Mechanical Performance and Analysis of Banana Fiber Reinforced Epoxy Composites

P.Shashi Shankar, Dr.K.Thirupathi Reddy and V.Chandra Sekhar

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, Aluminum oxide, boron, Aluminum etc.Now a day's Jute, Coir, Silk, Banana, Bamboo fibers and animal feathers are also utilized as a fiber. In the present work epoxy is used as matrix and Banana fibers are used as fibers for preparing the composites. In the preparation of specimen the fiber as taken as a continues fiber. The fiber as treated with NaoH and H_2O solutions. The specimen is to be prepared by varying the weight percentage of fiber (5% to 20%). The mechanical properties such as tensile strength, flexural strength and impact strength are to be validated. To determine the stresses, strains and displacements under various volume fraction of fiber is to be analyzed by using ANSYS software.

Keywords: Banana fiber, epoxy, Mechanical properties and ANSYS Software.

1. INTRODUCTION

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.

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LITRATYRE SUTVEY

2.0 Introduction

The chapter outlines some of the recent reports published in literature on mechanical behaviour of natural fibers based polymer composites with special emphasis on banana fiber reinforced epoxy composites.

2.1 Literature review

The mechanical properties of a natural-reinforced composite depend on many parameters, such as fiber strength, modulus, fiber length and orientation, in addition to the fiber-matrix interfacial bond strength. A strong fiber-matrix interface bond is critical for high mechanical properties of composites. A good interface bond is required for effective stress transfer from the matrix to the fiber where by maximum utilization of the fiber strength in the composite is achieved [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 [11]. The Compressive properties of the composites were evaluated before and after moisture absorption. The resulting banana fiber/epoxy composites were found to yield a flexural Strength of 34.99 MPa and compressive strength of 122.11 MPa when alkaline pre-treated with improved environmental exposure resistance. While the non alkaline pre-treated banana fiber/epoxy composites were found to yield a flexural strength of 40.16 Mpa and compressive strength of 123.28 MPa , with hypothermal resistance than pre-treated fiber composites with the same matrix. Flexural Modulus, Flexural Strength, Compressive strength for 55% pre-treated and non- pre-treated banana fiber reinforced polyester and epoxy values are recorded [12]. Carried out a comparative study of the mechanical properties of phenol formaldehyde composites reinforced with banana fibres and glass fibres. In this study composites were fabricated using banana fibre and glass fibre with varying fibre length and fibre loading. The analysis of tensile, flexural and impact properties of the composites revealed that the optimum length of fibre required for banana fibre and glass fibre are different in phenol formaldehyde resole matrix. Both fibres show a regular trend of increase in properties with fibre loading, interfacial shear strength values obtained from single fibre pull out test, which also revealed that the banana fibre and phenol formaldehyde resin[13]

3. MATERIALS AND METHODS

Banana empty fruit fibers were obtained from M/S kodali Arjuna rao & co., India. The fibers were extracted using decorating machine. The fiber has a diameter of 0.005-0.12 mm and the fiber as treated with 4% NaoH and H_2O solutions.

3.1 Mechanical properties

3.1.1 Tensile Testing

Tensile test specimens were made in accordance with ASTM D 638M to measure the tensile properties. The sample was 160 mm long, 12.5 mm wide and 3 mm thick; five identical specimens tested for each composition. Overlapping aluminium tabs were glue to the ends of the specimen with epoxy resin, filling the space at the tab overlap to prevent compression of the sample at the grip. The samples were tested at a cross-head speed of 0.5 mm/min and the strain was measured using an extensometer

3.1.2. Flexural Testing

Three-point bend tests were performed in accordance with ASTM D 790M test method I(procedure A) to measure flexural properties. The samples were 100 mm long, 25 mm wide and 3 mm thick. In three-point bending test, the outer rollers were 64 mm apart and the samples were tested at a strain rate of 0.5 mm/min. A three-point bend tested was chosen because it requires less material for each test and eliminates the need to accurately determine center point deflections with test equipment.

