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Design, Fabrication and Mechanical Evaluation of Coconut Coir–Glass Fiber

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Abstract: *This study develops and evaluates a hybrid composite composed of coconut coir and E-glass fiber embedded in an epoxy matrix for potential automotive and structural applications. Specimens were fabricated using hand lay-up and compression moulding techniques, followed by mechanical characterization under ASTM standards. Tests included tensile strength (ASTM D638), water absorption (ASTM D570), delamination during drilling, and pin-on-disc wear analysis. Results indicate that hybridization significantly improves tensile strength, reduces wear rate, and lowers water uptake compared to pure natural-fiber composites, while maintaining cost efficiency and sustainability. The synergy between coconut coir and glass fiber enhances strength, stiffness, and durability, making the hybrid composite a promising candidate for lightweight, eco-friendly engineering components.*

Keywords: Hybrid composite; coconut coir; glass fibre; epoxy; tensile strength; delamination; wear

I. INTRODUCTION

Hybrid composite materials have emerged as a promising class of engineered systems designed to combine the advantages of natural and synthetic fibers within a single polymer matrix. By integrating reinforcements such as coconut coir with E-glass fiber, these composites achieve a balance of mechanical strength, thermal stability, durability, and environmental sustainability that cannot be obtained from a single fiber type alone.

Natural fibers are lightweight, biodegradable, renewable, and cost-effective, but they often suffer from limitations such as high moisture absorption, reduced mechanical strength, and poor thermal resistance. In contrast, synthetic fibers such as glass fiber offer high tensile strength, stiffness, and durability, but they are expensive, non-biodegradable, and energy-intensive to produce. Hybridization of these two categories provides a synergistic effect: the shortcomings of natural fibers are compensated by the superior properties of synthetic fibers, while simultaneously reducing cost, density, and environmental impact compared to pure synthetic composites.

The growing demand for sustainable engineering solutions in automotive, aerospace, and construction industries has accelerated research into hybrid composites. These materials not only contribute to weight reduction and fuel efficiency but also align with global sustainability goals by reducing reliance on petroleum-based products. Furthermore, the ratio, orientation, and stacking sequence of natural and synthetic fibers can be tailored to achieve specific performance requirements, offering design flexibility for diverse applications.

In this study, coconut coir and E-glass fiber were selected as reinforcements in an epoxy matrix to fabricate hybrid composites using hand lay-up and compression moulding techniques. The mechanical properties were evaluated through tensile, wear, water absorption, and delamination tests under ASTM standards. The objective is to investigate the performance of these hybrid composites and assess their suitability for eco-friendly automotive and structural applications.

II. PROBLEM STATEMENT

The increasing demand for lightweight, durable, and sustainable materials in engineering applications has highlighted the limitations of using natural or synthetic fibers alone. Natural fibers such as coconut coir are biodegradable,

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renewable, and cost-effective, but they suffer from low mechanical strength, high moisture absorption, and poor thermal resistance. Conversely, synthetic fibers like E-glass provide excellent tensile strength, stiffness, and durability, yet they are expensive, non-biodegradable, and energy-intensive to manufacture.

This disparity creates a challenge in designing materials that simultaneously meet performance, cost, and sustainability requirements. Conventional composites based solely on synthetic fibers contribute to environmental concerns, while natural fiber composites often fail to achieve the mechanical reliability needed for industrial applications.

Hybridization offers a potential solution by combining natural and synthetic fibers within an epoxy matrix to balance their respective strengths and weaknesses. However, the optimal fiber ratio, stacking sequence, and fabrication method must be identified to achieve improved wear resistance, tensile strength, and dimensional stability. Addressing this problem is critical for developing eco-friendly composites suitable for automotive, aerospace, and structural applications, where both performance and sustainability are equally important.

III. OBJECTIVE & ANALYSIS

To develop high performance hybrid composites

This objective focuses on combining natural and synthetic fibers to achieve superior mechanical properties. The hybrid structure enhances strength, stiffness, and durability. It overcomes the limitations of using a single type of reinforcement. The result is a more reliable and efficient material for engineering use**.**

To promote sustainable product development

The project aims to reduce environmental impact by incorporating biodegradable natural fibers. This decreases reliance on non-renewable synthetic materials. It also helps lower carbon emissions and energy consumption. The goal is to support eco-friendly engineering solutions.

To study the effect of fiber hydridization

This involves understanding how different fibers interact within the composite. Natural fibers improve flexibility and damping, while synthetic fibers add strength. Their combination creates a balanced set of properties. This helps in designing materials for specific applications.

To optimize fiber ratio and stacking sequence

The arrangement and proportion of fibers significantly affect composite performance. This objective focuses on identifying the best configuration. Proper stacking improves load distribution and reduces failure. It also enhances overall efficiency and durability.

