



## Fabrication and Evaluation of Mechanical Behaviour in Hybrid Polymer Matrix Composites

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### ABSTRACT

In this paper, the composite laminates were fabricated to different weight percentage of uni-directional and stitched cross mat E-glass fibers, glass and Kevlar fiber reinforced with epoxy resins and hardener. For laminates fabrication epoxy matrix is maintained is constant weight percentage (60%) and glass fibers with different stacking sequences is added with various weight percentage. Mechanical behaviour of composites such as tensile property, flexural property & impact resistance are study in this investigation. The various geometry of E-Glass/Kevlar fiber reinforced laminates manufactured by hand lay-up method and followed by compression moulding technique. Where epoxy is constant (60%) and change the fiber percentage, specimens prepared with difference stacking sequences material are tested. The results show tensile strength and impact resistance are high to the stitched cross glass(SCM) fiber mat(40% ). The flexural strength and natural frequency is high in order to Chopped strand (CSM) mat(10%)/Kevlar(K) fiber(30%), CSM(30%)/K(10%).

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### Introduction

Composite material is one type of artificial mixture. It used to various forms such as classify in structure of matrix and reinforcements. Composites are materials that comprise strong load carrying material (known as reinforcement) embedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix, or binder (organic or inorganic) maintains the position and orientation constituents of the composites retain there of the reinforcement. Significantly, individual, physical and chemical properties; yet together they produce a combination of qualities which individual constituents would be incapable of producing alone.

A composite material refers to materials which have strong fibers, either continuous or non-continuous and is surrounded by weaker matrix material. Fibers act as the reinforcement while the matrix serves to distribute the fibers and also to transmit the load to the fibers. So, composite sheet metals are used for manufacturing the bodies of automobiles, airplanes, railroad cars and etc. Composite involves two or more component materials that are generally combined in an attempt to improve mechanical properties such as stiffness, strength, toughness, etc; the resulting properties are largely dependent on the distribution, relative amounts and geometries of constituents.

### Problem Description

Composites consist of two or more phases that are usually processed separately and then bonded, resulting in properties that are different from those of either of the component materials. Polymer matrix composites generally combine high-strength, high-stiffness fibers with low-density matrix materials (epoxy, polyvinyl, etc.) to produce strong & stiff materials that are lightweight. Laminates are generally built up from multiple layers of lamina; the fibers within each lamina are generally parallel, but laminates usually contain lamina with their fibers oriented in various directions. In this investigation, the composite material properties will be predicted, tested and discussed.

### Objectives of the work

The main objective of this project is to find out the maximum strength of the Glass Epoxy composite materials with Kevlar at various weight percentage .Other objectives in this project are,

- 1.To study the mechanical properties and applications of polymer composite material.
- 2.Fabrication of polymer matrix composite materials (glass, Kevlar with epoxy matrix) with different orientation and different weight percentage.
- 3.To evaluate the mechanical properties of glass, Kevlar with epoxy material such as tensile strength, flexural strength and impact strength.

### Fabrication Method

Glass fiber material consisting extremely thin fibers of about 0.005–0.010 mm in diameter were taken. The glass fibers are available in various thicknesses. Where uni-directional mat (UD-90<sup>0</sup>) and stitched cross mat (SC-45<sup>0</sup>), chopped strand mat and kevlar fiber is investigated in various weight percentages. Fiber mats are cut to the required size & shape.

Epoxy is a copolymer; that is, it is formed from two different chemicals. These are referred to as the "resin" and the "hardener". The resin consists of monomers or short chain polymers with an epoxide group at either end. Most common epoxy resins are produced from a reaction between epichlorohydrin and bisphenol-A, though the latter may be replaced by similar chemicals. The hardener consists of polyamine monomers, for ex. Triethylenetetramine (TETA). When these compounds are mixed together, the amine groups react with the epoxide groups to form a covalent bond. Each NH group can react with an epoxide group, so that the resulting polymer is heavily cross linked, and is thus rigid and strong. The process of polymerization is called "curing", and can be controlled through temperature and choice of resin and hardener compounds; the process can take minutes to hours. Some formulations benefit from heating during the cure period, whereas others simply require time, and ambient temperatures.