3.1.3 Impact Testing

Charpy impact test specimens were prepared in accordance with ASTM D 256M to measure the impact strength. The specimens were 63.5 mm long, 12.7 mm deep, 10 mm wide. A sharp file with included angle 45^o was drawn across the centre of the saw cut at 90^o to the sample axis to obtain a consistent starter crack. The samples were fractured in a plastic impact testing machine and the impact toughness was calculated from the energy absorbed and the sample width

The mechanical properties results are as shown in below table

4 MODELING AND ANALYSIS

4.0 Introduction of modeling

Solid modeling is the first step for doing any 3D analysis and testing, it also gives 3D physical picture for new products. FE models can be created easily from solid models by the process of meshing. Solid models can be prepared as testing models by giving this in ".stl" format to rapid prototyping machines. Rapid prototyping models give opportunity to show the model or assembly in presentation before it is manufactured. FE models can be manually for simple cases only. But if the model is of complex form (or) shape then, the only way for preparing FE model is "meshing the solid model" using a suitable computer program.

Commercially available solid modeling packages are

- I-DEAS
- PRO-E
- UNIGRAPHICS

In the present work the models are not much complicated, so modeling for various volume fractions and for various fiber angle orientations has been done in ANSYS 13.0.

4.1 Introduction of ANSYS

In order to reduce laboratory and experiments expenses, one would try to make predictions of a new material's behaviour and response by numerical simulations, with the chief goal being to speed up the trial and error experimental testing and to be able to simulate real phenomena that occur at the micro level of the composites that cannot be accurately implemented in the existing analytical models. The recent dramatic increase in computational power available for mathematical modeling and simulation raises the possibilities that modern numerical methods can play a significant role in the analysis of heterogeneous microstructures.

ANSYS is one of the finite element analysis (FEA) software which is working on computer based numerical technique for calculating the strength and behaviour of engineering structures. It can be used to calculate deflection, stress, vibration, buckling behaviour and many other phenomena. It can be used to analyze either small or large-scale deflection under loading or applied displacement. It can analyze elastic deformation, or permanently bent out of shape plastic deformation. The computer is required because of the astronomical number of calculations needed to analyze a large structure. The power and low cost of modern computers has made Finite Element Analysis available to many disciplines and companies. Useful for problems with complicated geometries, loadings, and material properties where analytical solutions cannot be obtained.

In the finite element method, a structure is broken down into many small simple blocks or elements. The behaviour of an individual element can be described with a relatively simple set of equations. Just as the set of elements would be joined together to build the whole structure, the equations describing the behaviours of the individual elements are joined into an extremely large set of equations that describe the behaviour of the whole structure. The computer can solve this large set of simultaneous equation. From the solution, the computer extracts the behaviour of the individual elements. From this, it can get the stress and deflection of all the parts of the structure. The stresses will be compared to allowed values of stress for the materials to be used, to see if the structure is strong enough

4.2 METHODOLOGY

The present research work deals with the evaluation of engineering properties by the elasticity theory based finite element analysis of reinforced composites. The fibers are arranged in the square array which is known as the unidirectional fiber composite. And this unidirectional fiber composite is shown in Fig. 1. It is assumed that the fiber and matrix materials are linearly elastic. A unit cell is adopted for the analysis. The measure of the volume of fiber relative to the total volume of the composite is taken from the cross sectional areas of the fiber relative to the total cross sectional area of the unit cell. This fraction is considered as an important pa is called fiber volume fraction (V_f) fig 2 shows an isolated unit cell.

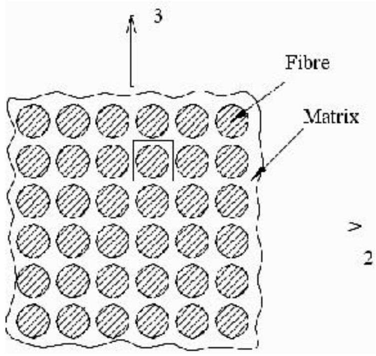

Fig.4.1: Concept of Unit Cells

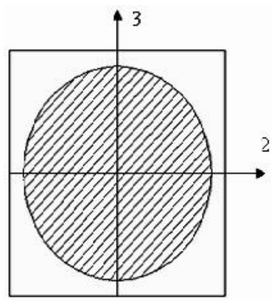

Fig.4.2: isolated Unit Cells of Square packed array

4.3 Numerical solution

Finite element method is an approximate numerical method which has been successfully used for solutions of problems in various fields, including solid mechanics, fluid mechanics and heat transfer. In the present work, the computational numerical analysis is done using ANSYS version 13.0 running on an Intel i3 processor system

Assumptions made for the present analysis were

- Fibers are uniformly distributed in the matrix;
- Fibers are perfectly aligned;

- There is perfect bonding between fibers and matrix;
- The composite lamina is free of voids and other irregularities; and
- The load is within the linear elastic limit.

