Quest Journals
Journal of Research in Mechanical Engineering
Volume 2 ~ Issue 3 (2014) pp: 12-17
ISSN(Online):2321-8185
www.questjournals.org

Research Paper

Non-Dimensional Fundamental Frequency of Cross and Angle ply laminated composite cylindrical panel

P. Jamuna Meera Bai
Senior Grade Lecturer, Department of Mechanical Engineering, Government School of Mines K G F, Karnataka, India.

Abstract
Spaceships, mechanical, chemical, aeronautical, and civic applications are just a few of the high performance engineering applications for laminated composites. For precise design and subsequent manufacturing, it became crucial to analyze these structures and their constituent parts using mathematical, experimental, or simulation-based models. Over the course of their useful lives, these structures withstand extreme weather, vibration, inertia excitation, and intense aural stimulation. The initial vibration/fundamental frequency mode is intrinsically linked to large amplitude, which leads to substantial stress and compression on the structural element, ultimately resulting in its wear. This emphasizes how important vibration analysis is for laminated constructions composed of composite and hybrid materials. We use code in the MATLAB environment to solve the equations and get the necessary results. Additionally, an ANSYS simulation model has been created and verified for every potential result, demonstrating the model's universal applicability. We have conducted a thorough examination of how vibration responses are affected by material properties, stacking order, thickness ratio, aspect ratio, modular ratio, and number of layers.
Keywords: *Fundamental Frequency, Composite Panel, FEM, ANSYS, Cross and Angle ply.*

I. Introduction

Nowadays, laminated composite shells are used for the structural elements of many contemporary cars, buildings, and historical and technical constructions. Compared to conventional materials like concrete, metal, and wood, laminated composites are much lighter. Excellent elastic qualities, exceptional corrosion resistance, great chemical resistance, and a low coefficient of thermal expansion are all attributes of composite materials. They are also very strong, particularly in relation to their weight or volume. The composites' adaptability for high-performance engineering applications is increased by their ability to modify their structural characteristics to satisfy particular needs. Since this immediately affects their cost and availability, mass production of composite structures is required to solve the present economic problems. These components must be examined using a mathematical and/or simulation-based model before design and manufacture can begin. Thin laminated composites with a panel-like form make up the outside skins of cars, spacecraft, and airplanes. As was previously indicated, aerodynamic heating from the operation of high-speed airplanes, rockets, and launch vehicles puts significant strain on the structural elements. The inherent frequencies, buckling, and deformations of these components are significantly influenced by this pressure. Because of its increased membrane stiffness relative to its bending stiffness, the shell panel can absorb a large amount of strain energy in its membrane without suffering from excessive deformations. if there is a method to transform the membrane's stored energy into bending energy, and the bulk of the strain energy in the shell is stored as membrane compression.

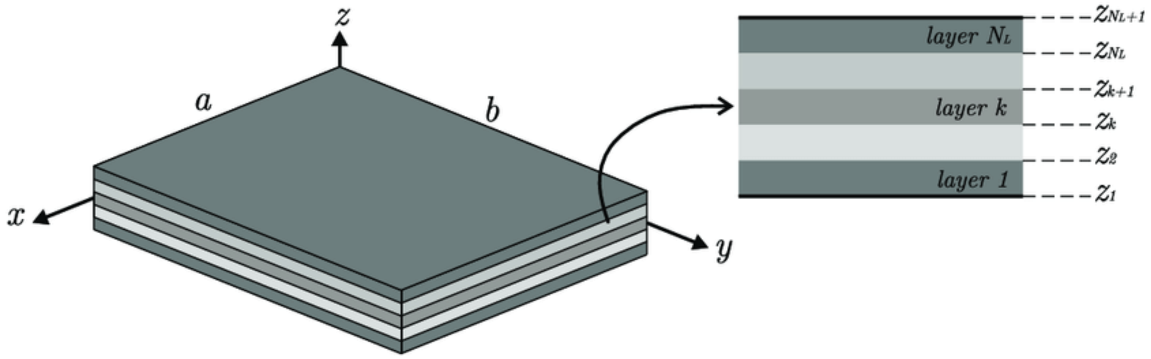

Figure 1: Laminated Composite Plate geometry and Stacking Sequency

Nowadays, laminated composite curved/flat panels have virtually taken the role of designed structural components because of their customized qualities. The remarkable energy absorption capacity of the panel designs is well recognized. Furthermore, the fundamental geometry of the panel is altered by the extra deformation brought on by the in-plane thermal/mechanical stress. As a result, the panel structure's stiffness characteristics are affected. Strong vibrations with a lot of amplitude cause stress and shorten life expectancy because they make people fatigued. It is well known that thin laminated structures are brittle, and that the structural geometry greatly influences how well they function overall under combined pressures.

