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# Evaluation of Impact Strength of Epoxy Based Hybrid Composites Reinforced with E-Glass/Kevlar 49

SUBHAN ALI JOGI\*, MUHAMMAD MOAZAM BALOCH\*\*, ALI DAD CHANDIO\*\*\*, IFTIKHAR AHMED MEMON\*, AND GHULAM SARWAR CHANDIO\*\*\*\*

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## ABSTRACT

In hybridization different fibers are stacked layer by layer to produce laminates have specific strength and stiffness and employed in light weight high strength applications. Physically mean fabricated hybrid composites used in aerospace, under water, body armors and armed forces establishment. In present work drop-weight impact response of hybrid composites were investigated by making laminates of hybrid composites. In Hybridization layers of E-glass (roving) and Kevlar 49 fabrics stacked with epoxy resin. The layers formulation was set up by hand layup method. Impregnation of epoxy resin of commercial grade (601A) in fabrics were accomplished by VRTM (Vacuum Bagging Resin Transfer Molding) technique. Layup placement of Glass fibers/ Kevlar at  $0^{\circ}/90^{\circ}$ ,  $45^{\circ}/45^{\circ}$  and  $30^{\circ}/60^{\circ}$  were set for this work. Mechanical properties such as impact strength, bear resistance and break resistance were analyzed by using ASTM D-256 and D-3763 standard. Experimental investigation was conducted using instrumented Dart impact and Izod Impact test. E-glass/Kevlar 49 at layup  $0^{\circ}/90^{\circ}$  and  $30^{\circ}/60^{\circ}$  exhibited improved impact strength than  $45^{\circ}/45^{\circ}$ . The surface morphology and fractography were also investigated by capturing different images of Specimens by using the SEM (Scanning Electron Microscopy). The fiber reinforcement and matrix fracture were also observed by using SEM. The SEM images suggest that epoxy resin tightly bonded with Kevlar fibers whereas Glass fibers were pulled out from laminations.

**Key Words:** Hybrid Composites, Bear Resistance, Break Resistance Glass/Kevlar Fiber Reinforced Composite, Vacuum Bagging Resin Transfer Molding, and Scanning Electron Microscopy.

## 1. INTRODUCTION

High strength aramid fibers placed as core materials in laminates for combination of strength and ductility. Hybrid composites known for their strength-to-weight ratio and ability to absorb energy when struck by bullet therefore used for making body armors for armed forces establishment. Aramid fibers have symmetric in their internal structure

(Zhu et. al. [1]). Aramid fibers extensively used in air craft design, boat hulls, sports goods and armed forces applications (Reis et. al. [2]). Kevlar fibers cross-linked with thermosetting resin to produced hardened product. Aramid fibers have specific strength and stiffness and incorporated matrix where toughness is required (Reis et. al. [3]). Layup placement and reinforcement fibers are

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Corresponding Author (E-Mail: subhan.2005@yahoo.com)

\* Department of Metallurgy & Material Engineering, Dawood University of Engineering & Technology, Karachi.

\*\* Department of Metallurgy & Materials Engineering, Mehran University of Engineering & Technology, Jamshoro.

\*\*\* Department of Metallurgical Engineering, NED University of Engineering & Technology, Karachi.

\*\*\*\* Department of Industrial Engineering & Management, Dawood University of Engineering & Technology, Karachi.

