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Research article

Influence of Angle Ply Orientation on Tensile Properties of Carbon/Glass and Kevlar/Glass Hybrid Composites

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A B S T R A C T

This study investigates the influence of angle ply orientation on the tensile properties of hybrid composites composed of carbon/glass and Kevlar/glass fibers. Hybrid composites have gained significant attention in engineering applications due to their superior strength-to-weight ratio and tailored tensile properties. By varying the ply orientation angles, we aim to understand how these configurations impact the tensile strength, flexural strength, and impact resistance of the composites. A series of composite laminates were fabricated using carbon/glass and Kevlar/glass fibers with different ply angles (0°/90°, 60°/30°). Tensile testing was conducted according to ASTM standards to evaluate the tensile, flexural, and compression properties of the composites. The results indicate that the ply orientation plays a crucial role in determining the overall tensile performance of the hybrid composites.

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1. INTRODUCTION

Hybrid composites, which combine different types of fibers within a single matrix, have emerged as critical materials in various high-performance applications due to their ability to offer a tailored balance of tensile properties. Specifically, the integration of carbon, glass, and Kevlar fibers in composite systems allows engineers to design materials that maximize the advantages of each fiber type. Carbon fibers contribute high stiffness and strength, glass fibers offer good impact resistance and cost-effectiveness, and Kevlar fibers provide excellent toughness and energy absorption. This unique combination makes hybrid composites ideal for use in aerospace, automotive, and marine industries, where both structural integrity and lightweight characteristics are paramount.

A key factor influencing the tensile performance of these hybrid composites is the angle ply orientation of the fibers. Angle ply orientation refers to the arrangement of fiber layers at specific angles relative to one another, significantly impacting the composite's tensile behaviour under various loading conditions. The orientation of plies affects critical properties such as tensile strength, flexural strength, and compression, thereby playing a vital role in optimizing the composite material for specific applications.

While extensive research has been conducted on the tensile properties of single-fiber composites, the literature on the influence of angle ply orientation in hybrid composites, particularly those combining carbon/glass and Kevlar/glass, is relatively limited [1]. Angle ply orientation can optimize the balance of stiffness and impact resistance in carbon/glass hybrids, yet the effects in Kevlar/glass hybrids remain underexplored [2].

This paper aims to address this gap by systematically investigating the influence of angle ply orientation on the tensile properties of carbon/glass and Kevlar/glass hybrid composites. Through experimental analysis, this study will explore how different fiber orientations affect key tensile properties such as tensile strength, flexural strength, and compression strength. The findings are expected to contribute to the optimization of hybrid composite materials, enhancing their application in advanced engineering fields where performance and reliability are crucial.

2. LITERATURE REVIEW

The use of hybrid composites, which combine different types of fibers within a single matrix, has emerged as a promising approach to achieving an optimal balance of tensile properties tailored to specific engineering applications. Among these, carbon/glass and Kevlar/glass hybrid composites have garnered considerable attention due to their potential to enhance strength, stiffness, and impact resistance [3, 4]. The orientation of fiber plies within these composites, known as angle ply orientation, is a critical factor that significantly influences their tensile behaviour. This section reviews the existing literature on the influence of angle ply orientation on the tensile properties of these hybrid composites.

Hybrid composites are designed to leverage the synergistic effects of combining different fibers, typically leading to improved tensile properties over single-fiber composites. Carbon fibers offer high stiffness and strength but are brittle, while glass fibers provide better impact resistance and are more cost-effective [2]. Kevlar fibers, known for their excellent toughness and energy absorption, are often used in applications requiring high impact resistance. The combination of these fibers in various configurations can result in composites that exhibit desirable properties for a range of structural applications [5].

Angle ply orientation has been widely studied in the context of single-fiber composites, with numerous studies highlighting its significant impact on tensile properties. For instance, demonstrated [6] that the orientation of plies affects the stiffness, strength, and failure mechanisms of carbon fiber-reinforced composites. The ply orientation determines the load distribution across the composite and influences its overall tensile performance. Similar effects have been observed in glass fiber-reinforced composites, where different ply angles resulted in varying degrees of tensile and flexural strengths [7,8]

However, studies focusing on hybrid composites are relatively scarce. On investigated the tensile properties of carbon/glass hybrid composites, revealing [5] that the orientation of plies plays a crucial role in determining the composite's stiffness and impact resistance. Their work showed that a balanced angle ply orientation could lead to an optimized combination of the stiffness from carbon fibers and the impact resistance from glass fibers. Meanwhile, on Kevlar/glass hybrid composites [4, 9,10] highlighted that specific ply orientations could enhance the overall toughness and energy absorption capabilities of the material.

While individual studies have explored the properties of carbon/glass and Kevlar/glass hybrid composites, comparative studies are limited. In a study [11] the authors compared the tensile and flexural properties of these hybrid composites and found that carbon/glass hybrids generally exhibit higher stiffness, while Kevlar/glass hybrids offer better impact resistance. However, their work did not extensively explore the role of ply orientation in these differences, leaving a gap in the understanding of how angle ply orientation influences the comparative performance of these hybrids.

