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Experimental Investigation and Free Vibration Analysis of Hybrid Laminated Composite Beam Using Finite Element Method

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Abstract: The present study aims at learning the mechanical behavior of Hybrid Synthetic fiber composites. The laminated composite beams are basic structural components used in a variety of engineering structures such as airplane wings, helicopter blades and turbine blades as well as many others in the aerospace, mechanical, and civil industries. An important element in the dynamic analysis of composite beams is the computation of their natural frequencies and mode shapes. This is important because composite beam structures often operate in complex environmental conditions and are frequently exposed to a variety of dynamic excitations. Free vibration analysis was carried out for identifying the natural frequencies. A dynamic analysis is carried out which involves finding of natural frequencies and mode shapes for different stacking sequences. Finally the non-dimensional natural frequencies of the beam are calculated by using ANSYS model of corresponding composite beam. Hybrid Composite Beams are made using the hand-lay-up process. E-Glass fiber and Carbon fiber are used as reinforcement in the form of Unidirectional and bidirectional fabric and Epoxy resin as matrix for the composite material of beams. Experiments are performed under Universal testing machine (UTM) and 3-point Bending Test. Flexural strength & Tensile strength were observed and compared to base values of epoxy polymer to perceive the change in strength. From the results, the influence of fiber orientations on the natural frequencies is investigated. Numerical analyses are carried out to study vibration behavior of composite laminated beams using ANSYS 15 software.
Keywords: Hybrid Composite beams, Vibration analysis, Finite element analysis, Natural frequencies, Mode shapes, ANSYS15

I. INTRODUCTION

A composite is a material consisting of two or more materials that are synthetically made with dissimilar materials. A composite material also must include chemically different constituent phases which are separated by a clear interface. Numerous composite materials are comprised of just two phases, one is known as the matrix which continuously surrounds the other constituent, which is called the dispersed phase. The properties of the reinforcement phase (i.e., volume fraction, shape and size of particles, distribution and orientation) define the properties of the composite. The roles of matrix in composite materials are to give shape to the composite part, protect the reinforcements to the environment, transfer loads to reinforcements and toughness of material, together with reinforcements. The role of reinforcements in composites is to get strength, stiffness and other mechanical properties.

A. Polymer Matrix Composites (PMCs)

The most common advanced composites are polymer matrix composites. These composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The reason for these being most common is their low cost, high strength and simple manufacturing principles.

Most commonly used matrix materials are polymeric. In general the mechanical properties of polymers are inadequate for many structural purposes.

In particular their strength and stiffness are low compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers. Secondly the processing of polymer matrix composites need not involve high pressure and doesn't require high temperature. Also equipment's required for manufacturing polymer matrix composites are simpler. For this reason polymer matrix composites developed rapidly and soon became popular for structural applications.

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B. Hybrid composite

Hybrid composites are more advanced composites as compared to conventional FRP composites. Hybrids can have more than one reinforcing phase and a single matrix phase or single reinforcing phase with multiple matrix phases or multiple reinforcing and multiple matrix phases. They have better flexibility as compared to other fiber reinforced composites. Normally it contains a high modulus fiber with low modulus fiber. The high-modulus fiber provides the stiffness and load bearing qualities, whereas the low-modulus fiber makes the composite more damage tolerant and keeps the material cost low. The mechanical properties of a hybrid composite can be varied by changing volume ratio and stacking sequence of different plies.

C. Natural frequency

If a system, after an initial disturbance, is left to vibrate on its own, the frequency with which it oscillates without external forces is known as its natural frequency. As will be seen later, a vibratory system having n degrees of freedom will have, in general, n distinct natural frequencies of vibration.

II. LITERATURE REVIEW

N. Nayak[1] This work is an experimental and numerical investigation on parametric study of vibration and buckling characteristics of industry driven woven fiber Glass-Carbon/epoxy hybrid composite panels. The effects of lamination sequence on the natural frequencies of vibration and buckling strength of the hybrid panels were studied in this investigation. The panels are cast using hand lay-up technique. The vibration study is carried out using B&K FFT analyzer, accelerometer, and impact hammer excitation. The experimental results are compared with the numerical predictions using the FEM based software package ANSYS 13.0. A very good agreement was observed between the experimental and ANSYS results. Pure carbon fiber plates possess higher strength in buckling and vibration compared to hybrid plates. In this way, the fabrication of hybrid laminates enables to optimize the structural response to external loads. Thus, composite structures can be designed for optimal structural, technological and economic response for a given geometry and state of stress of structural elements. C. Kyriazoglou[2] The work reported in this paper describes the development of a hybrid methodology for the prediction of damping properties of vibrating composite laminates. This hybrid methodology consists of experimental identification of damping, using vibration damping testing methods, and utilization of FEA. The finite element (FE) approach utilizes the concept of Rayleigh damping, and in particular mass proportional damping for the modeling of the damped response of vibrating systems. The association of damping properties with material reinforcement is highlighted. A series of continuous and woven, cross ply and quasi isotropic GFRP and CFRP coupons were vibrated. J. Alexander [3] This work focuses to compare vibration characteristics such as natural frequency and damping coefficient of BFRP composites with GFRP composites at various fiber orientations and end conditions. BFRP and GFRP composites with unidirectional cloth and Owen fabric are fabricated by compression molding machine and their mechanical properties were determined by using UTM as per ASTM standards. Vibration analysis of these materials was carried out by using modal analysis set up for various end conditions. Natural frequencies and damping coefficients were determined for all materials and end conditions. These results were compared with numerical results which are carried by using ABACUS software. Due to high damping coefficient of Basalt/epoxy composites and better vibration characteristics. P.S.Senthil Kumar [4] In this study the damping characteristics of Hybrid polymer composite, which can be used in many applications and in engineering structures. The investigation aims to develop glass-epoxy composite with addition of carbon (600mesh) fillers with different weight fractions and to characterize the mechanical and damping properties. The carbon filler are used reinforcement and fabricated using Hand lay-up and vacuum bag molding technique. The damping characteristics were evaluated using free and forced vibration test with different amplitudes. The result indicates that the damping characteristics improved with increase in weight percentage of carbon reinforcement content. Further it was found that glass fiber – epoxy matrix with 5% carbon particles better damping properties which can be used for structural application. Both glass and glass hybrid composite can be used to achieve vibration control, but from the results it is found that the Hybrid composite is comparatively more efficient than the glass reinforced composite. V. Tita[5]This work considers the dynamic behavior of components manufactured from fiber reinforced composite materials. To this end, some beams were made using the hand-lay-up process followed by a molding under pressure and heating. Experimental dynamic tests were carried out using specimens with different fiber orientations and stacking sequences. From the results, the influence of the fibers orientations as well as the stacking sequences on the natural frequencies and modal damping were investigated. Also, these experiments were used to validate the theoretical model and the results obtained from the finite element analysis. It is clear that changes in the laminate stacking sequences yield to different dynamic behavior of the component has different natural frequencies and damping factor for the same geometry, mass and boundary conditions. This gives the designer one additional degree of freedom to design the laminate. The possibility to change fiber orientations in order to get a more (or less) damped structure. This possibility makes once more these materials very attractive since it makes possible to obtain the desired natural frequencies and damping factors without increasing mass or changing geometry.

