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Experimental Investigation of Effect of Fibre Diameter on Tensile Properties of Jute – Banana Fibre (Hybrid) Reinforced Epoxy Composite

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***Abstract*--In this paper, the experiments of tensile tests are carried out using Jute -banana fibre (hybrid) reinforced epoxy composite. Samples of jute, banana and hybrid (jute-banana) fibre reinforced composites of different diameter used in this research. Fibres are of diameter 1mm, 2mm and 3mm in the form of yarns. As the diameter of fibres (volume fraction) increases the tensile strength increases. From the obtained results the percentage of elongation of jute, banana and hybrid (jute-banana) fibre reinforced composites is 14%, 9%and 8.5% respectively when it is loaded along the orientation of fibres and 10% , 7.5% and 6.7% when it is loaded perpendicular to the orientation of fibre. And it is found that the stress is maximum when it is loaded along the orientation of fibre and minimum value of stress when it is loaded perpendicular to the orientation of fibre. Increase in tensile strength is achieved by hybridization of jute and banana fibres. There is an enhancement of 39.39 % and 24% in tensile strength because hybrid based epoxy composite when compared to jute and banana reinforced epoxy composites. Finite element analysis using ANSYS software has showed that the differences of results obtained from these samples are not significant compared to experimental results. Definitely this shows the importance of this product and attracts many researchers for the improvement of this composite**.

Key Words: Fibres, Composite, Jute, banana, Hybrid, Tensile Strength, Elongation, Yarn, Reinforcement

I. INTRODUCTION

In the world of materials the development of composites material the most common advanced materials in the later part of 20th century has given a boost to the engineering field. Composites were developed mainly with the considerations high strength and light weight. The aerospace and defense sectors are responsible for this growth, which always gave thrust for light weight but high strength material. However, nowadays, all the fields of life like civil, transportation, medical and general construction industries are also extensively using composite materials. The word composite in the term composite material signifies that two or more materials are combined on a macroscopic scale to form a useful third material. The advantage of composite materials is that if well designed, they usually exhibit the best qualities of their components or constituents and often some qualities that neither constituent possesses. In the world of materials the development of composites material the most common advanced materials in the later part of 20th century has given a boost to the engineering field. Composites were developed mainly with the considerations high strength and light weight. The aerospace and defense sectors are responsible for this growth, which always gave thrust for light weight but high strength material. However, nowadays, all the fields of life like civil, transportation, medical and general construction industries are also extensively using composite materials. The word composite in the term composite material signifies that two or more materials are combined on a macroscopic scale to form a useful third material. Naturally, not all of the properties are improved at the same time nor is there usually any requirement to do so. In fact, some of the properties are in conflict with one another e.g., thermal insulation versus thermal conductivity. The objective is merely to create a material that has only the characteristics needed to perform the design task. The interest in natural fibre-reinforced composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana etc., as well as wood, used from time immemorial as a source of lignocelluloses fibres are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibres used for the manufacturing of composites. The natural fibre-containing composites are more environmentally friendly and are used in transportation (automobiles, railway coaches, aerospace etc.), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products etc.

Reinforcements for the composites can be fibres, fabrics particles or whiskers. Fibres are essentially characterized by one very long axis with other two axes either often circular or near circular. Particles have no preferred orientation and so does their shape. Whiskers have a preferred shape but are small both in diameter and length as compared to fibres. Fibres are the important class of reinforcements, as they satisfy the desired conditions and transfer strength to the matrix constituent influencing and enhancing their properties as desired. There are several methods of random fibre orientations, which in a two-dimensional one, yield composites with one-third the strength of a unidirectional fibre-stressed composite, in the direction of fibres. In a 3-dimension, it would result in a composite with a comparable ratio, about less than one-fifth. In very strong matrices, moduli and strengths have not been observed. Application of the strength of the composites with such matrices and several orientations is also possible. The longitudinal strength can be calculated on the basis of the assumption that fibres have been reduced to their effective strength on approximation value in composites with strong matrices and non-longitudinally orientated fibres. It goes without saying that fibre composites may be constructed with either continuous or short fibres. Experience has shown that continuous fibres (or filaments) exhibit better orientation, although it does not reflect in their performance. Fibres have a high aspect ratio i.e., their lengths being several times greater than their effective diameters. This is the reason why filaments are manufactured using continuous process. This finished filaments. Mass production of filaments is well known and they match with several matrices in different ways like winding, twisting, weaving and knitting, which exhibit the characteristics of a fabric. Since they have low densities and high strengths, the fibre lengths in filaments or other fibres yield considerable influence on the mechanical properties as well as the response of composites to processing and procedures.

Materials which are made by combining two or more different types of fibres in a matrix are called as “hybrid composites”. The natural fibres like jute, sisal, hemp, kenaf, and banana are renewable, non-abrasive and can be incinerated for energy recovery. They possess a good strength and cause little concern in terms of health and safety during handling. In addition, they exhibit excellent mechanical properties, have low density and are inexpensive. This good environmental friendly feature makes the materials very popular in engineering markets such as the automotive and construction industry. This made us to investigate the tensile properties of jute and banana fibre reinforced epoxy hybrid composites.

