# INVESTIGATION OF MECHANICAL PROPERTIES OF HARDENER RESIN COMPOSITES REINFORCED WITH JUTE AND GLASS FIBERS

A Thesis

by


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Department Of Mechanical Engineering

SONARGAON UNIVERSITY (SU)


SEPTEMBER 2025

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Submitted to the

DEPARTMENT OF MECHANICAL ENGINEERING

SONARGAON UNIVERSITY (SU)

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

of

Bachelor of Science in Mechanical Engineering

SEPTEMBER 2025

## CERTIFICATE OF APPROVAL

This is to certify that the thesis titled " **Investigation of mechanical properties of hardener resin composites reinforced with jute and glass fibers**" being submitted by Alamin Mia ID:ME2003022153, Anamul Hoque ID: ME2003022154, Md. Masud Rana ID: ME2201026231, Md. Shabuz Mia ID: ME2201026268 & Proshanto Chandra Dabe ID: ME2201026233 respectively, in partial fulfilment of the requirements for the award of the degree, Bachelor of Science in Mechanical Engineering, from Sonargaon University, is a record of bona fide work arrived out by them under my guidance and supervision.

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## DECLARATION

I hereby declare that the thesis titled **" Investigation of mechanical properties of hardener resin composites reinforced with jute and glass fibers ‘’**submitted to Sonargaon University, is my original work carried out under the guidance of **Shahinur Rahman**.

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.

I 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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## DEDICATION

This book dedicated to the brave martyrs of the July Revolution 2024.

A turning point of courage, sacrifice, and unyielding resistance. This work is also dedicated to all those who, directly or indirectly, played a role in shaping this historic moment. To the martyrs who gave their lives for freedom, to the activists who raised their voices against injustice, to the silent supporters who provided strength behind the scenes, and to the countless individuals whose hopes and dreams fueled this revolution.

May their sacrifices never be forgotten, and may their legacy continue to inspire generations in the pursuit of justice, dignity, and a better future.

## ACKNOWLEDGEMENT

We express our heartfelt gratitude to all those who have supported and guided us throughout the course of this research work. First and foremost, we extend our deepest thanks to our supervisor, **Shahinur Rahman**, Assistant Professor & Coordinator, Mechanical Department, for his invaluable guidance, encouragement, and constructive feedback, which have been instrumental in the successful completion of this thesis. We also wish to convey our sincere gratitude to **Professor Md. Mostafa Hossain**, Head of the Mechanical Department, for his continuous support, advice, and motivation throughout our academic journey. We also wish to acknowledge the support of Sonargaon University for providing us with the necessary resources and infrastructure to carry out our experiments and analyses. A special thanks to the laboratory staff for their assistance during the mechanical testing processes, which were critical to our study. We are immensely grateful to our peers and colleagues for their moral support and for fostering an environment of collaboration and learning. Their insightful discussions and suggestions enriched the scope of our research. Finally, we owe a debt of gratitude to our families for their unwavering encouragement, patience, and understanding throughout this journey. Their belief in us has been our greatest strength. This work would not have been possible without the collective contributions of everyone mentioned above.

## ABSTRACT

This thesis investigates the mechanical properties of epoxy resin composites reinforced with jute and glass fibers, aiming to develop eco-friendly materials with industrial applicability. This research focuses on the mechanical properties and performance analysis of jute fiber and glass fiber reinforced epoxy composites, particularly evaluating the effect of fiber orientation under various mechanical tests. Hybrid composites were fabricated using jute fibers oriented at 45°, 60°, and 90°, combined with glass fibers in an epoxy matrix. Mechanical testing included hardness and impact tests to understand the influence of fiber orientation on the overall properties of the composites. The results demonstrated a significant correlation between fiber orientation and the mechanical behavior of the composites. The 60° jute fiber orientation exhibited superior impact strength, attributed to its ability to absorb and dissipate energy more effectively under dynamic loading conditions. On the other hand, the 90° orientation resulted in higher hardness values, indicating better resistance to localized deformation. The 45° orientation showed balanced performance but did not surpass the other configurations in either hardness or impact strength. This study highlights the importance of fiber orientation in designing hybrid composites to achieve desired mechanical properties. By optimizing orientation, it is possible to tailor the composite for specific applications, such as automotive, aerospace, and structural components, where lightweight materials with enhanced strength and durability are crucial. These findings provide valuable insights for future development of sustainable, high-performance composite materials. Biodegradability studies revealed faster degradation rates for composites with higher natural fiber content, reflecting their environmental sustainability. They hold significant potential for applications in automotive, construction, and packaging industries. Future research should focus on optimizing material formulations, scaling up production processes, and conducting long-term performance studies to enhance commercial viability.

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# CHAPTER 1: INTRODUCTION

## 1.1 Introduction

Technological advancements are deeply intertwined with the development of innovative materials. Many modern technologies demand materials with unique combinations of properties that conventional materials such as metals, ceramics, and polymers cannot fully achieve. This is particularly evident in fields such as aerospace, underwater exploration, and transportation, where materials must exhibit characteristics like low density, high strength, impact resistance, and corrosion resistance. For instance, aerospace engineers often seek structural materials that combine light weight with high strength and excellent abrasion resistance. However, achieving such combinations in monolithic materials often involves trade-offs, such as increased density or reduced impact strength when stiffness is enhanced.

In composite materials, various types of fibers are used as reinforcement. They can be natural or synthetic. Due to its lightweight and eco-friendly nature, natural fibers are getting ample attention nowadays [2,3] . Natural fibers are not only cheap but also environmentally friendly, wholly or partially biodegradable, and renewable, which can be applied to attain novel and high-performance polymer materials. In addition, such composites exhibit adequate mechanical properties (i.e., tensile properties, fracture toughness, flexural stress-strain behavior, and fracture strength), rendering them more attractive to other composites. Due to renewability and easy availability in nature, these fibers are used as an alternative to synthetic fibers as a reinforcing medium [4,5].

Natural fibers can be found in sources like animals, plants, and minerals. Silk, wool, and hair are the kinds of fiber found from animal sources. Plant fibers are cellulose or lignocellulose, which are also divided into a variety of kinds. Among those, bast fibers are one of the most popular fibers. Examples of these include jute, flax, hemp, pineapple, sugarcane, oil palm, ramie, kenaf, roselle, mesta etc. [6,7]. Jute, however, is the least expensive among all of them and is abundant in nature. Jute production is mainly concentrated in the Ganges River delta. Bangladesh and India together produce 80 % of the world's total jute supply. Countries like Myanmar, Thailand, and Pakistan also produce in smaller quantities. Chemical composition of jute contains α-cellulose (45–63)%, lignin (21–26)%, and pentosans (18–21)% [8]. Due to its 'composite-like' structure along with strongly aligned long-chain molecules, jute is considered one of the most robust fibers with very little extensibility showing high flexural and torsional rigidities and thus they are used as a reinforcing agent in polymer composites as

considered in this study. The key advantages that glass fibers present include higher tensile strength, low manufacturing costs, great chemical stability, and better performance-to-cost ratio. These rendered them a great candidate for polymer reinforcement. Nowadays, glass fibers are used in a wide variety of areas including aerospace, automotive, marine, athletic and leisure goods, as well as construction and civil engineering. They are also used as filters and fibrous blankets for thermal and acoustic insulation without a matrix. Thus, glass fibers were selected to be used as reinforcements in polymer composites with jute in this experiment.

