Vibration Investigation of Damping Material in Composite Using Model Analysis Technique

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Abstract : *Considerable research work has been done to improve the dynamic properties (damping, frequency, etc.,) of fiber reinforced polymer (FRP) laminated composite in which the material damping is studied either with macro-mechanical analysis alone or the same with micro-mechanical analysis. Materials that possess high damping and high stiffness are not common in any mechanical components. Their vibration damping depends on the visco-elastic nature of the materials. They are mainly obtained from all categories of materials such as the damping by rubber, polymers. In this project we are taking composite cantilever beam structure having dimension 200×25mm. Material used for manufacturing cantilever beam was carbon fiber. For reduce vibration of cantilever beam we used different visco-elastic material Modal analysis and harmonic analysis of three composite plate will be perform in ANSYS 19 software. Experimental testing will be done using FFT analyzer and impact hammer for finding natural frequency. After that the comparative analysis will be carried out between the experimental and analysis results and after that the result & conclusion will be drawn.*

Keywords—Cantilever beam, visco-elastic material, ANSYS, FFT analyzer.

I. INTRODUCTION

The composite material are often defined because the system of fabric consisting of a mix of combination of two or more micro constituents insoluble in one another and differing in form and or in material composition. These materials are often prepared by putting two or more dissimilar material in such way that they function mechanically as one unit. The properties of such materials differ from those of their constituents. The requirements for satisfying the above mentioned condition are The composite material has to be man-made. The material must be a mixture of a minimum of two chemically distinct materials with an interface separating the components. Composite materials are more advanced composites as compared to conventional simple materials. Composite materials 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 simple materials.

Carbon-carbon composites have carbon fiber reinforced in matrix of carbon. Carbon- carbon composites are utilized in very heat environments up to 6000 °F (3315°C) and are 20 times stronger and 30% lighter than graphite fibers. Their advantages include ability to withstand high temperatures, low creep at high temperature, low density, good tensile and compressive strength, high fatigue resistance, high thermal conductivity and high coefficient of friction. Their disadvantages include high cost, low shear strength and susceptibility to oxidations at high temperature. These composites find application in space shuttle nose cone, aircraft brakes, mechanical fasteners etc. 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. Free vibration analysis was administered for identifying the natural frequencies

II. LITERATURE REVIEW

Li Ma et al. [1] has studied Auxetic materials and structures as a class of metamaterials have been extensively studied and evaluated for many applications. This paper focuses on the fabrication and vibration damping of the carbon fiber composite auxetic double-arrow corrugated sandwich panels (DACSPs). The negative Poisson's ratio effects of the composite auxetic DACSPs are analytically studied based on energy method. 3D finite element (FE) models combined with Modal Strain Energy (MSE) approach are developed to investigate their vibration and damping characteristics. To validate the numerical models in the present study, the composite auxetic DACSPs and such structures inserted with high damping layer are designed and manufactured. Modal vibration and three-point bending tests are conducted to investigate their vibration damping and bending responses. The results show that the 3D FE models combined with MSE approach are valid to predict the modal properties of the composite auxetic DACSPs.

Jin-Shui Yang et al. [2] has studied In this research it presents the defects can easily appear in composite lattice truss core sandwich structures during the complex preparation process, which may significantly affect the structural response and decrease the load-carrying capability. The purpose of this paper is to investigate the manufacturing defect sensitivity of modal vibration responses of carbon fiber composite pyramidal truss-like core sandwich cylindrical panels by modal experiments and finite element analysis. Defects including debonding between face sheets and truss cores (DFT), truss missing (DTM), face sheet wrinkling (DFW) and gap reinforcing (DGR) are introduced into the present intact specimen artificially and modal testing is conducted to study their dynamic behavior under free-free boundary conditions.

Dai Gil Lee et al. [3] has studied In order to improve the damping capacity of the column of a precision mirror surface grinding machine tool, a hybrid column was manufactured by adhesively bonding glass fiber reinforced epoxy composite plates to a cast iron column. To optimize the damping capacity of the hybrid column, the damping capacity of the hybrid column was calculated with respect to the fiber orientation and thickness of the composite laminate plate and compared to the measured damping capacity. From experiments, it was found that the damping capacity of the hybrid column was 35% higher than that of the cast iron column. Damp out the vibration and noise of machines and structures, surface damping treatments have been widely used because they are easy to implement to various structures and have good damping capacity for wide frequency and temperature ranges.
R. Chandra et al. [4] has studied basically our status of research on damping in fiber-reinforced composite materials and structures with emphasis on polymer composites has been reviewed in this paper. As a first step, composite damping mechanisms and methodology applicable to damping analysis is described. Further, the paper presents damping studies involving macro mechanical, micromechanical and viscoelastic (relaxation and creep) approach; models for inter phase damping, damping and damage in composites. Some important works related to improved damping models for thick laminates, improvement of laminate damping and optimization for damping in fiber-reinforced Fiber- reinforced composites are being increasingly used as alternatives for conventional materials primarily because of their high specific strength, specific stiffness and tailor able properties.

