A Study on Mechanical Properties of Hybrid Fiber Reinforced Polymer Composites

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Abstract:-These days almost all structures are being replaced with composite materials due to their high strength to weight ratio along with good mechanical properties. The composite properties will change based on the factors like size, shape, length, weight, nature and resin used. In current scenario to achieve the particular properties almost all industries are using the hybrid composites. In present work, four types of woven fabrics are taken i.e., Carbon, E-Glass, Flax and Bamboo. From these four types, a total of 4 composites (Carbon, E-Glass, Flax & Bamboo) and total of 6 hybrid composites (Flax + E-Glass, Bamboo + E-Glass, Flax + Carbon, Bamboo + Carbon, Bamboo + Flax and Carbon + E-Glass) are fabricated with ASTM D3039 and tested under tensile machine. The effect of hybrid composite models on the density, young’s modulus and yield strength are calculated. The best hybrid composite material is selected based upon the low density, high tensile strength and high young’s modulus.

Keywords: Hybrid composite, Carbon, E-Glass, Bamboo, Flax, Epoxy and Hardener.

I. Introduction

Composite material is a material made from two or more constituent materials with significantly different physical or chemical properties, which are combined to produce a material with characteristics which are stronger and more durable than the previous components. The previous individual components will form a bond which indeed increases the desirable characteristics. The latest material can be preferred for many reasons for it’s usage like stronger, harder, lighter, less expensive when compared to traditional materials. Composite material is generally classified into two different types, the first type of classification is usually made with respect to the matrix constituent and the second type of classification refers to the reinforcement. S. Prabhakaran[1] et al analysed in detail the damping and sound absorption characteristics of flax and glass fiber reinforced composites and found that flax fiber reinforced composite has 21.42% and 25% higher sound absorption coefficient and at low frequencies it has 51.03% higher vibration damping than the glass fibre reinforced composite and the weight, flexural strength and flexural modulus of flax fiber are...
between than glass fiber reinforced composites without sacrificing stiffness-to-weight ratios. Dakai Chen [2] et al analysed in detail the effect of ammonium polyphosphate and plasticizer poly (Butylene adipate-co-terephthalate) on the sound absorption property of ramie fibre, and found out composite with short ramie fiber reinforced PLLA composite. The SEM reveal micro-phase separation and porosity between single fibre bundles to short fibre makes more better acoustical absorptive. Y.Hong et al [3] analyzed in detail the damping characterizes of several advanced fiber reinforced composite Finite Element analysis is carried out based on modal strain energy method to find out modal shapes, modal frequencies and modal loss factor. By using different layer angels and layup sequences, the composite structure were optimized. They observed increase of frequency trend with carbon/glass fiber composite in bending made with layup sequence 0,90 and reverse trend with layup sequence of 30,45,60. Jean Marie Berthelot [4] et al done experiments on unidirectional glass and Kevlarfiber composite materials by using a cantilever beam for damping values and compared these results with literature models such as Adams-bacon analysis, Ni – Adama analysis and complex stiffness model. A deviation of 10 to 35 of fibre orientation is seen in Kevlarfiber composites he obtained better results in modelling than experimental due to the specimen difference in both. In ritz method the specimen is rectangular so width is considered while AB analysis doesn’t consider this width the inplane shear damping of shear energy to energy dissipated which is different for each analysis. Jean Marie Berthelot [5] et al carried out experiments viz., orthotropic composites with viscoelastic layers on a rectangular laminates using ritz method. Natural frequencies and along with modes are obtained, the transverse shear energies can be obtained in each layer and damping is evaluated for different energies and different angles of laminate. The strains in each viscoelastic layers are observed. If we take multiple damping layers, laminates and complex structures the damping modelling can be used by finite element procedure. Ahmed Alb- El- hamid hamada [6] et al carried out experiments on a composite with different cores (steel and aluminium) as well as composite material with different fiber orientation, aligned longitudinally, transversely making 45\(^0\) with each other and randomly oriented on which FFT is carried out and found that coatedlaminated beams have high damping ability than isotropic metal beams. Lamina coated has better than normal structure that too without change in natural frequency of structure.C.Kyriazoglou et al [7] carried out experiments of hybrid method which is applied to homogeneous material for damping by FEA and damping testing equipment. These both have good coordination while testing the specimen GFRP and CFRP which is done at 0\(^0\) and 90\(^0\) continuous GFRP lamina,woven (0\(^0\),90\(^0\)),GFRP 8HSW, woven (0\(^0\),90\(^0\)) and (+- 45\(^0\))5HSWFRP lamina are found. The objective of the problem is to study the mechanical properties of Plane Composites (carbon Epoxy, E-Glass Epoxy, Bamboo Epoxy and Flax Epoxy) and hybrid composites (Flax + E-Glass Epoxy, Bamboo + E-Glass Epoxy, Flax + Carbon Epoxy, Bamboo + Carbon Epoxy, Bamboo + Flax Epoxy and Carbon + E-Glass Epoxy).