Composite materials represent a revolutionary step in overcoming these limitations, offering extended property combinations and performance ranges. They are a testament to the ongoing pursuit of material optimization. While the concept of composites might seem recent, it is deeply rooted in nature. For example, wood is a natural composite consisting of cellulose fibers embedded in a lignin matrix. The cellulose fibers provide tensile strength and flexibility, while the lignin matrix offers stiffness and cohesion. Similarly, other examples, such as coconut shells and plant structures, illustrate the fundamental principles of fiber reinforcement used in composites [32].

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. Through 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 Types of Composites

Composite materials typically consist of two main constituents:

**1.2.1 Matrix (Binder):** The matrix serves to bind the reinforcements together, maintain their spatial arrangement, and transfer applied loads to the reinforcements. It also protects the reinforcements from environmental damage.

**1.2.2 Reinforcements:** The reinforcements provide strength, stiffness, and other desirable properties to the composite. They can take various forms, including particulate, discontinuous fibers, or continuous fibers, depending on the required properties.

### 1.3 Types of Matrix Material

Three main categories based on the matrix material are:

**1.3.1 Metal Matrix Composites:** These consist of a metal or metal alloy matrix reinforced with ceramic or metallic fibers or particles. MMCs offer excellent thermal conductivity, wear resistance, and high-temperature strength, making them ideal for applications in aerospace, automotive engines, and electronic packaging.

**1.3.2 Polymer Matrix Composites:** PMCs use polymer resins (such as epoxy, polyester, or thermoplastics) as the matrix material, combined with reinforcements like glass, carbon, or natural fibers. Due to their low density, cost-effectiveness, versatility, and ease of processing, PMCs are the most widely used type of composite materials. Applications range from lightweight automotive panels and sporting goods to marine structures and medical devices.

**1.3.3 Ceramic Matrix Composites:** CMCs comprise ceramic materials as the matrix, often reinforced with fibers like silicon carbide or alumina. These composites are known for their high temperature and chemical resistance, making them suitable for applications in gas turbines, heat exchangers, and aerospace components.

A classification scheme for various composite types based on reinforcement is given below [33]:

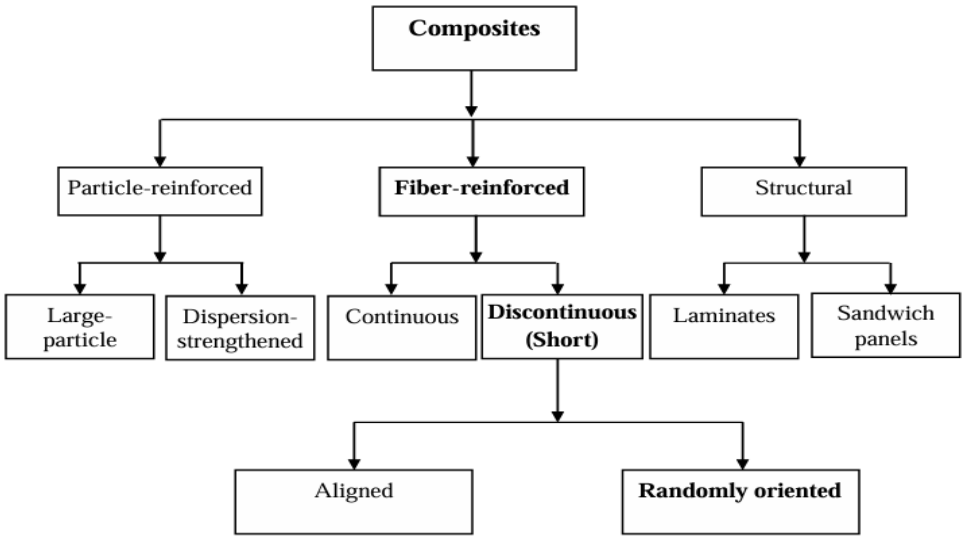



Figure 1: Scheme for various composite types based on reinforcement

### 1.4 Role of Natural Fibers in Sustainable Materials

The use of natural fibers in composite materials has gained significant attention due to their potential to address the environmental and sustainability challenges posed by conventional synthetic fibers such as glass, carbon, and aramid fibers. These synthetic fibers, widely used in thermosetting composites, are notoriously difficult to recycle and decompose, often persisting in landfill sites for generations. Their production processes emit substantial amounts of $CO_2$, nitrogen oxides ($NO_x$), sulfur oxides ($SO_x$), and particulate matter, all of which contribute to environmental degradation and health hazards. Even during disposal or recycling, grinding these materials generates harmful dust and fragments. In contrast, plant-based natural fibers offer an eco-friendly alternative with numerous advantages. Derived from renewable and abundant agricultural by-products, plant fibers are lightweight, biodegradable, and non-abrasive to processing equipment. They are also $CO_2$-neutral, meaning that when incinerated, the $CO_2$ released is offset by the amount absorbed during the plant's growth. The ability to produce complex shapes through one-step manufacturing processes further broadens their appeal across industries, ensuring their growing adoption in automotive, construction, appliance, and other sectors. Overall, the integration of natural fibers into composites aligns with global efforts to transition toward sustainable materials, reducing the reliance on fossil fuel-based resources while delivering economic and environmental benefits.

#### 1.4.1 Role of Synthetic Fibers in Sustainable Materials

Synthetic fibers, such as glass fibers, are widely utilized in reinforced composites for their superior mechanical properties. Glass fibers exhibit high tensile strength, stiffness, and impact resistance, making them suitable for applications demanding enhanced durability and performance. However, the environmental impact and non-biodegradable nature of glass fibers remain significant challenges.

## 1.5 Objectives of the Study

1.The main objective of the study is to investigate the influence of jute and glass fibers on the mechanical properties (Bending strength, Impact strength & Hardness) of hardener resin composites.

2. To evaluate the influence of jute fiber orientation (45°, 60°, and 90°) on the bending test , hardness of hybrid epoxy composites and impact resistance.

3. The potential of these natural fiber-reinforced composites for various applications (e.g., automobile , aerospace & marine , textile industry, packaging, construction & furniture, industrial application,) will be evaluated.

4. To contribute to the growing body of research on sustainable material design by exploring hybrid composites as a viable alternative to traditional materials.

## 1.6 Background

### 1.6.1 Development of Composite Materials Over Time

The development of composite materials over time showcases an impressive evolution that aligns with both technological advancements and environmental consciousness. In ancient times, early humans combined natural fibers like straw with mud to construct durable bricks and huts, harnessing the fundamental principles of composite technology. As civilizations progressed, the techniques refined during the middle Ages and Renaissance, such as lath and plaster walls and timber-framed buildings, further demonstrated the utility of combining different materials for structural benefits. The Industrial Revolution introduced significant advancements in material science, with iron and steel replacing wood in many applications. However, it was the early 20th century that saw the emergence of true synthetic composites with the invention of polymers like Bakelite and the development of fiberglass. These materials revolutionized various industries by offering high strength-to-weight ratios and durability. The mid to late 20th century continued this trend with the introduction of carbon fiber during the 1960s, becoming essential in aerospace, sports equipment, and automotive industries due to its exceptional properties. From the humble beginnings of mud and straw to the sophisticated and sustainable composites of today, the journey of composite materials is a testament to humanity's ingenuity and adaptability, constantly seeking better solutions for construction, transportation, and countless other applications.