Generally, not much of the papers have published on the jute-banana fibre reinforced Epoxy hybrid composites. Sapuan et.al. (2006) [1] conducted the experiments of tensile and flexural (three-point bending) tests were carried out using natural fibre with composite materials (woven banana fibre/epoxy). From the results obtained, it is found that the maximum value of stress in x-direction is 14.14 MN/m^2; meanwhile the maximum value of stress in y-direction is 3.398 MN/m^2. For the Young’s modulus, the value of 0.976 GN/m^2 in x-direction and 0.863 GN/m^2 in y-direction were computed. As for the case of three-point bending (flexural), the maximum load applied is 36.25 N to get the deflection of woven banana fibre specimen beam of 0.5 mm. The maximum stress and Young’s modulus in x-direction is recorded to be 26.181 MN/m^2 and 2.685 GN/m^2, respectively. Khalifa and Chappar (2014) [2] investigated the experiments of tensile tests are carried out using banana fibre reinforced epoxy composite. Fibres are of diameter 1mm, 2mm and 3mm in the form of yarns. And as the diameter of fibres (volume fraction) increases the tensile strength increases. From the obtained results the percentage elongation of banana reinforced epoxy composites is 9%. And it is found that the stress is maximum if it is loaded along the length of the fibre and minimum value of stress when it is loaded perpendicular to the length of fibre. Boopalan *et.al.* (2013)[3] Investigated the mechanical and thermal properties of raw jute and banana fibre reinforced epoxy hybrid composites. To improve the mechanical properties, jute fibre were hybridized with banana fibre. The jute and banana fibres were prepared with various weight ratios (100/0, 75/25, 50/50, 25/75 and 0/100) and then incorporated into the epoxy matrix by moulding technique to form composites. Addition of banana fibre in jute/epoxy composites of up to 50% by weight results in increasing the mechanical and thermal properties and decreasing the moisture absorption property. Ramesh *et.al.* (2013) [4] evaluated mechanical properties such as tensile and flexural properties of hybrid glass fibre-sisal/jute reinforced epoxy composites. Microscopic animations are carried out to analyze the interfacial characteristics of materials, internal structure of the fractured surfaces and material failure morphology by using Scanning Electron Microscope (SEM). The results indicated that the incorporation of sisal fibre with GFRP exhibited superior properties than the jute fibre reinforced GFRP composites in tensile properties and jute fibre reinforced GFRP composites performed better in flexural properties. Mishra and Biswas (2012)[5] experiments are carried out to study the effect of fibre loading on the physical and mechanical behaviour of these composites. Result shows the significant effect of fibre loading on the mechanical properties of the composites. Also, the formation of voids in the composites is an influencing factor on the mechanical properties. Shankar *et.al* (2013) [6] studied mechanical performance and analysis of banana fibre reinforced epoxy composites. 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 fibre. 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 fibre. Raghavendra *et.al* (2013) [7] conducted the experiment on mechanical properties of short banana fibre reinforced natural rubber composites, As the fibre concentrations increases tensile strength also increases. When fibre concentrations are less the matrix and fibre interface shows weak bonding. The incorporation of fibre into rubber matrix increases the hardness of the composite, which is related to strength and toughness. The close packing of fibres in the compounds increases the density while resilience decreases. The composites made from 15mm length banana fibres shows the maximum tensile strength and good tear strength. Dixit and Verma (2012) [8] the effect of hybridization on mechanical properties on coir and sisal reinforced polyester composite (CSRP), coir and jute reinforced polyester composite (CJRP), jute and sisal reinforced polyester composite (JSRP) were evaluated experimentally. The results demonstrate that hybridization play an important role for improving the mechanical properties of composites. The tensile and flexural properties of hybrid composites are markedly improved as compare to unhybrid composites. Sakthive and Ramesh (2013) [9] conducted an experiment on mechanical properties of natural fibre (banana, coir, sisal) It is found that polymer banana reinforced natural composites is the best natural composites among the various combination. It can be used for manufacturing of automotive seat shells among the other natural fibre combinations.

II. METHODOLOGY

Before starting the tensile tests, specimens are prepared of different volume fractions. Initially the fibres are extracted from Pseudo stem of fully grown banana plant. The stem is kept under the sunlight for 15 – 20 days. Then the dried fibres were soaked in water for at least 20 days. And again it is dried under the sunlight until all the moisture is taken out. And finally the stem is cut horizontally and then the fibres are extracted. Jute fibre has been obtained from the local sources. Yarns of diameter 1 mm, 2mm and 3mm yarns are prepared by process called spinning, of length 150 mm which is to be reinforced in composite.

Fig.2.1. Yarns prepared of banana fibres

The mould used for composite fibres is made from rectangular plywood 150mm in length and 50 mm in width, and it is coated with plastic tape so as to prevent epoxy from sticking to the plywood. Initially, the upper side is kept open and then after pouring the epoxy the upper side is closed during the curing time so as to avoid the debris entering the composite. Holes were drilled at the sides of the mould box of diameter 3mm for reinforcing of fibres through it so as to avoid the change in the orientation of fibres during layup.

Fig.2.2. Mould Box

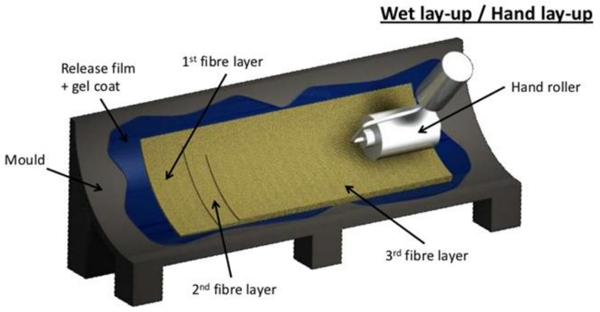

Fig. 2.3. Hand Layup process

The matrix that is used to fabricate the fibre specimen is epoxy of density 1.0 g/cm^3 and it is mixed with hardener of density 1.0 g/cm^3. The weight ratio of mixing epoxy and hardener is 3:1. Initially the mould box is cleaned and dried and then the mould box is coated with plastic tape. Epoxy is laid on the box and then the yarns are reinforced through the holes. Then again another layer of epoxy is laid on the fibres. Then the composite is kept it to dry at room temperature for 12 to 15 hours. Before performing the tensile test the specimen dimensions are measured i.e. initial length (L_i), width (W_i) and height (t_i).The specimens are made of dimension 150mm x 50mm x 10 mm. Specimens are prepared of diameter 1mm, 2mm and 3mm.