effective tools for fabrication of hybrid composites. E-glass fibers have high tensile strength and placed out for making stiff sandwich structure (Alam et. al. [4]). For light weight high strength applications reinforcement of Kevlar fibers with glass fibers have significant achievement to fabricate low density materials having enhanced impact strength (Wang et. al. [5]). Impact strength of hybrid composites strongly depends upon the selection of reinforcement and layup placement. Kevlar fibers have inter-laminar fracture toughness and working as core material for effective hybridization. Hybrid composites are fabricated by stacking layers by layers with vacuum bagging resin transfer molding technique. Thickness of the laminate maintained at around 3- 4mm according to ASTM standard (Reis et. al. [2]). Glass fiber reinforcement polymer has considerable application where light weight and high strength is required. Mechanical strength of composites material relies on the way of layup placement. The glass fibers as reinforcement materials are frequently used in aerospace and construction industries. Aramid fibers reinforcement polymers exhibit superior ultimate tensile strength, elastic modulus and impact energy (Reis et. al. [3]). Kevlar fiber of 5-7mm enhanced the delamination toughness. Kevlar fibers used as core material in lamination and improve the fracture toughness of the composite structures (Sohn et. al. [6]). Kevlar fibers have specific strength associated with failure mechanism and used in impact performance at low weight. Aim of present work is to discuss the experimental results obtained by changing angle ply orientation of reinforced materials. Impact properties of the materials are analyzed by calculating potential energy in joules by observing break and bear resistance of the materials using instrumented dart impact test. Izod impact test also conducted using izod impact tester to observe impact energy joules/meter.

## 2. EXPERIMENTAL WORK

### 2.1 Specimen Fabrication

Laminate of 9 layers 4mm thick were fabricated at room temperature under pressure of 30-100 Psi. Fabrication process is shown in Fig. 1(a-d). Sheets are prepared with E-glass/epoxy and E-glass/Kevlar epoxy by hand layup technique. The vacuum bagging resin transfer molding

technology was used in order to avoid air escape from the mold cavity and to improve the bonding of layers and matrix. Thermosetting resin is effective tool to improve the cross-linking between the thermoplastic and enhance the impact strength of the laminates. For specimen fabrication layup placement of 0°/90°, 45°/45° and 30°/60° were selected. Finally, the laminate cured at room temperature for 24 hours, curing was performed to transform thermoplastic liquid into hardened product. Layup placement of hybrid composites is given in Table 1.

### 2. DART IMPACT TEST

Drop weight impact tester designed to calculate break and bear resistance of fibers reinforcement in polymers. The drop-dart test conducted with various loading conditions at room temperature. The adjusted falling speed of impactor was 4.43m/s and 50 Joules of energy. Falling height in dart impact tester is 1000mm and falling mass is in range from 510-550g (Fig. 2).

ASTM D-3763 standard specimens for dart impact test were in square shape measuring 2x2in. Impact energy in form of potential energy (joules) was calculated by using  $PE = mgh$ .

### 2.3 Izod Impact Test

Izod impact test measure the toughness of the materials. The Izod impact powerfully depends on size of the specimen being tested because number of imperfection acts as stress raisers and deduce the fracture toughness of the laminate. The Izod impact test was conducted by selecting different specimens and these specimens were designed as per ASTM D-256 standard. The dimension of the specimens were 6.4x12.7x3.2 mm and radius of the notch was 0.25R having notch length of 2mm (Fig. 3 and Fig. 4 (a-d)).

## 3. SCANNING ELECTRONIC MICROSCOPY

Izod impact test specimens were selected for SEM. Abrasive disc (V101) cutter was used to separate the fracture zone. As received samples were investigated to analyze the angle ply orientation and surface morphology. SEM images with various magnifications were selected by using 5 KV secondary beam electrons. Experimental results such as

matrix fiberbond strength, fracture of laminate and arrangements fibers were evaluated by using scanning electronic microscopy (Fig. 5).

#### 4. RESULT AND DISCUSSION

The load bearing capacity of hybrid laminates were characterized by using Dart Impact Test. Specimens was

tested with different angle ply orientation, their resistances to penetration were observed by analyzing bear and break resistance. Considerable data have been generated regarding the bear and break resistance mentioned in the bar graph shown in Fig. 6 at GF 0°/90° and GFK 0°/90°, 45°/45° and 30°/60°.



