MECHANICAL CHARACTERISATION OF GLASS/EPOXY, CARBON/EPOXY, AND HYBRID COMPOSITE

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Abstract:Glass, Carbon and hybrid fiber material is a well-established branch of research in composite structures stability. It has a wide range of applications in engineering science and technology. Polymeric materials reinforced with synthetic fibers such as glass, carbon, and hybrid fiber provide advantages of high stiffness and strength to weight ratio as compared to conventional construction materials. Composite subjected to in-plane loads is an important consideration in the preliminary design of aircraft and launch vehicle components. The sizing of many structural subcomponents of these vehicles is often determined by stability constraints. The purpose of this project was to generate the experimental and analytical investigation, conducted to find out the mechanical properties. In analytical method, the different types of stress distributions were found out by using the ANSYS 12 software. In experimental method, the mechanical properties were found by using tensile test and flexural test in universal testing machine.

Composite fiber Plates are extensively used as structural members in aircraft design. The Glass fiber, carbon fiber and hybrid materials behavior of such has always received much attention by researchers. These materials were used access in the case of fuselage, wings, windows and doors. In some cases composite materials are used to reduce the weight of the structure. In aerospace and many other applications these structural components are also made up of composite material to further reduce the weight of the structure. The outstanding mechanical properties of composite structures, such as durability and corrosion-resistance characteristics combined with low density, make it more attractive compared to conventional materials.

Index Terms **- Glass fiber, carbon fiber, Kevlar fiber, properties, tensile test,and flexural test**

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1. INTRODUCTION

1.1Composite Materials

Composite tools are usually made from epoxy resin matrix and either E-glass or carbon fibers as reinforcements. Depending on the life cycle required, tools could be made from prepreg or by wet lay-up procedures. Prepregs generally require curing within an autoclave because of the elevated pressures. Because of the increased compaction available while curing in an autoclave, tooling fabricated from prepregs ate capable of a greater number of cure cycles than the wet lay-up method. In addition to greater compaction, autoclave curing offers better control of resin content and uniformity of reinforcement.

Laminates are composite material where different layers of materials give them the specific character of a composite material having a specific function to perform. Fabrics have no matrix to fall back on, but in them, fibers of different compositions combine to give them a specific character. Reinforcing materials generally withstand maximum load and serve the desirable properties.

Increasing use of composites in aerospace, aircraft and marine for primary structural applications necessitated a comprehensive study of environmental effect of on its structural properties. The durability of fiber reinforced composites can't be established by a single measure of behavior. It is probable that fatigue, fracture, viscoelasticity, Impact and environmental effects all compete to define composite materials. In order to utilize the full potential of composite materials, the optimum and safe design of structure, the studies on environmental become essential.

Aerospace structural engineers are always in search of materials with high specific strength and stiffness in their pursuit to procedure structures of low weight and cost. They realised that their ambition can be partially fulfilled by adapting to composite materials. Composite materials can be tailored to efficiently meet design requirements of strength, stiffness and other parameters all in different directions Current developments in composite materials are pointed toward combinations of unusually strong high modulus fibers and organic, ceramic or metal matrices. Such materials promise to be more efficient than any structural materi als known previously into regions unattainable only a few years ago.

The performance of composite materials may suffer during and after exposure to high temp and high moisture content environments. Therefore considerable efforts have been made in recent years to evaluate the response of composite materials to moist and hot environments.

Naturally, the composite materials will be subjected to a variety of real life environments. For example, one of the more extreme environmental conditions experienced by a composite component on fighter aircraft occurs during a supersonic dash. The aircraft dives from high altitude (outer surface temp -20 deg C to -55deg C) into a supersonic low altitude run during which the surface temperature rises in minutes to between 100 to 150 deg C as a result of aerodynamic heating. On reduction of the speed, the outer surface temperature drops rapidly at rates upto 500 deg C/min, thus exposing the composite to a thermal spike. On the other hand, some of the spacecraft structural components are exposed to very low temperatures from liquid helium (4 deg K) to liquid nitrogen (77 deg K).

1.2 HYBRID COMPOSITES

The Hybrid Composite frequently refers to the kinds of fiber reinforced materials, usually resin based, in which two types of fibres are incorporated into a single matrix. The concept is a simple extension of the composites principle of combining two or more materials so as to optimize the effects of less desirable properties. Any combination of dissimilar materials could be thought of as Hybrid.