Jung Do Suh et al. [5] has studied In order to improve the vibration characteristics of a spindle cover made of 2 mm thick steel plate for high speed machine tools, the cover was reinforced with carbon fiber epoxy composite material. Considering the mounting conditions and the vibration mode shape of the spindle cover, the stacking sequence and the thickness of the reinforced composite laminate were determined through finite element analysis. The relationship between the loss factor and the stacking sequence was also investigated. The steel-composite hybrid spindle cover was fabricated by co-cure bonding in an autoclave and its dynamic characteristics were tested

III. PROBLEM STATEMENT

It is generally known that excellent damping capacity is more and more urgent for many engineering applications such as aeronautics, shipbuilding and automotive industries with a requirement of vibration suppression and sound absorption. The reason for high damping is mainly due to intrinsic viscoelastic behavior, interface friction, damage, etc. With the development of materials science and technology, the use of fiber reinforced resin matrix composites is constantly increased owing to their high specific strength and high specific rigidity, and high damping properties in recent years, which also push such type of composite cellular and sandwich structures forward.

IV. OBJECTIVES

The fiber reinforced composites structures are usually subject to dynamic external loads during service. Vibration analysis of these structures plays a significant role in tailoring the parameters like damping, modal frequencies, and shapes.
Modeling of carbon fiber composite cantilever beam in CATIA V5 software.
Analyzing for stresses and deformation in both carbon fiber composite plate and carbon fiber - visco elastic composite cantilever beam using ANSYS software.
To perform modal analysis of both composite cantilever beam using ANSYS 19.
To manufacturing of carbon fiber - visco elastic composite cantilever beam using hand lay- up method
To perform experimental testing of both carbon fiber cantilever beam using FFT analyzer and impact hammer. Experimental testing and correlating results.

V. METHODOLOGY

Step 1:- I started the work of this project with literature survey. gathered many research papers which are relevant to this topic. After going through these papers, we learnt carbon fibre - visco elastic composite material properties and application
Step2:- After that the automobile components which are required for our project are decided.
Step 3:- After deciding the components, the 3D Model and drafting will be done with the help of CATIA software.
Step 4:- The modal Analysis of the components will be done with the help of ANSYS using FEA.
Step 5:- The Experimental Testing will be carried out.
Step 6:- Comparative analysis between the experimental & analysis result & then the result & conclusion will be drawn.

VI. ANALYSIS

The finite element method (FEM), is a numerical method for solving problems of engineering and mathematical physics. Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The analytical solution of these problems generally require the solution to boundary value problems for partial differential equations.

Table 1 - Material Properties of Epoxy carbon material

Properties of Outline Row 3: Epoxy Carbon UD (395 GPa) Prepreg

	A	B	C
1	Property	Value	Unit
2	Density	1.54E-09	mm^-3 t
3	Orthotropic Secant Coefficient of Thermal Expansion		
8	Orthotropic Elasticity		
9	Young's Modulus X direction	2.09E+05	MPa
10	Young's Modulus Y direction	9450	MPa
11	Young's Modulus Z direction	9450	MPa
12	Poisson's Ratio XY	0.27	
13	Poisson's Ratio YZ	0.4	
14	Poisson's Ratio XZ	0.27	
15	Shear Modulus XY	5500	MPa
16	Shear Modulus YZ	3900	MPa
17	Shear Modulus XZ	5500	MPa

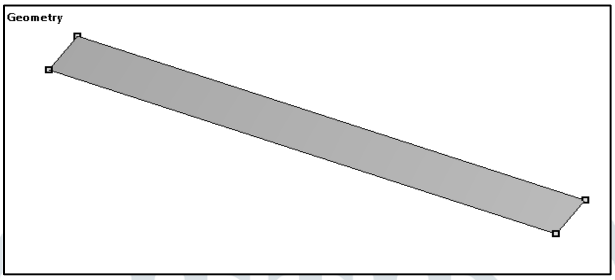
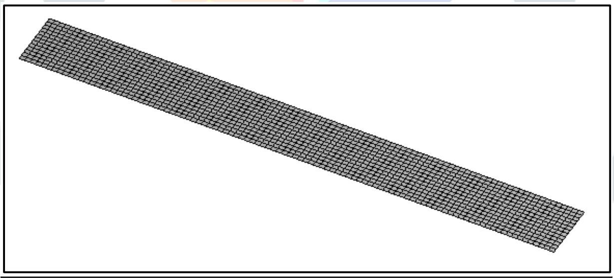


Fig. 3. Geometry of carbon fiber cantilever beam

VII. MESH

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient Multiphysics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time you have to wait for mesh generation.



