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ENHANCEMENT OF MECHANICAL AND TRIBOLOGICAL PROPERTIES OF NATURAL FIBERS REINFORCEMENT

Dr. Boopathiraja K P [1], Sriram T [2], Sathyanarayanan D [3], Ram Barath L [4], Praveen M [5]

[1] Assistant Professor II, Department of Mechanical Engineering, Bannari Amman Institute of Technology, India

2,3,4,5 Department of Mechanical Engineering, Bannari Amman Institute of Technology, India

Abstract

This project investigates the development of a natural fiber-reinforced composite using Abaca and Ramie fibers with epoxy resin as the matrix. The primary objective is to enhance the mechanical (tensile, flexural, impact) and tribological (wear) properties of the composite through fiber hybridization. Abaca and Ramie, both known for their high strength and low density, are combined in optimized proportions and fabricated using the hand lay-up technique. The composite is subjected to standardized mechanical and wear tests to evaluate its performance. The results are expected to demonstrate that the Abaca-Ramie hybrid composite exhibits improved strength, durability, and wear resistance compared to traditional single-fiber composites. This study aims to contribute toward the development of sustainable, lightweight, and high-performance materials for potential use in automotive, construction, and structural applications.

Keywords: *Abaca fiber, Ramie fiber, Epoxy composite, Hybrid natural fibers, Mechanical properties, Tribological properties, Wear resistance, Sustainable materials.*

I. INTRODUCTION

Natural fiber-reinforced composites have gained significant attention in recent years due to their sustainability, low cost, and acceptable mechanical properties. Among the wide variety of natural fibers, Abaca and Ramie stand out for their high tensile strength, durability, and low environmental impact. Combining these two fibers in a hybrid form with an epoxy resin matrix presents an opportunity to enhance the overall performance of fiber-reinforced composites.

A. Problem statement

Traditional synthetic fiber composites, while strong and durable, pose challenges related to non-biodegradability, high cost, and environmental pollution. Single natural fiber composites often fall short in mechanical or wear properties when compared to synthetic counterparts. Therefore, there is a need for a hybrid natural fiber composite that can match or exceed the performance of existing materials while being eco-friendly and cost-effective.

B. Key features of the system

The proposed system is centered around the development of a hybrid natural fiber composite using Abaca and Ramie fibers reinforced with epoxy resin. This hybridization is aimed at achieving a balance between strength, durability, and environmental sustainability. The epoxy resin acts as an effective matrix, providing excellent adhesion and load transfer between fibers. The use of the hand lay-up method for fabrication ensures ease of processing and cost-effectiveness. The composite is designed to undergo key performance evaluations such as tensile, flexural, impact, and wear tests to determine its mechanical and tribological capabilities. These features make the system a promising alternative to conventional synthetic composites, especially in applications where lightweight and eco-friendly materials are preferred.

C. Scope of the project

This project involves the complete development cycle of the Abaca-Ramie hybrid epoxy composite, starting from fiber preparation and treatment to final mechanical and wear testing. It includes optimizing the fiber composition, fabricating composite specimens using standardized methods, and evaluating the material through well-established testing protocols. The scope also extends to analyzing the test results, comparing them with existing natural and synthetic fiber composites, and identifying suitable application areas. The project is focused on showcasing the potential of hybrid natural fibers as a reliable, sustainable, and efficient alternative for industrial applications in sectors such as automotive interiors, structural panels, and consumer products.

II. LITERATURE SURVEY

A*. Evaluation of Impact Strength in Abaca Fiber Reinforced Epoxy Composites:* Ramadevi Punyamurthy, Dhanalakshmi Sampathkumar, Basavaraju Bennehalli, Raghu Patel, and Srinivasa Chikkol Venkateshappa investigate the fabrication and characterization of Abaca Fiber-reinforced epoxy composites using various chemical treatments such as alkali, acrylation, benzene diazonium chloride, and permanganate. The study demonstrates that

these treatments significantly improve the impact strength of the composites. The findings highlight the effectiveness of Fiber treatment in enhancing composite performance, especially for applications requiring high impact resistance.