Some Hybrids of current interest represent attempts to reduce the cost of the expensive composites containing reinforcements like Carbon by cheap, low quality fibres like Glass so as to have an optimized quality. Of equal importance is the reverse principle i.e. improving the quality of the cheap low quality fibres like Glass with expensive high quality fibres like Carbon and Kevlar without inflicting too much cost penalty. Hybrid composites provide wider possibilities to control material stiffness, strength and cost. A promising application of these materials is associated with the so- called Thermo stable-structures that do not change their dimensions under heating or cooling. For Composites e.g., with Glass of boron fibres, the longitudinal coefficient of thermal expansion is positive, while for other materials, e.g., with Carbon or Aramid fibres, it is negative. So, the proper combination of fibres with positive and negative coefficient can results in material with zero thermal expansion. In Aerospace applications, a familiar purpose of using Hybrids is to utilize the natural toughness of Glass Reinforced Plastics (GRP) or of Kevlar fiber reinforced Plastics (KFRP) to offset a perceived brittleness of typical Carbon fiber reinforced plastics (CFRP). From the designer’s point of view, the important aspect of using Hybrids is that provided there is adequate understanding of underlying mechanisms of Stiffening, Strengthening and Toughening, we can allow even a closer tailoring of Composites properties to suite specific requirements rather than using a single fiber type of Composites.

In the present work, Kevlar and Glass fibers are combined with Epoxy as the reinforcing matrix to obtain the hybrid composite laminate. Kevlar has relatively high tensile strength and high impact strength compared to Glass but weaker in compressive strength and flexural strength. By combining these fibers together, all these properties can be optimized as needed.

Table-1.2.1 Mechanical Properties of fibers

Material	Density, 10^3 Kg/m^3	Fiber diameter, μm	Young’s Modulus, Gpa	Tensile Strength, Gpa
Silica (E Glass)	2.5	10	70	1.5-2.0
carbon	1.8	15	230	3.3

SELECTION OF FIBER AND MATRIX MATERIAL

1.3 FIBER MATERIALS

A material created by combining two or more materials such that the final construction exploits certain properties from each. In the construction of glass, carbon fiber reinforced plastics, the high strength, high stiffness of the carbon fibers are combined with a low density stable matrix to create a combined material with desirable material properties. Contemporary composites results from research and innovation from past few decades have progressed from glass fiber for automobile bodies to particulate composites for aerospace and a range other applications.

A fiber which when encapsulated in a polymer rein matrix forms a composite fiber laminate. Also refers to a structural member designed to stiffen a molded part. The primary function of the reinforcement is to carry the loads along their longitudinal directions. Some of the common fiber reinforcing agents includes. Organic and inorganic fibers are used to reinforce composite materials. Almost all organic fibers have low density, flexibility, and elasticity. Inorganic fibers are of high modulus, high thermal stability and Possess greater rigidity than organic fibers and notwithstanding the diverse advantages of organic fibers which render the composites in which they are used.

Mainly, the following different types of fibers namely, glass fibers, silicon carbide fibers, high silica and quartz fibers, aluminum fibers, metal fibers and wires, graphite fibers, boron fibers, aramid fibers and multiphase fibers are used. Among the glass fibers, it is again classified into E-glass, A-glass, R-glass.

Glass fiber and **carbon fiber** are mostly used in the aviation industries. The material chosen for the project is

1. **Glass fiber**,
2. **Carbon fiber**,
3. **Glass/Carbon fiber (HYBRID)** especially woven fabric

1.3.1 GLASS FIBERS

Glass fibers are silica based (=50-60% sio2) and contain a host of the other oxides of calcium and iron. Glass fibers are the earliest known fibers used to reinforce materials. Ceramic and metal fibers were subsequently found out and put to extensive use, to render composites stiffer more resistant to heat.

Type of glass fibers

1. E-glass (Electrical glass)
2. C-glass (Corrosion resistive glass)
3. S-glass (Silica glass)

Table 1.3.1 Composition of different glass fibres

Composition	E-glass	C-glass	S-glass
SiO_2	55.2	65.0	65.0
$Al2O_3$	8.0	4.0	25.0
CaO	18.7	14.0	--
MgO	4.6	3.0	10.0
Na_2O	0.3	8.5	0.3
K_2O	0.2	--	--
B_2O_3	7.3	5.0	--

E-Glass

The chemical composition of the electrical glass fiber is mentioned in the above table.

1. E-glass is a good electrical insulator in addition to having good strength and reasonable Young’s modulus.
2. These are used for reinforcement of polyester, epoxy and phenolic resins.
3. It is quite cheap and it is available in variety of forms. Continuous strand is a group of 204 individual fibers, roving is a group of parallel strands. Chopped fiber consists of strand or roving chopped to lengths between 5 and 50mm.
4. Also available in the form of woven fabrics or non-woven mats.
5. The glass fiber material low cost when compare other fiber. The glass fiber specimen is shown in figure 1.

