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EFFECT OF FIBER ORIENTATION AND BOUNDARY CONDITIONS ON DAMPING IN CARBON FIBER REINFORCED COMPOSITES

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ABSTRACT

With amazing developments in design and manufacture of composite materials, they have gained popularity in high performance products that need to be lightweight, yet strong layered enough to harsh loads. Fiber reinforcement is used to improve mechanical properties like strength-to-weight and stiffness-to-weight ratios which are vital in weight sensitive applications such as aircraft and space vehicles. Damping being an important parameter to improve dynamic behavior of structure, numerical analysis is carried on the beams by using element model. By using harmonic analysis, the damping coefficients are computed by using half Power band-width method at varied boundary conditions and layer orientation in different direction.

Keywords- *Damping, Carbon reinforced fiber, Numerical analysis, fiber orientation.*

I. INTRODUCTION

Composite materials are engineered materials made from two or more constituent materials with significant difference in physical and chemical properties which remain separate and distinct on a macroscopic level within the finished products. Fiber reinforcement is generally used to improve mechanical properties. However designing and modeling of composite parts offer some challenges and disadvantages. These disadvantages, when know and controlled can be turn into advantage. In recent period, there has been a tremendous advancement in the science and technology of fiber reinforcement composite materials. The primary reason for their use is low specific gravities, high strength to weight and modulus to weight ratios, these materials are marked as superior than metallic material. In addition fatigue strength to weight ratio as well as fatigue damage tolerances of composite laminates showed excellent results in their use. For this reason fiber reinforced composites have emerged as a major class in structural material.

The damping in the structure can be attained by passive or active methods. In active damping the vibration is controlled by an external source of energy and makes use of sensors and actuators for sensing the vibration and activating to suppress the vibrations on real time. Use of sensors and actuators increase the complexity of the system in active damping, whereas in passive damping no external source of energy is employed but it is inherent property of the system to control the vibration by dissipating the system energy. The different sources of energy dissipation in fiber-reinforced composites are viscoelastic damping and thermo elastic damping [1]. Because of reduced system complexity passive damping is more reliable and cost effective for the composite structures than the active damping. Theoretical studies for damping of unidirectional CFRP in longitudinal flexure based on law of mixture and Cox model has been reported by Adams and Bacon [2].

Barakanov and Gassan [3] proposed a FEM/frequency dependent model based on complex stiffness approach and laminated theory to analyze damping in laminated composite beams. Loss factor for graphite-epoxy composite by complex eigen values and direct frequency response method exhibits a very good agreement. Kyriazoglou [4] described the development of a hybrid methodology for the prediction of damping properties of vibrating composite laminates to homogeneous materials. This hybrid methodology consists of experimental identification of damping, using vibration damping testing methods, and utilization of FEA. Jeng-shian [5], in finite element analysis observed that the fiber-reinforced composite laminates usually possess much higher value of thermal expansion coefficient in the transverse direction than in the longitudinal direction. He made parametric study of thermal buckling in laminated composites.
Shao Hui chang et al., [6] developed finite element based modal strain energy method for predicting the modal loss factor of laminated composite beams with integral viscoelastic layers. Both the frequency dependence of viscoelastic

damping materials and the contribution of energy dissipation due to fiber-reinforced composites are taken into account. Suzuki et al [7] developed a finite element model based on the multilayer theory and the higher-order theory for the vibration and damping analysis of laminated plates with viscoelastic inter layers. Vibration and damping analysis of glass fiber-reinforced laminated composite cantilever beams and plates are studied using finite element using shear deformation theory and also through experiments [8].

Further, damping for continuous fiber-reinforced composites in transverse flexure and transverse shear is determined using mechanics of material equations and correspondence principle with assumption that energy dissipation occurs in resin only. The theoretical and experimental results show that it is feasible to produce unidirectional CFRP lamina high longitudinal modulus and loss factor using highly dissipative resin matrix. Numerical results have shown that damping values were in some difference among prediction methods over the particular range of fiber orientation. Jean – Marie Berthlot [9] in this paper present an analysis of the damping of unidirectional fiber composites and different laminates. Ioana C.Fingnan [10], summarized some recent analytical and experimental results regarding the improvement and micromechanical levels. Lia FS et al [11] studied the behavior of unidirectional and symmetric angle-ply carbon fiber-epoxy laminates as well their interleaved composites.