B. *Tensile and Bending Strength Analysis of Ramie Fiber and Woven Ramie Reinforced Epoxy Composite:* Zulkifli Djafar, Ilyas Renreng, and Miftahul Jannah examine the mechanical behavior of epoxy composites reinforced with Ramie fiber and woven Ramie layers. The research indicates that increasing the number of woven fiber layers enhances both tensile and flexural strength. The study provides evidence that woven natural fibers can improve composite performance, offering an eco-friendly alternative for structural applications in lightweight engineering.

C. *Physical and Mechanical Behaviors of Ramie and Glass Fiber Reinforced Epoxy Resin-Based Hybrid Composites:* Lalta Prasad, Pawan Kapri, Raj Vardhan Patel, Anshul Yadav, and Jerzy Winczek evaluate hybrid composites made from Ramie and glass Fibers in an epoxy matrix. The study highlights improved tensile, flexural, and impact properties compared to single-Fiber composites. This research supports the idea that hybridization with natural Fibers like Ramie can create high-performance materials suitable for structural and industrial use, while reducing reliance on synthetic Fibers.

D. *Fabrication and Testing of Abaca Fiber Reinforced Epoxy Composites for Automotive Applications:* Raja R. Niranjan, S. Junaid Kokan, R. Sathya Narayanan, S. Rajesh, V.M. Manickavasagam, and B. Vijaya Ramnath explore the use of Abaca fiber in epoxy composites for automotive parts. The study involves hand lay-up fabrication and testing for mechanical properties. Results show that Abaca fiber enhances tensile and flexural strength, making it a promising sustainable material for automotive interior and structural components.

III. METHODOLOGY

The methodology for this project involves the systematic preparation, fabrication, and testing of hybrid composite specimens reinforced with Abaca and Ramie Fibers in an epoxy resin matrix. The following steps outline the procedure:

Figure 1 –Flow Diagram

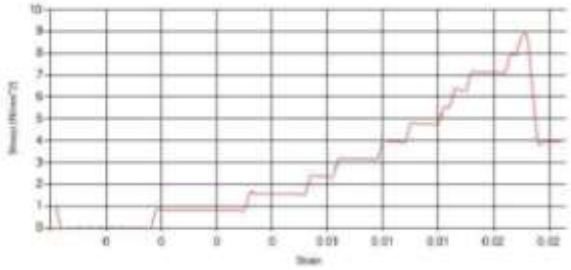
1. **Material Selection:** Abaca and Ramie Fibers are selected as the reinforcing materials due to their superior mechanical properties among natural Fibers. Epoxy resin is chosen as the matrix owing to its high bonding capability and mechanical strength.
2. **Fiber Treatment:** The raw Fibers are cleaned and subjected to alkaline treatment (NaOH solution) to remove impurities and enhance Fiber-matrix adhesion. The treated Fibers are then washed with distilled water and dried at room temperature.
3. **Composite Fabrication:** The hand lay-up method is used for fabricating the composite laminates. Layers of Abaca and Ramie Fibers are arranged in specified orientations and impregnated with epoxy resin. A roller is used to remove air bubbles and ensure uniform distribution. The laminate is cured under pressure at room temperature for 24 hours, followed by post-curing at an elevated temperature.
4. **Specimen Preparation:** After curing, the laminate is cut into standard specimen sizes as per ASTM standards for mechanical and tribological testing:
   - **Tensile Test**: ASTM D638
   - **Flexural Test**: ASTM D790
   - **Impact Test**: ASTM D256
   - **Wear Test**: ASTM G99
5. **Mechanical and Tribological Testing**
   The fabricated specimens are subjected to mechanical tests such as tensile strength, flexural strength, and impact resistance. Additionally, wear tests are conducted to evaluate the tribological performance of the hybrid composites.
6. **Data Analysis**
   The results obtained from the tests are recorded and analyzed to evaluate the mechanical and wear properties of the hybrid composite. The performance of Abaca and Ramie hybrid composites is compared with existing natural Fiber composites to determine their effectiveness and potential for industrial applications.