### 1.6.2 Characteristics of Jute and Glass Fibers

**Jute Fibers:** Jute fiber has distinct characteristics. It is recognized by its natural golden-brown color and a somewhat rough, coarse texture. Despite its texture, jute fibers exhibit high tensile strength, withstanding considerable pulling force without breaking. This makes it a robust material. It also offers good insulating properties, providing a barrier against temperature changes. Jute is breathable, allowing air circulation, beneficial in packaging and textile uses. It is also a relatively affordable fiber, making it an economically viable option for mass production. Jute can be blended with other natural or synthetic fibers to enhance specific properties or create novel materials.

General physical properties of Jute fiber:

- Density: The density of fibre is 1.48-1.50 gm/cm$^3$
- Moisture regain: Jute is highly hygroscopic in nature. Its moisture regain is 12-14% at standard condition.
- Strength: The tenacity of jute varies from 3.5-7 gm/denier.
- Colour: Varies from yellow to brown to grey depending upon condition of growth and retting etc.
- Elongation: Jute do not stretch to appreciable extent under tension. Its breaking elongation is 1-1.2% under normal atmospheric condition.
- Composition: Jute fibre contains cellulose (55-63%), hemicelulose (20-24%) and lignin (12-14%).
- Conductivity: It is very good insulator of heat and electricity.
- Elasticity: Jute has lower elasticity due to its stiffness and rigidity. This has advantages of jute to be used as bagging material as they retain their shape on loading.

**Glass Fibers:** Glass fiber is a micron-sized fibrous material made of glass by pulling or centrifugal force after high-temperature melting, and its main components are silica, calcium oxide, alumina, magnesium oxide, boron oxide, sodium oxide, and so on. There are eight types of glass fiber components, namely, E-glass fiber, C-glass fiber, A-glass fiber, D-glass fiber, S-glass fiber, M-glass fiber, AR-glass fiber, E-CR Glass Fiber.

General physical properties of glass fiber filaments:

- High tension-endurance: the tension-resistant is about twice as steel of unit weight.
- Good size stability: the ratio of elongation is about 3% ~ 4%.
- Good heat-endurance: it have the 50% ability of tension-endurance however the temperature of 340℃.
- The character of the resistance to chemical cauterization: it is not easy to be damaged by the chemical.
- Low water-absorptance: 0.1%.
- Good electronic characters: is has good electric-resistant.

### 1.6.3 Importance of Resin and Hardener in Composites

Resin and hardener are pivotal components in the fabrication of composite materials, each contributing essential properties that determine the final product's performance. Resin acts as the binding matrix that holds the reinforcing fibers together, thereby enhancing the composite's structural integrity by effectively transferring loads between the fibers. It also provides protection from environmental factors like moisture, chemicals, and physical damage, ensuring durability and longevity. Various types of resins, such as epoxy, polyester, and vinyl ester, offer different strengths, curing characteristics, and resistance to environmental factors, making them suitable for specific applications. The hardener, or curing agent, initiates the chemical reaction necessary to transform the liquid resin into a solid, durable material. It plays a crucial role in influencing the curing speed and working time, which can be adjusted based on the requirements of the project [37]. Proper selection and mixing of the hardener are essential for achieving optimal curing conditions, which enhances the mechanical properties and durability of the composite material. Common hardeners include amines, which are often used with epoxy resins, providing excellent curing characteristics and mechanical properties, and peroxides, which are typically used with polyester and vinyl ester resins to initiate curing through a free-radical mechanism. Together, the resin and hardener form a robust bond that results in a composite material with significantly improved mechanical properties, making it suitable for high-performance applications across industries such as aerospace, automotive, marine, and construction. Understanding the roles and properties of these components is crucial for selecting the appropriate combination to meet specific performance criteria, ensuring that the final composite material is strong, durable, and capable of withstanding demanding conditions.

## 1.7 Problem Statement

### 1.7.1 Environmental Challenges of Synthetic Fiber Composites

Synthetic fiber composites, while offering exceptional mechanical properties and versatility, pose significant environmental challenges. The production of these composites is energy-intensive and generates a high carbon footprint. The materials often involve non-renewable resources, leading to resource depletion. Additionally, synthetic composites are not easily recyclable, resulting in increased landfill waste [10]. Environmental degradation is another concern, as these composites can be susceptible to UV radiation, moisture, and chemical exposure, leading to reduced performance and safety issues. To mitigate these challenges, researchers are exploring eco-friendly solutions such as incorporating recycled and bio-based

materials, applying design for sustainability principles, and promoting recycling and circular economy models [10]. These efforts aim to reduce the environmental impact while maintaining the beneficial properties of synthetic fiber composites.

### 1.7.2 Mechanical Limitations of Existing Natural Fiber Composites

Despite their environmental advantages, natural fiber composites face several mechanical limitations. These include poor interfacial bonding between the fibers and the matrix, high water absorption, and variability in mechanical properties due to natural fiber heterogeneity. Such limitations can reduce their structural integrity and restrict their use in demanding applications, such as load-bearing structures. Addressing these challenges through surface treatments, optimized fiber-matrix compatibility, and hybrid reinforcement strategies is essential to enhance their performance and broaden their application scope [11].

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Introduction

The growing emphasis on sustainable materials has spurred research into natural fiber-reinforced composites as eco-friendly alternatives to synthetic options. Banana and Bamboo Fibers stand out for their abundance, biodegradability, and high specific strength, making them promising reinforcements in resin-based composites. When combined with hardener resin matrices, these fibers can yield composites with enhanced mechanical and physical properties, suitable for diverse applications. This review explores existing research on the performance of coconut and sugarcane fiber composites, focusing on their fabrication techniques, property optimization, and potential challenges, providing a basis for the current study.

## 2.2 Literature Review

Fiber-reinforced composites have become a key area of research due to their ability to combine lightweight structures with excellent mechanical properties. Hybrid composites, integrating both natural and synthetic fibers, are particularly promising as they blend performance with sustainability. This section provides an overview of prior studies focusing on the hardness and impact performance of fiber-reinforced composites, with a particular emphasis on hybrid configurations.

# CHAPTER 3: MATERIALS & METHODOLOGY

## 3.1 Materials

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 and mold plates were used during the fabrication process to facilitate smooth curing and easy removal of composite samples.

Glass Fiber, Epoxy resin and Epoxy hardener are purchased from Nawabpur, Dhaka 1100, Bangladesh, supplied by Syed Trade Internatinal. Jute Fiber are purchased from local market which was Kawran Bazar, Dhaka.



**Figure 2 : Glass Fiber & Jute Fiber**

## 3.2 Process of jute fibre & Glass Fiber composite synthesis by Hand Lay-Up process:

### Mold Preparation:

A mold of 300 mm × 300 mm dimensions was prepared and lined with a release film to prevent the composite from adhering to the mold surface. The release film also ensures ease of demolding and avoids surface defects on the composite. Proper cleaning and waxing of

the mold surface were carried out before applying the release film to enhance its effectiveness.