E. Sarlin[6]In this study, the damping properties of laminated structures consisting of steel, rubber or epoxy adhesive and glass fiber reinforced epoxy composite were studied. It was observed, that the use of weight fractions instead of volume fractions in the rule of mixtures provides a good average estimation of the damping behavior of the hybrid structure and the results of rule of mixtures method can be used as rough estimates during the design phase of hybrids of this kind. Kaushic Govindaraj[7]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 behavior 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 molding 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%). Delphine Carponcin[8] In this study A new hybrid nano composite for vibration damping has been elaborated. Ferroelectric lead zirconate titanate particles and carbon nano tubes are dispersed simultaneously in an engineering semi-crystalline thermoplastic matrix by an extrusion processing.. By vibration test, the first bending mode of the frequency response function has been followed and a significant damping inherent to poling is also recorded. These evolutions are heightened by the use of two constrained elastic layers. This work has revealed for the first time the real efficiency of a damping brought by the synergy of piezoelectric particles and conductive fillers. Using two different submicron fillers allows realizing the transduction local dissipation coupling required for persistent vibration damping. An experimental setup through a sandwich configuration has shown its ability to highlight the transduction local dissipation phenomenon for integrated vibration damping in polymeric systems. B. S. Ben[9] This article presents the methodology for finding material damping properties at higher frequency and at relatively lower amplitudes. The method employs combined Finite element and frequency response for finding the damping characteristics of composite materials, which are used in high frequency applications. The hybrid method has been implemented on carbon fiber reinforced polymer (CFRP) and glass fiber reinforced polymer (GFRP) plates. The tests were conducted using ultrasonic pulse generator with scan view plus software as virtual controller. The dynamic mechanical analysis was carried out in high range frequency sweep mode using the hybrid method. The materials have been characterized for damping parameters at their mode frequencies. The main advantage of this method is that the materials can be tested in high frequency range, specifically at its natural frequencies and at relatively low amplitudes and in a non-distractive way. Jyothish J Nair[11]The present study mainly deals with the fabrication of Glass/Epoxy Composites of 60-40% composition with Sea shell powder as filler material. The composite plates are manufactured. The percentage of sea shell powder was varied by 5%, 10% and 15% by volume. Modal Analysis is carried out using Fast Fourier Transform analyzer, accelerometer and impact hammer to determine the vibration characteristics of the Glass/Epoxy composite. The analytical results are obtained from NX Nastran. The experimental and Analytical results are compared and they were in good agreement with each other. Glass/Epoxy with 5% sea shell powder filler showed good vibration characteristics.

III. EXPERIMENTATION AND ANALYSIS

A. Fabrication of FRP By Hand Lay-Up method

Raw materials used in this experimental work are E-Glass fiber and Carbon fiber, Epoxy resin (LY556) and Hardener (HY951). The fiber piles were cut to size from the fiber cloth. Then the fibers were weighed and accordingly and the resin and hardeners were weighed to get fiber matrix ratio 1:1. Epoxy and hardener are taken in the ration 10:1 and they were mixed by using glass rod in a bowl. Care was taken to avoid formation of bubbles. Because the air bubbles were trapped in matrix may result failure in the material. The subsequent fabrication process consisted of first putting a releasing film on the mould surface. Next a polymer coating was applied on the sheets. Then fiber ply of one kind was put and proper rolling was done until all the fibers are wetted by the epoxy. Then resin was again applied, next to it fiber ply of another kind was put and rolled. Rolling was done using cylindrical mild steel rod. This procedure was repeated until two alternating fibers have been laid. On the top of the last ply a polymer coating is done which serves to ensure a god surface finish. Finally a releasing sheet was put on the top and a light rolling was carried out. Then a 20 kgf weight was applied on the composite. It was left for 48 hrs to allow sufficient time for curing and subsequent

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hardening.


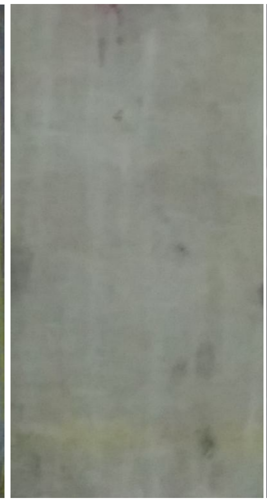
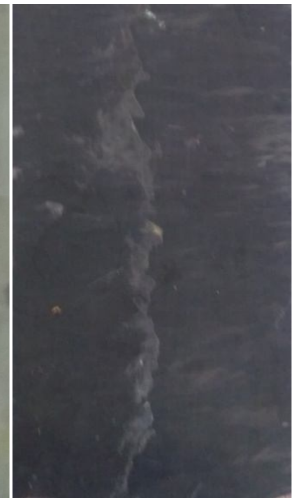

Fig1 E-glass/Epoxy Unidirectional ,Fig2 E-glass/Epoxy Biaxial , Fig3 Carbon /Epoxy Biaxial

Fig 4 Carbon/Epoxy unidirectional

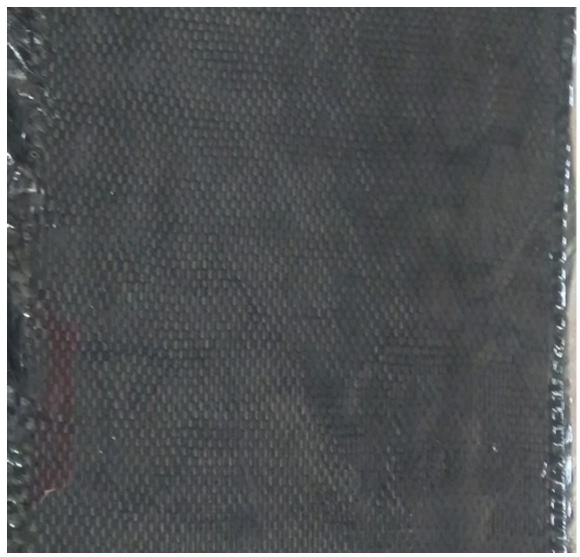

Fig5 Hybrid E-glass/ Carbon/ Epoxy Composite

B. Preparation of test specimens

A jig saw machine was used to cut each laminate into smaller pieces, for Tensile, Flexural and impact test specimens. The characterization of the composites reveals that the % weight and orientation of fibers is having significant effect on the mechanical properties of composites. All the mechanical testing methods that were carried out were based on American Standard Testing Methods (ASTM) to perform mechanical tests namely Tensile Test (ASTM D638), Flexural Test (ASTM D256) respectively.

