IOP Conf. Series: Materials Science and Engineering **402** (2018) 012135 doi:10.1088/1757-899X/402/1/012135

Evaluation of mechanical properties on banyan fiber reinforced polymer matrix composite using FEA

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Abstract. The use of natural fiber composites is considered as the green when compared to other man-made fibers. They are biodegradable, recyclable. They are inherently available with properties like low density, high strength to weight ratio and are low cost when compared to synthetic fibers. The main experiment is to use finite element analysis on banyan fiber composite beam. The composite beam is processed by using hand layout method. The composite beam is prepared in two different orientations where one is random orientation and the other is unidirectional orientation. The composite beam is made in three types. The first beam has epoxy resin and hardener. The second has banyan fiber in short strands with epoxy resin and hardener. The third has banyan fiber in powdered form with epoxy resin and hardener. Mechanical tests such as tensile test and impact test were carried out to find the properties of the composite. Finally, the mechanical properties are used to analyze the composite fiber using finite element analysis using ANSYS software for determining the deflection and stress properties. The study has been carried out in regards to the advantages of natural fiber over synthetic fiber.

Keywords. FEA, Natural fiber, Epoxy resin, Banyan fiber.

1. Introduction

The organic fibers usage is increasing day by day for the fabrication process of composites and attracted many researchers. Addition of organic fiber(Banyan) which is stronger in nature in composites gives the composites more strength to weight ratio. These composites are environment friendly and free of cost. It has no adverse effect on the environment [1]. This composite is Fiber reinforced polymer shortly known as FRP where epoxy resin is used as a matrix material to make perfect bond between the fibers and hardener is used to fasten the reaction of curing of composite. Since organic fibers are strong in nature and due to their low densities, they are capable of producing composites with homogeneous specific properties to those of E- glass fibers. The environmental awareness and consciousness around the world has created an interest in natural composite fibers and its applications in different fields. Natural fibers are considered as an alternative to synthetic fibers[2]for various fields. The natural fibers are used as reinforcement materials in matrix composites which is environment friendly and best usage of raw materials. There are benefits of natural fibers over traditional reinforcing materials like carbon fiber, glass fiber etc. Few properties of natural and synthetic fibers are shown in table 1[3]

Fibers	Density(g/cm^3)	Tensile strength(MPa)	Modulus(GPa)	Elongation at failure (%)	Moisture absorption
E-glass	2.55	2400-3500	073	3	-
Hemp	1.4	550-900	70	1.6	8
sisal	1.33	600-700	38	2-3	11
jute	1.46	400-800	10-30	1.8	12
Ramie	1.5	500	44	2	12-17
Coir	1.25	220	6	15-25	10
cotton	1.51	400	12	3-10	8-25
Carbon	1.4	4000	230-240	1.4-1.8	-
Flax	1.4	800-1500	60-80	1.2-1.6	7

Table 1. Mechanical Properties of natural and synthetic fibers [4]

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1.1 Fibers as the reinforcement (Fibrous Composites)

1.1.1. Random fiber (short fiber) reinforced composites. In short fiber reinforcement; the fiber length is on the order of 100 times the fiber OD. Since most fibers are shorter in diameter than long fiber. Short fibers look more like powder to the unassisted eye as shown in the figure 1. Short fibers are manufactured by cutting down the long fiber into powder. When compared to long and continuous fiber reinforcements, short fibers composites are the easiest to fabricate [4].

1.1.2. Continuous fiber (long fiber) reinforced composites. The long fiber which is length of 100mm was extracted from the raw material (banyan fiber) which is in the form of longer strands. Since they are low in density long fiber strands were dipped in the Naoh solution for one day and dried under the sun for a day before using. Then the fiber strands were made in the straight form for the unidirectional orientation of the composite as shown in the figure 2.