The fiber volume fraction is calculated as

$$V_f = \frac{\rho_m W_f}{\rho_f W_m + \rho_m W_f}$$

Where,

$V_f$  = volume fraction of fibers

$W_f$  = weight of fibers

$W_m$  = weight of matrix

$\rho_f$  = density of fibers

$\rho_m$  = density of matrix

They are first placed in an open, heated mold cavity. The mold is then closed and pressure is applied to force the material to fill up the cavity. A hydraulic ram is often utilized to produce sufficient force during the molding process. The heat and pressure are maintained until the plastic material is cured.

There are two different types of compounds most frequently used in compression molding: Bulk Molding Compound (BMC) and Sheet Molding Compound (SMC). SMC costs higher but can be pre-cut to conform to the surface area of the mold. The more evenly distributed material over the mold surface usually results in less flow orientation during the compression stage and, therefore, higher product consistency.

### Test Procedures

#### Flexural Test

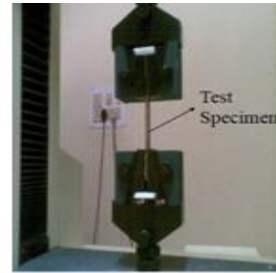


The Flexural test measures the force required to bend a plastic beam under a four point loading system. The test method is used for reinforced or unreinforced materials including high modulus composites and for materials that do not fail within the limits of ASTM D790 (a three point loading test). The major difference between the three point and four point flexural tests is the location of the bending moment. The four point bending method allows for uniform distribution between the two loading noses, whilst the three point bending method's stress is located under the loading nose. Since the flexural properties of many materials can vary depending on temperature, rate of strain and specimen thickness, it may be appropriate to test materials at varied parameters.

#### Tensile Test

Tensile testing is a fundamental mechanical testing method in which a sample is subjected to uniaxial tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties such as ultimate tensile strength, maximum elongation and reduction in area can be determined. In this test specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Specimens are prepared as per ASTM D3039 standard, which consist tabs at either ends. The universal testing machine (UTM) is used for testing with higher accuracy, the maximum capacity of machine

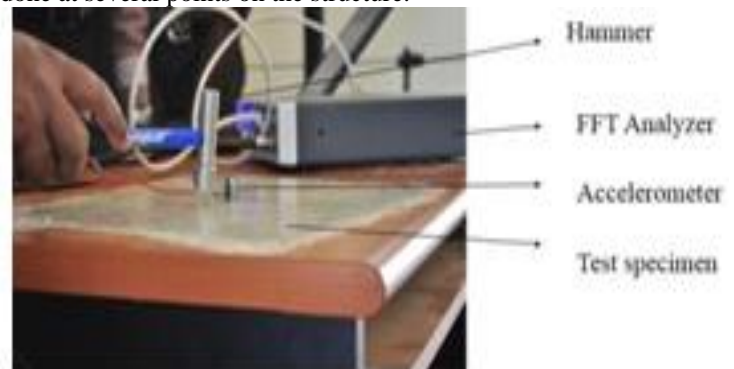
100 KN is used for testing, which operated on electronic control servo mechanism.



Speed rate is 2mm/min; the specimen is fixed between lower crosshead & intermediate cross head A material is gripped at both ends by an apparatus, which slowly pulls lengthwise on the piece until it fractures. The pulling force is called a load, which is plotted against the material length change, or displacement. The load is converted to a stress value and the displacement is converted to a strain value. A material is gripped at both ends by an apparatus, which slowly pulls lengthwise on the piece until it fractures. The pulling force is called a load, which is plotted against the material length change, or displacement. The load is converted to a stress value and the displacement is converted to a strain value.

#### Impact Hammer Test

It is a method of testing that allows us to find the natural frequencies (modes) of a test structure. This is commonly done using either impact hammer testing or shaker testing. Here we are going to deal only with impact hammer testing. we would impact the structure under test with a perfect impulse. This would be of infinitely short duration. This would result in constant amplitude in the frequency domain. Instead, we have a known contact time. The duration of this time is directly linked to the frequency content of the force applied. In hammer impact testing (modal testing) we use a special hammer with a load cell in its tip to measure the force of the impact. So, to test the structure we need to use the instrumented hammer to generate our impulse and then measure the response. This needs to be done at several points on the structure.



### Results & Discussion

#### Tensile Test (D638)

In this, breaking load to be found for polymer composites by using tensile testing machine. The size of the composites required for this test to be 250mm length, 25mm breadth and thickness 3mm. The specimen taken for testing is a glass/Kevlar with epoxy composite materials are as tabulated below. The sample composites were tested under tensile testing machine; in this the mechanical properties were found.

By using these tests the tensile load and tensile stress are determined for the glass/Kevlar with epoxy are tabulated as follows.