TABLE 1
ASTM Standards for different tests

S.No	Test Name	Astm Standard	Dimensions
1	Tensile test	D638-03	168X12.5X4
2	Flexural test	D256	100 X12.7X4

C. Tensile Test

In a broad sense, tensile test is a measurement of the ability of a material to with stand forces that tend to pull it apart and to what extent the material stretches before breaking. The stiffness of a material which represented by tensile modulus can be determined

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from stress-strain diagram.

According to ASTM (D638), dumbbell shape specimen is prepared for reinforced composite testing. The testing was done in standard laboratory. Tensile testing machine was used at cross-head speed of 2.5 mm/min. The specimens were positioned horizontally in the grips of the testing machine.

As the tensile test starts, the specimen elongates and the resistance of the Specimen increases and is detected by a load cell. This load value (F) is recorded until a rupture of the specimen occurred. The tensile test is performed in Tensometer and results are analyzed to calculate the tensile strength of composite samples.

Tensile modulus and modulus of elasticity was determined by

$$E = FL/A\Delta L$$

where F is the maximum load

L is the distance between the supports

A is the area of the specimen, and ΔL is the deflection (in mm) corresponding to the load F.

Typical points of interest when testing a material include ultimate tensile strength (UTS) or peak stress, offset yield strength (OYS) which represents a point just beyond the onset of permanent deformation and the rupture (R) or fracture point where the specimen separates into pieces.

Type of fiber = ‘‘Carbon fiber/ E-Glass fiber’’ Initial width = 25 mm. Height = 6 mm. Speed of jaw = 1.5 to 2.5 mm/min. Parameters to plot the graph = x-axis ‘‘deformation (mm)’’and y-axis ‘‘load (N) to calculate the required results.

Fig.6 Tensometer

Fig.7 sample loaded in Tensometer

D. Flexural test Three-point bending (flexural) test

Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. Sometime it is referred as cross breaking strength where maximum stress developed when a bar shaped test piece acting as a simple beam is subjected to a bending force perpendicular to the bar. This stress decreased due to the flexural load is a combination of compressive and tensile stresses.

There are two methods that cover the determination of flexural properties of material they are three point loading system and four point loading system. As described in ASTM D256, three-point loading system applied on a supported beam was utilized. Flexural test is important for designer as well as manufacturer in the form of a beam. If the service failure is significant in bending, flexural test is more relevant for design and specification purpose than tensile test. According to ASTM D256, specimens of test pieces were prepared with dimension of 100mm × 12.7mm × 4mm. The test pieces were tested flat wise on a support span resulting span-to-depth ratio of 16. This means the span is 16 times greater the thickness of specimen. The test pieces were then placed on two supports and load will be applied. The distance of two supports span (L) was fixed at 100mm.

The Tensometer is used for this testing. Before starting the flexural test, the initial length (L_0), width (b_0) and height (d_0), the length (L) and the middle point (L/2) between two supports are measured. Set the length of support from middle point (L/2) equal to 10 cm long. Then the specimen is placed onto two supports. The data for the four layer Carbon/ E-Glass fiber reinforced epoxy composites are as follows:

Type of fiber = ‘‘Carbon fiber/ E-Glass fiber. Initial width = 25 mm, Height = 6 mm, Speed of jaw = 5 mm/min.

Flexural test was done by Tensometer. The load applied at specified cross-head rate was fixed for a value within the ±10% of the calculated R using equation for calculation steps). The constant cross-head speed of 2.5 mm /min.

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$$R = \frac{ZL^2}{6d}$$

Where

R = rate of cross head motion, mm/min

Z = rate of straining of the outer fiber, mm/mm/min = 0.01

L = support span, mm

d = depth of beam, mm

The constant load was then applied on test piece and deflection is recorded. The testing will be terminated when the maximum strain in the outer surface of the specimen has reached the maximum strain of 5 % or rupture occurs. There were two important parameters being determined in the flexural test, they are flexural strength and flexural modulus in bending.

1) *Flexural Strength:* Flexural strength is the maximum stress in the outer specimen at the moment of break. When the homogeneous elastic material is tested with three-point system, the maximum stress occurs at the midpoint. This stress can be evaluated for any point on the load deflection curve using below equation.

$$\sigma_f = \frac{3PL}{2bd^2}$$

Where

σf = stress in the outer specimen at midpoint, MPa [psi]

P = load at a given point on the load deflection curve, N [lbf]

L = support span, mm

b = width of beam tested, mm

d = depth of beam tested, mm

2) *Flexural Modulus::* Flexural modulus is a measure of the stiffness during the initial of the bending process. This tangent modulus is the ratio within the elastic limit of stress to corresponding strain. A tangent line will be drawn to the steepest initial straight line portion of the load deflection curve and the value can be calculated using equation.