4.4 .Finate element method

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 Fig.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 is shown in Fig.3.

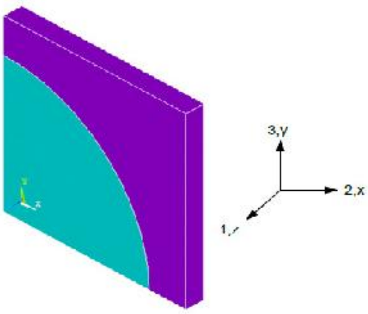

Fig.4.3: One-fourth portion of unit cell

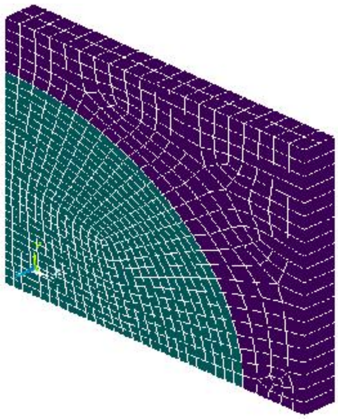

Fig.4.4: Finite Element mesh

4.5. 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.

$$V_f = \frac{\text{cross section area of fiber}}{\text{cross section area of unit cell}} \quad (3.1)$$

$$V_f = \frac{\frac{\pi}{4} r^2}{a^2} \quad (3.2)$$

r radius of fiber

a edge length of square unit cell

V_f volume fraction of fiber

4.6 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 modelling 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.

4.6 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

4.7 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 in table 3.1.

Table- 4.1: Typical properties of Fibers and Epoxy

Property	Symbol	Units	Banana	Epoxy
Young's modulus	E	Gpa	3.48	1.359
Poisson's ratio	V		0.28	0.3
Density	ρ	g/cm^3	1.35	1.2

5. RESULTS AND DISCUSSION

5.0. INTRODUCTION:

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

5.1. 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.

Table 5.1 Tensile Test Values

S.NO	Sample Id	Ultimate tensile load(N)	Ultimate tensile strength(Mpa)
1	Ba. F ,SAMPLE ID 5%	1120	22.62
2	Ba. F ,SAMPLE ID 10%	1360	27.87
3	Ba. F ,SAMPLE ID 15%	2010	45.18
4	Ba. F SAMPLE ID 20%	1620	38.30

The graph as drawn between percentage of fiber Vs ultimate tensile load

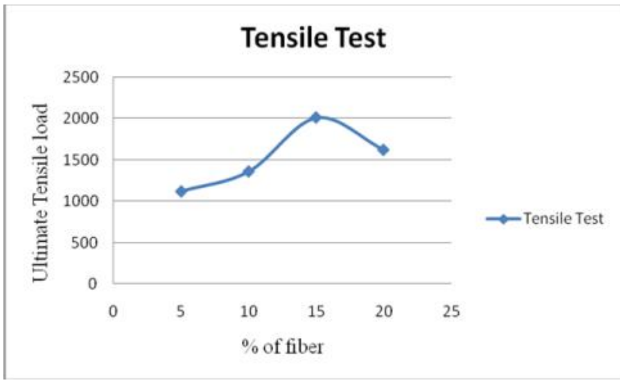

Fig. No 5.1 percentage of fiber Vs Ultimate load

5.2. Flexural Test

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

Table 5.2 Flexural Test Values

S.NO	Sample Id	Flexural load (N)	Ultimate tensile strength(Mpa)
1	Ba. F ,SAMPLE ID 5%	360	92.12
2	Ba. F ,SAMPLE ID 10%	340	87.31
3	Ba. F ,SAMPLE ID 15%	900	239.86
4	Ba. F ,SAMPLE ID 20%	1240	321.38

