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Mechanical Characterization of Arecanut Fibre Reinforced Epoxy Composite

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ABSTRACT: This study focuses on the fabrication and mechanical characterization of epoxy composites reinforced with areca nut fibre at a 50% weight fraction, utilizing the compression moulding technique. In response to the growing demand for sustainable engineering materials, arecanut fibre was selected due to its biodegradability, low cost, and abundant availability. Composite specimens were prepared and subjected to mechanical testing to evaluate their structural performance. Tensile and impact properties were assessed in accordance with ASTM D638 and ASTM D256 standards, respectively. Additionally, Fourier Transform Infrared Spectroscopy (FTIR) was conducted following ASTM E1252 to identify characteristic functional groups and confirm chemical interactions between the arecanut fibres and the epoxy matrix. The results demonstrated that the composites exhibited satisfactory mechanical strength and energy absorption capabilities. Overall, the study highlights the potential of arecanut fibre-reinforced epoxy composites for lightweight and environmentally friendly structural applications.

KEYWORDS: Arecanut fibre, Epoxy resin, Compression moulding, Mechanical characterization, FTIR analysis.

I. INTRODUCTION

In recent years, materials engineering has increasingly focused on the development of sustainable composites, driven by environmental concerns, the depletion of non-renewable resources, and the easy availability of natural fibres as viable alternatives to synthetic materials. Natural fibre-reinforced polymer composites have emerged as promising alternatives to synthetic counterparts due to their biodegradability, low cost, low density, and reduced ecological impact. These materials are increasingly being considered for various structural and non-structural applications across industrial sectors.

Arecanut fibre, derived from the outer husk of the areca nut (*Areca catechu*), is a lignocellulosic material that is abundantly available in India and other tropical agricultural regions. Despite being traditionally classified as agricultural waste, it possesses mechanical properties suitable for reinforcement in polymer matrices. Utilizing areca nut fibre in composite manufacturing not only adds value to agricultural residues but also supports rural resource utilization and waste reduction.



Fig. 1: Areca nut (*Areca catechu*)

In this study, Epoxy Resin Grade 103 and Hardener Grade 301 are employed as the matrix and curing agent, respectively. Epoxy 103 is known for its excellent mechanical strength, chemical resistance, and adhesion, while Hardener 301 ensures efficient cross-linking during the curing process. This matrix system provides a stable and compatible environment for natural fibre reinforcement.

Composites were fabricated using the compression moulding technique with a 50% areca nut fibre weight fraction, selected to ensure sufficient reinforcement. Mechanical performance was evaluated through tensile and impact tests in accordance with ASTM D638 and ASTM D256 standards. Additionally, Fourier Transform Infrared Spectroscopy (FTIR), conducted as per ASTM E1252, was used to identify characteristic functional groups and confirm chemical bonding between the fibre and matrix. This work aims to assess the applicability of arecanut fibre as a reinforcing agent in epoxy composites and promote its use in the development of lightweight, sustainable engineering materials.

II. MATERIALS AND METHODS

2.1 MATERIALS USED

The primary materials employed in the fabrication of arecanut fibre-reinforced epoxy composites are detailed as follows:

- **Arecanut Fibre:** Naturally sourced arecanut fibres were obtained from local agricultural regions. The fibres were manually extracted from the outer husk of the areca nut, thoroughly washed to remove impurities, and subsequently sun-dried to minimize residual moisture content. After drying, the fibres were cut into consistent lengths suitable for reinforcement in the polymer matrix.



Fig. 2: Arecanut Fibre

- **Epoxy Resin (Grade 103):** A high-performance epoxy resin, designated as Grade 103, was utilized as the matrix material. Procured from Sharon Enterprises, Cochin, Kerala, this resin is characterized by its superior mechanical strength, strong adhesive properties, and notable resistance to chemical degradation.
- **Hardener (Grade 301):** The curing agent used was Hardener Grade 301, also sourced from Sharon Enterprises. It was combined with the epoxy resin in a 10:1 weight ratio, facilitating efficient cross-linking and ensuring structural integrity during the curing process.

2.2 COMPRESSION MOULDING

The fabrication of arecanut fibre-reinforced epoxy composites was conducted using the compression moulding technique at the Central Institute of Petrochemicals Engineering and Technology (CIPET), Kochi. The composite formulation included 150 grams of arecanut fibre, 280 grams of resin, and 28 grams of curing agent. The thermosetting matrix system consisted of Grade 103 epoxy resin and Grade 301 hardener, combined in a 10:1 weight ratio. These materials, obtained from Sharon Enterprises, Kochi, are widely recognized for their excellent adhesive strength, durability, and resistance to chemical degradation. Arecanut fibres were locally sourced from agricultural byproducts,

manually cleaned, and sun-dried to eliminate residual moisture. For composite preparation, the resin and hardener were blended to create a uniform mixture with minimal air entrapment. The blend was first poured into a 200 mm × 200 mm × 6 mm mould, after which the fibres were introduced in sequential layers, alternating with the matrix, to promote optimal impregnation and fibre-matrix bonding.