$$E_B = \frac{L^3W}{48EI}$$

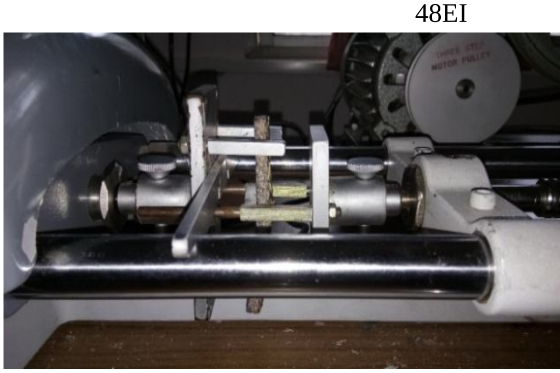

Fig.8 Experimental set Up for flexural testing

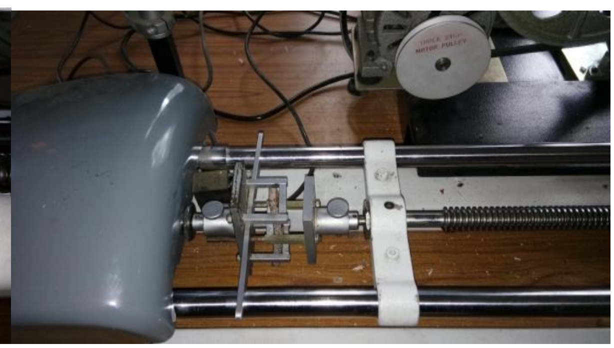

Fig.9 Sample loaded condition for flexural testing

E. Finite element analysis

Finite element algorithms have become a powerful tool in order to analyse and solve a wide range of engineering problems. One of the most challenging and most popular commercial all-purpose program used in finite element analysis is the commercial finite element software "ANSYS". The finite element analysis of laminated composite plates in this work is carried out using the software ANSYS 15 APDL. Finite Elements Model and Solution Procedure The 3D model of the cantilever unidirectional and Biaxial fiber reinforced polymer composite plate having dimensions 200 mm (length) × 30 mm (width) was constructed.

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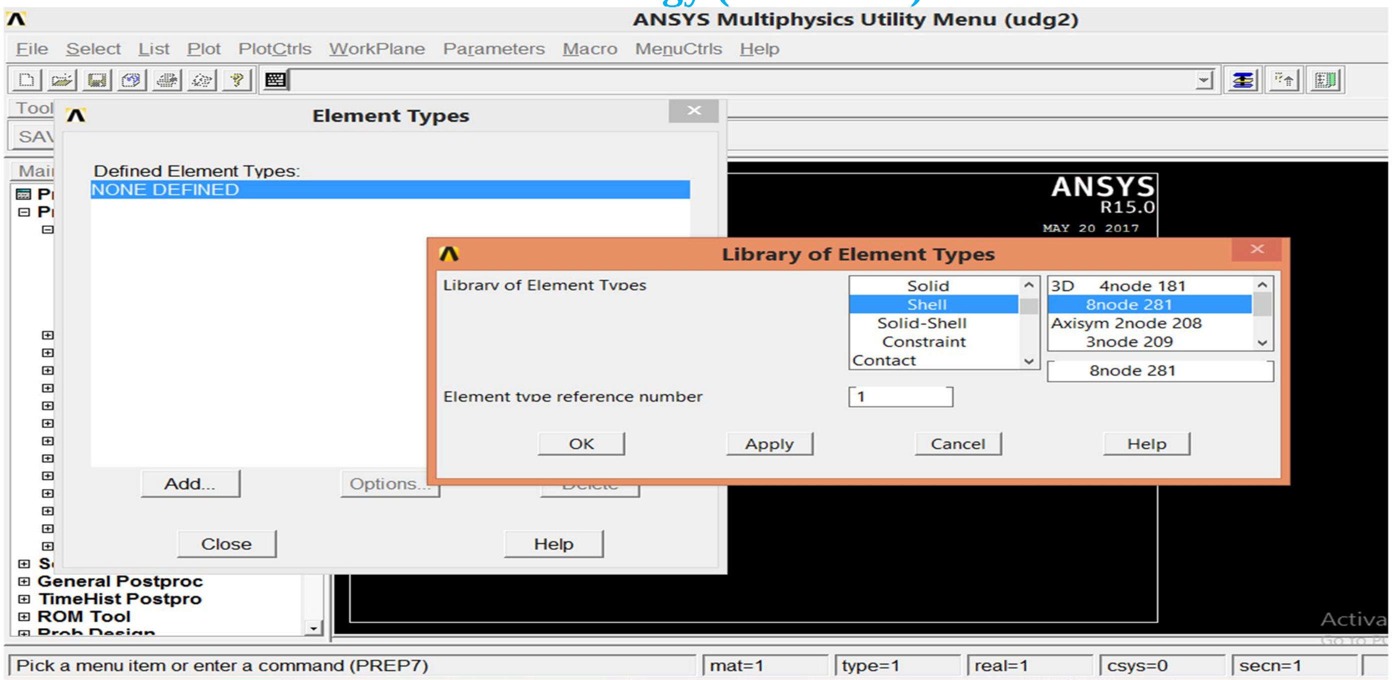

Fig.10 determining the element type of the composite layup

The plate thickness “t” was taken to be dependent on the fiber/matrix combination used in the laminas that made the plate. The ply thickness for composite plates was taken as 2.5 mm respectively. The plate was modeled as a plane area in ANSYS 15 and then meshed using eight noded quadrilateral shell element (SHELL281). The SHELL281 element is suitable for analysing thin to moderately-thick shell structures. The element has eight nodes with six degrees of freedom at each node: translations in the x, y, and z axes, and rotations about the x, y, and z-axes. The accuracy in modeling composite shells using these elements is governed by the first order shear deformation theory (FSDT) in which the transverse shear strain is assumed to be constant through the thickness of the shell. The plate was fixed on the edge having dimension of 30 mm. In order to carry out the modal analysis so as to obtain the first four mode shapes and natural frequency. The block Lanczos mode extraction method was used. An APDL code was written to carry out the above steps in FEA and to carry out further parametric study.

Evaluation of the nine elastic moduli to determine the composite material is orthotropic material. By solving the below equations we get the values of elastic constants of composite. Since we know the elastic constants of fiber and matrix materials are used to calculate the values for required composite material is as follows

Longitudinal Young’s modulus, E1

Transverse Young’s modulus, E2, E3

Major and Minor Poisson’s ratio, v12 *v*23 *v*13

In-plane shear modulus, G12 G23 G13

By using strength of materials approach

Ef=Elastic Modulus of Fiber

Em=Elastic Modulus of Matrix

Gf=Shear Modulus of Fiber

Gm=Shear Modulus of Matrix

vf=Poison's Ratio of Fiber

vm=Poison's Ratio of Matrix

V=Fiber Volume Fraction

Vm=Matrix volume fraction

Df=Density of Fiber

Dm=Density Ratio of Matrix

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Longitudinal young's modulus

E11=Ef*V+Em*(1-V)

Transverse young's modulus

E22=Em*(Ef+Em+(Ef-Em)*V)/(Ef+Em-(Ef-Em)*V)

Major poisson's ratio

v12=vf*V+vm*(1-V)

Minor poisson's ratio

v23=vf*V+vm*(1-V)*(1+vm-v12*Em/E11)/(1-vm^2+vm*v12*Em/E11)

Inplane Shear Modulus

G12=Gm*(Gf+Gm+(Gf-Gm)*V)/(Gf+Gm-(Gf-Gm)*V)

G23=E22/(2*(1+v23))

Density of composite

Den=Df*V+Dm*(1-V)

We assume the material is Transversely isotropic material

E33=E22=Transverse young's modulus

v13=v12=Axial poissons ratio for loading in x direction

G13=G12=Axial shear modulus i.e shear stress parallel to the fibers

TABLE 2

BY CALCULATING WE GET 9 ELASTIC CONSTANTS OF CARBON/EPOXY AND E-GLASS/EPOXY .