III. RESULTS AND DISCUSSIONS

Jute, banana and hybrid (jute-banana) reinforced epoxy composites were prepared and tested for tensile properties in universal testing machine. Parameters such as tensile strength, tensile modulus, and strain elongation were determined. For all the tensile test of the specimen the speed of the jaw is kept constant at 5mm /min. Specimens were loaded along the orientation of fibres and perpendicular to the orientation of fibres.

3.1. Jute Fibre Reinforced Epoxy Composite

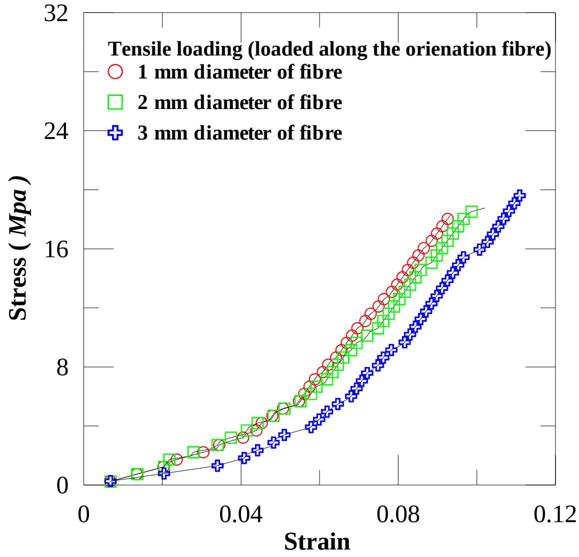

Fig.3.1 Effect of fibre diameter on tensile strength of jute reinforced epoxy composite

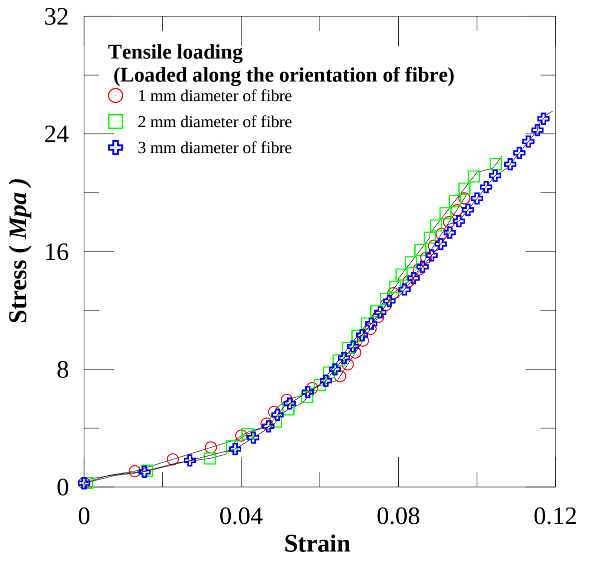

Fig.3.2 Effect of fibre diameter on tensile strength of banana fibre reinforced epoxy composite.

3.3. Jute-Banana (Hybrid) Fibre Reinforced Epoxy Composite

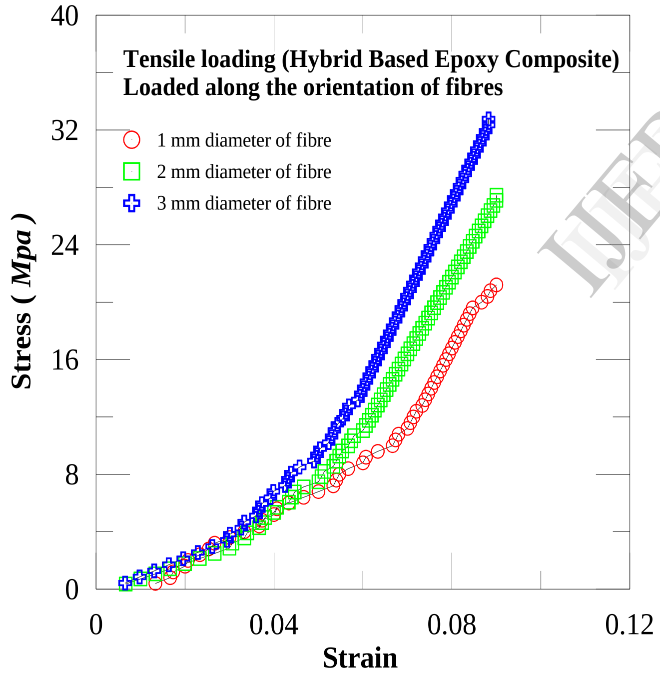

Fig.3.3 Effect of fibre diameter on tensile strength of jute –banana (hybrid) fibre reinforced epoxy composite.

Fig. 3.1 shows the effect of fibre diameter on tensile strength of jute reinforced epoxy composite. The loading is done along the orientation of the fibres. The diameter of jute fibres are 1mm, 2mm and 3mm. Figure clearly reveals that as the diameter increases the tensile strength also increases. This may be due to increase in tensile modulus and also increase in bonding between fibre and matrix.

Fig.3.2 shows the stress-strain diagram for reinforced epoxy composite for diameter 1mm, 2mm and 3mm in which loading is done along the orientation of fibre. Fig. 3.2 clearly shows that as the diameter of fibres tensile strength increases which in turn reveals that there is definite effect of volume fraction of fibres. This may be due to increase in interfacial bonding between fibres and matrix. Fig. 3.3 shows the stress-strain diagram for jute-banana (hybrid) reinforced epoxy composite. From the figure it is clear that there is enhancement in tensile properties. With increase in diameter of fibres, the tensile modulus and strength increases but decrease in strain. The tensile strength increases by using jute-banana fibre (hybrid) composite instead of reinforcing individually.