To reduce overall material cost

Natural fibers are generally cheaper than synthetic ones. By partially replacing synthetic fibers, the total cost can be reduced. This makes hybrid composites more economically viable. It also increases their industrial acceptance.

To improve interfacial bonding

Strong bonding between fibers and matrix is essential for load transfer. This objective studies methods to enhance adhesion. Better bonding results in improved strength and reduced material failure. It ensures long-term reliability of the composite.

Mechanical property analysis

The composite is tested under tensile, compressive, and flexural loads. These tests determine its strength and deformation behaviour. The results help compare hybrid composites with traditional materials. It identifies improvements achieved through hybridization.

Impact and fatigue analysis

The material is evaluated for its ability to withstand repeated and sudden loads. This is important for real-world applications like automotive parts. Hybrid composites often show better energy absorption. The analysis ensures durability under cyclic loading.

Thermal analysis

The composite is tested for heat resistance and thermal stability. Synthetic fibers improve high-temperature performance. Natural fibers may degrade at elevated temperatures. This study helps determine safe operating conditions.

Moisture and environmental analysis

Natural fibers tend to absorb moisture, which can affect performance. This analysis evaluates water absorption and resistance to environmental factors. It helps in understanding long-term durability. Preventive measures can also be suggested.

Microstructural analysis

The internal structure of the composite is examined using microscopic techniques. This helps identify fiber distribution and bonding quality. Defects such as voids or cracks can also be detected. It ensures proper fabrication and quality control.

Comparative performance analysis

Hybrid composites are compared with single-fiber and conventional materials. Parameters like strength, weight, and durability are evaluated. This highlights the advantages of hybridization. It supports material selection for applications.

Cost benefit analysis

This analysis compares production cost with performance gains. It evaluates whether the hybrid composite is economically feasible. Reduced cost with acceptable performance is a key goal. It helps industries adopt the material**.**

Application based analysis

The suitability of composites is tested for specific industries. These include automotive, aerospace, and construction sectors. Performance requirements vary across applications. This analysis ensures proper material selection for each use case.

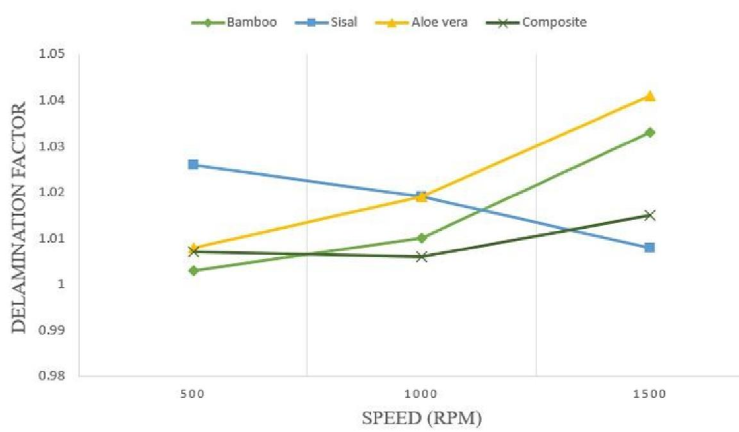

Figure 1. Delamination at entry for 3 mm drill

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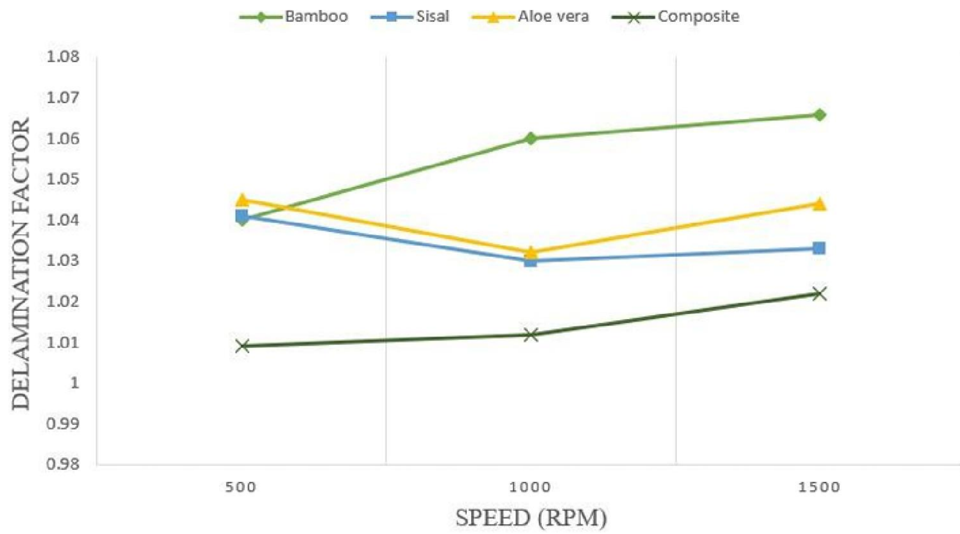