2. Experimentation

2.1 ASTM D3039

The specimen dimensions recommended by the ASTM D3039 for tensile test is shown in Figure 1.
2.2 Carbon Fibre Reinforced Polymer (CFRP)

Carbon fiber reinforced polymer (CFRP), or carbon fiber reinforced thermoplastic (CFRTP) is an very strong and light weight fiber reinforced plastic which contains carbon fibers. In CFRPs the reinforcement is the carbon fiber along with the matrix is usually a polymer resin. The material properties depends on those very two elements.

The main applications are guitar picks, laptop cases and audio Components such as loud speakers. The advantages are high tensile strength, low thermal expansion, light weight, corrosion resistant and electrical conductivity. The disadvantages are expensive in cost, Cracks propagation and holes are created while machining.

Two directional carbon woven fabrics are gathered from the market in the form of sheets of length 1.5 meters. The required length for the carbon lamina is 260 mm in length and 27 mm width and thickness of the sheet is 0.3 mm. The carbon woven sheet is shown in the below Figure 2.

![Carbon woven Fabric](image)

**Figure 2** Carbon woven Fabric

**Epoxy Resin:**

The type of epoxy resin used in this work is Araldite LY556 which chemically belongs to epoxies family 25ºC. The advantages of the epoxy resin are water resistant, low shrinkage, positive mechanical properties, excellent adhesive properties, chemical & Heat Resistance and very good electrical insulating properties.

The disadvantages of the epoxy resin are harmful to health and do not perform well in colder temperatures. Epoxy resin LY556 is used as the matrix for binding purpose to the carbon lamina which is shown in the below figure. Hardener HY951 is used for the epoxy resin as it is mixed with the 1:10 ratio of the epoxy resin which is shown in the below Figure 3.
The laminate’s of the Carbon Epoxy, E-Glass Epoxy, Flax Epoxy and Bamboo Epoxy are shown in the below Figure 4. Clear films are used for the preparation of the different lamina sheets for non sticky purpose.

2.3 Glass Fiber Reinforced Polymer (GFRP):

The reinforced polymers consisting of glass fibers are known as glass fiber reinforced polymers. Glass fibers have been around us for centuries, these are produced in bulk in strand form is done from 1932 when Games slayter a researcher accidentally discovered them at owens-illinois directed a jet of compressed air at a stream of molten glass and produced fibers.

The physical properties of GFRP are high corrosion resistance, low dielectric constant, higher electrical resistivity and high tensile strength. The applications of GFRP are automobile parts, home furniture, boats.

The advantages of GFRP are low modulus of elasticity, self abrasiveness, relatively low fatigue resistance, higher density compared to carbon fibers and organic fibers, high tensile strength and good insulation. The disadvantages are brittle and weak abrasive resistance.
Two directional E-Glass woven fabrics are gathered from the market in the form of sheets of length 1.5 meters. The required length for the E-Glass lamina is 260 mm in length and 27 mm width. The E Glass woven sheet is shown in the below Figure 5.

![E Glass woven Fabric](image)

**Figure 5** E Glass woven Fabric

### 2.4 Flax Fiber Reinforced Polymer

Flax fiber reinforced polymer is a natural polymer comes from the flowering plant which is of best family. It is comparatively has high strength than many natural fibers. The advantages of the FFRP are lower pollution level during production, CO2 Neutral, low cost, low Density, renewable resource and recyclable material.

The disadvantages of the FFRP composite are Stress – Strain response is nonlinear, highly inhomogeneous, degradation of properties and properties depend on growing and processing conditions.

Two directional flax woven fabrics are gathered from the market in the form of sheets of length 3 meters. The required length for the flax lamina is 260 mm in length and 27 mm width. The flax woven sheet is shown in the below Figure 6.

![Flax woven Fabric](image)

**Figure 6** Flax woven Fabric

### 2.5 Bamboo Fiber Reinforced Polymer

Bamboo fiber is cellulose fiber plant in grasses family which is produced from natural bamboo plant which is grown within 6 to 8 months of tall 40 m. Now days, bamboo fibers are using frequently in the market due to their own properties. There are around 1000 species of bamboo recognized worldwide. Its fiber has many advantages over cotton fiber. Applications: Textile industries, used for making fabric as meso, antibacterial property, moisture
absorption, elasticity, UV resistant, building materials, bathroom products, decorating items, hygiene products, etc.

Two directional bamboo woven fabrics are taken in the form of sheets of length 3 meters. The required length for the bamboo lamina is 260 mm in length and 27 mm width. The bamboo woven sheet is shown in the below Figure 7.

![Figure 7 Bamboo woven Fabric](image)

2.6 Laminates:

Bamboo epoxy laminate is made up of ten bamboo lamina (Fiber orientation of $0^0$, $90^0$) glued together by the epoxy resin and the final laminate figure is shown in the below Figure 8.

![Figure 8 Composite laminate (Bamboo Epoxy)](image)

Flax epoxy laminate is made up of three flax lamina (Fiber orientation of $0^0$, $90^0$) glued together by the epoxy resin and the final laminate figure is shown in the below figure 9.

