Study on Vibration Analysis of Composite Plate

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***Abstract*-- This paper represents the review on vibration analysis of composite plates. As we know that vibration and composite material are two main growing research topics now a days. Almost all the structural components subjected to dynamic loading in their working life and vibration affects 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 opportunity to designer and engineer to increase material efficiency, resulting in cost reduction and better utilization of resources. Composites materials application are wide in aerospace industries, automobile sector, manufacturing industries etc.**

Presents study involves extensive experimental work to investigate the free vibration of woven fiber glass/epoxy composites plates in free-free boundary condition and I am interested to do research in fixed-free boundary condition of composite plates. Vibration of plates depends greatly on its thickness, aspect ratio, boundary condition and fiber orientation. In this paper we studies different mode frequency for free vibration according to change in aspect ratio, thickness and fiber orientation. The specimens of woven glass fiber and epoxy matrix composite plates are manufactured by the hand-layup techniques. Elastic parameters are determined experimentally by tensile testing of specimens. An experimental investigation is carried out using modal analysis technique to obtain the natural frequencies by using FFT analyzer. Also another analysis runs on ANSYS to validate the results. This study may provide valuable information for researchers, engineers and composite material industries in design applications.

***Keywords-Composite material, vibration, Modal analysis, finite element analysis, FFT analyzer, Fixed-free Boundary condition*.**

I. INTRODUCTION

Literature review is focused on the different types of analysis of composite materials. Basically composite material is a combination of two or more number 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 begin in 1970s in aerospace industries, but now a days 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 have 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, vibration analysis of glass/epoxy composite plate under free-free boundary condition is conducted for analyze the effect of factors such as thickness of composites, fiber orientation angle and aspect ratio on the natural frequency. Lots of researchers do their work on free-free boundary condition hence I wish to do research in the field of Fixed-free boundary condition of composite plate and find out mode shape and natural frequency changes.

A. Scope

The scope of the study includes the following:

- Fabrication of Glass/Epoxy composite plate of having specific thickness.
- Experimental Modal analysis work conducted on FFT analyzer and also on ANSYS.
- Affecting parameters are fiber orientation angle, aspect ratio and thickness.

II. METHODOLOGY

In the present study, it is very important and necessary to develop proper composite plate fabrication method. There are lots of fabrication methods to develop composite plate. It is essential for the reader to know how these materials are made.The selection of afabrication process obviously depends on the constituent materials in the composite, with the matrix material being the key. 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. Perfect plan is necessary to achieve good results in conducting research. Simulation is carried out using analysis software ANSYS. FRF result, DOE data, and simulation results are compared.

A. Experimentation

1. Geometric Property

Woven fibered glass composites plates are taken as a specimen to construct and test. Seven numbers of plates are 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. The average thickness of the specimen was measured by a screw gauge having a least count of 0.01mm.

2. Fabrication Method

The most common materials are glass fiber and polyester resin, although higher performance materials can also be used. The single sided mold is invariably operatedat room temperature using an ambient curing resin. The reinforcementmay 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), bytaking a reversal from a male pattern. The GRP shell is often stiffenedwith local reinforcement, a wooden frame or light steel work to make it.The mold surface needs tobe smooth enough to give an acceptable surface finish and release propertiesand this is provided by a tooling gel coat that is subsequentlycoated with a release agent. The latter prevents the matrix resin frombonding to the mold surface and facilitates the de-molding operation. Itis common practice to use a surface tissue immediately after the gel coatto 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 reinforcementusing a brush or roller. This process is repeated for each layer of reinforcementuntil the required thickness is built up. For thick laminates,pauses need to be taken after a certain number of layers have been depositedto allow the exothermic heat to dissipate before additional layers aredeposited. Local reinforcements can be used to provide stiffness in specificareas and lightweight formers such as foams or hollow sections canbe laminated in for the same purpose. The process remains an important one for low volume manufacture, althoughincreasingly stringent emission regulations are forcing severalmanufacturers to explore the use of closed mold alternatives.

The percentage of fiber and matrix was 50:50 in weight at first, which will vary afterwards according to experiments. Fiber orientation also changes to study the different orientations of fibers on vibration. Below figure shows the hand lay-up techniques.

