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Evaluation of the Impact Properties of Glass/Kevlar Intra-Layer Hybrid Composites with Different Fabric Orientations

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Abstract— *This study investigates the impact properties of glass/Kevlar intra-layer hybrid composites with different fiber orientations. Three composite laminates were fabricated using a hand lay-up process with various stacking sequences: GK1 (0°, 90°)₂s, GK2 (+45°, -45°)₂s, and GK3 (0°, +45°, 90°, -45°)s. Impact behavior was assessed using a drop-weight test at three energy levels (10 J, 20 J, and 30 J). Load–displacement curves, peak load, and energy absorption were analyzed. Results revealed that the GK2 configuration exhibited the highest peak load (3.56 kN) at 30 J, attributed to its ±45° fiber orientation, while GK3 showed the lowest value (3.09 kN). The findings confirm that intra-layer hybridization and fiber orientation significantly influence energy absorption and impact resistance, providing useful insights for structural applications requiring high impact tolerance.*

Keywords— *Glass/Kevlar hybrid composites; impact resistance; drop-weight test; fiber orientation; stacking sequence.*

I. INTRODUCTION

Highlight a Composite materials have become indispensable in modern engineering due to their superior strength-to-weight ratio, corrosion resistance, and ability to be tailored for specific applications such as aerospace, automotive, and defense [1]. Within the wide range of composite systems, hybrid composites—which incorporate two or more types of fibers in a polymer matrix—have attracted significant attention because they combine the advantages of different reinforcements, offering balanced mechanical and impact properties that are difficult to achieve with single-fiber composites [2], [3].

Hybridization can be achieved in different forms: interlayer (alternating layers of different fibers), intralayer (fibers mixed within the same ply), and intrayarn (fibers combined within the same yarn) [2]. Among these, intralayer hybrids are particularly effective because they allow simultaneous distribution of different fibers within the same ply, improving load transfer, reducing stress concentration, and enhancing damage tolerance [3], [4].

Glass and Kevlar fibers are two of the most widely used reinforcements in hybrid laminates. Glass fibers provide excellent stiffness, tensile strength, and low cost, whereas Kevlar fibers contribute superior toughness, impact absorption, and resistance to crack propagation [5]. Therefore, their combination in hybrid laminates offers an effective balance of stiffness and toughness. Previous studies have confirmed that hybrid Kevlar/Glass composites show enhanced impact resistance, energy absorption, and structural stability compared to single-fiber composites [5], [6].

Recent years have witnessed several important contributions in the field of hybrid composites reinforced with glass and Kevlar fibers.

In (2023), Xu, Zhang, Shen, Huang, Qiu, and Wu investigated the low-speed impact of glass/Kevlar interlayer hybrid laminates, reporting that Kevlar content increased energy absorption whereas glass exterior layers improved peak load [7]. In another 2024 study, Zheng, Wang, Yang, Zhang, Chen, and Xu examined three-dimensional woven Kevlar/Glass hybrid composites and demonstrated that carbon and glass integration with Kevlar fibers significantly enhanced stiffness and impact resistance, providing balanced performance for structural use [8]. In the same year, Ahmad, Shah, Siddiqi, Afaq, Azad, and Arif developed and characterized Kevlar/Glass reinforced epoxy/vinyl ester laminates, confirming through computational and experimental approaches that ±45° orientations and optimized stacking sequences resulted in superior energy absorption and load redistribution [9].

Also, in (2023), Jensin Joshua compared intra-ply versus inter-ply Kevlar/Glass hybrids, showing that intra-ply laminates achieved higher energy absorption and better delamination resistance [10].

In ((2024), Ishtiaq, Anwer, Khalid, Khurram, and Rehman evaluated high GSM Glass–Carbon–Kevlar laminates across eleven stacking configurations and reported excellent tensile, flexural, and impact properties in selected designs [11]. The most recent (2025) work by Vasudevan, Vigneshwaran, Balasubramanian, and co-authors assessed intra-ply carbon–Kevlar composites and confirmed that ±45° fiber orientations provided superior peak load and reduced crack propagation compared to single-fiber laminates [12].

II. MATERIALS AND METHODS

Materials: Plain-woven glass/Kevlar hybrid fabrics were used with epoxy resin.

Layup Configurations:

GK1: (0°, 90°)₂s

GK2: (+45°, -45°)₂s

GK3: (0°, +45°, 90°, -45°)s

Specimens measured 100 × 150 mm according to ASTM D7136. Fabrication was performed via hand lay-up, with

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rolling for air removal and curing at room temperature for 48 h.

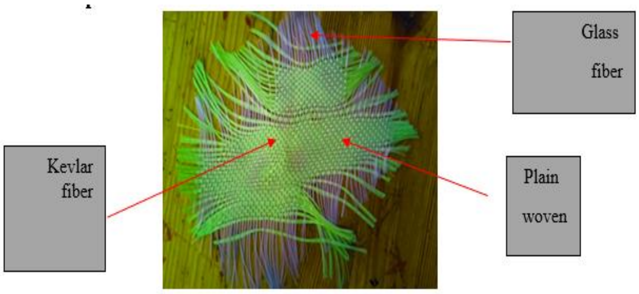


Fig. 1. Glass Kevlar hybrid fabric plain woven

Fig. 2. specimens

Impact Test: Drop-weight impact was carried out on a ZWICK/ROLLE HIT 230-F using a 4.075 kg hemispherical indenter at 10, 20, and 30 J energy levels (drop heights ~250 mm, 500 mm, 751 mm). Peak load, displacement, and absorbed energy were recorded.

