EXPERIMENT OF A COMPOSITE MATERIAL BASED ON SYNTHETIC FIBER (GLASS FIBER) AND NATURAL FIBER (JUTE FIBER)

A Thesis by

Muzammel Hossain; ID: ME2103025367
Fahad Hossain; ID: ME2103025368
Md. Shafiqul Islam; ID: ME2201026166
Delwar Hossen; ID: ME2201026312
Azizul Islam; ID: ME2201026161
Mahfuja Biswas; ID: ME2103025209



Department Of Mechanical Engineering

Sonargaon University (SU)

SEPTEMBER 2025

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Supervisor :
Shahinur Rahman
Assistant Professor & Coordinator



Submitted to the

DEPARTMENT OF MECHANICAL ENGINEERING

SONARGAON UNIVERSITY (SU)

In partial fulfillment of the requirements for the award of the degree

Bachelor of Science in Mechanical Engineering

SEPTEMBER 2025

DECLARATION

I hereby declare that the thesis titled "Experiment Of A Composite Material Based On Synthetic Fiber(Glass Fiber) And Natural Fiber(Jute Fiber)" submitted to Sonargaon University, is our original work carried out under the guidance of **Shahinur Rahman**,Assistant professor and Coordinator,Department of Mechanical Engineering,Sonargaon University(SU).

The work embodied in this thesis has not been submitted, in part or full, to any other university or institution for the award of any degree or diploma. All the data, analyses, and findings presented in this thesis are the results of my research work. Any work or information obtained from other sources has been duly acknowledged and referenced in accordance with the academic and ethical guidelines of the university.

We take full responsibility for the authenticity and accuracy of the data and results presented in this thesis. Furthermore, I declare that this thesis complies with all the regulations and requirements prescribed by the institution for the submission of academic research work.

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Muzammel Hossain	Fahad Hossain
ME2103025367	ME2103025368
……	……
Md. Shafiqul Islam	Delwar Hossen
ME2201026166	ME2201026312
……	……
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ME2201026161	ME2103025209

Certification

This is to certify that the thesis titled **"Experiment Of A Composite Material Based On Synthetic Fiber(Glass Fiber) And Natural Fiber(Jute Fiber)"** is a record of the candidate's original research work carried out under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of **Bachelor of Science in Mechanical Engineering** from **Sonargaon University.**

Supervisor :
Shahinur Rahman

Assistant Professor & Coordinator
Department of Mechanical Engineering
Sonargaon University
Dhaka 1215, Bangladesh

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Abstract

This study investigates the mechanical behavior of hybrid composites made from jute fiber and glass fiber reinforced with epoxy resin, with particular emphasis on the role of fiber orientation. Hybrid samples were fabricated with jute fibers arranged at 45°, 60°, and 90°, in combination with glass fibers within the epoxy matrix. The composites were evaluated through impact and hardness tests to determine how orientation affects their overall performance.The experimental findings revealed a clear dependence of mechanical properties on fiber orientation. Composites with a 45° jute fiber alignment displayed the highest impact,hardness and bending strength, owing to their enhanced energy absorption capacity during dynamic loading. Meanwhile, the 60° orientation resulted in superior hardness, indicating stronger resistance against localized surface deformation. The 90° orientation showed balanced performance but did not surpass the other configurations in either hardness,impact or bending strength.These results emphasize the importance of selecting appropriate fiber orientations to tailor composites for specific applications. Optimized orientation can significantly enhance the design of lightweight structural materials, making them suitable for use in automotive, aerospace, and construction industries. Overall, the study contributes useful insights toward the development of sustainable and high-performance hybrid composites .

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Composite materials are engineered systems made from two or more distinct phases that remain separate and identifiable on a macroscopic level, yet together exhibit properties superior to those of the individual constituents. Typically, they consist of a matrix material and a reinforcing phase. The matrix, often a polymer, metal, or ceramic, acts as the binding medium, while the reinforcement, generally in the form of fibers or particles, provides strength and stiffness.The concept of composites is not new; natural composites such as wood and bone have existed for millions of years. However, engineered composites have gained importance in modern industries, particularly since the mid-20th century. Their high strength-to-weight ratio, resistance to corrosion, tailorable mechanical properties, and design flexibility make them increasingly attractive compared to conventional materials like steel or aluminum.

