VIBRATION OF CIRCULAR CYLINDRICAL SHELLS USING FINITE ELEMENT ANALYSIS

G. Tarakrishnamanohar, Research Scholar, UCEOU, Hyderabad, India
Dr. M. Chandrasekhar Reddy, Professor, UCEOU, Hyderabad, India

ABSTRACT

This work is aimed at free vibration analysis of cylindrical shell. Using the ANSYS Parametric Design Language (APDL), which is based on First-order Shear Deformation Theory (FSDT), the effect of various parametric ratios, such as the diameter of the cylinder to the thickness of the cylinder (D/t ratio) and the length of the cylinder to the diameter of the cylinder (L/D ratio), for cylindrical shells is studied for various boundary conditions, such as CC, CS, and CF (S - simply supported, C - Clamped, and F - Free). For the CC boundary conditions, the study has been compared using several materials with various characteristics, such as Young's modulus, Poisson's ratio, etc.

Keywords: Cylindrical shells, APDL, First-order Shear Deformation Theory, Vibration, Finite Element Analysis

I. Introduction

In many engineering domains, including pipelines, rockets, oil tanks, maritime structures, aerospace applications, railroads, and other uses, cylindrical shells are a crucial structural element. The examination of vibration features such as mode shape and natural frequency becomes a fascinating area of research whenever dynamic stresses are applied to cylindrical shells. Numerous academics have investigated vibration analysis of simple shells, such as conical, spherical, and cylindrical shells [1]. Among them, Gurve and Satankar [2] used the Finite Element Method (FEM) to investigate the curve shell's free vibration characteristics. Using APDL under various boundary conditions, the impact of the radius of curvature and the orientation of stiffeners with varying cross sections on natural frequency are investigated. Additionally, they looked at the impact of other factors with CCCC (C-clamped) boundary conditions, such as aspect ratio and thickness ratio. According to He et al. [3], a variational method is investigated to study the free and forced vibration of joined cylindrical-spherical shells subjected to classical boundary conditions. They developed the theoretical model using Donnell shell theory. Rawat et al [4] developed free Vibration Analysis of Thin Circular Cylindrical Shell with Closure Using Finite Element Method The vibration properties of a conical shell with a fixed support for the conical shell were explored by Bao and Liu [5]. They have utilized MATLAB to do a numerical calculation of the first nine modes using Donel shell theory. Then, an element model of a conical shell was constructed with the aid of the ANSYS Workbench simulation platform FEM, and convergence verification was carried out on ANSYS. The natural frequencies of short and long stiffened cylindrical shells exposed to clamped-clamped boundary conditions were studied by Stanley and Ganesan [6]. They employed semi-analytic FEMs for analysis, and the outcomes are contrasted with previous experimental and theoretical findings. Blevins [7] used direct calculation of natural frequency and mode shapes under various boundary conditions to study the free vibration behaviour of cylindrical curved panels. An upgraded dynamic stiffness approach was presented by Tian et al. [8] to investigate the forced and free vibration of combined conical-cylindrical shells under generic boundary conditions. Flügge shell theory is used to develop the motion equations of each shell component. The vibration properties of the concave thin-walled conical shell were investigated by He et al. [9]. In order to confirm the scaling rules, they also looked at the model test. This study examines the effects of different parametric ratios on the natural frequency of a cylindrical shell: "using APDL the codes were based on FSDT for different boundary conditions like CC, CS, and CF (S - simply supported, C - Clamped, and F - Free)". Examples of these ratios are the diameter of the cylinder to the thickness of the cylinder (D/t ratio), and the length of the cylinder to the diameter of the cylinder (L/D ratio)." For the CC boundary conditions, the study has been compared using several materials with various characteristics, such as Young's modulus, Poisson's ratio, etc.

II. Methodology

2.1 Modal Analysis of Cylindrical Shell

The model under investigation in this research was created using ANSYS 18.0, and the ANSYS workbench was used to perform the cylindrical shell's modal analysis. In this investigation, the effects of free vibration on natural frequencies are examined for various parametric ratios. Since continuous systems, such as curve shells and beams, have an infinite degree of freedom, partial differential equations are necessary to determine the results when these structures vibrate.