II. NUMERICAL ANALYSIS

The analysis is done by using Solid46 element in ANSYS. The element is defined with 8 layers symmetrically laminated. The element has three degrees of freedom at each node and the translations in x, y and z directions. The dimensions and necessary parameters like length, width, thickness of the beam, young's modulus, Poisson ratio, damping value, density and material properties are given during the modeling of the beam. After generating the model the beam is divided into finite elements like nodes by using meshing phase. The beam is constrained in all degrees of freedom, for the cantilever beam it is constrained at one end and loading is done at the other end, for simply supported beam it is constrained at both the ends and loading is done at the middle and Harmonic analysis is carried out in the solution phase. In the time historic process the graphs are obtained, from Fig.1 the damping values are calculated by using half power bandwidth formula,

Displacement, $d = h / \sqrt{2}$
Damping factor $\beta = (f_2 - f_1) / (2*f)$

Where,
h = Height of the peak
d = Displacement
f_1 = the distance between origin and the line intercepted by frequency curve (to the left) and the horizontal line drawn at a distance d from the X – axis.
f_2 = the distance between origin and the line intercepted by frequency curve (to the right) and the horizontal line drawn at a distance d from the X-axis.

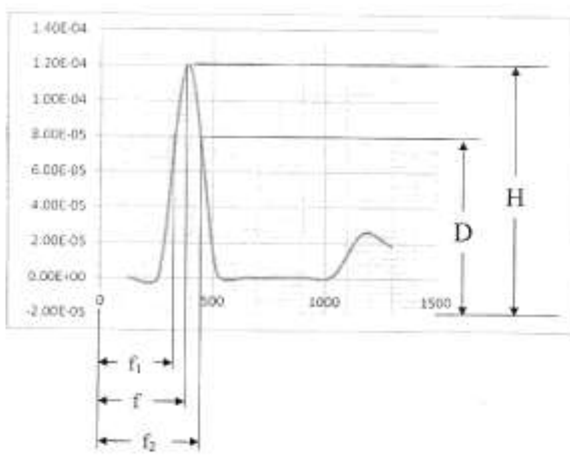

Fig.1: Overview of frequency Vs Displacement

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A. Input Parameters of carbon fiber Reinforced Plastics

1. Geometric properties

Length of the beam, L = 0.5m
Width of the beam, W = 0.02m
Thickness of the beam T =0.002m
Thickness of each layer T =0.00025m

2. Material properties

Young's Modulus E_X =106GPa
Young's Modulus E_Y =8.6GPa
Young's Modulus E_Z =8.6GPa
Shear Modulus G_{xy} =4.59GPa
Shear Modulus G_{yz} =4.59GPa
Shear Modulus G_{zx} =4.59GPa
Poisson's Ratio xy =0.02281
Poisson's Ratio yz =0.02281
Poisson's Ratio xy =0.28
Density =1630kg/ m^3

3. Loading and constraints

Load P =10N
Constraints: a) simply supported beam
b) Cantilever beam

4. Modeling properties

Frequency range :0 – 500Hz
Material Damping: 0.01
Number of Layers: 8
Orientation of layers: 0^0, 30^0, 45^0, 60^0, 90^0
Orientation of alternate layers: 0^0-30^0, 0^0-45^0, 0^0-60^0, 0^0-90^0.

B. Analysis of Cantilever Beam

Analysis of cantilever beam subjected to point load at the free end is considered. The beam is constrained in all degree of freedom is subjected at the other end. The damping values are obtained from the displacement vs. frequency graph which was obtained by solving the model with the help of harmonic analysis.