Statistics	
Nodes	1414
Elements	1300

Fig 4 Mesing of carbon fiber cantilever beam

After meshing of specimen nodes are 1414 and elements 1300.

VIII. BOUNDARY CONDITION

A boundary condition for the model is the setting of a known value for a displacement or an associated load. For a particular node you can set either the load or the displacement but not both. The main types of loading available in FEA include force, pressure and temperature. These can be applied to points, surfaces, edges, nodes and elements or remotely offset from a feature.

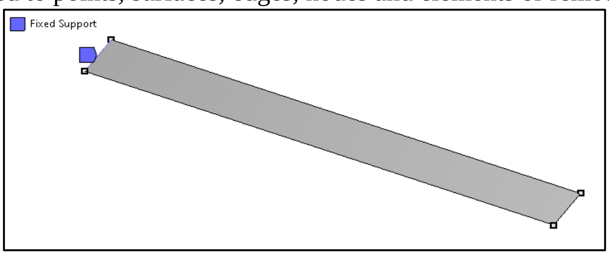


Fig.5. Boundary condition for static structural analysis

IX. PLY ORIENTATION

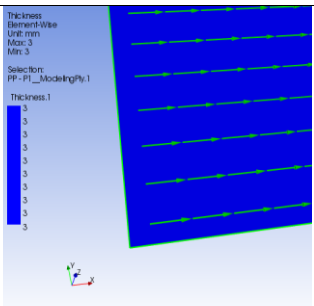
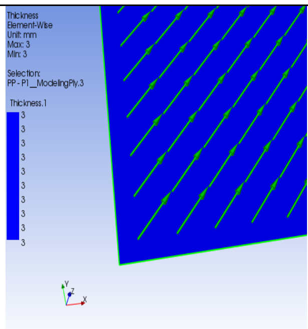
	
0- DEGREE PLY ORIENTATION THK= 1MM	45- DEGREE PLY ORIENTATION THK =1MM

Fig.6. Boundary condition for static structural analysis

X. WORKFLOW FOR DEFINING COMPOSITE MATERIAL

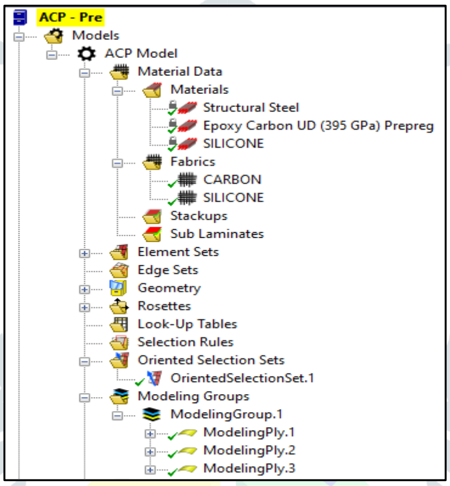


Fig.7. Workflow for defining composite material

Modal analysis

Modal analysis is a process of extracting modal parameters (natural frequencies, damping loss factors and modal constants) from measured vibration data. Since the measured data can be in the form of either frequency response functions or of impulse responses, there are frequency domain modal analysis and time domain modal analysis. The fundamental of modal analysis using measured frequency response function data is about curving fitting the data using a predefined mathematical model of the measured structure. This model assumes the number of DoFs of the structure, its damping type and possibly the number of vibration modes within the measured frequency range. These assumptions should dictate the mathematical expression of each FRF curve from measurement. As a result, the subsequent work will be a curve fitting process trying to derive all modal parameters in a mathematical formula of an FRF using measurement data.

