Mechanical Performance and Analysis of Banana Fiber Reinforced Epoxy Composites

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ABSTRACT

The use of composite materials in engineering field is increasing day by day. A composite material is a materials system composed of a combination of two or more micro or macro constituents that differ in form and chemical composition and which are essentially insoluble in each other. It consists of mainly two phases i.e. Matrix and Fiber. The fibers may be polymers, ceramics, metals such as nylon, glass, graphite, Aluminium oxide, boron, Aluminium etc.Now a day's Jute, Coir, Silk, Banana, Bamboo fibers and animal feathers are also utilized as a fiber.

In the present work polyester is used as matrix and Banana fibers are used as fibers for producing the composites. In the preparation of specimen the fiber length has to be taken as 160mm for tensile strength and 100 mm for flexural test and 63.5mm for impact test. The specimen is to be produced by varying (20%) the weight percentage of fiber. The mechanical properties such as tensile strength, impact strength and flexural strength are to be validated. Its resistance to chemicals such as Hcl, NaoH, Ccl4, and H2o are to be tested. To determine the stresses, strains and deformation under various fiber volume percentages is to be analyzed by using ANSYS software.

Keywords *–Ansys, banana, fiber, tensile strength*, matrix

I. INTRODUCTION

A composite is usually made up of at least two materials out of which one is the binding material, also called matrix and the other is the reinforcement material (fiber, Kevlar and whiskers). The advantage of composite materials over conventional materials stem largely from their higher specific strength, stiffness and fatigue characteristics, which enables structural design to be more versatile. By definition, composite materials consist of two or more constituents with physically separable phases. However, only when the composite phase materials have notably different physical properties it is recognized as being a composite material. Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. Significantly, constituents of the composites retain their individual, physical and chemical properties; yet together they produce a combination of qualities which individual constituents would be incapable of producing alone. The reinforcement may be platelets, particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material. Long fibers that are oriented in the direction of loading offer the most efficient load transfer. This is because the stress transfer zone extends only over a small part of the fiber-matrix interface and perturbation effects at fiber ends may be neglected. In other words, the ineffective fiber length is small. Popular fibers available as continuous filaments for use in high performance composites are glass, carbon and armid fibers

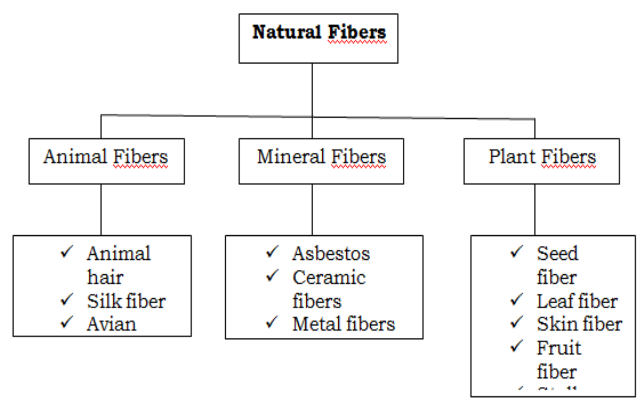


Fig:-1 Classification of Natural Fibers

II. LITERATURE SURVEY

[1]. Modification to the fiber also improves resistance to moisture induced degradation of the interface and the composite properties

[2]. Mechanical properties of natural fibers, especially flax, hemp, jute, banana and very good and many complete with glass fiber in specific strength and modulus

[3, 4]. A number of investigations have been conducted on several types of natural fibers such as kenaf, hemp, flax, bamboo, banana and jute to study the effects of these fibers on the mechanical properties of composite materials

[5, 6]. Information on the usage of banana fibers in reinforcing polymers is limited in the literature. In dynamic mechanical analysis, Laly et al

[7] 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

[8]. 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

[9]. 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 40mm 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

[10].tested banana fiber and glass fiber with varying fiber length and fiber content as well as Luo and Netravali