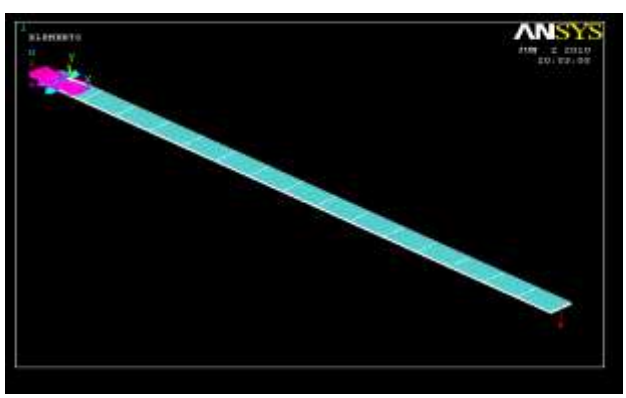

Fig.2 : Simulation of Cantilever beam

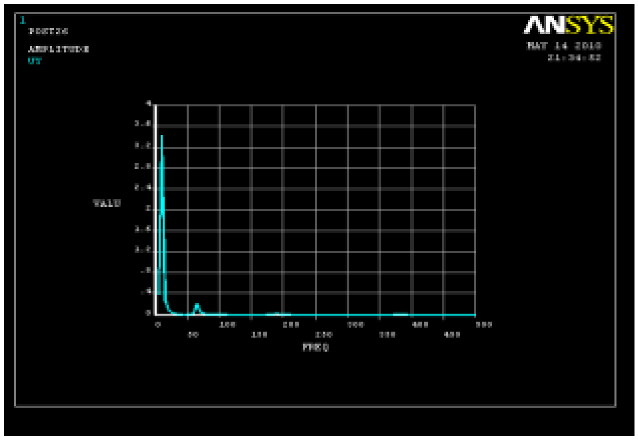

Fig.3 : Variation of displacement with frequency for Carbon Reinforced Composites for 0^0 orientation.

Frequency response of 0^0 degree orientation of cantilever beam in Carbon Reinforced Composites from numerical analysis is presented in Fig.3. It is observed that the peaks are obtained in the range of 50-100HZ and 150-250HZ. By considering these peaks damping ratio is calculated by half power bandwidth.

Similarly graphs were drawn for other orientations and the damping ratio is calculated.

1. *For Alternate layers*

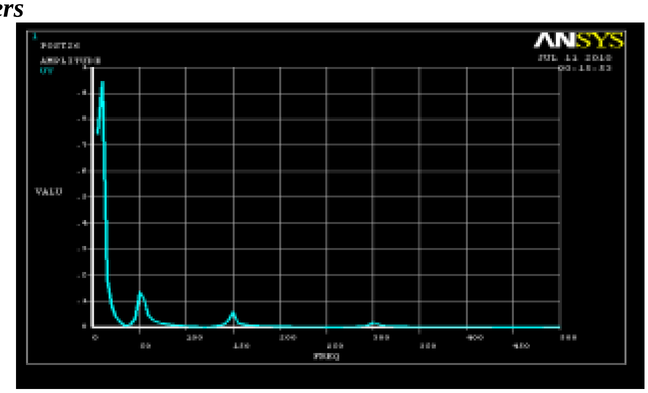

Fig.4 : Variation of displacement with frequency in alternate layers for Carbon Reinforced Composites from 0^0-30^0 orientation.

Frequency response of alternate layers in 0^0-30^0 orientation of cantilever beam in Carbon Reinforced Composites from numerical analysis is presented in Fig 4. It is observed that the peaks are obtained in the range of 0 -100HZ and 100-200HZ. By considering these peaks damping ratio is calculated by half power bandwidth method.

2. *Damping Ratios of Cantilever Beam in Carbon Reinforced Composites*

Damping ratios of cantilever beam in Carbon Reinforced Composites are obtained by using half power bandwidth by calculating the values from the graphs under different orientations.

Table 1: Values of damping ratios under various orientations of layers for cantilever Beam

CANTILEVER BEAM ORIENTATION	MODE1	MODE2
0^0 All Layers	0.0928	0.0130
30^0degree All layers	0.0625	0.0303

45^0 degree All layers	0.0692	0.0742
60^0 degree All layers	0.0454	0.0434
90^0 degree All layers	0.0636	0.0363
$0^0 – 30^0$Alternatively	0.0588	0.0198
$0^0 – 45^0$ Alternatively	0.05	0.0419
$0^0 – 60^0$Alternatively	0.04	0.0464
$0^0 – 90^0$Alternatively	0.0392	0.0275

C. Analysis of Simply Supported Beam

Analysis of Simply supported beam is subjected to point load at the middle of the beam is considered. The beam is constrained in all degree of freedom is subjected at both the ends. The damping values are obtained from the displacement vs. frequency graph which was obtained by solving the model with the help of harmonic analysis.

