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Frequency Response of Composite Laminates at Various Boundary Conditions

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ABSTRACT: *The increasing use of tailored composite materials in the design of plate type structural elements has necessitated the study of vibration behavior of composite laminates. This project is focused on determination of natural frequencies of the multi layered composite laminates at various boundary conditions experimentally. Two different types of composite materials Carbon fiber –reinforced epoxy resin and Basalt fiber-reinforced Epoxy resin composite materials are considered for this analysis. The influence of the various boundary conditions, material properties, thickness on the natural frequency of the composite laminates is investigated. Finally the results of the laminates are to be compared.*

Keywords*: vibration behavior, natural frequencies, basalt fiber,multi layered composite laminates, various boundary conditions.*

NOMENCLATURE

E_{11}, E_{22} - Young's Modulus in longitudinal and transverse directions respectively
G_{12} - In-plane shear modulus
ν - Poisson's ratio
ρ - Material mass density
ω - Natural frequency
$\{\varphi\}_i$ - Eigenvector representing the mode shape of the i^{th} natural frequency
ω_i - i^{th} natural circular frequency (radians per unit time)
u, v, w - Displacement components along x, y, z directions respectively

I. INTRODUCTION

A large variety of fibers are available as reinforcement for composites. The desirable characteristics of most fibers are high strength, high stiffness, and relatively low density. Glass fibers are the most commonly used ones in low to medium performance composites because of their high tensile strength and low cost.Basalt is a natural material that is found in volcanic rocks. It is mainly used (as crushed rock) in construction, industrial and high way engineering. One can also melt basalt (1300-1700°C) and spin it into fine fibres. When used as (continuous) fibres, basalt can reinforce a new range of (plastic and concrete matrix) composites. It can also be used in combination with other reinforcements (e.g. basalt/glass).Basalt fibers have high thermal stress compared to any other fiber.

Due to the requirement of high performance material in aerospace and marine structures, the prospect of future research of composite material, such as FRP (Fibre Reinforced Plastic) is very bright. Analysis of natural frequency and properties of composite plate has started from 40 years ago.

The natural frequencies and mode shapes of a number of Graphite/ Epoxy and Graphite/Epoxy-Aluminum plates and shells were experimentally determined by Crawly [1] (1979). Natural frequency and mode shape results compared with finite element method.

Alam and Asani[2] (1986) studied the governing equations of motion for a laminated plate consisting of an arbitrary number of fiber-reinforced composite material layers have been derived using the variation principles. Each layer has been considered to be of a special orthotropic material with its directional elastic properties depending on the fiber orientation. A solution for simply supported rectangular plate is obtained in series summation form and the damping analysis is carried out by an application of the correspondence principle of linear viscoelasticity.

Narita and Leissa[3] (1991) presented an analytical approach and accurate numerical results for the free vibration of cantilevered, symmetrically laminated rectangular plates. The natural frequencies are calculated for a wide range of parameters: e.g., composite material constants, fiber angles and stacking sequences.

Qatu and Leissa[4] (1991) analyzed free vibrations of thin cantilevered laminated plates and shallow shells by Ritz method. Convergence studies are made for spherical circular cylindrical, hyperbolic, paraboloidal shallow shells and for plates. Results are compared with experimental value and FEM. The effect of various parameters (material number of layers, fiber orientation, curvature) upon the frequencies is studied.

A combined experimental and numerical study of the free vibration of composite GFRP plates has been carried out by Chakraborty, Mukhopadhyay and Mohanty[5] (2000). Modal testing has been conducted using impact excitation to determine the respective frequency response functions. FEM results, NISA package results compared with experimental results.

Frequency response of composite shell-plate combinations was studied by G. Karthikeyan and A. Joseph Stanley[6] (2008).Natural Frequencies of fiber-reinforced composite circular plate and cylindrical shell are determined separately as well as for the shell-plate combination with clamped-clamped and simply supported boundary conditions by performing modal analysis on an eight noded, linear layered SHELL 99 element with six degrees of freedom per node

Analysis of mechanical properties and free vibration response of composite laminates was done by Mr.M.Prabhakaran[7] (2011).

Yogesh Singh[8] (2012) performed free vibration analysis of the laminated composite beam with various boundary conditions.

