"The Investigation of new carbon epoxy composite material to replace at applications of costly, heavy & rustable steel at tensile loadings."

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Abstract: The word composite in the term composite material signifies that two or more materials are combined on a macroscopic scale to form a useful third material. Here in this paper, we are investigating about the Epoxy glass fiber composites which are good for structural engineering of high strength and low weight and high stiffness. Aero planes and space vehicles are important to low weight structures in which glass composite materials are useful. The study of composite materials involves many topics for example manufacturing processes, anisotropic, elasticity strength of anisotropic materials and micromechanics. Particularly, Here in this paper we are going to compare the experimental and FEA results of the carbon epoxy composite material which can helpful for us to take decision of replacement at applications of costly, heavy & rustable metals used at tensile loadings.

Introduction: The usual design criterion for composite material is based on trying to get the best material which will give desired structural properties. For this it is required to analyze the factors which affect on that properties and how these properties are improved. Elastic constants are basic and important properties for the structural materials hence analysis of elastic constants is essential while designing the composite material and only one method for finding these constants is not sufficient.

In this project work modulus of elasticity for orthotropic (glass epoxy) composite lamina is found by experimentally and by using finite element method, as many times theoretical and finite element approach for these may not give true results.

The objective of this paper is to analyze theoretically, experimentally and by finite element method the mechanical behavior of composite material.

Epoxy glass fiber **c**omposites are good for structural engineering for high strength and low weight and high stiffness. Aero planes and space vehicles are important low weight structures in which glass composite materials are useful. The study of composite materials involves many topics for example manufacturing processes, anisotropi, elasticity strength of anisotropic materials and micromechanics. Composite material means two or more materials are combined to form a useful material. Properties are- Strength, Fatigue Life ,Stiffness, Temperature dependent, Corrosion Resistance, Thermal Insulation, Wear Resistance, Thermal Conductivity, Attractiveness, Acoustical Insulation, Weight.

Literature Survey:

Composite materials are ideal for structural application where high strength to weight and stiffness to weight ratios are required. Aircraft and spacecraft are typical weight sensitive structures in which composite materials are cost effective. Again composite material can be designed according to desired properties for getting the required properties of composite material analysis of these properties is essential.

An advanced book on mechanics of composite material by R. Jones covers applications of composite materials and micromechanical and macro-mechanical behavior of lamina and laminates as well as the design of the composite structure. They have derived theoretical methods for the analysis of composite materials.[11] An advanced book on mechanics of composite material by Autar K. Kaw covers applications of composite materials and micromechanical and macro-mechanical behavior of lamina and laminates as well as the design of the composite structure. They have derived theoretical methods for the analysis of composite materials and explained PRIMAL Software for micro and macro mechanical analysis of lamina.[12] A book on metal matrix composite by N. Chawla and K. K. Chawla has given the micromechanical analysis for the composite material. They have used some numerical methods for micromechanical analysis of the composite material.[13]

In the investigation of effects of randomness on band gap Formation in Models of Fiber-Reinforced Composite Panels Having Quasirandom Fiber Arrangements, Large-scale deterministic simulations are performed to observe the band gap formation in composite models having quasirandom fiber arrangements. Different quasirandom fiber arrangements are computationally generated using the same control parameters. Statistical parameters are used to quantitatively describe the fiber arrangements. Subsequently, a series of arrangements is generated from each base line arrangement by scaling up the coordinates of fiber centers, while the fiber diameter remains unchanged to study the effects of fiber spacing. Simulation results are compared with the corresponding case of ideally regular fiber arrangement. The most interesting observation is that the slight randomness in the fiber arrangements enhances the band gap phenomenon by introducing a few secondary band gaps adjacent to the primary band gap.[1][9]

A mechanism-based progressive failure analyses (PFA) approach is developed for fiber reinforced composite laminates. Each ply of the laminate is modeled as a nonlinear elastic degrading lamina in a state of plane stress according to Schapery theory (ST). In this theory, each lamina degrades as characterized through laboratory scale experiments [2]. Special Features are built into a user-defined material subroutine that is implemented through the commercial finite element (FE) software ABAQUS in conjunction with classical lamination theory (CLT) that considers a laminate as a collection of perfectly bonded lamina [3]. The success of the present PFA methodology is encouraging and points the way for extending the methodology to analyze other structural configurations.

In a study of stiffened panels subjected to shear loading a Composite Structures [4]. Experimental and analytical results are presented for a progressive failure of stiffened composite panels with and without a notch and subjected to the in-plane shear loading well into the post-buckling regime. Good agreement between experimental data and numerical results is observed for the stitched stiffened composite panels studied [5].

