EFFECT OF LAYUP PLACEMENT ON TENSILE PROPERTIES OF E-GLASS/KEVLAR 49 EPOXY BASED HYBRID COMPOSITES

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ABSTRACT: *Hybrid composites have great potential for engineering applications by strength- to- weight ratio characteristics. The composite materials are anisotropic and their mechanical properties can be controlled by effective use of fibers and fiber placement orientation angles. In the present work, laminates are fabricated with E-glass/epoxy and E-glass/Kevlar epoxy of commercial grade (601A). Vacuum bagging resin transfer molding technique was employed in the preparation of sheets. ASTM-3039 standard was used for the preparation of specimens. In order to investigate the effect of layup placements, the layers were placed on an open mold at 0°/90°, 45°/45° and 30°/60° angles. An attempt has been made to evaluate mechanical properties such as tensile strength, tensile modulus and peak load. The results obtained revealed that Glass fiber Kevlar orientated at 0°/90° possess superior mechanical properties.*

Keywords: Hybrid composites, Tensile properties, Kevlar 49, Glass fibers, Vacuum Bagging Resin Transfer Molding technique.

INTRODUCTION

The composite materials are made by combination of two or more than two materials having distinct phase. Among the materials hybrid composites are those composites which contain different fibers at different weight % and orientations. There is a range of advantages of composite materials over other conventional materials such as improvement in tensile strength, impact strength, flexural strength, stiffness and fatigue characteristics. The composite materials are being widely used in aerospace, automobile, ships, sports goods, etc. [1,2].

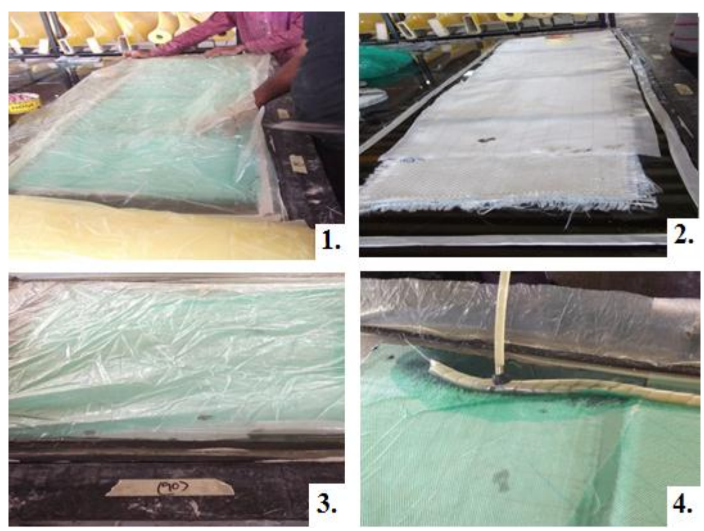
High strength Aramid fiber with trade name Kevlar 49 is an ideal reinforcement material for structural and aerospace industries where large deformation and toughness is required. For strength –to- weight concern Aramid fiber is five times better than steel [2]. Kevlar fibers are effective for resistance to penetration when struck by the bullet and used for making bullet proof jackets in the armed forces and for other military applications. Failure mechanism of Kevlar fibers is not in a brittle manner, when failure takes place in Kevlar fibers it converted into small fibrils. The fibrils are molecular strands that combine to form Kevlar fibers, each fibrils have own capacity to absorb energy that's why Kevlar fibers have high value of toughness [3,4]. Reinforcement fibers, angle ply orientation and volume fraction are effective tools for fabrication of composite materials for specific applications. The fabrics of glass have high strength and placed out the layers for making tough and stiff laminates. Epoxy resin and epoxy hardener has bonding strength and employed within layers of fibers to produce rigid and environment resistance materials [4]. Kevlar fibers reinforcement with glass fibers has tremendous achievement to produce less dense materials having improved strength [5,6]. The mechanical properties of composites materials are strongly depend upon the proper reinforcement of fibers and their orientation angles. Aramid fibers have in-plane strength and employed within the layers of composite laminates [7,8,9].

