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Experimental Strategy to Optimize Fiber Volume Fraction and Orientation in Strengthening Banana Composites

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Abstract

Composites find significant uses in domestic and infrastructure industries through recent advances in materials. In recent years, natural fiber based epoxy resin composite has become important as important industrial resources, given their superior material properties and decomposability. This research is based on the mechanical characteristics of composites using bananas and coir fibers added with ash particles. The evaluation of the Mechanical Property is based on the NABL-approved ASTM Standards. For composites, including compression moulding, spray operation, pultrusion, hand layup, there are various manufacturing techniques available. The easiest way to do this work is to lay hands. Such composites are generated in terms of fiber length and volume fraction as specific combinations. The fiber treatment using an alkaline solution of 1% NaOH is used to reduce decomposability and to increase lifetime chemical therapy. Mechanical measures such as tensile examination, flexural check, and impact studies can research the effect of the ash particle percentage. Mechanical properties have been shown to be significantly improved.

Keywords: Fiber length, Volume fraction, Banana fibre, Coir fibre, NABL, NaOH

1. INTRODUCTION

Because of the growing need for environmentally sound products and the need for lower prices for conventional fibers. Researchers continued to work on natural fiber (i.e. bio-composites) composites. Sustainability and environmental protection are driving the adoption of renewable, biobased materials. Fibre-reinforced composites offer eco-friendly solutions for structural

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applications, combining natural and synthetic fibres [1].The composites contain enhanced resins made of carbon, synthetic and carbon fibre. Natural fibres, having various advantages, are a substance of low density producing relatively light, high-specific composites. Such fibers actually minimize reliance on both domestic and foreign oil and offer significant cost advantages, rapid production and a highly renewed fuel. The study of Response Surface Methodology and Artificial Neural Network to optimize banana fiber-epoxy composites, achieves remarkable mechanical properties with R2 scores of 0.969, 0.984, and 0.954 [2].Significant late developments have also been made regarding the use of natural fiber (e.g. mango, cellulose, jute, cotton, wheat, kenaf, coir, and bamboo, for example). In the control system, polypropylene composites filled with coir fiber were more flexural efficient than composites with lignin as compatibility [6]. When lignin was integrated as a compatibilizer, there was no improvement in tensile properties at all. In this research we study the use of polypropylene composite enhanced by coir fiber for automotive applications. Surface treatment increased the mechanical properties such as tensile strength, bending, and impact strength. Blinding with composite fiber showed improved bending strength. NaOH treated composites with fibre / polyester showed improved tensile strength [3]. Due to chemical treatments on fibers, the water absorption tendency of the composite was reduced [3]. The importance of fiber length and fiber in composites with short banana fiber filled polyester. With a fiber length of 30 mm the maximum tensile strength was achieved, and the impact strength of the fiber composite was 40 mm. When the volume of fiber rose to 40%, the tensile strength improved by 20% and the impact strength increased by 34% [4]. The mechanical characteristics of coir composites strengthened by fibre. The percentage of coir fibers was up to 80% and composites were tight to charge up to 50% and were agglomerated afterwards. Lignin as a physical effect compatible with coir fiber-reinforced polypropylene composites was conducted a systematic study [5]. Natural fibers, such as sisal and banana, are increasingly recognized as low-cost, lightweight, and eco-friendly alternatives to glass fibers in composites, offering comparable specific properties[7]. Bio-fiber-reinforced plastic composites have garnered attention due to environmental advantages, lower cost, lighter weight, and recyclability. Banana and silica-reinforced composites affect mechanical properties[8]. Investigations into biocomposites, using eco-friendly polymers like PLA, TPS,

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cellulose, and PHAs, have gained attention for their potential to create environmentally compatible and degradable materials[9]. Natural fiber
composites are employed for enhancing strength, cost-efficiency, and weight optimization in engineering applications. Banana fiber, treated with sodium hydroxide, was used to reinforce epoxy and vinyl ester resins alongside coconut shell powder in a hand-moulding process. The study analyzed mechanical properties, including tensile, impact, and flexural strengths, and used Scanning Electron Microscope for adhesion and surface morphology comparison[10].

