

# A Review on Structural Investigation and Experimental Behavior of Kevlar Fiber

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**Abstract** - We all are well familiar with the different types of fiber reinforced composites and its applications. As a Kevlar fiber has its own unique properties that have significant application in various fields. To increase the fiber utilization for tremendous emerging application needs the detail study of structural and behavioral pattern. This paper gives a detail review of structural and experimental behavior of Kevlar fiber.

**Keywords**— Kevlar fiber, structural study, experimental view

## I. INTRODUCTION

The compounds are used in a variety of applications where structural integrity and mechanical properties should be maintained in the face of adverse conditions such as pipes and tanks.[1]

Composites powered by carbon, glass and annular fibers are often used in aircraft structures, building structures, wind turbines and sports equipment. However, due to its breakage and generally an easy-to-break matrix, it is more susceptible to impact damage and is a glass fiber-reinforced composite (GFC) and Kevlar reinforced composite (KRC) has less impact resistance. The combination of two closely integrated fibers, such as Kevlar and CFRP, continuously improves capacity and impact resistance. Weight loss, impact resistance. Fatigue contributes to about 55% of aircraft structure failures. [2]

Fiber-reinforced polymer alloys have received great attention due to their high specific strength and toughness and are used as a kind of high performance material in the aerospace, marine and automotive industries. In order to improve the delineation hardness of composite laminates, attempts have been made to break down matrix resin from rubber particles, metal fibers and various powders.[3]

The results showed that Kevlar has good tensile strength and therefore it can be a good alternative to conventional materials for many applications in the mechanical engineering industry. Kevlar is a Paris Armide synthetic fiber that has good tensile modules, a high strength to weight ratio and a high energy absorption capacity. It also has good ballistic impact resistance, especially designed for defense applications. Kevlar composites were experimentally subjected to ballistic impact tests and improved sequences were shown on multi-structured multi-layer fabrics. Kevlar

fiber as reinforcement and polycarbonate (PC) and acrylonitrile-butadiene-styrene (ABS) as a matrix [5].

Kevlar is the most used material for physical protection because it has more effect than synthetic fibers such as carbon, glass, etc. Shock waves caused by ballistic effect can cause severe wear and tear to the wearer. Different researchers have demonstrated the ballistic performance of natural fibers based polymer compounds. (Crova, Malwa, Mallow, Kenaf, Bagsy, Rami and Bamboo). Research has focused on the effect of editing epoxy matrix with different weights. Ballistic performance of composites was enhanced by graphene nanoplates (GNPs) with Kevlar / cocas nucifera shells [7].

A matrix of fiber-linked composites (FRCs) glues the fibers together and, in turn, transmits the force to the fibers, which provide greater strength and flexibility. Due to its high strength, low viscosity and low volatility, epoxy is the most popular thermosetting polymer available and shrinking rates compared to other thermosetting polymers. [9]

Vacuum auxiliary resin transfer molding process is a preferable process for less insecure and flawless fiber pieces. Fiber volume and stacking order are important parameters that should be considered for obtaining better composite materials with superior mechanical properties. The proposed work focuses on the manufacture of covalent and E-Glass-reinforced epoxy matrix composites to maximize the hybrid structure of different volume ratios and impact and bending behavior through vacuum assisted resin transfer molding. The author's inclusion of Kevlar fibers in the phenolic resin reduced the friction ability. The reason is that glass fiber composites have weaker compression than other fiber-reinforced resins, but can also be attributed to the resin matrix.

## II. MATERIAL AND MANUFACTURING PROCESS

Two four-layer laminates were fabricated using hybrid fabric with e-glass and Kevlar 49 fibers and orthophilic unsaturated thermosetting polyester resin, which is Novapole-120 (Fig. 1 (a)). The two pieces use different methods of hybridization of more reinforced fabrics, as shown in Figure 1 (b) and (c). The hybrid fabric in Fig. 1 (b) is a hybrid-stranded two-dimensional textile, that is, each of the standalone E-fibers comprising of fibers and Kevlar 49 fibers, in both

directions (weft and warp), obtained from the Tax Lugs Company. And is commercially known as the KV-650.