Fig: 1

PROPERITIES OF E-GLASS

1. Density is quite low and the strength is quite high.
2. Young's modulus is moderate.
3. Thus strength to weight ratio is high but the modulus to weight ratio is only moderate.
4. Moisture decreases the strength.
5. Glass fiber are also susceptible is called static fatigue that is , when subjected to a constant load for an extended time period , glass fibers can undergo subcritical crack growth. This leads to failure over time at loads that might be safe when considering instantaneous loading.

Table 1.3.2 Properties of E-glass

Properties	Value	Unit
Density	2.55	g/cm^3
Tensile strength	1750	MPa
Young's modulus	72.3	GPa
Co-efficient of thermal expansion	$4.7*10^{-6}$	K^{-1}

ADVANTAGES OF GLASS FIBER

1. High tensile strength and strain to failure.
2. Heat and fire resistance.
3. Chemical resistance.
4. Moisture resistance.
5. Thermal and electrical properties are also cited as reason for it use.
6. It is by far the most widely used fiber, primarily because of its low cost.
7. But its mechanical properties are not comparable with other structural fibers.

1.4. EPOXY - CHEMICAL RESISTANCE

Epoxy is one of the major thermoset matrix materials.

The term epoxy is a general description of polymers which are based on molecules that contain epoxide groups. An epoxide group is oxirane structure, a three member ring with one oxygen and two carbon atoms. Epoxies are polymerizable thermosetting resins containing one or more epoxide groups curable by reaction with amines, acid, alcohols, phenols, acid anhydrides, or mercaptanes.The polymers are available in a variety of viscosities from liquid to solid.

Epoxies are used widely in resins for prepregs and structural adhesives. The advantages of epoxies are high strength and modulus, low levels of volatiles, excellent adhesion with glass fiber, low shrinkage, good chemical resistance, and ease of processing. Their major disadvantages are brittleness and the reduction of properties in the presence of moisture. The processing or curing of epoxies is slower than polyester resin. The cost of the resin is also higher than the polyesters. Processing techniques include autoclave molding, filament winding, press molding, vaccum bag molding, resin transfer molding and pultrusion.

Curing temperatures vary from room temperature to approximately 350 of.

The most common cure temperatures range between 250 of and 350 of .The use temperature cures generally yield greater temperature resistance. Cure pressures are generally considered as low pressure molding from vaccum to approximately 100psi (700kpa).

The extensive use of epoxy resin is due to

1. The ease with which it can be processed.
2. Excellent mechanical properties.
3. High hot and wet strength properties (150^{o}C)
4. Resistance to degradation by water and other solvents.

Epoxy (polyepoxide) is an epoxide polymer that cures when mixed with a catalyzing agent or "hardener". Epoxy resin have an excellent electrical, thermal, and chemical resistance. It is common to increase the strength of epoxy with fibrous reinforcement or mineral fillers. The variety of combinations of epoxy resins and reinforcements provides a wide latitude in properties obtainable in molded parts.

1.5 USES OF ADHESIVE PROPERTIES

1.5.1ARALDITE LY 556 AND HARDENER HY 951

Araldite LY 556 is a solvent-free epoxy resin of medium viscosity. It can be mixed hardener HY 951 to give casting of good mechanical and electrical properties. Castings are characterized by good rigidity and excellent volume resistivity.

The mixing proportion is as follows:

ARALDITE LY 556 - 100 PARTS BY WEIGHT.

HARDENER HY 951 - 10-12 PARTS BY WEIGHT.

The hardener HY 951 is thoroughly mixed with the resin. If a large quantity of mixture is to be prepares the resin must be cooled, as otherwise strong exothermic heat is developed and the mixture will gel in a short time.

Pot life 30-60 minutes at 20^{o}C

Curing 14-24 hours at 20^{o}C

When large quantities are cured it is advisable gel the mixture first at room temperature followed by curing at higher temperature which minimizes the possibility of cracking due to excessive exothermic.

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1.6. FABRICATION OF COMPOSITE PLATE AND TEST SPECIMEN:

Introduction

Fabrication of laminated composites includes selecting a material system or a group of material systems and determining the stacking sequence for the laminate based on applied loads and constraints on optimizing and constraining factors such as cost, weight as related to aerospace and availability. Based on all the factors, glass/epoxy and carbon/epoxy, hybrid laminated composite plates were fabricated.

1.7. PREPARING THE MOULD

Remove any dust and dirt from mold. If mold is of plaster, wood, or new fiberglass, apply soft wax and buff with soft towel. Spray or brush with PVA, parting compound and allow to dry. If mold material is glass, metal, ceramic, or well-cured fiberglass, apply three coats of hard wax, carnauba type, buffing between each coat.

