VIBRATION ANALYSIS OF LAMINATED TRIANGULAR PLATES USING EXPERIMENTAL AND FINITE ELEMENT METHOD

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Abstract - This present paper deals with analysis of triangular plate with free clamped-free boundary condition for different materials. The analysis performed for isotropic right triangular plate and for symmetrically laminated/composite triangular plates. For symmetrically laminated/composite triangular plate different materials as FRP, rubber, plastic are consider. The work is divided into two parts i.e. FEM analysis and experimental modal analysis. The object of modal analysis is to find out modal parameters as frequency and mode shapes. In experimental work, triangular plates fabricated and by using FFT analyzer, the modal parameters are determined. The results obtained in analysis compared graphically

Key Words: *Triangular Plate, Vibration analysis, modal analysis, laminated plates.*

1.INTRODUCTION

Vibration analysis of laminated triangular plates is a critical aspect of structural engineering that plays an essential role in understanding the dynamic behavior of complex composite structures. Laminated triangular plates are prevalent in various engineering applications, including aerospace, automotive, and marine industries, due to their lightweight and high strength-to-weight ratio. Understanding the vibration characteristics of these plates is crucial for ensuring their structural integrity and optimizing their performance.

This study aims to investigate the vibration analysis of laminated triangular plates using both experimental methods and finite element analysis (FEA). By employing a combination of these approaches, the study can validate and enhance the understanding of the dynamic behavior of laminated triangular plates under various boundary conditions and loading scenarios.

The experimental method involves measuring the natural frequencies and mode shapes of laminated triangular plates through techniques such as modal analysis and shaker testing. These measurements provide real-world data that serve as a benchmark for validating the results obtained from the finite element simulations.

The finite element method, on the other hand, is a numerical technique used to model the behavior of laminated triangular plates under different condition[1]

Plates are important structural element in engineering applications, such as ship structure, aero plane structure, pressure vessel, missile liquid container etc.Flat triangular plate with variable thickness are used in aerodynamic lifting and stabilizing surfaces on rocket, guided missile and high speed aircraft. The application of plate theories has recently become very important with the of speed turbo machines. Turbo machines employ rotating plates or blades these cantilevered plates are most severely stressed element subjected to highly fluctuating forces. The dynamic analysis of these elements is of critical importance for safe operation of these units.[2]

Laminated/composite plates are used in aerospace engineering application because of their many advantages over isotropic plates, for example, composites have higher strength-to-weight and stiffness-to-weight ratios. Maximization of these advantages can lead to better and more spacecraft that are economical design[3]

2. LITERATURE REVIEW

➢ **Avadesh K. Sharma and N.D. Mittal, 2010. Review on Stress and Vibration Analysis of Composite Plates. Journal of Applied Sciences, 10: 3156-3166.**

In this study, we have discussed the free vibration analysis of composite laminated plates. The first-order shear deformation theory (FSDT) has been employed widely to establish finite element models for free vibration analysis of the composite laminated plates. The effects of lamination and extension-bending coupling, shear and twistcurvature couplings on the lowest frequencies and corresponding mode shapes for free vibration of laminated anisotropic composite plates was investigated using a finite element method with quadratic interpolation functions and five engineering Degrees of Freedom (DOF). The free and forced vibration response of laminated composite folded plate structures was predicted by a nine-node Lagrangian platebending finite element with five engineering DOF per node that incorporated rotary inertia.

➢ **Aydogdu and Timarci (2003)**

Studied the vibration analysis of cross-ply laminated square plates subjected to different sets of boundary conditions. The analysis is based on a five-degree-of-freedom shear deformable plate theory. The requirement of the continuity conditions among the layers for the symmetric cross-ply laminated plates are fulfilled by the use of the shape functions incorporated into this theory which, also, unifies the two-dimensional shear deformable plate theories developed previously.[4]

➢ **Liu et al. (1999)**

The shape control and active vibration suppression of laminated composite plates with integrated piezoelectric sensors and actuators. The model is based on the classical laminated plate theory and the principle of virtual displacements. Four-node rectangular Nonconforming plate bending elements are used to model the laminated composite plate.

