International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 08 | August - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

SIMULATION AND TESTING CHARACTERIZATION OF BANANA FIBER REINFORCED IN EPOXY COMPOSITE LAMINATE

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Abstract - Nowadays in India the production of banana is 13.5 million ton per annum & the manufacturing is cheap, renewable, & eco- friendly with low cost, low density, & low continuity as compared to other synthetic fiber. Banana fiber is a best fiber with good mechanical properties such as UV protection, moisture absorption, bio degradable etc. The natural fiber which as wide range of uses but banana fiber is with high strength which can be blended easily with cotton fiber or synthetic fiber to produce composite material. Various natural fiber such as coir, sisal, jute, & banana are used as reinforcement. In this work we are going to do simulation & testing characterization of banana fiber reinforced in epoxy resin are taken for the development of the hybrid composite material. By supposing the ideal helix / fiber angle. The fiber angle is chosen for the work is 0℃, 30℃, 45℃, 60℃, & 90℃. The behavior is determine by considering displacement, stresses, & strain. When the BFRC (Basalt fiber reinforced concrete) laminate is subjected to various loading mainly tensile, compression, & flexural loading. It is observed that 0℃ & 45℃ are the optimum fiber/helix angles found while working with banana fiber at various loading condition. Following ASTM guidelines, the laminate is created by hand lay-up technique. At conclusion of the study, the result of the analytical and experimental work are validated.

***Key Words*:** Banana fiber composite, Simulation, Ansys.

1. INTRODUCTION

The banana pseudo-stem comes to mind when thinking about the several natural fiber types that may be used in thermoplastic composites. Figure 1.1 shows that bananas are a plant that is extensively cultivated over the globe. Figure demonstrates that the regions closest to the equator have the highest levels of output. Figure 1.2 illustrates how the production of bananas has increased in the least developed nations as well. The world's least developed nations, which consist of 34 African nations, 13 Asian/Pacific nations, and 1 Latin American nation, make up 12% of the global population but less than 2% of the world's GDP. The incentive needed for material that is plentiful among populations in poor countries is satisfied by the banana plant, as necessary. The banana pseudo-stem, as seen in Figure 1.4, is the portion of the plant that would stand in for a tree trunk in terms of the plant itself. Instead of a mock-stem, the plant's base is made up of the densely clustered pods seen in Figure 1.5. Today, banana trees are planted in practically all tropical areas. They are widely cultivated in Queensland and Northern New South Wales in Australia. The banana plant, which may grow between 3.0 m and 9.0 m in height and resembles a tree in look and stalk but is devoid of woody structure, according to Mickels (1990). The stalk's 200–370 mm outer diameter is made up of layers of overlapping leaf stalks that encircle a concave core. Each stalk has a tall, dark-green leaf that is around 360 mm by 600 mm in size. Long multi-celled fibers that run lengthwise through the pulpy tissues of long leaves or leaf stems may be found in the stalk.

Table 1.1: Production & Origin details of the Banana Fibers

Botanical	Musa Ulugurensiswarb
Plant Origin	Leaf, bast
Production per metric Ton	200

Table 1.2: Chemical Composition of the Banana Fiber

Cellulose	64-65
Hemi Cellulose [%]	6-19
Lignin [%]	21
Pectin [%]	3-5
Ash [%]	1-3
Extractive [%]	3-6

Table 1.3: Physical Properties of the Banana Fibers

Property	Value
Diameter (mm)	1-3
Length(mm)	1000-5000
Aspect Ratio [l/d]	1500
Moisture Content (%)	60

Characteristics of Banana Fibers

Although banana fiber looks somewhat similar to bamboo and ramie fiber, it is finer and has higher spinning capabilities. The chemical make-up of banana fiber includes cellulose, hemicellulose, and lignin. In general, it is a robust fiber. Its extension is less. Depending on the extraction and spinning processes, it has a nice sparkling look. It has a good humidity immersion and feather light. It absorbs and releases moisture very quickly. It may be categorized as an eco-friendly fiber since it is biodegradable and has no detrimental effects on the environment. It has a 2400 Nm average fineness. Nearly all spinning techniques, including as ring, open-end, best fiber, and semi-worsted spinning, may be used to spin it. In terms of composition and mechanical characteristics, different lignocellulose fibers are well defined. Although the relative amounts of these components vary widely amongst various plant species, all of these fibers will include a mix of cellulose, hemicellulose, and lignin. Even within the same plant, the mechanical characteristics of different cellulosic fibers may vary significantly. The mechanical characteristics of plant fibers derived from stems of the plant are often better than those of plant fibers derived from leaves or fruit coat.