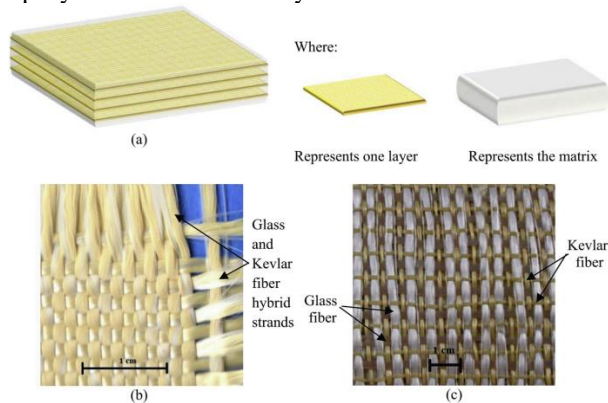


Figure.1 : Hybrid of Kevlar 49 and E-glass Fiber

The hand-up process was used to obtain the fragments and 1% methyl ethyl Ketone peroxide (MEKP) as the catalyst of the matrix while the composite fragments were fixed at ambient temperature[1].The interlaced fabrics were provided in a roll in which the carbon fibers are attached in the direction of the dislocation and the annular fibers act as weights (fig. 1). The unit cell represents the smallest recombination pattern of a fiber cloth, the average area of the unit cell used in hybrid fiber cloth, which is 15.75 mm.

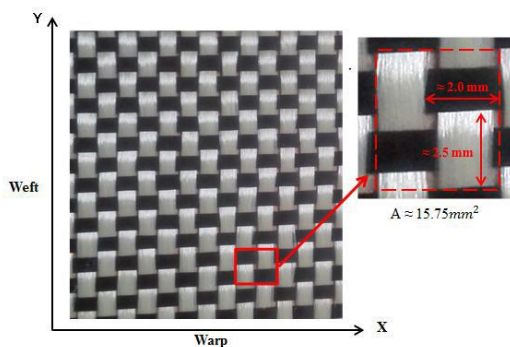


Figure. 2 : Woven carbon-Kevlar cloth

The annular fibers were first cut into approximately 3 mm long sections and the amount of cut fibers was measured by weight at a surface density of 10 g / mA. Within a tolerance of 0.001 grams. The final fiber / composite volume ratio for the laminate was 63%. Finally, the sliced annular fibers were stained with mixed resin and coated uniformly in the center plane of the fragment, as shown in Fig. 2.

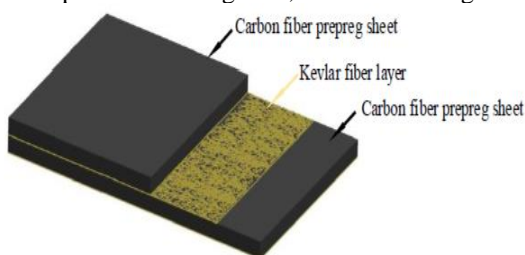


Figure. 3 : Sandwich Structure of kevlar and carbon fiber  
Fig. The sandwich structure is adopted, with carbon fiber prepreg sheet at the top and bottom, and Kevlar-fiber layer in the middle. [3]

Z-fiber architecture has a very tight set of cannon and weight fibers, one of the possible ways Z-fibers can perform in the process of making. This path is shown in yellow and connects all layers through thickness. However, there are several different pathways that can be created that create different types of architecture, such as two binding fibers or, depending on the desired volume fraction of each second layer, is tied through the binding yarn.

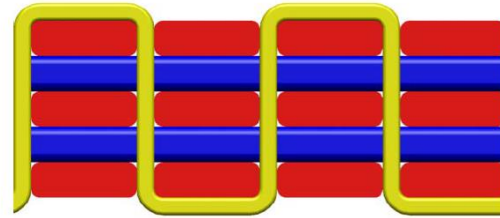


Figure. 4 : Z fiber path

Figure shows the yellow color path represents the course that the Z-fiber follows during the weaving process. Here are some details about the Z Fiber Path. After that it was performed they were infected with SC15 polymer matrix materials using a VRTM method. The material properties of each component are given in Table 1 for reference. Each component is given in Table 1 for reference.

