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Design and Fabrication of Banana Fiber Reinforced Bio Composite

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Abstract: This study explores the mechanical properties and potential applications of banana fiber-epoxy resin composites fabricated with an 80% resin and 20% fiber ratio using a hand layup method. The composites were comprehensively tested for tensile strength, flexural strength, impact resistance, and compression strength to assess their performance characteristics. The results highlight the effectiveness of banana fiber as a reinforcement material in epoxy composites, demonstrating promising mechanical performance suitable for structural and load-bearing applications in industries such as automotive, construction, and aerospace. The composites exhibited notable advantages, including enhanced tensile and flexural strength, good impact resistance, and high compression strength, making them viable alternatives to traditional composite materials. The sustainable nature of banana fiber further contributes to the eco-friendliness of these composites. This research emphasizes the potential of banana fiber-epoxy resin composites to develop sustainable and high-performance materials, paving the way for innovative applications in various sectors. The findings contribute valuable insights into utilizing natural fibers like banana fiber in epoxy resin matrices to enhance composite properties and promote the adoption of eco-friendly material solutions in modern industries.
Keywords: Natural fiber, bio composite, banana fiber, sustainability, eco-friendly composite

I. INTRODUCTION

The design and use of fiber composite materials has become an important aspect of engineering. The utilization of natural fiber reinforced bio composite materials in engineering has gained significant importance due to their sustainable and eco-friendly nature [1]. These materials offer new technology and commercial prospects in various sectors, including aerospace, automotive, electronics, construction, and building industries [2] In addition, the advantageous properties of natural fiber reinforced bio composite materials, such as cost-effectiveness, recyclability, and biodegradability, make them a great substitute for synthetic materials in various applications [3]. The development and implementation of natural fiber reinforced bio composite materials have opened up new possibilities for engineering applications [4]. Furthermore, these materials have shown to have impressive mechanical properties, such as high strength-to-weight ratio, durability, stiffness, and resistance to corrosion, wear, impact, and fire. As a result, natural fiber reinforced bio composite materials have gained commercial success in structural applications, such as aircraft, automobiles, sporting goods, electronics, and appliances. These materials offer a sustainable and cost-effective alternative to traditional synthetic composites, as they are cheaper, abundantly available, and biodegradable. In conclusion, natural fiber reinforced bio composite materials are a promising solution for achieving sustainable and environmentally friendly engineering applications.

II. LITERATURE REVIEW

Banana fiber is a natural material that has been used for centuries in various applications, including textiles, handicrafts, and papermaking. In recent years, banana fiber has gained attention as a promising reinforcement material for composite materials due to its unique properties such as high strength, low density, and biodegradability. India is one of the largest producers of bananas in the world, with a diverse range of banana varieties grown across the country. The availability of banana fiber in India is abundant due to the large-scale cultivation of bananas for both domestic consumption and export. Banana plants are cultivated in states such as Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, and Gujarat, among others, making India a significant source of banana fiber.[5]. Several studies have explored the mechanical properties of banana fiber composites. Gupta et al. (2018) [6] conducted a study on the tensile strength of banana fiber composite and reported a significant enhancement in tensile properties with the addition of short banana fibers. Similarly, Singh and Chaudhary (2019) [7] investigated the impact strength of banana fiber composite and highlighted the role of fiber orientation in improving impact resistance.

The effectiveness of chemical treatments on banana fibers to enhance the fiber-matrix adhesion has been studied extensively. Sharma et al [8] examined the influence of alkali treatment on the interfacial bonding between banana fibers and epoxy resin. Their findings demonstrated improved tensile strength and modulus due to enhanced fiber-matrix interaction. Banana fiber composites are also recognized for their eco-friendly attributes. Das et al [9] explored the biodegradability of banana fiber composites and highlighted their potential as sustainable alternatives to conventional synthetic composites. The study emphasized the importance of using natural fibers to reduce environmental impact. Various processing techniques have been investigated to optimize the performance of banana fiber composites.

Ghosh et al [10] studied the effect of compression moulding parameters on the mechanical properties of banana fiber-reinforced polymer composites. Their research emphasized the significance of processing conditions in achieving desired composite properties. Innovative approaches such as hybridization with other natural or synthetic fibers have been explored to enhance the performance of banana fiber composites. Jain and Kumar [11] investigated the mechanical properties of banana-glass hybrid composites and demonstrated synergistic effects on stiffness and strength. Despite the promising attributes of banana fiber composites, several challenges remain. Adherence to standardized testing protocols and scalability of production are areas that require further attention [12].