The graph as drawn between percentage of fiber Vs Flexural load as show in below

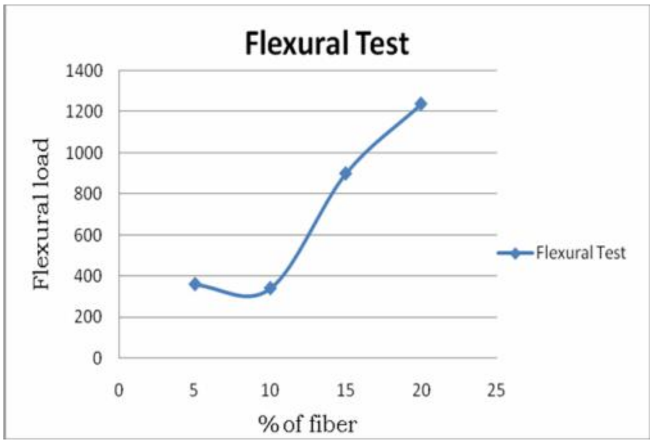

figure 5.2 Percentage of fiber Vs Flexural load

5.3. Impact Test

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

Table 5.3 Impact Test Values

S.NO	Sample Id	Impact Charpy Vs room temperature (J)
1	Ba. F ,SAMPLE ID 5%	2
2	Ba. F ,SAMPLE ID 10%	6
3	Ba. F ,SAMPLE ID 15%	12
4	Ba. F ,SAMPLE ID 20%	10

The graph as drawn between percentage of fiber Vs Impact values as shown in below

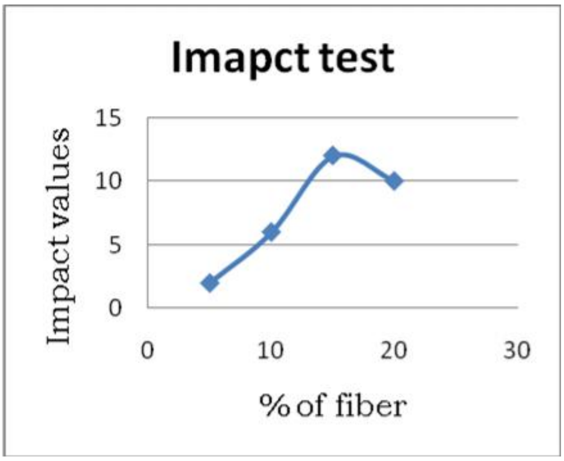

Fig . No 5.3 % of fiber Vs Impact values

5.4. Analysis Results

Coming from analysis part by using ANSYS software by changing the volume fraction of the fiber from 5% to 20% the stresses, strains and deflection values are decreased as shown in below