Elastic Constants	carbon/epoxy	e-glass/epoxy
E11	116.7e09	37.7e09
E22	6.7e09	6.49e09
E33	6.7e09	6.49e09
*V*12	0.3050	0.255
V23	0.3672	0.3139
V13	0.3050	0.255
G12	2.57e09	2.50e09
G23	2.45e09	2.47e09
G13	2.57e09	2.50e09

Then the shell layup is done and the modeling of composite layup is done using rectangle dimensions 200mmX30mm. Next we go for meshing of the model. Meshing is done by selecting fine mesh globally and meshing is done through out the composite. After Meshing boundary conditions are applied i.e cantilever condition is applied . so that it is fixed at one end. Model analysis is done to get the Natural frequency and Mode shapes of the model.

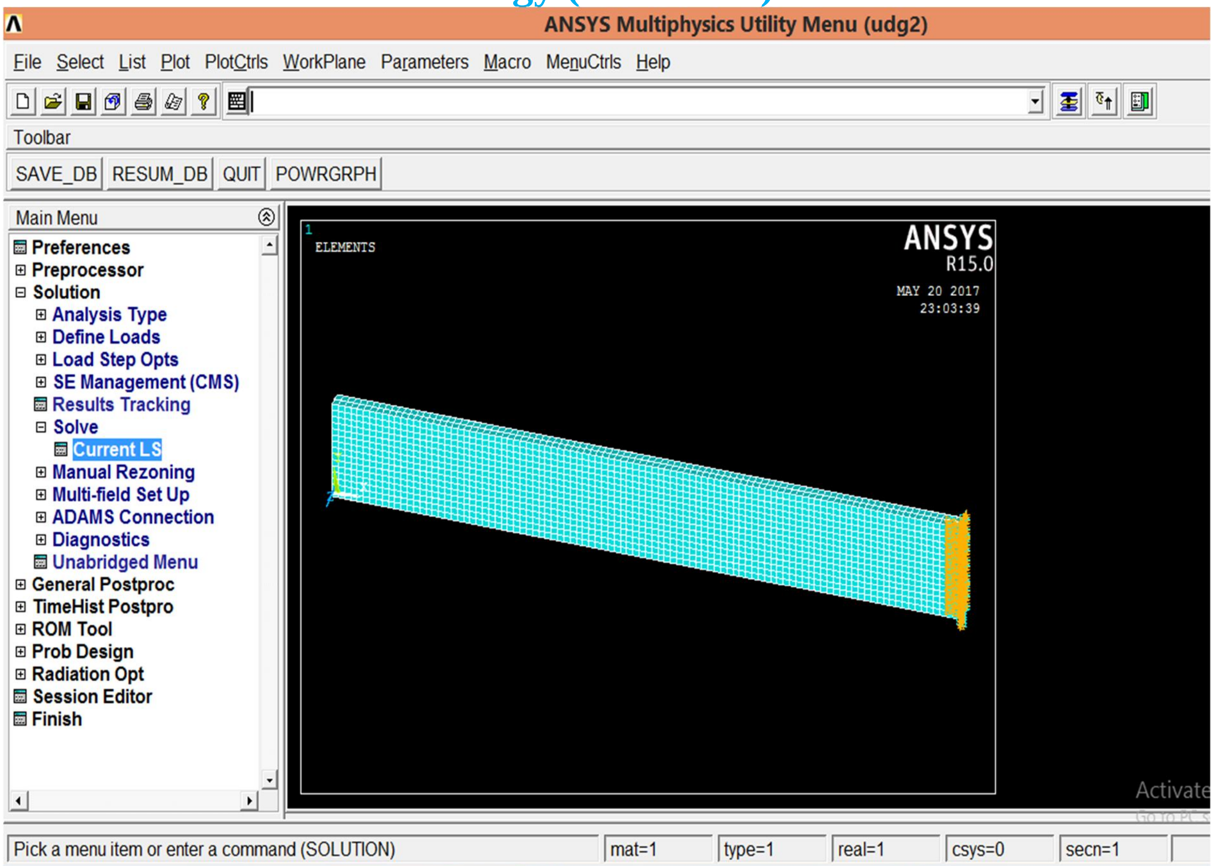

Fig.12 Meshing and Boundary Conditions applied final model

IV. RESULTS AND DISCUSSIONS

A. *Tensile test results*

Tensile test was also carried out on Tensometer in accordance with ASTM standard. All the specimens were of dog bone shape of dimension (168x12.5x4) mm^3. The results are tabulated in the table below. Samples are given names as T1, T2, T3, T4, T5, T6. T_1- Carbon Uni-Direction, T_2- (Hybrid)Carbon and E-Glass Bi-Direction, T_3- Carbon Bi-Direction, T_4- E-Glass Bi-Direction, T_5- E-Glass Uni-Direction, T_6- (Hybrid)Carbon and E-Glass Uni-Direction.

