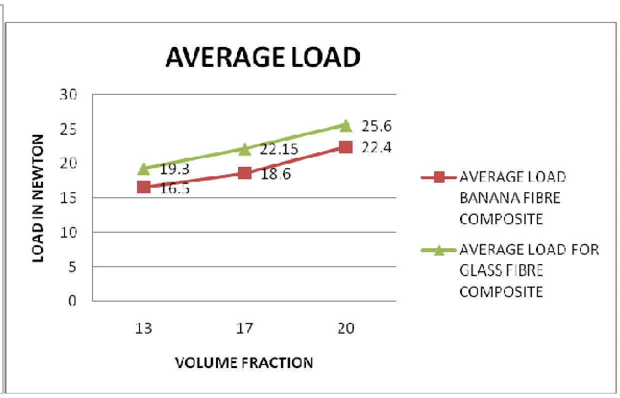


Fig 6 Plot of average load from test

Fig 7 Plot of Fracture toughness values.

Table 4.2 Experimental fracture toughness values

COMPOSITE	Fiber Length (mm)	Volume Fraction	Experimental Fracture Toughn-ness (Kic)
Banana fiber composite	10	13/100 17/100 20/100	4.07 4.59 5.53
Glass fiber composite	10	13/100 17/100 20/100	4.75 5.4 6.8

Conclusion

In this study, the effects of chopped glass fiber and banana fiber content on the fracture property of polyester composites were investigated. Fracture toughness tests were performed on GFRP and BFRP composites with fiber fraction volume percentages of 0.13, 0.17, 0.20 Vf, It is observed that the fracture toughness of banana fiber reinforced composite is in close agreement with glass fiber. As India is one of the largest banana producing countries in the world the use of its fiber and its wastes for producing useful components would be very attractive on the economic point of view. Banana fiber and its composites can be further attractive if a suitable cost–effective design method of fiber separation and its composite production may increases its application to a greater extent. Thus we conclude that the systematic and persistent research in the future will increase the scope and better future for banana fiber and it composites.

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