(a) PEEL PLY PLACEMENT



(b) BAGGING WITH SEALING TAP



(c) BAGGING FOR GF 0°/90°



(d) RESIN TRANSFER

FIG. 1. VRTM PROCESS

TABLE 1. LAYUP PLACEMENT WITH DIFFERENT ORIENTATION

Layers Formation	Layers	Layers of Glass Fiber (Roving)	Layers of Kevlar Fibers 49	Angle of Orientation GF	Angle of Orientation of KF
A	09	09	-	(0°/90°)	-
B	09	05	04	0°	90°
C	09	05	04	30°	60°
D	09	05	04	45°	45°

The recorded results of bear and break resistance of glass fiber-reinforced epoxy at  $0^\circ/90^\circ$  and glass/Kevlar fibers –reinforced epoxy at  $0^\circ/90^\circ$ ,  $45^\circ/45^\circ$  and  $30^\circ/60^\circ$  were found to be 7.40, 11.11, 18.52, 21.01, 9.87, 12.34, 17.28 and 19.75J respectively. The obtained results of several orientations have conformity with results reported by Babu et. al. [7]) and Rajesh at. al. [8]), that experiments were conducted by designing 11 layers laminate composite as compared to our 9 layers laminate composite. The experimental results of impact energy (J) were carried by the study of different specimens. Bar graph in Fig. 6 shows variation in data by change in layup placement of laminates. Hybrid composite Sheet of GFK at  $0^\circ/90^\circ$  has

remarkable performance under loading conditions of dart- dart. The GFK at  $0^\circ/90^\circ$  and  $30^\circ/60^\circ$  have high energy absorption capacity then  $45^\circ/45^\circ$  orientation. It can also be analyzed from the reported results that bear and break resistance of glass fibers-Kevlar at angle ply  $0^\circ/90^\circ$  was 46.71% greater than  $45^\circ/45^\circ$  layup placement and 6.71% better than  $30^\circ/60^\circ$  orientation. It is also be studied that impact energy of glass fibers-reinforced epoxy at  $0^\circ/90^\circ$  has less energy results from glass fibers-Kevlar-reinforced epoxy at  $45^\circ/45^\circ$  placement. Fig. 6 shows that GF-reinforced epoxy has low energy absorption than other layup placement. Fig. 7(a-d) shows the fracture specimen at different layup placement.



FIG. 2. DART IMPACT TESTER



FIG. 3. IZOD IMPACT TESTERS

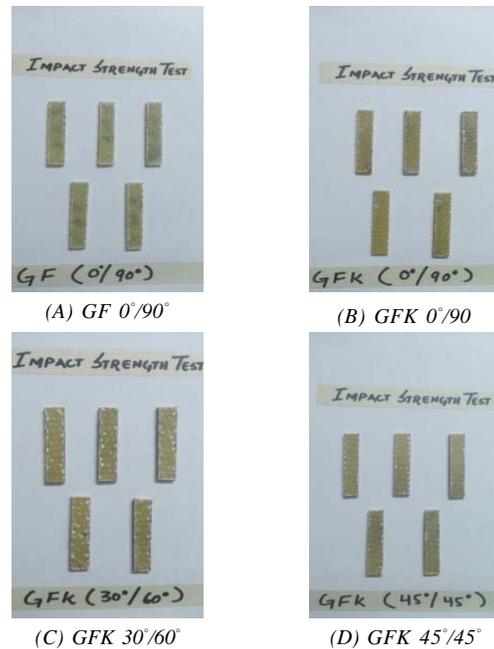


FIG.4. SPECIMENS WITH DIFFERENT ORIENTATIONS



FIG.5. JEOL JSM-6390A (SEM)

Fig. 8 shows variation of impact strength by different layup placement of glass fiber/epoxy and glass/Kevlar epoxy. Some difference in impact strength between the hybrids composites can be seen from the graph given in Fig. 8. Fig. 8 presents that glass-Kevlar bonded with epoxy at  $0^\circ/90^\circ$ ,  $45^\circ/45^\circ$  and  $30^\circ/60^\circ$  layup placement exhibits upgrade impact strength compared with glass fiber jointed with epoxy at  $0^\circ/90^\circ$ . The computed impact strength of GFK  $0^\circ/90^\circ$  is 7.6% greater than GFK  $45^\circ/45^\circ$ . If impact strength of GFK  $0^\circ/90^\circ$  compared with GFK  $30^\circ/60^\circ$ , it's computed value was 10.47% higher than GFK  $30^\circ/60^\circ$ . Same finding were reported in literature of Alam et. al. [4] and Valena et.al. [9]). By the understanding of bar graph in Fig. 8 shows that change in fibers orientation does not effective in enhancement of impact strength of hybrid laminates but replacement of fibers is useful for the improvement hybrid composites.

