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Study on Vibration Analysis of Composite plate

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ABSTRACT

The energy produced by road roughness is dissipated through shock absorbers. Energy-harvesting shock absorber is capable for recovering that energy. It absorbs road vibrations and converts it into electrical energy. In this paper, design of regenerative suspension system is proposed, for improving the energy harvesting efficiency. Mechanical motion rectifier is used to convert oscillatory vibration into unidirectional rotation of generator. Static structural analysis is carried out to identify displacement and stresses by using software. In this project, a mechanical rack and pinion system is used to generate power through regenerative shock absorber. The validation is done by using experimental evaluation. The model achieved more than 50% efficiency at high frequency in oscillatory motion. This model can be used effectively in vehicles for power generation.

Keywords— **DC motor, Energy harvesting shock absorber, Mechanical motion rectifier, Regenerative shock absorbers, Rack and pinion.**

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I. INTRODUCTION

The 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 after only four decades, it is developed in most of the industries. There is an increase in composite material characteristics 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 and stability, vibration study is very important. But still the effect of vibration could not be minimized to satisfy level. Several parameters affect the vibration of composite plates nonetheless an aspect ratio and number of layers are two main important parameters which is needed to explore.

The dynamic performance of laminated composite plate has received great attention in the past. In order to solve the plate problem two main steps must be taken; the choice of plate theory and the choice of the solution method. CLPT (classical lamination plate theory), FSDT (First order shear deformation theory) [7] and HSDT (Higher order shear deformation theory) [1] are the main three plate theories. The governing equation can be solved using either numerical method (FEM, Differential quadrature method, Mesh-free method, Meshless [13], Ritz method, and Galerkin method) or analytical method (ex. Power series method). Earlier work finished with the design of various plate theories. Developing more accurate governing equation and solving that equation numerically was the general work in this field. Very few researchers investigated their work experimentally, but lots of researcher did their work numerically. Recently Meshless

and more accurate methodsexplored by scholars. Free-free boundary conditions are the most popular topics amongst the investigators. In this exploration experimental analysis and fix-free boundary conditions are the two main gaps. So fulfill that gap propose work was intended to investigate the vibration of composite plate having fix-free boundary conditions experimentally.

In this exploration, vibration analyses of E-glass and epoxy composite plates are studied. Vibration analysis with respect to change in aspect ratio and number of layers has been investigated in this research. This researchfocuses on the fix-free boundary conditions. Fix-free boundary conditions are same as that of cantilever structure. Experimental and analytical work carried out to find out the mode shapes of vibration, after getting the fundamental natural frequency of vibration of each plate. In the future, composites will utilize even better fibers and resins, many of which will incorporate Nano-materials. Dedicated university programs and research institutions will continue to develop improved materials and ways to manufacture them into products. Additionally; composites are on the path towards being more environmentally friendly.

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 analyser and simulation in ANSYS.
- Aspect ratio and Number of layers were the affecting parameters of this experiment.

II. METHODOLOGY

In this research work, it was vital and necessary to develop composite plates. There are lots of fabrication methods to develop composite plate. The selection of a fabrication process evidently depends on the constituent materials in the composite; with the matrix material is the key 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

- Geometric Property: 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 lengths remain constant throughout the study. The average thickness of the specimen was measured by a screw gauge having at L.C. Of 0.01mm. Below fig. 1 shows wet/ hand lay-up plates of composite materials.

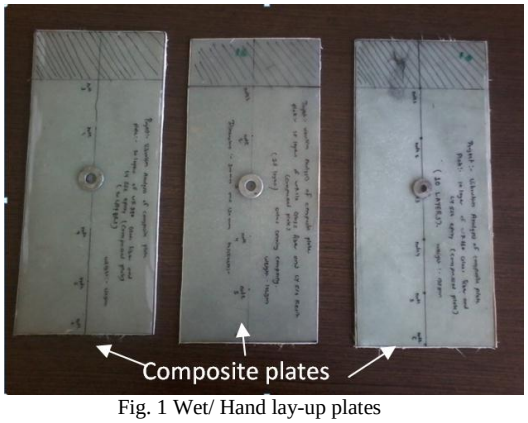

Fig. 1 Wet/ Hand lay-up plates

- Fabrication Method: 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 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. Once the gel coat has hardened sufficiently, the reinforcement is laid in one layer at a time. Catalysed 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. E-fiberglass as a layer of the composite and epoxy as a binder is used to create hard composite materials. The percentage of fiber and matrix was 50:50 in weight at first, which will differ afterwards according to experiments.
- Determination of Material Constant: The fibers used in modern composites have 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 υ. The test specimen 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 cutter machine. After cutting in the cutting machine, it was polished in the polishing machine. At least three specimens were tested and mean value adapted. Value of ρ investigated from the mass of the plate. The value for υ taken from the manufacturer's catalogue which is 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. Plates are clamped by the C-Clamp According to boundary conditions. Additional 5cm provided on the plate for holding.