Fig.3.4 shows the tensile strength of epoxy composite. In this the loading is done perpendicular to the orientation of fibre. The tensile strength decreases when it is loaded perpendicular to the orientation of fibre instead of loading along the orientation of fibres. This shows that the jute fibres are directional oriented. Similar trends can be seen in banana fibres reinforced epoxy composite and Hybrid fibres reinforced epoxy composite shown in Fig.3.5 and Fig.3.6 respectively.

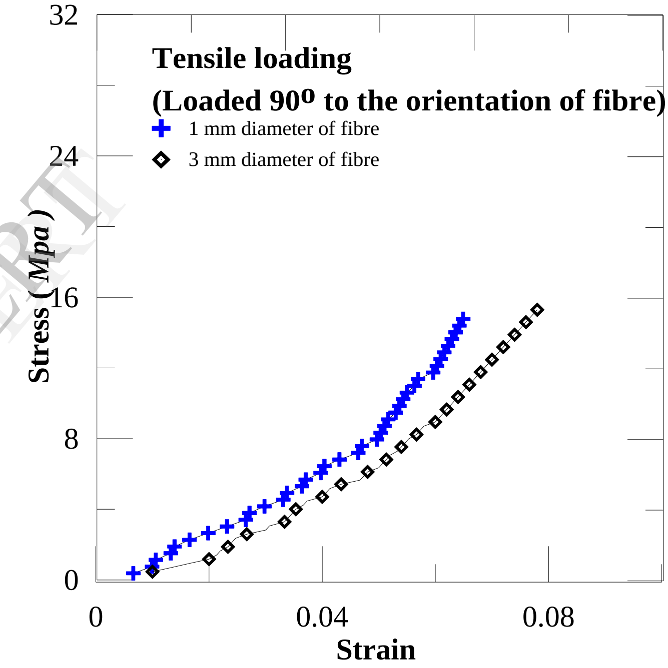

Fig.3.4 Effect of fibre diameter on tensile strength of jute fibre reinforced epoxy composite.

Fig.3.6 and Fig.3.7 shows the comparison of individual jute and banana fibre reinforced epoxy composites and jute-banana (hybrid) fibre based epoxy composite for particular diameter of fibre. Minimum and maximum tensile strength is noted in jute fibre reinforced epoxy composite and jute-banana (hybrid) fibre based epoxy composite respectively. It clearly reveals that banana fibre reinforced epoxy composite has better tensile properties than jute fibres reinforced epoxy composites. Tensile modulus enhances with hybrid composites compared to the jute and banana fibres reinforced individually. This may be due to better adhesion of banana fibre with matrix material.

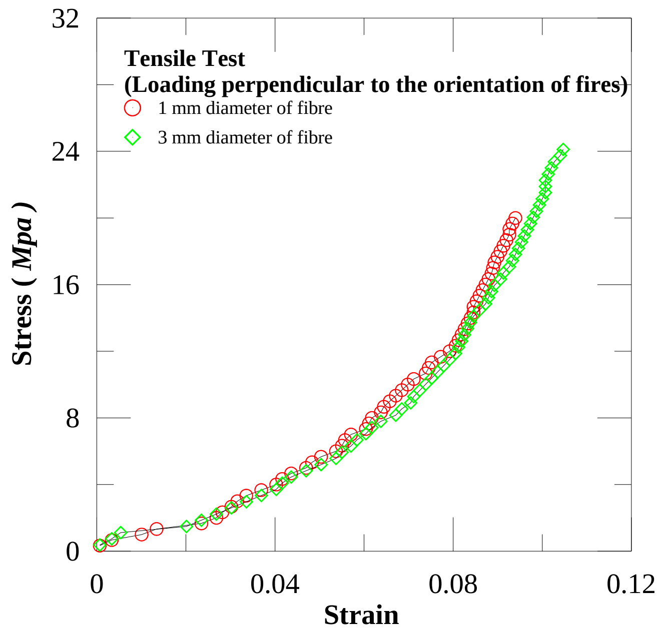

Fig.3.5 Effect of fibre diameter on tensile strength of banana fibre reinforced epoxy composite.

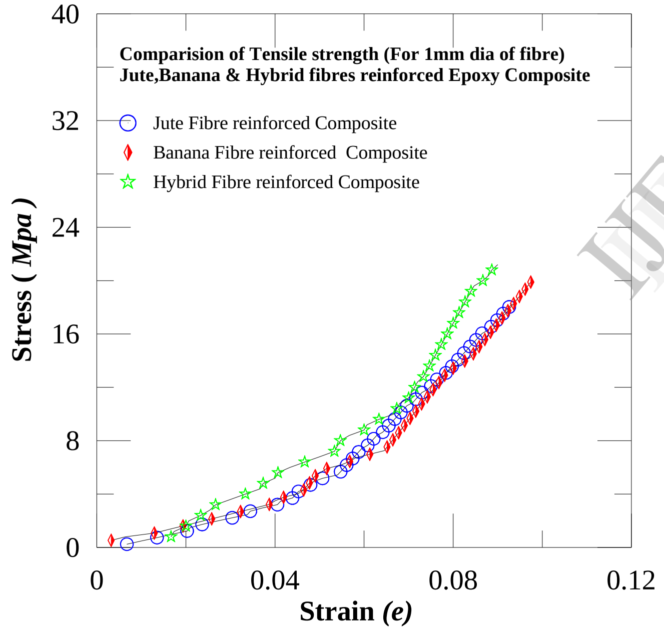

Fig.3.6 Comparison of jute, banana and hybrid fibres reinforced epoxy composites.