Transverse normal lines in the FSDT are inextensible and transverse normal rotate so that they do not remain perpendicular to the mid surface after deformation, meaning that straight lines perpendicular to the plate's mid surface remain straight before and after deformation" [1]. Throughout the thickness of the plates, there is a continuous transverse shear strain and stress.

$$\begin{aligned}\ddot{\emptyset}(u,v,w,t) &= x_0(u,,v,t) + w_u\\ \ddot{\emptyset}(u,v,w,t) &= y_0(u,,v,t) + w_v\\ \ddot{\emptyset}(u,v,w,t) &= z_0(u,,v,t) + w_w\end{aligned} \tag{1}$$

where x, y, and z are the displacement of any point on the layer of the plate a time t. u, v, and w are the coordinate axes of the material also x_0, y_0, z_0 are displacement point at the mid plane. φ_u ,φ_v are the rotation of normal to the mid surface about x and y material principal axes including thickness stretching term [1].The modal frequency of vibrating structure can be obtained by eigen value equation by solving Block Lancoz method.

$$([K]-[m^2])\delta) = \{0\}$$

where ω is the structure's natural frequency, [K] is stiffness, [m] is a mass matrix, and {δ} is the mode shape of the corresponding frequency. By using the Block-Lancoz approach to solve the Eigen Value Equation, the modal frequency of a vibrating structure may be determined. There is a possibility that elements will be lost if the model is imported into ANSYS from another modeling program. The model to be explored in this study is developed in ANSYS 18.0.

Since modelling a cylindrical shell is not a difficult effort and ANSYS can provide a basic modelling module. The model and mesh creation are depicted in Figures 1 and 2, respectively.

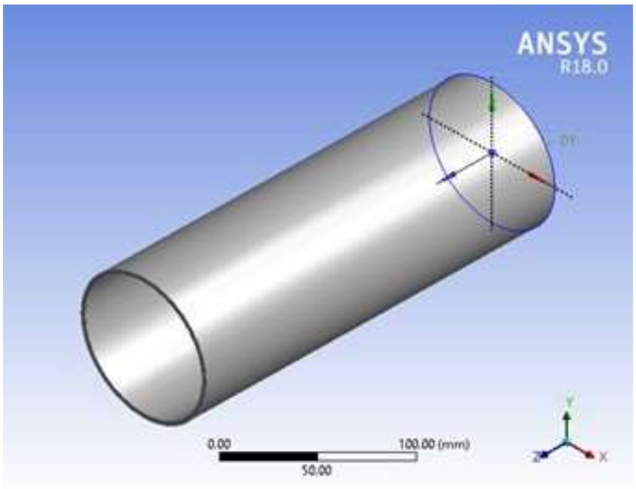

Fig.1.Modelling of Cylindrical Shell

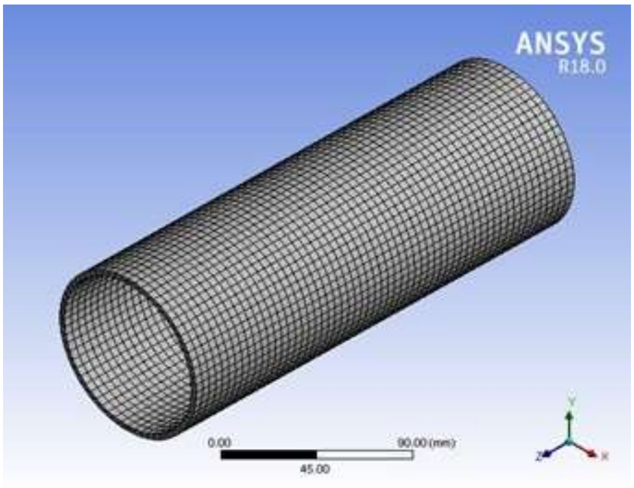

Fig.2 Mesh generation

2.2 Results and Discussions

2.2.1 D/t ratio's impact in cylindrical shell

The cylindrical shell is made of an aluminium alloy with material parameters of E = 71 GPa, ρ = 2699 kg/m3, and μ = 0.34. The length and thickness of the cylinder remain constant during the analysis, but the diameter changes to maintain the D/t ratio. Table 1 listed below represent the ratios of D/t and Diameters of cylindrical shell.

Table 1 Ratios of D/t and Diameters of cylindrical shell

D/t Ratio	Diameters (in mm)
30	90
35	105
40	120
45	135

Table 2 listed below represents the dimensions (mm) employed in the cylinder. Length L = 250 mm, thickness t = 3 mm

Table 2: The variation of Natural frequency (in Hz) w.r.t. D/t ratio for a cylindrical shell with different boundary conditions.