**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 oriented 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.

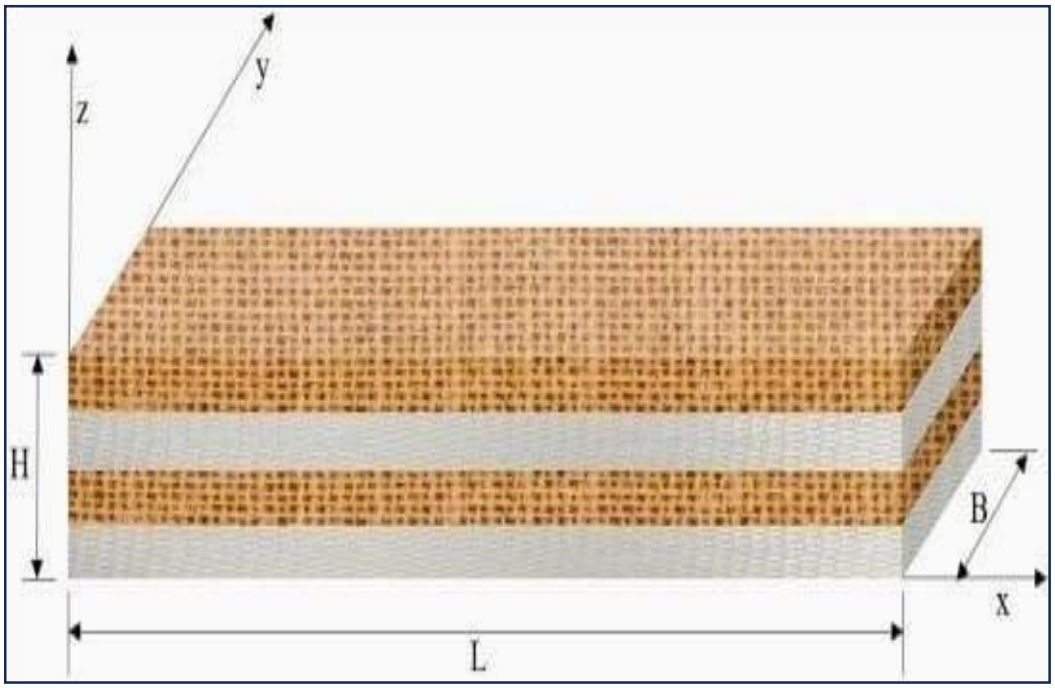



**Figure 3 : Layering**

**Fabrication Procedure:**

In this study, manual hand layup method is used for preparing composite laminates as shown in **Fig- 4.** First of all, Thin plastic sheets are used at the top and bottom of the mould plate to get a good surface finish of the product. Reinforcement in the form of woven mat jute fabrics and Glass fibers are cut as per the mould size and placed at the surface of mould after perspex sheet. Then epoxy in liquid form is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and poured onto the surface of mat already placed in the mould. The epoxy is uniformly spread with the help of the brush. The second layer of mat is then placed on the epoxy surface and a roller is moved with a mild pressure on the mat-epoxy layer to remove any air trapped as well as the excess epoxy present. The process is repeated for each layer of epoxy and mat, till the required layers are stacked. After placing the plastic sheet, should be covered with a mould plate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature. The mould is opened and the developed composite part is taken out and further processed. For epoxy based system, normal curing time at room temperature is 24 - 48 hours.



**Figure 4 : Laminates making using hand lay-up technique**

**Demolding and Finishing:**

1. After complete curing, the composite is carefully removed from the mold.

2. Excess edges and irregularities are trimmed for a smooth finish.

3. Cutting the specimen perfectly.



**Figure 5 : Cutting the specimen**

### 3.3 Mechanical Tests

#### 3.3.1 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 100kg load, which is suitable for softer materials like the composites tested are shown in **Fig-06.** 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 6: Hardness testing of composite**

### 3.3.2 Bending Test

Bending is also known as flexural bending. Flexural test was performed following the ASTM standard using the Universal Testing Machine UTM. Samples were prepared with dimensions of (150 × 150 × 4.5 $mm^3$). The distance between the specimen supports was 100 mm and the loading force was applied to the specimens at a crosshead speed of 5 mm/min until the specimens fractured. Flexural strength is the ability of the material to applied bending forces perpendicular to the longitudinal axis of the specimen. The flexural test specimen of jute fiber composites and experimental setup for flexural testing of composite specimen and UTM are shown in **Fig-7.**



**Figure 7 : Bending test of composites**

### 3.3.3 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 8 : Impact testing of composites**

## 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.

## CHATPER 04: RESULT & ANALYSIS

**4.1 Examination of Physical Characteristics:** Initially, no measurable mass loss was detected across all samples on the first day. By the third day, only minimal degradation was observed in the bioplastics, indicating an initial adaptation phase for microbial activity in the new environment. As biodegradation progressed, heightened microbial colonization and activity led to a notable increase in weight reduction across all bioplastic samples. Additionally, it was evident that a higher concentration of bamboo and banana fibers contributed to an accelerated decomposition rate, highlighting their role in enhancing the biodegradability of the material.

**4.2 Hardness Test Result:**

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 **12**, **10** and **13** showing consistent surface resistance.

• **60° Orientation**: Hardness values were slightly higher, with readings of **10**, **8.5** and **9**. The improved performance at 45° indicates better stress distribution due to the alignment of fibers.

• **90° Orientation**: Samples exhibited hardness values ranging from **11, 8** and **9** with variability likely caused by inconsistent fiber alignment at this orientation.

The results demonist 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.

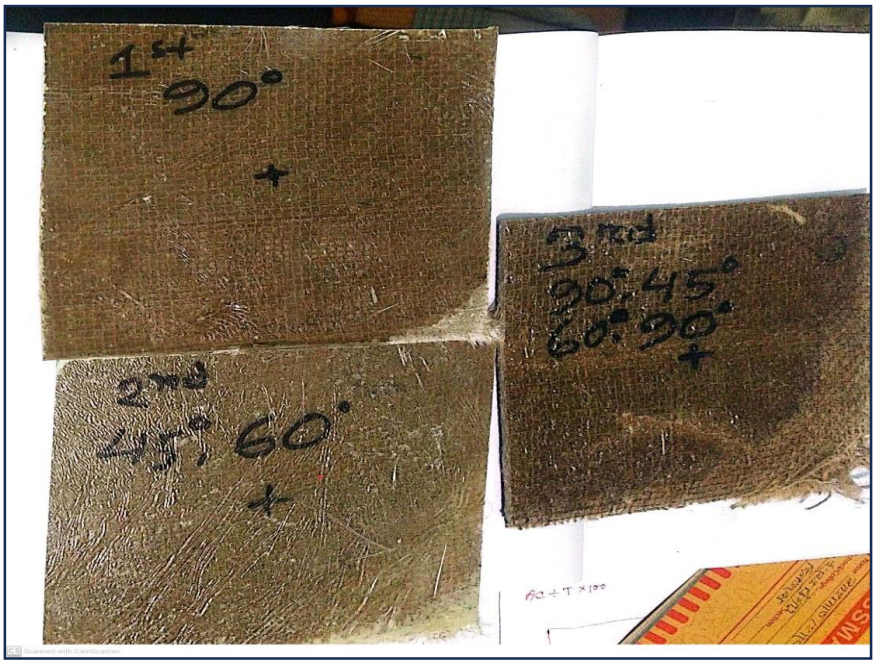



**Figure 9 : Hardness test specimen**

**Data Table for Hardness Test:**

| Fiber Orientation | 45° | 60° | 90° |
|---|---|---|---|
| Specimen No. | Hardness (kg) | Hardness (kg) | Hardness (kg) |
| 1. | 12 | 10 | 11 |
| 2. | 10 | 8.5 | 8 |
| 3. | 13 | 9 | 9 |
| Average | 11.67 | 9.17 | 9.33 |

