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An Effect of Number of Layers and Modular Ratios on the Vibration Behaviour of Laminated Composite Plate

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Abstract
A few examples of high-performance engineering applications for laminated composites include applications in the fields of aerospace, mechanical engineering, chemical engineering, aerospace engineering, and civic engineering. The use of mathematical, experimental, or simulation-based models to conduct an analysis of these structures and the components that comprise them became an essential step in the process of exact design and subsequent manufacture. These constructions are able to survive severe weather conditions, vibration, inertia excitation, and high auditory stimulation for the duration of their useful lifetimes. The first vibration/fundamental frequency mode is inextricably tied to a big amplitude, which causes the structural element to experience significant stress and compression, which eventually leads to the element's wear. Consequently, this highlights the significance of vibration analysis for laminated structures that are made up of composite and hybrid materials respectively. For the purpose of solving the equations and obtaining the required answers, we make use of code inside the MATLAB environment. Furthermore, an ANSYS simulation model has been developed and validated for each and every possible outcome, which demonstrates the model's capacity to be practically applicable in every situation. A comprehensive investigation of the ways in which vibration responses are influenced by the qualities of the material, the stacking order, the thickness ratio, the aspect ratio, the modular ratio, and the number of layers has been carried out inside our organization.
Keywords: *Number of Layers, Modular Ratio, Vibration, Composite Panel, FEM, MATLAB.*

I. Introduction

These days, laminated composite shells are used for the structural components of a wide variety of modern automobiles, buildings, as well as historical and technological projects. Conventional materials such as concrete, metal, and wood are much heavier than laminated composites, which are significantly lighter. The properties of composite materials include a low coefficient of thermal expansion, excellent chemical resistance, outstanding corrosion resistance, and excellent elastic capabilities. Composite materials also have a low coefficient of pressure. In addition to this, they are very robust, taking into account either their weight or their volume. The capability of the composites to vary their structural features in order to fulfill certain requirements contributes to the enhanced flexibility of the composites for high-performance engineering applications. In order to address the current economic issues, it is necessary to manufacture composite buildings in large quantities. This is because the cost and availability of these structures are instantly impacted. Before beginning the design and manufacturing process, it is necessary to conduct an analysis of these components by means of a mathematical and/or simulation-based model. For automobiles, spaceships, and aircraft, the outside skins are made of laminated composites that are very thin and have the shape of panels. It was said before that the structural components are subjected to a large amount of strain as a result of the aerodynamic heating that is caused by the operation of high-speed aircraft, rockets, and launch vehicles. This pressure has a large amount of effect on the intrinsic frequencies, buckling, and deformations of these components. As a result of the shell panel's higher membrane stiffness in comparison to its bending stiffness, it is able to absorb a significant amount of strain energy in its membrane without experiencing severe deformations. If there is a way to convert the energy that is stored in the membrane into bending energy, and the majority of the strain energy that is stored in the shell is stored as membrane compression, then the membrane would be able to bend.