TABLE 3

THE TENSILE PROPERTIES OF COMPOSITE SPECIMENS

Sample Id	Load in N	Elongation in mm	Young's modules Mpa
T_1	5530	4.5	107.7
T_2	6099	4.3	118.93
T_3	3520	2.3	69.04
T_4	5850	3.9	114.34
T_5	6570	4.1	128.26
T_6	8080	4.3	157.56

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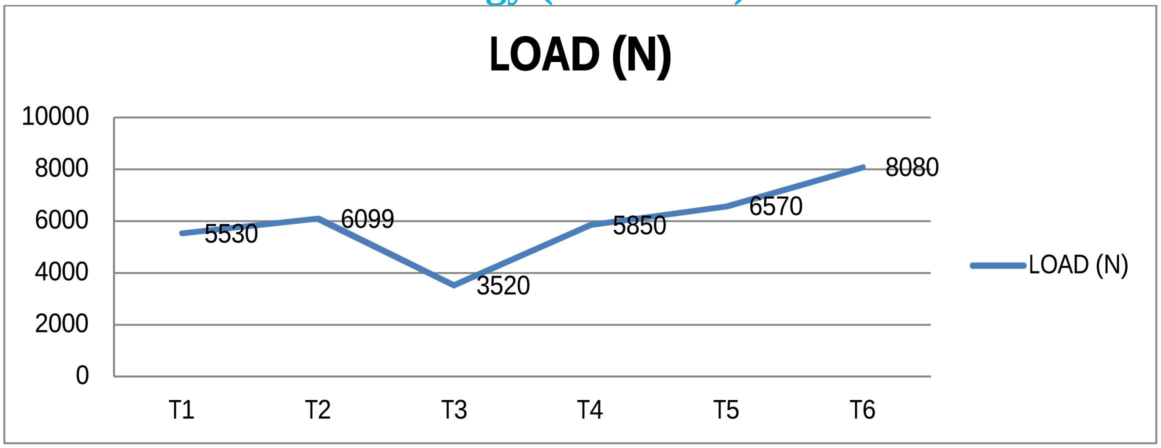

Fig.13 Graph represents Loads that are withstand by the composite beams

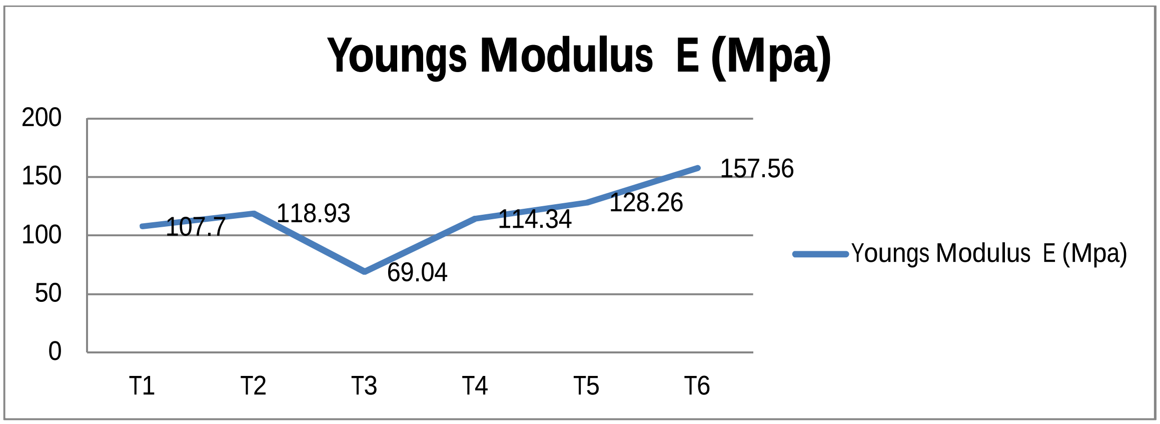

Fig.14 Graph represents Young's Modulus of Different Composite samples

By comparing the values of the different samples obtained from tensile test and that are represented in the graph. From graph we can say thatT_6- (Hybrid)Carbon and E-Glass Uni-Direction is having higher value of load capacity 8080N and elongation 4.3mm and young's modulus .

B. Flexural test Three-point bending (flexural) test result

TABLE 4

Flexural Modulus values of composite samples

Sample Id	Load in N	Elongation in Mm	Flexural Modulus (Mpa)
F_1	950	5.3	55134.75
F_2	320	6.6	14913.64
F_3	150	9.0	5126.56
F_4	1030	13.9	22792.92
F_5	1390	8.6	49715.75
F_6	1520	5.7	82025.03

Flexural test is conducted on different composite samples as per ASTM standards and the samples are taken as per the dimension

100mmX12.7mmX4mm. All six samples are taken and experiment is conducted on Tensometer. The test samples are named as F_1, F_2, F_3, F_4, F_5, F_6.

F_1- Carbon Uni-Direction, F_2- (Hybrid) Carbon and E-Glass Bi-Direction, F_3- Carbon Bi-Direction, F_4- E-Glass Bi-Direction, F_5- E-Glass Uni-Direction, F_6- (Hybrid) Carbon and E-Glass Uni-Direction.

The above table shows the load and elongation and flexural modules values of composites with different orientations. Comparing the all results of composite specimens. It is seen that F_6- (Hybrid) Carbon and E-Glass Uni-Direction was having higher value of load capacity 1520N and elongation 5.7mm and flexural modules is 82025.03 Mpa.

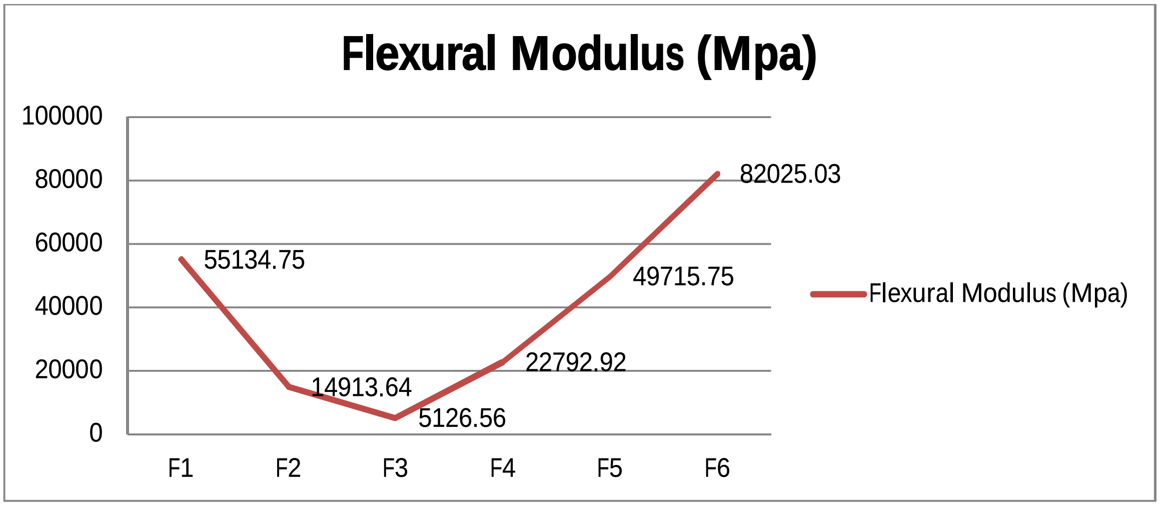

Fig.15 Graph represents Flexural Modulus for different Composite samples

C. Natural Frequency using ANSYS 15

Model analysis has been done to get Natural frequency and Mode shapes of different orientation of fibers in composite samples in Ansys 15 APDL software. Hybrid E-glass and carbon fiber composites are modeled and analysis is carried out as procedure explained in previous session.