Today, composites play a central role in aerospace (aircraft fuselage, rotor blades), automotive (body panels, bumpers), marine (boat hulls, propeller shafts), civil engineering (bridges, panels, reinforcement bars), sports equipment (tennis rackets, bicycles), and renewable energy (wind turbine blades).As industries move toward lighter and more energy-efficient designs,composites are expected to dominate next-generation materials.

One critical factor influencing the performance of these hybrid composites is fiber orientation. The anisotropic behavior of composites, stemming from the alignment of fibers, affects key mechanical properties, including impact resistance, hardness, and loadbearing capacity. Proper alignment and hybridization of fibers can result in materials tailored to specific industrial applications, offering optimized performance and weight reduction .This research investigates the mechanical properties and performance of hybrid epoxy composites reinforced with jute and glass fibers, with a specific focus on the impact of jute fiber orientation (45°, 60°, and 90°). Through bending, hardness, and impact tests, this study aims to optimize fiber orientation to advance the development of sustainable, high-performance materials for various industrial applications. By leveraging the complementary properties of jute and glass fibers, this work contributes to the growing field of bio-based hybrid composites, addressing environmental concerns while meeting engineering demands.

1.2 LITERATURE REVIEW

Fibers are the most critical reinforcement in polymer composites. Their orientation, volume fraction, and inherent properties determine the final performance of the composite. Fibers are broadly categorized into natural fibers and synthetic fibers.

Natural fibers

Jute, coir, hemp, flax, and sisal are examples of natural fibers. Among them, jute fiber is one of the most widely available lignocellulosic fibers, particularly in Bangladesh and India. Jute is inexpensive, renewable, biodegradable, and has a relatively low density, making it attractive for lightweight composites.Despite these advantages, jute has drawbacks, such as high moisture absorption, variability in quality, and relatively poor thermal and chemical resistance.

Synthetic fibers

Glass, carbon, and aramid are the most commonly used synthetic fibers. Among these, glass fiber is particularly popular because of its high tensile strength,good stiffness, resistance to environmental degradation, and comparatively low cost compared to carbon or aramid fibers. Glass fibers have been extensively used in aerospace and civil structures. However, glass fibers are non-biodegradable, energy-intensive to produce, and relatively heavier than natural fibers.

Thus, natural fibers are attractive from a sustainability and cost perspective, while synthetic fibers remain indispensable for high-performance applications.

Composites and Performance

The hybridization of natural and synthetic fibers combines the strengths of both materials, resulting in composites with improved mechanical performance and sustainability.Hybrid composites that integrate jute and glass fibers have shown improved hardness, impact resistance compared to composites made from either fiber alone. Fiber orientation also plays a crucial role in determining composite performance. For instance, unidirectional fibers may enhance hardness along the load direction, while bidirectional or random orientations improve toughness and impact resistance.

Mechanical Testing of Composites

Hardness,impact and bending tests are essential for evaluating the surface durability and energy absorption capacity of composites. Studies have demonstrated that the inclusion of glass fibers significantly enhances hardness,while hybrid configurations with natural fibers improve energy absorption.For example, composites with bidirectional fiber alignment exhibit better impact resistance than those with unidirectional configurations, underscoring the importance of fiber orientation in hybrid composites.

This research builds on existing literature to examine the combined effects of jute and glass fibers in hybrid epoxy composites. By focusing on fiber orientation and its impact on hardness and impact resistance, this study aims to provide practical insights into optimizing hybrid composites for lightweight, durable, and sustainable applications.

1.3 OBJECTIVES

The main objectives of this research are:

1. To fabricate epoxy-based composites reinforced with jute fibers, glass fibers, and their hybrid combination.

2. To prepare composite laminates at orientations of 45°, 60°, and 90°.

3. To evaluate the mechanical properties of the composites using hardness, impact and flexural/bending tests following ASTM standards.

4. To compare the mechanical performance of natural & synthetic fiber based composite.

5. To analyze the influence of fiber orientation on strength, stiffness, and energy absorption.

CHAPTER 2: MATERIALS AND PROPERTIES

2.1 MATERIALS USED

The materials used in this study include:

Jute Fiber: Natural jute fabric with a density of 300 gsm was used as reinforcement.

Glass Fiber: Woven glass fiber fabric with a density of 400 gsm was utilized for its superior mechanical properties.