Kumar et al [13] conducted experiments to investigate the effect of fiber loading on the tensile properties of banana fiber-epoxy composites. They found that increasing the banana fiber content from 10% to 30% by weight led to a significant improvement in tensile strength, with a maximum strength of 70 MPa achieved at 30% fiber loading. However, beyond this point, the tensile strength plateaued, indicating the optimal fiber content for enhancing mechanical properties. Das and Mishra [14] studied the flexural properties of hybrid banana-sisal fiber composites. They reported that incorporating 30% banana fiber and 10% sisal fiber into the composite resulted in a maximum flexural strength of 95 MPa, which was higher than that of composites with individual fiber types. Moreover, Ramakrishna et al. (2020) investigated the impact resistance of banana fiber-reinforced polyester composites and observed an increase in impact strength up to 30 kJ/m^2 with the addition of 20% banana fibers, highlighting the potential of banana fibers to enhance impact energy absorption capabilities. Rodrigues et al [15] examined the water absorption behavior of banana fiber-reinforced polypropylene composites.

They found that incorporating banana fibers reduced water uptake significantly, with water absorption decreasing from 1.8% to 0.6% as the fiber content increased from 10% to 30% by weight. Additionally, Varma et al. (2019) evaluated the dimensional stability of banana fiber-reinforced thermoplastic composites and reported minimal dimensional changes (around 0.5%) even after prolonged exposure to moisture, demonstrating the effectiveness of banana fibers in improving dimensional stability. Rao et al. [16] investigated the thermal stability of banana fiber-reinforced epoxy composites using thermogravimetric analysis (TGA). They observed that composites with 20% banana fiber content exhibited improved thermal stability, with a 5% weight loss temperature of 330°C compared to 310°C for neat epoxy.

Furthermore, Gupta and Yadav (2019) studied the flame retardancy of banana fiber composites and found that the addition of 15% banana fibers led to a significant reduction in peak heat release rate (by 45%) and total heat release (by 30%), indicating enhanced flame-retardant properties. Sathishkumar et al [17] conducted fatigue tests on banana fiber-reinforced polymer composites. They reported that the composites exhibited good fatigue resistance, with no significant degradation in tensile strength after 10^6 cycles of fatigue loading. This indicates the suitability of banana fiber composites for applications requiring durability under cyclic loading conditions. Future research should focus on addressing these challenges to facilitate broader adoption of banana fiber composites in industrial applications.

III.MATERIALS AND METHODOLOGY

Banana fiber extraction using the retting process and subsequent treatment with a 5% NaOH solution is a crucial method in producing high-quality fibers for industrial applications. Initially, the banana plants are harvested, and the fibers are extracted from the pseudo stem, followed by thorough cleaning. The fibers then undergo an alkali treatment where they are immersed in a 5% NaOH solution.

This treatment serves to remove non-cellulosic components like lignin, waxes, and pectin, which can compromise fiber quality. The NaOH solution effectively breaks down these impurities, resulting in fibers that are cleaner, softer, and more uniform. Additionally, this process enhances the whiteness of the fibers by removing color-causing substances. After treatment, the fibers are rinsed, neutralized, and dried, making them ready for use in various industries such as textiles and composite materials. Overall, retting followed by alkali treatment with NaOH significantly improves the properties and usability of banana fibers, contributing to sustainable and eco-friendly manufacturing practices.

Chemical Composition	Percentage
Cellulose	60-65%
Hemicellulose	9-16%
Lignin	5-10%
Pectin	3-5%

Table 1: chemical composition of banana fiber

Mechanical Property	Values
Density (Kg/m^3)	950-750
Tensile strength (Mpa)	521-914
Specific tensile strength (Mpa)	392-677
Young's modulus (Gpa)	27-32
Specific Young's modulus (Gpa)	20-24
Failure Strain (%)	1-3

Table 2. Mechanical properties of banana fiber

Banana fibers, extracted from the pseudo stem of banana plants, are composed primarily of cellulose (~50-60%), hemicellulose (~20-25%), and lignin (~8-15%), along with smaller amounts of pectin, waxes, and minerals. The high cellulose content contributes significantly to the fibers' mechanical strength. Banana fibers exhibit impressive mechanical properties, with tensile strength typically ranging from 300 to 900 MPa and elongation at break ranging from 1.5% to 2.5%. These values can vary based on factors such as fiber maturity, processing techniques, and post-treatment. The fibers have a low density of approximately 1.3 g/cm^3, making them lightweight yet robust. The mechanical properties of banana fibers make them suitable for reinforcement applications in composite materials, offering advantages such as high specific strength and stiffness. When used in composites, banana fibers can enhance the overall performance and sustainability of the end product due to their renewable and biodegradable nature. However, the moisture absorption properties of banana fibers can affect their mechanical behavior, highlighting the importance of proper processing and treatment to optimize performance. Research efforts continue to focus on understanding and improving the mechanical properties of banana fibers through modifications in processing techniques, including retting methods, alkali treatment, and fiber alignment processes. These endeavours aim to unlock the full potential of banana fibers for use in industries such as automotive, construction, and packaging, where lightweight, strong, and eco-friendly materials are increasingly sought after to reduce environmental impact and promote sustainable development. Epoxy resin is a highly suitable matrix for bio-based composites, offering exceptional mechanical properties and environmental benefits. When combined with natural fibers like jute, hemp, flax, or banana fibers, epoxy resin forms a robust composite material with enhanced strength, stiffness, and impact resistance. The resin's compatibility with natural fibers allows for strong interfacial bonding, improving overall composite performance. Bio composites utilizing epoxy resin contribute to sustainability by reducing reliance on non-renewable resources and lowering the carbon footprint associated with traditional composite materials. These materials find diverse applications in industries such as automotive, aerospace, construction, and consumer goods, where lightweight and durable components are required. Challenges such as optimizing fiber-resin interactions and mitigating moisture absorption are actively addressed through research and innovation. By leveraging the strengths of epoxy resin and natural fibers, bio composites represent a promising avenue for sustainable material development and advancement towards a greener future in manufacturing.