Figure 2. Delamination at exit for 3 mm drill

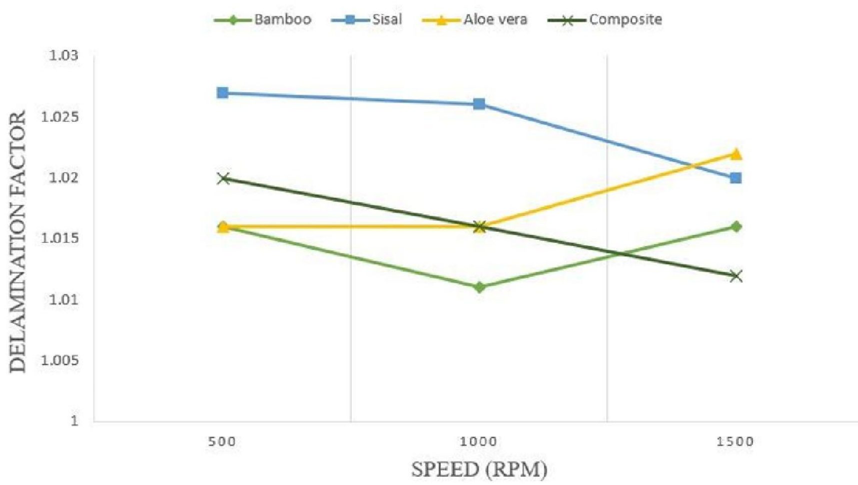

Figure 3. Delamination at entry for 6 mm drill

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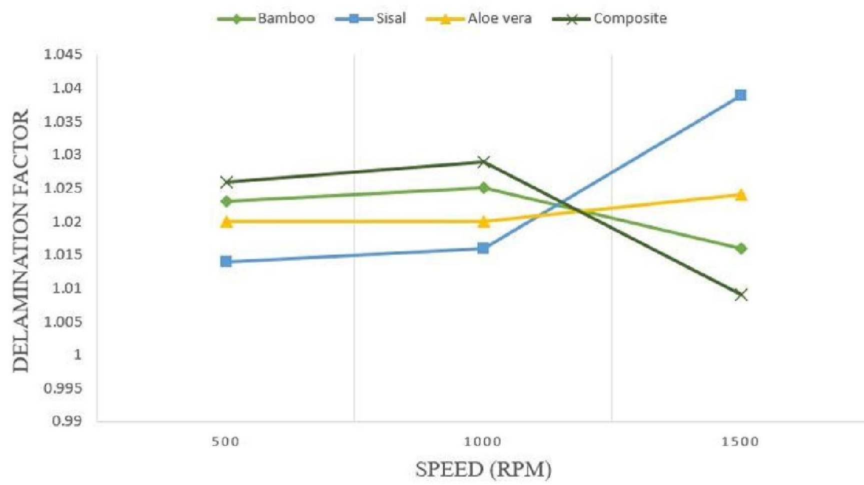

