# Study of the vibratory behavior of the laminate structure A4, under the effect of different parameters reinforcing

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**Abstract**— This study consists of the free vibratory behavior analysis of composite plates laminated; vibration in displacement of all structures rests primarily on the research of the frequencies and the clean modes, the main axis of this contribution is the enhancement and the discussion of the reinforcement fibers orientation, the effects various geometry of plate and the ratio orthotropic of the material on the oscillation frequencies. The application of the model paper size A4 that says we have taken into consideration in the simulation, meets the objective of our study and the results are then validated by available literature results.

Keywords— Structure; Plate; A4; Vibration; Frequency; Composite; Laminated

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## 1 INTRODUCTION

In recent advances, laminated plates made of composite materials have been using intensively in many engineering application such as aerospace, marine and civil infrastructure, etc., because they possess many favorable mechanical properties such as high stiffness to weight and low density. This is particularly meaningful in aerospace and submarine structures which require high stiffness and weight-saving [1].

The classical methods focus on thin plates and assume a straight line normal to an undeformed middle surface to remain straight and normal after middle surface deformation. But the neglect of transverse shear deformation and rotary inertia in thick plate analysis results in an overestimation of natural frequency and buckling load and underestimation of bending deflection. As the stiffness factor is greater than a certain value, the frequency parameter changes very slowly [5]. The effect of transverse shear deformation and rotary inertia was considered by Reissner [4] and Mindlin [3] in an effort to develop a more accurate thick plate model. In this first-order shear deformation theory (FSDT), it is assumed that a straight line originally normal to the middle surface remains straight.

Jiu and Chen [12] gave exact solutions for free vibration analysis of SSSS rectangular plates using Bessel functions, Misra [14] studied the free vibration analysis of isotropic plate using multiqudric radial basis function

Reddy [13] conducted a finite element code based on the theory of Yang-Norris-Stavsky and confirm to asymmetric laminates, he considered composite "cross-ply" and "angle-ply" of which two sides are simply supported and the other two sides are either simply supported or free, or fixed [15, 16].

## 2 METHOD OF CALCULUS

The composites materials are more difficult to model than an isotropic material such as iron or steel. We need to take special care in defining the properties and orientations of the various layers since each lay may have different orthotropic material proprieties. In this section, we will concentrate on the following aspects of building a composite model by choosing the proper element type.
Shell99 is an 8-node, 3-D shell element with six degrees of freedom at each node. It is designed to model thin to moderately thick plate and shell structures with a side-to-thickness ratio of roughly 10 or greater. The Shell99 element allows a total of 100 uniform- thickness layers (see Figure 1). Alternately, the element allows 50 layers with thickness that may vary bilinearly over the area of the layer. If more than 100 layers are required, you can input you own material matrix. The element also allows failure criterion calculation [2].

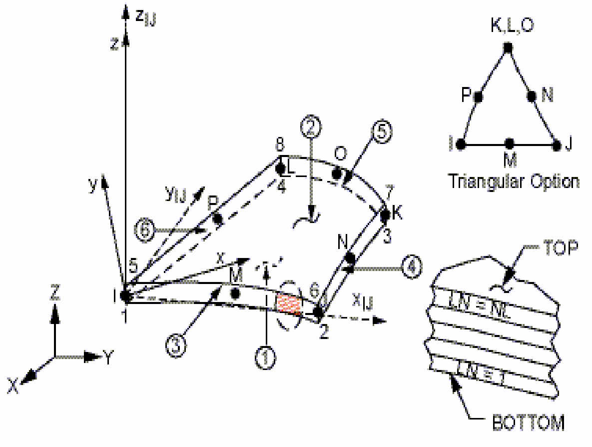

Fig. 1. Shell 99, 100-Layer Structural Shell [7].

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## 3 NUMERICAL EXAMPLES

Consider the model of a square orthotropic plate (length a, thickness h with four-layer laminate [0°/90°/90°/0°] ) with simply supported boundary conditions.
The material parameters are:
Young's modulus: $E_1$= 40 x 106 N/m2, $E_2 = E_3$ = 1x106 N/m², $G_{12} = G_{13}$ = 6 x 105 N/m², $G_{23}$ = 5 x 105 N/m², are the shear modulus in the 1–2, 2–3, 3–1 planes, respectively
Poisson's ratio $\upsilon$ = 0.25 and density $\rho$ = 1 mg/mm³, where subscripts 1 and 2 indicate-D, directions parallel and perpendicular to the fibers, respectively.
The laminated plate are assumed to be of the same thickness, mass density, and made of the same linearly elastic composite material. Due to symmetry, only the below left quadrant of the plate is modeled and uniform meshes 6 x 6 with N = 49 nodes per side and 36 elements (see Figure 2).
The elements of the grid are quadrilateral elements with 8 nodes. The number of elements was given in order to obtain enough precision in the results

