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A Comparative Study on the Mechanical Properties of Caryota Urens and Sisal Fiber Reinforced Composites

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I. INTRODUCTION

In recent times, the global focus on sustainable development and environmental preservation has greatly impacted the domain of materials science and engineering. Among the numerous advancements, natural fiber-reinforced polymer composites have gained attention as viable substitutes for traditional synthetic composites due to their environmental friendliness, renewability, biodegradability, and affordability [1]. These materials are increasingly being utilized in automotive parts, marine industry construction materials, packaging, and consumer products [1],[2].

In this research study, among the natural fibers, Caryota urens and sisal fibers are selected to make natural composite materials due to their biodegradability, availability, and low cost. This study investigates composites reinforced with pure Caryota urens, pure sisal, and a hybrid mix of Caryota urens and sisal (50:50 weight ratio) to determine whether hybridization can yield a material with enhanced or balanced mechanical performance compared to individual fiber composites. A 50:50 ratio was chosen to study the mechanical properties of the blend after mixing in equal amounts by weight and the difference between the mechanical properties of pure Caryota urens and pure sisal fibers.

The aim of this research is to compare and evaluate the mechanical properties of composite materials reinforced with pure Caryota urens fibers, pure sisal fibers, and a mix of both fibers at a 50:50 weight ratio to assess their potential for sustainable applications.

II. LITERATURE REVIEW

Natural fiber-reinforced composite materials are increasingly being used as sustainable alternatives to synthetic materials due to their biodegradability, cost-effectiveness, and sufficient strength. Among these, sisal fiber has been well studied for its high tensile strength, toughness, and good resin adhesion, making it suitable for automotive and marine applications. Quantitative studies indicate that Sisal fibers possess a density of 1.2 g/cm³ and a significant tensile strength ranging from 507 to 855 MPa, with an average value of approximately 681 MPa [2]. In contrast, despite its promising mechanical and thermal properties, Caryota urens fiber has been rarely explored.

Previous studies have shown how the mechanical properties of different natural fibers can be modified by combining them. However, limited research has been conducted on the hybridization of Caryota urens and Sisal fibers. Therefore, this study aims to fill this research gap by comparing their individual and combined mechanical performance and evaluating their potential for lightweight, environmentally friendly applications.

III. MATERIALS AND METHODS

A. Raw materials

Caryota urens fibers are extracted manually from the stem area after removing unwanted leaf debris. Sisal fibers are extracted from the sword-shaped leaves of the Agave sisalana plant by a process of manual decortication. The leaves are crushed and scraped with a mechanical or hand decorticator when freshly cut to remove the fleshy pulp and release the fibrous strands. The length of a single extracted Caryota urens fiber is more than 30 cm while individual sisal fibers can be as long as 100 cm. Both were thoroughly sun dried to minimize the moisture content. To ensure the uniformity and compatibility with composite preparation process, the raw fibers were cut into small pieces before being composited.

B. Composite Preparation

Composite specimens were fabricated using hand-laying techniques, a commonly used method to produce fiber-reinforced polymer composites. A 3D printed mold was used to shape specimens made from polylactic acid (PLA) using

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additive manufacturing. The mold dimensions were adjusted according to the required sample for each mechanical test. The natural fibers were randomly packed into the mold and polyester resin were added. The mold dimensions were adjusted according to the required sample for each mechanical test. The polyester resin and hardener were mixed at a ratio of 1.5:100 by weight [3] to ensure proper crosslinking and curing performance. Three types of fiber configurations were used for the comparative analysis: pure Caryota urens fiber, pure sisal fiber, and hybrid mix of Caryota urens and sisal (50:50) respectively. Following the hand lay-up process, the laminated samples were subjected to a uniform 50 N compressive load to ensure even compaction and resin distribution of the composite. The composites were then cured at room temperature for 24 h under this applied load to achieve structural stability and optimal mechanical bonding.

C. Evaluate Mechanical Properties

To compare the mechanical behavior of the composite's samples reinforced with Caryota urens fibers, sisal fibers, and a hybrid combination of both fibers were subjected to standardized mechanical tests. The evaluation comprised three different tests: tensile strength, impact resistance, and hardness.

