STUDY ON VIBRATION ANALYSIS OF COMPOSITE PLATE

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Abstract— As we all know that vibration and composite material are two main growing research topics these days. Almost all the structural components subjected to dynamic loading in their working life and vibration affects the working life of the structure so it is very important in designing a structure to know in advance its response and to take necessary steps to control the structural vibration and its amplitude. Composite material gives chances to designers and engineers to increase material efficiency, therefore resulting in cost reduction and better utilization of resources. Composites materials applications are wide in aerospace industries, automobile sector, manufacturing industries etc.

The present study involves extensive experimental works to investigate the free vibration of woven E-fiber Glass/Epoxy composite plates in fix-free boundary conditions. The specimens of woven E-glass fiber and epoxy matrix composite plates are manufactured by the hand-lay-up technique which is most suitable and efficient manufacturing technique for composite manufacturing. Elastic properties of the plate are also determined experimentally by tensile testing of specimens using computerized universal testing machine TUE-C-400. ASTM standard was used to test the material. An experimental investigation is carried out using modal analysis technique with VA4Pro FFT Analyzer, impact hammer and contact accelerometer obtain the Frequency Response Functions. Also, this experiment is used to validate the results obtained from the ANSYS 15.0 and theoretical calculations based on governing equation of vibration. The effects of different geometrical parameters including number of layers, aspect ratio of woven E-glass fiber composite plates are studied in fix-free boundary conditions in details. This study provides valuable information for researchers and engineers in design applications.

Index Terms— Composite material, vibration, Modal analysis, finite element analysis, FFT analyzer, Fixed-free Boundary condition.

I. INTRODUCTION

Literature review focuses on the different types of analysis of composite materials. The basically composite material is a combination of two or more numbers of materials. It is simply made by putting several materials together and creating a product that is stronger than the sum of their materials. History of advance composites begins in 1970s in aerospace industries, but nowadays after only four decades, it is developed in most of the industries. There is possibility that increase in composite material characteristics using the latest technology and various manufacturing methods has raised its application range. Along with progress in technology, metallic parts are replaced by composite materials in various industries. In many cases materials encounter vibrations in machines and mechanisms. The effect of vibration is very prominent whether it is small in amplitude or large. Considering the aero plane wings the effect of vibration can be severe as those are flexible structures. Due to the effect of vibration, strain in the wings increases. This can cause instability. To make the structure more flexible without compromising its strength, vibration study is very important. But still the effect of vibration could not be minimized to satisfy level.

In this paper work, basically vibration analysis of E-glass and epoxy composite plate was studied in which we analyzed the effect of factors such as number of E-glass fiber layers in composite material and an aspect ratio of reinforcement and matrix material by weight which was E-glass fiber and Epoxy on the fundamental natural frequency. Lots of researchers did their work on free-free boundary condition. This research totally focuses on the fix-free boundary conditions. Fix-free boundary conditions same as that of cantilever object boundary conditions. Rather than fundamental natural frequency we found different mode shapes of vibrations experimentally and analytically in this research.

The scope of the study includes below important points:

- Fabrication of E-Glass/Epoxy composite plate according to research requirement.
- Experimental Modal analysis work conducted on FFT analyzer and also on ANSYS.
- Aspect ratio and Number of layers were the affecting parameters of this experiment.

II. METHODOLOGY

In this research work, it was very important and necessary to develop proper composite plate and fabrication method to manufacture those plates. There are lots of fabrication methods to develop composite plate. It is essential for the reader to know how these processes. The selection of a fabrication process obviously depends on the constituent materials in the composite; with the matrix material is the dominant factor. Selection of reinforcement material also plays important role in the selection of manufacturing method. The name of fabrication processes given below:-

1. Hand lay-up.
2. Spray-up.
3. Automated lay-up.
4. Pultrusion process.
5. Filament winding.
6. Resin transfer molding.

Hand lay-up method was used to fabricate composite plate which was best suited for manufacturing those plates. Perfect plan is necessary to achieve good results to perform research. Simulation is carried out using analysis software ANSYS 15.0. FRF result, simulation results and theoretical results were compared. Methodology is a brief description about experimentation of the research.