This work presents an experimental study of testing of two different woven Composite laminates i) Glass/Epoxy and ii) Basalt/Epoxy composite plates using various boundary conditions. The experimental results have been compared with that obtained from the Composite pro software. Fabrication method and elastic properties of the plate determined from tensile test method. Variation of natural frequency with different parameter is studied.

II. METHODOLOGY

2.1THEORY AND FORMULATION

Modal testing is the most widely used method. Modal testing is an experimental procedure in which the natural frequencies of a structure are determined by vibrating the structure with a known excitation. While it vibrates, the structure will behave in such a way that some of the frequencies will not respond at all or be highly attenuated, and some frequencies will be amplified in such a way that the only limiting factor is the energy available to sustain the vibration. These frequencies, where the structure resonates, are the natural frequencies ofthe structure.

By free vibration we mean the motion of a structure without any dynamic equation external forces or support motion. The motion of the linear SDF systems without damping specializes to

$$[M]\{\ddot{u}\} + [K]\{u\} = \{0\} \qquad (1)$$

where [K], the structure stiffness matrix.

For a linear system, free vibrations will be harmonic of the form:

$$\{u\} = \{\varphi\}_i \operatorname{Cos} \omega_i t \qquad (2)$$

where $\{\varphi\}_i$ = eigenvector representing the mode shape of the i^{th} natural frequency.

ω_i = i^{th}natural circular frequency (radians per unit time)

t = time

Thus Equation (1) becomes

$$(-\omega_i^2 [M] + [K]) \{\varphi\}_i = \{0\} \qquad (3)$$

This equality is satisfied if either $\{\varphi\}_i = \{0\}$ or if the determinant of $([K] - \omega^2 [M])$ is zero. The first option is the trivial one and, therefore, is not of interest. Thus, the second one gives the solution:

$$\left| [K] - \omega^2 [M] \right| = 0 \qquad (4)$$

This is an eigenvalue problem which may be solved for up to n values of ω^2 and n eigenvectors $\{\varphi\}_i$ which satisfy Equation (3) where n is the number of DOFs.

Rather than outputting the natural circular frequencies $\{\omega\}$, the natural frequencies (f) are output; where:

$$f_i = \omega_i / 2\pi \qquad (5)$$

2.2. EXPERIMENTAL PROGRAM

2.2.1 FABRICATION: In order to respect the assumption of classical theory of bending of thin plates with small deflections, keep the thickness of the plate smaller than 1/5th of the largest dimension of the plate. The thickness of the test plates was even more reduced up to 1/10th of the largest dimension of the plate, in order to keep resonant frequencies of the test structure as low as possible, thus assuring good vibration measurements.

The hand lay-up process is the oldest, simplest, and most labour intense fabrication method. In hand lay-up method liquid resin is placed along with reinforcement (woven glass fiber/basalt fiber) against finished surface of an open mould. Chemical reactions in the resin harden the material to a strong, light weight product. The resin serves as the matrix for the reinforcing glass fibers, much as concrete acts as the matrix for steel reinforcing rods. The percentage of fiber and matrix was 50:50 in weight.

The material constants are determined experimentally by performing unidirectional tensile tests on specimens cut in longitudinal and transverse directions, and at 45° to the longitudinal direction, as described in ASTM standard: D 638-08 and D 3039/D 3039M. Four specimens(two glass fiber and two basalt) are considered for analysis.

Table 1. Material Properties Of The Glass/Epoxyand Basalt/Epoxy Laminates

Properties	E_{11}	E_{22}	G_{12}	ν_{12}	P
Glass - Epoxy	**40.4968GPa**	**6.913GPa**	**2.667GPa**	**0.269**	**1796.94 Kg/m^3**
Basalt-Epoxy	**46.4 GPa**	**6.54 GPa**	**2.512 GPa**	**0.251**	**1572.32 Kg/m^3**

2.2.2vibration Testing Setup And Procedure

The Vibration testing equipment consisting of a Vibration generator, Accelerometer, Oscilloscope, Power oscillator, are arranged and connected as per the guidance manual. The plate was excited in a selected point by means of vibration generator. The resulting vibrations of the plate in a select point are measured by an accelerometer. The accelerometer was mounted on the plate. The signal was then subsequently input to the oscilloscope (analyzer), where its frequency spectrum was also obtained. The response point was kept fixed at a particular point and the location of excitation was varied throughout the plate.