2. LITERATURE REVIEW

Foroutan et al. [1], (2021) has conducted a research on the use of eggshell powder and banana fiber as biomaterial fillers to strengthen concrete made from fish bones, chicken waste, and chicken femur and beaks, as well as concrete reinforced with chicken waste. Chicken (femur and beak) and fishbone byproducts were utilized to make hydroxyapatite (Hap) powder, which was then employed as a green absorbent to reduce Cd2+ in aqueous medium. At 900 °C, the Hap powder was produced and then analyzed using physiochemical methods. The crucial factor in eliminating Cd2+ is the pH of the solution. The maximum Cd2+ removal was attained at pH 6, 25 °C, 80 minutes of contact time, and 2g/L absorbent material. The quasi-second-order model in kinetics and the Freundlich model in isotherm both provided good fits to the Cd2+ adsorption data. Using Hap chicken (femur and beak) and Hap fish bone, the greatest Cd2+ absorption capacities were found to be 22.94 mg/g, 21.45 mg/g, and 21.54 mg/g, respectively. Exothermic Cd2+ adsorption using Hap powder minimized spontaneous and unintentional collisions at the liquid-solid interface. After several processes of recovering the required particles, the Cd2+ absorption efficiency did not significantly drop. The suggested adsorbents also decreased other effluent characteristics (from the shipbuilding sector) besides Cd2+. The use of hydroxyapatite powder is anticipated to be a low-cost and environmentally benign way for getting rid of metals like Cd2+.

Rodgers et al. [2], (2021) This experimental investigation sought to ascertain how adding banana fibers to concrete affected its microstructural (microscopic morphology and Energy Dispersive X-ray Spectroscopy) and mechanical (compression, splitting tension, and flexure) characteristics. We evaluated banana fiber-based concrete mixes with varied fiber lengths (40, 50, and 60 mm) and fiber concentrations (0.1, 0.2, 1.0, 1.5, and 2.5%). Only at lower fiber levels of up to 0.25% for all fiber lengths was it discovered that the addition of banana fibers to concrete had a substantial influence on compressive strength. Shorter fibers performed better than longer ones at greater doses than 0.25%, however fiber length had no discernible effect on compressive strength at lower fiber levels up to 0.25%. favorable increase in fiber content effect at considerably lower fiber doses of up to 1% on the tensile strength of concrete. Similar to this, longer fibers were found to be more effective than shorter ones when it came to influencing the tensile strength of concrete at lower fiber levels of up to 1%. Only when shorter fibers were utilized at lower fiber doses did the addition of banana fibers have a significant influence on the flexural strength of concrete. Additionally, greater fiber-to-matrix bonding and a decrease in matrix porosity improved the microstructure of concrete, which improved the composite's mechanical characteristics. By reducing the interplanar spacing and lattice structure of banana fiber-reinforced concrete (BFRC), banana fibers also led to changes in the phases of the composite structure. Banana fiber addition should be kept to a maximum of 1% of the total fiber content, ideally utilizing shorter fiber lengths, for best results.

Niyasom et al. [3], (2021) Banana fiber and eggshell powder have been explored for use as biomaterial fillers in concrete reinforcement. These materials are generated from agricultural and post-consumer waste. All three of these post-consumer and agricultural waste products—eggshell powder, banana fiber, and water hyacinth fiber—were used as biomaterial fillers for concrete reinforcement. By adding the 0.02 and 0.05 ratios (by weight) of bio-fillers to concrete, the physical (water absorption, bulk density, and true density) and mechanical (compressive strength, tensile strength, flexural strength, and maximum load) properties of seven experimentally obtained concrete formulas were enhanced. These results demonstrated that the finest concrete composite formulas were created by adding 0.05 ratio (by weight) of eggshell powder and curing for 28 days. The best bio-filler for concrete composite is eggshell powder. In concrete Formula 6 (obtained by mixing 0.05 ratio (by weight) of eggshell powder), the bulk density, true density, water absorption, compressive strength, tensile strength, flexural strength, and maximum load are all calculated as follows: are 2.245 0.040 g/cm3, 2.252 0.033 g/cm3, 1.62% 0.16%, 22.08 0.66 MPa, 157.33 35.