Fig 3.8.shows the effect of diameter of fibres on tensile strength. Due to reinforcing of jute-banana fibres in a common matrix there is an enhancement in tensile properties.

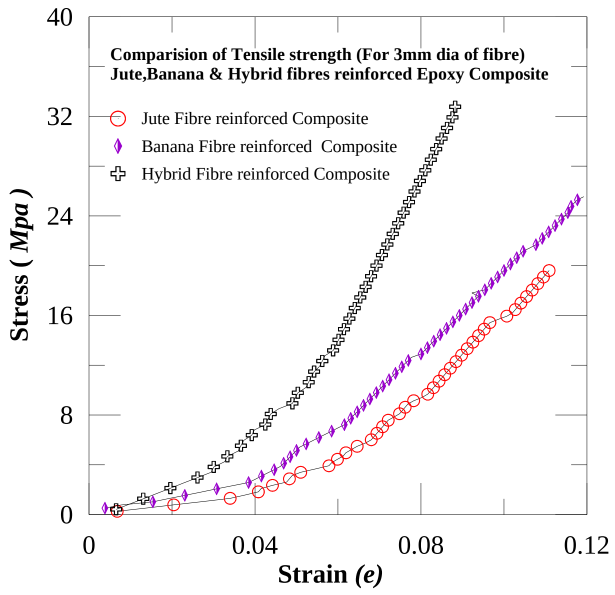

Fig.3.7 Comparison of jute, banana and hybrid fibres reinforced epoxy composites.

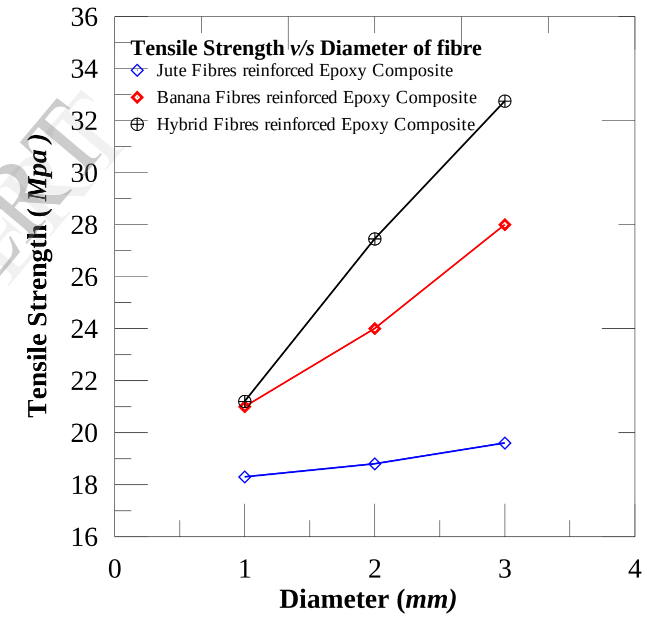

Fig.3.8 Effect of fibre diameter on tensile strength of jute, banana and hybrid fibres reinforced epoxy composites.

Fig.3.12, 3.16, 3.21 shows the comparison of experimental results with Finite Element Approach. From the plots it is clear that experimental results are almost equal to the finite element method. FEM models are shown in figure for jute fibre reinforced epoxy composites (Fig.3.9.-3.11), banana fibre reinforced epoxy composite (Fig.3.13-3.16.) and jute-banana (hybrid) fibre reinforced epoxy composite (Fig.3.18-3.21).

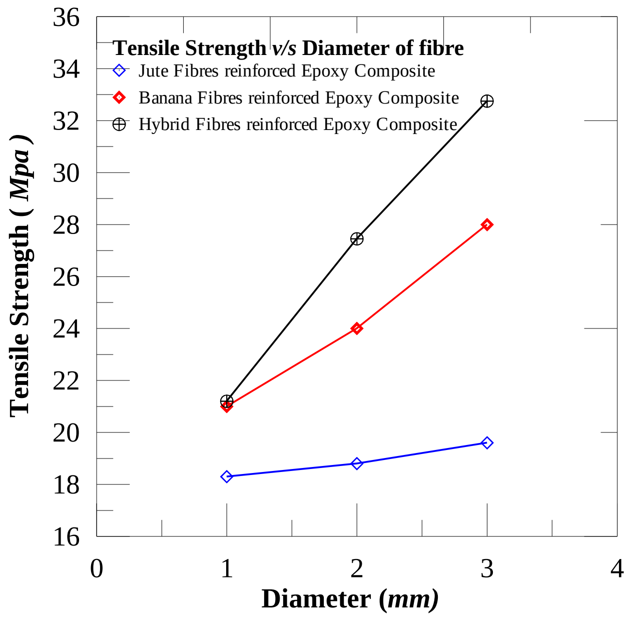

Fig.3.8 Effect of fibre diameter on tensile strength of jute, banana and hybrid fibres reinforced epoxy composites.

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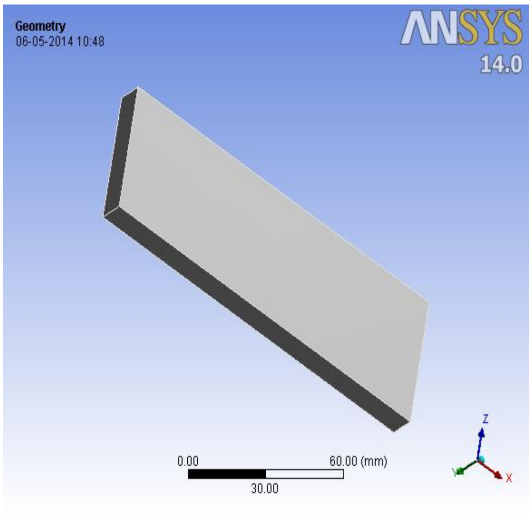

Fig.3.9 shows the geometric model for the banana fibre reinforced epoxy composite.

