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Manufacturing of Natural Fiber-Reinforced Recycled Polymer

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Abstract - *The growing concerns over environmental sustainability have led to an increased interest in the development of eco-friendly materials in the field of manufacturing. One promising approach is the utilization of natural fiber-reinforced recycled polymers, which combine the advantages of both renewable natural fibers and recycled plastic materials. This study explores the manufacturing process, mechanical properties, and environmental benefits of natural fiber-reinforced recycled polymer composites. Natural fiber of kenaf is incorporated into recycled polymers to enhance the material's strength, durability, and biodegradability while reducing reliance on petroleum-based polymers. The production process involves the careful selection and treatment of fibers and polymers to ensure optimal bonding and performance. The mechanical properties, including tensile strength, flexural strength, and impact resistance, are evaluated, and the results show significant improvements in comparison to non-reinforced recycled polymers. Additionally, the environmental impact of using recycled polymers and natural fibers is analyzed in terms of reduced carbon footprint, energy consumption, and waste reduction.*

Key Words: Natural fibers, Reinforced polymers, Mechanical properties, Biodegradability, Waste reduction.

1.INTRODUCTION

The global shift towards sustainability has necessitated the development of innovative materials that not only meet performance requirements but also minimize environmental impact. One promising solution lies in the use of natural fiber-reinforced recycled polymers. With the increasing accumulation of plastic waste and the environmental concerns surrounding its disposal, recycling plastics has become essential. At the same time, natural fibers, derived from renewable resource of kenaf offer a biodegradable alternative to synthetic fibers traditionally used in composite materials. Recycled polymers, when combined with natural fibers, create composite materials that harness the strengths of both components—enhancing the mechanical properties of recycled plastics while improving their environmental profile. These natural fibers act as reinforcement agents, providing improved strength, stiffness, and impact resistance to the recycled polymer matrix. Additionally, the natural fibers are sourced from agricultural waste or by-products, which not only helps reduce waste but also promotes circular economy practices.

1.1 Materials and Methods

The materials used in this study included natural fiber of kenaf, which were sourced, cleaned, and treated with alkaline and silane solutions to improve their compatibility with recycled polymers. Recycled poly latic acid (PLA) were selected as the polymer matrix due to their availability and favorable processing characteristics. The composites were fabricated by extruding the natural fibers with recycled polymers using compression molding to produce test specimens. The mechanical properties of the composites were evaluated through tensile, flexural, and impact tests, while water absorption and biodegradability were also assessed. A life cycle assessment was conducted to estimate the environmental impact, including energy consumption and waste reduction. Statistical analysis was performed to compare the results across different fiber and polymer combinations.

1.2 Properties of natural fibers-reinforced polymers

Incorporating kenaf fibers into polylactic acid (PLA) matrices significantly influences the mechanical and morphological properties of the resulting composites. Studies have demonstrated that unidirectional kenaf fiber-reinforced PLA composites exhibit tensile strengths up to 223 MPa and flexural strengths around 254 MPa. These strengths increase linearly with fiber content up to 50%, highlighting the positive impact of higher fiber reinforcement. sustainability by promoting recycling and utilizing renewable resources. Additionally, processing parameters such as molding temperature and fiber volume fraction play crucial roles in determining the mechanical attributes of the composites. Research indicates that composites fabricated at a molding temperature of 170°C and a fiber volume fraction of 35% achieve optimal tensile and flexural strengthsScanning Electron Microscopy (SEM) analyses provide insights into the fracture surfaces of these composites. SEM images reveal that bleached kenaf fibers display a rougher surface texture, enhancing interlocking with the PLA matrix and resulting in improved mechanical properties.

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2. Methodology

The methodology for this project begins with the collection of defective 3D printed models, where PLA waste is gathered from faulty parts and broken down into small flakes for further processing. Natural fibers are then extracted from Kenaf, a plant known for its strength and durability. These fibers are cleaned and prepared before undergoing plasma treatment, which enhances their surface properties and improves bonding with the PLA flakes. Following this, the plasma-treated Kenaf fibers are mixed with the PLA flakes to form a composite material. The combination is processed into a sandwich-type matrix, where layers of PLA are sandwiched between the natural fibers, ensuring a uniform and strong composite structure. Once the composite is prepared, test specimens are fabricated by molding or cutting the material into standardized shapes suitable for mechanical testing. These specimens are then subjected to a series of mechanical tests, including compressive strength, flexural strength, and tensile strength tests, to assess the material's performance under different stresses. The results of these tests, including stress-strain data, provide insights into the effectiveness of the composite in terms of its mechanical properties, offering valuable information on its potential for various applications.