Fiber Structure	Material Properties					
	$E_1$	$E_2$	$\nu_{12}$	$\nu_{23}$	$G_{12}$	$G_{23}$
Carbon	40.03	2.50	0.2	0.25	2.70	0.70
Glass	16.56	16.56	0.22	0.22	6.74	6.74
Kevlar	16.24	16.24	0.36	0.36	8.12	8.12
SC-15	0.360	---	0.35	---	---	---

Table1 : Material Properties of each component

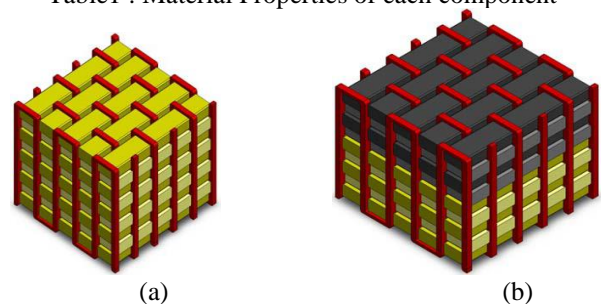


Figure. 4.1 : Orientation of Z-fiber

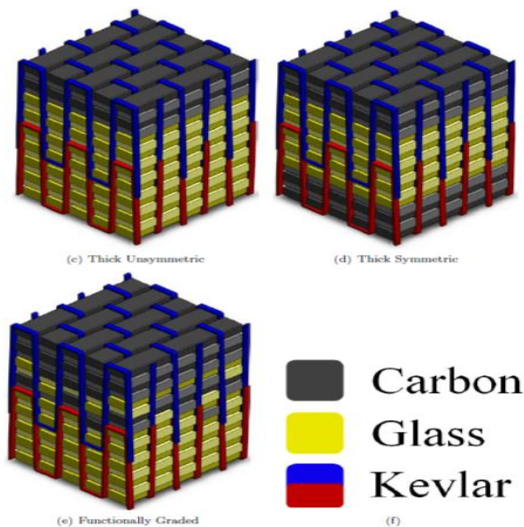


Figure. 4.2 : Orientation of Z-fiber

The Z-fiber for these samples is glass just shown as Kevlar to differentiate it from the rest of the glass fiber tow bundles, thin unsymmetrical [4].

The figure 5 (a) shows the fiber in unprocessed manner and figure 5 (b) shows the fiber in woven roving mat chopped in either direction.

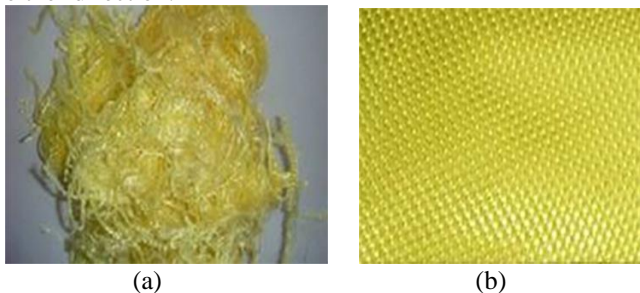


Figure. 5: (a) Unprocessed Kevlar fiber, (b) Woven Kevlar fiber, Epoxy LY 556 and Resin HY951 are used

There are different types of Kevlar with its own unique set of properties and performance characteristics such as Kevlar 29, 49, 100, 119, 129, 149 etc. Table.2 depicts the properties of different types of Kevlar fibers.

Yarn properties	Kevlar 29	Kevlar 49	Kevlar 100	Kevlar 119	Kevlar 129	Kevlar 149	Twaron
Tensile strength (GPa)	3.6	3.6-4.1	3.0	3.1	3.45	3.4	3
Elastic modulus (GPa)	83	131	60	55	97	143	178
Elongation (%)	3.0	2.8	2.9	3.1	3.4	2.3	3.3
Density (g/cc)	1.44	1.45	1.44	1.44	1.45	1.47	1.44

Table 2: Properties of different types of Kevlar.

Kevlar is a polymer; this means that it is made up of a large number of the same basic unit, called a monomer, which are attached to each other to form a long chain. Kevlar fiber showing in below diagram.

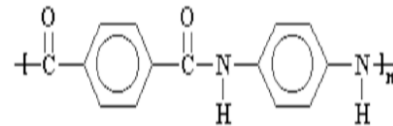


Figure. 6 : Structure of Kevlar polymer

The aramid fabric used in this study is Kevlar 29. The density and the thickness of Kevlar 29 fabric are 1.44 g/cm<sup>3</sup> and 0.33 mm, respectively. A thermoset liquid epoxy resin (D.E.R.331) with joint amine type (905-3S) curing agent was used as the matrix.