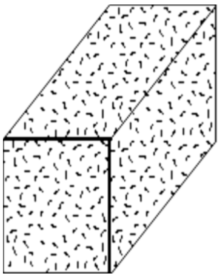

Figure 1. Random fiber (short fiber) reinforced composites

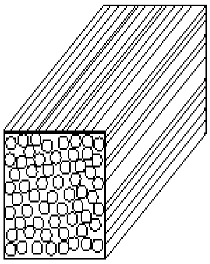

Figure 2. Continuous fiber (long fiber) reinforced composites

2. Raw materials and Methodology

2.1 Raw materials

2.1.1 Banyan fiber. The natural fibers usually differ depending upon the properties, source and segregation techniques used for the fibers. Banyan tree fiber which is a long living plant, has a major source in fibers over a long period of time in many applications in manufacturing. It is generally having good potential as a reinforcing material in composites. The extracted fiber from the aerial roots shown in the figure 3.And the powdered form of fiber after Naoh treatment as shown in the figure 4.

Figure 3. Extracted banyan fiber from aerial root

Figure 4. Random fibers of powdered form

*2.1.2. Epoxy Resin***.** It is used as a binding material which is otherwise known as matrix material to make a perfect bond between the fibers. It is mostly used as thermoset plastic in polymer matrix composites.

2.1.3. Triethylenetetramine (HY 951). Triethylenetetramine (TETA) is an organic compound used as a hardener. It is an oily liquid which is colourless but assumes yellowish colour due to impurities formed by air oxidation. It is generally soluble in polar solvents and typically reactive to amines.

2.2 Fabrication of the composite fiber

2.2.1. Alkaline Treatment. The most commonly used chemical treatment for natural fibers are reinforcement of thermoplastic and thermoset plastics. The fibers undergo disruption of hydrogen bonds in the network structure that increase in surface roughness and fiber strength. This procedure involves strengthening of fibers. In addition of NaOH to natural fibers alters the ionization of the hydroxyl group to the alkoxide.[3]

2.2.2. Polymer-Hardener mixture preparation. The fiber samples measurement must be proper to get composition of the composite. The polymer amount is taken as per the calculation and 10% of hardener is used. Next the mixture is stirred thoroughly until it becomes warm. The mixture must be mixed properly otherwise air bubbles will be formed. The hardener which is a fast reactant so it should be taken in less than a minute to stop from causing an error in the composite mixture reaction.

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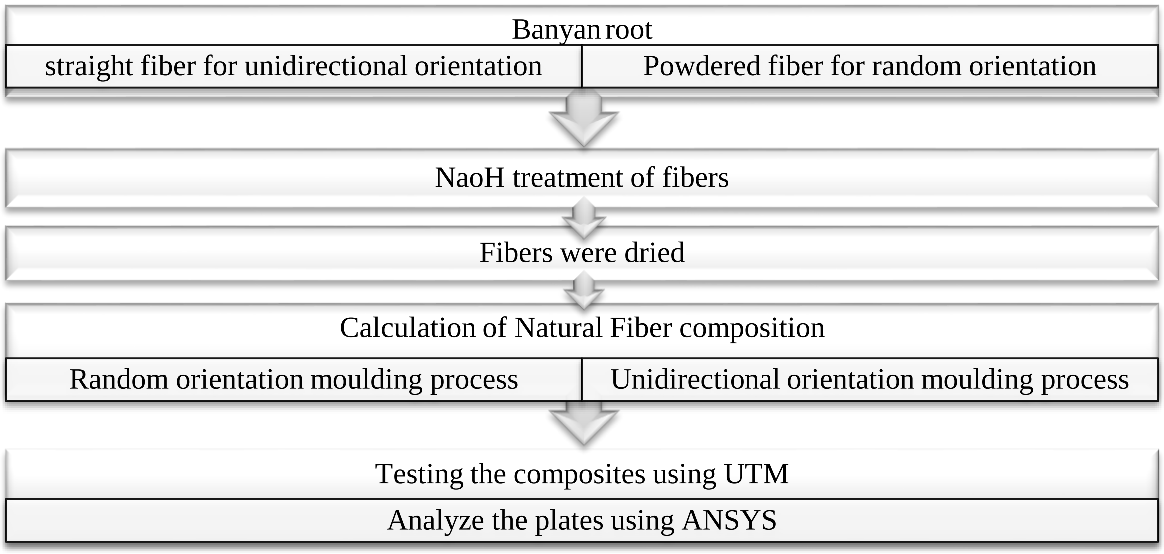
2.3 Methodology