➢ **Wang et. al.(2002)**

Studied the free vibration analysis of skew fiberreinforced composite laminates based on first-order shear deformation plate theory. Numerical examples of isotropic and composite rectangular plates having different fiber orientations angles, thickness ratio and aspect ratio have been solved. Long list of references on free vibration analysis of laminated composite rectangular plate given

➢ **Timothy and Nayfeh (1996)**

Developed the analysis and numerical calculations for the exact free vibration characteristics of simply supported, rectangular, thick, multilayered composite plates and assumed that each layer of the composite plate is of arbitrary thickness, is perfectly bonded to adjacent layers, possesses up to orthotropic material symmetry and that its material crystallographic axes are oriented either parallel or perpendicular to the plate's boundaries .

➢ **Liz and Ricardo (2007)**

Study of the vibration of angle-ply symmetric laminated composite rectangular plates with edges elastically restrained against rotation and translation. Also, new numerical results are presented and some results are compared with existing values in the literature. The free vibration characteristics of laminated composite and sandwich plates

➢ **International Journal of Structural Stability and DynamicsVol. 18, No. 11, 1850144 (2018)**

The study deals with numerical and experimental investigations on the vibration behavior of fiber-metal-laminated (FML) plates, a new aircraft material. A finite element (FE)-based formulation is established for the plate using the first-order Reissner–Mindlin theory, including both fibers and metals of different material properties in alternate layers.

➢ **EV Prasad, SK Sahu - 2017 - dspace.nitrkl.ac.in**

In this study it is observed that very less amount of work is available on fiber metal laminated plates. So the present study deals with numerical and experimental vibration analysis of fiber metal laminated plates. The effects of different factors such as aspect ratio and boundary conditions on the natural frequencies of woven fiber metal laminated plates are presented.[5]

3.METHODOLOGY

1. **Preparation of the Sample:**
   - Fabricate laminated triangular plates with specified materials and layup sequence.
   - Prepare the specimens according to the required dimensions and tolerances.
2. **Instrumentation:**
   - Equip the test setup with accelerometers or other vibration sensors at key locations on the plate.

- Set up a suitable excitation system such as a shaker or impact hammer.

3. **Testing Procedure:**
- Conduct modal analysis tests to determine the natural frequencies and mode shapes.
- Apply excitation to the plate at predetermined points and measure the response with the sensors.
- Perform multiple tests to ensure consistency and reliability of the results.

4. **Data Acquisition and Analysis:**
- Use data acquisition systems to record the vibrational response of the plate.
- Analyze the data to identify natural frequencies and mode shapes.
- Validate the experimental setup with a reference structure if possible.

5. **Comparison with Numerical Results:**
- Compare experimental results with numerical predictions from FEM analysis to validate the accuracy of the experimental data.

6. **Modeling the Plate:**
- Create a 3D model of the laminated triangular plate using CAD software.
- Define the material properties, layup sequence, and boundary conditions for the model.

7. **Meshing:**
- Generate a suitable mesh for the triangular plate, ensuring adequate resolution for capturing the modes of interest.
- Refine the mesh around areas with high stress concentrations if necessary.

8. **Setting up the Analysis:**
- Apply boundary conditions such as fixed, simply supported, or free edges depending on the physical setup.
- Define the excitation parameters for the analysis.

9. **Solving the Model:**
- Use FEM software to solve the model and compute natural frequencies and mode shapes.
- Validate the model by comparing the results with known solutions or benchmark cases.

10. **Post-Processing:**
- Analyze the mode shapes and natural frequencies from the simulation.
- Generate visualizations of the mode shapes for better understanding of the plate's dynamic behavior.
- Validation and Comparison:
- Compare the FEM results with experimental data for validation and correlation.
- Adjust the model as needed to improve accuracy.

11. **Correlation and Validation:**
- Compare results from experimental tests and FEM analysis to validate the accuracy of the methods.
- Identify and resolve any discrepancies between the two approaches.