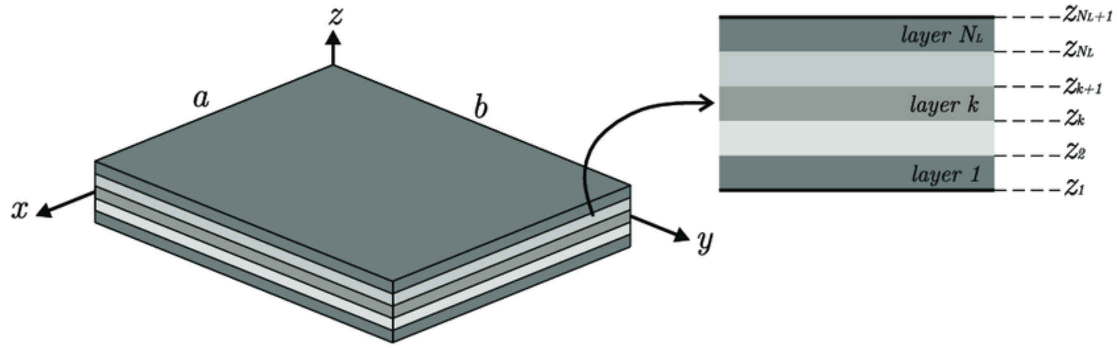

Figure 1: Laminated Composite Plate geometry and Stacking Sequency

As a result of the tailored properties that they possess, laminated composite curved/flat panels have almost assumed the function of planned structural components in today's world. There is widespread recognition of the amazing energy absorption capability of the panel designs at this point. In addition to this, the additional deformation that is brought about by the in-plane thermal and mechanical stress causes the basic geometry of the panel to be significantly changed. As a consequence of this, the stiffness properties of the panel structure are altered negatively. Strong vibrations that have a lot of amplitude lead individuals to get exhausted, which in turn causes stress and reduces the average lifespan of the population. It is well knowledge that thin laminated structures are brittle, and that the structural geometry has a significant impact on the degree to which they operate effectively when subjected to combined forces over their whole.In order to have a practical understanding of how laminated composite curved/flat panels respond structurally to vibration, it is essential to have this understanding. In order to make use of laminated composite structural components, modeling and analysis have become essential. This is due to the fact that these challenges are both exciting and challenging. When it comes to accurately predicting the fundamental frequency characteristics, it is very necessary for designers to model these structures. Through the use of parametric inquiry, the effects of layered structural geometries, material qualities, loading types, and the limitations that they impose are all elucidated. The purpose of this section is to bring attention to the present problem by discussing previous research that was conducted by a variety of academics.

II. Literature Review

Through the use of previously published research, this section analyzes the vibrational characteristics of laminated structures. When it comes to academics who are predicting and creating structures using new and current principles, the vibration behavior of laminated structures presents a significant difficulty. Kant and Swaminathan [1] developed a mathematical model that was analytically solved in order to explore the free vibration behavior of sandwich and laminated composite plates. This model was based on the higher order refined theory. The problems of stability and free vibration in laminated (angle- and cross-ply) composite plates are addressed by Matsunaga [2–3] via the use of power series expansion technologies. Putcha and Reddy [4] conducted research on the stability and vibration characteristics of laminated plates by using an enhanced plate theory. The static and vibration characteristics of laminated composite shells are examined and solved with the help of Navier's-type exact solution and the HSDT kinematic model that was developed by Reddy and Liu [5]. The buckling and vibration characteristics of laminated and isotropic plates were examined by Ferreira et al. [6] using the finite element method of discrete techniques. The finite element technique (FEM) was used by Bhar et al. [7] in order to determine the structural reactions of laminated composite stiffened plates. This was done within the context of the first-order shear deformation theory (FSDT) and the higher-order shear deformation theory (HSDT) kinematics. A unique higher order shear deformation theory is used by Mantari et al. [8] in order to examine the static and dynamic features of laminated composite plates. For the purpose of analyzing the free vibration parameters of moving laminated composite plates, Xiang and Kang [9] used the CLPT. Using a meshless global collocation technique within the framework of the First-order Shear Deformation Theory (FSDT), Xiang et al. [10] explore the natural vibration behavior of laminated composite shells. This is done in order to better understand the behavior of these shells. For the purpose of addressing the bending and vibration behaviors of laminated composite plates, Cui et al. [11] make use of the discrete shear gap technique. This approach is based on the midplane kinematics of the first-order shear deformation theory (FSDT). Hatami et al. [12] conducted an investigation into the vibration characteristics of laminated composite plates by using a meshless local collocation approach that was founded on thin plate spline radial basis functions. Using the Generalized Differential Quadrature (GDQ) technique in the HSDT kinematics, Viola et al. [13] conducted an investigation into the study of the free vibration of doubly-curved laminated shell panels. Through the use of