Epoxy Resin and Hardener: A-grade epoxy resin and its corresponding hardener were employed as the matrix material to ensure strong bonding and mechanical stability.

Additional Materials: A release film(using polythene bag) and mold plates were used during the fabrication process to facilitate smooth curing and easy removal of composite samples.

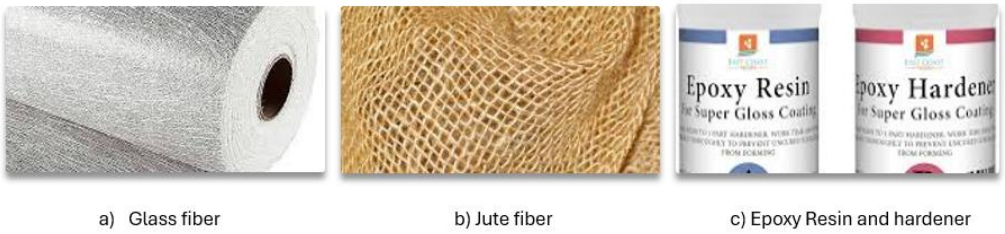


Figure 2.1: Glass Fiber, Jute Fiber & Epoxy resin and hardener

2.1 MATERIAS PROPERTIES:

Jute Fiber:

Jute is a natural fiber known for its eco-friendly characteristics.

1. Physical Properties

- **Density**: ~1.3–1.46 g/cm³ (low compared to synthetic fibers).
- **Tensile Strength**: ~250–350 MPa.
- **Young's Modulus**: ~20–55 GPa.
- **Elongation at Break**: ~1.5–1.8%.

2. Mechanical Properties
- Low tensile strength compared to synthetic fibers like glass.
- Moderate impact resistance.
- Good energy absorption due to its toughness.

3. Thermal Properties
- Thermal degradation starts at ~200–230°C.
- Low thermal conductivity, making it a good insulator.

4. Chemical Properties
- Hydrophilic Nature**:** High moisture absorption (8–12%), which can lead to swelling or degradation in wet environments.
- Resistance to weak acids but prone to degradation in alkaline conditions.

5. Environmental Properties
- Biodegradable and renewable.
- Environmentally sustainable with low carbon emissions during production.

Glass Fiber:

Glass fibers are synthetic fibers made primarily from silica and are widely used in reinforced composites.

1. Physical Properties
- **Density**: ~2.5–2.6 g/cm³ (higher than jute).
- **Tensile Strength**: ~1,200–2,000 MPa.
- **Young's Modulus**: ~70–80 GPa.
- **Elongation at Break**: ~2.5–4.8%.

2. Mechanical Properties
- High tensile and compressive strength.
- Excellent stiffness and rigidity.
- Good impact resistance compared to natural fibers.

3. Thermal Properties
- Can withstand high temperatures (up to 800°C for E-glass fibers).
- Low thermal expansion coefficient.

4. Chemical Properties

- **Hydrophobic Nature**: Resistant to water and moisture.
- Chemically inert to acids and bases, making it highly durable in harsh environments.

5. Environmental Properties

- Non-biodegradable.
- Energy-intensive production process.
- Recycling is possible but not as environmentally sustainable as natural fibers.

2.2 TEST SPECIMEN PREPARATION

After curing, the 300×300×10 composite plates were removed from the mold and trimmed to ensure uniformity. Specimens for mechanical testing were prepared as follows:

Bending Test: The accuracy of results depends heavily on how well the test specimen is prepared. Standards such as ASTM D79.Sample were cut 150mm×150mm×4.5mm.

Hardness Test: Samples were tested directly from the 150mm×150mm×4.5mm plates for surface hardness using a durometer.

Impact Test: Square specimens were cut 50mm×10mm×4.5mm to the required dimensions based on ASTM D256 standards to evaluate the impact resistance.

Each sample was carefully inspected for defects, such as voids or delamination, to ensure the reliability and consistency of test results. Specimens were stored in controlled conditions to prevent moisture absorption before conducting the tests.