XI. MODE SHAPES RESULTS

MODE SHAPE 1

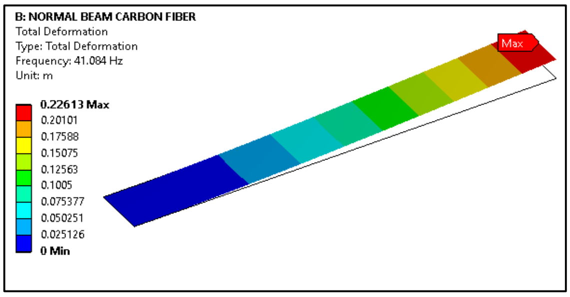


Fig 8 Natural frequency of normal carbon fiber beam at mode shape 1

MODE SHAPE 2

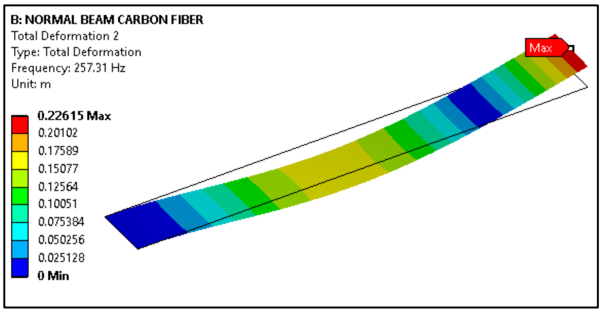


Fig 9 Natural frequency of normal carbon fiber beam at mode shape 2

MODE SHAPE 3

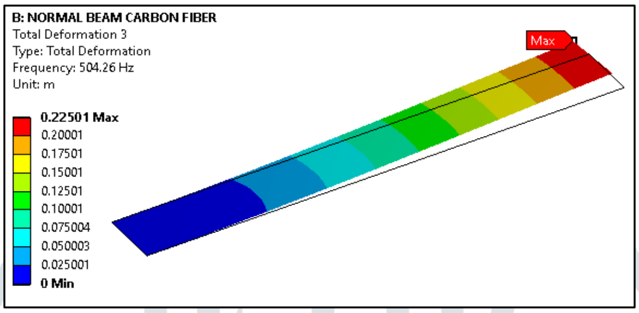


Fig 10 Natural frequency of normal carbon fiber beam at mode shape 3

MODE SHAPE

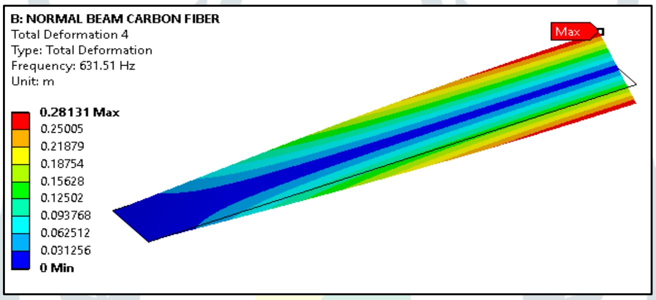


Fig 11 Natural frequency of normal carbon fiber beam at mode shape 4

MODE SHAPE 5

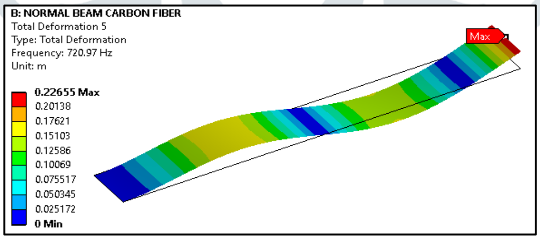


Fig12 Natural frequency of normal carbon fiber beam at mode shape 5

HARMONIC ANALYSIS
Boundary condition

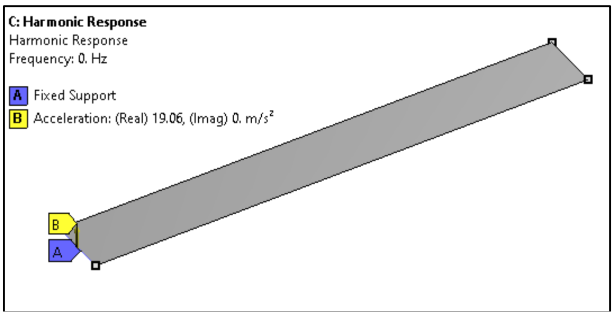


Fig 13 Boundary condition of normal carbon fiber beam

For harmonic analysis of normal carbon fiber beam we applying 2g acceleration given at base and find acceleration amplitude or frequency response of structure.