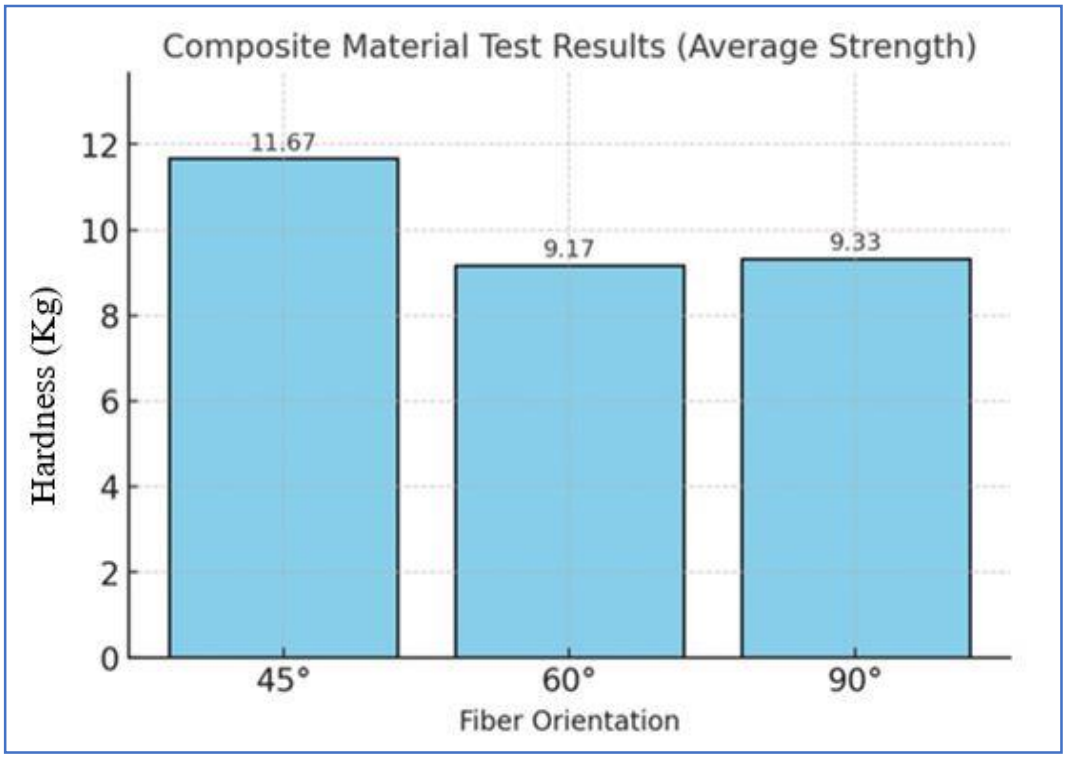



**Figure 10 : Hardness of composites**

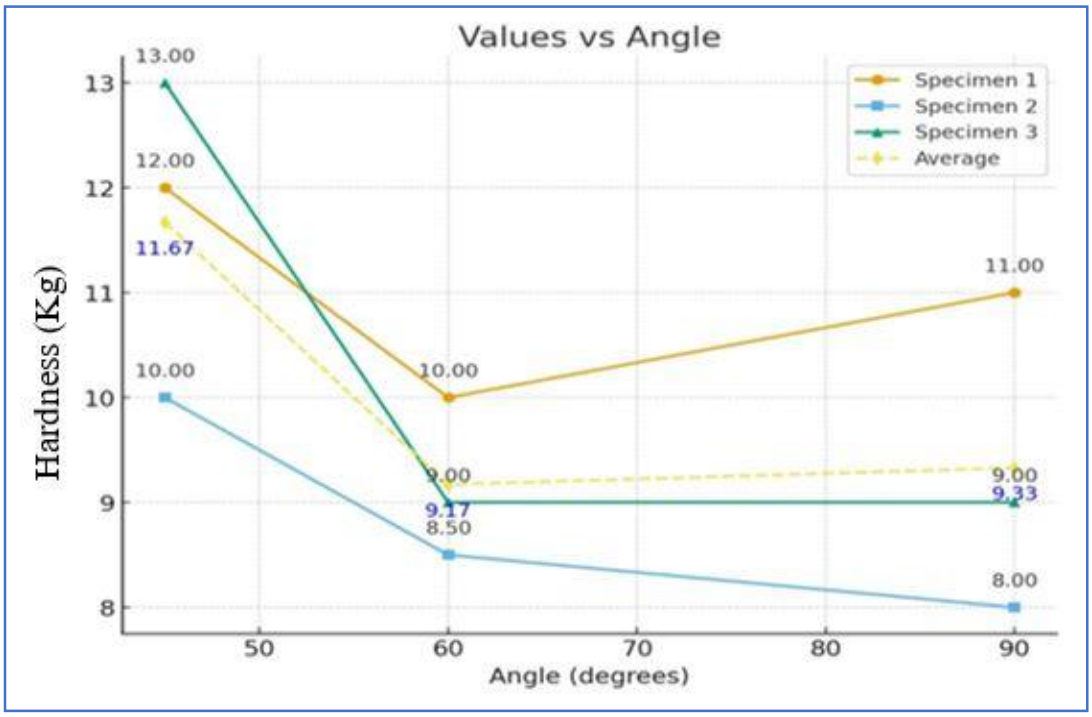



**Figure 11 : Hardness comparison of different compositions**

- **Comparision hardness test results of jute and glass fiber at different angle:**

**(45° Orientation)→ Hardness = 11.67**

- At **45°**, our results and the reference results show high hardness, with our configuration showing slightly better performance (11.67). Highest hardness value among all samples.
- The alternating pattern promotes better stress distribution and bonding, reducing weak zones in the composite.
- Strongest and most wear-resistant material.

**(60° Orientation)→ Hardness = 9.17**

- At **60°** (our result) vs. **90°** (reference), the hardness is comparable, with **90°** yielding slightly lower values (~ 9.17). Shows the lowest hardness of the three samples.
- Likely reasons:
    - Weak bonding at the transition point between the glass and jute layers.
    - Uneven stress transfer due to non-uniform layer distribution.

**(90° Orientation) → Hardness = 9.33**

- 90° orientation provides better hardness (~ 9.33) than **0°** orientation (~10).
- Provides moderate hardness and more flexibility.

**4.3 Bending Test Result:**

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 1.5 MPa, 2 MPa, and 1.7 MPa. 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 2 MPa, 1.25 MPa, and 1.75 MPa. 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 1.25 MPa, 1.5 MPa, and 1.75 MPa. This orientation displayed weak resistance due to poor load transfer along the fiber direction, making it the least effective configuration under bending loads.




**Figure 12 : Specimen after Bending test**

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.