In this work, hybrid composites were fabricated by stacking layer by layer by using vacuum resin transfer molding. Thickness of the laminate maintained at around 3-4mm according to ASTM standard [1].

EXPERIMENTAL WORK

(a) Specimen Fabrication

Figure 1 shows the fabrication of laminates by using te open mold technique. Hybrid composite sheets of 9 layers with 4mm thickness were fabricated at room temperature under the pressure of 30-100psi in shape of square plates by hand layup technique. The vacuum bagging resin transfer molding techniques were employed in order to avoid air leakage from the mold cavity and to enhance the boding between the layers with matrix. E-glass fiber (Roving) grade 600GSM with thickness of 0.6mm stacked with Kevlar 49 of 0.5mm thickness. The epoxy resin commercial grade and epoxy hardener at the ratio of 3:4 were selected for fabrication of sheets. In this study, specimens were prepared at different fiber orientation such as 0˚/90˚, 45˚/45˚ and 30˚/60°, as shown in Figure 3. All the specimens were prepared according to ASTM-3039 standard, schematic diagram is given in Figure 2.



Figures 1: Fabrication sequence for preparation of specimens. (1) Bagging with sealing tap, (2) Peel ply placement, (3) Bagging for GF (0˚/90˚) and (4) Resin transfer molding process.

The laminate of same thickness of E-glass fibers (Roving) and epoxy as matrix were also made at 0˚/90˚ layup placement. Finally, curing of thermosetting was carried out at room temperature for 24 hours, purpose of curing was to transform the liquid into hardened product. Table 1 indicates the layup placement of hybrid composites at different layers.

Table 1. Layers and fibers orientation of each laminates structure.

Layers formation	Layers	Layers of Glass fiber (Roving)	Layers of Kevlar fibers 49	Angle of orientation G.F	Angle of orientation of K.F
A	09	09	_	(0°/90°)	-
B	09	05	04	0°	90°
C	09	05	04	30°	60°
D	09	05	04	45°	45°

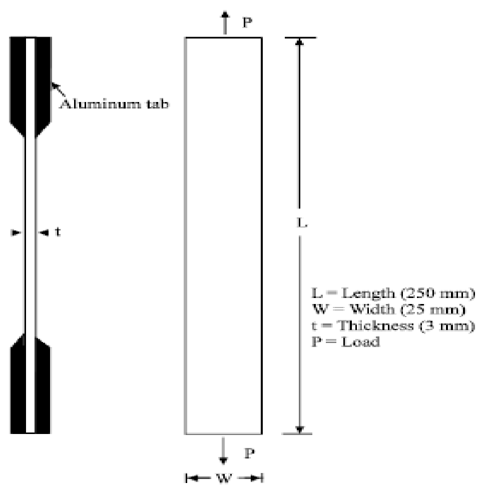


Figure 2. Sample dimensions for tensile test (ASTM-3039).

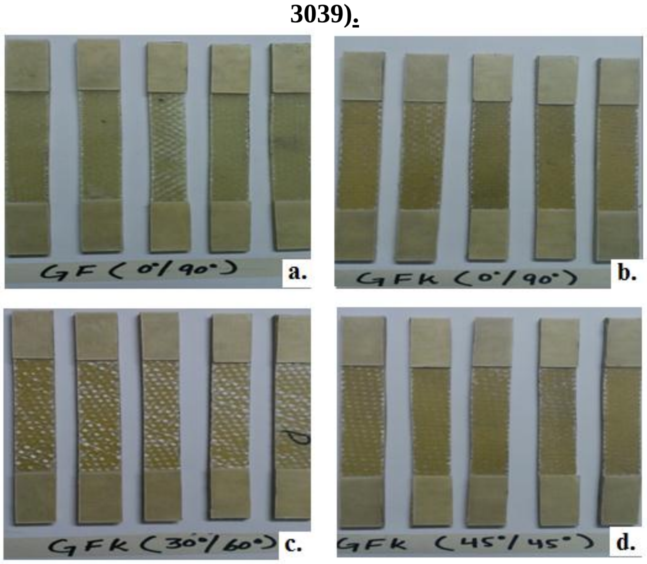


Figure 3. (a) Specimens of Glass fiber at 0°/90° angle, (b) Specimen of Glass fiber Kevlar at 0°/90°, (c) specimens of Glass Fiber Kevlar at 30°/60° and (d) Specimens of Glass Fiber Kevlar at 45°/45°.