Nguyen et al. [4], (2021) Modern flame retardants are organic compounds with phosphorus or halogen groups that aren't necessarily evenly distributed across polymers. Thus, they may greatly lower the quantity of traditional flame retardant materials by utilizing a little amount of nanoclay and Multi-walled Carbon Nanotubes (MWCNTs) the material with additives, giving it the best possible flame-retardant qualities. Nanoclay and MWCNTs may be used to decrease the detrimental impact that conventional flame retardants have on the mechanical characteristics of the polymer substrate. In this study, nano clay I.30E and MWCNTs are combined with epoxy in the chosen percentages of 2% and 0.02% by weight, respectively. The mixture is mechanically stirred for 7–9 hours at a speed of 3000 rpm at a temperature of 80°C, followed by ultrasonic vibration for 6 hours at 65°C to improve the mechanical properties and flame retardant of the nano composite materials.

Prabhu et al. [5], (2021) Banana natural fibers have attracted the attention of researchers because to their low cost, ease of availability, strength, and advances in properties such as mechanical, wear, electrical, and thermal. The banana plant is cultivated all over the globe and is often used to manufacture culinary goods, mainly banana fruit, as well as a number of home items made of banana fibers. Banana stem natural fiber, which was used as a reinforcing material for composite construction, has potential. It is essential that this review include the impacts of hybridization given the huge quantity of research on banana fiber reinforced polymer composites that has been published as well as the excellent features that this banana fiber reinforcement provides. In-depth information regarding how various hybrid composites using banana fiber and several other natural/synthetic fibers in polymer matrixes have enhanced performance, notably in terms of their mechanical and thermal characteristics, is provided in this condensed review article. The review estimated a 30–50% increase in all mechanical metrics, including tensile, flexural, and impact strength. There have also been improvements in heat and moisture resistance.

3. DATA ANALYSIS

Table 3.1: Material Properties of Banana Fiber at different Fiber Angles

Fiber Angle(^{0})	Exx (MPa)	Eyy (MPa)	Ezz (MPa)	Vxy	Vyz	Gxy (MPa)
0	14050	4555	4555	0.33	0.170	1724
30	12042	5113	5113	0.33	0.170	2232
45	10299	5790	5790	0.33	0.170	2594
60	8830	6613	6613	0.33	0.170	2811
90	7614	7614	7614	0.33	0.170	2883

To ensure that the experimental data is collected under the best possible circumstances, this study employs the Taguchi robust design technique. Results for the Analysis of Mean (ANOM) and Analysis of Variance (ANOVA) are obtained using the statistical program Minitab 15.0. In order to authenticate the findings, the confirmation test is carried out under ideal circumstances. The foundation of the engineering