#### 4.1 Scanning Electronic Microscopy

For the fabrication of hybrid laminate aramid fibers 49/glass fibers reinforced epoxy at different layup placement were considered for study. Aramid fiber has in-plane impact strength and placed in core for making sandwich structure. Aramid fiber has trade name Kevlar is effective tool to suppress the specific strength and stiffness. Kevlar fiber has resistance to penetration and bonding capability and used in civil and military establishment for making the

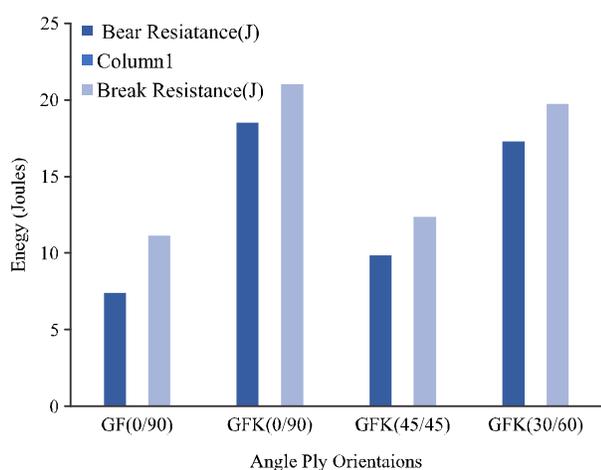


FIG. 6. BAR GRAPH SHOWS THE BEAR AND BREAK RESISTANCE CHARACTERISTICS OF GF $0^\circ/90^\circ$  AND GFK  $0^\circ/90^\circ$ ,  $45^\circ/45^\circ$  AND  $30^\circ/60^\circ$



(a) GLASS/KEVLAR-REINFORCED EPOXY  $0^\circ/90^\circ$



(b) GLASS/KEVLAR-REINFORCED EPOXY  $30^\circ/60^\circ$



(c) GLASS/KEVLAR-REINFORCED EPOXY  $45^\circ/45^\circ$



(d) GLASS-REINFORCED EPOXY  $0^\circ/90^\circ$

FIG. 7. SPECIMEN AFTER FRACTURE

components parts (Reis et. al. [3]). The scanning electronic microscopy discovered the layup placement and fractography of laminate. Fig.9 identified the epoxy resin bonded with glass fibers at 0°/90° before fracture.

The cross-sectional view of glass fibers-reinforced epoxy was seen in Fig. 9 at 0°/90 orientations. The solution of epoxy resin and hardener were placed between the layers of hybrid composites laminate. Fig. 9 shows perfect sequential layers of glass fibers adhesive with epoxy.

Pictorial view of GF 0°/90° shows delimitation was taken place at the centre of impact zone. Impact strength of laminates was reduced by pull out the glass fibers from the sandwich structure by minimum energy absorptions. The placement of layers at different angles were not increase the impact energy of composites but selection fibers in hybridization is very important to enhance the impact strength. Izod tested specimens of GFK 0°/90° have