1.8. APPLYING THE GEL-COAT

1. If gel-coat is to be brushed on, allow first coat to cure and then apply the second coat to make sure there are no light spots.
2. If gel-coat is to be sprayed on with a gel-coat gun, spray up to a thickness of .015” to 020”.

When gel-coat has cured long enough that your fingernail cannot easily scrape it free (test at edge of mold where damage will not show on part) then proceed with next step.

1.9 LAY-UP SKIN COAT

Glass fibers of dimension 300x300mm are cut from the big roll. Brushes catalyzed resin over gel-coat, and then apply the mat. Work with roller adding more resin where necessary until all white areas in mat fibers have disappeared and all air bubbles have escaped. Resin-rich areas weaken the part. Where rollers will not reach, brushes must be used. When this step is complete, clean all tools in acetone. Allow skin coat to cure before next step.

2. LAYING FIBERGLASS REINFORCEMENT

Apply each layer as in step 3, but it will not be necessary to wait for curing between these layers. Be sure to shake all acetone out of brushes and rollers before applying resin. Acetone drips can result in uncured spots in the lay-up.

2.1. TRIM

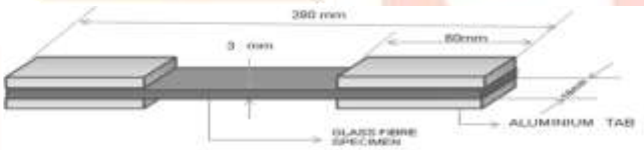
On a small lay-up, the fiberglass laminate which hangs over the edge of the mold can be trimmed off easily with a razor knife if you catch the "trim stage," of the period after the lay-up has gelled but before it has hardened. On a larger lay-up, it can be trimmed with a saber saw and coarse sand paper.

2.2. CURE

It may take from two hours to overnight, depending upon turnover desired, temperature, canalization, and nature of the part. If laid up in a female mold, longer cure will affect shrinkage and easier parting. In the case of the male mold, the part comes off more easily before it shrinks appreciably. If the part is subject to warping, a longer cure may be necessary. In any case, when the part is removed it should be supported in its desired shape until fully cured.

2.3 TEST SPECIMEN

Figure 2 Test Specimen



- The GFRP laminate obtained from the compression moulding machine will be having the dimensions of 300x300x3mm.
- As per ASTM D3039 standard the dimensions of the tensile test specimen should be 280x18x3 mm.
- To prepare the specimens from the laminate, Water jet cutting machine which uses abrasive sand mixed with water as cutting tool is used.
- Aluminum tab of dimension 60x20x3mm is cut.

Aluminum tab is fixed with the tensile test specimen using Araldite

Fabrication of laminated composites includes selecting a material system or a group of material systems and determining the stacking sequence for the laminate based on applied loads and constraints on optimizing and constraining factors such as cost, weight as related to aerospace and availability.

2.4 TENSILE TEST (ASTM 3039)

Tensile test is known as a basic and universal engineering test to achieve material parameters such as ultimate strength, yield strength, % elongation, % area of reduction and Young's modulus. These important parameters obtained from the standard tensile testing are useful for the selection of engineering materials for any applications required.

The tensile testing is carried out by applying longitudinal or axial load at a specific extension rate to a standard tensile specimen with known dimensions (gauge length and cross sectional area perpendicular to the load direction) till failure. The applied tensile load and extension are recorded during the test for the calculation of stress and strain.

Using the load versus elongation data together with experimental measurements of the sample cross section and gauge length, plot stress-strain diagrams for each of the three specimens. For each material determine: the 02% offset yield strength, the ultimate tensile strength, and the percent elongation to failure. The tensile characterization was conducted according to ASTM

D3039 testing standard using a 133KN Instron machine in displacement control test mode. These tests are conducted at displacement rate of 5.08 mm/min (0.2 inches/min). Data for load, displacement and strain were obtained from the test procedure.

The dimension of tensile specimen according to **ASTM 3039** as follows;

Length	- 280 mm
Width	- 18 mm
Thickness	-3 mm
Gauge length	- 50 mm
Tab length	- 60mm

2.5 FLEXURAL TEST (ASTM D-790)

These test methods cover the determination of flexural properties of unreinforced and reinforced plastics, including high-modulus composites and electrical insulating materials in the form of rectangular bars molded directly or cut from sheets, plates, or molded shapes. These test methods are generally applicable to both rigid and semi rigid materials. However, flexural strength cannot be determined for those materials that do not break or that do not fail in the outer surface of the test specimen within the 5.0 % strain limit of these test methods. These test methods utilize a three-point loading system applied to a simply supported beam.