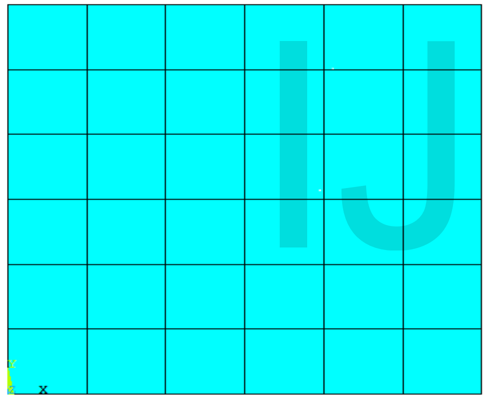

Fig. 2. Mesh of plate

## 4 RESULTS AND DISCUSSION

Results obtained of model Shell 99 is in table 1, for comparison, the normalized frequencies are defined

4. Results and Discussion

as: $\varpi = \omega a^2 \sqrt{\rho / E_2} / h$ (01)

The percentage differences, between the two methods with respect to the continuous case are estimated according to the following formula (02):

[% Difference = [(value of method 1- value of method 2)/ value of method 2] ×100 (02)

The normalized frequency is shown in Table 1 and the difference between the results of Ansys (shell 99) and FSDT [1] is in Table 2.
The geometrical ratios of the laminated plate are given as follows: ratios a/h = 10, 20, 25, 50, and 100, respectively.

The results of the present method is compared with the exact solutions using FSDT, the results show that are agrees well with the available results given in Chien H. Thai and all [1], Zhen and Wanji [6] and Wu and Chen [9].

TABLE 1
EFFECT OF THICKNESS-TO-LENGTH RATIO ON THE NON-DIMENSIONAL FREQUENCY PARAMETER OF A [0°/90°/90°/0°] SSSS.

| Methods | a/h | | | | |
|---|---|---|---|---|---|
| | 10 | 20 | 25 | 50 | 100 |
| Zhen [8] | 15,165 | 17,803 | 18,240 | 18,902 | 19,157 |
| Wu [9] | 15,069 | 17,636 | 18,055 | 18,670 | 18,835 |
| HSDT [1] | 15,070 | 17,662 | 18,087 | 18,718 | 18,882 |
| FSDT [1] | 15,130 | 17,643 | 18,055 | 18,658 | 18,820 |
| Present | 15,130 | 17,750 | 18,036 | 18,650 | 18,810 |

*Where: SSSS = simply supported on all four edges, ῶ frequency parameter*

The first four shapes modes of the left quadrant plate with a/h = 50 are plotted in Figures 3.

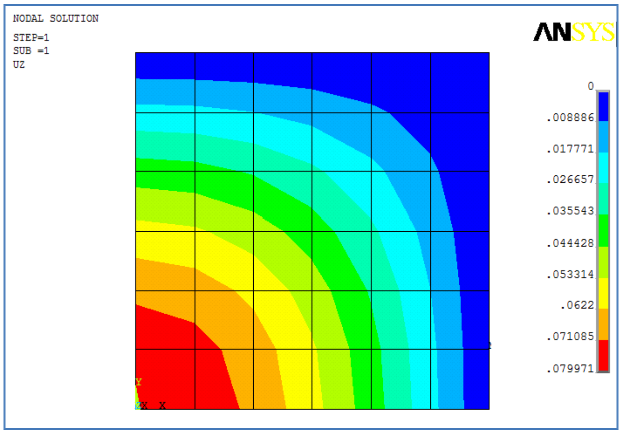

Fig. 3. 1. Mode shape 2 of a [0°/90°/90°/0°] SSSS laminated plate.

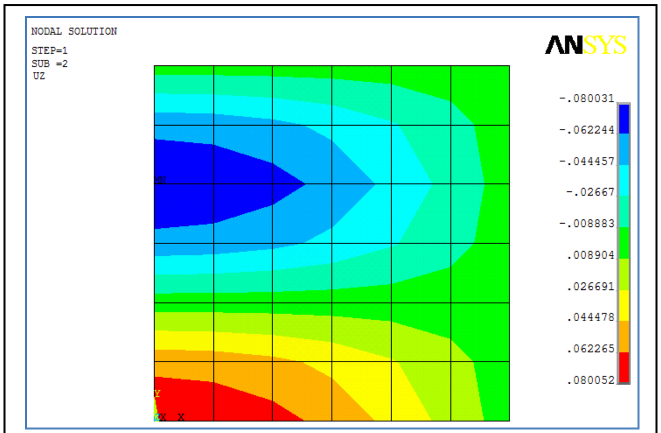

Fig. 3.2. Mode shape 2 of a [0°/90°/90°/0°] SSSS laminated plate.