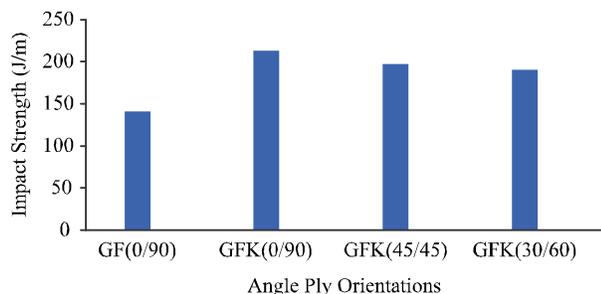


FIG.8.BAR GRAPH SHOWS IMPACT STRENGTH GLASS FIBERS-REINFORCED EPOXY AT 0°/90° AND GLASS/KEVLAR –REINFORCED EPOXY AT VARIOUS ANGLES

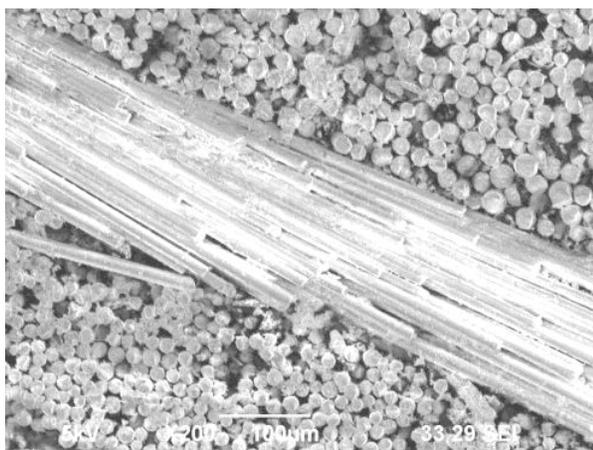


FIG. 9. IDENTIFICATION OF LAYUP PLACEMENT OF GLASS FIBERS REINFORCED EPOXY AT 0°/90° BEFORE FRACTURE

maximum impact strength than glass fiber - reinforced epoxy at same layup placement, similar data were calculated by Reis et.al. [2]) Fig. 10.

Nine layers of glass fiber-Kevlar at 0°/90° were seen in images of scanning electronic microscope. Five alternating layers of glass fibers and four layers of aramid fibers placed in sequence stacked layer by layer by epoxy were shown Fig. 11. Selected micrograph at different magnification reported that Kevlar adhesive with epoxy whereas some glass fibers were delaminated from hybrid composites. Young's modulus of laminates relies on fiber reinforced epoxy. The proper use of fibers improves the mechanical strength of hybrid laminates. Similar findings were also reported by number of researchers Satish et. al. [10]) and Reis et. al. [2]). In order to understand the in-plane fracture toughness, hybrid composites strongly depends on fibers matrix bond strength and selection of fibers. The finding from experimental data is good agreement with literature.

SEM micrograph in Fig. 12 shows that Kevlar fibers bonded with epoxy, whereas the glass fibers deboned from the hybrid laminates. By the investigation of image given in the Fig. 13 it was understood that impact strength of hybrid composites depend on way of layup placement. By insightful of experimental results at 0°/90°, 45°/45° and 30°/60° it was observed that that fibers orientation 0°/90° have better impact strength and stiffness.