Result

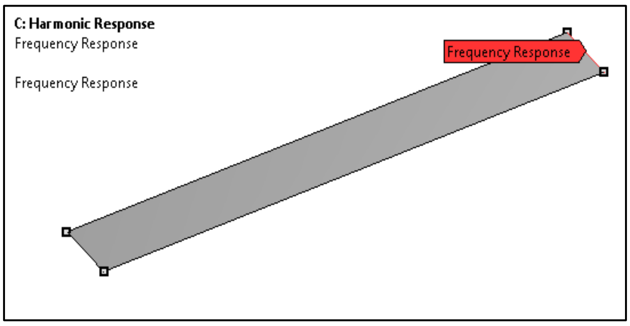


Fig 14 Harmonic response of normal carbon fiber beam

Frequency Response

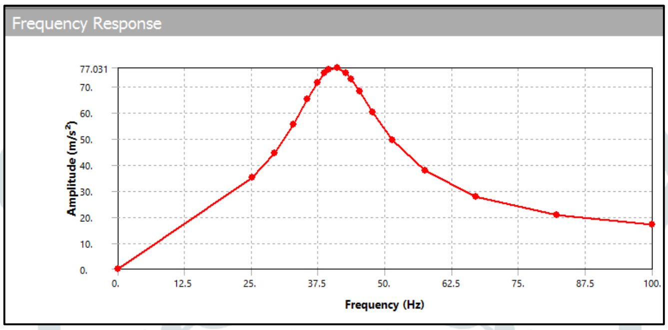


Fig 15 Graph of Amplitude Vs Frequency

FEA of carbon fiber - silicon cantilever beam

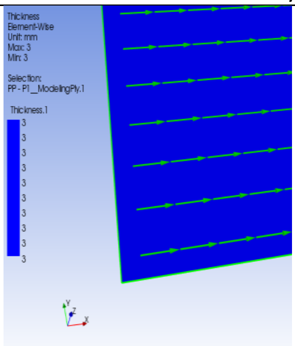
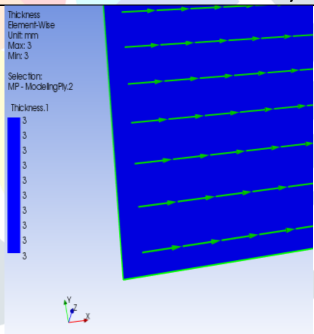
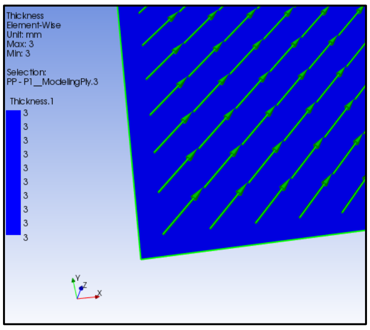
Layer 1	Layer 2
	
0- Degree Ply Orientation Thickness= 1mm	(Silicon Layer) Thickness = 1mm

Fig.16. Boundary condition for silicon beam

Layer 3



45- Degree Ply Orientation
Thickness =1mm

MODE SHAPES RESULTS

MODE SHAPE 1

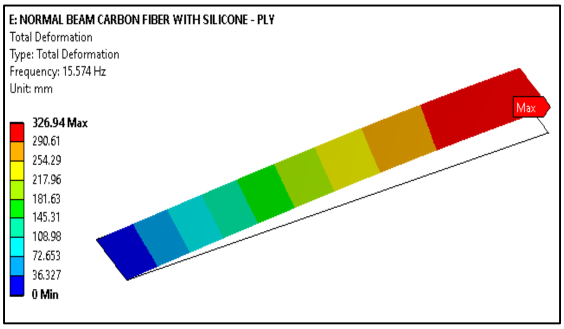


Fig 17 Natural frequency of normal carbon fiber with silicon beam at mode shape 1

MODE SHAPE 2

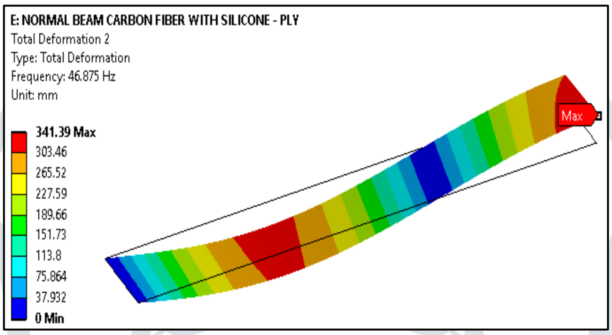


Fig 18 Natural frequency of normal carbon fiber with silicon beam at mode shape 2

MODE SHAPE 3

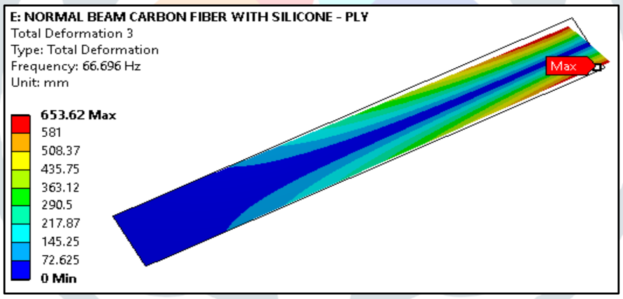


Fig 19 Natural frequency of normal carbon fiber with silicon beam at mode shape 3

MODE SHAPE 4

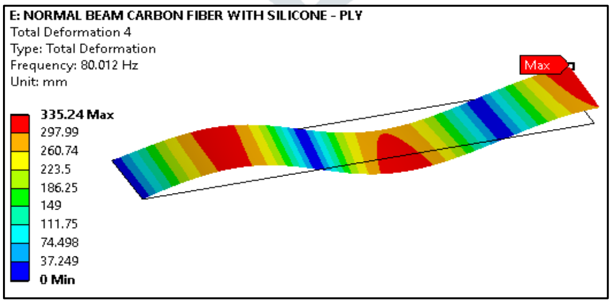


Fig 20 Natural frequency of normal carbon fiber with silicon beam at mode shape 4