It is essential to have a practical grasp of how laminated composite curved/flat panels react structurally to vibration. Because of the fascinating and difficult nature of these issues, modeling and analysis have become necessary for the usage of laminated composite structural elements. In order to precisely forecast the fundamental frequency characteristics, it is essential for designers to model these structures. The impacts of layered structural geometries, material properties, loading types, and their constraints are all clarified via parametric investigation. In order to highlight the current issue, this part will discuss earlier research done by different academics.

II. Literature Review

Using the existing literature, this part investigates the vibration properties of laminated structures. For academics who are anticipating and constructing structures utilizing new and existing concepts, the vibration behavior of laminated structures is a major challenge. Based on the higher order refined theory, Kant and Swaminathan [1] created an analytically solved mathematical model to investigate the free vibration behavior of sandwich and laminated composite plates. Matsunaga [2–3] uses power series expansion to solve the issues of stability and free vibration in laminated (angle- and cross-ply) composite plates. Using an improved plate theory, Putcha and Reddy [4] investigated the stability and vibration properties of laminated plates. The static and vibration properties of laminated composite shells are analyzed and solved using Navier's-type exact solution and the HSDT kinematic model developed by Reddy and Liu [5]. Using the FSDT, Ferreira et al. [6] investigated the buckling and vibration properties of laminated and isotropic plates. In the framework of the first-order shear deformation theory (FSDT) and the higher-order shear deformation theory (HSDT) kinematics, Bhar et al. [7] used the finite element method (FEM) to ascertain the structural responses of laminated composite stiffened plates. Mantari et al. [8] investigate the static and dynamic properties of laminated composite plates using a novel higher order shear deformation theory. The CLPT was used by Xiang and Kang [9] to analyze the free vibration properties of moving laminated composite plates. The natural vibration behavior of laminated composite shells is investigated by Xiang et al. [10] using a meshless global collocation approach within the context of the First-order Shear Deformation Theory (FSDT). The discrete shear gap approach, based on the midplane kinematics of the first-order shear deformation theory (FSDT), is used by Cui et al. [11] to address the bending and vibration behaviors of laminated composite plates. Using a meshless local collocation technique based on thin plate spline radial basis functions, Hatami et al. [12] investigated the vibration properties of laminated composite plates. Viola et al. [13] investigated the analysis of the free vibration of doubly-curved laminated shell panels using the Generalized Differential Quadrature (GDQ) approach in the HSDT kinematics. The free vibration responses of doubly-curved laminated composite shell panels were obtained by Tornabene et al. [14] using HSDT kinematics analysis. By developing a thorough and precise solution approach utilizing the FSDT, Jin et al. [15–16] investigated the vibration responses of many composite laminated structures, such as annular plates, cylindrical, conical, and spherical shells. Nguyen-Van et al. [17] used a mixed interpolation smoothing quadrilateral element within the context of the FSDT to investigate the buckling behavior of laminated plate/shell. Thai and Kim [18] used two variable refined plate theories to determine the free vibration responses of laminated composite plates. Using a finite element (FE) model based on the higher order zigzag theory (HOZT), Kumar et al. [19] were able to determine the structural reactions of sandwich shells and laminated composites. Dozio [20] used the Ritz approach to determine the free vibration responses of rectangular composite plates that were single-layer and symmetrically laminated.

III. Methodology : Finite Element Method And ANSYS

In today's world, the finite element method (FEM) is extensively used and considered to be the most reliable tool for designing any building. This is mostly owing to the fact that it is more accurate than other analytical or numerical techniques. The ability to predict the reactions of a wide variety of commodities, components, assemblies, and subassemblies is one of its first and most important functions. Because of its capacity to considerably cut down on the amount of time and money connected with physical testing, finite element modeling (FEM) is presently being used widely across all modern industries. In addition, it has the power to speed up and improve innovation while providing a higher level of accuracy. An extensive number of industries and analysts make use of ANSYS, which is a finite element analysis (FEA) tool that is extensively utilized and well recognized in the business.

There are a number of technical domains that make use of ANSYS at the present time, including the aircraft industry, the electronics industry, the transportation industry, the home appliance industry, and the power generation industry. ANSYS has expanded its reach into various industries, which has made it useful for applications like as fatigue analysis, nuclear power plant analysis, and medical analysis. Based on the thermal and/or mechanical stresses, it is possible to conduct thermal, mechanical, or thermo-mechanical analysis on a variety of structures according to their respective stresses. In addition, ANSYS is used widely in the fields of ion projection lithography, electrothermal analysis of superconductor switching components, and mechanical vibration analysis of an acoustic sounder for the purpose of detuning a high-frequency oscillator.

