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Investigation Of Stacking Layer Effect on The Kenaf Hybrid Composite Mechanical Properties for Automotive Application

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Abstract: The field of automotive manufacturing continually seeks innovative, sustainable materials with an emphasis on mechanical robustness. The study is aimed at investigating the Kenaf fibers' potential as an alternative to synthetic fiber composites in automotive bumper beams, shedding light on the mechanical properties of this hybrid composite. The primary focus lies on the impact of different fiber orientations: unidirectional, bidirectional, and 45-degree angles. Using the hand layup process, a natural fiber composite served as the material for constructing the sample, tested for mechanical properties with a Universal Testing Machine. Findings from both tensile and flexural tests illuminate the mechanical properties of Kenaf fiber composite, providing valuable insights into its utilization potential. The Kenaf hybrid composite showcased viable mechanical properties, suggesting its potential for automotive applications. The research establishes Kenaf fibers as a promising, sustainable alternative that could revolutionize the automotive industry without compromising structural integrity.

Keywords: Kenaf fiber automotive, mechanical properties, hybrid composite, hand layup process, tensile test, flexural test

1. Introduction

The ability of modern technological advancement to satisfy fabrication requirements has prompted researchers to look at material innovation. It is vital to make sure the cutting-edge materials can be employed in a number of practical applications that could lead to affordable and eco-friendly solutions. The fiber from the kenaf plant, which is frequently found in tropical and subtropical areas of Africa and Asia, has been used to manufacture rope, bags, and carpets. A great replacement for traditional synthetic fiber composites is the use of kenaf fiber composites. Consumer safety is jeopardized by the presence of hazardous chemicals in fiberglass and other composite materials made of synthetic fibers. This study examines natural fiber's potential to replace synthetic fiber in vehicle bumper beams by analyzing its mechanical properties [1].

Designers can concentrate more on creating lightweight bumper beams since the overall weight of a composite car bumper beam may be lowered. Manufacturers can develop features that meet the requirements of a certain structure for a specific purpose [2] by selecting the optimal combinations of reinforcing and matrix materials. The rate of global automobile production is anticipated to have climbed to 76 million vehicles annually. Due to the scarcity of petroleum

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supplies, the cost of products derived from petroleum would probably increase soon. An estimated 250 million barrels of crude oil would be saved if cars were 25% lighter. It's possible that manufacturers would consider including more natural fiber in their new products given that adopting low-density natural fibers could cut weight by 10 to 30 percent [3]. Due to its subpar mechanical properties and some manufacturing limitations, agricultural-based materials are currently exclusively employed in non-structural and semi-structural car components.

Natural fiber composites are less expensive, require less energy during production, and have low tool wear rates. Additionally, they do not exhibit splintering, which is perfect in several applications. Additionally, they exhibit exceptional formability, acoustic characteristics, and thermal insulation properties. Hybridization of natural fibers provides a means of outperforming the mechanical properties of only employing natural fibers [4]. This study aims to create a kenaf hybrid that will enhance the desirable mechanical characteristics of the vehicle's structural elements known as bumper beams.

2. Methodology

2.1 Size of Kenaf Fiber and Fiberglass

The kenaf fiber yarn was obtained in which will later be used in the hybrid composite fiber mixture. The kenaf fiber yarn is cut into 20 cm piecesand is prepared where it will be utilized into three different fiber orientation samples. The high strength-to-weight and stiffness-to-weight ratios of the fiber composites are crucial characteristics that must be determined. By using composite materials like fiberglass, it is possible to reduce weight by 30% to 50% while gaining strength and stiffness over steel sections of comparable thickness [5,6]. This problem can be resolved by using the proper resin matrix and fiber orientation. In this study, fiberglass sheets will also be utilized.

The kenaf fiber for all three samples were cut into 20 cm long whereas the fiberglass is cut according to the size of the mold. In this case, for sample 1 and 2, the fiberglass is cut with a size of 40x25 cm will be combined with a weight of 100 grams of kenaf fiberwhereas in sample 3, the fiberglass is cut into a size of 40x40 cm and will be combined with a weight of 200 grams of kenaf fiber. All samples were given two layers of fiberglass with a weight of 12 grams per layer for samples 1 and 2 as shown in Fig. 1 and 24 grams per layer for sample 3. Glass andkenaf fiber are sufficiently prepared to accommodate the 30 samples needed for thetensile and flexural testing.