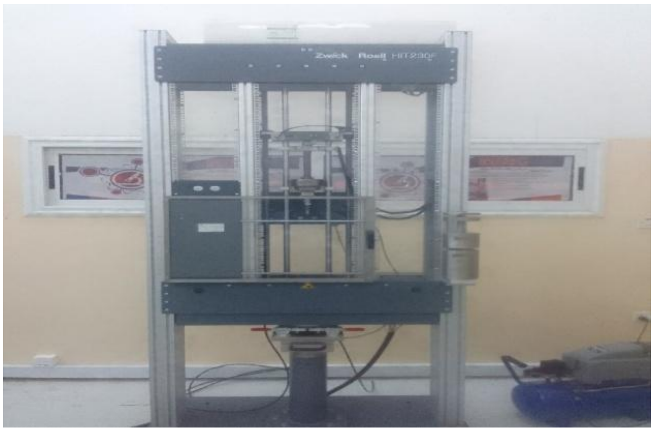


Fig. 3. Zweick / Rolle Hit 230-F Drop Weight Test

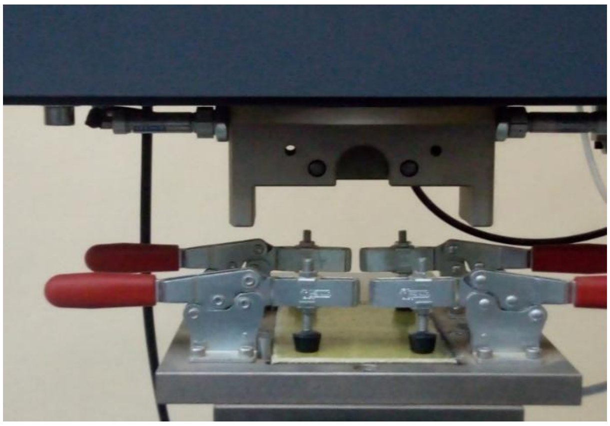


Fig. 4. Specimen under impact test

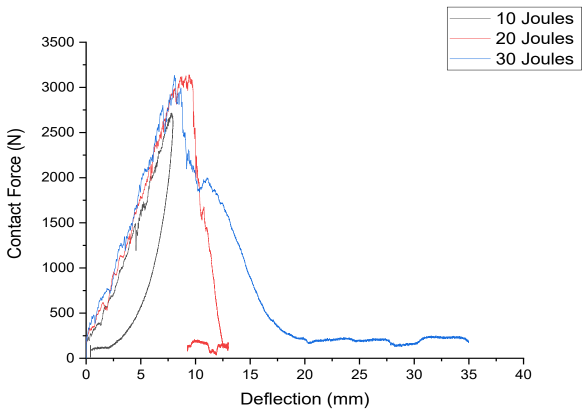
III. Results and Discussion

The load-displacement plots at different energy levels have been obtained by using the drop weight testing method in order to analyze the impact damage, sample GK1, GK2 and GK3 were struck with energy of 10J, 20J, 30J, the results were obtained from test were showed in table below

Impact properties of obtained from the test

Sample	Impact energy (J	Force max (KN)	Displacement (mm)
GK1	10	2.71	0
	20	3.137	13
	30	3.133	20
GK2	10	2.70	0
	20	2.94	12.5
	30	3.568	19.5
GK3	10	2.80	0
	20	3.04	12.5
	30	3.09	19.8

GK2 performed best, achieving the highest peak load at 30 J due to its ±45° fiber orientation which promotes stress redistribution and mitigates delamination. GK3 exhibited the lowest peak load at high energy, confirming the influence of stacking complexity. The results are consistent with earlier studies [1]–[6], where ±45° orientations were linked to improved energy absorption and damage tolerance.