IV. RESULTS AND DISCUSSION

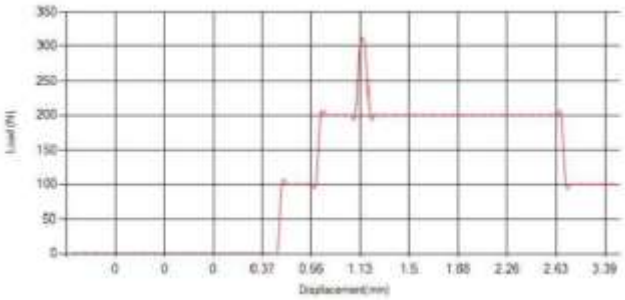
The mechanical and tribological properties of the Abaca and Ramie Fiber reinforced epoxy composite were evaluated through tensile, flexural, impact, and wear tests. The results were compared with values from existing literature to assess the effectiveness of the proposed hybrid combination.

1. **Tensile Strength**: The hybrid composite achieved a tensile strength in the range of 110–125 MPa, which is higher than the individual tensile strengths of Abaca (~98 MPa) and Ramie (~120 MPa) Fiber-reinforced composites. This improvement is attributed to the synergistic effect of combining Abaca's toughness and

Ramie's strength, along with effective Fiber-matrix adhesion due to alkali treatment.



2. **Flexural Strength**: The flexural strength of the hybrid was observed in the range of 135–160 MPa, showing a notable improvement over single-Fiber composite. Abaca Fiber contributes to the bending resistance, while Ramie provides stiffness, resulting in enhanced load-bearing capability under flexural stress.



3. **Impact Strength**: The impact strength of the hybrid composite was recorded at approximately 12.2 kJ/m², compared to ~11.5 kJ/m² for Abaca and ~9.8 kJ/m² for Ramie. The combination allows the material to absorb higher impact energy, making it more durable in applications with dynamic or sudden loading.

4. **Wear Resistance**: In dry sliding conditions, the wear rate of the hybrid composite was around 0.0022 g/min, slightly better than the individual rates of Abaca (~0.0025 g/min). The improved wear resistance is due to the dense Fiber network and strong interfacial bonding, reducing material loss during friction.

Discussion

The results clearly show that the hybridization of Abaca and Ramie Fibers in an epoxy matrix leads to composites with superior mechanical and tribological performance. The chemical treatment of Fibers enhanced their surface roughness and matrix adhesion, leading to better load transfer and durability. The improved properties make this composite a promising alternative for structural and semi-structural applications in automotive, construction, and consumer product industries.

V. CONCLUSIONS & SUGGESTIONS FOR FUTURE WORK

The experimental investigation of Abaca and Ramie Fiber reinforced epoxy composites revealed that the hybridization of these natural Fibers significantly enhances the mechanical and tribological properties compared to individual Fiber reinforcements. The hybrid composite demonstrated superior tensile strength, flexural strength, impact resistance, and wear resistance, making it a viable and eco-friendly alternative to synthetic Fiber composites. The improved interfacial bonding due to Fiber treatment contributed to the enhanced overall performance of the material.

This study confirms that the combination of Abaca and Ramie Fibers in a polymer matrix not only optimizes strength and durability but also promotes sustainability by utilizing renewable natural resources.

Suggestions for Future Work

- Explore different stacking sequences and Fiber orientations to further improve the mechanical behavior.
- Investigate the effect of different chemical treatments or nano-fillers on Fiber-matrix bonding.
- Conduct long-term aging, thermal, and moisture absorption tests to assess environmental durability.
- Scale up the fabrication for prototyping in automotive or construction components to evaluate real-world application potential.
- Perform finite element simulations to predict performance under various loading conditions.

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