HSDT kinematics analysis, Tornabene et al. [14] were able to acquire the free vibration responses of doubly-curved laminated composite shell panels. The vibration responses of a wide variety of composite laminated structures, including annular plates, cylindrical, conical, and spherical shells, were explored by Jin et al. [15–16]. This was accomplished by devising a solution technique that was both comprehensive and exact, that made use of the FSDT. For the purpose of analyzing the buckling behavior of laminated plate/shell, Nguyen-Van et al. [17] used a mixed interpolation smoothing quadrilateral element inside the framework of the FSDT. For the purpose of determining the free vibration responses of laminated composite plates, Thai and Kim [18] used two different variable refined plate theories. The structural responses of sandwich shells and laminated composites were able to be determined by Kumar et al. [19] by the use of a finite element (FE) model that was based on the higher order zigzag theory (HOZT). For the purpose of determining the free vibration responses of rectangular composite plates that were single-layer and symmetrically laminated, Dozio [20] used the Ritz technique.

III. Methodology : Finite Element Method And ANSYS

In the modern world, the finite element technique, often known as FEM, is widely used and is regarded as the most trustworthy instrument for the design of any construction. This may largely be attributed to the fact that it is more accurate than other methods of analysis or numerical computation. In the first place, one of its most significant tasks is the capability of predicting the responses of a broad range of different commodities, components, assemblies, and subassemblies. At the current time, finite element modeling (FEM) is being used extensively across all contemporary industries. This is mostly due to the fact that it has the capability to significantly reduce the amount of time and money that is associated with physical testing. Furthermore, it has the capability to expedite and enhance the process of invention while simultaneously delivering a better degree of accuracy. A large number of businesses and analysts make use of ANSYS, which is a finite element analysis (FEA) tool that is widely used and well-known in the industry. ANSYS is a tool that is widely employed.ANSYS is now used in a variety of technical fields, such as the aviation business, the electronics industry, the transportation industry, the home appliance industry, and the power generation industry. These are only few of the technical domains that make use of ANSYS. As a result of ANSYS's expansion into a variety of sectors, the software has been valuable for applications such as fatigue analysis, analysis of nuclear power plants, and analysis of medical data. It is possible to perform thermal, mechanical, or thermo-mechanical analysis on a range of structures according to their various stresses. This analysis may be based on the thermal and/or mechanical stresses that are present throughout the structure. Additionally, ANSYS is used extensively in the disciplines 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. These applications are all associated with the process of detuning a high-frequency oscillator.

IV. Results And Discussions

During the previous discussion, it was suggested and described that ANSYS is used to generate a finite element code that is dependent on the mathematical panel model that was presented. An investigation of the free vibration of laminated composite shell panels was developed for the five degrees of freedom (DOFs) model. A study like this one was carried out. A comparison of the results with those that are available in the existing body of research is carried out as a component of the investigation into the validity and accuracy of the algorithm that is the subject of the present study. Additionally, a simulation model that is meant to cross validate the existing mathematical model is developed in ANSYS by applying code that was written in ANSYS parametric design language (APDL). In order to test the constructed model, it is helpful to do a comparative study of the answers that are generated by MATLAB code and ANSYS (using the Block-Lanczos technique) and those that are available in the published literature. One may make the observation, on the basis of the findings of the validation and convergence study, that the present findings demonstrate a high degree of concordance with the literature that was previously available. Within the context of this study, we investigate the impact that a wide variety of combinations of parameters, such as the thickness ratio (a/h), the lay-up scheme, and the support condition, have on the vibration responses of composite shell panels. The attributes of the material will be shown in the table below.

Table 1 Material properties of the laminated composite structures

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

4.1 Vibration analysis using ANSYS model

Figure 2 illustrates the free vibration responses of a cross-ply laminated composite flat panel with a thickness of $[0/90]_2$ for both S-S-S-S and C-C-C-C supports. Changing the thickness ratio (a/h=10, 20, 50, and 100) and the modular ratio (E1/E2=10, 20, 30, 40, and 50) allows for the generation of the answers.