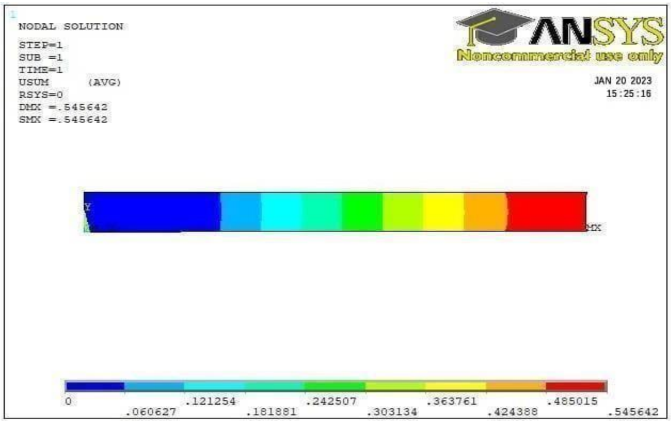

Figure 3.1: Max. Displacement of BFRC at 0° Fiber Angle for Tensile test

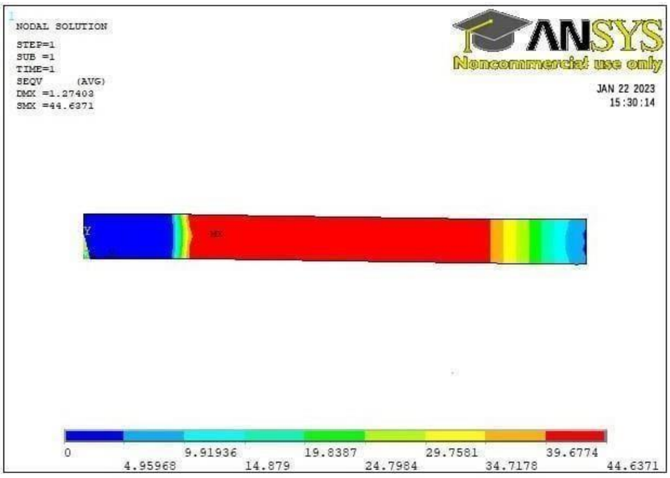

Figure 3.2: Max. Von Mises Stress of BFRC at 0° Fiber Angle for Tensile

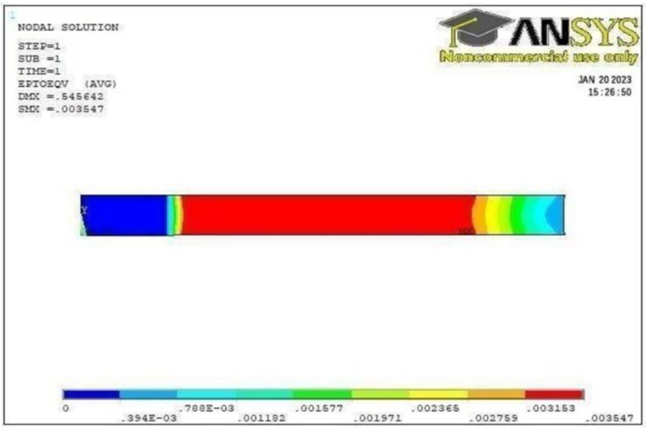

Figure 3.3: Max. Von Mises Strain of BFRC at 0^0 Fiber Angle for Tensile Test

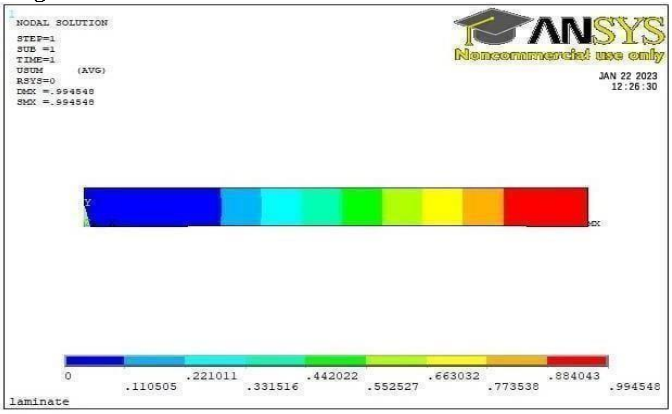

Figure 3.4: Max. Displacement of BF RC at 90^0 Fiber Angle for Tensile Test

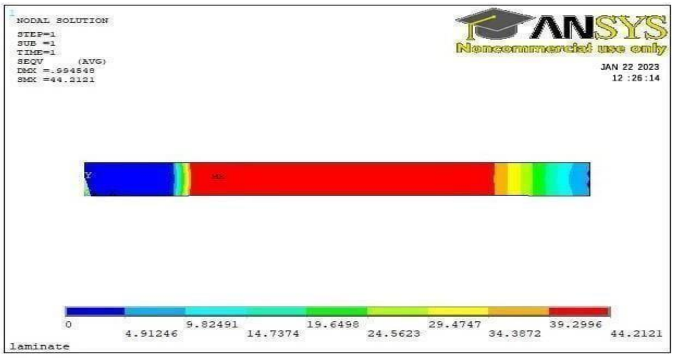

Figure 3.5: Max. Von Mises Stress of BFRC at 90^0 Fiber Angle for Tensile Test

Table 3.2: Observations of BFRC from ANSYS for Tensile Test

Fiber Angle (^{0})	Displacement (mm)	Von Mises Stress (MPa)	Von MisesStrain
0	**0.5456**	**44.63**	**0.0035**
30	1.1623	44.20	0.0071
45	1.2740	43.19	0.0078
60	1.101	44.13	0.006
90	0.9945	44.21	0.0053

Table 3.3: Observations of BFRC from ANSYS for Compression Test

Fiber Angle(^{0})	Displacement (mm)	Von Mises Stress(MPa)	Von MisesStrain
0	**0.2861**	**23.19**	**0.0018**
30	0.6095	23.19	0.0037
45	0.6079	23.07	0.0036
0	0.5777	23.14	0.0033
90	0.5215	23.18	0.0028

Table 3.4: Observations of BFRC from ANSYS for Flexural Test

Fiber Angle(^{0})	Displacement (mm)	Von Mises Stress (MPa)	Von Mises Strain
0	0.7924	64.65	0.016
30	0.6904	59.26	0.010
45	**0.6813**	**69.64**	**0.008**
60	0.9664	68.84	0.103
90	0.9610	56.02	0.116

- The optimum fiber angle for tensile test is 0^0.
- The optimum fiber angle for compression test is 0^0.The optimum fiber angle for flexural test is 45^0.
- The overall optimum fiber angles for tensile, compression, and flexural are 0^0 & 45^0.The optimum fiber angles are present, but in this work I have selected 0^0 for Tensile and Compression tests, and for Flexural test 45^0 optimum fiber angle is selected based on the minimum displacement criteria.

4. FABRICATION AND TESTING OF BANANA FIBER REINFORCED COMPOSITE (BFRC)