2.3.1. Hand lay -up method. The preparation starts with the creating of the mould. As the preparation of the FRP does not require high temperature, it is prepared under normal temperature [5]. The prepared solution is poured in to the mould made of cardboard as shown in the figure 5. Then it is allowed to cure under normal temperature.

Figure 5. Hand lay-up method

3. Test procedure

The specimen is prepared according to ASTM standards for testing. The specimen is cut in dog bone shape of 165x19x3mm for Tensile testing according to standards [3] as show in the figure 7.

Figure 6. Ultimate tensile testing machine

Figure 7. Specimens of dog bone shape for tensile test

3.1 Tensile test

Tensile test is conducted to observe the material properties of the composites. The specimen of required dimension was deformed with an increasing tensile load which is applied along the axis of material at a constant rate as shown in figure 8. The specimens were deformed at a constant rate and are shown in figure 9.

Figure 8. Specimen under loaded condition

Figure 9. **S**pecimens after tensile test

4. Results and Discussion

4.1Tensile test

The tensile test results were compared and are shown in table 2.

Table 2. Tensile Test Result.

Sample No.	CS Area [mm²]	Peak Load [KN]	% Elongation	UTS [N/mm²]	Young's Modulus N/mm²	Strain
1. plain glass	21.62	0.180	3.33	6.145	312	.019
2.Unidirectional	21.62	0.280	2.12	9.617	801	.012
3 .Random	21.62	0.330	1.67	11.541	1229	.009

Tensile test on different specimen is influenced by the strength and modulus of fiber and resin when the thickness of the laminate is increased, the strength also gets increased in strength. When comes to the hybrid composites, the addition of fibers substantially increases the tensile strength. There is an increase in strength in sample 3 comparison with sample 2. This may be due to the

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locking of these particles in the interspace. Finer the particles added greater the tensile strength as well as greater the young's modulus.

4.2 Finite Element Analysis

Finite element model is created using ansys and analysed for different loads. Meshing is done with tetrahedral element and material properties are assigned (figure. 10). Cantilever beam subjected to point load at free end is modelled and analysed for different loads (60, 120, 180N) and three material properties such as random orientation, unidirectional and plain glass.

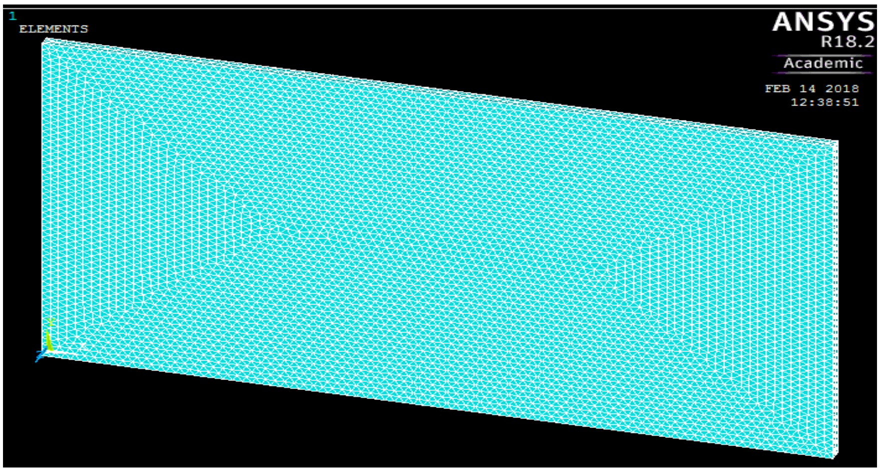

Figure 10. Meshing of the composite.