Figure: 3

The dimension of tensile specimen according to ASTM D-790 as follows;

Length	- 154 mm
Width	- 12.7 mm
Thickness	- 3 mm
Gauge length	- 50 mm
Tab length	- 60mm

RESULTS AND DISCUSSION

3. INTRODUCTION

In this section, The composite specimen of glass fiber, carbon fiber and hybridization of fiber on the mechanical performance of ultimate stress and flexural stress is validate by using load versus displacement .In this project three various types of fiber are used and comparing the tensile stress value for tensile tested specimen which are shown in the chart bar1 . In bar 1 the values are calculated by experimentally by using universal testing machine. In bar 2 the same stress values is compared with glass/epoxy, carbon/epoxy and hybrid fiber for flexural (compressive) test .The values are shown as different colors. The results of experimental and analysis work aimed at examining the result compared with experimental values obtain from this project work is divided into two test method.

3.1. CHARACTERIZATION OF TESTING PERFORMANCE

The mechanical properties from the data collected include ultimate tensile strength (UTS), Young's modulus and maximum strain. The results obtained from the ultimate tensile test are shown in graph. The hybrid composite material systems showed some changes in the UTS, Young's modulus, and maximum strain compared to the baseline advanced composite with glass fiber and carbon fiber. The experimental results showed some variations in the averaged values obtained based on material properties.

The results of testing in flexural test (three-point bending) of glass, carbon and hybrid fiber-reinforced epoxy composites are described. This loading mode has been chosen in order to increase the variety of failure modes and of fracture mechanisms. The main failure modes observed are tensile and delamination, with a transition at a fiber volume fraction of about 46%. This mode transition is detectable by monitoring various mechanical properties and acoustic emission data against the fiber volume fraction.

The results from the tensile tests show significant changes in the ultimate tensile strength and the modulus of hybrid material configuration compared glass fiber, carbon fiber. The fatigue tests also showed significant change in the fatigue life characteristics and fatigue models of the baseline composite like glass, carbon and the hybrid. Finally however, the hybridization showed average improved properties when compare to the glass/ carbon fiber and Carbon fiber having more strength when compare to the glass and hybrid. The variation of tensile and flexural strengths of the composites with the fiber content. A gradual increase in tensile strength as well as flexural strength with the weight fraction of fiber is noticed. It may be mentioned here that both tensile and flexural strengths are important for recommending any composite as a candidate for structural applications.

3.2 EXPERIMENTAL STUDY

An experimental model that considers ultimate strength and maximum deflection of stress is compared with analytical result as shown in the below tabular Colum .Here the average value is calculated from the three various tested specimen like glass fiber , carbon fiber and hybrid (glass/carbon) fiber. In each fiber three specimens are tested to find out the valuated average value. In ansys the maximum load is used to find out the percentage. In comparison tables has shown the percentage deviation. In this project the percentage of glass fiber 7% and hybrid is 6.3% deviation found .carbon fiber is 25%more than glass fiber and hybrid fiber.

Initially carbon give a good percentage of the response of carbon-epoxy composites when compare to the glass fiber and hybrid fiber.

TENSILE TEST –GLASS FIBER

SL.NO	ULTIMATE STRENGTH	AVERAGE	ANSYS VALUE	%
1. 2. 3.	228.44 235.24 239.53	234.40	252.38	7%

Table: 3.2.1

TENSILE TEST –CARBON FIBER

SL.NO	ULTIMATE STRENGTH	AVERAGE	ANSYS VALUE	%
1. 2. 3	477.124 460.405 503.206	480.245	648.89	25%

Table:3.2.2

TENSILE TEST –HYBRID FIBER

SL.NO	ULTIMATE STRENGTH	AVERAGE	ANSYS VALUE	%
1. 2. 3	387.963 362.903 356.771	369.212	394.179	6.3%

Table:3.2.3

3.3 FLEXURAL TEST

An experimental model that considers ultimate breaking point and maximum displacement point is calculated by using 3-point bending test. Then the value is compared with analytical result as shown in the below tabular Colum .Here the average value is calculated from the three various tested specimen like glass fiber , carbon fiber and hybrid (glass/carbon) fiber. In each fiber three specimens are tested to find out the valuated average value. In ansys the maximum load is used to find out the percentage. In comparison tables has shown the percentage deviation. In this project the percentage of glass fiber 4.2% and hybrid is 48 % deviation found .carbon fiber is higher 51% more than glass fiber and hybrid fiber. Glass is very low strength when compare to carbon fiber and hybrid.

