ISSN 2395-1621

Effect of Geometric Parameter on Free Vibration Analysis of Glass Fiber Epoxy Composite Laminated Plate With and Without Cut outs

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ABSTRACT

This paper present a combined experimental and numerical study of free vibration of E- glass fiber epoxy composite plates. Composite laminates were manufactured by compressive molding technique of unidirectional glass fiber with stacking sequence [0/90˚] orientation. Cutting of plates by using water Jet machining technique as per required dimensions that is with different size of plates with and without cutouts. Also coupons were manufactured as per ASME standards, to find out flexural strength, compressive strength, and tensile strength of E-glass fiber composite laminated. It is important to determine the vibrational characteristic of composite plate. Free vibration of plate is greatly depending on the thickness and the boundary condition. Plate with a cutout shows a dynamic characteristic due to this cutouts in a structure is to expose vibration sometimes due to cutout resonance condition is occur leads to fail in a structure. So it is necessary to predict the resonant frequency of this structure .The purpose of this paper is to study natural frequencies of free vibration of plate using ANSYS computer packages. Number of different boundary conditions are involved in both side fixed and cantilever boundary condition .Here the analysis of plate is carried out for uniform thickness.

Keywords— **ANSYS, composite laminates, FFT analyzer, free vibration, Geometric parameter, glass fiber etc**

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

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.

A fiber reinforced composite material that consists of fiber and matrix. These two or more constituents that are combined at a macroscopic level which are insoluble in each other and differ in form or chemical compositions. The reinforcing phase material may be in the form of fibers, particles or flakes and they are responsible for carry loads and the stresses which the composite is subjected to and the matrix phase materials are generally continuous such as polymer, metal, carbon and glass work of matrix is to distribute the force and stresses uniformly among the reinforcement and binds the reinforcement. It prevents fiber from external damage [1].

Composite structures have been widely used in many engineering examples in aeronautical, automotive, and marine structures. The more common composites used are laminated composite plates which are typically made of different layers bonded together. Basically, each layer is generally orthotropic and has a different orientation of the fibers. In addition to the advantages of high strength (as well as high stiffness) and light weight, another advantage of the laminated composite plate is the controllability of the structural properties through changing the fiber orientation angles and the number of plies and selecting proper composite materials.

In order to achieve the right combination of material properties and service performance, the dynamic behavior is the main point to be considered. To avoid the typical problems

caused by vibrations, it is important to determine: a) natural frequency of the structure; b) the modal shapes to reinforce the most flexible regions or to locate the right positions where weight should be reduced or damping should be increased.

In structural acoustics, recent work in sound transmission through laminated structures has shown that the fundamental frequency is a key parameter. The natural frequencies are sensitive to the orthotropic properties of composite plates and design-tailoring tools may help in controlling this fundamental frequency. The understanding of prediction models facilitates the development of such tools. Due to the advancement in computer aided data acquisition systems and instrumentation, Experimental Modal Analysis has become an extremely important tool in the hands of an experimentalist. This work presents an experimental study of modal testing of glass fiber Epoxy cantilever and fixed composite plates. A program based on FEM is developed. The experimental results have been compared with that obtained from the finite element analysis. Variation of natural frequency with different parameter is studied [2].

A. Importance of Cutouts

Cut out is an integral part of almost every structural element including laminated composite plates. They are used in civil, mechanical, aerospace and automotive industry extensively. For various practical reasons we always need to provide cut out in these structures. Cut-outs serve the purpose of access vents for the mechanical and electrical systems such as passage of electrical wires, hydraulic lines etc .Many times designers just use cut-outs of various shapes and size for quality control, to Reduce the weight the weight of structures and also to alter the natural frequencies of structures to make them safe

in case of hazardous vibrations. Cut-outs in structural members like plates tend to change its dynamic characteristics to some extent. This change is obvious whenever the structure is exposed to large vibrations. Many a times these cut-outs may lead to failure under lower stress and also sometimes due to undesired resonance. So it is utmost necessary to predict the resonant frequencies of these structures with cu-touts. The extensive range of practical applications of cut-outs in plates requires a better understanding of the vibrations and stability properties of laminated plates with cut-outs [3].