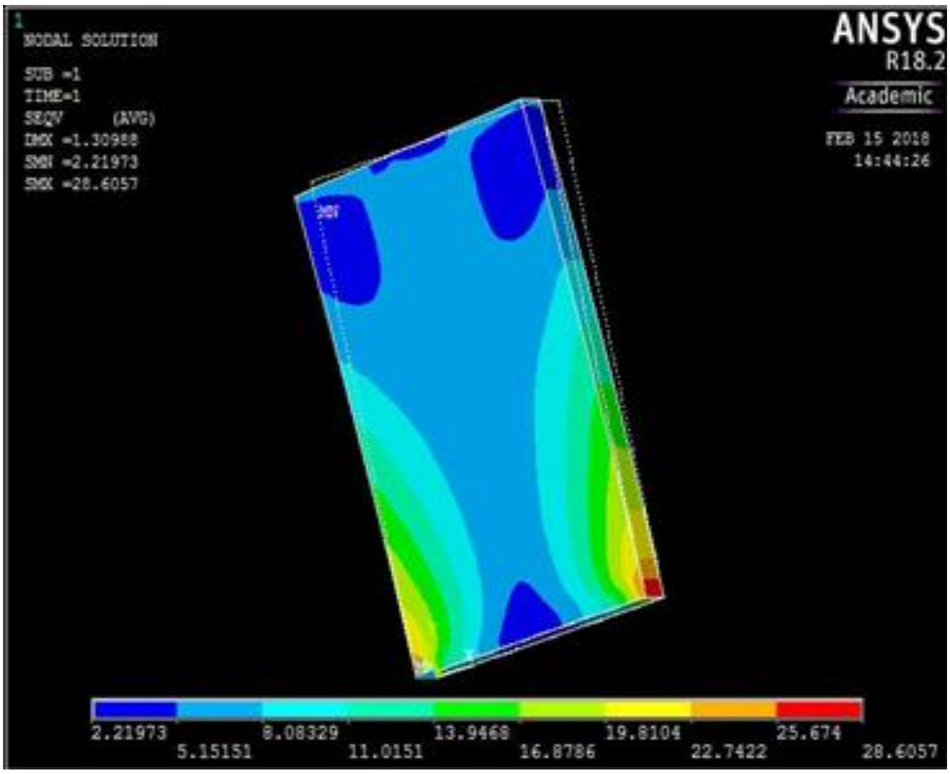

Figure 11. Composite subjected to Von Mises stress Concentration.