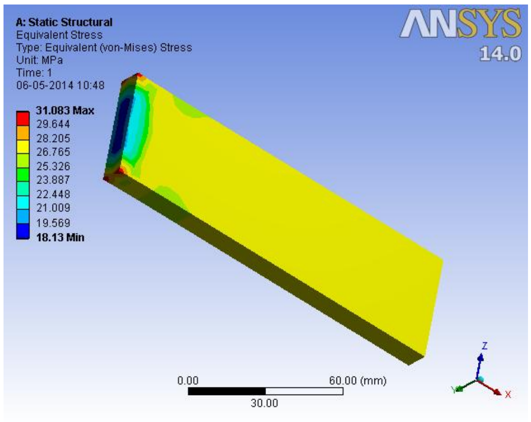

Fig.3.10 shows the Von-Misses stress model of banana fibre reinforced epoxy composite, for the diameter of 3mm fibre loaded along the orientation of fibre.

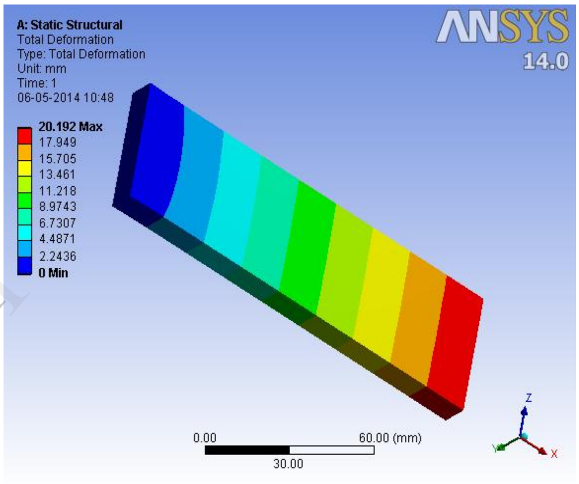

Figure 3.11 shows the deformed model of banana fibre reinforced epoxy composite, for the diameter of 3mm fibre loaded along the orientation of fibre.

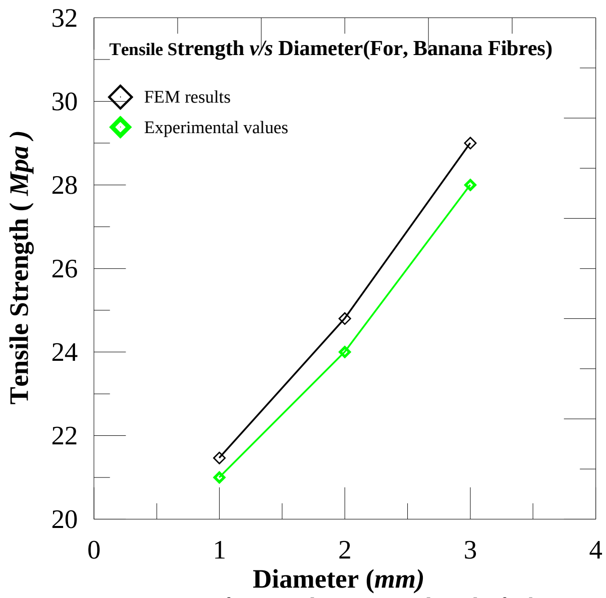

Fig.3.12 Comparison of FEM and experimental results for banana reinforced epoxy composites.

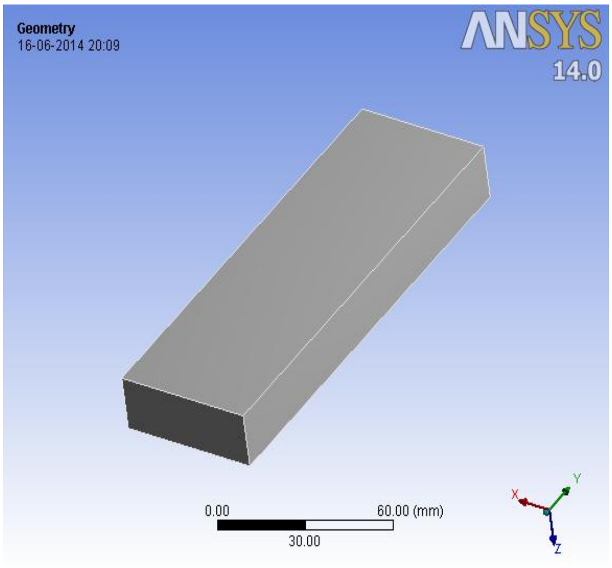

Fig.3.13 shows the geometric model for the jute fibre reinforced epoxy composite.

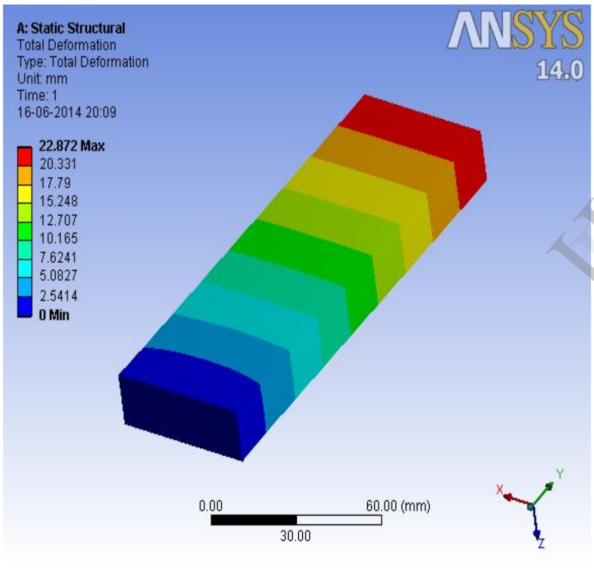

Fig.3.14 shows the deformed model of jute fibre reinforced epoxy composite, for the diameter of 3mm fibre loaded along the orientation of fibre.