In the investigation of Theoretical and Experimental Dynamic Analysis of Fiber-Reinforced Composite Beams, inherent anisotropy allows the designer to tailor the material to achieve the desired performance requirements[6][10]

A simple experimental layout consisting of a shaker and a pair of miniature accelerometers was used to investigate the natural vibration modes of a cantilever sandwich beam with a transversely flexible core [7]. The natural vibration frequencies of the sandwich cantilever were measured over a wide range of frequencies, and the anti-symmetric and symmetric natural vibration modes of the soft-core sandwich cantilever were experimentally established. Experiments show that the damping properties of the foam core are manifest most noticeably in the case of the symmetric vibration modes, whereas the influence on the anti-symmetric modes is insignificant [8].

In this paper work modulus of the elasticity for orthotropic (glass epoxy) composite lamina is found by experimentally and by using finite element method as many times theoretical and finite element approach for these may not give true results.

The objective of this paper is to analyze theoretically, experimentally and by finite element method the mechanical behavior of the composite material.

Objectives:

1. To find out mechanical properties of glass epoxy composite materials experimentally & by finite element method
2. Investigation of glass epoxy composite material to replace at applications of costly, heavy & rustable metals used at tensile loadings

Steps used for Investigation of Glass fiber Epoxy material:

A specimen rod is molded & casted for tests. Density & Modulas of elasticity of that material is determined by these test to use these values in FEM analysis.FEM results are validated experimentally using UTM , Following steps are followed for experimental validation.

1. Development of Suitable fixture setup is done.
2. Selections of location of deflection measurement
3. Deflection measurement at predefined loading conditions.
4. Comparison of Values obtained from FEM analysis and those from experimental methods.

Broadly the steps are:

Glass fiber epoxy model making

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Molding of Epoxy material

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Epoxy solution preparation

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Testing of Epoxy material by using UTM

↓

Reading and observation noting

↓

FEA analysis through ANSYS

↓

Comparison between two

↓

Conclusions

Glass fiber Epoxy model making: Araldite chemical CY230 with the hardener HY951 is used as epoxy-matrix. This is heated in oven and mixed with in proper proportion. After cooling it will become solid and that solid specimen is used as glass epoxy model for testing.

Molding of Epoxy: White acrylic sheet is used for mold preparation of 2mm thickness. The plates are cut from the sheet according to mold size. Mold size selected for the epoxy specimen is 265 X 45 X 35 mm. Five plates are cut one for base having size 265 X 35 mm2, two side plates of 265 X 45 mm2 and two plates of 35 X 45 mm2 size is used. These plates are cut. All sides of plates are finished and made Holes with diameter of 2.5 mm are drilled for joining the sheets by using the feviquick and box is made with one open side. Then mold is cleaned. The wax or clay material is pasted in each joint to avoid the leakage. One side of the mold is kept open to pour the mixture. Thus mold is prepared & inspected it carefully for leak.

Epoxy Solution Preparation: Araldite solution of CY230 with the hardener of HY951 is separately heated in the oven for about 2.5 hours at a rate of 75 to 95 degree to remove moisture and air bubble. The heated solution is cooled slowly at room temperature. The hardener HY951 is added slowly to CY230 & HY951 mixture by weight is 100:10 During mixing, mixture is stirred continuously The mixture is stirred for about 25min. now it is ready for pouring into mold. Simultaneously acrylic mold is chemically cleaned. Then this mixture is poured in to mold very cautiously to avoid formation of air bubbles. The mold is completely filled by the mixture. At this position, the mold is kept for curing at room temperature for one day. That model is kept on plane surface for five days to become hard. After five day it is taken for test.

Testing of Epoxy to Obtain Stress Strain Curve: Finished specimen of epoxy is taken and its dimensions and cross sectional area is measured. The marking of center line along the length is done. From center line forty mm marking on both sides is done. Then that specimen is fixed in the UTM. This process is repeated up to failure of specimen by increasing load gradually deformation is recorded for each step of load. For applied load the stress in the direction of load is calculated and from recorded deformation strain for the respective applied load is calculated. From stress strain modulus of elasticity is found.

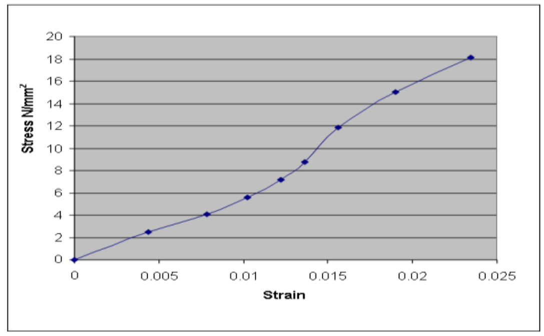
Instrument used for the experimentation:
UTM
Manufacturing Company: Tesla
Manufacturing Year: 2006
Capacity: 10000Kg

Experimental results:

Load (gm)	**Stress N/mm^2**	**Defor mation mm**	**Strain**	**Modulus of Elasticity N/mm^2**
800	2.4985	0.90	0.0044	569.10
1300	4.0601	1.60	0.0078	520.20
1800	5.6217	2.10	0.0102	548.784
2300	7.1833	2.50	0.0122	589.03
2800	8.7449	2.80	0.0137	640.25
3800	11.8681	3.20	0.0156	760.30
4800	14.9914	3.90	0.019	788.01
5800	18.1146	4.80	0.0234	773.64

From above results average value of modulus of elasticity is **649 N/mm^2**

Graph: Stress strain diagram for glass fiber specimen based on above table.