IV. Results And Discussions

It was proposed and explained in the previous debate that a finite element code reliant on the provided mathematical panel model is developed using ANSYS. Generated for the five degrees of freedom (DOFs) model is a free vibration study of laminated composite shell panels. This research was conducted. A comparison of the outcomes with those that are accessible in the literature is done as part of the inquiry on the validity and accuracy of the algorithm under current study. Furthermore generated in ANSYS by employing code created in ANSYS parametric design language (APDL) is a simulation model designed to cross verify the current mathematical model. Comparative analysis of the responses produced by MATLAB code and ANSYS (by means of the Block-Lanczos approach) and those that are accessible in the published literature helps to verify the developed model. Based on the validation and convergence research results, one can note that the current results show a great degree of agreement with the previously existing literature. Within the framework of this work, we explore the effect on the vibration responses of composite shell panels of many combinations of factors, like the thickness ratio (a/h), the lay-up scheme, and the support condition. The table below shows used material properties.

Table 1 Material properties of the laminated composite structures

M1:	E_1/E_2=25 v_{12}=v_{13}=0.25	G_{12}=G_{13}=0.5E_2 ρ=1	G_{23}=0.2E_2
M2:	E_1/E_2=open v_{12}=v_{13}=0.25	G_{12}=G_{13}=0.6E_2 ρ=1	G_{23}=0.5E_2

4.1 Free vibration analysis using ANSYS model

In addition to the examples shown above, a number of other novel cases of flat, spherical, and cylindrical panels have been solved by adjusting the geometrical parameters while making use of the same material qualities that were mentioned in the preceding section. The free vibration responses of an antisymmetric cross-ply (0/90)2 laminated cylindrical panel are analyzed for two distinct supports, SSSS and CCCC, and the results are reported in Figure 2. Additionally, for the purpose of computing, this study makes use of a number of additional geometrical factors, including four thickness ratios (a/h=10, 20, 50, and 100) and five curvature ratios (R/a=5, 10, 20, 50, and 100) of the cylindrical panel. It is interesting to see that the replies are following the same sorts of pattern as the examples that were shown before under the paragraph.

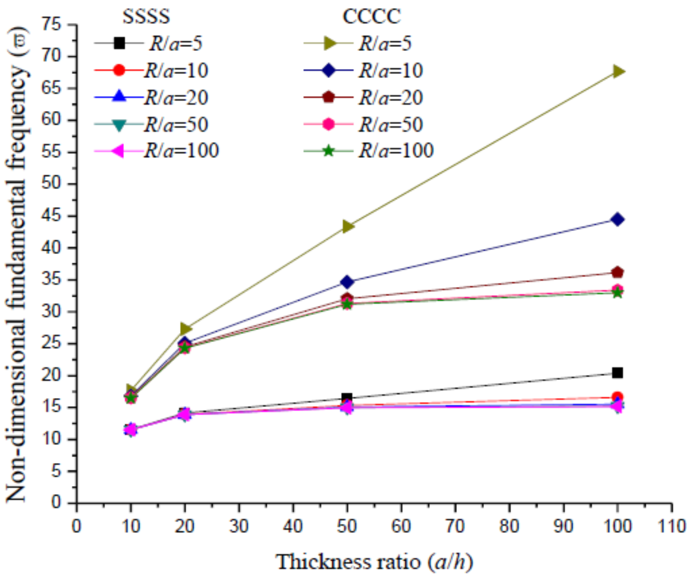

Figure 2 : Non-dimensional fundamental frequency of cross-ply $(0^0/90^0)_2$ laminated composite cylindrical panel

In this particular instance, the analysis of the fluctuation of non-dimensional fundamental frequency responses of the laminated composite angle-ply $(\pm 30)_2$ cylindrical panel is carried out by assuming the same material qualities, geometrical dimensions, and support circumstances. The plots of the non-dimensional fundamental frequency responses may be seen in Figure 3. A further intriguing observation is that the vibrational behavior of angle-ply laminated panels follows the same line as that of cross-ply laminates. This is something that should be taken into consideration.