All specimens were prepared according to the appropriate ASTM (American Society for Testing and Materials) standards, ensuring reliability in results. The Brinell Hardness Tester was employed to determine the surface hardness of each composite sample. For impact resistance, the Izod Impact Test machine was used to measure the energy absorbed by the material during fracture. Tensile strength was determined using a universal testing machine (UTM) following the relevant ASTM guidelines.

IV. Results and Discussion

A. Impact Test

The impact strength of the composites was assessed at a striking velocity of 3.46 m/s and ASTM D256 was followed. As shown in the Fig. 1 the impact strength values were 0.039 J/mm^2, 0.0218 J/mm^2, and 0.00154 J/mm^2 for Sisal fiber, Caryota urens, and 50:50 mixed fiber composite respectively. The Sisal fiber composite had highest impact energy absorption, an indication of greater toughness and enhanced impact load resistance among these test samples.

B. Hardness Test

Brinell hardness tests were conducted with a 5 mm indenter, 125 N load, and 5s dwell time in accordance with ASTM E10. According to the Fig. 2 the hardness values do not show significant differences among these three types of

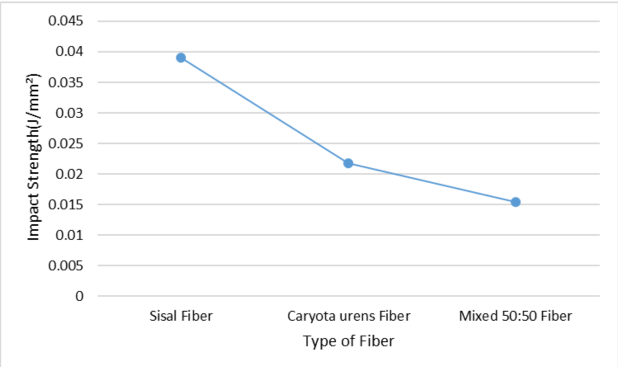

Fig. 1. Impact strength of fiber samples

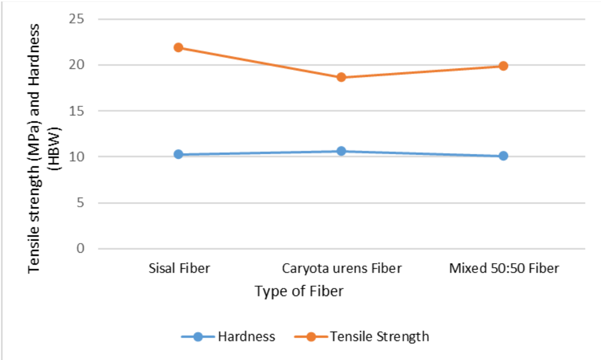

Fig. 2. Tensile strength and the Hardness of fiber samples

samples. It indicates 10.598 HBW for Caryota urens, 10.27 HBW for Sisal, and 10.08 HBW for the mixed composite.

C. Tensile Test

ASTM D3039 was followed for conducting the tensile test. As shown in the Fig. 2 the tensile strength values were 18.5956 MPa for Caryota urens, 21.8386 MPa for Sisal, and 19.8492 MPa for the mixed composite. Sisal fiber composite showed maximum tensile strength which indicates the higher stiffness and effective stress transfer capacity under uniaxial loading among these samples.

The overall performance exhibits a balance in strength, hardness, and impact resistance for the composites. The Sisal fiber composite was best terms of tensile strength and impact strength compared to Caryota urens. The 50:50 mixed composite exhibited moderate performance in all aspects, effectively balancing the characteristics of two fibers. However, the hybridization did not exceed the individual performance of pure Sisal. It is suggested that the structural integrity relies heavily on the stronger Sisal constituents while the mixed composite balances the material properties.

V. Conclusion

This study compared the mechanical properties of composite materials reinforced with pure Caryota urens fibers, pure Sisal fibers, and a 50:50 blend of the two that is proving the potential of both natural fibers as sustainable composite reinforcements. The Sisal fiber composite was best in tensile and impact and is thus best suited for strength and toughness requiring applications while the 50:50 mixed composite exhibited moderate performance in all aspects when comparing the Sisal, Caryota urens and 50:50 mixed fiber samples due to the fiber strength of each individual fiber. The bonds may be varied due to the fiber strength and should be further research. Based on the observed mechanical performance, these composites show significant potential for sustainable engineering uses in automotive, aerospace, and marine applications that require lightweight and environmentally friendly materials for interior panels, parts, and semi-structural components [2].

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