5% volume fraction of fiber

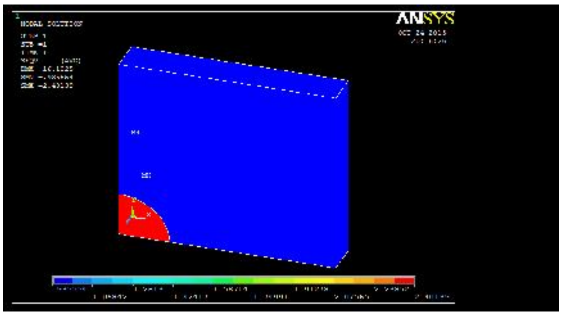

Fig 5.4. von misses stress

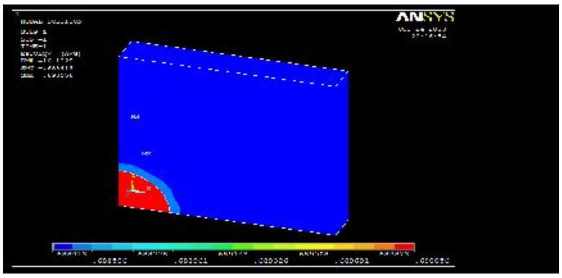

Fig 5.5 von misses strain

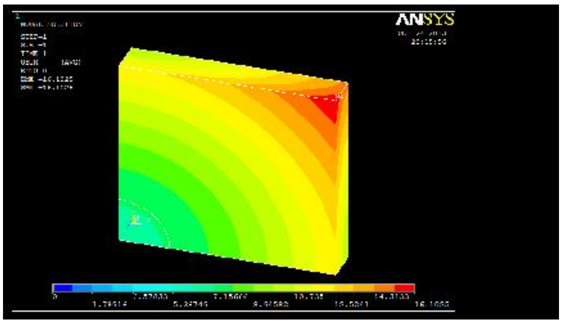

Fig 5.6 Displacement vector sum

10% volume fraction of fiber

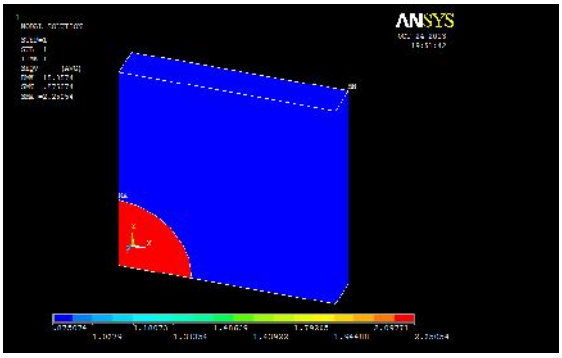

Fig 5.7 Von misses stress

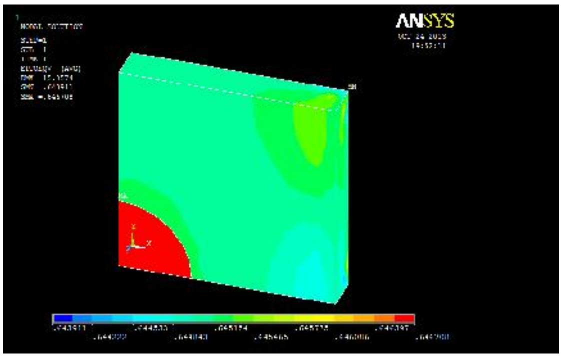

Fig 5.8 Von misses strain

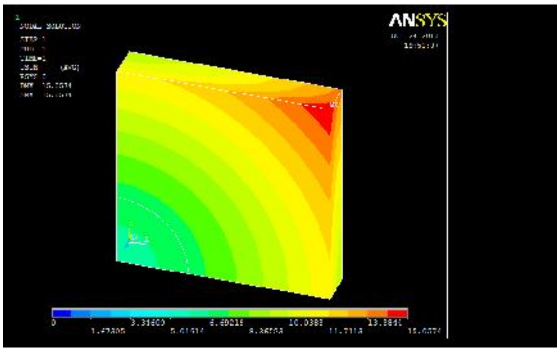

Fig 5.9 Displacement vector sum

15% volume fraction of fiber

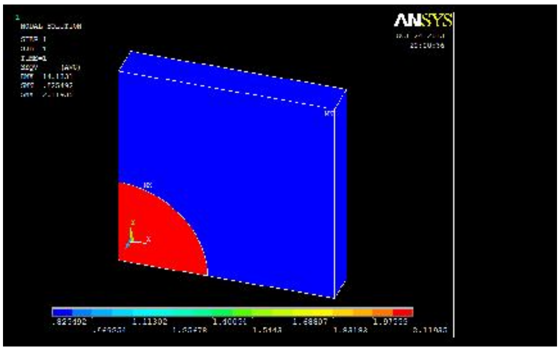

Fig 5.10 Von misses stress

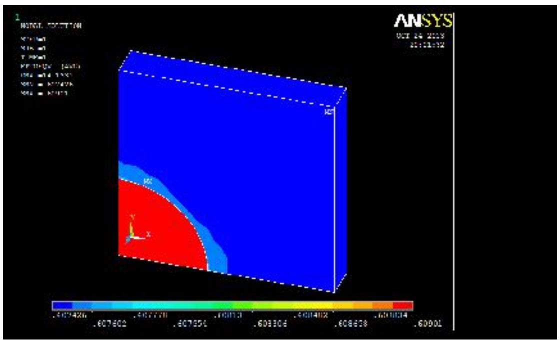

Fig 5.11 Von misses strain

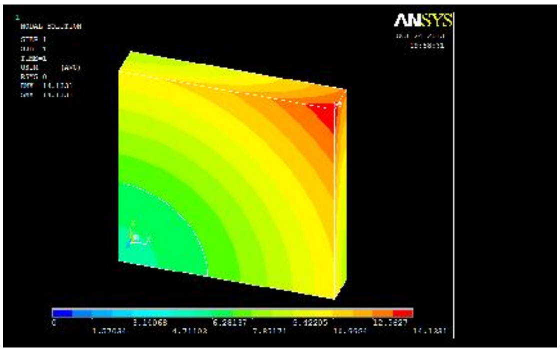

Fig 5.12 Displacement vector sum

20% Volume fraction of fiber

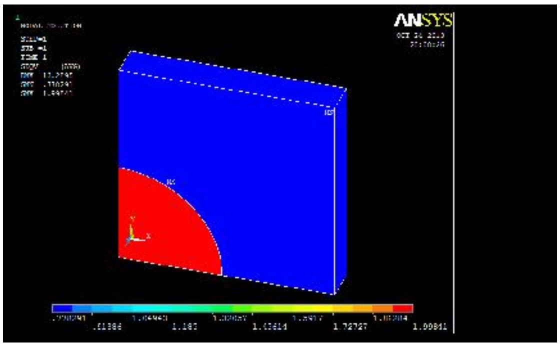

Fig 5.13 Von misses stress

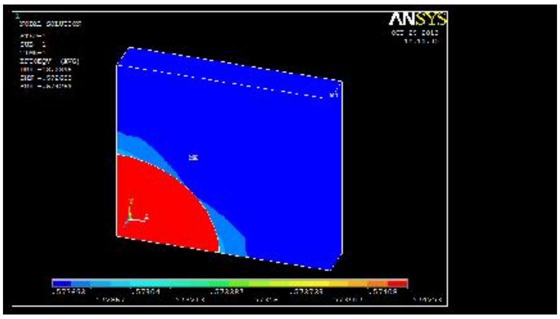

Fig 5.14 Von misses strain

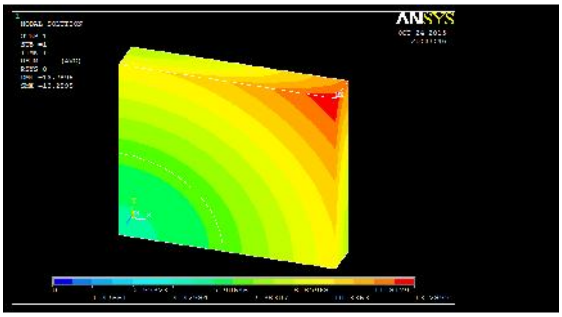