Figure 2.2: Specimen cutting

CHAPTER 3: FABRICATION OF COMPOSITES

The composite samples were fabricated using the hand lay-up method followed by compression molding. The following steps outline the fabrication process in detail:

3.1 MOLD PREPARATION

To fabricate composites, a mild steel (MS) mold was used for its durability and dimensional accuracy.
Mold Dimensions: 300 mm × 300 mm × 10 mm.
Material: MS plate.
Surface Treatment: Polythene is used as an agent for easy removal of composites.
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3.2 LAYERING CONFIGURATION

The composite samples consisted of four layers, arranged in the following sequence: jute fiber – glass fiber – jute fiber – glass fiber. This specific sequence ensures a balanced distribution of the reinforcing fibers and provides a hybrid structure combining the properties of both jute and glass fibers. For each sample, the jute fiber layers were oriented at specific angles to investigate the effect of fiber orientation on mechanical properties:
Sample 1: Jute fibers orientation at 45°
Sample 2: Jute fibers oriented at 60°
Sample 3: Jute fibers oriented at 90°

This variation in orientation is intended to analyze the anisotropic behavior of the composites under mechanical loading.

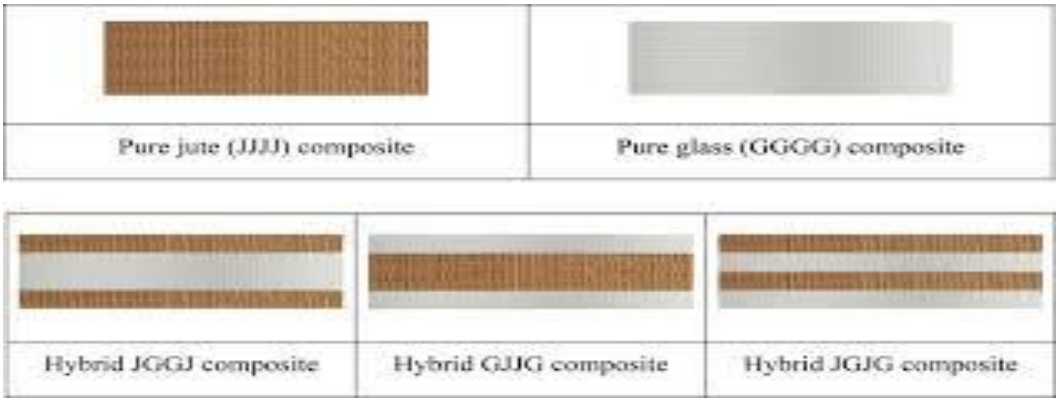


Figure 3.1: Layering

3.3 RESIN APPLICATION

A high-grade epoxy resin, known for its excellent adhesion and mechanical properties, was used as the matrix material. The resin was mixed with a hardener in a 100:1 ratio by weight, following the manufacturer's guidelines to achieve optimal curing and cross-linking. The mixture was stirred thoroughly to ensure homogeneity and to prevent unmixed regions that could weaken the composite. The resin-hardener mixture was evenly applied to each layer using a roller to ensure complete impregnation of the fibers. Special attention was given to eliminate air bubbles during the application process, as trapped air can lead to voids and reduce the mechanical strength of the composite.

3.4 COMPRESSION AND CURING

After stacking and impregnating the layers, the composite laminate was placed in the mold and subjected to uniform pressure using a compression molding machine. This step ensured proper compaction of the layers, reduced void content, and enhanced the fiber-matrix bonding. The composite was allowed to cure at room temperature for 24 hours to achieve initial hardening.

The detailed fabrication process ensures the production of high-quality composite samples, suitable for subsequent mechanical testing and performance analysis.

CHAPTER 4: EXPERIMENTAL PROCEDURE

4.1 MECHANICAL TESTS PERFORMED

The mechanical properties of the jute and glass fiber-reinforced epoxy composites were evaluated through two key tests:

1. Hardness Test :

The Shore B hardness of the composite samples was measured using a durometer as per ASTM D2240 standards. Samples were prepared with dimensions of 150 × 150 × 4.5 mm^3. In addition, the Rockwell hardness test was conducted using a Rockwell B steel ball indenter under a 100 kg load, which is suitable for softer materials like the composites tested. The hardness values were recorded as numerical readings, representing the material's resistance to deformation under the applied load. Higher values indicated greater hardness. All measurements were performed under controlled environmental conditions to ensure accuracy and repeatability.