3. OBJECTIVES

1. Selection of the matrix and the reinforcement materials based on the literature study.
2. Investigate the Effect of Angle Ply Orientation on Tensile properties.
3. Compare the Tensile Properties of Carbon/Glass and Kevlar/Glass Hybrids.
4. Analyze the failure mechanisms and interfacial bonding within the composites using scanning electron microscopy.
5. To determine the optimal ply orientation that maximizes the tensile properties of these hybrid composites.

4. EXPERIMENTAL DETAILS

4.1 Fabrication of FRP based Angle Ply Hybrid Composites

Fabrication, materials and methods used for the processing angle ply hybrid specimen were discussed in this chapter. The methodology related to the preparation of Composites laminated were fabricated at room temperature by hand layup technique. Proper care was taken during fabrication of laminates to ensure uniform thickness minimum voids in the material and maintain homogeneity. The vacuum bag process is carried out after hand layup process. This method produces high-quality moulding, with complete exclusion of air bubbles and improvement to the inner surface of the moulding, which is not in contact with the mould.

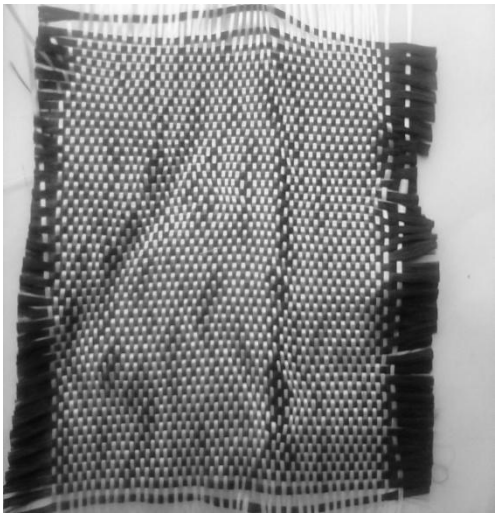


Fig. 1. Carbon/glass bi woven hybrid cloth.



Fig. 2 Kevlar/glass bi woven hybrid cloth.

The entire test specimen has been prepared as per the ASTM standard. After obtaining the hybrid laminate of size 0.5mx0.5m with 3mm thickness. Depending upon the no of specimens required specimen drawing has to be mark on the surface of the laminate.

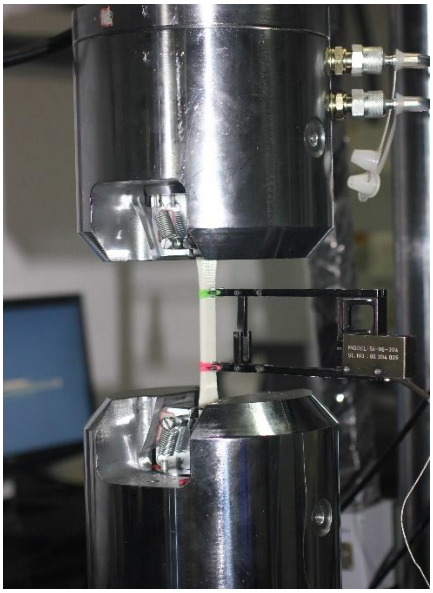


Fig. 3. Tensile specimen held in UTM Machine.



Fig. 4. Kevlar/Glass-Tensile test specimen.

Table 1. Tensile (Carbon/Glass Data).

Type of specimen	Orientation	Peak load (KN)	Peak stress (MPa)	Tensile Modulus (GPa)	Specific Strength (MPa/kg/m³)	Avg Specific Strength (MPa/kg/m³)	Specific modulus (MPa/kg/m³)	Avg Specific modulus (MPa/kg/m³)
Carbon/Glass	$0^0/90^0$ Tensile	31.26	428.16	34.9	0.30	0.31	24.20	25.01
		31.45	432.58	37.92	0.30		26.30	
		33.53	455.60	35.35	0.32		24.52	

Type of specimen	Orientation	Peak load (KN)	Peak stress (MPa)	Tensile Modulus (GPa)	Specific Strength (MPa/kg/m³)	Avg Specific Strength (MPa/kg/m³)	Specific modulus (MPa/kg/m³)	Avg Specific modulus (MPa/kg/m³)
Carbon/Glass	$60^0/30^0$ Tensile	8.14	113.77	13.70	0.08	0.078	9.50	9.46
		7.32	101.56	14.14	0.07		9.81	
		8.31	113.67	13.08	0.08		9.07	

Table 2. Tensile (Kevlar/Glass Data).