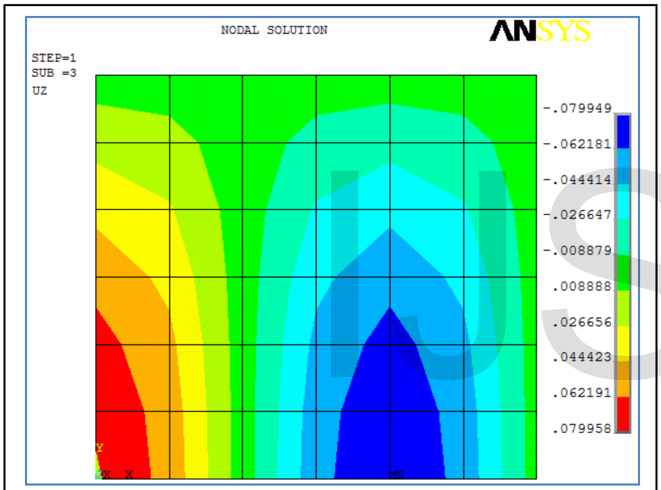

Fig. 3.3. Mode Shape 3.

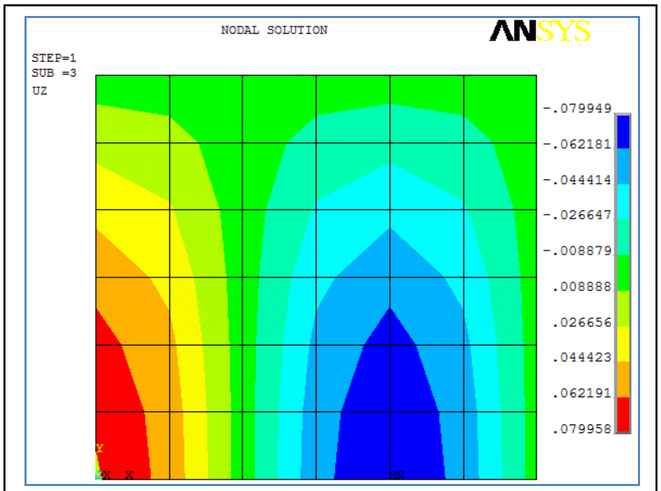

Fig. 3.4. Mode Shape 4.

In the Figure 4, we see that the ratio a/h increases the frequency slightly

TABLE 2

THE DIFFERENCE BETWEEN THE RESULTS OF ANSYS (SHELL 99) AND FSDT [1] OF PLATE OCCURS AS

| a/h | FSDT [1] | Present | %Difference |
|---|---|---|---|
| 10 | 15,130 | 15,130 | 0,00 |
| 20 | 17,640 | 17,750 | -0,62 |
| 25 | 18,055 | 18,036 | 0,11 |
| 50 | 18,658 | 18,650 | 0,04 |
| 100 | 18,820 | 18,810 | 0,05 |

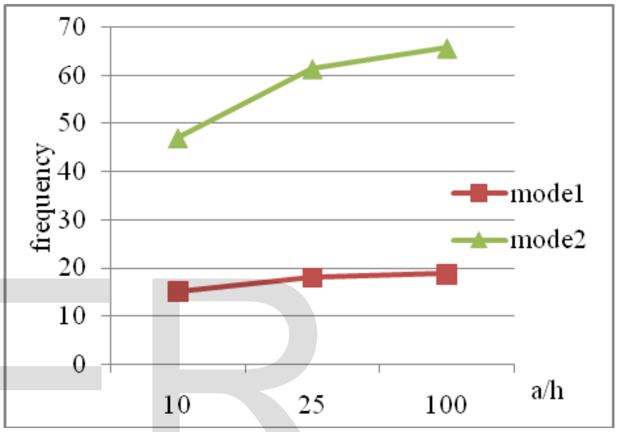

Fig.4. Relationship between frequency and a / h for mode 1 and 2.