![Figure 9 Composite laminate (Flax Epoxy)](image)

E Glass epoxy laminate is made up of six E Glass lamina (Fiber orientation of $0^0$, $90^0$) glued together by the epoxy resin and the final laminate figure is shown in the below Figure 10.
Figure 10 Composite laminate (E Glass Epoxy)

Carbon epoxy laminate is made up of six carbon lamina (Fiber orientation of $0^\circ$, $90^\circ$) glued together by the epoxy resin and the final laminate figure is shown in the below Figure 11.

Figure 11 Composite laminate (Carbon Epoxy)

A Hybrid reinforced polymer Composite laminate having combination of Flax + E Glass is made up of two flax lamina’s and three E Glass lamina (Fiber orientation of $0^\circ$, $90^\circ$) glued together by the epoxy resin and the final laminate figure is shown in the below Figure 12.

Figure 12 Hybrid Composite laminate (Flax +E-Glass Epoxy)

A Hybrid reinforced polymer Composite laminate having combination of Bamboo + E Glass is made up of three Bamboo lamina’s and three E Glass lamina (Fiber orientation of $0^\circ$, $90^\circ$) glued together by the epoxy resin and the final laminate figure is shown in the below Figure 13.

Figure 13 Hybrid Composite laminate (Bamboo + E-Glass Epoxy)
A Hybrid reinforced polymer Composite laminate having combination of Flax + Carbon is made up of two flax lamina’s and two Carbon lamina (Fiber orientation of $0^0, 90^0$) glued together by the epoxy resin and the final laminate figure is shown in the below Figure 14.

**Figure 14** Hybrid Composite laminate (Flax + Carbon Epoxy)

A Hybrid reinforced polymer Composite laminate having combination of Bamboo + Carbon is made up of four bamboo lamina’s and three Carbon lamina (Fiber orientation of $0^0, 90^0$) glued together by the epoxy resin and the final laminate figure is shown in the below figure 15.

**Figure 15** Hybrid Composite laminate (Bamboo + Carbon Epoxy)

A Hybrid reinforced polymer Composite laminate having combination of Bamboo + Flax is made up of three bamboo lamina’s and two flax lamina (Fiber orientation of $0^0, 90^0$) glued together by the epoxy resin and the final laminate figure is shown in the below Figure 16.

**Figure 16** Hybrid Composite laminate (Bamboo + Flax Epoxy)

A Hybrid reinforced polymer Composite laminate having combination of Carbon + E Glass is made up of three carbon lamina’s and three E Glass lamina (Fiber orientation of $0^0, 90^0$) glued together by the epoxy resin and the final laminate figure is shown in the below Figure 17.

**Figure 17** Hybrid Composite laminate (Carbon +E-Glass Epoxy)
Note: The above specified specimens are fabricated up to 3 sets, i.e., each variety is fabricated with 3 specimens.

3. Testing and Results

Tensile test on the specimens is performed by the universal tensile machine which uses the standards of ASTM D3039 and the calculated results and the density of the plane composites are shown in Figure 18.

![Density Graph](image1.png)

**Figure 18** Densities of the Plane Composites

From the above figure, it is shown that the maximum value of the density takes place with the E Glass Epoxy and minimum value of the density takes place with bamboo Epoxy. The young’s modulus of the plane composites are shown in the below Figure 19.

![Young's Modulus Graph](image2.png)

**Figure 19** Young’s Modulus of the Plane Composites

From the above figure, it is shown that the maximum value of the young’s modulus takes place with the Carbon Epoxy and minimum value of the density takes place with
Bamboo Epoxy. The tensile strength of the plane composites are shown in the below Figure 20.

![Tensile Strength](image)

**Figure 20** Tensile Strength of the Plane Composites

From the above figure, it is shown that the maximum value of the tensile strength takes place with the carbon epoxy and minimum value of the tensile strength takes place with bamboo epoxy. The densities of the hybrid composites are shown in the below Figure 21.

![Density](image)

**Figure 21** Densities of the Hybrid Composites

From the above figure, it is shown that the maximum value of the density takes place with the Carbon + E Glass Epoxy and minimum value of the density takes place with Flax + Carbon Epoxy. The young’s modulus of the hybrid composites are shown in the below Figure 22.
From the above figure, it is shown that the maximum value of the young’s modulus takes place with the Carbon + E Glass Epoxy and minimum value of the density takes place with Flax + E Glass Epoxy. The tensile strength of the hybrid composites are shown in the below Figure 23.

**Figure 23** Tensile Strength of the Hybrid Composites

From the above figure, it is shown that the maximum value of the Tensile Strength takes place with the Carbon + E Glass Epoxy and minimum value of the Tensile Strength takes place with Bamboo + Flax Epoxy.

**4. Conclusions**

From the experimental results for the mechanical properties of the plane composites, carbon epoxy posse’s higher young’s modulus and higher tensile strength. Bamboo epoxy having less young’s modulus and less yield strength values. From the hybrid composite test results, carbon + E Glass epoxy hybrid composite posses higher young’s modulus and higher yield strength compared to other materials. So, it is recommended to use Carbon + E-Glass Epoxy hybrid composite for higher load applications.
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