FLEXURAL TEST –GLASS FIBER

SL.NO	ULTIMATE STRENGTH	AVERAGE	ANSYS VALUE	%
1. 2. 3	400 450 300	383.3	366.934	4.2%

Table: 3.2.4

FLEXURAL TEST –CARBON FIBER

SL.NO	ULTIMATE STRENGTH	AVERAGE	ANSYS VALUE	%
1. 2. 3	750 700 800	750	363	51.6%

Table: 3.2.5

FLEXURAL TEST –HYBRID FIBER

SL.NO	ULTIMATE STRENGTH	AVERAGE	ANSYS VALUE	%
1. 2. 3	650 700 750	700	362.66	48%

Table: 3.3.1

3.4 TENSILE TEST RESULT

The maximum failure loads were predicted by using the load Vs. Displacement curve. The ultimate failure load elongation and max stress of the each specimen graph is shown was below. In **figure 1** shows the load vs. displacement curve for glass fiber which explain that the more tensile strength obtained is 228.495 N/mm^2

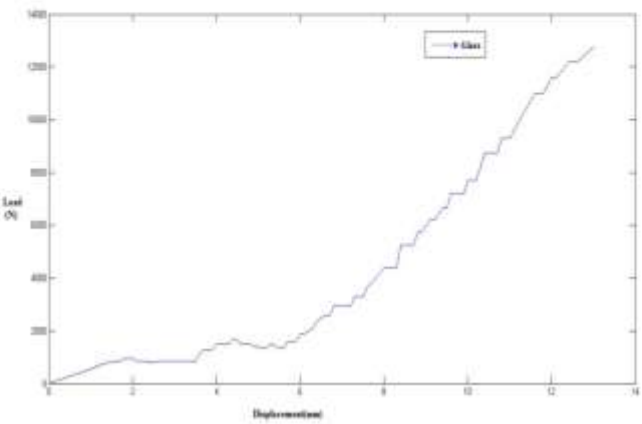


Figure: 1 Graph of load Vs. displacement curve drawn for glass fiber

In **figure 2** shows the load vs. displacement curve for carbon fiber which explain that the more tensile strength obtained is 460.405 N/mm^2

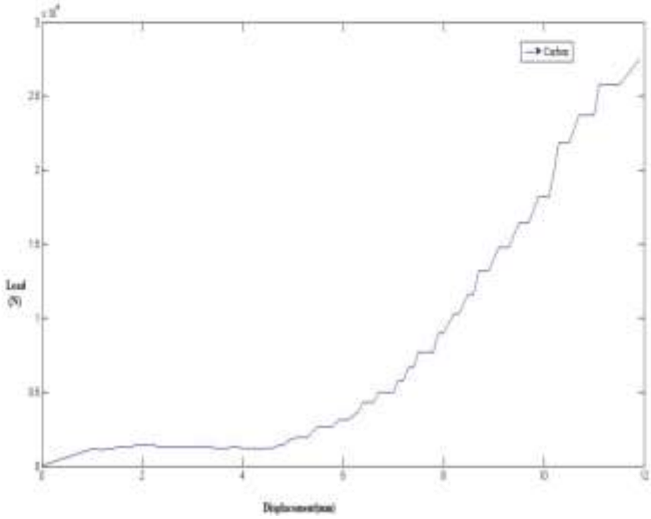


Figure: 2 Graph of load Vs. displacement curve drawn for carbon fiber

In **figure 3** shows the load vs. displacement curve for hybrid fiber which explain that the more tensile strength obtained is 387.963 N/mm^2

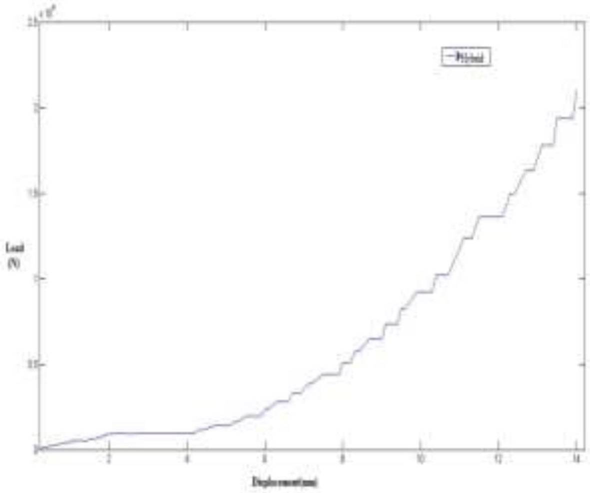


Figure: 3 Graph of load Vs. displacement curve drawn for Hybrid (glass/carbon) fiber

3.4.1 COMPARISON OF TENSILE TEST RESULTS

(Glass epoxy, carbon epoxy, Glass/Carbon/epoxy)

Graph shows the comparison of load vs. displacement for glass/epoxy, carbon/epoxy and Glass/carbon/epoxy which explain maximum tensile strength is obtained for carbon fiber and least is Glass fiber, hybrid as a intermediate value. Carbon fiber high tensile strength occurs in this experimental value.