2.2 Stacking Layer Orientation of Kenaf and Fiberglass

The kenaf fiber and fiberglass are layered alternately to create the hybrid composite fiber samples as shown in Fig. 1. Measurement of the thickness of the car bumperwill be used to determine the layer quantity and, in this research, the thickness of the hybrid composite fiber will be 3.5 cm. Three alternative stacking layer orientations wereused for the samples containing four layers of kenaf and fiberglass in each orientation. Bidirectional, 45-degree, and unidirectional stacking layer orientations are used as shown in Fig. 2. This is performed to determine whether the tensile and flexural properties of the hybrid kenaf fiber composites are affected by the stacking of layers [7].

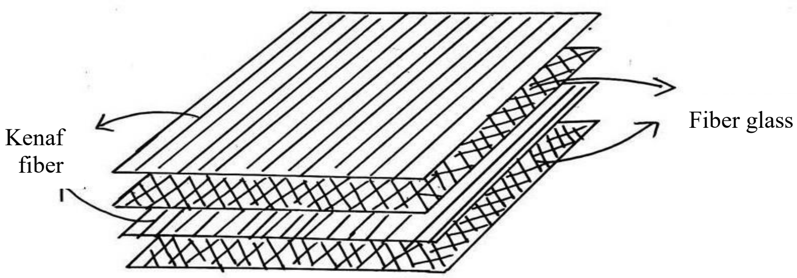

Fig. 1 - Stacking layer of kenaf and fiberglass hybrid composite

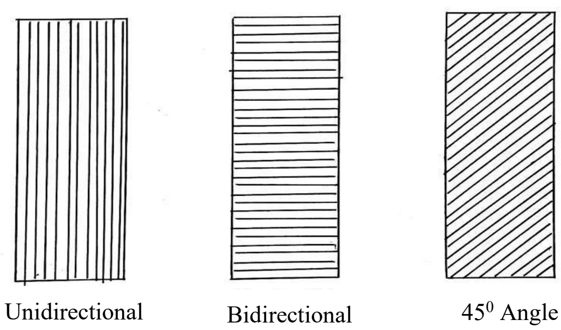

Fig. 2 - Sketching of stacking layer orientations of kenaf and fiberglass hybrid composite

2.3 Epoxy Resin

Epoxy resin is used to construct the hybrid composite fiber sample sets. SmoothOn EpoxAmite 100 will be the name under which the product will be made using the resin-to-fiber ratio approach. The Epoxy Laminating Resin is represented by Part A, whereas the 103 Slow Epoxy Curative Hardener is represented by Part B. The ratio of Parts A and B is 100A:28.4B in the mixture. In this method, for sample 1 and 2, part A will weigh 225.1 grams, while part B will weigh 63.9 grams where, it will combine with a total weight of 289 grams for the hybrid composite fiber made of kenaf and fiberglass in order to create the hybrid composite fiber samples. Whereas for sample 3, the part A will weigh 450.6 grams and part B will weigh 128 grams combined to a total of 578.6 grams.

2.4 Vacuum Bagging Hand Lay-up Method

The process utilized for making hybrid composite fiber samples is known as vacuum bagging handlay-up. This method requires the mold to be prepared on a clean, wax-polished glass surface. Next, the mold's sides were constructed using double-sided tape so that the epoxy resin mixture can be poured into the mold's center. The kenaf fiber was manually laid out before a fiberglass layer is put on top of it as shown in Fig. 3(a). A 70% weight epoxy matrix and a 30% weight total fiber loading were used to produce the composites. The composites were vacuumed to remove excessepoxy resin using vacuum bagging and to ensure the surface of the composites are flatand no void of air bubble occurs as shown in Fig. 3(b). They were allowed to cure for 24 hours at room temperature.