Cutouts are necessary for assembling the components, damage inspection, access ports, electrical lines and fuel lines, opening in a structure to serve as doors and windows, provide ventilation, to reduce weight and for accessibility to other parts of the structure. It is needed at the bottom plate for passage of liquid in liquid retaining structures. It is well known that these structures are exposed to the undesirable vibration, extra amount of deflection and many more during their service life and again these plate structures having cutout may change the responses considerably. As discussed earlier, the plates having the cutouts reduce the total weight which in turn affect the vibration response similarly it also reduces the total stiffness and the bending behavior changes automatically.

II.EXPERIMENTAL METHOD

A .Fabrication Technique of Composite Laminates

To meet the wide range of needs which may be required in fabricating composites, the industry has evolved over a dozen separate manufacturing processes as well as a number of hybrid processes. Each of these processes offers advantages and disadvantages. Hand lay-up and spray-up are two basic molding processes. They are mostly application specific. The hand lay-up process and the spray lay-up process is the oldest, simplest fabrication method of composites.

A hand lay-up technique is of common since it is more economical, no skilled labor is required and no special tooling and equipment are required so obviously manufacturing cost can be reduced. On the other hand this technique has ability to produce complex components with minimum manufacturing time, therefore production rate is increased. In recent year particularly due to the interest generated in automotive industry, there is more development in manufacturing methods that can support mass production rates. Compression molding, pultrusion, and filament winding represents three such a manufacturing processes.1970s.Resin transfer molding (RTM)is another manufacturing process that have received significant attention in both aerospace and automotive industries for its ability to produce composite parts with complex shapes at relatively high production rates[4].

B. Fabrication of E-Glass Laminated Composites

In a composite laminates, fibers and resin are combined in a specific proportion to form a lamina. Depending on the type of resin used, the lamina may be put into the final structural shape at the time of lay-up or lamina is formed first and put into the structural later.

Fig.1:LY554 IN Epoxy and HY 951Hardener
Fig.2E-Glass Fiber Rolling Sheet

A number of parameters like curing temperature, pressure, humidity, fiber distribution, etc. Which affect the mechanical properties cannot be easily controlled. These result in the variation of stiffness coefficient, which introduce a factor of uncertainty in the response of structure. The manufacturing of composite plate was done by contact molding in an open mold by hand lay-up process. The

material require for manufacturing of composite plates are glass fiber as a reinforcement, Epoxy as a resin, Hardener as a catalyst(12% of the weight of epoxy)and polyvinyl alcohol as a releasing agent.
In initial a flat mold was selected of dimension 150*600mm. Ply was cut from roll of unidirectional glass fiber of dimension 147*470mm in 0-90˚ orientations. Detail procedure is outlined below:

Fig.3 Compressive Molding Process

1.Clean the surface of mold so that no dirt or oil is present on mold surface for improving quality of laminated composite plates.
2. Apply polyvinyl alcohol on cleaned surface of mold on bottom surface for better surface finish and for easy of plate after curing from mold.
3.First a transparent sheet was kept on the mold of dimension 147×470mm for better surface finish of laminated composite plates.
4. Apply resin epoxy as a gel coat using brush.
5.Place layer of 0˚on first layer of dimension 147×470mm and pressed by roller so that trapping of air is completely avoided.
6. Apply again resin epoxy by using brush.
7. Now place different piles of fiber orientation 90˚ of dimension 147×470mm .This process is continued up to 10 layers apply a roller so that air which may be entrapped was removed after that again place again 90˚ and repeat same procedure up to 20 layers .
8. The thickness of laminated plate after 20 layers is 3.8 mm because for one layer of fiber we obtained a thickness of 0.19mm so that 20×0.19 mm gives 3.8mm thickness of laminated plate.
9. Again a transparent sheet was kept on the mold on top surface of dimension 147×470mm for better surface finish of laminated composite by applying polyvinyl alcohol inside the sheet as releasing agent.
10. A heavy flat mold was selected on the top of plate plates for compressing purpose.
11.This mold are clamped on both sides excessive resin which is present inside the mold get release outside the mold and air which may be entrapped was removed using clamping method.
12. The plates were left for a minimum of 48 hours for air curing before being transported.