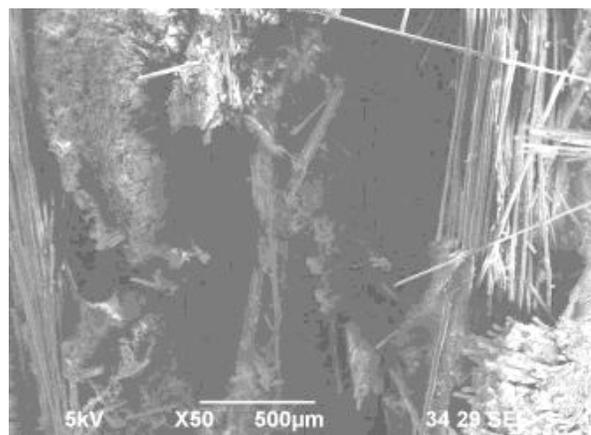


FIG. 10. FRACTURE OF SPECIMEN GF –REINFORCED EPOXY AT 0°/90°

Fig. 14 shows way of placing the fibers at 30°/60° layup for making the laminate. The surface morphology of hybrid composites clearly shows the direction of fibers reinforced epoxy. By the study of SEM images of Izod test specimen it was clear that at 0°/90° orientation have higher Impact energy then 45°/45° and 30°/60°. In specimen where fibers orientated at 45°/45° and 30°/60° direction has variation in results, fibers are broken and pulling out from the laminations because of stress concentration. In case of 0°/90° fibers are bonded with epoxy because fibers arranged parallel to the load directions. The layup placement of fibers reinforced in matrix at 45°/45° and 30°/60° have specific strength and elongation. Fig.14 indicated that fibers are pulled out because the delimitation and failure laminate with single blow.

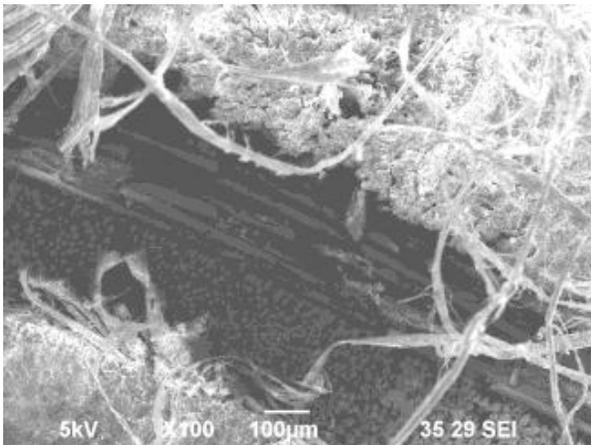


FIG.11. SHOWS NINE LAYERS OF GFK AT 0°/90° BEFORE FRACTURE

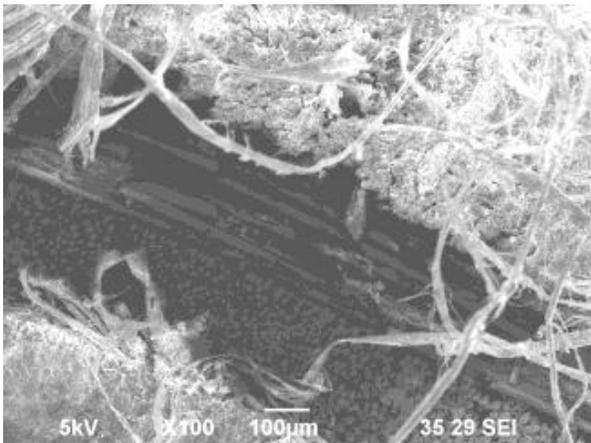


FIG. 12. FRACTURED SEM IMAGE OF GFK AT 0°/90°

Fig. 15 represents the nine layers of glass and Kevlar fibers adhesive with epoxy. In 45°/45°, placement the glass fibers pasted out from laminates during the sectioning by abrasive wheel cutter. From the surface study of 45°/45° direction it was observed the bonding strength of fibers depends also upon the fiber layup and proper selection of for fibers in laminations. Composites are physically mixed and their properties are based on layup placement fibers and adhesion fibers with matrix. The placement of fibers at 0°/90° has bonding strength than 45°/45° and 30°/60°. The layup placement 45°/45° superior over 0°/90° and 30°/60° have force per unit area at fracture.

Pictorial view given in Fig. 16 shows the delimitation after complete pulling out of fibers are because of increase of stress concentration and specimen were failed by minimum energy absorption.

