Vibro Acoustic Analysis of Laminated 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 givingexcellent 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 modeshapes 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 fromexperiment.
Keywords: Laminated composite plate, vibration analysis, acoustic analysis, sound waves, FEM, ANSYS.
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I. INTRODUCTION

Acoustics is the study of the sound waves including it generation, propagation, and effects. Acoustic or sound pressure is the difference between the average local pressure of medium and pressure within sound wave at same point and time. The sound is a travelling wave created by a vibrating object and propagated through a medium (gas, liquid, or solid) due to particle interactions. Thus, sound waves cannot travel through a vacuum. A sound wave propagates in the form of longitudinal waves comprising of successive compression and rarefaction of the elastic medium as shown in the Fig. 1 (courtesy: http://hyperphysics.phy-astr.gsu.edu). Sound pressure is nothing but pressure fluctuations about ambient atmospheric pressure. The entire acoustic spectrum can be divided into three sections: audio, ultrasonic, and infrasonic. In general, the range of acoustic wave is audible to human isin between 20 Hz to 20,000 Hz. The ultrasonic region consists high frequency waves i.e. greater than 20,000 Hz. Application of ultrasonic waves is in imaging technologies, sonography. Infrasonic has very frequency waves and theyare used to geological study like earthquakes. Structural Acoustics is the study of the interaction of vibrating structures with adjacent fluid along with the accompanying radiated or scattered sound. Nowadays Structural acoustics became an important field in almost every industry. Any structure which consist relative motion tends To vibrate from low frequency to high frequency. These vibrations produce pressure fluctuations in surrounding medium. In some cases, pressure fluctuations cause vibration in adjacent structures.

These fluctuations are nothing but acoustic waves. Structures typically plates, shells, membranes under transient or oscillatory loads are the common sound source. Vibration characteristics of structure can significantly change because of a presence of a fluid medium. These effects can adversely affect the dynamics of a system can be studied. Especially for coupled analysis of systems interaction between fluid and structure also called as FSI is of great concern. Noise can be defined as disagreeable or undesired sound. Many industries like transportation, construction are involved in a continuous effort to optimize noise and vibration characteristics.

The noise inside the vehicle compartment in mainly structural borne and it is low frequency generally less than 400 Hz. Internal sound field of the compartment is affected by the acoustic behavior of cavity, dynamics of surround structure and fluid-structure coupling. Resonant frequencies and acoustic mode shape primarily depend on the design of enclosed cavity.

Sound and vibration are generally controlled by active and passive methods. In the active vibration control method, piezoelectric materials are used as sensors and actuators in flexible structures. Whereas, in the passive control method different materials used such as barriers, absorption materials, damping materials and vibration isolation.Barriers and absorption materials are used to attenuate sound which is already propagating in medium while damping materials and vibration isolation used to reduce structural borne vibrations subsequently reducing noise. For effective noise control, we can use different combinations of above materials.

II. PREVIOUS WORK

Schmauder et al. [2023] investigated mechanical behavior of ZrO2/NiCr 80 20 compositions FGMs are analyzed and compared with experimental results. And also found that new parameter matricity controls the stress level of composite, globally and also locally. analyzed time dependent heat conduction in no homogeneous FGMs. Laplace transforms technique is used to solve initial boundary value problem. Results obtained for finite strip and hollow cylinder having exponential variation of material properties.

Shao et al. [2022] presented stress analysis of FG hollow circular cylinder in combined mechanical and thermal environment by considering linearly increasing temperature. Temperature dependent material properties are considered and solution for ordinary differential equations are solved by Laplace transforms technique.

Farhatnia et al. [2021] presented stress distribution for composite beam having FGM in middle layer. Temperature dependent material properties are considered for uniform temperature gradient. Presented nonlinear analysis of FGMs in thermal environment by changing material variation parameter,aspect ratio, and boundary condition re analyzed with higher order displacement model. Nonlinear simultaneous equation is obtained by Navier's method and equations are solved by Newton Raphson iterative method.

Abotula et al. [2019] studied stress field for curving cracksin FGMs for thermo-mechanical loading. Using strain energy density criterion effect of curvature parameters,temperature gradients on crack growth directions, non- homogeneity values are found and discussed. Studied parametric study of FGM plate by varying volume fraction distribution and boundary conditions. Static analysis of FGM plate has studied bysigmoid law and compared with literature.

Kruntcheva (2017) called these combined mode shapes as acoustic structural resonances and they possess both high order displacement and high order pressure amplitude. proposed the spectral formulation to evaluate radiated noise contributions of automotive body panels to interior sound pressure levels. He introduced a function called acoustic sensitivity which was the base of model.

Ding and Chen (2016) put theoretical algorithm to compute interior noise contributed from a local structural panel of an elastic thin-walled cavity. This approach can be used to identify noise source in the vehicle compartment. It is suitable for low-frequency range but it is not suitable for investigation where the maximal dimension of a local panel is larger than the minimal acoustical wavelength of a frequency range.

Nefske, Wolf et al. (2015) did finite element formulation to compute acoustic modes and resonant frequencies of vehicle compartment. Identification of critical panels around the compartment and its noise level was done by forced vibration analysis.

Kim, Lee et al. (2012) used the practical method to reduce noise in the vehicle passenger compartment. This method uses interior pressure in terms of modal parameters and structural acoustic modal coupling coefficients of vehicle body and compartment.