**Data Table of Bending Test:**

| Specimen No. | 45° Load (Mpa) | 60° Load (Mpa) | 90° Load (Mpa) |
|---|---|---|---|
| 1. | 1.5 | 2 | 1.25 |
| 2. | 2 | 1.25 | 1.5 |
| 3. | 1.7 | 1.75 | 1.75 |
| Average | 1.75 | 1.67 | 1.5 |

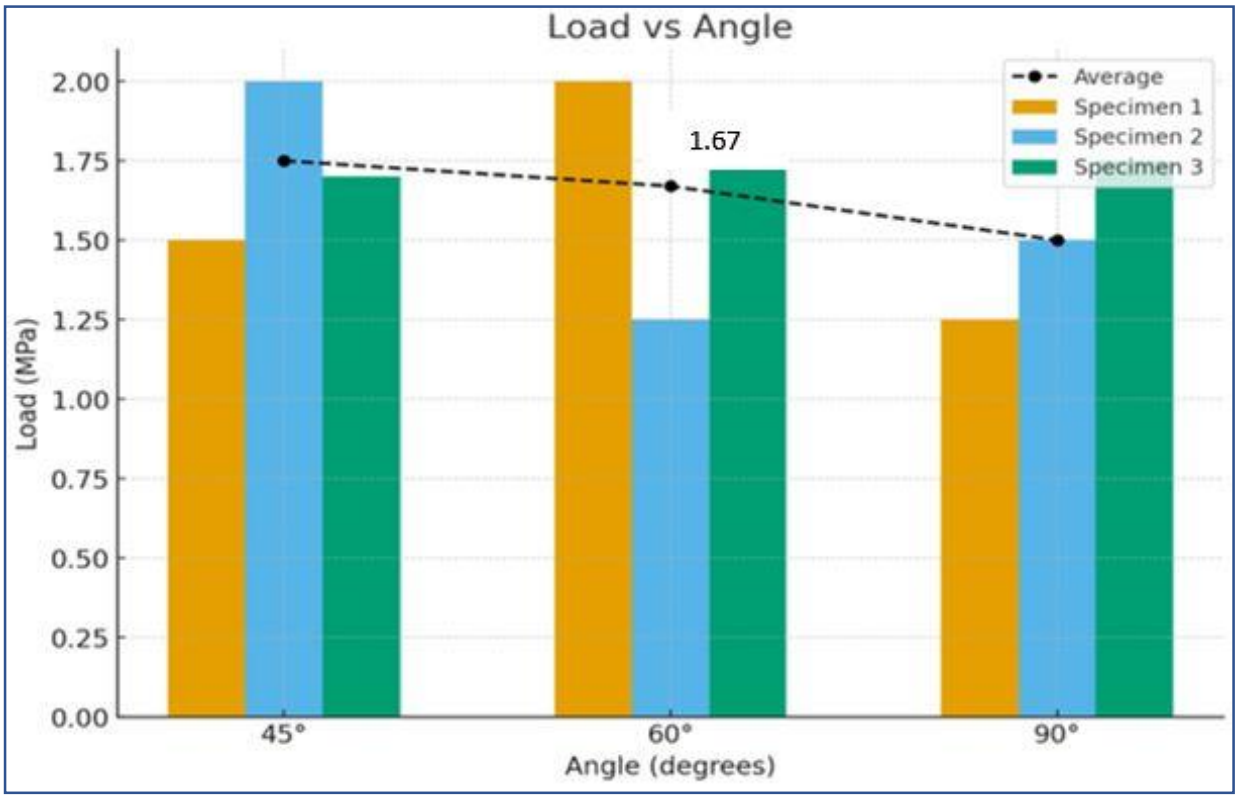



**Figure 13 : Load of Bending Strength**

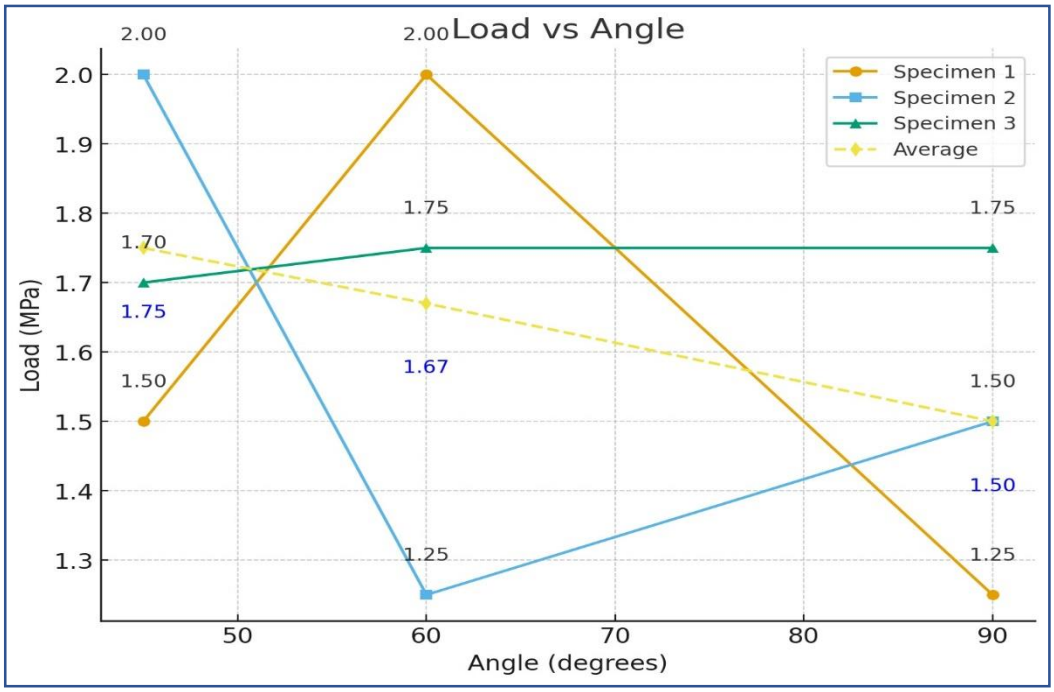



**Figure 14: Bending Strength comparison of different compositions**

- **Comparision bending test results of jute and glass fiber at different angle:**

**(45° Orientation)→ Load = 1.75 Mpa**

At **45°**, both your results and the reference results demonstrate superior impact resistance, with your results slightly better performing (1.75 vs. 1.5 Mpa). This indicates that fibers oriented at 45° to the load direction provide better resistance to shear and distribute stresses more effectively.

**(60° Orientation)→ Load = 1.67 Mpa**

**At 60°** orientation the strength slightly decreases to 1.67 MPa.

Still fairly good, but less efficient in resisting bending compared to 45°.

**(90° Orientation) → Load = 1.5 Mpa**

The lowest bending strength (1.50 MPa) is observed. Here, fibers are aligned perpendicular to the load direction. Most of the stress is carried by the weaker matrix material instead of the fibers, resulting in reduced performance.

### 4.4 Impact Test Result :

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 **3.5 ft-lb**, **3.25 ft-lb**.

• **60° Orientation:** Samples exhibited higher energy absorption, with values **of 2 ft-lb**, **1.75 ft-lb**. This orientation provided better impact resistance, likely due to optimized load transfer between fibers.

• **90° Orientation:** The samples showed varying energy absorption, with values of **1.5 ft-lb, 1.25 ft-lb.** Despite higher absorption in some cases, variability suggests potential misalignment or uneven stress distribution at this angle.