The process of polymerization is called "curing", and can be controlled through temperature and choice of resin and hardener compounds, the process can take minutes to hours. The mold is placed in woven and heating up to temperature 100˚c after that cooling up to room temperature. So that fiber properties can be regain again.

Fig.4 Manufacturing of laminated plates

III. STRENGTH OF LAMINATED FIBER COMPOSITES

Strength is more difficult to predict than elastic properties because it depends on the mechanisms of damage accumulation and failure as well as properties of the constituents, and the failure behavior of fiber composite is complex. Sometimes failure occur in a laminates can be depends on many aspects of the composite construction, including the fiber type and distribution, the fiber aspect ratio, l/d ratio, and the quality of the interfacial bond between the fibers and the matrix.
Much of the software currently available for predicting the strengths of fiber composites .Because of the complex nature of failure in many types of composite, considerations of strength and toughness are closely interrelated[5].

A .Tensile Test

Tensile strength testing has been one of the most common physical property testing methods of by a number of researchers and manufacturers worldwide. However, the number of publications on the subject has been limited. The American Society for Testing and Materials (ASTM) has a tensile test standard designed to determine the tensile properties of unreinforced and reinforced plastics in the form of standard dumbbell (dog-bone) shaped test specimens. 'ASTM D638-Standard Test Method for Tensile Properties of Plastics' .This test standard was originally designed for the plastic materials.

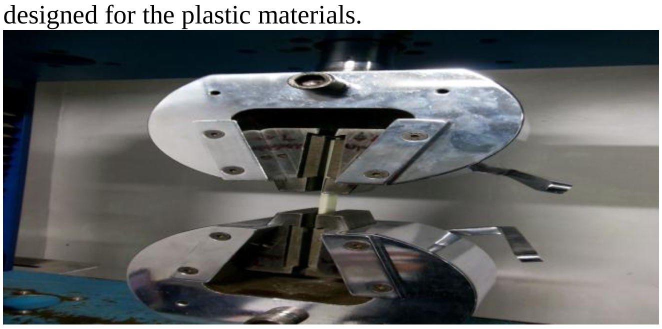

Fig.5 Specimen Loaded in Tensile Test Equipment

Fig.6 Tensile Properties of Glass Fiber with 0/90˚ Orientation

Table 1: Tensile Strength (ASTM D 638-03)

Sample Identification	Material	Maximum Load(N)	Tensile Strength (Mpa)
1. Sample	E-Glass Fiber 0/90˚	25529.0	357.341
2. Sample	E-Glass Fiber 0/90˚	17787.0	343.179
3. Sample	E-Glass Fiber 0/90˚	19149.2	399.566

B. Compressive Test

Compression tests provide information about the compressive properties of plastics. Compressive properties include modulus of elasticity, yield stress, deformation beyond yield point, and compressive strength (unless the material merely flattens but does not fracture). Materials possessing a low order of ductility may not exhibit a yield point. In the case of a material that fails in compression by a shattering fracture, the compressive strength has a very definite value. In the case of a material that does not fail in compression by a shattering fracture, the compressive strength is an arbitrary one depending upon the degree of distortion that is regarded as indicating complete failure of the material. Many plastic materials will continue to deform in compression until a flat disk is produced, the compressive stress (nominal) rising steadily in the process, without any well-defined fracture occurring.