Figure 3.2: Rockwell Hardness Test Machine

2. Impact Test :

The impact resistance of the composites was evaluated using the Charpy impact test as per ASTM D256 standards. Square specimens, 50 × 6 × 4.5 mm^3 in dimension, were prepared and visually inspected for defects such as voids or delamination to ensure consistency. During testing, specimens were subjected to a pendulum impact until fracture occurred. The energy absorbed by the material during fracture was recorded to determine its toughness and yield strength. This test also provided insights into the effect of strain rate on the material's fracture behavior and ductility. Specimens were stored in a controlled environment to prevent moisture absorption before testing.



Figure 3.3: Charpy-Izod Impact Test Machine

3. Bending Test :

The Shore B hardness of the composite samples was measured using a durometer as per ASTM D79 standards. Samples were prepared with dimensions of 150 × 150 × 4.5 mm^3. Bending Test measures a material's flexural strength, stiffness, and ductility, showing how much it can bend before breaking. A defect-free specimen is prepared and placed on a three- or four-point bending machine. Load is applied until failure, recording maximum load, deflection, stress, and strain to assess material quality.



Figure 3.4: Bending Test Machine

4.2 TESTING ORIENTATIONS

The mechanical tests were conducted on composite samples with varying jute fiber orientations to evaluate the influence of fiber alignment on mechanical performance.

Sample 1: Jute fibers oriented at 45°

Sample 2: Jute fibers oriented at 60°.

Sample 3: Jute fibers oriented at 90°.

For each sample, the jute-glass fiber sequence (jute-glass fiber-jute-glass fiber) and the orientation of the jute fibers were maintained consistently during fabrication. This allowed for a comparative analysis of the effect of fiber orientation on hardness and impact resistance.

All tests were conducted in a controlled environment to ensure reliability and reproducibility of results.

CHAPTER 5: RESULTS AND DISCUSSION

5.1 HARDNESS TEST RESULTS

The hardness test results for the composite samples with varying jute fiber orientations (45°, 60°, and 90°) are summarized below:

- **45° Orientation**: The samples displayed hardness values of **50**, **52.5** and **55** showing consistent surface resistance in Kg.

- **60° Orientation**: Hardness values were slightly higher, with readings of **45**, **47** and **49** showing consistent surface resistance in Kg.

- **90° Orientation**: Samples exhibited hardness values ranging from **42, 45 and 44** showing consistent surface resistance in Kg with variability likely caused by inconsistent fiber alignment at this orientation.

The results demonst rate that fiber orientation significantly impacts the hardness of the composite. The 45° orientation yielded the most consistent and higher hardness values, likely due to the balanced contribution of both jute and glass fibers.



Figure 5.1: Hardness testing with specimen

Specimen No.	45° Orientation Load in kg	60° Orientation Load in kg	90° Orientation Load in kg
1.	50	45	42
2.	52.5	47	45
3.	55	49	44
Average	52.5	47	43.67