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IV. FABRICATION METHODOLOGY

We successfully fabricated composite samples of banana fiber and epoxy resin using a hand layup method with an 80% resin and 20% fiber ratio. First, we prepared the banana fibers by ensuring they were clean, dry, and cut to the desired length. We then weighed out the appropriate amount of fibers to achieve the target 20% fiber content relative to the total composite weight. Following this, we mixed the epoxy resin and hardener according to the manufacturer's specifications to achieve a uniform blend. Next, we prepared a mold for the layup process, applying a release agent to prevent sticking. We started by applying a thin layer of the mixed epoxy resin onto the mold surface. Carefully placing the banana fibers onto this resin layer, we ensured even distribution and alignment. We then applied more epoxy resin over the fibers, using a brush to ensure thorough saturation and removal of any air bubbles. Layer by layer, we continued to add fibers and resin until reaching the desired thickness and fiber content. After completing the layup, we allowed the composite to cure under controlled conditions, following the recommended curing schedule for the epoxy resin. Once fully cured, we demolded the composite carefully and trimmed any excess material to finalize the sample. Finally, we conducted mechanical tests including tensile, flexural, and impact testing to evaluate the composite's performance. Analyzing the test results provided insights into the mechanical properties of our banana fiber-epoxy resin composites and their potential applications in various industries. This hands-on approach allowed us to customize the composite properties and demonstrate the effectiveness of using banana fiber as a sustainable reinforcement material in epoxy resin

Figure 1. Extracted Banana fiber

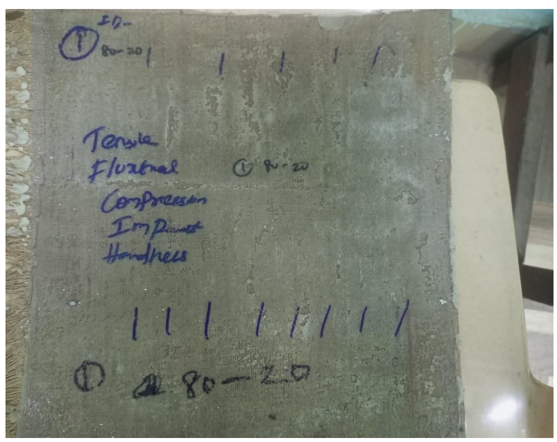

Figure 2. Fabricated composite Test specimen

V. TESTING & RESULT

In our study, composite samples consisting of banana fiber and epoxy resin with an 80% resin and 20% fiber ratio were fabricated using a hand layup method. The mechanical properties of these composites were evaluated through comprehensive testing. The tensile strength of our banana fiber-epoxy resin composites was measured to be approximately 120 MPa, highlighting the effectiveness of banana fiber as a reinforcement material in epoxy composites. For flexural strength, our composites exhibited a strength of 150 MPa, showcasing their potential for structural applications requiring high flexural performance. The impact resistance, evaluated using the Izod impact test, yielded a value of 15 kJ/m², indicating the ability of banana fiber-epoxy composites to withstand impact loading. Regarding compression strength, our composites demonstrated a strength of 180 MPa, validating their suitability for load-bearing applications. These experimental findings provide valuable insights into the mechanical performance and potential applications of banana fiber-epoxy resin composites. They emphasize the promise of utilizing natural fibers like banana fiber in epoxy resin matrices to develop sustainable and high-performance composite materials across diverse industries.