MODE SHAPE 5

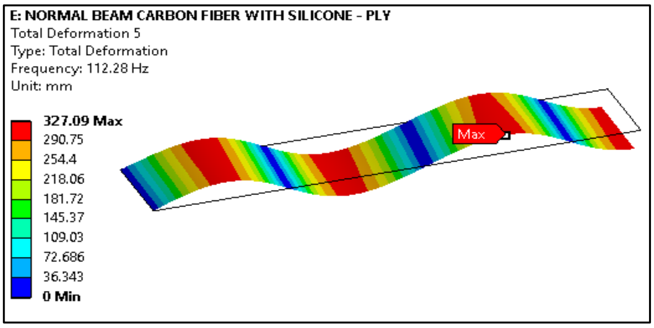


Fig 21 Natural frequency of normal carbon fiber with silicon beam at mode shape 5

HARMONIC ANALYSIS

Boundary condition

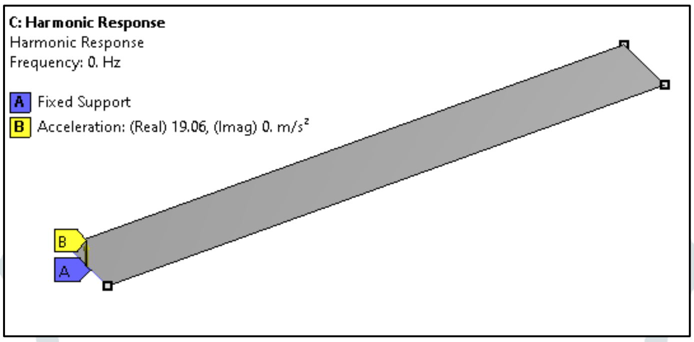


Fig 22 Boundary condition of normal carbon fiber with silicon beam

For harmonic analysis of normal carbon fiber with silicon beam we applying 2g acceleration given at base and find acceleration amplitude or frequency response of structure.

Result

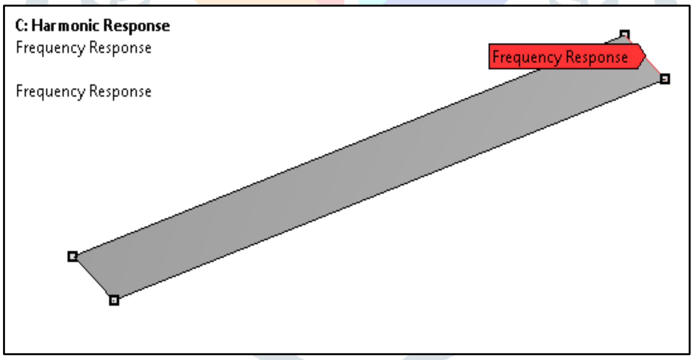


Fig 23 Frequency repose of normal carbon fiber with silicon beam

Frequency Response

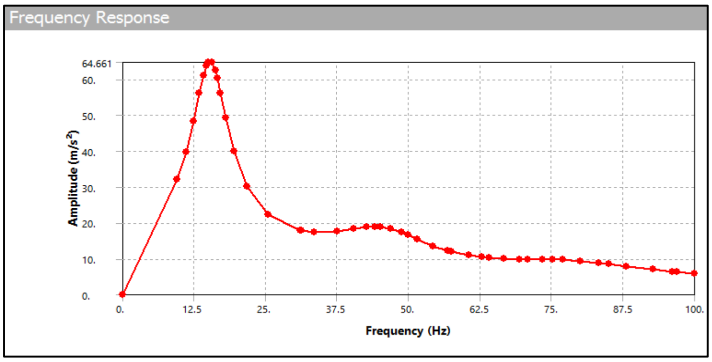


Fig 24 Graph 2 - Graph of Amplitude Vs Frequency

Manufacturing of composite specimen

- Carbon fibre sheet is cut out with respective dimension 3 layers.
- Solution is prepared with epoxy (50 ml) and hardener (1.5 bottle cap) is poured and gently stirred to form homogeneous solution.
- Specimen is firmly hold in hands then firstly epoxy solution is applied at first layer is applied then simultaneously epoxy and second layer is applied to form reinforced carbon fibre layer on it.
- After reinforcement keeping it to dry for 24 hours then after with the help of grinder removing hard edges and ready for experimental testing.