Table 5.2: Data Table of Hardness Test

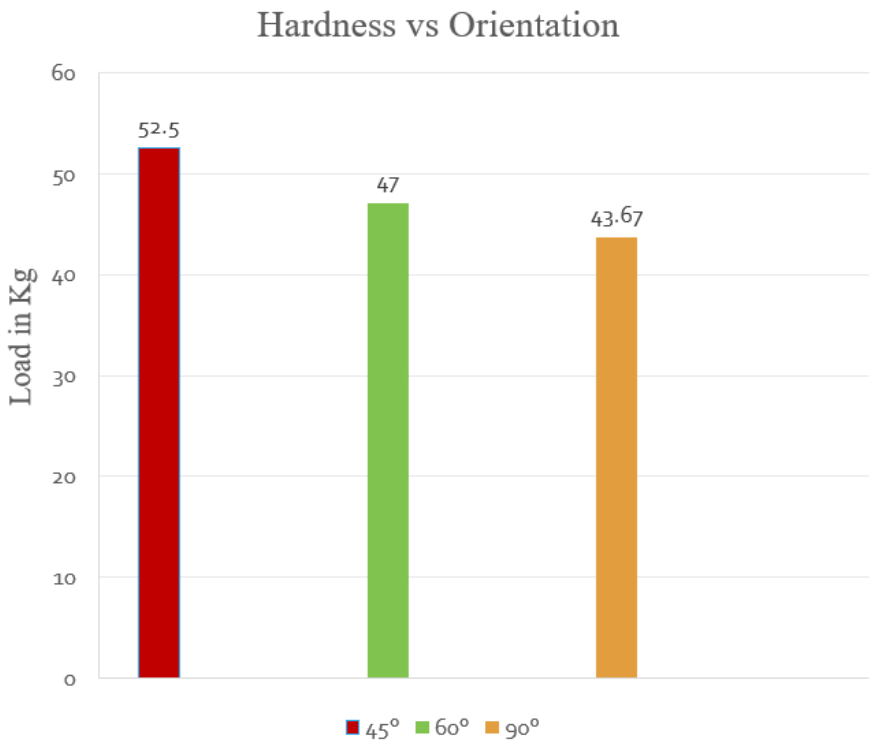


Figure 5.3: Hardness vs orientation graph

Comparison:

1. At **45°**, our results and the reference results show high hardness, with our configuration showing slightly better performance (avg. 52.5kg)
2. At **60°** (our result) the hardness is slightly lower values (avg. 47kg).
3. **90°** orientation provides lower hardness than **60°** (avg. 43.66kg)

5.2 IMPACT TEST RESULTS

The impact resistance of the composite samples was evaluated based on the energy absorbed during testing, with the results categorized by fiber orientation:

- **45° Orientation**: Impact energies recorded were **3.3,3.25 and 3.44 in ft-lb**.

- **60° Orientation**: Samples exhibited higher energy absorption, with values of **2.3,2.2 and 2.49 in ft-lb**.

- **90° Orientation**: The samples showed varying energy absorption, with values of **2.1,2.15 and 2.23 in ft-lb**. Despite higher absorption in some cases, variability suggests potential misalignment or uneven stress distribution at this angle.



Figure 5.4: Impact test specimens after testing

The results indicate that the 45° fiber orientation provides superior and consistent impact resistance, emphasizing its suitability for applications requiring enhanced toughness.

Comparatively, the 60° and 90° orientations demonstrated lower performance, with variability in energy absorption likely due to non-optimal fiber alignment.

In summary, both the hardness and impact test results underline the critical influence of fiber orientation on the mechanical performance of jute and glass fiber-reinforced epoxy composites. The 45° orientation emerged as the most effective configuration for achieving a balance of surface hardness and impact resistance.

Specimen No.	45° energy (ft.lb)	60°energy (ft.lb)	90° energy (ft.lb)
1.	3.30	2.30	2.10
2.	3.25	2.20	2.15
3.	3.44	2.49	2.23
Average	3.33	2.33	2.16

Table 5.5: Data Table of Impact Test

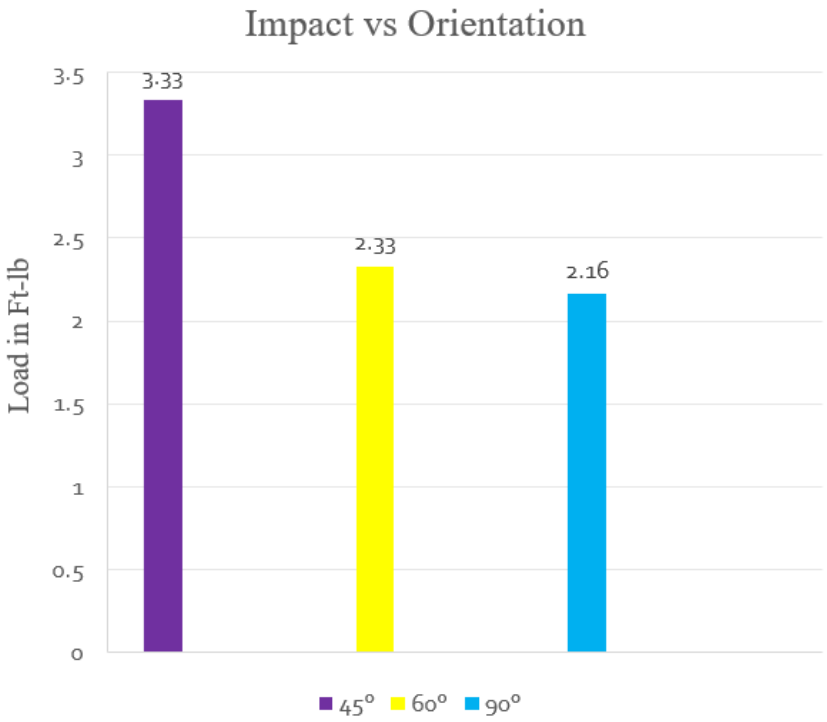


Figure 5.6: Impact vs orientation graph

Comparison:

1. At **45°**, both your results and the reference results demonstrate superior impact resistance, with results slightly outperforming (avg. 3.3 ft-lb).
2. **60°** orientation (avg. 2.33 ft-lb) is slightly lower.
3. **90°** orientation (avg. 2.16 ft-lb) performs slightly lower than **60°.**

5.3 BENDING TEST RESULTS

The bending strength of the composite samples was evaluated under three-point bending, with the results categorized by fiber orientation:

- **45° Orientation:** Samples exhibited the highest and most consistent bending strength, with values of 300,283 and 288 in N. This orientation provided superior load distribution and effective stress transfer, resulting in enhanced resistance against bending failure.
- **60° Orientation:** The recorded strengths were moderate, with values of 173,177 and 178 in N.Although performance was relatively stable, the results indicate slightly reduced bonding efficiency compared to 45° orientation.
- **90° Orientation:** Samples showed the lowest bending strength, with values of 142,149 and 147 in N. This orientation displayed weak resistance due to poor load transfer along the fiber direction, making it the least effective configuration under bending loads.



Figure 5.7: Bending test specimens after testing

The findings indicate that the 45° fiber orientation demonstrates superior bending resistance, making it highly suitable for structural applications requiring strength and reliability.Comparatively, the 60° and 90° orientations exhibited weaker performance, which may be attributed to less effective stress transfer and fiber alignment.

Specimen No.	45° Load in N	60° Load in N	90° Load in N
1.	300	173	142
2.	283	177	149
3.	288	178	147
Average	287	176	146

Table 5.8 : Data Table of Bending Test

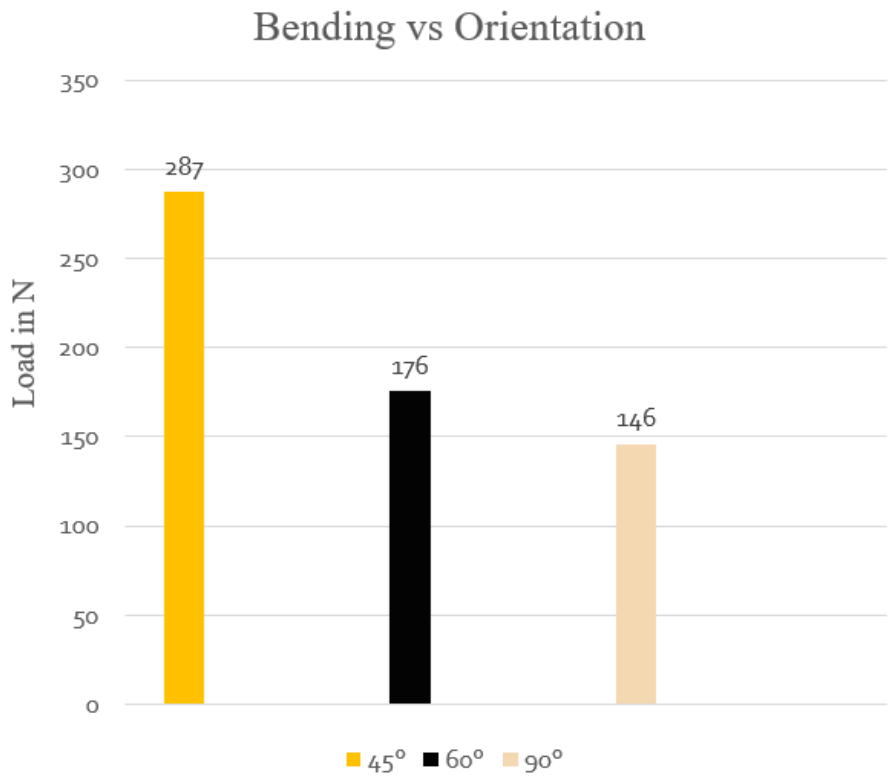


Figure 5.9: Bending vs orientation graph

Comparison:

1. At **45°**,results demonstrate superior flexural resistance with better performing (avg. 287N).
2. 60° orientation (avg. 176N) is slightly better than **45°** .
3. 90° orientation (avg. 146N) performs lower than **60°**.