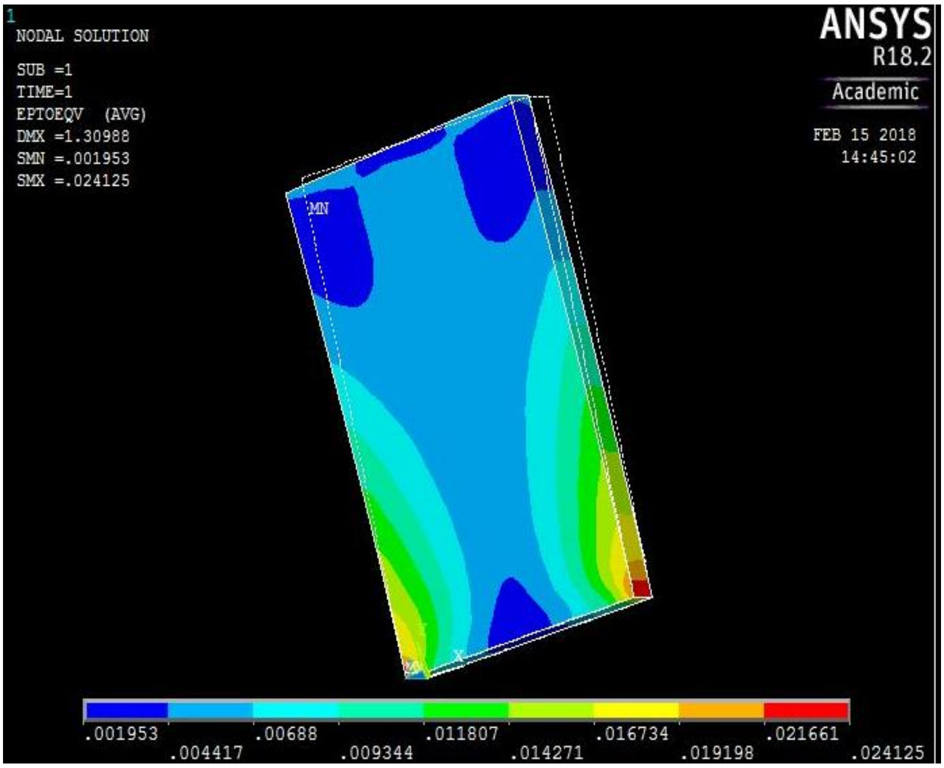

Figure 12. Composite subjected to Von Mises strain concentration.

Figure.11 and Figure.12 shows the distribution of stress and strain across the composite for random orientation of fiber with the force of 180 N. Deflection is less and stress concentration is higher compared to other samples.

The deflection of the composite beam and the stress intensity of the material are found along y axis as shown in the figure 13

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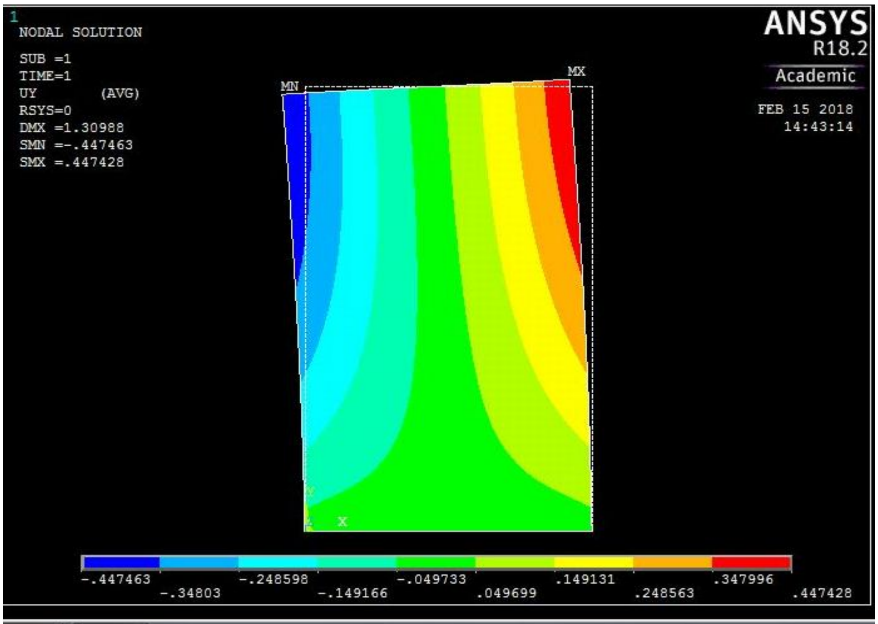

Figure 13. Deflection in the composite Beam

Finally the properties such as stress, strain and displacement of different hybrids subjected to different loads were obtained from Ansys and results are compared. (Figure 14-16).