XII. EXPERIMENTAL TESTING

The experimental approval activity is finished by utilizing FFT Operation testing (Fast Fourier Transform) analyzer. The FFT range analyzer tests the informational signal, figures the extent of its sine and cosine parts, and shows the range of these deliberate frequency segments. The upside of this strategy is its speed. Since System activity FFT range analyzers measure all frequency parts simultaneously, the method offers the chance of being many occasions quicker than conventional simple range analyzers. Fourier examination of an occasional capacity alludes to the extraction of the arrangement of sines and cosines which when superimposed will duplicate the capacity. This investigation can be communicated as a Fourier arrangement activity. The quick Fourier change is a technique for activity scientific strategy for changing an element of time into an element of frequency. Some of the time it is depicted as framework changing from the time space to the frequency area. It is valuable for all strategy investigation of time-subordinate

FFT analysis

FFT is one principle property in any succession being utilized as a rule. To discover this property of FFT for some random succession, many changes are being utilized. The significant issues to be seen in discovering this property are the time and memory the board. Two unique calculations are composed for figuring FFT and Autocorrelation of some random succession. Correlation is done between the two calculations concerning the memory and time administrations and the better one is pointed. Examination is between the two calculations composed, thinking about the time and memory as the main fundamental limitations. Time taken by the two changes in finding the basic recurrence is taken. Simultaneously the memory expended while utilizing the two calculations is additionally checked. In light of these perspectives it is chosen which calculation is to be utilized for better outcomes

DEWE-43 Universal Data Acquisition Instrument

At the point when associated with the rapid USB 2.0 interface of any PC the DEWE-43 turns into an amazing estimation instrument for simple, computerized, counter and CAN-transport information catch. Eight concurrent simple sources of info test information at up to 204.8 kS/s and in blend with DEWETRON Modal Smart Interface modules (MSI) a wide scope of sensors are upheld Voltage Acceleration Pressure Force Temperature Sound Position RPM Torque Frequency Velocity And more The included DEWE Soft application programming includes incredible estimation and examination capacity, transforming the DEWE-43 into a committed recorder, extension or FFT analyzer.

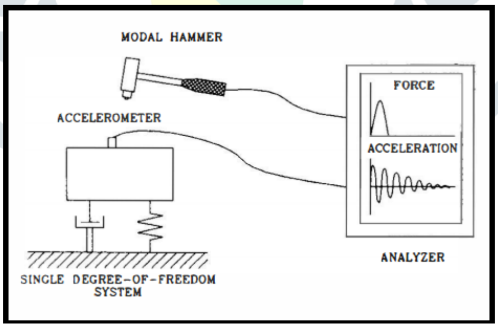


Fig25. Block diagram of FFT

XIII. EXPERMENTAL PROCEDURE

Initially fixture is designed according to existing boundary condition as per FEA results.
FFT consists of impact hammer, accelerometer, data acquisition system in which each supply is applied to DAS and laptop with DEWSOFT software to view FFT plot.
Accelerometer is mounted at surface as per high deformation observed in FEA results along with initial impact of hammer is placed for certain excitation to determine frequency of respective mode shapes.
After impact FFT plot are observed on laptop and comparison of FEA and experimental results are analyzed.

Fig26 Vibration test mechanism.

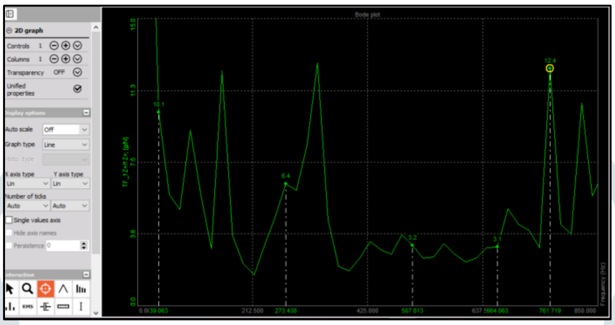


Fig 27. FFT plot of carbon fibre specimen

Tabular Data

	Mode	Frequency [Hz]
1	1.	41.084
2	2.	257.31
3	3.	504.26
4	4.	631.51
5	5.	720.97

Table 1 Comparison of FEA and FFT results

NATURAL FREQUENCY (Hz) MODE SHAPE	FEA	EXPERIMENTAL
1	41.08	39.06
2	257.31	273.43
3	504.26	507.81
4	631.51	664.03
5	720.97	761.79