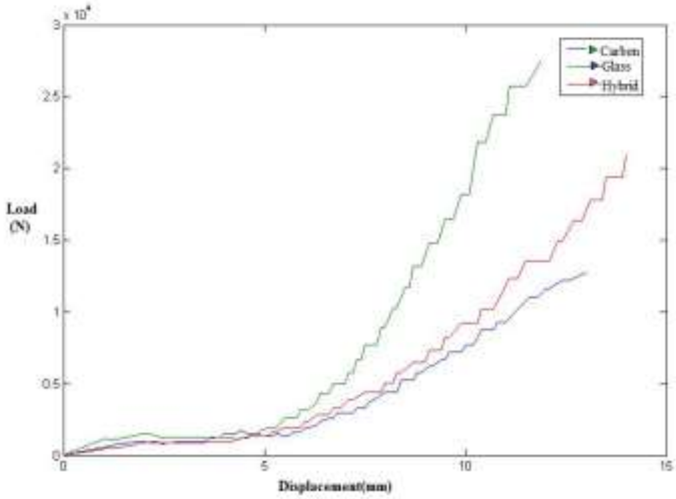


Figure: 4 Comparative graph of load Vs. displacement curve drawn for glass fiber ,carbon fiber and hybrid

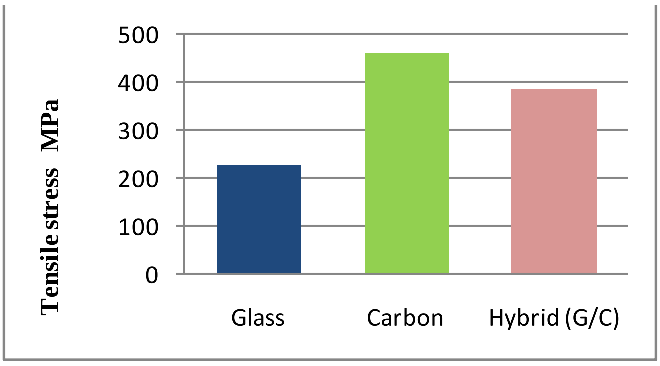


Figure: 5 Comparative graph of ultimate tensile stress curve drawn for glass fiber, carbon fiber and hybrid

3.4.2 FLEXURAL TEST RESULT

In three points bending test the maximum failure loads were predicted by using the load Vs. Displacement curve. The ultimate failure strength and max stress of the each specimen graph is shown was below. In **figure 6** shows the load vs. displacement curve for glass fiber which explain that the more flexural strength obtained is 450 N/mm^2

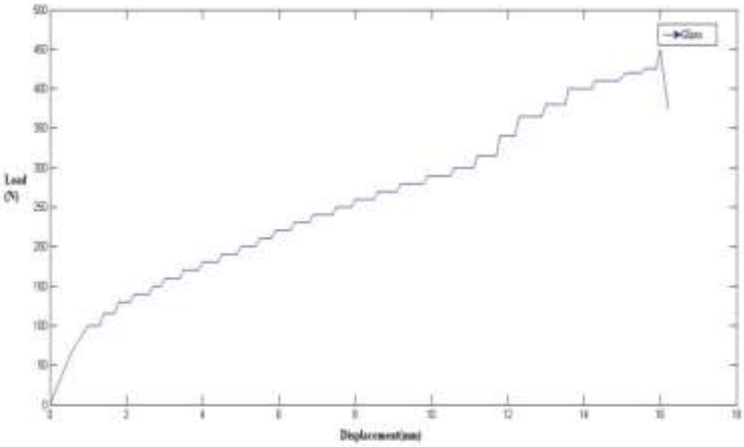


Figure: 6 Graph of load Vs. displacement curve drawn for glass fiber

In **figure 7** shows the load vs. displacement curve for Carbon fiber which explain that the more flexural strength obtained is 750 N/mm^2

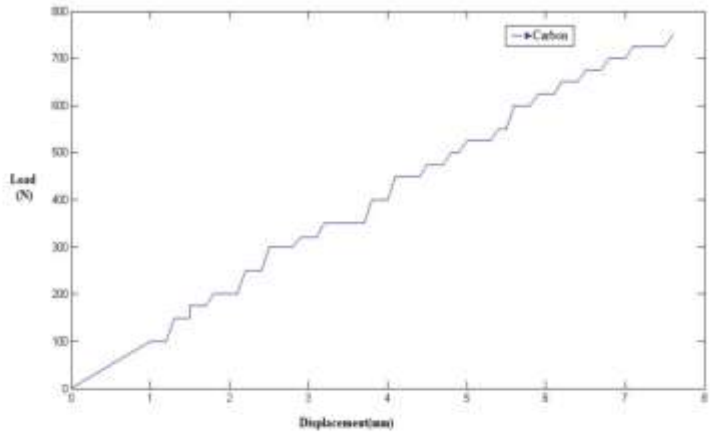


Figure: 7 Graph of load Vs. displacement curve drawn for Carbon fiber

In **figure 8** shows the load vs. displacement curve for hybrid (glass/carbon) fiber which explain that the more flexural strength obtained is 650N/mm^2