Next we consider a six layer [0°/90°]3 simply supported plate, the reliability of result by ANSYS used shell 99 is also shown for the effect of various modulus ratios $E_1/E_2 = 10, 20, 30$ and 40. With the thickness to length ratio a/h = 5

Figure 5 represents a stacking of the layers of plate laminated simulated on the computation software of structures ANSYS.

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LAYER STACKING
ELEM    =   36
TYPE    =    1
REAL    =    1
LAYERS :
TOTAL   =    6
SHOWN  :
FROM  1 TO   6          Layer#                    Material#
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The first normalized frequencies $\varpi = \omega a^2 \sqrt{\rho/E_2}\,/h$ derived from the present method are listed in Table 3. The results of the present method is compared with results of Akavci [ 10 ] and Aydogdu [11].
It is clear that the present results exhibit high reliability to the all solution and are very stable in case of a wide range of $E_1/E_2$ ratio.

TABLE 3

EFFECT OF E1/E2 RATIO ON THE NON-DIMENSIONAL FREQUENCY PARAMETER OF A [0°/90°]3 SSSS LAMINATED PLATE.

| Methods | $E_1/E_2$ | | | |
|---|---|---|---|---|
| | 10 | 20 | 30 | 40 |
| Akavci [ 10 ] | 8,40 | 9,92 | 10,86 | 11,51 |
| Aydogdu [11] | 8,41 | 9,93 | 10,88 | 11,53 |
| Ansys | 8,34 | 9,93 | 10,89 | 11,54 |

## 5 APPLICATION

In this numerical example a rectangular plate laminate (figure 6), dimension paper sizes A4 (210 mm x297 mm), with tree-layer laminate [0°/90°/0°] and simply supported boundary conditions, the plate is modeled and uniform meshes 8 x 8
The material parameters are:
$E_1$=23,5 GPa, $E_2$=$E_3$=9,4 GPa, $G_{12}$=$G_{13}$=2,5 , $G_{23}$=1,8, Poisson's ratio $\upsilon_{12}$ = 0,.08, $\upsilon_{13}$ = 0,35, $\upsilon_{23}$ = 0,38
and ρ =1463 Kg/m3 (CUGNON and SCHORDERET, [17])

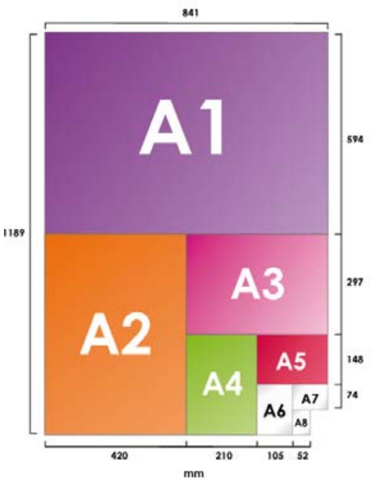

Fig. 6: paper sizes in the series A4, A5

THE FIRST FOUR SHAPES MODES OF THE LEFT QUADRANT PLATE'S SIZES IN THE SERIES A5 AND A4 ARE PLOTTED IN TABLE.4.

The resulting obtained is satisfied, we note that the frequencies of the plate A4 are almost double that of the A5 because the surface (a x b ) was doubled relatively of format.

TABLE 4

THE FIRST FOUR SHAPES MODES OF THE LEFT QUADRANT PLATE'S SIZES IN THE SERIES A5 AND A4

| Seize | Mode 1 | Mode 2 | Mode 3 | Mode 4 |
|---|---|---|---|---|
| A4 | 3,457 | 10,274 | 25,689 | 27,071 |
| A5 | 6,951 | 20,563 | 51,366 | 54,450 |

## 6 CONCLUSION

This work offers a contribution to the study of vibration of the laminated plates of composite materials having an elastic orthotropic mechanical behavior from the numerical approach. The simulation is made using software ANSYS, applying a procedure of calculation with the respect of the steps described by this software, the vibration analysis has been performed using finite element method.
For checking of the present analysis, has numerical example has been solved and compared with other published solutions; the principal findings which we can identify from the analysis of these results are as follows:
- The results of the finite element model are in good agreement with the results available in the literature.
- The resulting obtained is satisfied, we note that the frequencies of the plate A4 are almost double that of the A5 because

the surface (a x b ) was doubled relatively of format.

- Frequency parameter changes very slowly when the length-thickness ratio believes.
- The fundamental frequency of the laminated composite plates increases when the ratio of orthotropic increases.

Finally, this method of modeling for quick solutions opens new which occurred for the design of structural composites making it possible to determine the necessary frequencies.

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