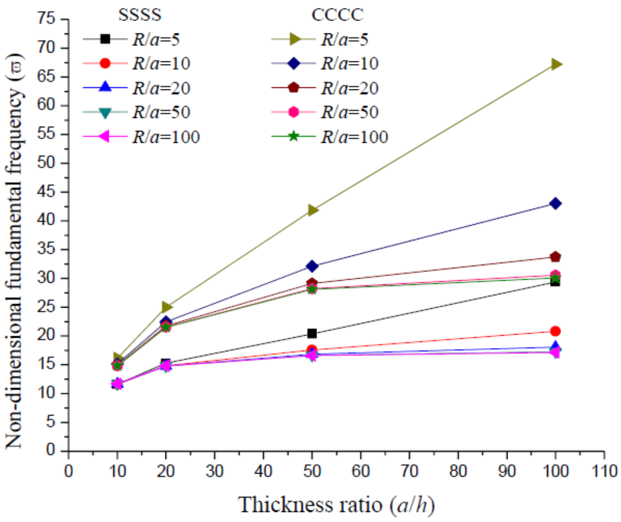

Figure 3 : Non-dimensional fundamental frequency of angle-ply $(\pm 30^0)_2$ laminated composite cylindrical Panel

A laminated composite spherical panel is analyzed for five various thickness ratios (a/h=5, 10, 20, 50, and 100), five aspect ratios (a/b=1, 2, 5, 10, and 15), and five curvature ratios (R/a=5, 10, 20, 50, and 100). In addition to the aforementioned, the panel is also analyzed for five distinct aspect ratios. The study was performed in ANSYS for laminated spherical panels with symmetric cross-ply (0/90) S and angle-ply (±45) S laminates. These panels were laminated using SSSS, CCCC, and CFFF. Figure 4 displays the non-dimensional fundamental frequency responses that were obtained from the experiment mentioned above.

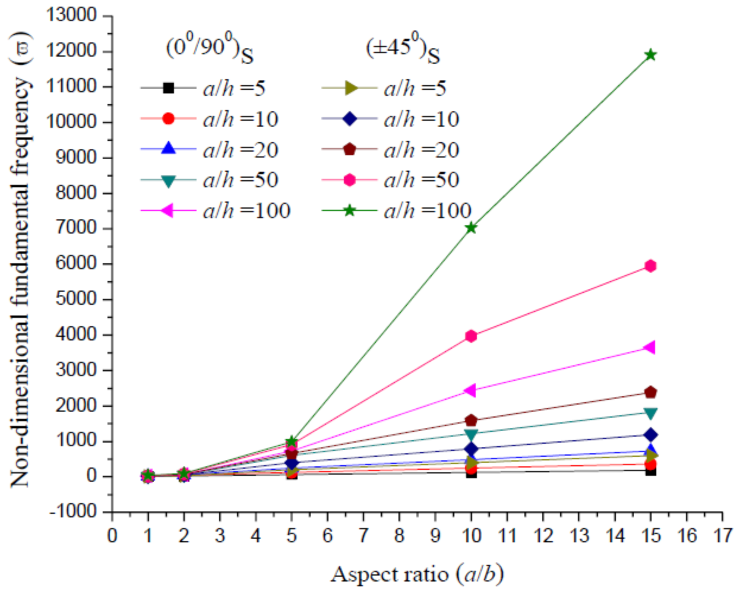

Figure 4 : Non-dimensional fundamental frequency responses of simply supported laminated composite spherical shell panel (*R*/*a*=10)

V. Conclusions

This component makes use of the general panel model that was developed in order to examine the free vibration characteristics of laminated composite panels. The free vibration of the panel is calculated by using the eigenvalue formulation and solving the issue with the help of the finite element method (FEM) code that is implemented in MATLAB and the APDL code that is used in ANSYS. Within the scope of this work, the fundamental frequency of a number of different geometries is investigated in relation to the impacts of thickness ratio, aspect ratio, modular ratio, stacking sequence, and different support conditions. It is possible to derive the following conclusions on the basis of the numerical data available.

While raising the curvature ratio produces a decrease in these responses, increasing the modular ratio and the aspect ratio both result in an increase in the non-dimensional fundamental frequency responses. This is in contrast to the drop that occurs when the curvature ratio is increased. A large amount of impact is exerted on the non-dimensional fundamental frequency by the modular ratio, the aspect ratio, and the support conditions. The lay-up arrangement has a significant impact on the dimensionless fundamental frequency, which results in a significant effect.