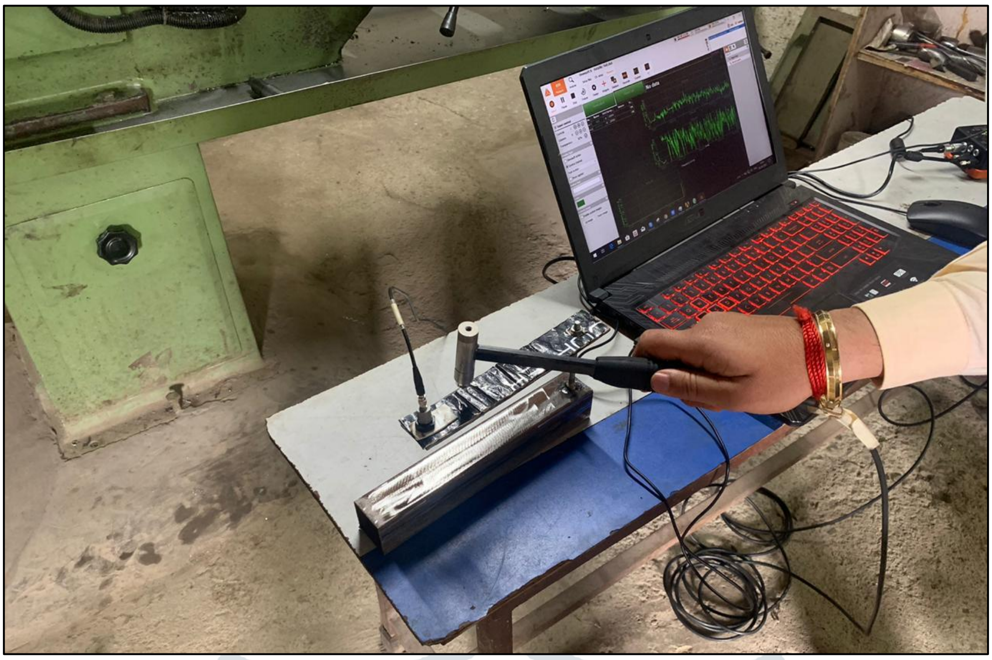


Fig28. Experimental testing

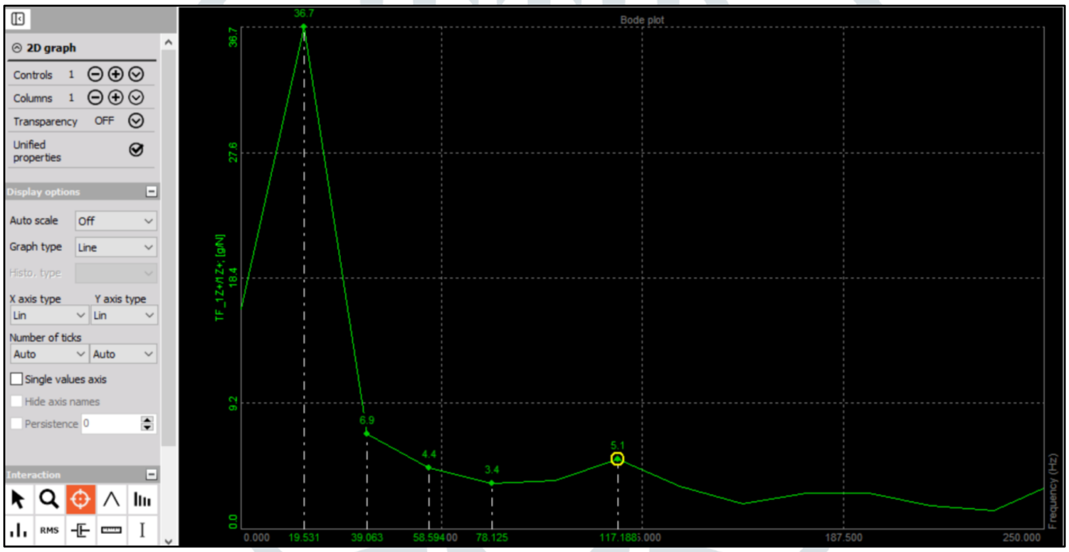


Fig.29 FFT plot of carbon fibre specimen with silicon

	Mode	Frequency [Hz]
1	1.	15.574
2	2.	46.875
3	3.	66.696
4	4.	80.012
5	5.	112.28

Table 2.Comparison of FEA and FFT results

NATURAL FREQUENCY (Hz) MODE SHAPE	FEA	EXPERIMENTAL
1	15.57	19.53
2	46.87	39.06
3	66.69	58.59
4	80.01	78.12
5	112.28	117.18

XIV. SUMMARY/CONCLUSION

In this project we are investigate the vibration characteristics of composite cantilever beam using FEA And Experimental testing.
From FEA result conclude that due to inclusion of visco- elastic material like silicon in composite cantilever beam acceleration amplitude of structure decreases.
Due to silicon material used in carbon composite beam acceleration amplitude decreases from 77.031 m/s^2 to 66.64 m/s^2.
It is observed from FFT and FEA result that natural frequency are similar in range for comparison of experimental and numerical results.

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