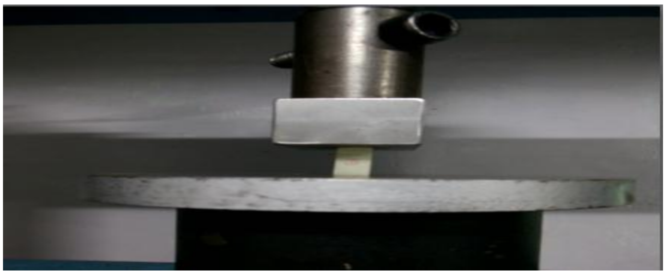

Fig.7 Specimen Loaded in Compressive Test Equipment

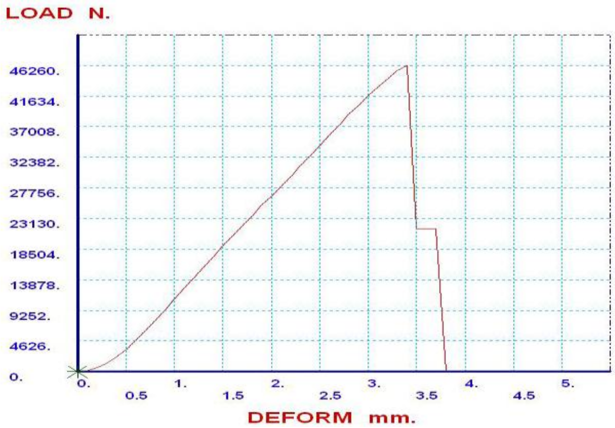

Fig.8 Compressive Properties of Glass Fiber with 0/90˚ orientation

Table 2: Compressive Strength (ASTM D 695-02)

Sample Identification	Material	Maximum Load(N)	Compressive Strength (Mpa)
1. Sample	E-Glass Fiber 0/90˚	46256.0	309.255
2. Sample	E-Glass Fiber 0/90˚	41914.6	280.460
3. Sample	E-Glass Fiber 0/90˚	45148.6	301.608

C. Flexural Test

The flexural tests are conducted to determine the mechanical properties of resin and laminated fiber composite materials. Further, these tests are used to determine the inter laminar shear strength of a laminate, shear modulus, shear strength, tensile and compression moduli along with flexural and shear stiffness. These tests are not only used for composites but also for sandwich beams.

These tests are simple one. Further, they need simple instrumentation and equipment required. These tests conducted on beams of uniform cross section. These beam specimens do not require the end tabs.

There are two methods to carry out these tests. The beam is a flat rectangular specimen and is simply supported close to its ends. In the first method the beam is centrally loaded. Thus gives three point bending. Since there are three important points (two end supports and one central loading point) along the span of the beam this method is called as *three-point bending* test. In the second method the beam is loaded by two loads placed symmetrically between the supports. In this method there are four important points (two end supports and two loading points) along the span of the beam. Thus, it gives four-point bending. Hence, this method is called *four point bending*.

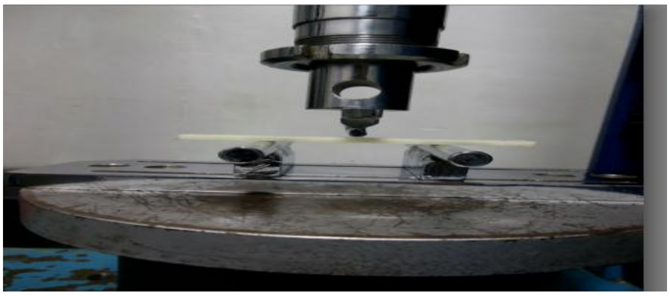

Fig.9 Specimen Loaded in Flexural Test Equipment.

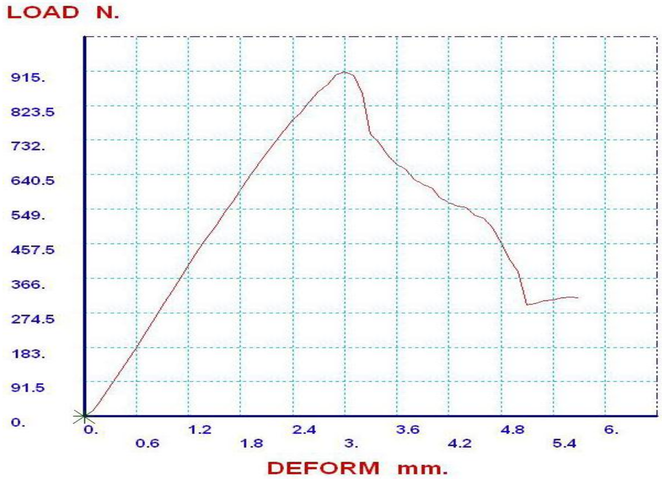

Fig.10 Flexural Properties of Glass Fiber with0/90˚ orientation

Table 3: Flexural Strength (ASTM D 790-03)