TABLE 5

Natural Frequency of different composite samples with 3 mode frequencies

Laminate	Mode	Natural Frequency
E-Glass/ Epoxy Uniaxial [0/0]	1	89.593
	2	486.23
	3	499.08
E-glass/Epoxy Biaxial [0/90]	1	54.371
	2	338.73
	3	389.62
Carbon/Epoxy Uniaxial [0/0]	1	113.58
	2	584.87
	3	861.86
Carbon/Epoxy Biaxial [0/90]	1	80.676
	2	499.84
	3	522.78
Hybrid E-glass/carbon/Epoxy Uniaxial [0/0]	1	120.40
	2	525.93
	3	704.05
Hybrid E-glass/carbon/Epoxy Uniaxial [0/90]	1	76.01
	2	470.90
	3	494.11

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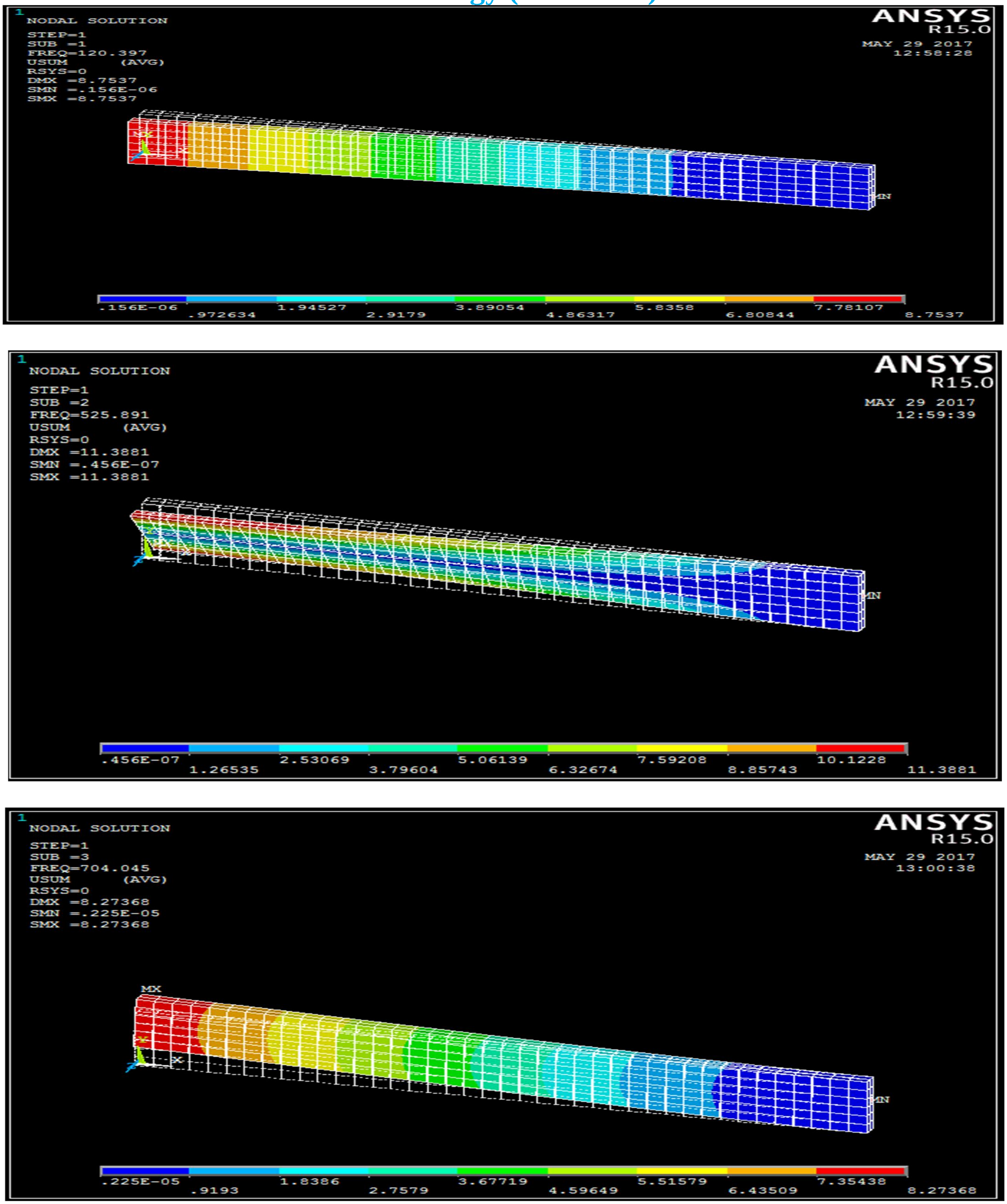

Fig.16 Representing the Mode Shapes, Displacement and Natural Frequency of Hybrid E-Glass/Carbon/Epoxy [0/0]Unidirectional Composite Beam

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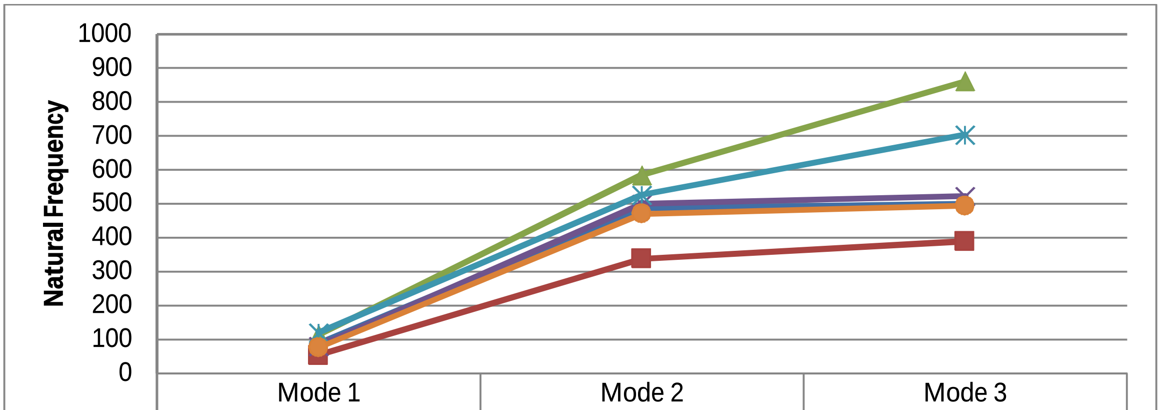
From the above table the values of Natural Frequency are obtained from ANSYS15 by using model analysis. We can say that Hybrid E-glass/carbon/ epoxy uniaxial [0/0] sample has high Natural frequency 120.397 than any other samples .Their mode Shapes are Represented above.