**Table 1. Weight percentage of fiber and matrix for study set 1**

| Designation | Fiber                     | Matrix          |
|-------------|---------------------------|-----------------|
| M1          | UD (22Wt %) +SC (18 Wt %) | Epoxy (60 Wt %) |
| M2          | UD (8Wt %) +SC (32 Wt %)  | Epoxy (60 Wt %) |
| M3          | SC (40Wt %)               | Epoxy (60 Wt %) |

**Table 2. Weight percentage of fiber and matrix for study set 2**

| Designation | Fiber                      | Matrix          |
|-------------|----------------------------|-----------------|
| M4          | CSM (30Wt %) + K (10Wt %)  | Epoxy (60 Wt %) |
| M5          | CSM (20Wt %) + K (20 Wt %) | Epoxy (60 Wt %) |
| M6          | CSM (10Wt %) + K (30Wt %)  | Epoxy (60Wt %)  |

**Table 3. Results of Tensile Test**

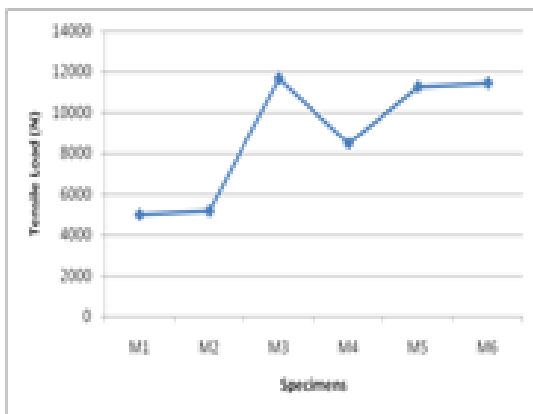
| Composites | Tensile Load (N) | Tensile Stress (N/mm <sup>2</sup> ) |
|------------|------------------|-------------------------------------|
| M1         | 5025.349         | 67.002                              |
| M2         | 5210.042         | 69.465                              |
| M3         | 11666.984        | 155.557                             |
| M4         | 8487.357         | 113.168                             |
| M5         | 11274.368        | 150.328                             |
| M6         | 11458.708        | 152.781                             |

**Table 4. Results of Flexural Test**

| Composites | Flexural load (N) | Flexural Strength (Mpa) |
|------------|-------------------|-------------------------|
| M1         | 109.997           | 137.305                 |
| M2         | 87.25             | 70.471                  |
| M3         | 255.266           | 206.177                 |
| M4         | 232.536           | 187.818                 |
| M5         | 231.585           | 187.049                 |
| M6         | 290.768           | 238.851                 |

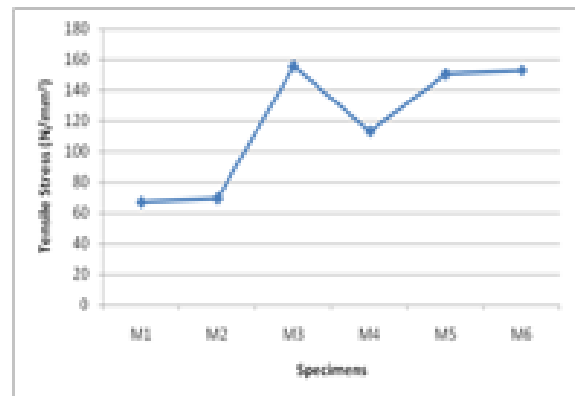
**Table 5. Results of Impact Hammer Test**

| Composites | Natural Frequency (Hz) |
|------------|------------------------|
| M1         | 256.25                 |
| M2         | 1737.5                 |
| M3         | 1818.75                |
| M4         | 2006.25                |
| M5         | 1600                   |
| M6         | 1381.25                |



Experiments were conducted on Glass/Epoxy laminate composite specimens with varying fiber weight percentages to evaluate the tensile properties. The matrix cracking of hybrid specimens under the maximum stress  $\sigma_{max}=155.55N/mm^2$ ; the density is defined as the average number of matrix cracks in each hybrid layer per unit length in the longitudinal direction. It shows the side surface of KFRP & GFRP hybrid specimens with matrix crack, de-lamination under maximum stress  $\sigma_{max}=155.55N/mm^2$ . It is observed that from the experiment