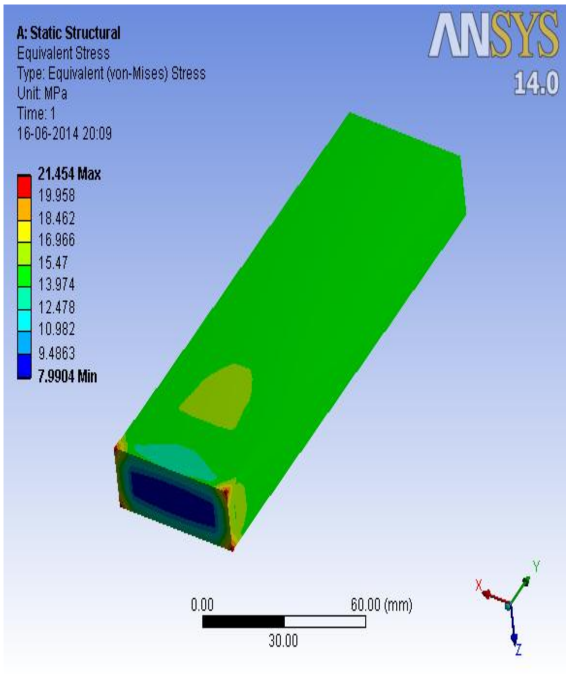

Fig.3.15 shows the Von-misses stress model jute fibre reinforced epoxy composite, for the diameter of 3mm fibre loaded along the length of fibre.

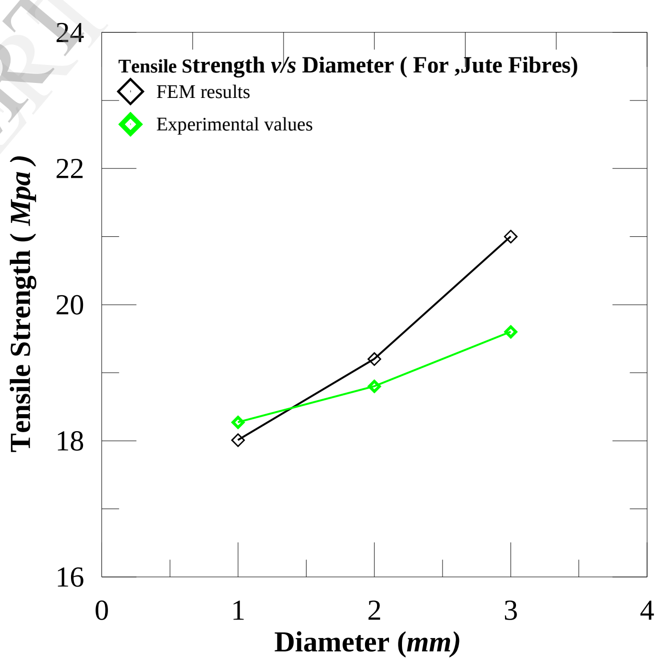

Fig.3.16 Comparison of FEM and experimental results for jute reinforced epoxy composites.

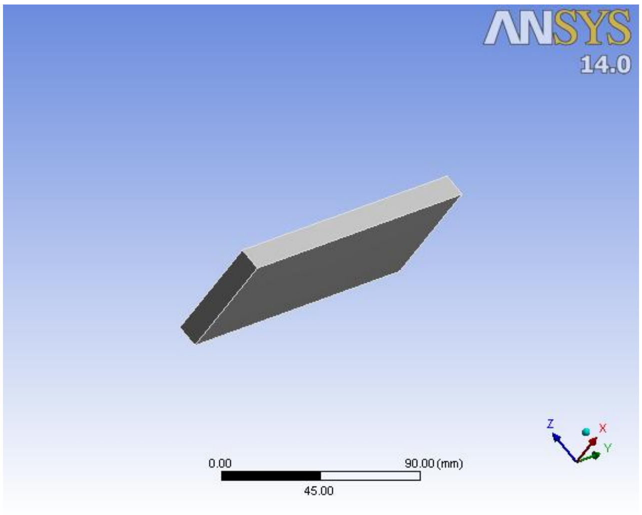

Fig.3.17 shows the geometric model for the jute-banana fibre (hybrid) reinforced epoxy composite.

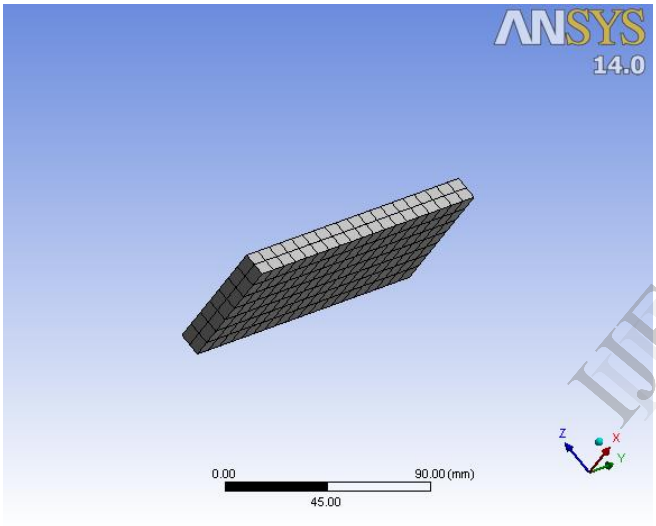

Fig.3.18 shows the meshed model for the jute-banana fibre (hybrid) reinforced epoxy composite.