A) Experimentation

a) Geometric properties: Woven E-glass fiber composite plates were taken as a specimen to conduct a test. The numbers of plates were taken. Plates prepared by hand lay-up by placing various layers of glass fiber on each other. The maximum length of plate is 25 cm. Plate widths and length remains constant throughout the research. The average thickness of the specimen was measured by a screw gauge having at L.C. Of 0.01mm.

b) Fabrication Method: Wet lay-up and autoclave is two important techniques to be considered for fabrication of composite materials. The hand lay up or wet lay-up processing techniques and autoclave techniques, processes have one thing in common: The deposition of different layer is done by hand. The most common materials are E-glass fiber and polyester resin, although higher performance materials can also be used. The single sided mold invariably operates at room temperature using an ambient curing resin. The reinforcement may be in the form of chopped strand mat or an aligned fabric such as woven roving's. The usual feature of hand laminating is a single sided female mold, which is often itself made of glass fiber reinforced plastics (GRP), by taking a reversal from a male pattern. The GRP shell is often stiffened with local reinforcement, a wooden frame or light steel work to make it. The mold surface needs to be smooth enough to give an acceptable surface finish and release properties and this is provided with a tooling gel coat that is subsequently coated with a release agent. The latter prevents the matrix resin from bonding to the mold surface and facilitates the de-molding operation. It is common practice to use a surface tissue immediately after the gel coat to mask any reinforcement print-through on the outer surface. Once the gel coat has hardened sufficiently, the reinforcement is laid in one layer at a time. Catalyzed resin is then worked into the reinforcement using a brush or roller. This process is repeated for each layer of reinforcement until the required thickness is built up. For thick laminates, pauses need to be taken after a certain number of layers have been deposited to allow the exothermic heat to dissipate before additional layers are deposited. Local reinforcements can be used to provide stiffness in specific areas and lightweight formers such as foams or hollow sections can be laminated in for the same purpose. The process remains an important one for low volume manufacture, although increasingly stringent emission regulations are forcing several manufacturers to explore the use of closed mold alternatives.

We use E-fiberglass as a layer of the composite and epoxy as a binder to create hard composite materials. The percentage of fiber and matrix was 50:50 in weight at first, which will vary afterwards according to experiments. Below figure 1 shows the hand lay-up techniques.

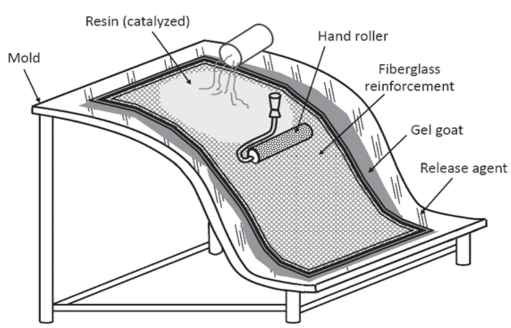

Fig. 1: Wet / Hand lay-up Fabrication process[16].

c) Determination of Material Constant: The fibers used in modern composites has strengths and stiffness's far above those of traditional bulk materials. The characteristics of woven E-fiberglass/epoxy composite plate which can be determined completely by two material constants E and ν. A composite plate according to experiment variations was manufactured to evaluate material constant. The constants E determined experimentally by performing tensile test on specimen as described in ASTM standard D-638. The specimen of same size plates was cut themselves by diamond cutter or by any cutting machine. After cutting in the cutting machine, it was polished in the polishing machine. At least three specimens were tested and mean value adapted. ρ also required for the simulation in ANSYS. This can be determined by measuring the mass of the plate divided by the volume of that plate. We took the average value for ν from the manufacturer's catalogue which was 0.275.