III. MATERIALS & METHODS

BANANA INFORMATION

Banana is in *Musa* family. Banana plant is a large perennial herb with leaf sheaths that form pseudo stem. Its height can be 10-40 feet (3.0-12.2 meters) surrounding with 8-12 large leaves. The leaves are up to 9 feet long and 2 feet wide (2.7 meters and 0.61 meter). Its fruits are approximately 4-12 inches (10.2-30.5centimeters) . Different parts of banana trees serve different needs, including fruits as food sources, leaves as food wrapping, and stems for fiber and paper pulp. It is available throughout Thailand and Southeast Asian, India, Indonesia, Malaysia, Philippines, Hawaii, and some Pacific islands. This source of fibers provides great strength, used generally in particular products, such as tea bags and Japanese yen notes. Typically, banana plants are grown in 3 types; (1) food source, (2) decorative plants, and (3) starch and fibers sources (abaca). Abaca fiber has a long history as a leading cordage fiber of the world, known as Manila hemp. Abaca is one kind of banana plants. The fiber is obtained from outer layers from the stalks of the abaca plant. It is light, strong, and durable. After extraction and dry, it provides a white lustrous color fiber. One particular characteristic of the abaca fiber over all other fibers of its class is the great strength and resistance to the action of water, therefore its particular adaptability for marine ropes. However, abaca's fruit is not human food source. It is specifically grown for fiber cultivation. Instead of growing banana tree only for fruit consumption and discard the trunks, the use of banana fibers after the fruits are harvested should be explored. Therefore, the focuses of this research is on banana fruit plant.

Cellulose (%)	62-64
Hemi Cellulose (%)	19
Lignin (%)	5
Moisture content (%)	10-11.5
Density (g/cm^3)	1.35
Flexural modulus (GPa)	2-5
Tensile strength (Mpa)	53.7
Young's modulus (Gpa)	3.48

Table-1 Properties of Banana Fiber

Impact test of Composite

Standard test method, ASTM D256-97, for impact properties of fiber reinforced composites has been used to test the unidirectional composite specimens. The specimens are prepared to dimension of 63.5*12.7*10mm width. A V-notch is provided with a sharp file having an included angle of 450 at the centre of the specimen, and at 900 to the sample axis. The depth of the specimen under the notch is 10.16+0.05mm or 10.16-0.05mm.

The impact testing equipment compiles with ASTM standards. Depending on the volume fraction of the specimen, one of the four hammers has to be selected to break the sample. The hammer is fixed to the pendulum in such a way that it will make initial contact with the specimen on a line 22mm above the top surface of the clamping vice. The sample is fixed to the vice as a vertical cantilever beam in such a way that the notch faces the striking edge of the hammer and aligned with the surface of the vice. The pendulum hammer is released from its locking position which is at an angle of 1500 with respect to the axis of specimen with a striking velocity of 2.46m/sec.The sample is stripped and energy is indicated in joules by the pointer on the respective scale. The impact energy is calculated as per the ASTM standards.

The composite samples are prepared in five different percentages of banana fiber (0wt%, 5wt%, 10wt%, 15wt% and 20 %). The entrapped air bubbles (if any)are removed carefully with a sliding roller and the mould is closed for curing at a temperatureof40°C for 24 hrs . After curing the specimens of suitable dimension are cut for mechanical tests.

Fig: - 2 Before Testing

Fig: - 3 After Testing

IV. MODELING & ANALYSIS

STATIC ANALYSIS

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads. If the stress values obtained in the analysis crosses the allowable values it result in the failure of the structure in the static condition itself. To avoid such a failure, this analysis is necessary.

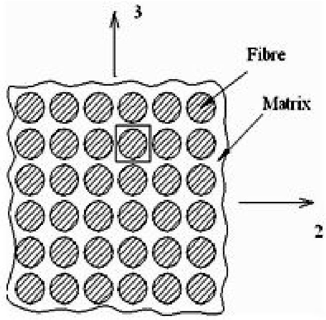
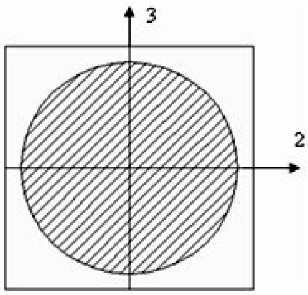


Fig: - 4 Concept of Unit Cells

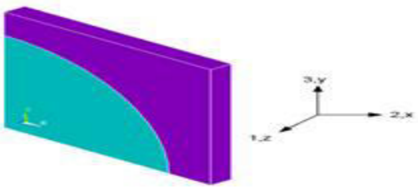


Isolated unit cells of square packed array

Finite Element Model

In the study of the Micromechanics of fiber reinforced materials, it is convenient to use an orthogonal coordinate system that has one axis aligned with the fiber direction. The 1- 2-3 Coordinate system shown in Figure.4.3 is used to study the behavior of unit cell. The 1 axis is aligned with the fiber direction, the 2 axis is in the plane of the unit cell and perpendicular to the fibers and the 3 axis is perpendicular to the plane of the unit cell and is also perpendicular to the fibers. The isolated unit cell behaves as a part of large array of unit cells by satisfying the conditions that the boundaries of the isolated unit cell remain plane.