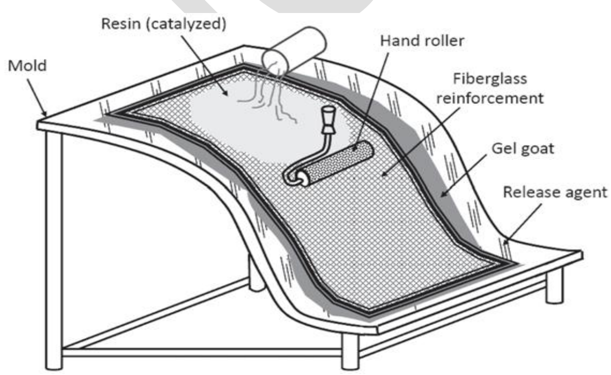

Fig. 1.Wet/Hand lay-up fabrication process

3. Determination of material constants

The fibers used in modern composites have strengths and stiffness's far above those of traditional bulk materials. The characteristics of woven fiber glass/epoxy composites plate which can be determined completely by two material constants E and υ. Composite plate having 8 layers is manufactured to evaluate the material constants. The constants E and υ are determined experimentally by performing tensile test on specimen as describe in ASTM standard: D 638-08 and D 3039/D 3039 M-2006. The specimen of same size plates were cut themselves by diamond cutter or by hex saw. After cutting in the hex saw, it was polished in the polishing machine. At least three specimens were tested and mean value adapted.

III. TESTING

FFT analyzer is used to analyze vibration in the specimen of having fixed-free boundary condition.

A. Test setup

Apparatus: Following apparatus will be used to perform the experiment:

- Impact Hammer.
- Accelerometer.
- Multi-channel Vibration Analyzer (At least two-channel).
- A PC or a Laptop loaded with software for modal analysis.
- Test-specimen (A cantilever held in a fixture).
- Power supply for the PC 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 impact hammer. The plate is at Free-Free condition.

B. Test procedure

- Prepare the plate: Measure the length on the fixture that holds the composite plate and leave the margin of that length on the plate. Divide the remaining length of plate into six parts and mark node numbers at each division – from 1 to 7. Let node 7 bethe fixed end. Fix the accelerometer to the plate at node 4 but on the face of the plate opposite to the marking and node number up. Fix the plate into slot on the fixture so that simply supported beam is formed.
- 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 necessary 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 simply supported beam one by one. Impacts will be given on nodes 2, 3, 4, 5,6 and 7; node 7 is fixed and node 1 is free. Accelerometer is connected at node 5. 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.
- Observe the curve and read frequencies that correspond to peaks of the FRF.

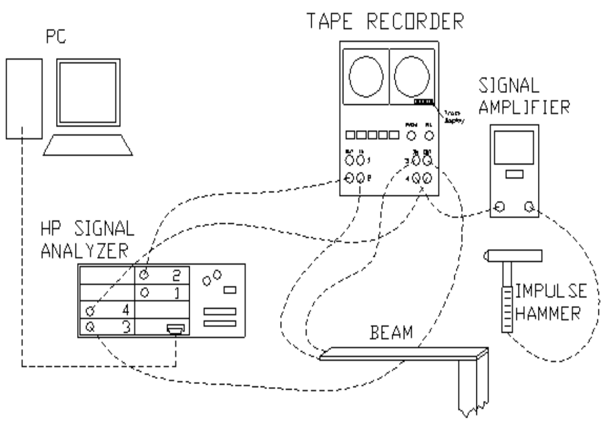

Fig. 2. Experimental setup

C. Ansys FEA model

FEA involves three stages of activity:

- Preprocessing
- Processing
- Post processing.

In the study, FEA is conducted using ANSYS software. To modal the composite plate linear layer Shell 99 element is used. The plate is at free-free boundary condition. Degrees of freedom are UX, UY, UZ, ROTX, ROTY, ROTZ.