(b) Tensile Tests

Tensile test is fundamental mechanical testing method in which standard test specimens are subjected to uniaxial tension and compression. Stress-strain curve is the result obtained from the tensile test in which tensile modulus, tensile strength, percentage elongation and percentage in area reduction is calculated [1]. The 50KN Electronic universal testing machine as shown in Figure 4 was used to conduct tensile test. Five standard test specimens of each orientation were prepared as per ASTM-3039 standard for tensile test (Figure 3). Specimens were placed between the flat grip of tensile testing machine and load is applied. The strain rate was adjusted at 2mm/min till the failure of test specimen occurred.

Figure 4: 50KN Electronic Universal Testing Machines.

RESULTS AND DISCUSSION

Figure 5(a-d) shows stress-strain results of E-glass/epoxy (0°/90°) and E-glass/Kevlar-49 epoxy hybrid laminates with orientations (0°/90°), (45°/45°) and (30°/60°), respectively. The laminates were fabricated by using vacuum bagging resin transfer molding technique. Figure 5(a) shows maximum tensile strength values for E-glass/Kevlar 49 epoxy based hybrid composites with angle ply (0°/90°) having parallel alignment of the longitudinal axis of the fibers. Graphical results from the tensile test exhibited in Figure 5(b) in which lay-up placement 0°/90° are in good agreement [3]. The similar findings were reported by Alam *et al.* and Hossain *et al.* [2, 6]. The peak stress or ultimate tensile strength observed at angle ply of 0°/90° with 63.34% deformation, which is greater than angle ply of 45°/45°, similarly statistical analysis of tensile strength results of angle ply 30°/60 is found to be 61.44% deformation. The ultimate tensile strength or peak stress value in layup placement of Glass fiber at 0°/90° is much greater than 45°/45° and 30°/60 but lesser than Glass fiber Kelver at 0°/90°.

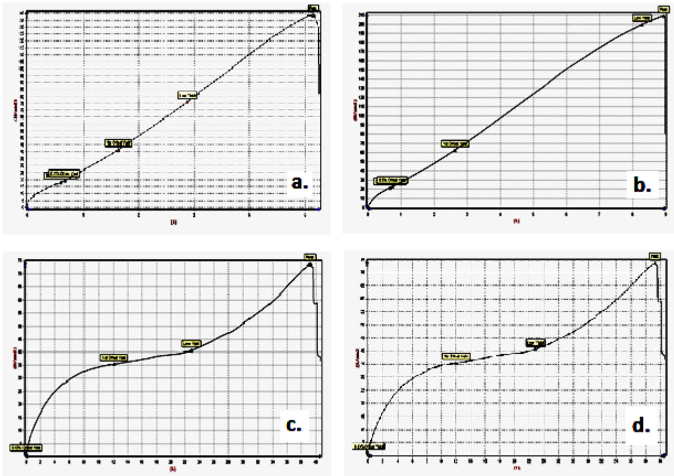


Figure 5: a. Stress-Strain Curve of E-glass Fibers/epoxy at (0°/90°) angles, b. Stress-Strain Curve of Glass Fibers – Kevlar-49 at (0°/90°) angles. c. Stress-Strain Curve of Glass Fibers – Kevlar-49 at (45°/45°) angles and d. Stress-Strain Curve of Glass Fibers – Kevlar-49 at (30°/60°) angles.

It can be concluded that the composites fabrication direction of fibers in the matrix influences the mechanical properties of the designed composite. Figures 5(b) and 5(c) indicate the specimens with the fiber orientation 0°/90° and 45°/45° have highest and the lowest value of tensile strength, but in case of elongation (%) their value is reverse. Figure 5(b) shows the angle ply orientation of 0°/90° have maximum value of tensile strength than other orientations (45°/45° and 30°/60°). So it could be due to equal distribution of externally applied load on specimen having angle ply orientation at 0°/90°. Similar conclusions are drawn by Satish *et al*. [10]. Above discussed results are further elaborated in the form of bar chart in Figure 6, which clearly indicates that composite with glass fiber Kelver at 0°/90° has 200MPa peak stress value.