However, the present work represents only the natural frequencies of the composite laminates.

ACCELEROMETER VIBRATIONGENERATOR

SPECIMEN TESTING APPARATUS SET UP

2.2.3 SOFTWARE PROGRAM:

Helius: CompositePro (version 4.2) Software is employedfor design and analysis of composite laminates also providing accurate solutions for vibration of laminates.

3. RESULTS AND DISCUSSION:

The natural frequency in Hz is obtained theoretically by calculating the stiffness of the specimen and comparisons of results between the theoretical, experimental and software result at various boundary conditions are tabulated.

Due to limitations (voltage limit) in the experimental set up the results of higher modes could not be interpreted. In experimental result, natural mode of frequency varies within a range with respect to software result. Un-damped natural frequency is considered in the program and damping was present in the system. So, the natural frequency from the experiment should less than the actual value. But the difference between both the results is reasonable. The reasons are:

Since I have taken rectangular pieces of specimen, elastic modulus may decrease than the exact value. So, natural frequency can be decreased.

There may be variation of elastic properties of the plate, as the sample cut from the plate was different from the plate used in the case vibration testing. Tensile properties may vary with specimen preparation and with speed and environment of testing.

Table 2- One End Fixed (Cantilever)

MATERIAL	THEORETICAL	EXPERIMENTAL	SOFTWARE
GLASS (1)(3mm)	17.25	18	28.75
GLASS(2)(3.5 mm)	18.35	20	33.45
BASALT (CRIMMED)(3 mm)	18.442	21	23.96
BASALT(WOVEN)(3mm)	18.959	20	33.64

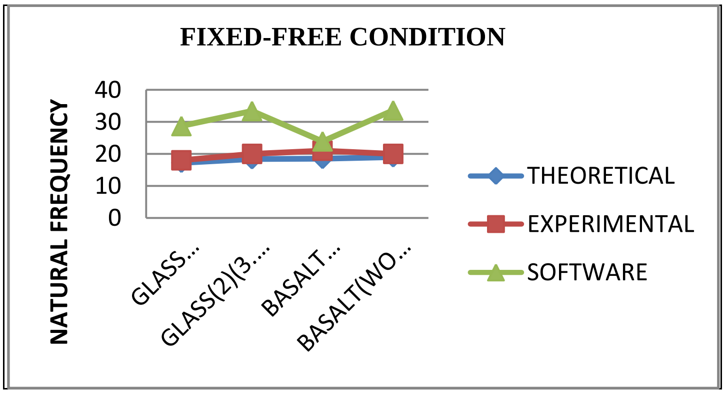
Table 3- Fixed-Fixed Condition

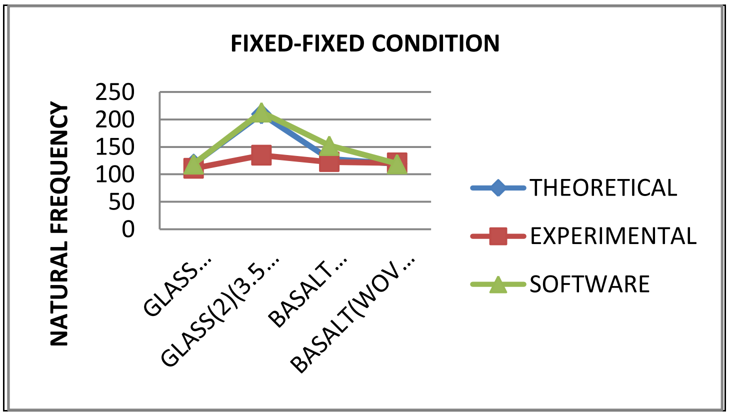
MATERIAL	THEORETICAL	EXPERIMENTAL	SOFTWARE
GLASS (1)(3mm)	119.25	111	118.73
GLASS(2)(3.5 mm)	210	235	213.46
BASALT (CRIMMED)(3 mm)	128.388	123	125.5
BASALT(WOVEN)(3mm)	119.52	121	119.1