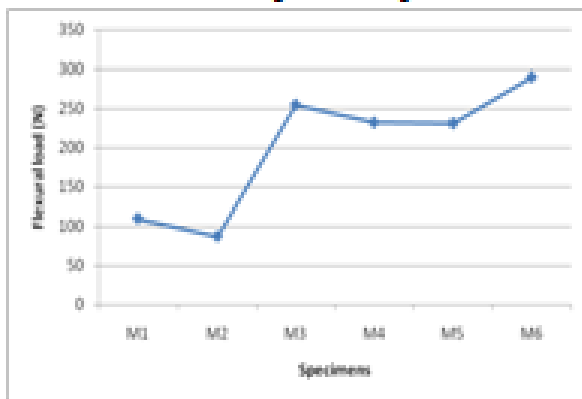
Kevlar fibers are damaged more than the glass fibers, since Kevlar is more brittle in nature than glass fibers.



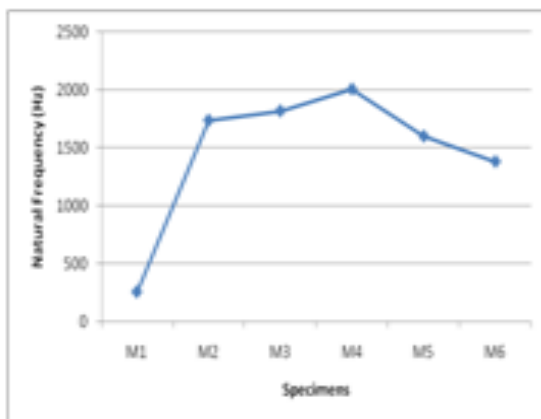
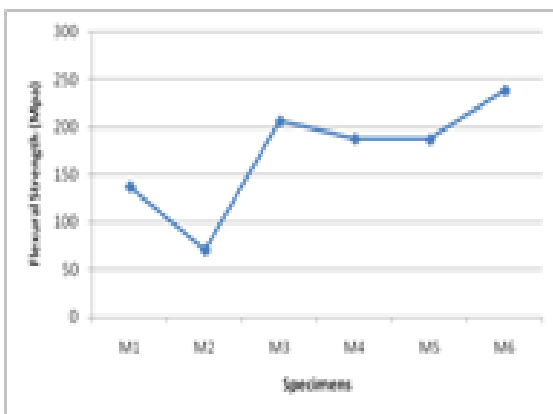
**Flexural Test**

In this, breaking load to be found for polymer composites by using flexural testing machine. The size of the composites required for this test to be 127mm length, 13mm breadth and thickness 3mm. The sample composites were tested under flexural testing machine; in this the mechanical properties were found. By using these tests the flexural load and flexural

strength are determined for the glass/Kevlar with epoxy are tabulated as follows.



During flexure, the fiberglass mesh on the tensile side can stop the micro-cracks propagation while the randomly dispersed short glass fibers can bridge cracks at short intervals and reduce their propagation rate. Where Kevlar (30%)/glass (10%) with epoxy shows higher flexural strength (238.81MPa). It shows further enhancement in flexural strength may be achieved by improving the interface bond between fiber mesh and polymer matrix.



### Impact Hammer Test

It is a method of testing that allows us to find the natural frequencies (modes) of a test structure. This is commonly done using either impact hammer testing or shaker testing. Here we are going to deal only with impact hammer testing. We would impact the structure under test with a perfect impulse. This would be of infinitely short duration. This would result in constant amplitude in the frequency domain.

The short fibres could play an important role in absorbing impact energy through their elastic-deformation and bridging plies together. However, when the content of Kevlar fibers

increased beyond 10wt. %, it is found that the maximum propagation energy decreases significantly. According to the results obtained, it was found that the addition of 10 wt% short Kevlar fibers into glass fiber composite was shown to be the advisable reinforcement content to achieve better impact strengths.

### Conclusion

This experimental investigation of mechanical behaviours of glass/Kevlar with epoxy composites leads to the following conclusions:

- This work shows that successful fabrication of a glass/Kevlar with epoxy composites is possible by compression moulding technique.
- The tensile test has been concluded that the composites SC fiber (40%) shows the better performance.
- The flexural test has been concluded that the composite CSM (10%)/Kevlar (30%) with epoxy (60%) M6 shows the better performance.
- The impact test has been concluded that the composite CSM (30%)/Kevlar (10%) with epoxy (60%) M4 shows the better performance.
- The impact hammer test has been concluded that the composite CSM (30%)/Kevlar (10%) with epoxy (60%) M4 shows the better performance.

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