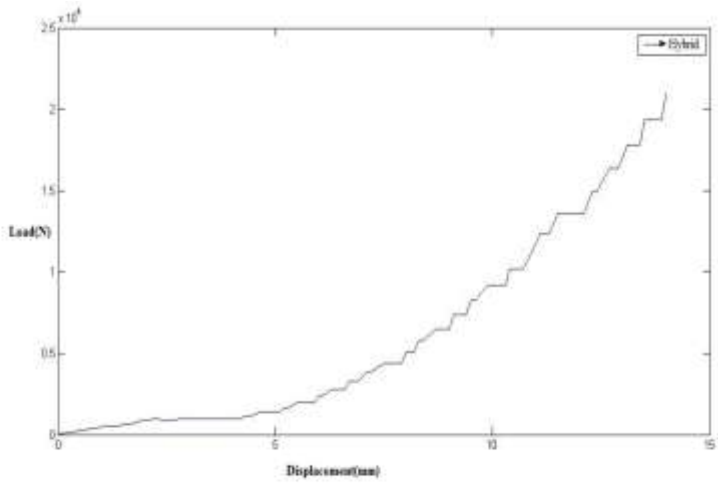


Figure: 8 Graph of load Vs. displacement curve drawn for Hybrid (glass/carbon) fiber

3.4.3.COMPARISON OF FLEXURAL TEST RESULTS

In figure 9, Graph shows the comparison of load vs. displacement for glass/epoxy, carbon/epoxy and Glass/carbon/epoxy which explain maximum flexural strength is obtained for carbon fiber and least is Glass fiber, hybrid as an intermediate value. Carbon fiber have high flexural strength occurs in this experimental value.

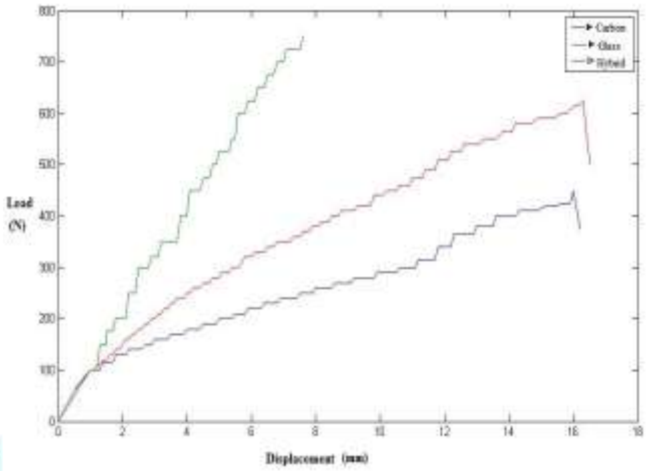


Figure: 9 Comparative graph of load Vs. displacement curve drawn for glass fiber, carbon fiber and hybrid

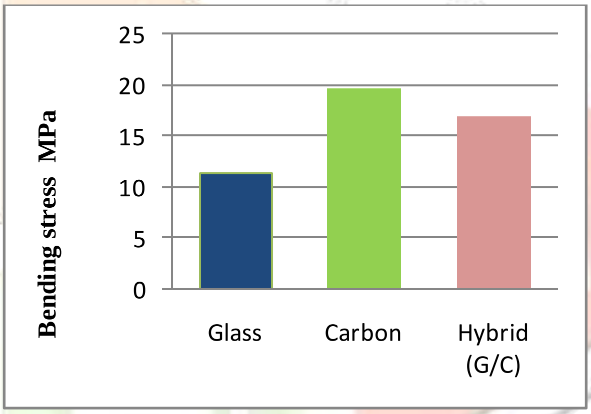


Figure: 10 Comparative graph of load Vs. displacement curve drawn for glass fiber, carbon fiber and hybrid

4. CONCLUSION

The result of various characterization tests are reported here. They include evaluation of tensile strength; flexural strength has been studied and discussed. The composite specimen of glass fiber, carbon fiber and hybrid of fiber on the mechanical performance of ultimate stress and flexural stress is validated by using load versus displacement. The experimental results are validated using the computational results.

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