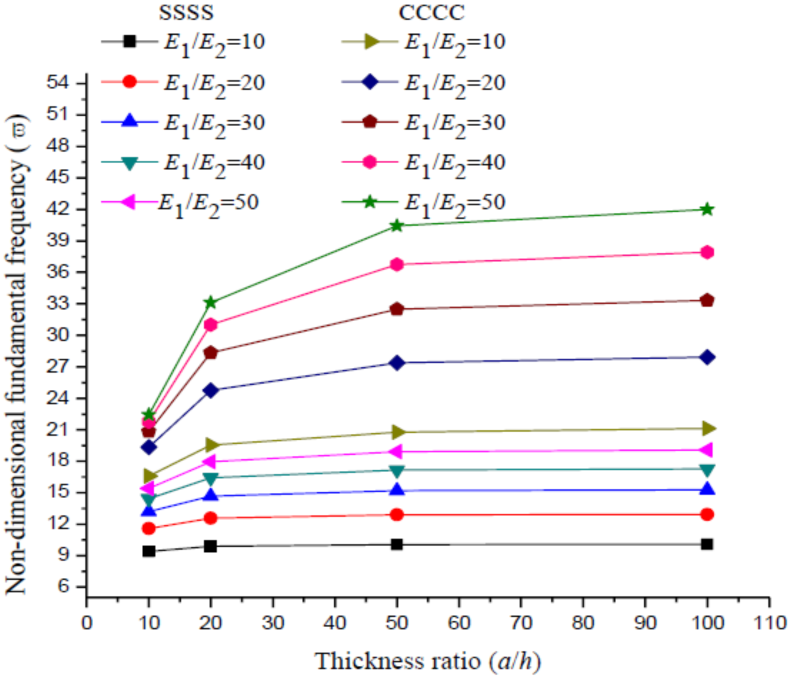

Figure 2 Non-dimensional fundamental frequency of cross-ply ($0^0/90^0$)2 laminated composite flat panel

The influence of the number of layers and support circumstances (C-C-C-C and C-S-C-S) on the vibration behavior is investigated in this current instances, and the results are provided in Figure 3 and Figure 4, respectively. Within the context of these numerical examples, the calculation is carried out by using the material property M2 in conjunction with six thickness ratios (a/h = 5, 10, 15, 20, 50, and 100), five modular ratios (E1/E2 = 10, 20, 30, 40, and 50), and a variety of lay-up schemes [$(0/90)_2$, $(0/90)_3$, $(0/90)_5$]. Due to the fact that the picture makes it abundantly evident that the nondimensional fundamental frequency grows as the thickness ratio and the modular ratio increase, this behavior is to be anticipated for any laminated construction. One thing that has been observed is that when the number of layers of the flat panel rises, the non-dimensional fundamental frequency of the flat panel likewise increases.

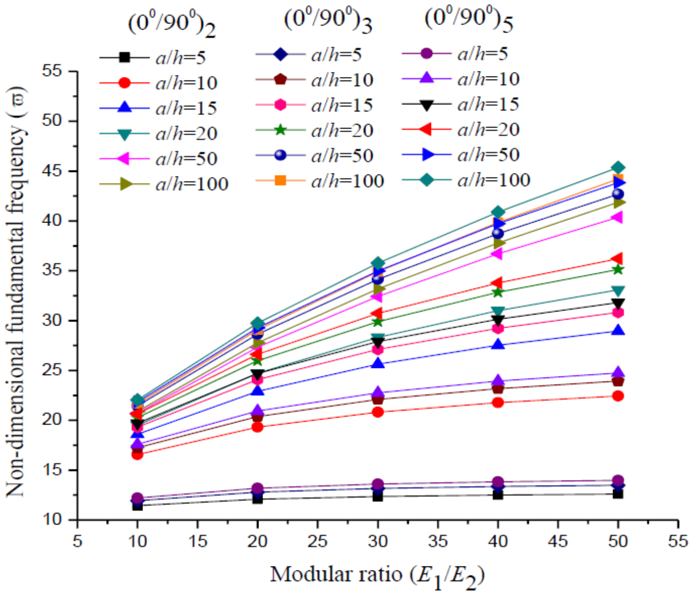

Figure 3 Non-dimensional fundamental frequency of clamped laminated composite flat panel