Fig. 3: Compression Moulding Machine

Compression was applied using a hydraulic press at a force of 30 tons (approximately 150 bar) to ensure proper consolidation. The filled mould was cured at ambient temperature (around 25 °C) for 24 hours. Upon curing, the laminate was removed and machined into specimens for testing. Tensile strength was evaluated according to ASTM D638 and impact resistance per ASTM D256. Fourier Transform Infrared Spectroscopy (FTIR), performed in line with ASTM E1252, was used to identify functional groups and confirm chemical interactions within the composite.





Fig. 4: Fabrication of Arecanut Fibre Reinforced Epoxy Composites

CHARACTERIZATION

- **Tensile Testing :** Tensile testing was conducted at CIPET Kochi using a Universal Testing Machine (UTM) in accordance with ASTM D638 standards. Standard dumbbell-shaped specimens were evaluated at a constant crosshead speed to determine tensile strength, Young's modulus, and elongation at break. These parameters provided insights into the composite's load-bearing capacity and deformation characteristics.
- **Impact Testing (Izod Notched) :** Impact performance was assessed at CIPET Kochi using the Izod notched method as per ASTM D256. Notched specimens were mounted vertically and subjected to a single strike from a pendulum hammer. The energy absorbed during fracture was recorded to evaluate the material's toughness and resistance to crack initiation under dynamic loading.
- **FTIR Spectroscopic Analysis :** Fourier Transform Infrared Spectroscopy (FTIR) was employed in accordance with ASTM E1252 to investigate the chemical structure and interactions between the epoxy matrix and arecanut fibres. The analysis was performed at CIPET Kochi using infrared absorption spectroscopy to identify functional groups and assess fibre-matrix compatibility. The presence of characteristic peaks indicated successful chemical bonding, supporting the integration of natural fibres within the polymer matrix.

III. RESULT AND DISCUSSION

3.1 FTIR ANALYSIS

The FTIR spectrum of the sample reveals characteristic absorption bands corresponding to both natural lignocellulosic fibers and an epoxy resin matrix. A broad peak around 3300 cm^{-1} is attributed to O-H stretching vibrations, indicating the presence of hydroxyl groups typical of cellulose-based materials such as areca nut fiber. Peaks near 2920 cm^{-1} correspond to aliphatic C-H stretching, commonly found in both the fiber and resin components. A sharp absorption band observed at approximately 1730 cm^{-1} is associated with C=O stretching vibrations, suggesting the presence of ester or carbonyl groups originating from either the epoxy matrix or hemicellulose in the fiber. The region around 1600 cm^{-1} may represent aromatic C=C stretching or water-related bending vibrations. Bands in the $1000\text{--}1100\text{ cm}^{-1}$ range are due to C-O stretching, confirming polysaccharide structures, while the 915 cm^{-1} peak is a signature of the epoxide ring present in the resin. Additionally, the absorption near 897 cm^{-1} corresponds to β -glycosidic linkages, which are typical of cellulose. These spectral features confirm that the material under investigation is a natural fiber-reinforced polymer composite, consisting of lignocellulosic fibers embedded in an epoxy matrix.

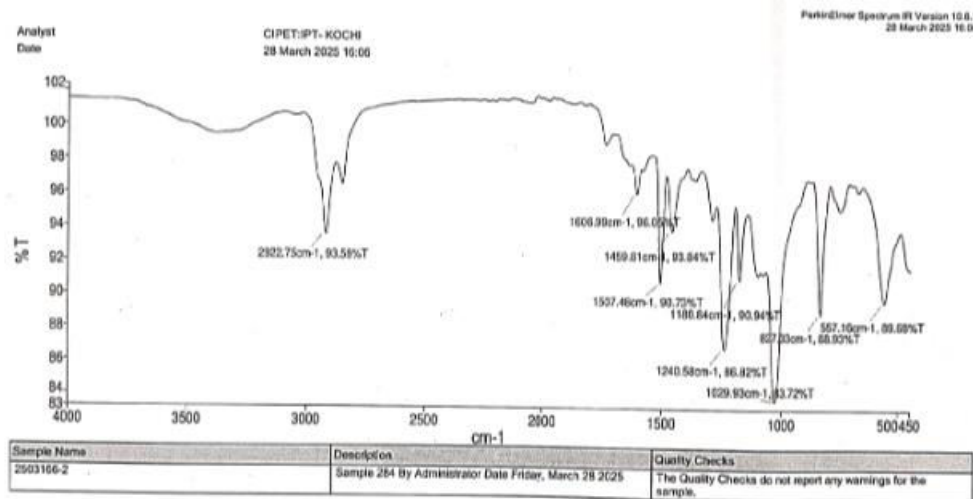


Fig. 5: FTIR Analysis

3.2 TENSILE TEST

The load vs displacement graph provides a clear representation of the material's mechanical behavior under applied force. The initial linear portion of the curve reflects the elastic region, wherein the material deforms proportionally to the applied load and returns to its original shape upon unloading. As the load increases, the curve transitions into a nonlinear region, indicating the onset of plastic deformation, where permanent structural changes occur. The maximum load sustained by the material was 1660.0 N at a corresponding displacement of 3.46 mm, representing its ultimate load-bearing capacity. Beyond this point, a decline in load suggests the initiation of material softening or failure. These results indicate that the material possesses significant strength and ductility, rendering it suitable for applications requiring both structural integrity and the ability to undergo controlled deformation.

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