12. **Sensitivity Analysis:**
- Perform sensitivity analysis to understand the effects of different parameters (e.g., material properties, boundary conditions) on the vibrational response.

13. **Optimization:**
- Use the validated FEM model for design optimization, aiming to achieve desired vibrational characteristics such as natural frequencies and mode shapes.

4. PROCESS OF PROJECT

1. **Literature Review:**
- Research existing studies on vibration analysis of laminated triangular plates.
- Familiarize yourself with existing experimental and finite element methods used for such analyses.

2. **Material Selection and Plate Preparation:**
- Choose the appropriate materials for the laminated triangular plates based on the project's objectives.
- Fabricate the laminated triangular plates according to the chosen specifications.[8]

3. **Finite Element Model Setup:**
- Create a finite element model of the laminated triangular plate using appropriate software (e.g., ANSYS, COMSOL).
- Define the plate's geometry, material properties, boundary conditions, and any constraints.
- Choose an appropriate mesh size and type for accurate results.

4. **Experimental Setup:**
- Set up an experimental apparatus to measure vibrations in the laminated triangular plates.
- Use sensors (e.g., accelerometers) and data acquisition systems to record the plate's vibrational response.
- Ensure the experimental conditions match the model's boundary conditions for better correlation.

5. **Finite Element Analysis:**
- Run the finite element analysis on the model to obtain the plate's natural frequencies and mode shapes.
- Analyze the results and compare them with experimental data.
- **Experimental Testing:**
- Perform experimental tests on the laminated triangular plates.
- Excite the plates using techniques such as modal hammer testing or shaker tests.
- Record the vibrational response of the plates.[9]

6. **Data Analysis:**
- Compare the experimental results with the finite element analysis results.
- Analyze discrepancies between the two sets of data.

- Identify possible sources of error or differences, such as modeling assumptions or experimental setup.

7. **Optimization and Refinement:**

- Based on the comparison between experimental and finite element results, refine the finite element model as needed.
- Adjust the experimental setup to improve measurement accuracy, if necessary.

8. **Reporting and Documentation:**

- Prepare a detailed report documenting the project process, including the setup, methodology, results, and analysis.
- Include charts, graphs, and tables to present data clearly.
- Discuss the implications of the findings and potential areas for further research.

9. **Presentation:**

- Present your findings to relevant stakeholders or academic audiences, if required.
- Consider creating a poster or presentation slides to effectively communicate your work.
- These steps provide a general framework for the project; specific details may vary depending on the project's scope and objectives.

5. IMPLEMENTATION

Experimental Setup:

Fig:- Experimental Setup of FFT Analyzer

Fig:- Final Model

CONCLUSION

Agreement between Experimental and FEA Results: The comparison between the experimental data and FEA results showed good agreement in terms of natural frequencies and mode shapes. This validates the accuracy and reliability of the finite element model developed for the analysis of laminated triangular plates. Effect of Lamination and Material Properties: The study demonstrated that the lamination sequence and material properties have a significant impact on the vibration characteristics of the triangular plates. Variations in these parameters can lead to noticeable changes in the natural frequencies and mode shapes.[10]

Design Implications: The findings provide valuable insights for the design and optimization of laminated triangular plates in engineering applications. Understanding the influence of different parameters on vibration characteristics can help in developing more efficient and stable structural designs.

Methodology Contribution: This study contributes to the field of vibration analysis by providing a comprehensive approach that combines experimental and computational methods. This approach can be applied to other complex structural systems for accurate and reliable vibration analysis.

While the study achieved its objectives, there are some limitations that should be acknowledged. The complexity of the experimental setup and potential measurement errors may have influenced the results. Additionally, the finite element model could be further refined for more intricate lamination patterns.[11]

Future research in this area could focus on exploring the effects of different boundary conditions and loading scenarios on the vibration behavior of laminated triangular plates. Investigations into advanced materials and lamination techniques could also provide new insights and lead to innovative structural designs.

Overall, this study provides a solid foundation for further research in the vibration analysis of laminated triangular plates and supports the use of both experimental and finite element methods for accurate structural analysis.[13]

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