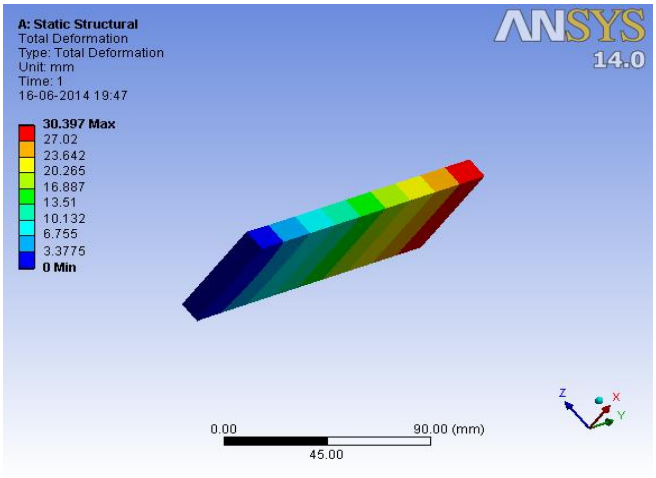

Fig.3.19 shows the deformed model of jute-banana (hybrid) fibre reinforced epoxy composite, for the diameter of 3mm fibre loaded along the length of fibre.

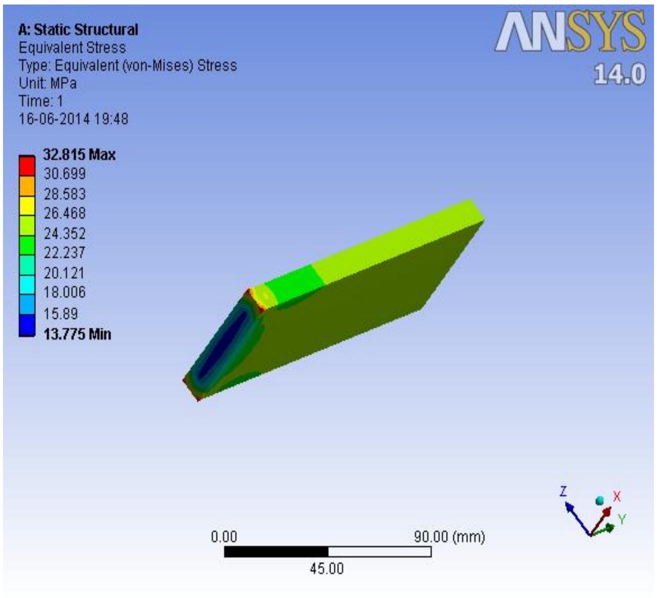

Fig.3.20 shows the Von-Misses stress model of jute-banana (hybrid) fibre reinforced epoxy composite, for the diameter of 3mm fibre loaded along the length of fibre.

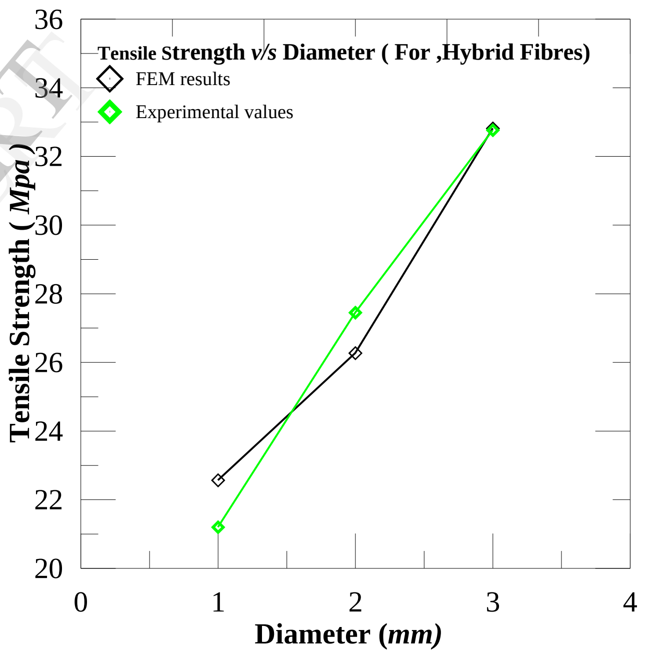

Fig.3.21 Comparison of FEM and experimental results for jute-banana (hybrid) fibre reinforced epoxy composite.

IV. CONCLUSIONS

Samples of Jute fibre reinforced epoxy composite, banana reinforced epoxy composites and jute-banana (hybrid) reinforced epoxy composite were prepared and tested for tensile properties in universal testing machine. Parameters such as tensile strength, tensile modulus, and strain elongation were determined. For all the tensile test of the specimen the speed of the jaw is kept constant at 5mm /min. The jute, banana and hybrid fibres have definite effect on the tensile strength of composite. There is enhancement in tensile strength due to the reinforcement of fibres when compared to the neat epoxy. Tensile strength is more when it is loaded along the orientation of fibre and it becomes weak when it is loaded perpendicular to the orientation of fibre. As the fibre diameter increases the tensile strength increases and the tensile strain decreases. Tensile strength of hybrid (jute-banana) fibres is more when compared to the individual jute fibre and banana fibre reinforced epoxy composite. There is an enhancement of 39.39 % and 24% in tensile strength because hybrid based epoxy composite when compared to jute and banana reinforced epoxy composites. Due to increase in interaction between fibre/matrix enhances the tensile strength. The experimental results obtained are almost similar to the Analytical results.

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