2. MATERIALS & MANUFACTURING

Banana fibers obtained from local resources along with epoxy resin are the components used in this project. The density of the epoxy resin is 1.22 g / cc.[12] The epoxy resin is stirred thoroughly until fiber mattresses have been inserted into the matrix. Almost 24 hours later and under constant stress, each laminate in the mold was healed at room temperature. Banana fibers are obtained from local sources, as shown in the figure. After 8 hours, banana fibers had been removed from the fiber, dried out in the sun and dried out 24 hours in the oven.

Figure 1: Chemical Treatment

Figure 2: Test Specimens

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Figure 3: Final Fabricated Laminates

3. MECHANICAL TESTING

3.1 TENSILE TESTING

A basic, universal design test for material parameters including the ultimate force, capacity, percentage lengthening, reduction performance and Yung's module is known as the uniaxial tensile test. The selection of engineering materials for every required use helps with such important parameters resulting from regular tensile inspections.[11,15] The tensile testing takes place at a specific extension specimen at a specific rate until a failure by applying the length or axially to the standard, renowned tensile specimen (the measuring length and the transverse area of the loading direction). During stress and pressure testing, the tensile load and extension are reported.

The major part of the exhibit is the section of the gage. In comparison with the specimen, the cross-sectional zone of the measuring section is reduced in order to localize deformation and failure. The measuring length is the region over which measurements are made and focuses on the reduced section. The distances between the ends of the measurement section and shoulders should be large enough to prevent the larger ends from constraining the deformation of the measurement section. We have selected 200X 20 X 3 mm3 according to the ASTM D3039 [14].

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Tensile test Result:

Table 1: Tensile Testing Results

Sr. No.	Composition	Fiber Orientation (°)	U.T.S. (N/mm^2) Trial 1	U.T.S. (N/mm^2) Trial 2	Average U.T.S. (N/mm^2)
1	A (30/70)	0	15.336	15.093	15.21
		45	7.012	6.895	6.95
		90	5.903	4.322	5.11
2	B (40/60)	0	39.670	34.225	36.94
		45	9.835	5.593	7.71
		90	5.551	5.367	5.46
3	C (50/50)	0	18.015	13.925	15.97
		45	12.084	10.174	11.113
		90	8.537	3.086	5.81

Table 1 shows the results of tensile test according to the various compositions of banana fiber and epoxy resin along with the change in fiber orientation. The result shows good results for 40/60 composition.

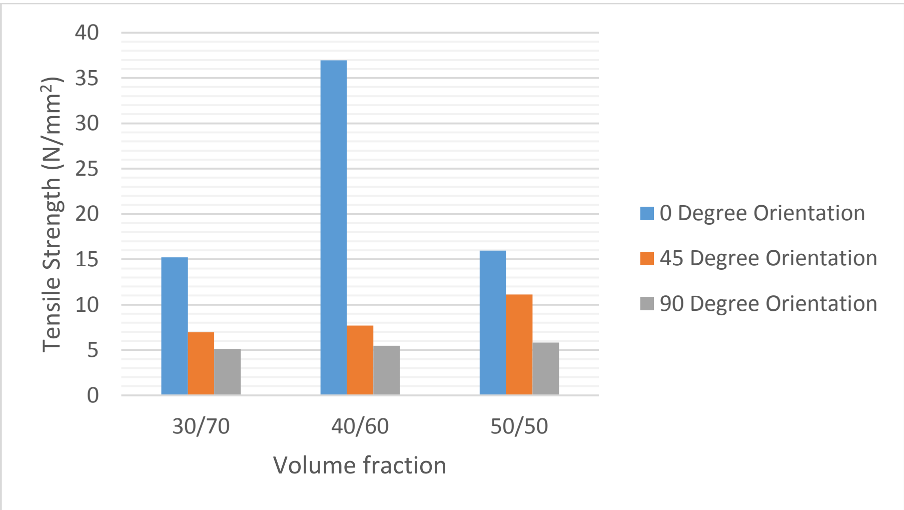

Figure 4: Comparison of experimental results of tensile test

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3.2 FLEXURAL TESTING

Flexure research involves bending a substance instead of pressure to establish the interaction between bending force and deflection. [13] Delicate products like pottery, mortar, mud and glass are commonly used in Flexural processing. It can also be used to analyze the actions of materials that translate their normal life, including wire isolation or other elastomeric products. The test results also are susceptible to specimens, load geometry and stress, but there are also certain disadvantages to this approach.[12]