Fig 5.15 Displacement vector sum

Table 5.4 stress, strains and displacement vector sum for different volume fraction of fiber

Volume fraction of fiber	Radius of arc (mm)	Von misses stress (Mpa)	Von misses strain (Mpa)	Displacement vector sum (mm)	Young's modulus (Gpa)
5	11.83	2.40139	0.690056	26.1025	3.479993
10	16.9034	2.25054	0.646708	15.0574	3.479994
15	20.72	2.11935	0.60901	14.1331	3.479992
20	24.05	1.99841	0.574253	13.2895	3.480017

The below graph as drwan between various volume fraction of fiber Vs stress,strains,displacement vector sum

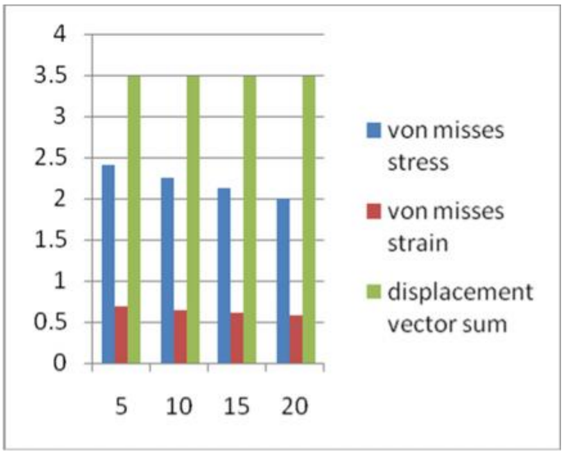

Fig 5.16 volume fraction of fiber Vs von misses stress, strain, displacement vector sum

The Below graph shows between Volume fraction of fiber Vs Young's modulus

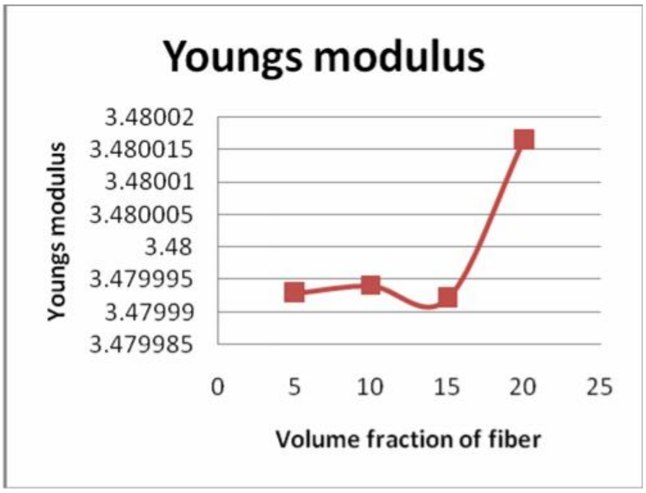

Fig 5.17 Volume fraction of fiber Vs Young's modulus

6. 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.