B. Test procedure

- Prepare the plate: Measure the length of the fixture that the plate 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 on the plate at node 3. Fix the plate into the C-clamp that provides support to the cantilever plate.
- 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 after another. 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.

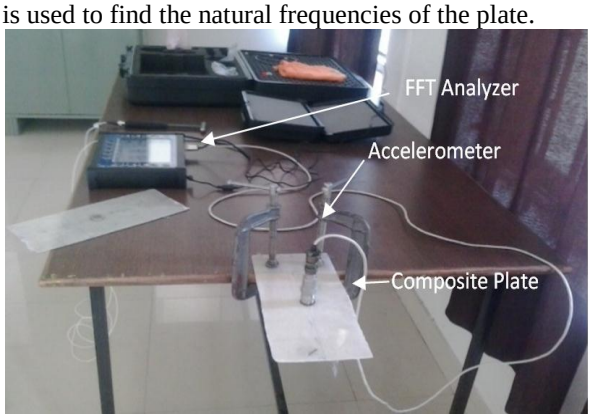

Fig. 2 Experimental setup

C. Analysis of composite plate

FEA involves three stages of activity:

- Pre-processing
- Processing
- Post processing.

In thisexploration, FEA analysis conducted using ANSYS software. Shell 8node-281 element has used to model the plate in Mechanical APDL.

Small deformation of the plate structure is given as:

$$[M]\{\ddot{u}\} + [c]\{\dot{u}\} + [k]\{u\} = \{F(t)\}$$

For free un-damped vibration, the equation reduces to:

$$[M]\{\ddot{u}\} + [k]\{u\} = \{0\}$$

If the modal coordinates are employed the equation becomes:

$$\{[K] - \omega^2[M]\}\{\varphi_n\} = \{0\}$$

There are various methods of finding the natural frequencies ω_i and the modal vectors$\{\varphi_n\}$once the system mass $[M]$ and stiffness matrix $[K]$ are formulated. The necessary constitutive relations have also been formed. The element is capable of solving transverse shear deformation through the implementation of first order shear deformation theory. The element stiffness matrix can be expressed as:

$$[K]_n = \iint_{-1}^{+1} [B]^T [D][B]|J|\partial\xi\,\delta_n$$

Numerical integration is done by Gaussian quadrature formulae. The consistent element mass matrix is generated using,

$$[M]_n = \iint_{-1}^{+1} [N]^T [m][N]|J|\partial\xi\,\delta_n$$

Effect of rotary inertia is neglected. and analytical result values. Data analysis shows less percentage errors. It indicated that the direction of this research is in a right approach.

IV. RESULTS AND DISCUSSION

The consequences of plate show that a number of mode shape increases the natural frequency also increases. Validation is done by comparing experimental, theoretical

A. Effect of aspect ratio on the natural frequency

To study the effect of aspect ratio three different types of replicate were manufactured, which was made up of 1, 1.5, 2 aspect ratios. Aspect ratio consists of weight ratio of matrix and reinforcement material. The graph (fig. 3) Indicate the natural frequency of vibration by 3 various methods.

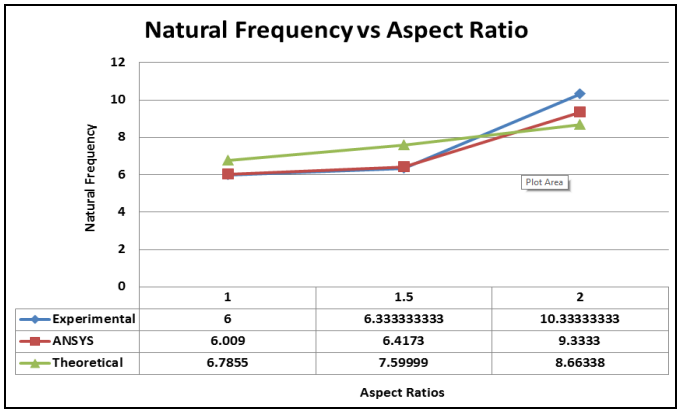

Fig. 3 Effect of aspect ratio on the natural frequency

Above fig. 3 shows that as aspect ratio increases natural frequency of vibration also increases. Theoretical reading shows linearity in the calculations, whereas an experimental and analytical result shows certain non-linearity. Aspect ratio 1 shows less frequency and aspect ratio 2 shows maximum frequency.