Assaf and Guerich (2008) proposed the numerical prediction of noise transmission loss through sandwiched plate. Sandwiched plate made up of viscoelastic core sandwiched between two elastic faces and subjected to acoustic plane wave or diffuse sound field excitation. studied the sound transmission loss through viscoelastic sandwich panels into the rectangular enclosure.

Song, Hwang et al. (2003) investigated structural vibration control for coupled acoustic system using modal testing, finite element method, piezoelectric material and robust LQG controller. The paper used structural vibration control instead of fully structural acoustic coupling control. The robust LQG controller can reduce interior noise as well as structural vibrations.

Li and Zhao (2002) proposed the finite element formulation for modelling of the dynamic behavior of laminated plate incorporated with piezoelectric layers and viscoelastic layer based on FSDT. 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 et al. (2001) investigated acoustic radiation from

laminated composite plate reinforced by doubly periodic parallel stiffeners. proposed analytical modeling technique to find out modal and structural acoustic behavior 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.determined the loss factors at different frequency ranges for a sandwich plate. Studied vibro-acoustic characteristics of laminates composites by performing numerical solution using FEM and BEM. proposed finite element modeling to analyze vibro-acoustic response of sandwich plate under constrained layer damping treatment.

III. METHODOLOGY

The solution of a real life problem involving an arbitrary plate geometry and complicated loading and boundary conditions cannot be easily realized using analytical methods. A numerical analysis technique, especially finite element analysis method, is suited most to solve such problems. This chapter includes basics of acoustic waves, fundamental wave equation. Finite element formulation for uncoupled, coupled acoustic analysis investigated. Also simple first order shear deformation theory is studied for analysis of laminated composite plates. Used to approximate thedisplacement fields rotating shaft.

IV. CONCLUSIONS

Vibration and acoustic analysis of CFRP and GFRP plates were carried out experimentally. The effect of ply orientation and number of layers on coupled vibro-acoustic behaviour of plates has been analysed for various combinations. Results obtain from experiments were validated with ANSYS results and found to be in excellent agreement. In the present work, it is found that combined modes shapes are formed because of resonance of natural frequencies of the structure and acoustic cavity.

REFERENCES

Y.Miyamoto, W.A.Kaysser, B.H.Rabin,A.Kawasaki and R.G.Ford,P[2021] Functionally Graded Materials: Design, Processing and Applications, Kluwer Academic Publishers, London.

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ISSN: 2582-8150

Schmauder S. and Weber U.[2020] Modelling of functionally graded materials by numerical homogenization, Archive of Applied Mechanics, 71pp. 182-192.

Sladek J., Sladek V. and Zhang Ch.[2019] Transient Heat Conduction Analysis in Functionally Graded Materials by the Meshless Local Boundary Integral Equation Method, Computational Materials Science, 28 pp.494-504.

Shao Z.S. and Ma G.W.[2018] Thermo-mechanical Stresses in Functionally Graded Circular Hollow Cylinder with Linearly Increasing Boundary Temperature, Composite Structures, 83: pp. 259-265.

Farhatnia Fatemesh, Sharifi Gholam-Ali and Rasouli Saeid.[2017] Numerical and Analytical Approach of Theromechanical Stresses in FGM Beams, Proceedings of the World Congress on Engineering, 2: pp. 1-6.

Jyothula Suresh., Bathini Sidda., Bathini Eshwara Reddy C. and Kontakkagari VIjaya Kumar.[2015] Nonlinear Thermal Analysis of Functionally Graded Plated Using Higher Order Theory, Innovative Systems Design and Engineering, 2 pp. 1-14.

Sandberg, G. and P. Göransson (1988). "A symmetric finite element formulation for acoustic fluid-structure interaction analysis." Journal of sound and vibration 123(3): 507-

Chandra, N., Raja S., K.V. Nagendra Gopal (2014). "Vibro-acoustic response and sound transmission loss analysis of functionally graded plates." Journal of sound and vibration 333(22): 5786-5802.

Cook, R. D. (2007). Concepts and applications of finite element analysis, John Wiley & Sons.

Ding, W. and H. Chen (2001). "A symmetrical finite element model for structure–acoustic coupling analysis of an elastic, thin-walled cavity." Journal of sound and vibration 243(3): 547-559.

Ding, W. and H. Chen (2002). "Research on the interior noise contributed from a local panel's vibration of an elastic thin-walled cavity." Applied Acoustics 63(1): 95-102.

Everstine, G. (1997). "Finite element formulatons of structural acoustics problems." Computers & Structures 65(3): 307-321.

Everstine, G. C. (1981). "A symmetric potential formulation for fluid-structure interaction." Journal of sound and vibration 79(1): 157-160.

Foin O., Nicolas J., Atalla N. (1999). "An efficient tool for predicting the structural acoustic and vibration response of sandwich plates in light or heavy fluid." Applied Acoustics 57(3): 213-242.

Hosseini-Toudeshky H., Karimi M., Mohammadi B. (2011). "Acoustic Fatigue Crack Growth Prediction in Coupled Air Structures." Key Engineering Materials 452: 293-296.

Hufenbach W., Kroll L., Holste C., Täger O., and Barkanov E. (2001). "Design of dynamically loaded fiber-reinforced structures with account of their vibro-acoustic behavior." Mechanics of composite materials 37(2): 145-152.

Jacobsen, F. and J. Polack (2007). "An Elementary Introduction to Acoustics." Acoustic Technology, Technical University of Denmark, Orsted-DTU.

Kim S. H., Lee J. M., Sung M. H. (1999). "Structural-acoustic modal coupling analysis and application to noise reduction in a vehicle passenger compartment." Journal of sound and vibration 225(5): 989-999.