III. TESTING

FFT analyzer is used to analyze vibration in the specimen of having fix-free boundary condition. The instrument which converts the input signals, with time as an independent variable, into frequency spectrum and displays it in graphical form is called as spectrum analyzer or FFT analyzer.

A) Test Setup

Instruments: Following instruments used to perform the experiment:

- Impact Hammer.
- Accelerometer.
- Multi-channel Vibration Analyzer (At least two-channel).
- A PC/Laptop loaded with software for modal analysis.
- Test-specimen (A cantilever held in a fixture).
- Power supply for the instruments and vibration analyzer, connecting cables for the impact hammer and accelerometer, fasteners and spanner to fix the specimen in the fixture, and adhesive/wax to fix the accelerometer).

The connections of all the instruments are done as per the guidance manual. The plate was excited by the impact hammer when the plate was in a fix-free condition. C-clamp required for holding the plate according to boundary conditions. Additional 5cm provided at the end of the plate for the hold.

B)Test Procedure

- Prepare the plate: Measure the length of the fixture that holds the composite plate and leave the margin of that length on the plate. Divide the remaining length of plate into five parts and mark node numbers in each division – from 1 to 6. Let node 1was the fixed end. Fix the accelerometer to the plate at node 3 but on the face of the plate opposite to the marking and node number up. Fix the plate into the C-clamp that provide support to the cantilever plate.

Fig. 2: Experimental setup

- Connect the wires and cables.
- Switch on the power supply. Open the software of vibration analysis and experimental modal analysis installed on the PC/laptop. Provide essential inputs and make necessary settings in the software. Ensure that there is proper supply and communication between the devices connected.

Now we shall provide impacts by the impact hammer on the nodes marked on the cantilever plate one by one. Impacts will be given with nodes 1, 2, 4, 5 and 6; node 1 is fixed and node 6 is free. The accelerometer is connected to node 3. Signals from the impact hammer and the accelerometer will be received by the vibration analyzer for each impact provided one by one and will be compared and analyzed by the software. Curve known as Frequency Response Function (FRF) will be generated by the software that is used to find the natural frequencies of the plate.

C)Analysis of composite plate

FEA involves three stages of activity:

- Preprocessing
- Processing
- Post processing.

In the study, FEA analysis will be is conducted using ANSYS software. To modal the composite plate proper Shell element will be used. The plate is in a fix-free boundary condition. Degrees of freedom are UX, UY, UZ, ROTX, ROTY, ROTZ. We used shell 8node-281 element for lay-up modeling of plate in mechanical APDL.

IV. DATA ANALYSIS

Table I: Natural Frequency with various aspect ratios.

	Frequency in Hz					
	Aspect Ratio 1:1		**Aspect Ratio 1:1.5**		**Aspect Ratio 1:2**	
No	**Ex**	**ANSYS**	**Ex**	**ANSYS**	**Ex**	**ANSYS**
1	2	2.117	2	2.42	2.333	2.863
2	6	6.009	6.333	6.417	10.33	9.333
3	14.33	13.72	15.6666	15.875	25.3333	24.095
4	20.33	22.01	28	26.832	29	29.768
5	24.66	24.98	36.6666	35.14	55.3333	58.038
6	42	42.91	49.6666	47.895	59.3333	61.165
7	46	45.22	53.6666	55.422	75.6666	75.31
8	50	51.50	56.3333	56.949	96	102.1

Table II: Natural Frequency with different number of layers

	Frequency in Hz					
	10 Layers		**15 Layers**		**20 Layers**	
No	**Ex**	**ANSYS**	**Ex**	**ANSYS**	**Ex**	**ANSYS**
1	2	1.8001	2.33333	2.1348	2.33333	2.6698
2	5	5.0422	8.66666	8.9161	11.3333	11.161
3	8.66666	7.5992	15.6666	13.419	18.6666	16.884

4	12.6666	12.596	21.6666	22.23	31.6666	31.501
5	17	16.507	25.6666	25.262	42	41.412
6	30	32.103	38	38.21	55.666	56.993
7	49.6666	49.686	51.333	56.478	73.3333	75.099
8	53.3333	56.51	58.3333	60.404	85.6666	86.214

This table clearly shows that the changes in aspect ratio and number of layers change the natural frequency of the plates. These are the 8 mode shapes of the vibration of the plates.