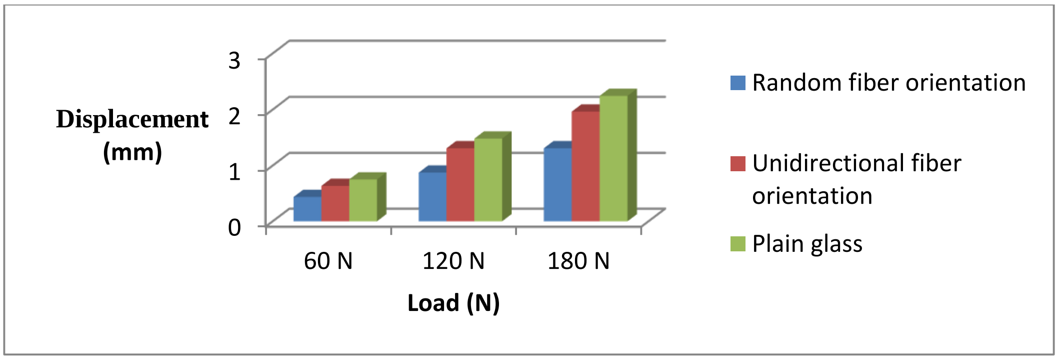

Figure 14. Load Vs Displacement

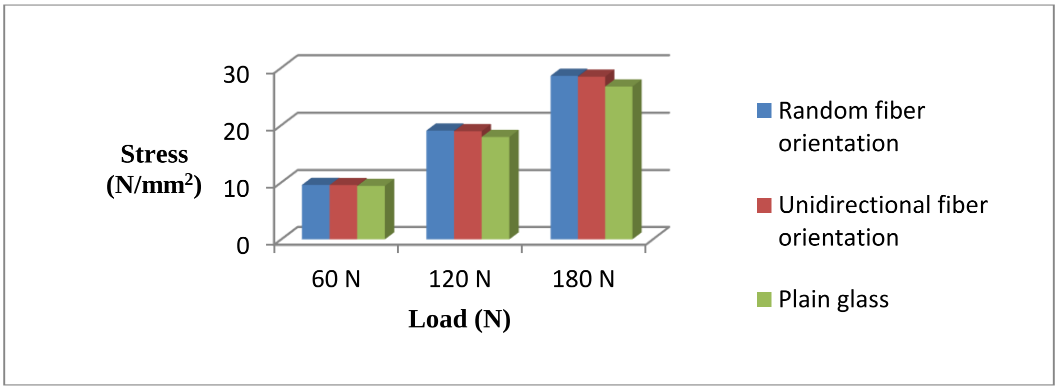

Figure 15. Load Vs Von Mises Stress

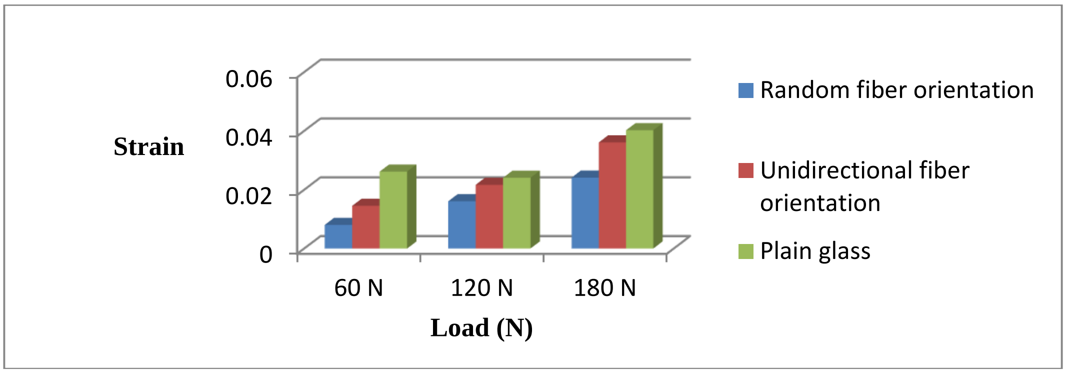

Figure 16. Load Vs Von MisesStrain

It is found that Random fiber orientation is having better mechanical properties when compared to other two hybrids in terms of tensile strength and deflection.

5. Scope and Conclusion

Using FEA three samples of banyan fiber composites are analysed under three loading conditions and it is evident that random fiber composite is having good strength and material properties. Tensile strength of the random orientation of fiber is more when compared to unidirectional orientation and plain glass. Plain glass is subjected to more displacement when compared to other two hybrids. From strain values, random orientation shows less strain compared to other composites. From the FEA analysis it is concluded that random orientation composite is stronger in terms of tensile strength and weight carrying capacity. Since natural fiber is having high strength, they can replace synthetic fibers in various applications such as automobiles, marine applications[6][7].

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