CHAPTER 6: CONCLUSIONS AND FUTURE SCOPE

6.1 CONCLUSIONS

This study evaluated the mechanical performance of jute and glass fiber-reinforced epoxy composites by conducting hardness and impact tests on samples with different jute fiber orientations (45°, 60°, and 90°). The key findings are as follows:

Hardness Test:
The **45° orientation** exhibited the highest hardness values among the three configurations (average: **52.5kg**), clearly outperforming both the **60°** and **90°** orientations (average**: 47kg** and **43.66kg** respectively). This indicates that the **45°** fiber alignment provides superior resistance to surface indentation, while the relatively lower hardness at **60**° and **90°** suggests less effective stress distribution.

Impact Test:
The **45° orientation** exhibited superior impact resistance, absorbing the highest energy during testing (average: **3.33 ft-lb**). It outperformed the **60°** (average: **2.33 ft-lb**) and **90°** (average: **2.16 ft-lb**) orientations, confirming its effectiveness in optimizing energy absorption.The decreasing trend from **45°** to **90°** indicates that fiber orientation plays a vital role in impact strength, with more favorable energy absorption observed at lower angles.These results emphasize the significance of orientation in tailoring mechanical properties, with the **45°** orientation emerging as the optimal configuration for maximizing impact resistance.

Bending Test:
The **45° orientation** demonstrated the highest and most consistent bending strength among the three configurations (average: **287 N**), outperforming both the **60°** and **90°** orientations (average: **176N** and **146N** respectively). This indicates superior load distribution and effective stress transfer at **45°**, while the lower performance at 60° and 90° suggests reduced bonding efficiency and weaker resistance to bending loads.

6.2 FUTURE SCOPE

This research lays the foundation for further exploration of hybrid fiber composites. Future work can focus on:

1. Additional Mechanical Tests: Evaluating tensile and fatigue properties to gain a comprehensive understanding of the composite's mechanical behavior.
2. Effect of Fiber Volume Fraction: Investigating how varying the proportions of jute and glass fibers influences mechanical properties.
3. Moisture and Environmental Testing: Assessing the performance of composites under different environmental conditions, such as humidity, temperature, and UV exposure.
4. Alternate Resin Systems: Exploring the use of bio-based or modified epoxy resins to further improve the sustainability of the composite.
5. Optimization of Fabrication Techniques: Studying advanced manufacturing methods, such as vacuum bagging or resin infusion, to minimize voids and enhance mechanical properties.
These future directions will enable the development of optimized hybrid composites for applications in automotive, aerospace, and structural industries, ensuring sustainability without compromising performance.

6.3 Applications of Jute-Glass Fiber Based Composites:

Jute-glass fiber composites find diverse applications, particularly in the automotive, construction, and furniture industries, where they serve as lightweight, cost-effective materials for components like structural parts, interior panels, and roofing. Their improved mechanical and impact properties, compared to jute composites alone, make them suitable for sportswear components, furniture, and even potential aerospace applications due to their enhanced strength-to-weight ratio.

Key Applications:

- **Automotive:**Used for interior parts, body panels, and even some structural components, offering a lighter and more sustainable alternative to traditional materials.
- **Construction:**Suitable for creating lightweight building elements such as roofing sheets, doors, panels, and decorative items, leveraging jute's natural insulating properties.
- **Furniture & Household:**Applications include armchairs, decorative items, tables, and other home furnishing products, providing a sustainable wood replacement.
- **Sportswear:**Explored for engineering components like skateboards, demonstrating sustainable strength and cost savings over traditional wood.
- **Aerospace:**The lightweight nature and good mechanical characteristics of these composites make them candidates for non-structural and structural applications in the aerospace sector.
-

Benefits of the Composites

- **Enhanced Mechanical Properties:**The combination of jute and glass fibers improves tensile strength, bending strength, impact strength, and stiffness compared to jute-only composites.

- **Light weight:**The resulting composite material is significantly lighter than conventional materials, which is advantageous in automotive and aerospace applications.
- **Cost-Effectiveness:**The incorporation of low-cost natural jute fibers with glass fibers can lead to overall cost savings in material production.
- **Sustainability:**Utilizing renewable jute fibers contributes to developing more eco-friendly and biodegradable composite materials.

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