Fig. 3 - (a) Kenaf fiber preparation for vacuum bagging hand lay-up method; (b) hybrid composite fiber after vacuum bagging is applied and left to cure for 24 hours

2.5 Tensile and Flexural Testing

For the tensile testing, five samples of the hybrid composite fiber that has been prepared using the first orientation were prepared in accordance with ASTM D3039, which is the standard test method for tensile properties of polymer matrix composite materials. The samples had dimensions of 200 mm in length, 25 mm in width, and 3.5 mm in thickness, with a gauge length of 150 mm. The sample will then be subject to the tensile forces of the Universal Testing Machine. In order to get more accurate findings, the tensile test will continue with new samples that are in two additional distinct orientations, with each sample being repeated five times. Tensile tests on hybrid kenaf fiber and glass fiber composites under fiber orientation help evaluate properties, such as the ultimate tensile strength (UTS) [8]. The UTS is an essential indicator of the composite's capability to withstand a tensile load before failure [6].

The flexural test was conducted by following the ASTM D790-03 standard. The dimensions of the samples were 130 mm in length, 13 mm in width, and 3.5 mm in thickness. The crosshead velocity was 1.5 mm per minute. The 100 mm span length was utilized. To begin the flexural test, the remaining five samples of the hybrid composite fiber of the first orientation will be placed on the Universal Testing Machine. Similar to the earlier tensile test, the flexural test will continue with new samples of the other two distinct orientations, with each sample being conducted five times. These experiments were crucial in identifying the precise mechanical characteristics of each orientation, particularly the flexural strength. Finding the best fiber arrangement that offers optimized mechanical qualities for varied applications requires a thorough study of these three orientations.

3. Results & Discussion

3.1 Tensile Test

Fig. 4, 5 and 6 show the average UTS of each orientation for tensile test of all the samples. From the graphs, it is observed that unidirectional orientation had an average UTS value of 46.84 MPa, 45-degree orientation had an average UTS value of 23.46 MPa whereas bidirectional had an average UTS value of 20.31 MPa.

Based on the results from the tensile tests, the unidirectional orientation was found to have the highest ultimate tensile strength compared to the 45-degree angle and bidirectional orientations. This improvement in tensile strength can be attributed to the efficient alignment of fibers in a single direction, maximizing the load-bearing capability in that particular direction. The fibers in the unidirectional orientation provide maximum reinforcement along the main force direction, resulting in a higher resistance against tensile forces and, ultimately, a higher tensile strength.

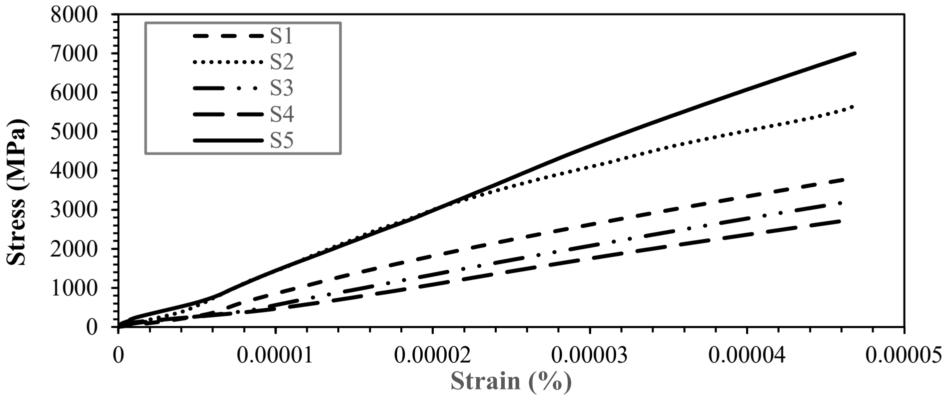

Fig. 4 - Stress vs. Strain graph for tensile test on five kenaf-fiberglass hybrid samples in unidirectional orientation

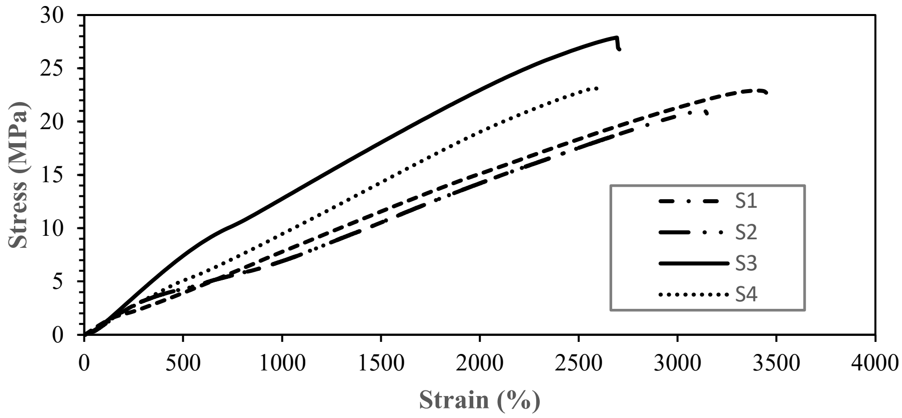

Fig. 5 - Stress vs. Strain graph for tensile test on five kenaf-fiberglass hybrid samples in 45-degree orientation