IV. DATA ANALYSIS

Plate	Mode no.	Experimental frequency(Hz)	Simulation frequency(Hz)	Error (%)
Glass/epoxy plate with aspect ratio 1:1	1	224.6	210.7	6.18
	2	576	618	7.29
	3	1298	1197	7.78
Glass/epoxy plate with aspect ratio 1:1.5	1	332	283	14.75
	2	791	881	10.21
	3	1562	1467	6.11

Table1.Natural frequency with various aspect ratios.

Plate	Mode no.	Experimental frequency(Hz)	Simulation frequency(Hz)	Error (%)
Glass/epoxy plate with aspect ratio 1:2	1	400.4	308	21
	2	927.7	960	3.61
	3	1845	1787	3.14

Table 2.Natural frequency with various aspect ratios.

Plate	Mode no.	Experimental frequency(Hz)	Simulation frequency(Hz)	Error (%)
Glass/epoxy plate with [45/-45] fiber orientation	1	224.6	223.86	0.32
	2	476	584	18.15
	3	1093	1.37	5.12
Glass/epoxy plate with [30/-60] fiber orientation	1	255.13	262	2.67
	2	661	634	3.36
	3	1296	1214	6.3

Table 3.Natural frequency with various fiber orientations.

This table clearly shows that the change in aspect ratio and fiber orientation changes the natural frequency of plate.

V. RESULT AND DISCUSSION

The experiment shows lower value at [45/-45] fiber orientation and increases natural frequency for [30/-60]. Maximum 6 % error possesses between experimental and simulation results. Natural frequency increases with increase in the aspect ratio. Experimental values and simulation study are compared with each other. There are lots of errors between experimental value and simulation value because:

1. Same plates are not used for tensile test and vibration test.
2. No accurate lay-up on the plates because of hand operation.
3. Speed and environment of testing.

I am also expecting a same kind of results that as thickness, aspect ratio and fiber orientation changes natural frequency and mode shapes also changes. Above results graphs shown below:-

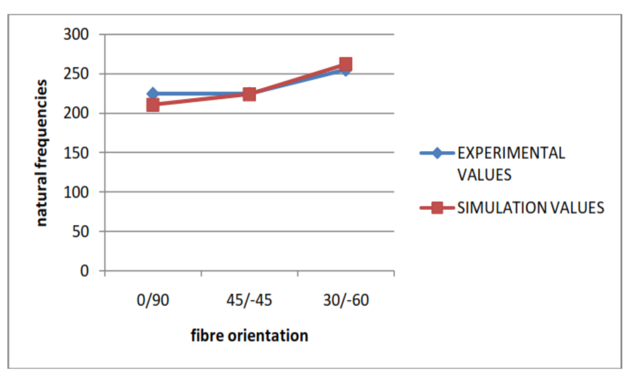

Fig. 3.Effect of fiber orientation on natural frequencies.

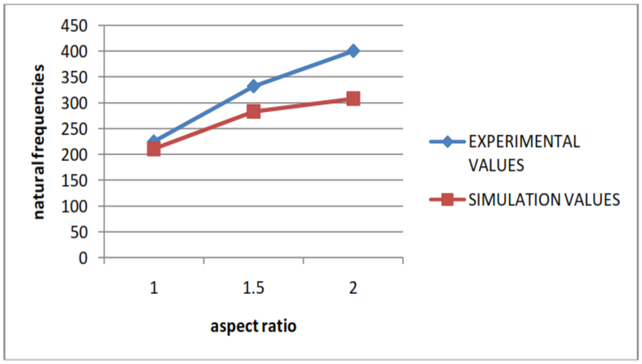

Fig. 4.Effect of aspect ratio on Natural frequency.

VI. CONCLUSIONS

Composites have attractive mechanical and physical properties. The values of fundamental natural frequencies of the plate obtained by a combination of Fiber glass epoxy and resin in various aspect ratios and various fiber orientation of the plate. FFT analyzer plays very important role to validate the results of ANSYS. Experimental and analytical both results showing the same result pattern which is satisfactory.

Manufacturing consideration plays an important role in design part. I have also wanted to analyze the effect of different fabrication factors such as curing time, curing temperature and volume fabrication ratio so as to optimize the fabrication process. This is the future scope of this paper.

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