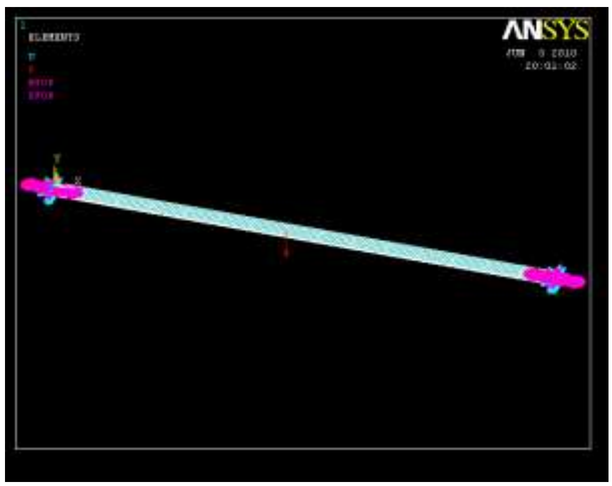

Fig.5 : Simulation of Simply Supported Beam

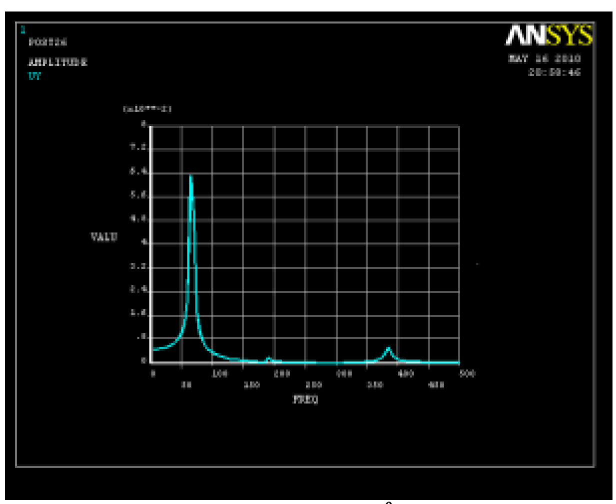

Fig.6 : Variation of displacement with frequency for 0^0 orientation of simply supported beam.

Frequency response of 0^0 orientations of Carbon Reinforced Composites of simply supported beam from numerical analysis is presented in Fig.6. It is observed that the peaks are obtained in the range of 150 – 250 HZ and 350 – 450 HZ. By considering these peaks damping ratio is calculated by half power bandwidth.

1. For Alternate layers

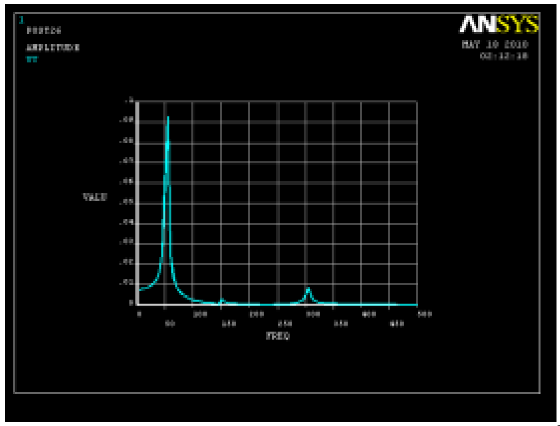

Fig.7: Variation of displacement with frequency in alternate layers for 0^0-30^0 orientation.

Frequency response of alternate layers in 0^0-30^0 orientation of simply supported beam with Carbon Reinforced Composites from numerical analysis is presented in Fig.7. It is observed that the peaks are obtained in the range of 100 –150 Hz and 150-250 Hz. By considering these peaks damping ratio is calculated by half power bandwidth.

2. Damping Ratios of Simply Supported Beam

Damping ratios of simply supported beam in Carbon Reinforced Composites are obtained by using half power bandwidth by calculating the values from the graphs given above under different orientations.