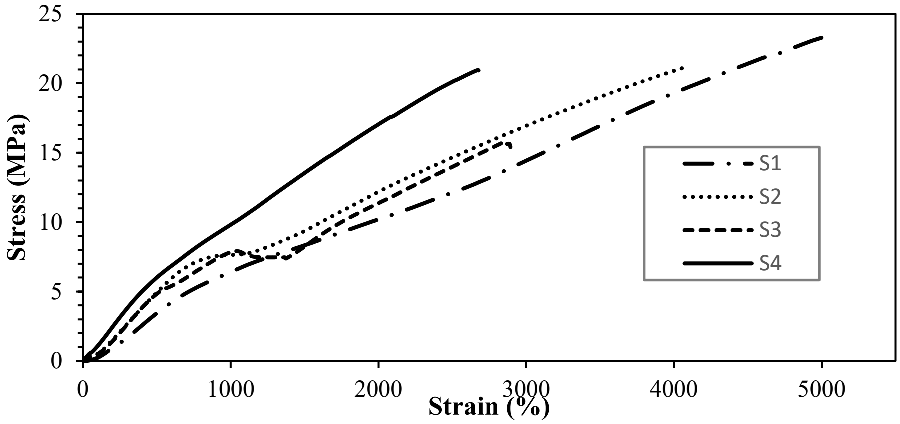

Fig. 6 - Stress vs. Strain graph for tensile test on four kenaf-fiberglass hybrid samples in bidirectional orientation

3.2 Flexural Test

Fig. 7, 8, and 9 show the average flexural strength of each orientation for all the samples. From the graphs, it is observed that unidirectional orientation had an average flexural strength value of 15.95 MPa, 45-degree orientation had an average flexural strength value of 27.83 MPa whereas bidirectional had an average flexural strength value of 13.86 MPa.

The 45-degree angle orientation was determined to have the highest flexural strength when compared to the unidirectional and bidirectional orientations, according to the findings of the flexural testing. The effective load distribution and the optimized interaction of fibers in the 45-degree configuration are responsible for the increase in flexural strength. The balanced reinforcement in both in-plane and out-of-plane directions produces improved mechanical performance in 45-degree angle orientation, offering superior resistance to complicated loads encountered in certain applications.

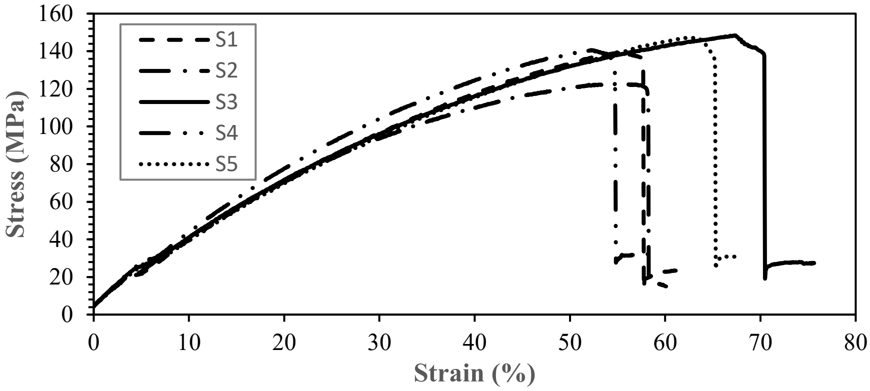

Fig. 7 - Stress vs. Strain graph for flexural test on five kenaf-fiberglass hybrid samples in unidirectional orientation