Banana Fiber: We bought banana fibers from Go Green Products in Chennai, India. The banana plant is where the fiber for bananas is found.

Figure 4.1: Banana Fiber

Resin:

From JK Chemicals in Fattah Nagar, Hyderabad, resin is obtained. Polyester Resin is the kind of epoxy resin that was employed in this thesis. Polyester resin, glass fiber, calcium carbonate, and additives are combined to create polyester resin, a low viscosity resin. Glass-fiber reinforced polyesters offer high modulus and tensile strength. $[C_{10}H_8O_4]_n$ is the chemical formula for polyester resin. The resin's melting point ranges from 250 to 280 ^{0}C. 1.32-1.38 g/ml is roughly how dense it is. It has a refractive index that varies from 1.54 to 1.72.

Accelerator or (Hardener):

JK Chemicals in Fattah Nagar, Hyderabad, is where the accelerator is obtained. Cobalt Naphtha Nate was employed as the thesis's accelerator. Cobalt and naphthenic acid derivatives are combined to make it. The autoxidative cross-linking of drying oils uses these coordinated complexes as an oil drying agent. $CoC_{22}H_{14}O_4$ is the chemical formula for it. It has a density of around 960 kg/m3. Its melting point is around 284 ^{0}F, 413 K, or 140 ^{0}C. About 150^{0}C (302 ^{0}F, 423 K) is its boiling point. Approximately 48.89 ^{0}C (120 ^{0}F, 322.04 K) is where it flashes. Its temperature for automatic ignition is 276 ^{0}C.

Catalyst:

MEKP [Methyl Ethyl Ketone Peroxide] is the catalyst used in this thesis and is applied to polyester resins and vinyl ester resins. When the catalyst and resin are mixed, a chemical reaction occurs, creating heat that cures the resin. Its molecular formula is $C_8H_{18}O_6$. Its density is about 1.170 g/cm3. Its melting point varies from 284 ^{0}F (413 K) to 39.63–126.1 ^{0}C. Its boiling point ranges from 469.22 to 664.16 ^{0}F (516.05 to 624.35 K), or 242.9 to 351.2 ^{0}C. The flash point is located at around 75 ^{0}C (167 0F, 348.15 K).