Figure 4. Delamination at exit for 6 mm drill

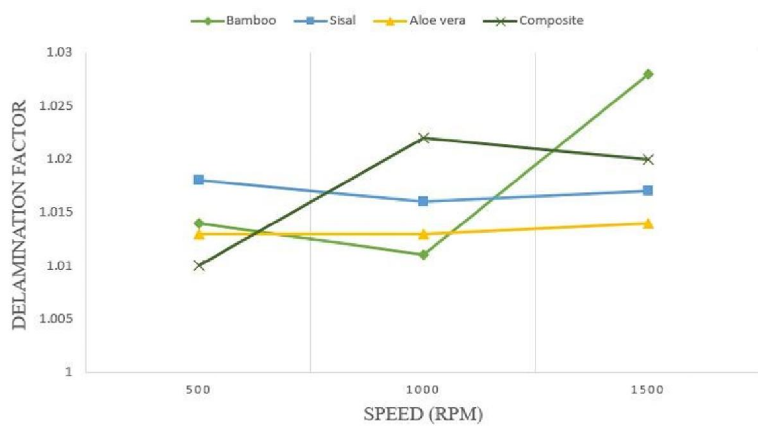

Figure 5. Delamination at entry for 9 mm drill

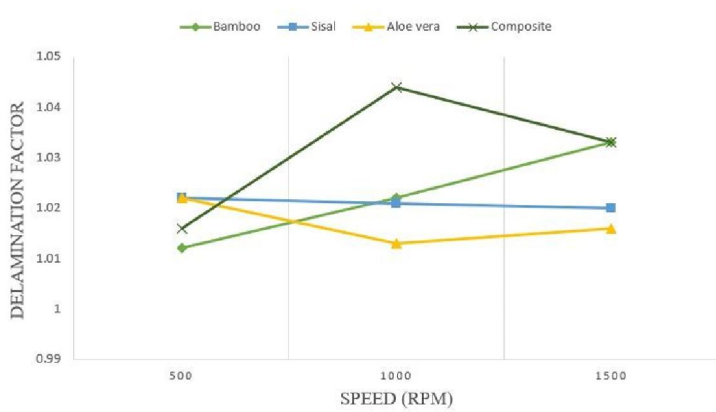

Figure 5. Delamination at exit for 9 mm drill

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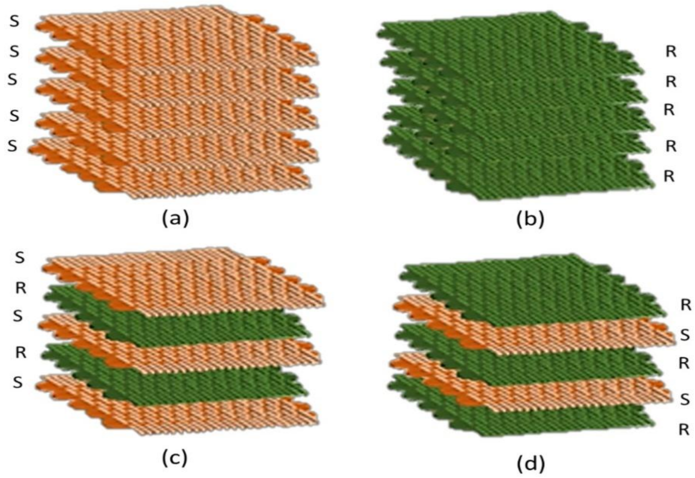

Figure 1. Types of layers in a composite

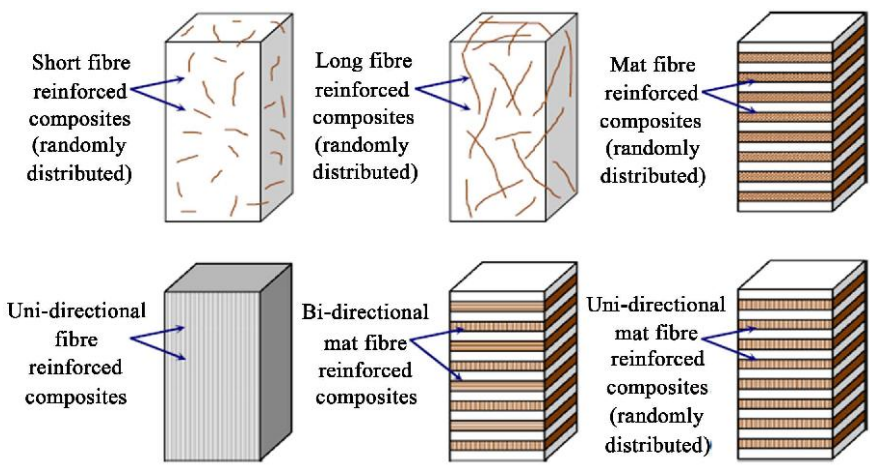

Figure 2. Different type of fiber orientation used for the laminate manufacturing.

Figure 2. Different types of fibers orientation used for the laminate manufacturing.

IV. CONCLUSION

The experimental study on coconut coir–glass fiber reinforced epoxy hybrid composites demonstrates the potential of hybridization in achieving a balance between mechanical performance, cost efficiency, and sustainability. Fabrication using hand lay-up and compression moulding techniques produced specimens with improved tensile strength, wear resistance, and dimensional stability compared to pure natural fiber composites. The inclusion of E-glass fiber compensated for the lower strength and moisture sensitivity of coconut coir, while the natural fiber contributed to weight reduction, energy absorption, and eco-friendliness.

Testing under ASTM standards confirmed that the hybrid composites exhibit adequate hardness, stable frictional behaviour, and reduced water absorption, making them suitable for automotive braking components and other engineering applications where durability and sustainability are critical. Microscopic analysis further validated strong fibre–matrix bonding and reduced porosity, ensuring long-term reliability.

Overall, the study highlights that coconut coir–glass fiber epoxy hybrid composites can serve as a viable alternative to conventional synthetic composites, offering both environmental and economic advantages. Future work may focus on optimizing fiber ratios, enhancing interfacial bonding through chemical treatments, and evaluating long-term durability under real-world operating conditions.

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