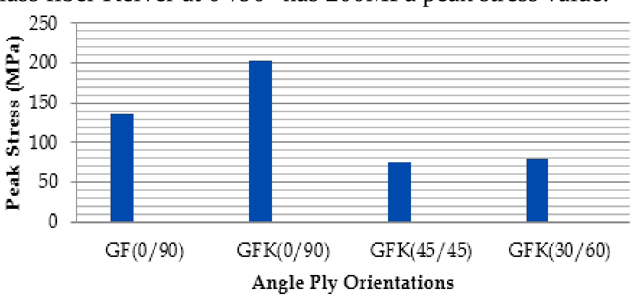


Figure 6: Tensile strength of GFK at different angle ply orientations.

The density is defined as the average number of matrix cracks in each hybrid layer per unit length in the longitudinal directions. From Figure 7(a) it can be observed that specimen for GFK with 0˚/90˚ orientation has failed in brittle manner with a maximum value of tensile strength i.e., 230.60 MPa. This can be explained that the strength of the composite is increased by the interlocking of rovings during tensile loading due to deformation. Figure 7(c) indicates the angle ply orientation of 45˚/45˚ matrix nucleated from the central part of the specimen and delimitations appears at the surface of fractured specimens. The damage initiation takes time by interleaving the angle ply orientations of hybrid composites. Figure 7(a-d) reveals that angle ply at 0˚/90˚ has maximum matrix fibers bond strength and has superior value of tensile strength than other orientations. Whereas, fiber orientation at 45˚/45˚ and 30˚/60˚ exhibits higher percentage of elongations as compared with 0˚/90˚ orientation.

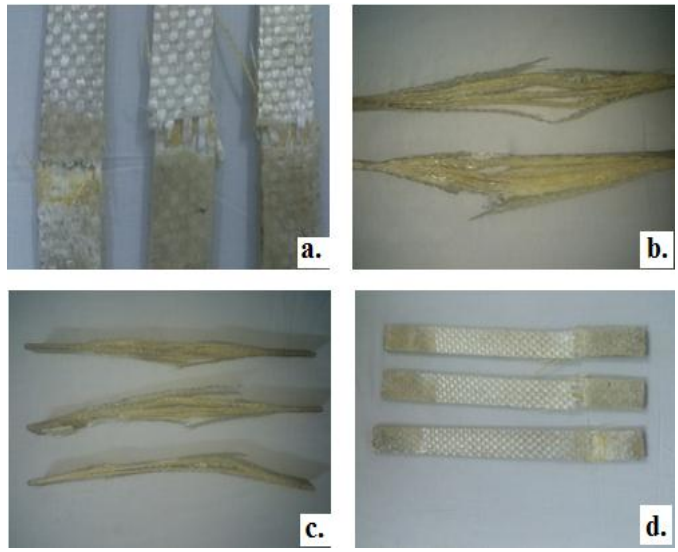


Figure 7. Matrix cracking behavior of samples at different ply orientations after the tensile tests. (a) Glass fiber Kevler at 0°/90°, (b) Glass fiber Kevler at 30°/60°, (c) Glass fiber Kevler at 45°/45° and (d) Glass fiber at 0°/90°.

CONCLUSION

Experimental investigations were carried out to study the tensile properties of the Glass fiber Kevlar hybrid composites. The difference in orientation significantly improves the mechanical properties of laminates. The glass fibers Kevlar at 0°/90° orientation possess maximum value of tensile strength than 45°/45° and 30°/60° oriented fibers by lay-up method. From the designing point of view, it can be concluded that where strength and toughness are required the angle ply orientation 0°/90° is an affective tool to produce mechanically sound structure, but in case, where the specific strength and elongations are required, the laminates at the angle of 30°/60° and 45°/45° are best choice.

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