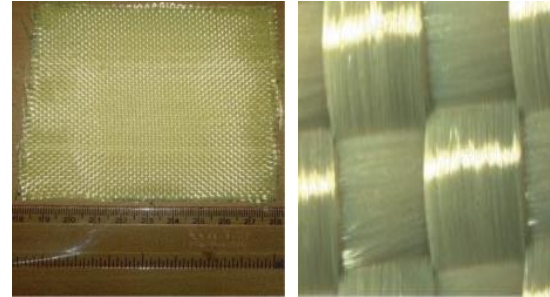


Figure.7: Plain two-dimensional Kevlar fabric.

Kevlar has a unique combination of high strength, high modulus, toughness and thermal stability. It was developed to meet the demands of industrial and modern technology applications. Many types of annular caviar are currently manufactured to meet widespread end-use. Kevlar is a chemical fiber, an organic fiber from a family of fragrant polyamides. Molecular formula: C<sub>14</sub>H<sub>14</sub>N<sub>2</sub>O<sub>4</sub>. Density 1.44, breaking power -328, braking-2920 MPa. Tensile Modules 70500 MPa Interval length 3.6%.



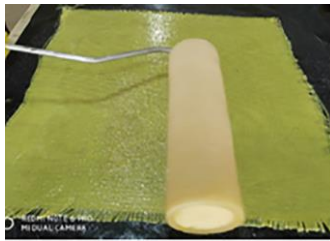
Figure.8: (a) Kevlar fiber 29 (woven), (b) Kevlar fiber 29 (Foam)

Egg shells are bio-waste and readily available from the food industry as waste, which have high compressive strength and good binding properties that we use. So we chose this material to make the patterns. Here are two samples in which eggs are not treated and treated.



(a) (b)



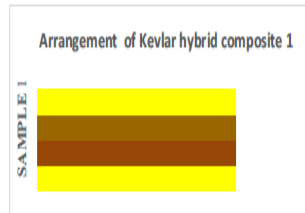


(c)

Figure.9: (a) Before Chemical process Egg shell, (b) After Chemical process Egg Shell, (c) Fabrication of Kevlar fiber



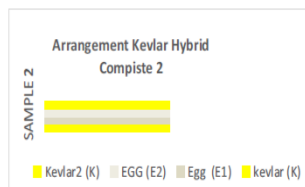
(a)



(b)



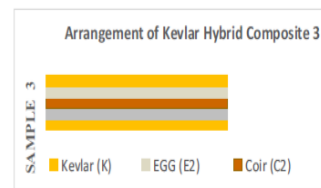
(c)



(d)



(e)



(f)

Figure.10: (a) Sample 1, (b) Layer arrangement Sample 1, (c) Sample 2, (d) Layer arrangement Sample 2, (e) Sample 3, (f) Layer arrangement Sample 3

Epoxy resins are the most commonly used resins. Epoxy LY 556 resin, chemically belonging to the “epoxide” family is used as the matrix material. The low temperature curing epoxy resin (Araldite LY 556) and the corresponding hardener (HY 951) are mixed in a ratio of 3:1 by weight as recommended.



Figure.11: Reinforced fibers chopped carbon and short Kevlar fiber used for epoxy composite system

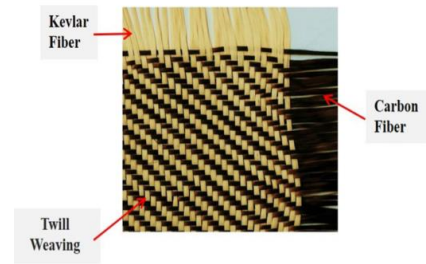


Figure.12: CKS-220 Carbon/Kevlar Hybrid Fabric  
The specimens identifications, associated with this hybrid composite laminate, are described below and used to better understand the comparative analyses between their mechanical properties:

- CLCO - CL specimens with carbon fibers in the direction of the applied load and in the original condition (without hole);
- CLKO - CL specimens with Kevlar fibers in the direction of the applied load and in the original condition (without hole);
- CLCH - CL specimens with carbon fibers in the direction of the applied load and with a circular hole;
- CLKH - CL specimens with Kevlar fibers in the direction of the applied load and with a circular hole.

### III. EXPERIMENTAL TENSILE TESTING

The Author taking at three different fiber directions, They are 0°, 45° and 90° below Figure [1].