**Figure 15 : Specimen before Impact test**



**Figure 16 : Specimen after Impact test**

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.

**Data Table of Impact Test:**

| Specimen No. | 45° energy (ft.lb) | 60° energy (ft.lb) | 90° energy (ft.lb) |
|---|---|---|---|
| 1. | 3.5 | 2 | 1.5 |
| 2. | 3.25 | 1.75 | 1.25 |
| Average | 3.38 | 1.88 | 1.38 |

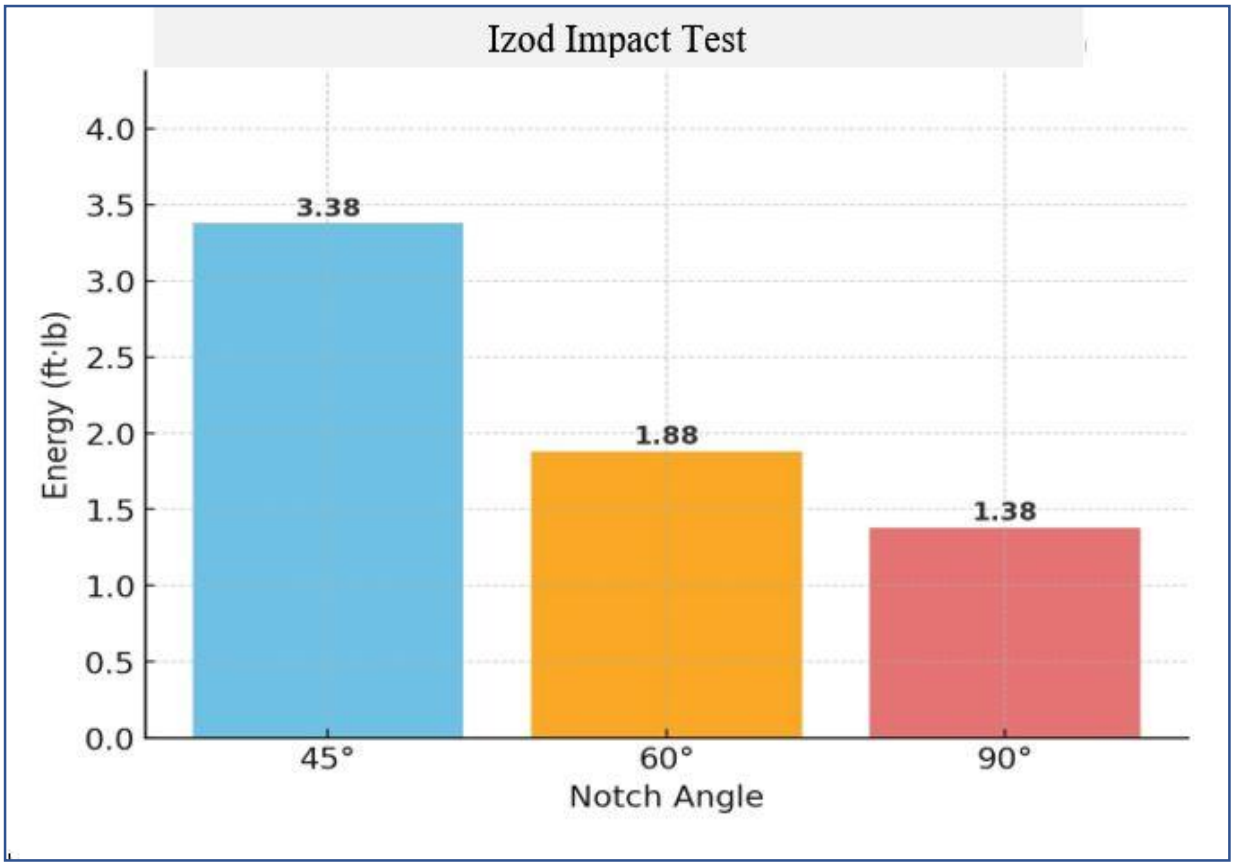



**Figure 17 : Energy of Impact Strength**

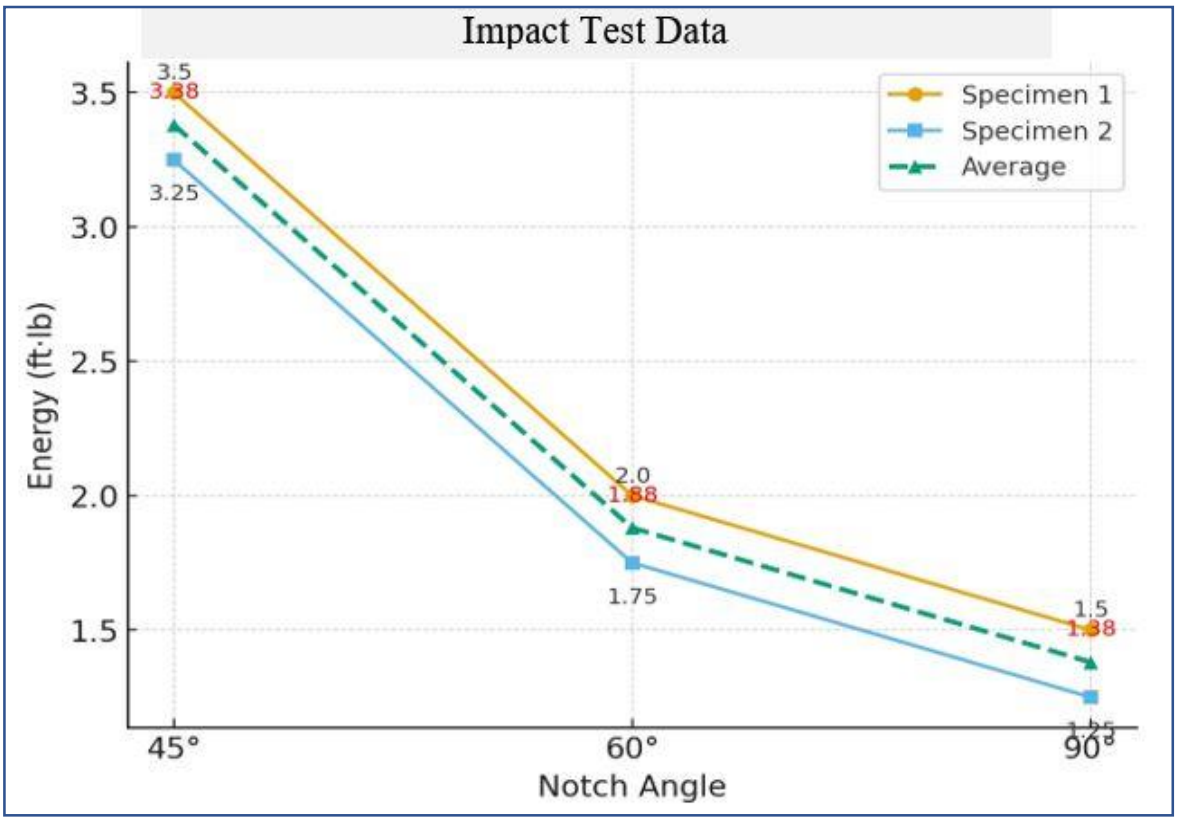



**Figure 18: Impact Strength comparison of different compositions**

- **Comparision impact test results of jute and glass fiber at different angle:**

**(45° Orientation) → energy = 3.38 ft-lb**

At **45°**, both your results and the reference results demonstrate superior impact resistance. Highest impact energy absorption (3.38 ft·lb). Fibers at 45° provide effective energy dissipation through shear and fiber–matrix interaction. This orientation allows cracks to deviate, improving toughness.