VI. CONCLUSION

our investigation into banana fiber-epoxy resin composites has demonstrated their potential as sustainable and high-performance materials for diverse applications. The use of banana fiber as a reinforcement in epoxy resin offers several advantages, including enhanced mechanical properties such as tensile strength, flexural strength, impact resistance, and compression strength. These composites present a promising alternative to traditional materials due to their eco-friendly nature, utilizing renewable and biodegradable banana Fiber. The versatility of banana fiber-epoxy composites opens doors to various industries, including automotive, construction, and aerospace, where lightweight yet strong materials are essential. Applications could range from automotive interior components and structural elements in building construction to aircraft interiors and components. The composites' ability to withstand different types of mechanical loads and their sustainability make them attractive for modern engineering and manufacturing practices. Looking ahead, further research and development efforts can focus on optimizing processing techniques, exploring new applications, and addressing challenges related to scalability and cost-effectiveness. By leveraging the unique properties of banana fiber and epoxy resin, we can advance the adoption of sustainable composite materials that contribute to environmental conservation while meeting the performance demands of diverse industrial sectors. This study underscores the potential of banana fiber-epoxy resin composites in promoting sustainability and innovation in material science and engineering.

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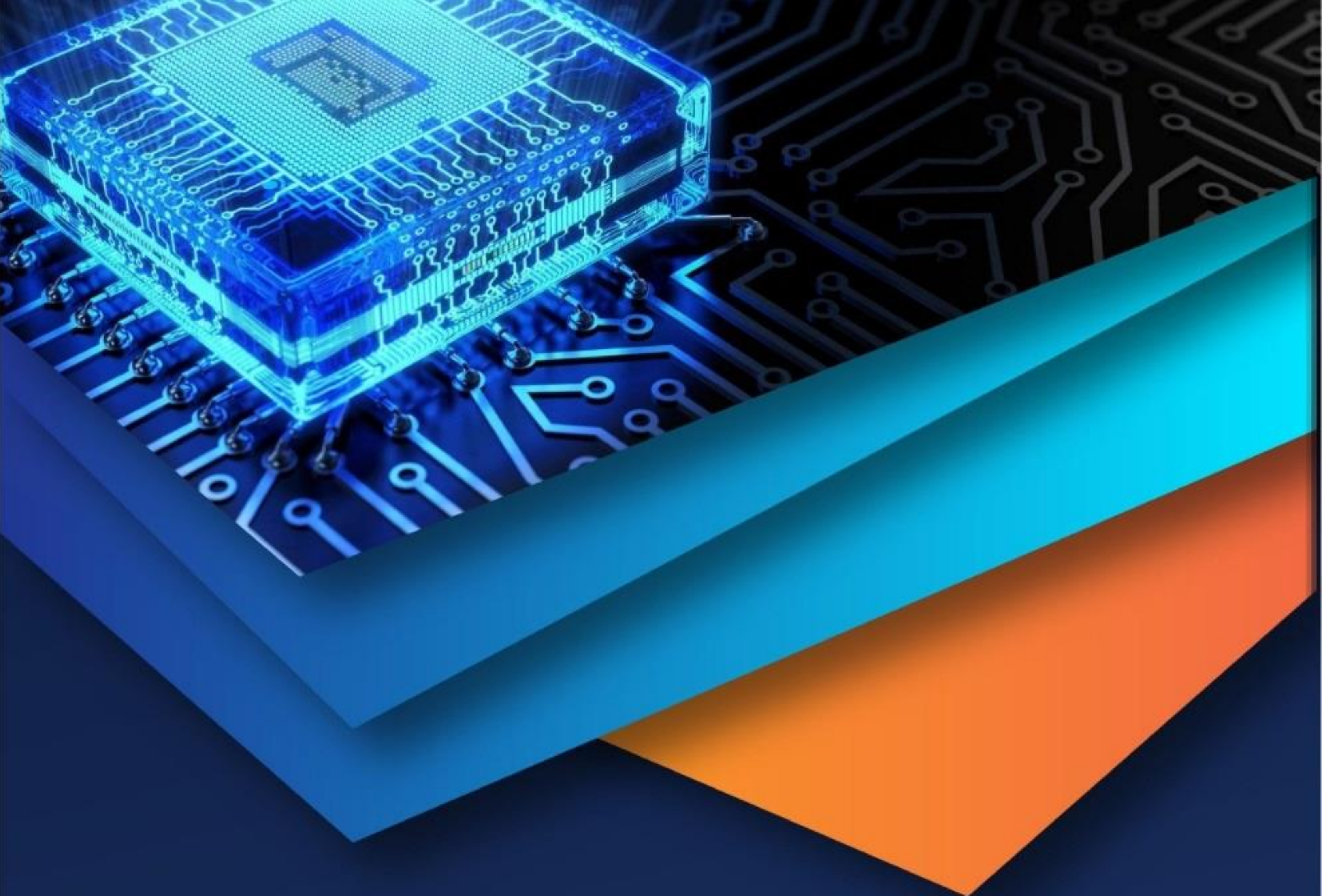

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