Sample Identification	Material	Maximum Load(N)	Flexural Strength (Mpa)
1. Sample	E-Glass Fiber 0/90˚	912.38	148.431
2. Sample	E-Glass Fiber 0/90˚	833.0	355.044
3. Sample	E-Glass Fiber 0/90˚	916.3	430.343

IV .PROPERTIES OF E-GLASS FIBER COMPOSITE PLATE

Modulus of Elasticity, E1 = 36.2868 Gpa
Modulus of Elasticity, E2 = 5.36126 Gpa
Modulus of Elasticity, E3 = 5.36126 Gpa
Shear Modulus, G12 = 2.16705 Gpa
Shear Modulus, G13 = 1.95952 Gpa
Shear Modulus, G23 = 1.95952 Gpa
Poisson Ratio, V12 = 0.217
Poisson Ratio, V13 = 0.217

A. General Specification

The lamina of composite plate was made by glass fiber in unidirectional .The test plate made of E-glass fiber and epoxy resigns has been used here. The thickness of glass fiber used is 0.19mm and width of fiber 3.8mm.It has a total 20 layers of equal thickness which are arranged as [0/90˚]as shown in above figure 2.The size of each plate was kept 125mm×100mm for cantilever boundary condition and 150mm×100mm for fixed boundary condition also cutouts were provided at the center .The different size of cutouts used of dimensions 10mm,20mm and 30mm diameters.

V. EXPERIMENTAL SETUP

Fig.11 Experimental set-up

The experimental set up used by us in the laboratory was a frame which has all the utilities for providing cantilever, fixed end conditions to the plates for testing. The components used for modal testing are [6]

A. Accelerometer

The Accelerometer is a device used for the sensing the vibration from the plates after the excitation has been made on it.

B. Modal hammer

Modal hammer are also known as Impact hammers. Their prime function is to provide a calculated amount of excitation to the structure. The type of structure varies from small to medium sizes. The accelerometer then picks up the response of the structure and sends it back to the FFT analyzer. We can apply a perfect excitation to the plate without adding any extra mass to the structure.
The sensitivity of the impact is measured with the help of built in sensors inside the hammer. It also has some built in mechanism to remove unwanted noise from outward source. The result is thus a clean and smooth output signal. The variable tips of the impact hammers can be changed based upon the type of structure. This determines the amplitude and band width of excitation.

C.FFT Analyzer

FFT Analyzer main purpose is to receive a time varying signal from the accelerometer and convert it into a frequency based signal.

D. Pulse labshop

Pulse lab shop is the platform used in the computer to investigate the data from the FFT Analyzer and produce the required frequency response .It has wide range of applications in static and dynamic analysis of structures. One of the great feature of pulse is that real time analysis and results can be obtained from this. Thus we can use it in field and verify the results immediately.

VI.DISCUSION

The objective of this paper is to find out natural frequency of E- glass fiber laminated composite plate with and without cutouts considered a various geometric parameter such as size of cutouts, boundary conditions ,ply 0/90˚ orientation and perform a finite element analysis in ANSYS simulation software which can be validated experimentally by FFT analyzer.

VII. CONCLUSION

Composite laminates were manufactured by compressive molding technique of unidirectional glass fiber with stacking sequence [0/90˚] orientation also coupons were manufactured as per ASME standards, to find out flexural strength, compressive strength, and tensile strength of E-glass fiber composite laminated. Coupons are tested as per ASTM standard gives a strength of composite laminated plate. Tensile testing of composite laminates obtained by ASTM D 638-03 is 366.69Mpa.Compressive testing of composite laminates by ASTM D 695-02 is 297.10.Also flexural test is conducted that is three point bend test of composite laminates by ASTM D 790-03 is 401.26.Modeling can be done in ANSYS simulating software with a 0/90˚ ply orientation natural frequency obtained after performing modal analysis is validated experimentally by FFT analyzer.

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