**(60° Orientation) → energy = 1.88 ft-lb**

**60°** orientation (1.88 ft-lb) performs slightly better than **0°** (2 ft-lb). Fibers are less effective in resisting impact as angle increases.

**(90° Orientation) → energy = 1.38 ft-lb**

**90°** orientation (1.38 ft-lb) is slightly lower. Fibers are perpendicular to the load, so the matrix bears most of the impact, leading to brittle failure.

### 4.5 Comparative Table: Jute–Glass Fiber Epoxy Hybrid Composite vs Industrial Materials:

| **Property** | **Composite (45°, Best Orientation)** | **Typical Industrial Materials** | **Comparative Remarks & Potential Alternatives** |
|---|---|---|---|
| Hardness (Rockwell | 10–13 HR | - **Softwood**: 5–15 HRL<br>- **Hardwood**: 20–40 HRL<br>- **Unreinforced Epoxy**: 10–20 HRL<br>-**ABS / Nylon Plastics**: 15–30 HRL<br>-**Aluminum (annealed)**: ~15 HRB (≈25–30 HRL)<br>- **Mild Steel**: 60–100 HRB | Comparable to softwood, epoxy, and low-hardness plastics**;** much lower than metals. Suitable alternative to wood-based boards and some plastic housings. |
| Impact Resistance (ft-lb) | ~3.25–3.5 ft-lb | - **Wood (pine)**: ~2–5 ft-lb<br>- **Epoxy resin**: ~1–2 ft-lb<br>- **ABS plastic**: ~3–7 ft-lb<br>- **Aluminum alloy**: ~20–30 ft-lb<br>- **Steel**: 50+ ft-lb | Comparable to wood and epoxy**,** and close to ABS plastics; far below metals. Best suited for lightweight, low-impact panels or casings**.** |
| Bending Strength (MPa) | 1.25–1.7 MPa | - **Wood (pine)**: ~40–80 MPa<br>- **Plywood**: ~30–60 MPa<br>- **Epoxy resin**: ~20–50 MPa<br>- **ABS plastic**: ~60–110 MPa<br>- **Glass fiber composites**: 200–500 MPa<br>- **Aluminum**: 150–300 MPa - **Steel**: 250–600 MPa | Much lower than wood, plastics, metals, and reinforced composites. Not suitable for structural or load-bearing parts. Could be used in non-structural covers, partitions, or panels**.** |

**Improvement avenues**: To make this composite more competitive, you might try increasing fiber volume fraction, optimizing fiber alignment, better bonding at fiber–matrix interface, perhaps adding fillers (ceramic, harder particles), or post-treatment (surface coatings, hard coatings).

- **Comparative Applications of Jute-Glass Fiber Epoxy Hybrid Composites**

| Sector | Conventional Materials | Jute-Glass Hybrid Composite (Alternative) | Advantages |
|---|---|---|---|
| **Automotive** | Steel, Aluminum, Pure Glass Fiber Composites | Interior panels, dashboards, non-load structural parts | Lightweight, cost-effective, fuel efficiency |
| **Construction** | Steel rods, Plywood, Cement boards | Wall panels, boards, partition sheets | Eco-friendly, moderate strength, reduced weight |
| **Aerospace** | Carbon/Glass Fiber Composites | Interior panels, insulation, secondary components | Weight reduction, sustainable, cheaper |
| **Marine** | Glass Fiber Laminates | Boat interior panels, flooring, covers | Good strength, water resistance, lower cost |
| **Furniture & Sports** | Wood, Plastics, Pure Synthetic Composites | Chair frames, helmets, rackets, sports boards | Lightweight, durable, eco-friendly alternative |

# CHAPTER 5: CONCLUSION

## 5.1 Conclusion

This research comprehensively examined the investigation of mechanical properties of resin composites reinforced with jute and glass fibers, emphasizing their potential as sustainable and mix of natural and synthetic materials. 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:

**Bending Test:** The **45° orientation** demonstrated the highest and most consistent bending strength among the three configurations (average: **1.75 MPa**), outperforming both the **60°** and **90°** orientations (average: **1.67 MPa** and **1.5 MPa**, 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.

**Hardness Test:** The **45° orientation** exhibited the highest hardness values among the three configurations (average: **11.67**), clearly outperforming both the **60°** and **90°** orientations (average**: 9.17** and **9.33** 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: **3.38**). It outperformed the **60°** (average: **1.88**) and **90°** (average: **1.38**) 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.

**5.2 Future Scope:**

**1. Additional Mechanical Tests**: Evaluating tensile, flexural, 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. **Manufacturing Process Efficiency**: Develop cost-effective production methods to improve market adoption.

7. **Industrial Application Testing**: Evaluate performance in sectors like automotive, construction, and sustainable packaging to assess commercial potential.

## ➢ Comparision with other journal

| Reference / Material | What They Tested (Orientation, Materials) | Key Results | Comparison to our Data | Possible Reasons for Differences |
|---|---|---|---|---|
| Influence of Fiber Orientation on Mechanical Response of Jute Fiber-Reinforced Polymer Composites. (MDPI) | Jute fiber composite; orientations compared: 0° vs 45°. Bending (flexural) strength and deformation behavior tested. (MDPI) | At 0°, the composite had a **higher maximum load / strength** than at 45°. However, 45° orientation showed more uniform deformation and delayed failure in some cases. (MDPI) | In our work, 45° gave highest bending strength among tested orientations (higher than 60° and 90°). This aligns somewhat with the idea that non-0° orientations can sometimes give better or more balanced performance, but differs in that many papers see 0° oriented fiber being best for load direction. | Differences in materials (type of fiber, matrix), fiber volume fraction, test geometry, bonding quality, whether loading is purely bending vs mixed, and possibly degree of anisotropy. Also, when load is aligned exactly with fibers (0°) in many studies, that gives maximum strength in that direction. But when bending, shear, or off-axis loads are involved, an intermediate angle (like 45°) may distribute stresses more evenly. |
| Effect of Fibre Orientation on Impact Damage Resistance of S2/FM94 Glass Fibre Composites for Aerospace Applications. (MDPI) | Glass fiber composite; tested different fiber orientations under impact. Aim: evaluate impact damage, energy absorption. (MDPI) | Showed that orientation has a strong effect on the amount of damage and energy absorbed; some orientations lead to better resistance to impact damage. (MDPI) | our data like wise shows 45° orientation having superior impact resistance (highest energy absorbed) compared to 60° and 90°. So there is good agreement with literature in that intermediate/off-axis orientations can sometimes help in impact loading. | Again, differences like fiber type (glass vs whatever you used), thickness, specimen dimensions, impact energy level, how "impact resistance" is measured (from damage area, cracking, or energy absorption) will affect the numerical values. Also, in some composites, 0° or near 0° might outperform in impact if the impact is aligned with fiber direction; you need to check whether your test was aligned or off-axis. |

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