SPECIFICATIONS OF UTM:

Machine Model: UTN-40 (400KN) Machine Serial No: 17/0703. Least count: 0.001 mm

Figure 4.2: Specimen before Performing Tensile Test

Figure 4.3: Specimen after Performing Tensile Test

Figure 4.4: Specimen before Performing Flexural Test

Figure 4.5: Specimen after Performing Flexural Test

Table 4.1: Experimental Tensile strength of BFRC under Tensile Loads

Specimen No	Peak load (KN)	Tensile strength (MPa)
1	3.4	43.08
2	3.7	43.15
3	3.2	43.02
Average	**3.43**	**43.08**

Table 4.2: Experimental Compressive strength of BFRC under CompressiveLoads

Specimen No	Peak load (KN)	Compressive Strength (MPa)
4	1.78	22.595
5	1.81	22.606
6	1.75	22.587
Average	**1.78**	**22.595**

Table 4.4: Experimental Flexural strength of BFRC under Flexural loads

Specimen No	Peak Load (KN)	Flexural Strength (MPa)
7	0.4	69.44
8	0.43	69.60
9	0.37	69.30
Average	**0.4**	**69.44**

5. RESULTS AND DISCUSSIONS

Under the circumstances of tensile, compression, and flexural loads, simulation was performed using ANSYS Software. The ideal fiber angle for the experiment was determined via simulation. Epoxy resin was used as the matrix material to create the composite, which was then tested using a universal testing machine to gather experimental data. The tables below display the computational and experimental results of tensile, compression, and flexural testing.

Table 5.1: Simulation and Experimentation Results of BFRC for TensileTest

Fiber	Displacement (mm)			Von Mises Stress (MPa)			Von Mises Strain	
Angle (⁰)	ANSYS	EXP	Variation (%)	ANSYS	EXP	Variation (%)	ANSYS	EXP
0	0.5456	0.4876	10.64	44.63	43.28	3.02	0.0035	0.0026
30	1.1623	-	-	44.24	-	-	0.0071	-
45	1.2740	-	-	43.99	-	-	0.0078	-
60	1.101	-	-	44.13	-	-	0.006	-
90	0.9945	-	-	44.21	-	-	0.0053	-