Figure 5: Flexural testing machine

Figure 6: Mounting of Specimen on Flexural testing machine

Flexural test Result:

Table 2: Flexural Testing Results

Sr. No.	**composition**	**Fiber orientation (^{0})**	**Flexural Strength (N/mm^2)**		**Average Flexural Strength (N/mm^2)**
			Trial 1	**Trial 2**	
	A (30/70)	0	21.504	18.127	19.72

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1		45	15.556	13.878	14.72
		90	10.894	11.105	10.99
2	B (40/60)	0	43.247	47.203	45.23
		45	28.786	27.877	28.33
		90	15.700	11.805	13.75
3	C (50/50)	0	40.471	45.490	42.98
		45	37.941	35.495	36.71
		90	26.249	23.312	25.03

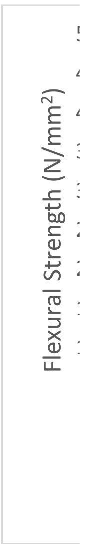

Figure 7: Comparison of bending force for different volume fractions and orientation of fibers

The bending strength and bending module are most often measured with a flexure test. The maximum stress on the outermost fiber on the compression side or the stress side of the sample is called bending power. From the incline is measured the flexural module of the stress versus the stress deflection curve. The ability to resist flexure or to bend the sample materials can be assessed using both. The results show that 40/60 has better characteristics. The above finding reveals that with increasing fiber length and fiber orientation bending strength gradually increases.

4. Conclusion

The experimental investigation focused on the mechanical properties of banana fiber/epoxy composites with varying volume fractions and fiber orientations. The study yielded several key findings:

Tensile Properties

Tensile testing is a fundamental method for evaluating the mechanical performance of materials under axial loading. In the context of banana fiber/epoxy composites, the study examined how varying the fiber orientation and volume fraction affected tensile strength. The results revealed intriguing insights into the behavior of these composites.

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One noteworthy observation was the relationship between fiber orientation and tensile strength. It was found that as the fiber orientation degree increased, the tensile strength gradually decreased. This phenomenon can be attributed to the reduced efficiency of the fibers in resisting the applied load as they deviate from the axial direction. In other words, fibers oriented parallel to the direction of the applied force contribute more effectively to the overall strength of the composite.

Additionally, the study identified that the maximum tensile strength (36.94 N/mm²) was achieved when using a 40% volume fraction of banana fibers with a 0-degree fiber orientation. This specific combination of volume fraction and orientation resulted in the highest tensile strength, demonstrating the importance of optimizing these parameters for desired mechanical properties.

Understanding the relationship between fiber orientation and tensile strength is crucial for tailoring banana fiber/epoxy composites to specific applications. Engineers and material scientists can use this knowledge to design composites that meet the required strength criteria, which may vary depending on the intended use, from structural components to consumer products.

Flexural Properties

Flexural testing is another key method for assessing the mechanical behavior of materials, particularly those subjected to bending forces. The study also investigated the flexural properties of banana fiber/epoxy composites, focusing on the impact of fiber orientation and volume fraction.

In contrast to the findings in tensile testing, the study revealed that flexural strength increased with an increasing fiber orientation degree. This is an intriguing result, as it indicates that fibers oriented away from the bending axis contribute more effectively to resisting flexural loads. This behavior can be attributed to the enhanced stiffness provided by fibers oriented at higher angles to the applied force.

Remarkably, the highest flexural strength (43.247 N/mm²) was observed when using a 40% volume fraction of banana fibers with a 0-degree fiber orientation. This specific combination yielded the optimal flexural performance of the composites. It is essential to note that achieving high flexural strength is crucial in applications where the material must endure bending forces without failure.

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The finding that flexural strength increases with an increasing fiber orientation degree underscores the multifaceted nature of composite materials. Different mechanical properties can be tailored to suit specific applications by adjusting fiber orientation and volume fraction. For applications that require both tensile and flexural strength, a careful balance of these parameters may be necessary to meet the desired performance criteria.

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