V. RESULTS AND DISCUSSION

Above Data analysis shows that as aspect ratio increases natural frequencies also increases. This results validated by experimental, theoretical and analytical method. In this research, we found a less number of % error between experimental and analytical result. This clearly shows that we did research in a right way.

1) Effect of aspect ratio on natural frequency

To examine the effect of aspect ratio three different types of plates were fabricated, which was made up of 1, 1.5, 2 aspect ratio. The Natural frequency of free vibrations was obtained by experimental, analytical, theoretical method to fix-free boundary condition. The graph of aspect ratio verses frequency plotted below.

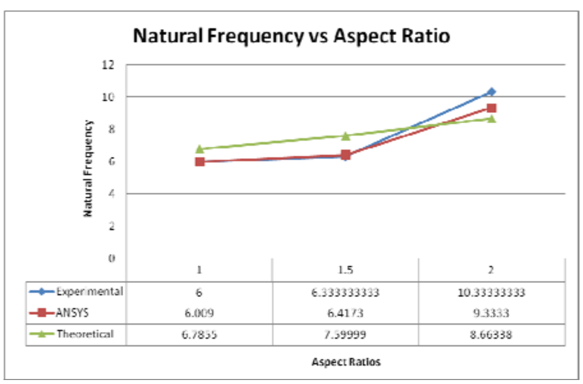

Fig. 3. Effect of fiber orientation on natural frequency.

Above graph clearly shows that as aspect ratio increases the natural frequency also increases as expected. There is a considerable variation in the natural frequency in experimental readings, whereas theoretical calculations shows linearity.

2) Effect of number of layers on natural frequency

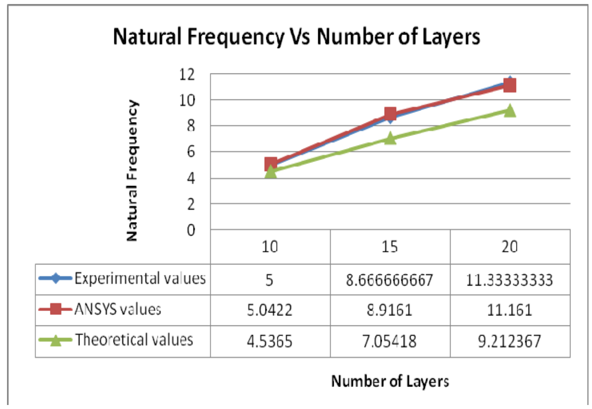

Fig. 4. Effect of aspect ratio of natural frequency

In order to know the effect of the number of layers on the natural frequency three types of plates were manufactured with different number of layers. The variation of natural frequency with different number of layers shown in fig. 4. The result obtained from free vibration of the plates of both experiment and ANSYS was in good agreement. As observed from fig. 4 numbers of layers have an influence on the dynamic behavior of the laminated plate. As the number of layers increases the natural frequency also increases.

VI. CONCLUSION

In the present study, all experimental, analytical and theoretical study was conducted for woven roving E-glass epoxy composite plate. Different results were presented to show that the effect of different parameters like aspect ratio and number of layers in fix-free boundary condition. Numerical analysis has been carried out by ANSYS software and the result obtained from ANSYS are giving good agreement with the experimental results. Experimental results and analytical results show some percentage errors because of manufacturing defects, experiment defects, etc., but % errors between them were within range of a good agreement. This experimental method had explored to predict the dynamic behavior of E-glass woven composite plate, in order to design panels or other similar structures used in different applications such as automobile industry, aerospace, civil, marine and other high performance structures.

VII. ACKNOWLEDGEMENT

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NOMENCLATURE:

E -Young's modulus of Elasticity
υ -Poisson's ratio
ρ –Density

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