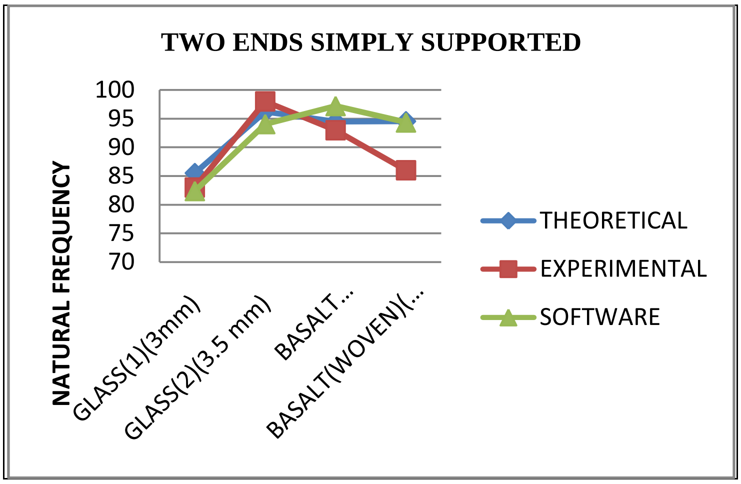
Table 4- Two Ends Simply Supported

MATERIAL	THEORETICAL	EXPERIMENTAL	SOFTWARE
GLASS(1)(3mm)	85.5	83	82.37
GLASS(2)(3.5 mm)	96.22	98	94.05
BASALT (CRIMMED)(3 mm)	94.5	93	97.2
BASALT(WOVEN)(3mm)	94.55	86	94.33

3.2 GRAPHICAL COMPARISION:







VI. CONCLUSION

The natural frequencies of two varieties of composite laminates have been reported, from different boundary condition (cantilever, two edge fixed, simply supported),it is found that the natural frequency of all edge fixed plate is very higher. Basalt/Epoxy specimen showed better resistance to vibration than Glass/Epoxy specimen. Natural frequencies are obtained using Composite Pro package for different types of laminated composites. It was found that natural frequency increases with increase in mode ofvibration from software result.

REFERENCES

[1]. 1.“Frequency response of composite shell-plate combinations”,G. Karthikeyanand A. Joseph
[2]. Stanley. Department of Aerospace Engineering,Madras Institute Technology, Anna University, Chennai
[3]. 2. A. Joseph Stanley and N. Ganesan, “Frequency Response of Shell-Plate Combinations.” *Composite & Structures*, Vol. 59, No.6, P. No. 1083-1094 (1996)
[4]. 3.Thesis on “Vibration Analysis of Woven Fiber Glass/Epoxy Composite Plates” by ParsuramNayak, Department of Civil Engineering, NIT Rourkela(2008)
[5]. 4. Chakraborty S., Mukhopadhyay M., Mohanty A. R., “Free Vibrational Responses of FRP Composite Plates: Experimental and Numerical Studies”, Journal of Reinforced Plastics and Composites, (2000)
[6]. 5. Jones, R. M., “Mechanics of Composite Materials”, McGraw Hill, New York (1975)
[7]. 6.” Analysis Of Mechanical Properties And Free Vibration Response Of Composite Laminates”, Mr.M.Prabhakaran, International Journal of Mechanical & Industrial Engineering, Volume-1 Issue-1, 2011
[8]. 7. Robert I. Goldman, “Mode Shapes and Frequencies of Clamped - Clamped Cylindrical Shells.” *AIAA Journal*, Vol. 12, No.12, P.No.1755-1756.
[9]. 8. “Natural frequency charecteristics of composite plates with random properties”-S.Salim, N.G.R.Iyengar, D.Yadav, Department of Aerospace, IIT Kanpur, Journal on Structural Engineering and Mechanics, Vol 6. No 6 (1998)(659-671)
[10]. 9.Vibration of Laminted Shells and Plates-MohamadS.Qatu
[11]. 10. “Vibration characteristics of glass fabric/epoxy composites with different woven structures”-
[12]. XuLei, Wang Rui, Zhang Shujie and Liu Yong-*Journal of Composite Materials* 2011 45: 1069
[13]. 11. Basalt Fiber Reinforced Polymer Composites-Dr. Richard Parnas, Dr. Montgomery Shaw,
[14]. Qiang Liu-The New England Transportation Consortium,August, 2007.