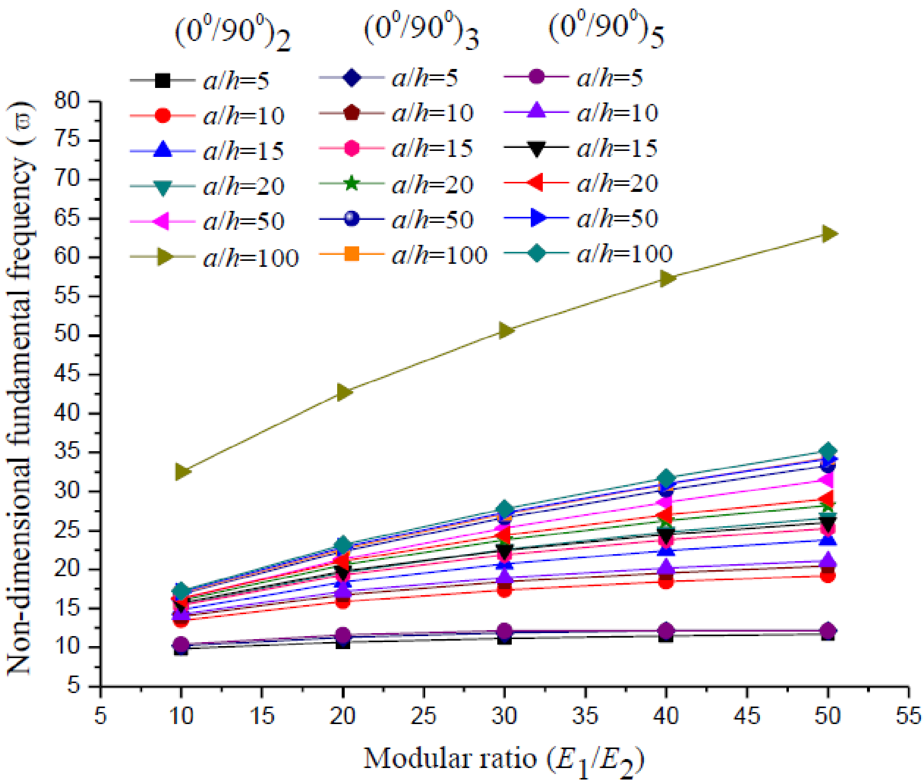

Figure 4 Non-dimensional fundamental frequency of C-S-C-S laminated composite flat panel

V. Conclusions

Specifically, this component takes use of the general panel model that was built in order to investigate the free vibration characteristics of laminated composite panels. For the purpose of calculating the free vibration of the panel, the eigenvalue formulation is used, and the problem is resolved with the assistance of the finite element method (FEM) code that is developed in MATLAB and the APDL code that is utilized in ANSYS. The fundamental frequency of a variety of different geometries is explored within the scope of this study in connection to the affects of thickness ratio, aspect ratio, modular ratio, stacking sequence, and various support conditions. This investigates the fundamental frequency of a number of distinct geometries. Based on the numerical data that is currently accessible, it is feasible to arrive at the findings that are summarized below.

An increase in 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 non-dimensional fundamental frequency responses, which are reduced when the curvature ratio is increased. Compared to the decline that takes place when the curvature ratio is raised, this is the opposite of what happens. The modular ratio, the aspect ratio, and the support conditions all have a significant influence on the non-dimensional fundamental frequency. This impact is significant enough to be considered significant. A considerable effect is produced as a consequence of the lay-up arrangement, which has a major influence on the dimensionless fundamental frequency.

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