Similarly we have tested the modulus of elasticity for the composite material which comes around 1640 N/mm^2

Analysis Using FEM

The rod subjected to loads. Stress analysis is done using Finite Element Method.

Following steps are followed for stress analysis:

1. CAD model of rod is prepared by using dimensions.
2. Finite element mesh is generated.
3. Stress analysis of model is done by using software ANSYS.
4. Analysis of stress distribution, deformation is done.

ANSYS Results for Specimen: Length of specimen = 60 mm.

Load Kg	**Stress N/mm 2**	**Defor mation mm**	**Strain**	**Modulus of elasticity N/mm2**
1000	103	9.757	0.1587	1503
2000	103.87	9.443	0.116	1503.87
3000	102.78	14.31	0.177	1502.78
4000	103.5	18.96	0.234	1503.5
5000	103.26	23.75	0.293	1503.26

Modulus of elasticity by FEM analysis = **1503.28 N/mm2**

{Fiber String Specimen: Initial length of glass-fiber = 205 mm, Dia.of glass fiber 2mm,Area of glass fiber π x r x r = 3.141 mm2}

Fig1: Strain in specimen

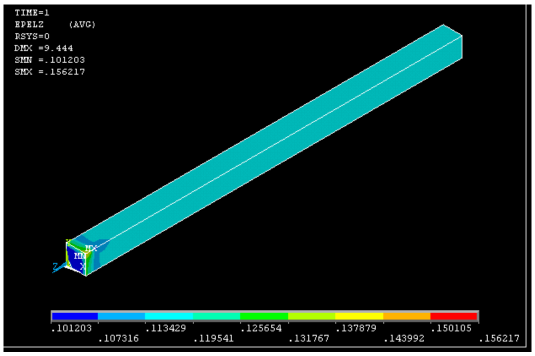
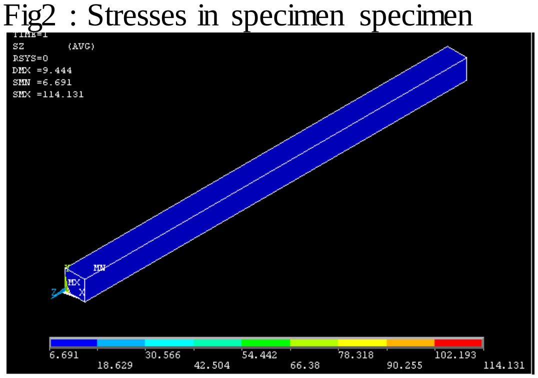


Fig2 : Stresses in specimen specimen



Similarly, FEA analysis is done for the fiber string and modulus of elasticity getting as 583 N/mm^2

Result & *Conclusion:* **G**lass fiber string is tested for finding modulus of elasticity. Modulus of elasticity is found from experimental results and from stress strain graph. In this paper modulus of elasticity obtained for glass fiber string is 583 N/mm2.

Table: Comparative modulus of elasticity

Material	**Modulus of elasticity experimental N/mm^2**	**Modulus of elasticity by FEM N/mm^2**
Fiber string	649	583
Composite specimen	1640	1503

- Percentage error in modulus of elasticity measured by experimental method as compared to calculated by ansys 9%.

Attempts have been made to fabricate a composite material made of glass fiber and epoxy material. Stress-strain curve for fiber, epoxy and composite material have been found out. Modulus of elasticity for glass fiber string, epoxy and composite specimens found by experimentally. The value of modulus of elasticity for glass fiber is calculated experimentally. It is observed in this analysis that the value of modulus of elasticity for single fiber is different than that of fiber string. Stress strain curve is drawn from experimental results to calculate modulus of elasticity. From that it is observed that there is slight difference because of following reasons.

1. In experimental analysis glass fibers are in the form of string and modulus of elasticity may change from string to string.
2. In finite element analysis by using ANSYS plane stress condition assumed but thickness of composite specimens is slightly more and axis symmetry is considered but specimens are not exact symmetric.

From experimental data and stress strain diagram it is seen that composite specimen behaves elastically up to point of failure and is subjected to brittle fracture. The fiber volume fractions of the specimens are near about 13 percent.

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