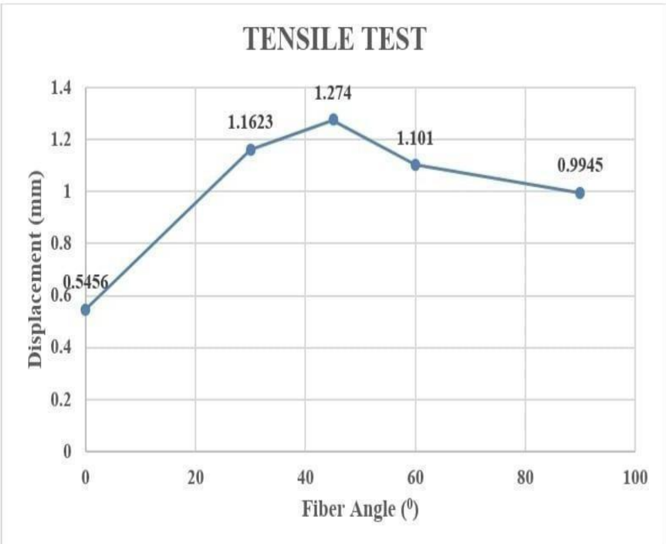

Figure 5.1: Simulation Displacements at Various Fiber Angles for Tensile Test

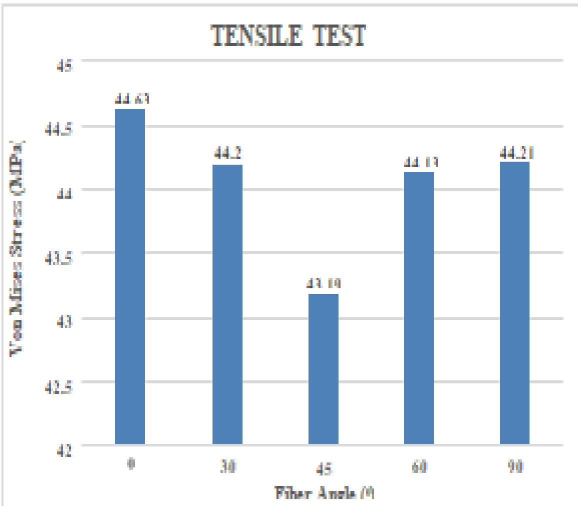

Figure 5.2: Simulation Von Mises Stresses at Various Fiber Angles for Tensile Test

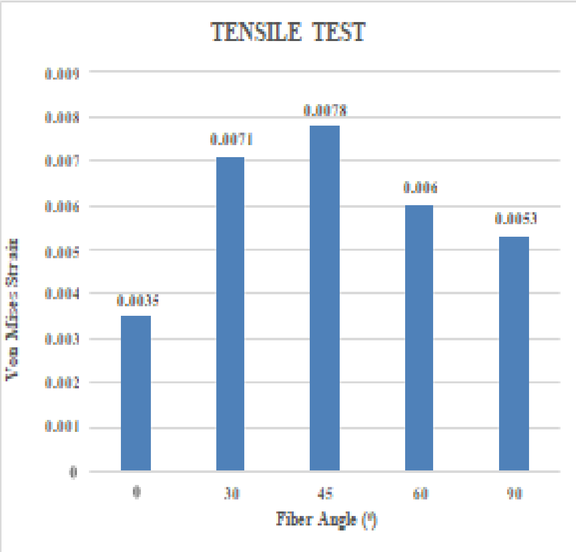

Figure 5.3: Simulation Von Mises Strains at Various Fiber Angles forTensile Test

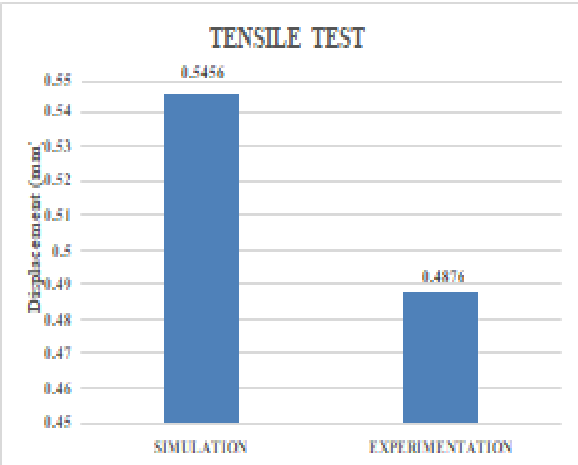

Figure 5.4: Simulation and Experimentation Displacements at Optimum FiberAngle of 0^0 for Tensile Test

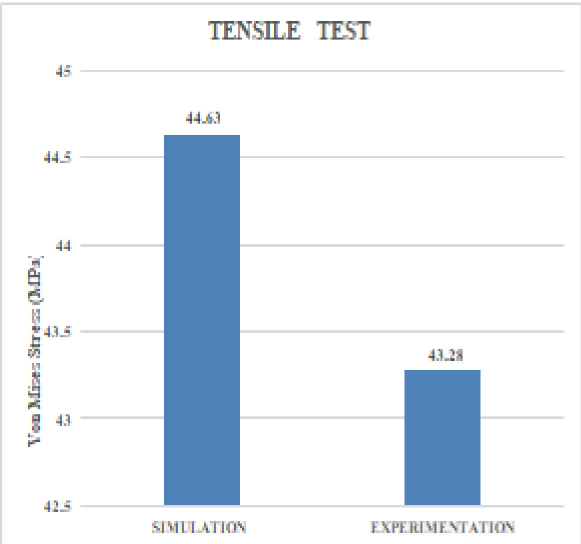

Figure 5.5: Simulation and Experimentation Von Mises Stressesat Optimum Fiber Angle of 0^0 for Tensile Test