The Load- Displacement impact curve of sample GK1(0,90)2s

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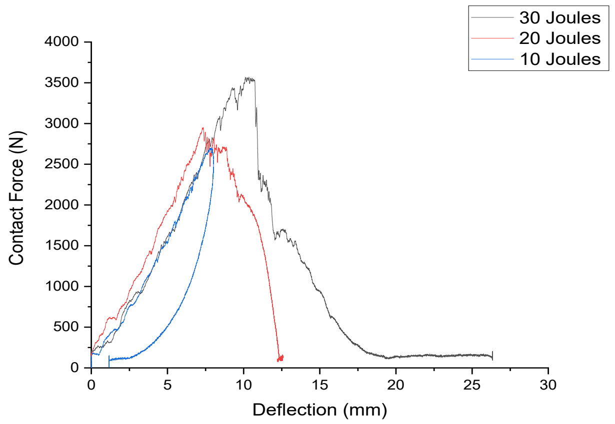
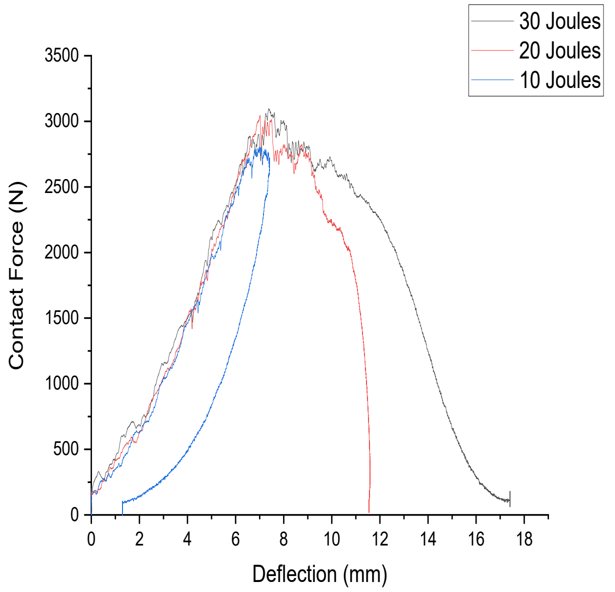
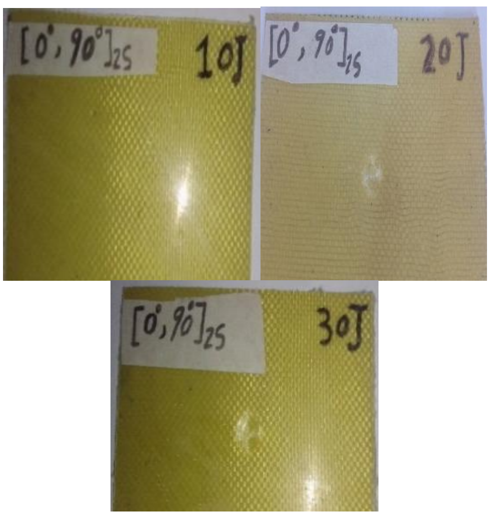


The Load- Displacement impact curve of sample GK2 (45,45)2s



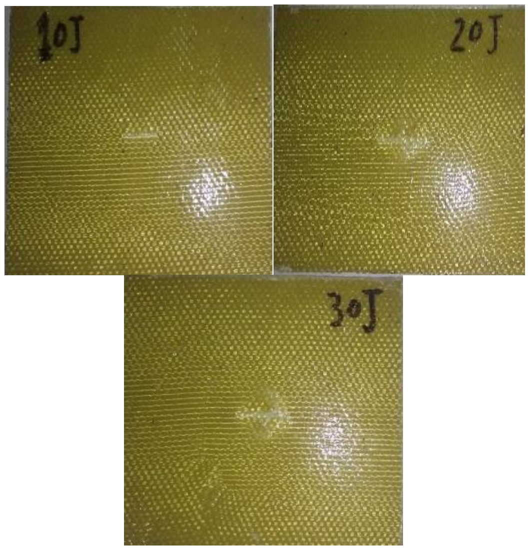
The Load- Displacement impact curve of sample GK3 (0,+45,90,-45)2s



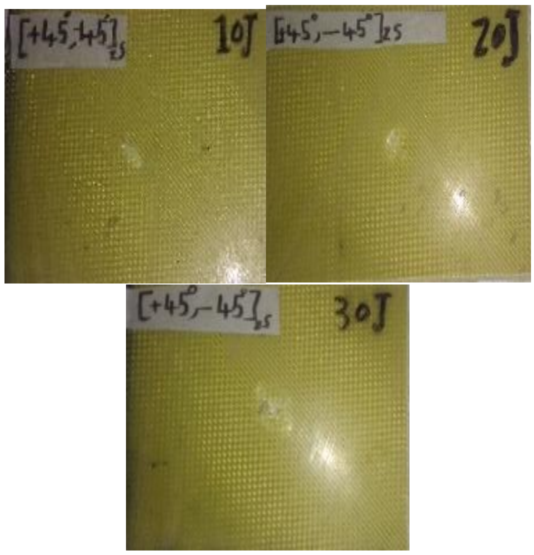
GK1 specimen face side after the drop weight test at 10,20,30J

Failure mode:

The absorbance energy of the impact test which indicates the peak load, displacement at peak load of all hybrid specimens, and the figures shows the damage size of all samples in low energy level only matrix cracking and the energy was absorbed completely by all specimens, in medium and high energy level the damage size increase and different peak loads and displacement, GK2 showed highest peak loads due to the orientation of fiber +45, -45.



GK1 specimen back side after the drop weight test at 10,20,30J



GK1 specimen back side after the drop weight test at 10,20,30J

IV. Conclusion

This study evaluated the drop-weight impact response of intra-ply glass/Kevlar laminates with different orientations. GK2 (+45°, -45°)2s achieved the best performance, confirming that ±45° orientations play a decisive role in enhancing impact resistance. The findings align with recent literature and provide design insights for hybrid composites in aerospace, automotive, and structural applications requiring high impact tolerance.

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