Type of specimen	Orientation	Peak load (KN)	Peak stress (MPa)	Tensile Modulus (GPa)	Specific Strength (MPa/kg/m³)	Avg Specific Strength (MPa/kg/m³)	Specific modulus (MPa/kg/m³)	Avg Specific modulus (MPa/kg/m³)
Kevlar/Glass	$0^0/90^0$ Tensile	29.54	409.93	29.21	0.29	0.286	21.08	21.98
		30.51	406.46	34.89	0.29		25.17	
		29.50	393.86	27.29	0.28		19.69	

Type of specimen	Orientation	Peak load (KN)	Peak stress (MPa)	Tensile Modulus (GPa)	Specific Strength (MPa/kg/m³)	Avg Specific Strength (MPa/kg/m³)	Specific modulus (MPa/kg/m³)	Avg Specific modulus (MPa/kg/m³)
Kevlar/Glass	$60^0/30^0$ Tensile	9.42	132.96	11.34	0.096	0.096	8.18	7.68
		9.81	133.39	11	0.10		8.46	
		8.96	126.49	8.86	0.091		6.39	

Specimens were prepared for three different orientations such as 0/90, 60/30 in order to evaluate tensile properties. Different tests specimens such as Tensile, flexural were prepared as per ASTM standard. Since the laminate is hard, it is not possible to cut by hacksaw or other cutting methods. Hence it is done by abrasive water jet machining process. For Tensile specimen ASTM standard D 3039 has been used.

5. RESULTS

Fibre–matrix debonding, matrix crack and fibre pull out is more evident in hybrid composite carbon/glass, compared to Kevlar/glass hybrid composites. Fracture of fibre with little or no pull out of glass fiber is visible from the image (Fig. 5).

5.1 SEM Analysis

Fibre–matrix debonding, matrix crack and fibre pull out is more evident in hybrid composite carbon/glass, compared to Kevlar/glass hybrid composites. Fracture of fibre with little or no pull out of glass fiber is visible from the image (Fig. 5).

This may be because of lesser extensibility of glass fibers under tensile loading. SEM micrograph of the carbon/glass or Kevlar/glass hybrid composite (Fig. 6) reveals that fiber bundle deboned and cracks in matrix. It is observed from the SEM that glass fibre shows more densified and compact structure than the carbon or Kevlar fibers, thus, the tensile properties of carbon/glass fibers are higher compared with Kevlar/glass fibers.

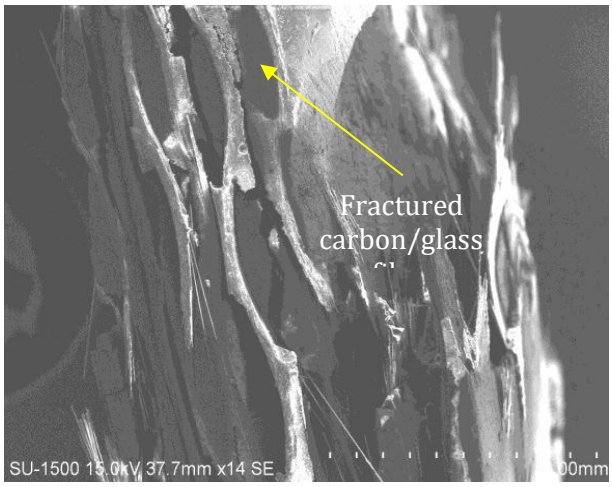


Fig. 5. Fractured Carbon / Glass Tensile Test Specimen.

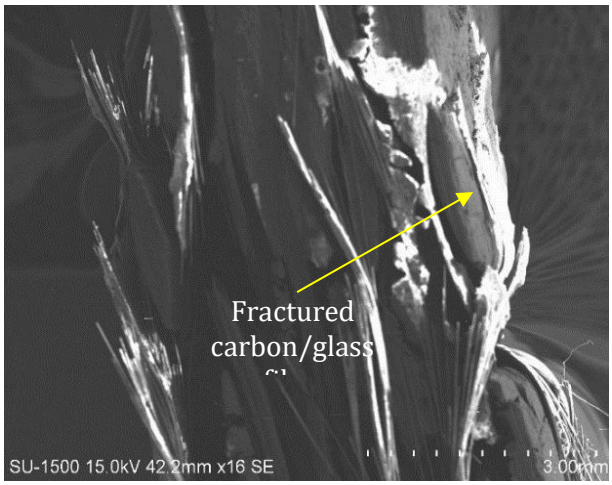


Fig. 6. Fractured Kevlar / Glass Tensile Test Specimen.

6. CONCLUSIONS

The stiffness, strength, and modulus of hybrid specimens, using different fiber systems as the core and an epoxy resin matrix, were evaluated according to ASTM standards. The results from simple tests on these hybrid specimens show excellent agreement with the expected values.

The tensile properties of composite materials are influenced by their structure, volume fraction, and interfaces. In tensile tests, 0°/90° hybrid composites showed superior strength, as glass fibers at 90° carry most of the load, with carbon fibers. Tensile tests revealed that the specific strength of carbon/glass hybrid composites increased by 7.74%, 20.2% in the 0°/90°, 60°/30° orientations, respectively, compared to Kevlar/glass hybrids. However, the specific modulus of Kevlar/glass composites showed a slight increase of 12.11%, 18.81% over carbon/glass hybrids failing first due to their brittleness. Scanning electron micrographs confirmed good interfacial bonding but also revealed voids, which degrade strength, with optimal properties observed in the 0°/90° orientation.

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