B. Effect of aspect ratio on the natural frequency

In order to know the effect of number of layers on the natural frequency of composite material three plates were manufactured with different number of layers. The variations of layers are 10, 15 and 20. The variation of natural frequency with different number of layers displayed in fig. 4:

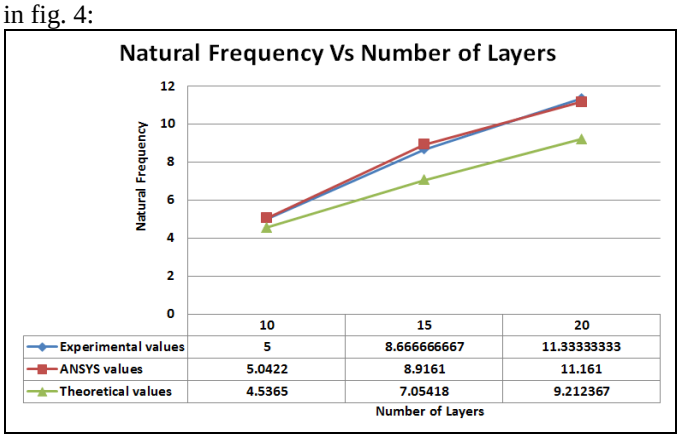

Fig. 4 Effect on number of layers on the natural frequency

The results obtained for free vibration of composite plates for both experimental and ANSYS was in good agreement. It is observed from above fig. 4 that a number of the layer increases the natural frequency also increases. Numbers of layers have a large influence on geometry as well as the dynamic behavior of composite materials. The Percentage error between experimental and theoretical is greater than the percentage error between experimental and analytical.

C. Mode shape study in detail

Displacement vector and mode shape at various nodes displayed in the below fig. 5. This helps to understand the dynamic behaviour of the plate. Below image is the core of the analytical solution.

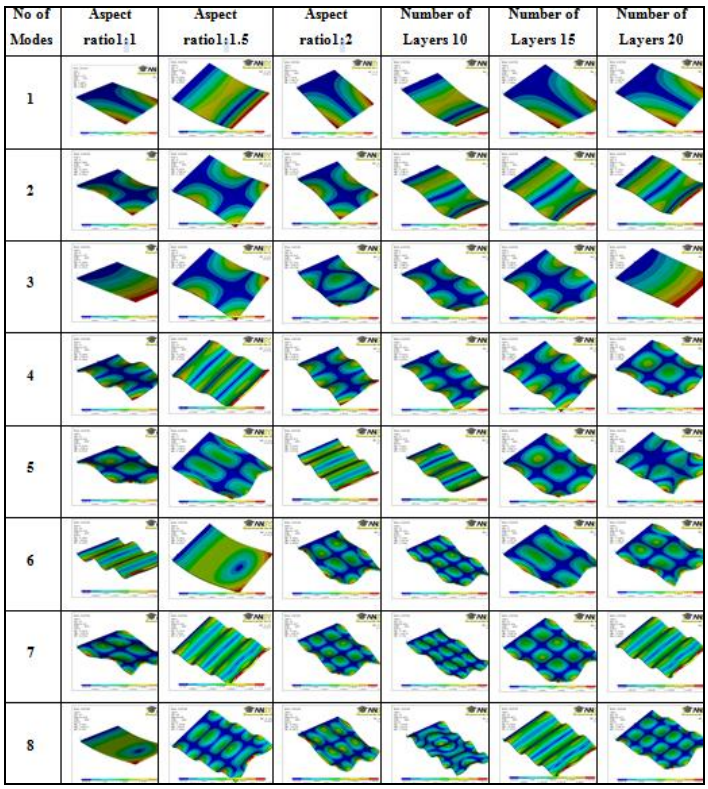

Fig. 5 Detail mode shape study

VI. CONCLUSION

In this present study, all experimental, analytical and theoretical study was conducted on woven roving E-glass epoxy composite plate. Different results were expressed to show that the effect of different parameter like aspect ratio and number of layers on the fundamental natural frequency of composite plates having fix-free boundary condition. Fix-free boundary condition acted like cantilever structure. Numerical analysis has been carried out by ANSYS 15.0 software and the results obtained from ANSYS are giving good agreement with the experimental results. Results show some percentage errors because of manufacture errors, experimental errors and other different types of errors. But the range of percentage errors is within the limit of modal analysis. This research found the dynamic behavior of composite plates as aspect ratio and number layer changes. Plates study helps to design panels or other similar structures used in different applications such as automobile industry, aerospace, civil, marine and other high performance structures.

These types of projects have lots of future scope because lots of parameters affect the vibration of composite plates and also dedicated university and research institute will continue to develop improved materials and the ways to manufacture them into products. Additionally, composites are on the path towards being more environmentally friendly. This type of research covers large research areas so limits for research should be decided first. This project covers three large topics of design composite materials, vibrations and study of plates and shells.

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NOMENCLATURE:

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

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