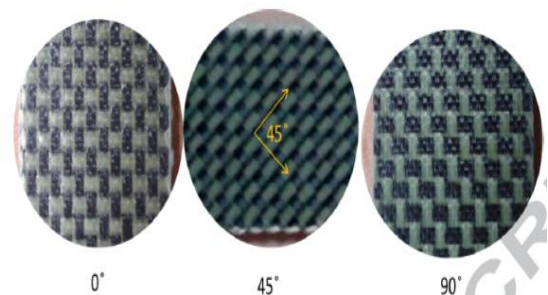


Figure 13: Carbon-Kevlar hybrid composite cut at three different fiber directions

Fiber direction s[ ° ]	Tensile strength[M Pa]	Tensile Modulus[G Pa]	Elongati on at break (mm)	Poisson 's Ratio
0	554 ± 26.9	54.95 ± 1.67	6.31 ± 0.1	0.1
45	110.5 ± 3.81	6.35 ± 0.13	61.42 ± 1.4	-
90	467.5±41.8	23.67 ± 1.2	11.05 ± 0.9	0.05

Table. 3: Result of Tensile test

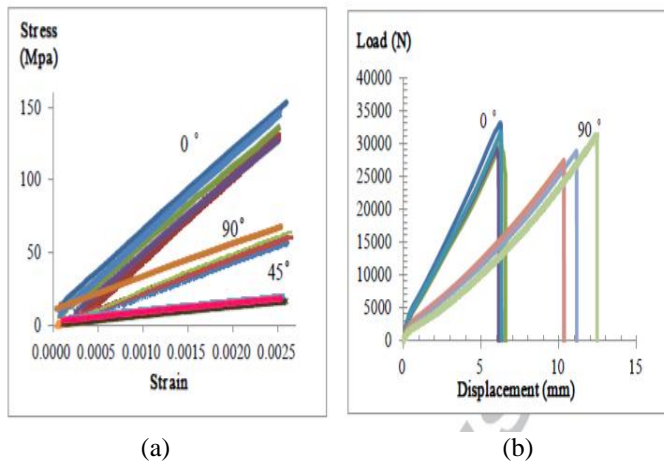


Figure 14: (a) Stress-strain curves of the hybrid Composite at different fiber directions (b) Load Displacement curve of hybrid composite cut at 0° and 90° fiber

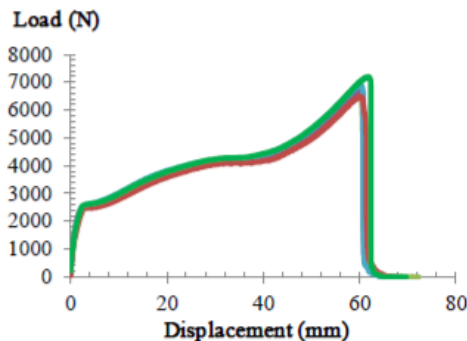


Figure 15: Load-displacement curves of Hybrid composite cut 45° grain direction

The effective modules of different architectures can be seen in Table 3. It should be noted here that the proportions of proportional samples are due to different levels of strain insulation (carbon side vs. glass side) hybridization and error inequality, which leads to bending.

The average curves obtained in the unconnected tensile tests, which are the original condition for the test samples, are the disciplinary tests. (0/90) and GLO ( $\pm 45$ ) of Fig.16. The stresses are shown in the diagram. For the GLO (0/90) test samples, the behavior between the tension and the length of the pieces was linear, but for the GLO ( $\pm 45$ ).

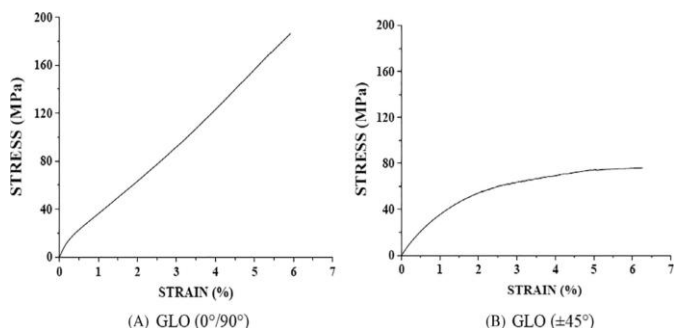


Figure 16: Stress-strain diagram (average curves) GL laminate (original condition)

With respect to the average curve profiles obtained in the uniaxial tensile tests for test specimens with a central hole,

GLH (0/90) and GLH ( $\pm 45$ ) exhibited similar behavior to that of test specimens in the original condition.