Table 5.2: Simulation and Experimentation Results of BFRC for Compression Test

Fiber	Displacement (mm)			Von Mises Stress (MPa)			Von Mises Strain	
Angle (°)	ANSYS	EXP	Variation (%)	ANSYS	EXP	Variation (%)	ANSYS	EXP
0	**0.2861**	**0.258**	**9.82**	**23.19**	**22.59**	**2.58**	**0.0018**	**0.0015**
30	0.6095	-	-	23.19	-	-	0.0037	-
45	0.6079	-	-	23.07	-	-	0.0036	-
60	0.5777	-	-	23.14	-	-	0.0033	-
90	0.5215	-	-	23.18	-	-	0.0028	-

Table 5.3: Simulation and Experimentation Results of BFRC for Flexural Test

Fiber Angle (°)	Displacement (mm)			Von Mises Stress (MPa			Von Mises Strain	
	ANSYS	EXP	ariation (%)	ANSYS	EXP	ariation (%)	ANSYS	EXP
0	0.7924	-	-	64.65	-	-	0.016	-
30	0.6904	-	-	59.26	-	-	0.010	-
45	**0.6813**	**0.6552**	**3.83**	**69.64**	**69.44**	**0.29**	**0.008**	**0.006**
60	0.9664	-	-	68.84	-	-	0.103	-
90	0.9610	-	-	56.02	-	-	0.116	-

6. CONCLUSIONS

Simulation and experimentation approaches were carried out to determine the behavior of Banana Fiber Reinforced Composite under various loading conditions. The following are the conclusions drawn from the results obtained from simulation and experimentation.

- **Average Tensile Strength** of BFRC is **Maximum** at fiber angle of $\mathbf{0^0}$ i.e. **44.63 MPa** in simulation (ANSYS) and **43.28 MPa** in experimentation when compared withother fiber angles. The percentage variation between simulation and experimentation is found to be **3.02%**.
- **Average Compressive Strength** of BFRC is **Maximum** at fiber angle of $\mathbf{0^0}$ i.e. **23.19MPa** in simulation (ANSYS) and **22.59 MPa** in experimentation when compared with other fiber angles. The percentage variation between simulation andexperimentation is found to be **2.58%**.
- **Average Flexural Strength** of BFRC is **Maximum** at fiber angle of $\mathbf{45^0}$ i.e.**69.64 MPa** in simulation (ANSYS) and **69.44 MPa** in experimentation when compared with other fiber angles. The percentage variation between simulation and experimentationis found to be **0.29%**.
- **Displacement** for both **tensile** and **compression** tests is **Minimum** at fiber angle of $\mathbf{0^0}$ i.e. **0.5456 mm** in simulation (ANSYS) and **0.4876 mm** in experimentation for tensile test and **0.2861 mm** in simulation (ANSYS) and **0.258 mm** in experimentation when compared with other fiber angles at percentage variations of **10.64%** & **9.82%**.

- **Displacement** for **flexural test** is **Minimum** at fiber angle of **45^0 i.e. 0.6813 mm** in simulation (ANSYS) and **0.6552 mm** in experimentation when compared to other fiber angles at percentage variation of **3.83%**.
- It is observed that, 00 and 450 are the Optimum fiber angles for banana fiber reinforced composite under tensile, compression and flexural loadings condition.

ACKNOWLEDGEMENT

It's my pleasure to acknowledge with deep appreciation to all those who have helped and guided me all through the project work.

I wish to express my deep sense of gratitude to my Project Guide **Sri. P. Seemarani**, Assistant Professor, Mechanical Engineering Department, JBIET for his extremely valuable guidance and hearted co-operation throughout the project.

I wish to express sincere thanks to P.G Coordinator, **Mr. G. Gopinath**, Assistant Professor, Department of Mechanical Engineering, for timely guidance, technical Inputs and suggestions in spite of his busy schedule.

I also thank **Dr. Anoop Kumar Shukla**, Head of the Department, Department of Mechanical Engineering, for encouraging me throughout the project by giving necessary technical guidance.

A special thanks to **Dr. P.C. Krishnamachari,** Principal, JBIET and Management of JBIET for providing facilities to this project.

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