6.1 SCOPE FOR FUTURE WORK

- Similarly the composite can be prepared a hybrid composite by adding different fibers.
- Can also do the SEM analysis For this composites

7. REFERENCES

Journal Papers

[1]. Karnani R, Krishnan M and Narayan R, “Biofiber-reinforced polypropylene composites” polymer Engineering and science, 37(2), 1997, 476-48.

[2]. Joseph K, Mattoso L. H. C, Toledo R. D, Thomas S, Carvalho L.H. de, Pothen L, Kala S and James B, “Natural fiber reinforced thermoplastic Composites. In Natural Polymers and Agrofibers Composites”, ed. E. Frollini, A.L. Leão and L.H.C. Mattoso, 159-201, 2000, Sãn Carlos, Brazil: Embrapa, USP-IQSC, UNESP.

[3]. Van de Velde K and Kiekens P,Thermal degradation of flax : The determination of kinematic parameters with thermogravimetric analysis ,83 (12), Journal of Applied Polymer Science,pp.2634-2643.

[4]. Frederick T.W and Norman W, “Natural fibers plastics and composites”, Kluwer Academic Publishers, New York .

[5]. Mansur M.A and Aziz M.A, “Study of Bamboo-Mesh Reinforced Cement composites” Int. Cement Composites and Lightweight Concrete”, 5(3), pp. 165-171.

[6]. Gowda T.M, Naidu A.C.B, and chhaya R, “Some mechanical Properties of untreated Banana Fabric-Reinforced Polyester Composites”, Journal of Composites Part A: Applied Science and Manufacturing, 30(3), pp.277-284.

[7]. Laly A. Pothana, Zachariah Oommenb, and Thomas S, “Dynamic Mechanical Analysis of Banana Fiber Reinforced Polyester Composites”, Composites Science and Technology, 63(2), 2003, pp. 283-29

[8]. Corbiere-Nicollier T, Laban B.G, Lundquist L, Leterrier Y,. Manson J.A.E and Jolliet O, “Life Cycle Assessment of Biofibers Replacing Glass Fibers as Reinforcement in plastics”, Resources Convertion and Recycling, 33(4), pp. 267-287.

[9]. Pothan L.A, Thomas S and Neelakantan, “Short Banana Fiber Reinforced Polyester Composites: Mechanical, Failure and Aging Characteristics”, Journal of Reinforced Plastics and Composites, 16(8), pp. 744-765.

[10]. Joseph S, Sreekala M. S, Oommen Z, Koshyy P, and Thomas S, “A Reinforced with Banana Fibers and Glass Fibers”, Composites Science and Technology, 62(14), 2002, pp. 1857-1868.

[11]. Luo S, Netravali A. N, “mechanical and thermal properties of environmentally friendly green composites made from pineapple leaf fibers and poly(hydroxybutyrate-co-valerate) resin”, Polymer composites, 20(3), pp.367-78.

[12]. Lina Herrera-Estrade,Selvum Pilly and Uday Vaidya. Mechanical properties of woven banana fibre reinforced epoxy composites. *Material and Design, 27*: 689-693

[13]. Joseph et. al Press forming of short natural fiberreinforced biodegradable resin: Effects of fiber volume and length on flexural properties *Polymer Testing, 24*:1005–1011

Books:

[1] M W Hyer. 1998. *Stress Analysis of Composite Materials*. WCB McGraw-Hill.

[2] R M Jones. 1975. *Mechanics of Composite Materials*. Scripta Book Company.

[3] Autar K.Kaw.2006. *Mechanics of Composite Materials.* CRC Press.

[4] Issac M Danial. 1994 *Engineering Mechanics of Composites.* Oxford University Press.

[5] *ANSYS Reference Manuals,* 2012.