2.1 Extraction and treatment of natural fiber

The extraction and treatment of natural Kenaf fibers begin with soaking the Kenaf stalks in water to remove impurities such as lignin and pectin. This soaking process, which lasts from a few hours to several days, softens the non-fibrous components, making it easier to separate the fibers from the rest of the plant material. After soaking, the stalks are brushed manually or mechanically to extract the long, strong fibers, removing any remaining woody material. The extracted fibers are then cleaned thoroughly to ensure they are free from contaminants. To further enhance their properties, the fibers undergo plasma treatment. In this step, the fibers are exposed to ionized gas, typically oxygen or nitrogen, which modifies the fiber's surface by creating roughness and introducing functional groups like hydroxyl or carboxyl groups. This treatment increases the surface energy of the fibers, improving their ability to bond with the PLA matrix. The treated fibers are now ready for use in reinforcing the PLA composite, ensuring a strong bond and enhancing the overall mechanical properties of the material.

2.2 Composite Matrix Formation

The matrix formation involves combining the plasma-treated Kenaf fibers with PLA flakes to create a composite material. The process begins by carefully selecting and preparing the PLA flakes, which are sourced from defective 3D printed models. These PLA flakes serve as the polymer matrix in which the natural fibers will be embedded. Once the PLA flakes and treated Kenaf fibers are ready, they are mixed together in a controlled ratio to ensure a proper distribution of the fibers within the polymer matrix. The fiber content and arrangement are critical to achieving the desired mechanical properties, as a higher fiber content generally improves the strength and stiffness of the composite.Next, the mixture of PLA flakes and fibers is processed into a sandwich-type matrix. This typically involves using an extrusion or compression molding technique. In extrusion, the fibers and PLA are fed into an extruder, where they are melted and mixed under controlled heat and pressure. The resulting material is then formed into a continuous sheet or preform. Alternatively, in compression molding, the mixture is placed into a mold, and heat and pressure are applied to form the desired shape and thickness of the composite.During the molding process, the fibers are layered between the PLA, creating a sandwich structure, which improves the mechanical properties by providing reinforcement along multiple planes. The matrix is then cooled and solidified, creating a composite material with enhanced strength, stiffness, and durability. This final composite is ready to be cut into test specimens for mechanical testing and performance evaluation.

2.3 Mechanical Testing

Mechanical testing and Scanning Electron Microscopy (SEM) analysis are essential to evaluate the performance and microstructure of the bio-composite materials used in FDM printing. Mechanical testing involves conducting a series of tests to assess the strength, durability, and behavior of the printed bio-composite specimens under various loading conditions. Tensile testing is performed using a universal testing machine (UTM) to measure tensile strength, elongation at break, and Young's modulus, providing critical information about the material's ability to resist deformation when stretched. Compression testing is also carried out to assess how the material performs under compressive forces, determining compressive strength and stiffness. Impact testing, typically, evaluates the toughness and energy absorption capacity of the material by subjecting it to sudden impacts and measuring its resistance to breakage or cracking.

Fig -1: SEM images.

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3. CONCLUSIONS

In conclusion, the manufacturing of natural fiber-reinforced recycled polymers presents a promising solution to the growing environmental concerns associated with plastic waste and the need for more sustainable materials. By combining recycled polymers with natural fibers, such as jute, hemp, and flax, it is possible to create composite materials that not only offer improved mechanical properties but also significantly reduce the environmental impact of traditional plastic manufacturing. The use of natural fibers enhances the strength, stiffness, and durability of the recycled polymer matrix, while also contributing to biodegradability and reducing dependence on petroleum-based plastics. Furthermore, this approach supports the circular economy by promoting the recycling of waste materials and reducing the overall carbon footprint of production processes.

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