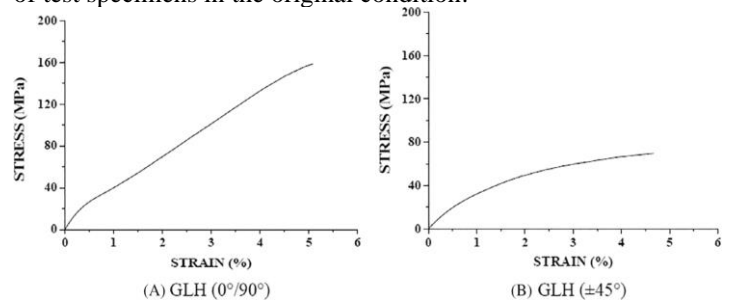


Figure 17: Stress-strain diagram (average curves) GL laminate (central hole condition)

The tensile test of composites was conducted by universal testing machine at specified load and cross head speed, range. Image showing tensile test conducted Kevlar hybrid composite specimen on Universal Testing Machine Before and after tension on specimen.

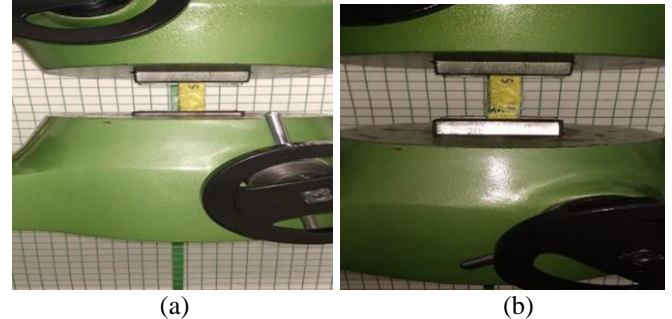


Figure 18: (a) Tensile test setup specimen on UTM before testing (b) Tensile test setup specimen on UTM after testing

Sr. No	Specimen Name	Sequence s of Layer Arrange ment	Tensile modul us (GPa)	Tensile streng th (GPa)	Force (KN)	Thick ness (mm)
1	T1(SK C)	(K + C1 + C2 + K)	50.58	53.6	6.2	5
2	T2 (SKE)	(K + E1 + E2 + K)	47.21	55	6	5
3	T3(SK EC)	(K + E1 + C2 + E2 + k)	52.72	59.3	6.4	5

Table 4: Tensile behaviors of Kevlar hybrid composite

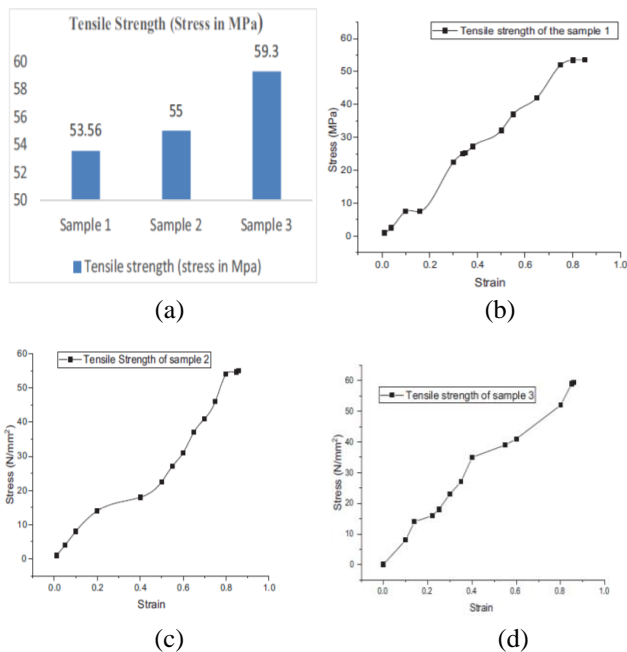


Figure. 19: (a) Tensile strength of Kevlar hybrid composite  
(b) Tensile strength of Sample 1 (c) Tensile strength of Sample 2  
(d) Tensile strength of Sample 3

#### CONCLUSION

A detailed review on orientation pattern, mechanical properties, experimental behavior, have been carried out by the different researcher is reported in this paper. Kevlar has a good strength, toughness and better thermal behavior compared with other fiber. The different orientation of the Kevlar fiber leads to give the considerable changes in the behavior. Tensile testing of Kevlar for different orientation gives the significant change in the tensile strength.

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