Review Paper on Vibration and Acoustic Analysis of Composite Plate

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ABSTRACT

Conventional materials such as steel, aluminium etc. are used in industries because of their high strength and stiffness. But composite materials have taken their places because they are giving excellent strength and stiffness with low weight. Currently, many industries such as automobile, aerospace, trains, buildings are using sandwich materials to reduce noise level. These sandwich materials consist of sheets of conventional materials which are bonded by polymers, plastics to reduce vibration and noise. In this study, vibration and acoustic analysis of laminated composite plate are carried out experimentally. Carbon fibre reinforced polymer and glass fibre reinforced polymer plates are used to study low frequency vibration and their effect of surrounding air medium. Combined modes shapes are formed because of resonance of natural frequencies of the structure and acoustic cavity. These combined mode shapes generally occur in low frequency region and possesses both high-order displacement and high-order pressure amplitude. The effect of number of plies and ply angle are investigated on the natural frequency and the pressure amplitude. The finite element simulation model is developed to validate the results obtained from experiment.

Keywords: Acoustic analysis, ANSYS, composite plate, FEM, sound waves, vibration analysis

I. INTRODUCTION

This study aims to develop a finite element formulation for structural acoustic analysis for laminated composite plates surrounded by air medium. Carbon fibre reinforced polymer (CFRP) and Glass fibre reinforced polymer (GFRP) plate with various fibre orientations are used for this study.

- Mathematical model is developed based on first order deformation theory for laminated composite structures
- Investigate vibration behaviour of CFRP and GFRP plates experimentally.
- Study the various properties of sound waves generated by plate vibration.
- Study the effect of various fibre orientations on vibration and acoustic parameters.
- Validate these results with finite element software package ANSYS.

II. STRUCTURAL ACOUSTIC ANALYSIS

There are several finite element formulations to solve structural acoustics and fluid structural interactions. The acoustic fluid can be modelled by finite element formulations based on fluid pressure, displacement, displacement potential and velocity potential, each of them has advantages in different situations. Everstine

(1997) developed the finite element formulations for fluid domain based on pressure and displacement, radiation and scattering from elastic structures, fluid structure eigenvalue problem for added mass and interior fluid problems. Sandberg and Göransson (1988) proposed the symmetric finite element formulation for coupled acoustic vibration in which pressure and displacement potential used to define the fluid. Olson and Bathe (1985) proposed model for the symmetric finite element analysis of fluid-structure interaction problem using pressure and velocity potential as degrees of freedom in the fluid region and displacement in the solid region.

For external problems, it is must take into account unbounded fluid domain, otherwise due to a reflection of propagating acoustic waves frequency response of the system will differ considerably. In the analysis done by Vogel and Grandhi (2012) when the thickness of structure was changed from 1mm to 10mm, pressure was reduced by nearly 20dB. This thickness change also affects the frequency at which maximum pressure is observed. Ding and Chen (2001) carried out coupled acoustic analysis of elastic thin-walled cavity excited by both exterior structural loading and interior acoustic sources using the symmetric finite element formulation. Foin, Nicolas *et al*. (1999) proposed a new tool that describes the vibro-acoustics of baffled, simply supported, multi-layered plate in both light and heavy fluids. 2D extension of the Ungar's model was used for evaluating equation of motion of the plate. 11

Which found considerably accurate when compared to simplified discrete layer theory used for multi-layered plated. This method reduces the size of mass and stiffness matrix resulting in less computing time without decreasing in the precision of results.

III. STRUCTURAL ACOUSTIC ANALYSIS FOR LAMINATED COMPOSITE STRUCTURES

Thai and Choi (2013) investigated laminated composite plates using simple first order shear deformation theory which had only four unknown and had strong resemblance with classical plate theory. Yin, Gu *et al*. (2007) investigated acoustic radiation from laminated composite plate reinforced by doubly periodic parallel stiffeners. Anders, Rogers *et al*. (1992) proposed analytical modelling technique to find out modal and structural acoustic behaviour of locally activated SMA hybrid composite panel using Ritz method, classical laminated plate theory, and finite panel acoustic radiation theory. Chandra, Raja *et al*. (2014) presented analytical solutions for determining transmission loss and vibro-acoustic response of FGM plate using simple FSDT. Nilsson (1990) determined the loss factors at different frequency ranges for a sandwich plate. Hufenbach, Kroll *et al*. (2001) studied vibro-acoustic characteristics of laminates composites by performing numerical solution using FEM and BEM. Assaf, Guerich *et al*. (2010) proposed finite element modelling to analyse vibro-acoustic response of sandwich plate under constrained layer damping treatment.

IV. RESEARCH METHODOLOGY

In the present investigation, natural frequencies of rectangular laminated composite plates for various ply angles are studied by means of experiments. These vibrations generate acoustic waves in surrounding medium. To study the acoustic behaviour of plates, pressure variations are measured at specified location. The results obtained by the experiments are compared with the finite element package (ANSYS).

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V. EXPERIMENTAL SETUP

The experimental setup will consists of the plate clamped in one end of the frame forming cantilever position. The accelerometer is attached at the free end to measure acceleration. The Microphone is held at a distance of approximately 1cm above the plate. It will give pressure variation at that point in Pascal. Experimental data was collected by tapping the centre of the plate with an impact hammer. Dimensions of plates were 180mm×150mm and thicknesses of the plate were 1.5mm or 3mm depending on number of plies. NI cDAQ-9178 instrument will be used to collect data from microphone, accelerometer and impact hammer. This data was processed for further study using LabVIEW software.

VI. FINITE ELEMENT SIMULATION MODEL

Vibration and acoustic analysis of composite plate was carried out in finite element simulation. Simulation model consist of structure domain, fluid domain and fluid-structure interface. Structure domain was modelled using SHELL181 element while fluid domain is modelled using FLUID29. Fluid-structure interface was specified on common nodes for structure and fluid domain.

VII. RESULTS TO BE OBTAINED

7.1 Convergence Study for Natural Frequency Parameter

The convergence of presently developed model is carried out for various laminated plates. Structural and acoustic domains are modelled in finite element simulation ANSYS.

7.2 Comparison Study of Natural Frequency Obtained From Experiments and Finite Element Simulation

Natural frequencies of CFRP and GFRP plates obtained from the experiment are compared with frequencies computed from finite element simulation, ANSYS.

7.3 Comparison of Pressure Wave Obtained From Experiment and Finite Element Simulation

The acoustic pressure was measured at a specially located point in air medium surrounding vibrating plate. The point was located around 1cm above the plate. Time interval set for analysis was 2 seconds. Coupled analysis was performed in ANSYS for same laminated composites and boundary conditions.

7.4 Comparison of Structural and Acoustic Frequencies of Cfrp (±45) At Low-Frequency Region

Vibration and acoustic output data obtained from the experiment were further processed for finding FFT curves for displacement and pressure.

VIII. EFFECT OF FIBER ORIENTATION ON THE FREQUENCY AND THE PRESSURE FOR LAMINATED PLATE

Vibration and acoustic analysis of laminated composite plate were done to study the effect of different ply angles and number of plies on the natural frequency of plate and pressure variations.

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