References

[1]. Viola, F. Tornabene, and N. Fantuzzi, "General higher order shear deformation theories for the free vibration analysis of completely doubly-curved laminated shells and panels," Compos. Struct., vol. 95, pp. 639–666, Jan. 2013.
[2]. F. Tornabene, E. Viola, and N. Fantuzzi, "General higher order equivalent single layer theory for free vibrations of doubly-curved laminated composite shells and panels," Compos. Struct., vol. 104, pp. 94–117, Oct. 2013.
[3]. G. Jin, T. Ye, X. Jia, and S. Gao, "A general Fourier solution for the vibration analysis of composite laminated structure elements of revolution with general elastic restraints," Compos. Struct., vol. 109, pp. 150–168, Mar. 2014.
[4]. G. Jin, T. Ye, Y. Chen, Z. Su, and Y. Yan, "An exact solution for the free vibration analysis of laminated composite cylindrical shells with general elastic boundary conditions," Compos. Struct., vol. 106, pp. 114–127, Dec. 2013.
[5]. T. Kant and K. Swaminathan, "Analytical solutions for free vibration of laminated composite and sandwich plates based on a higher order refined theory," Compos. Struct., vol. 53, pp. 73–85, 2001.
[6]. H. Matsunaga, "Free vibration and stability of angle-ply laminated composite and sandwich plates under thermal loading," Compos. Struct., vol. 77, no. 2, pp. 249–262, Jan. 2007.
[7]. H. Matsunaga, "Vibration of cross-ply laminated composite plates subjected to initial in-plane stresses," Thin-Walled Struct., vol. 40, no. 7–8, pp. 557–571, Jan. 2002.
[8]. N. S. Putcha and J. N. Reddy, "Stability and natural vibration analysis of laminated plates by using a mixed element based on a refined plate theory," Journal of Sound and Vibration, pp. 285-300, 1986.
[9]. J. N. Reddy and C. F. Liu, "A higher order shear deformation theory of laminated elastic shells," Int. J. of Eng. Sci., vol. 23, pp. 319–30, 1985.
[10]. A. J. M. Ferreira, C. M. C. Roque, A. M. A. Neves, R. M. N. Jorge, C. M. M. Soares, and K. M. Liew, "Buckling and vibration analysis of isotropic and laminated plates by radial basis functions," Compos. Part B Eng., vol. 42, no. 3, pp. 592–606, Apr. 2011.
[11]. A. Bhar, S. S. Phoenix, and S. K. Satsangi, "Finite element analysis of laminated composite stiffened plates using FSDT and HSDT: A comparative perspective," Compos. Struct., vol. 92, no. 2, pp. 312–321, Jan. 2010.
[12]. J. L. Mantari, A. S. Oktem, and C. Guedes Soares, "Static and dynamic analysis of laminated composite and sandwich plates and shells by using a new higher order shear deformation theory," Compos. Struct., vol. 94, no. 1, pp. 37–49, Dec. 2011.
[13]. S. Xiang and G. W. Kang, "Local thin plate spline collocation for free vibration analysis of laminated composite plates," European J. of Mecha. A/Solids, vol. 33, pp. 24-30, 2012.

[14]. S. Xiang, Z. Y. Bi, S. X. Jiang, Y. X. Jin and M. S. Yang, "Thin plate spline radial basis function for the free vibration analysis of laminated composite shells," Compo. Struct., vol. 93, pp. 611–615, 2011.
[15]. X. Y. Cui, G. R. Liu and G. Y. Li, "Bending and vibration responses of laminated composite plates using an edge-based smoothing technique," Engineering Analysis with Boundary Elements, vol. 35, pp. 818–826, 2011.
[16]. S. Hatami, M. Azahari and M. M. Sadatpour, "Free vibration of moving laminated composite plates," Compo. Struct., vol. 80, pp. 609-620, 2007.
[17]. H. Nguyen-Van, N. Mai-Duy, W. Karunasena, and T. Tran-Cong, "Buckling and vibration analysis of laminated composite plate/shell structures via a smoothed quadrilateral flat shell element with in-plane rotations," Comput. Struct., vol. 89, no. 7– 8, pp. 612–625, Apr. 2011.
[18]. H.-T. Thai and S.-E. Kim, "Free vibration of laminated composite plates using two variable refined plate theory," Int. J. Mech. Sci., vol. 52, no. 4, pp. 626–633, Apr. 2010.
[19]. A. Kumar, A. Chakrabarti, and P. Bhargava, "Finite element analysis of laminated composite and sandwich shells using higher order zigzag theory," Compos. Struct., vol. 106, pp. 270–281, Dec. 2013.
[20]. L. Dozio, "In-plane free vibrations of single-layer and symmetrically laminated rectangular composite plates," Compos. Struct., vol. 93, no. 7, pp. 1787–1800, Jun. 2011.