Table 2: Values of damping ratios under various orientations of layers for Simply Supported Beam.

Simply Supported Beam Orientation	MODE1	MODE2
0^0 All Layers	0.0394	0.0454
30^0 All layers	0.032	0.0339
45^0 All layers	0.0346	0.022
60^0 All layers	0.0435	0.0459
90^0 All layers	0.0324	0.0428
0^0 – 30^0 Alternatively	0.0066	0.0198
0^0 – 45^0 Alternatively	0.0101	0.0207
0^0– 60^0 Alternatively	0.00685	0.0399
0^0– 90^0 Alternatively	0.00103	0.0385

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III. RESULTS AND DISCUSSION

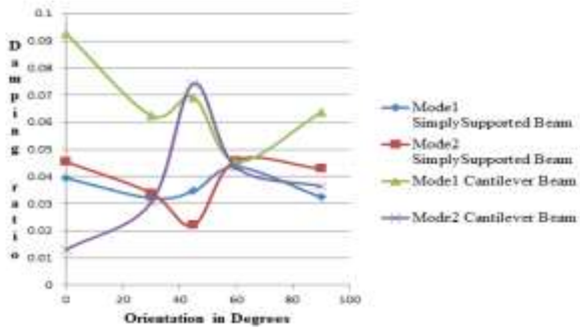

Fig.8 variation of damping ratio with fiber orientation for Carbon Reinforced Composites

Variation of damping ratio with respect to fiber orientation for is as shown in the Fig.8 and it is observed that the damping ratio for mode1 Cantilever Beam composites is higher than other values. There is a gradual increase in mode2 cantilever beam at 45^0. The values of mode1 and mode2 of simply supported beam coincide at 30^0 and 60^0 .

IV. CONCLUSIONS

The behavior of laminated composite beams studied by changing orientation of fiber in different direction to enhance damping ratio. For these study material properties of carbon reinforced plastics are used. From this study, it is evident that simply supported beam shows much better damping than the cantilever beam, also layers at 0^0 ,45^0 and (0^0 -30^0) orientation shows much better damping.

REFERENCES

1. *R Chandra, S P Singh and K Gupta, 'Damping studies in fiber-reinforced composites-a review', Composite structures, 1999, 46, 41-51.*
2. *R.D. Adams and D.G.C. Bacon.'Effect of fiber orientation and laminate geometry on the Dynamic properties of CFRP'.J. composite materials 1973, 7, 402-428.*
3. *Barakanov RG, Gassan J.'Frequency response analysis of laminated composite beams'. Mech Comp Mater 1994, 30(5), 664-74*
4. *C.Kyriazoglou. Finite element prediction of damping of composite GFRP and CFRP laminates - a hybrid formulation - vibration damping experiments and Rayleigh damping'. J.Compose sci technol 2005.*
5. *Jeng-Shian Chang. 'Finite element analysis of buckling of antisymmetric angle-ply laminates according to transverse shear and normal deformable higher order displacement theory'. Composite and Structures 1990, 37,925-946.*
6. *Shao Hui Zhang, Hua Ling Chen.'A study on the damping characteristics of Laminated composites with integral viscoelastic layers'. Composite Structures 2005.*
7. *Suzuki K, Kazuro K, et al. 'Vibration and damping prediction laminates with constrained viscoelastic layers numerical analysis by a multilayer higher-order-deformable finite element and experimental observations'. Mech Adv Master Struct 2003,10(1),43-75.*
8. *Colakoglu. 'Damping and Vibration analysis of polyethylene fiber Composite under varied temperature'. Turkish J.Eng.env.Sci 2006; 30; 351-357.*
9. *Jean-marie Berthelot. 'Damping analysis laminated beams and plates using the ritz method'. Composite structures 2005.*
10. *Ioana C.Finegan, Ronald F.Gibson.'Recent research on enhancement of damping in polymer Composites'. Composite Structures 1999, 44, 89-98.*
11. *Lia FS,Su Ac,Hsu TC.' Vibration damping of interleaved carbon fiber-epoxy Composite beams'. J Comp Mater 1994, 28(18), 1840-54.*