Due to symmetry in the geometry, material and loading of unit cell with respect to 1-2-3 coordinate system it is assumed that one fourth of the unit cell is sufficient to carry out the present analysis. The 3D Finite Element mesh on one fourth portion of the unit cell



One-fourth portion of unit cell.

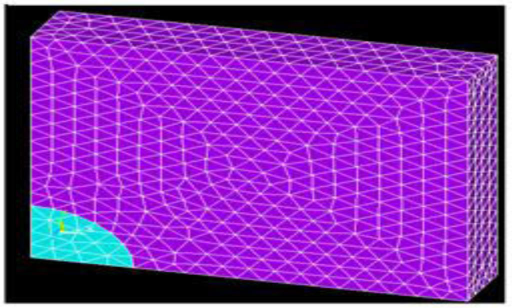


Fig:- 5 Finet Element Mesh

Geometry

The dimensions of the finite element model are taken as

- X=100 units,
- Y=100 units,
- Z=10units.

The radius of fiber is calculated is varied to the corresponding fiber volume.

$$Vf = \frac{\text{cross section area of fiber}}{\text{cross section area of unit cell}}$$

$$Vf = \frac{\frac{\pi}{4} r^2}{a^2}$$

r radius of fibre
a edge length of square unit cell
Vf volume fraction of fibre

Element type

The element SOLID186 of ANSYS V13.0 used for the present analysis is based on a general 3D state of stress and is suited for modeling 3D solid structure under 3D loading. The element has 20 nodes having one degree of freedom i.e. temperature and with three degrees of freedom at each node: translation in the node x, y and z directions respectively.

Static analysis is performed by considering pre-determined conditions (i.e boundary conditions & point load) using ANSYS 13.0 software.

Boundary conditions

Due to the symmetry of the problem, the following symmetric boundary conditions are used

- At x = 0, Ux = 0
- At y = 0, Uy = 0
- At z = 0, Uz = 0

In addition, the following multi point constraints are used.

- The Ux of all the nodes on the Area at x =100 is same
- The Uy of all the nodes on the Area at y =100 is same
- The Uz of all the nodes on the Area at z = 10 is same

Materials

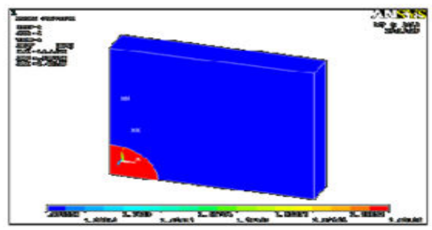
Two different types of fiber reinforced composite materials considered in this investigation, they are

- Epoxy composite
- Banana fiber

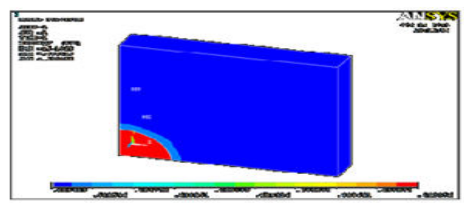
The typical properties of the two different composite materials are illustrated

Property	Symbol	Units	Banana	Epoxy
Young's	E	Gpa	3.48	1.359
modulus	V		0.28	0.3
Poisson's ratio	ρ	g/cm³	1.35	1.2
Density				

Table: 2 typical properties of Fibers and Epoxy



Von misses stress for 5% volume fraction of fiber and matrix



, Von misses strain for 5% volume fraction of fiber and matrix

V. RESULTS & DISUCSSION

This chapter discusses the results of experimental values and analysis of the continuous fiber reinforced epoxy composite

Tensile Test

The specimens (5%, 10%, 15%, 20%) are prepared as per the ASTM standards and to find out the ultimate tensile strength as shown in below.

VI. CONCLUSION

- In this work the three mechanical properties are evaluating as per the ASTM standards and analyzed the stress, strain and deflection by using ANSYS 13.0 software package.
- The Ultimate tensile strength value maximum at 15% (45.18Mpa) and decreasing starting from 15% to 20% (45.18Mpa to 38.30 Mpa) of the fiber.
- The flexural strength value slightly decreasing from 5% (92.12%Mpa) to 10% (87.31Mpa) and

after that the value increased from 10% to 20% (87.31 Mpa to 321.38 Mpa) of the fiber.

- The impact value maximum at 15% (12J) of the fiber and the value decreasing from 15% to 20% (12J to 10J) of the fiber.
- Coming from analysis part by using ANSYS software by changing the volume fraction of the fiber from 5% to 20% the stresses (2.40139Mpa to 1.99841Mpa), strains (0.690056Mpa to 0.574253Mpa) and displacement values (26.1025mm to 13.2895mm) are decreased.

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