Fr_3- Carbon Uni-Direction, Fr_6- (Hybrid) Carbon and E-Glass Bi-Direction, Fr_4- Carbon Bi-Direction, Fr_2- E-Glass Bi-Direction, Fr_1- E-Glass Uni-Direction, Fr_5- (Hybrid) Carbon and E-Glass Uni-Direction.



	Mode 1	Mode 2	Mode 3
Fr1	89.593	486.23	499.08
Fr2	54.371	338.73	389.62
Fr3	113.58	584.87	861.86
Fr4	80.676	499.84	522.78
Fr5	120.4	525.93	704.05
Fr6	76.01	470.9	494.11

Fig.17 Natural Frequencies of different Modes are represented in the graph

V. CONCLUSION

In this study, modal analysis was carried out using finite element software for laminated cantilever composite plates to predict the modal frequencies. Various fiber/matrix combinations were investigated for different fiber orientations. The effect of hybridization and different laminate stacking sequence was also investigated. The conclusions are summarized as follows

The synthetic fiber reinforced epoxy hybrid composites are successfully fabricated using hand lay-up technique. The Carbon/E-Glass/Epoxy Uni-Direction hybrid composite maximum Young's modules 157.56 Mpa and maximum elongation 4.3mm and maximum load 8080 N. The Carbon/E-Glass/Epoxy Uni-Direction hybrid composite maximum flexural modules 82025.03 Mpa and maximum elongation 5.3mm and maximum load 1520 N. The Carbon/E-Glass/Epoxy Uni-Direction hybrid composite maximum Natural Frequency 120.40 Hz compared to remaining laminates. The natural frequencies are sensitive to the orientation of the outermost layers of the laminates. As the orientation outermost layer is changed from 0° to 90°, the natural frequency decreases. By increasing the weight percentage of Carbon and E-Glass fiber, the mechanical properties also increases up to certain limit. Further, addition causes them to decrease due to poor interfacial bonding between fiber and matrix.

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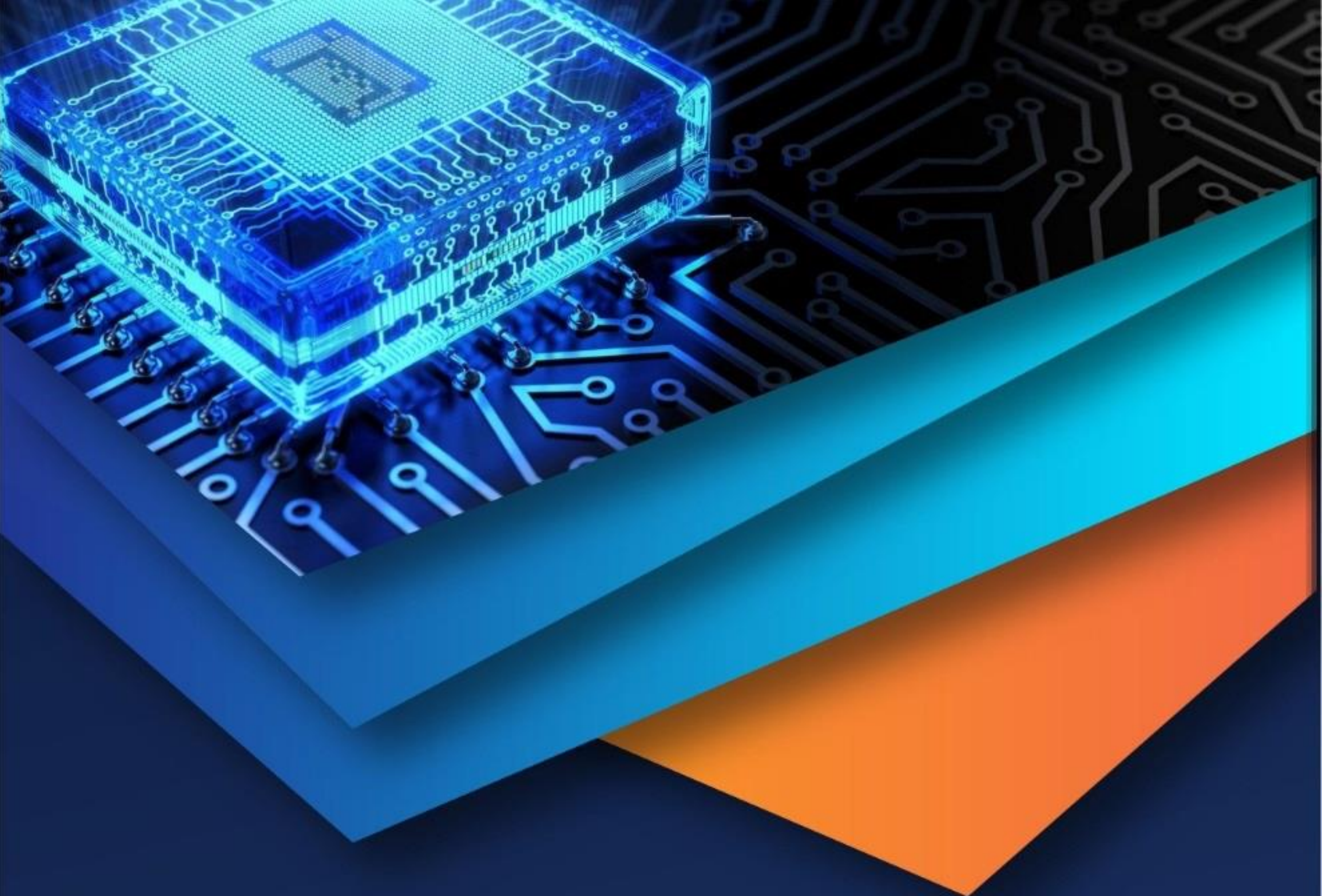

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