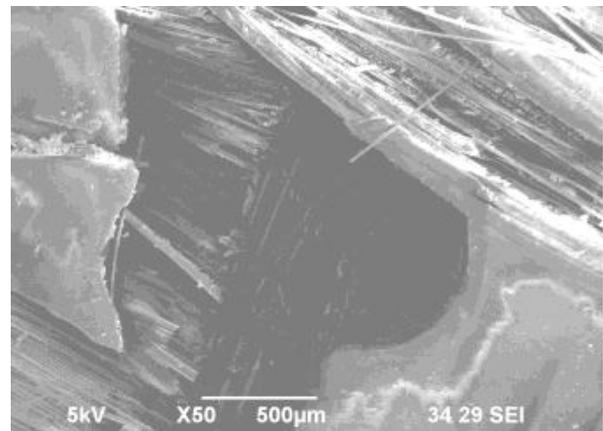


FIG. 14. SEM MICROGRAPH OF GFK30°/60° AT FRACTURE

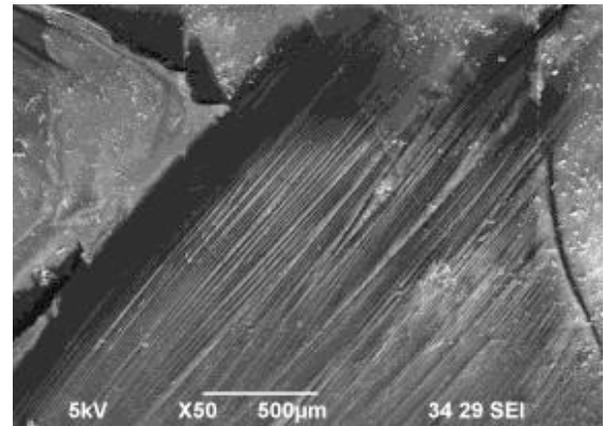


FIG. 13. SEM IMAGES OF GFK 30°/60° AT LAYUP PLACEMENT

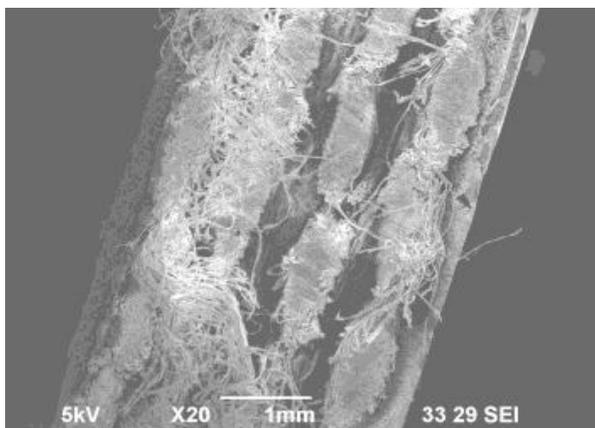


FIG. 15. MICROGRAPH OF GFK AT 45°/45° BEFORE FRACTURE

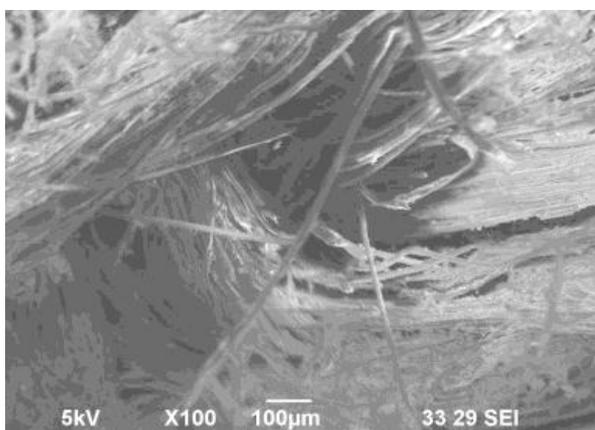


FIG. 16. IMAGE OF GFK 45°/45° AFTER FRACTURE

## 5. CONCLUSION

Experimental investigations were conducted to enhance the impact toughness of glass/epoxy and glass/Kevlar epoxy composites. From Dart impact test it was concluded that orientation GFK 0°/90° and 30°/60° have improved impact toughness than 45°/45° whereas GF 0°/90° have lowest value. But the surface and fracture study suggest that at 0°/90° orientation has better fracture strength than other orientations. Therefore, it can be concluded that best results can be obtained for designing the structures at 0°/90° layup placement but as far as specific strength is concern angle ply orientation 45°/45° is suitable.

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