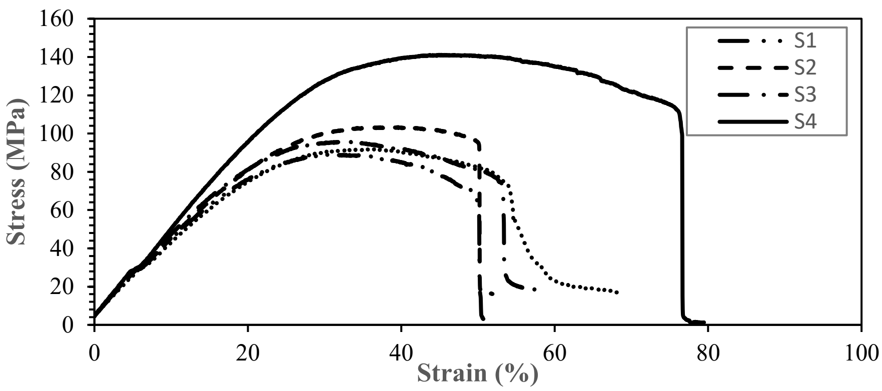

Fig. 8 - Stress vs. Strain graph for flexural test on five kenaf-fiberglass hybrid samples in 45-degree orientation

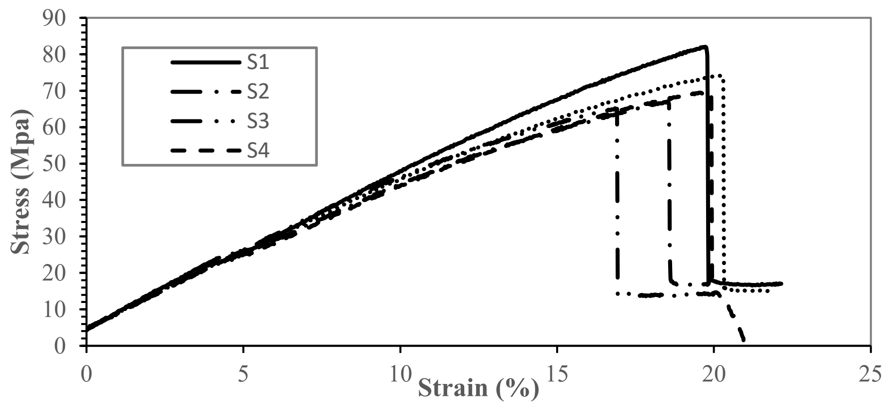

Fig. 9 - Stress vs. Strain graph for flexural test on five kenaf-fiberglass hybrid samples in bidirectional orientation

4. Conclusion

The research into the hybrid composite composed of kenaf fiber and fiberglass has underscored its promising mechanical performance, making it a viable candidate for automotive applications. The study's principal focus on ascertaining the impact of fiber orientation provides valuable insights into optimizing these properties for automotive applications. The research offers pronounced indications of hybrid kenaf-glass fiber composites poised to serve as sustainable and eco-friendly alternatives to conventional synthetic fiber composites. By modified fiber orientation, these composites propose an advantageous path forward in creating lightweight and environmentally friendly automotive components, aligning with the industry's shift towards eco-friendly solutions.

Based on the findings presented earlier, this study has provided valuable insights into the mechanical properties exhibited by hybrid kenaf fiber and glassfiber composites. The primary focus was on determining the most suitable fiber orientation for enhancing these properties and potentially replacing conventional synthetic fiber composites in automotive applications. In evaluating the tensile and flexural properties of hybrid composites, three fiber orientations were considered: unidirectional, 45-degree angle, and bidirectional. From the results, the unidirectional orientation showed the best arrangement for tensile with having the highest ultimate tensile strength (UTS) whereas the 45-degree angle orientation emerged as the superior arrangement, showing the highest flexural strength when compared to its counterparts.

Nevertheless, further research is needed to fully comprehend the most effective hybrid compositions and fiber orientations for specific application requirements, and to address any potential drawbacks associated with these composites. More focus could be given in future studies to optimizing fiber volume fractions, hybridization patterns, and manufacturing techniques. In summary, the initial findings from the research serve as a promising starting point for the incorporation of hybrid kenaf fiber and glass fiber composites in the automotive industry. The research forms a stepping stone for further exploring how these composites can be modified and optimized to contribute to a more sustainable and efficient automotive industry.

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