D/t Ratio	Mode No	CC	SC	CF
30	1	2335.4	1946.9	1139.4
	2	2336	1947.8	1141
	3	3260	3158.2	1169.8
	4	3262	3160.3	1169.8
	5	3970.5	3429.7	2489.5
35	1	2350.6	1942.8	916.19
	2	2350.8	1943.1	916.76
	3	2589.7	2440.8	1299.1
	4	2590	2441.1	1299.1
	5	3908.9	3583.4	2169
40	1	2223.1	1996.6	809.36
	2	2223.5	1996.7	809.55
	3	2398.3	2029.4	1408.5
	4	2398.3	2029.7	1408.5
	5	3356.7	3293.4	1668.2
45	1	2025.5	1796.4	768.56
	2	2025.9	1796.9	768.75
	3	2447.4	2064.3	1334.4
	4	2447.5	2063.4	1335.1
	5	2749.2	2664.1	1500.5

2.2.2 The effect of L/D ratio in cylindrical shell

Aluminum alloy is used in the cylindrical shell with material properties, E = 71 GPa, ρ = 2699 kg/m^3, μ = 0.34. Diameter and thickness of the cylinder (Figure 1) are fixed throughout the analysis, Whereas the lengths are variable to satisfy the L/D ratio. Dimensions (mm) used in the cylinder shown in Table.3.
D = 90 mm and thickness t = 3 mm

Table.3. Ratios of L/D and Length of cylindrical shell

L/D Ratio	Length (mm)
1	90
1.5	135
2	180
2.5	225

Table 4: The variation of Natural frequency (in Hz) w.r.t. the L/D ratio for a cylindrical shell with different boundary conditions

L/D	Mode No	CC	SC	CF
1	1	6543.7	5821	2848.9
	2	6545.1	5822.7	2849
	3	7643.9	6933.3	3405.4
	4	7644.7	6933.6	3409
	5	7666.2	7185.5	5163.2
1.5	1	4526.6	4097.3	1720.5
	2	4527.9	4098.9	1721.4
	3	4904	4250	3050.5
	4	4904.5	4250.3	3050.8
	5	6372.4	6186.1	3073
2	1	3485.9	2933.7	1331.4
	2	3486.2	2934.2	1332.7
	3	3726.2	3484.2	1996
	4	3728.5	3486	1996.1
	5	5744.1	5171	2992.5
2.5	1	2653.1	2208.6	1181.3
	2	2653.6	2209.3	1182.9
	3	3370.5	3233	1396
	4	3372.4	3235	1396
	5	4887.4	3930.3	2858.7

2.2.4. The effect of different materials

Aluminium alloy, structural steel, titanium alloy, and gray cast iron are employed in the cylindrical shell to examine their influence on natural frequencies in free vibration with CC boundary conditions at D/t = 30, L = 250 mm, and thickness t = 3 mm. The material properties are presented in Table 5.

Table 5: Properties of different materials

Materials	Young Modulus (E),GPa	Density(ρ),kg/m^3	Poisson’s ratio,(μ)
Aluminum alloy	71	2699	0.34
Structural steel	212	7800	0.3
Titanium Alloy	96	4620	0.36
Gray cast iron	83.33	7200	0.28

Table 6: Shows the natural frequencies for first the five modes for different materials with CC boundary condition.

Mode No.	Aluminum alloy	Structural steel	Titanium Alloy	Gray cast iron
1	2335.4	2326.7	2105.5	1801.5
2	2336	2327.4	2106.1	1802
3	3260	3221.2	2965.1	2481
4	3262	3223.2	2967	2482
5	3970.5	3985.9	3551.2	3101.2

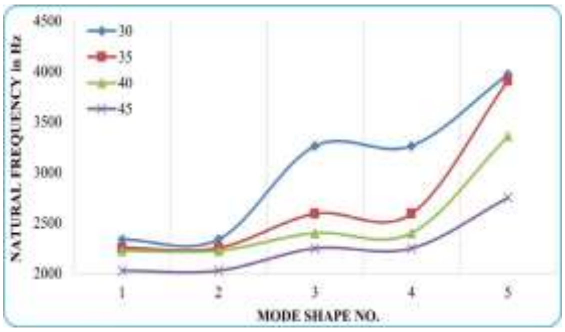

Fig.3: Variation of the frequency w.r.t. D/t ratio for a cylindrical shell with CC boundary condition.

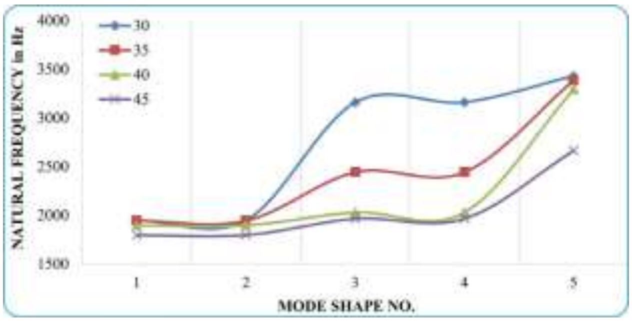

Fig.4: Variation of the frequency w.r.t. D/t ratio for a cylindrical shell with CS boundary condition

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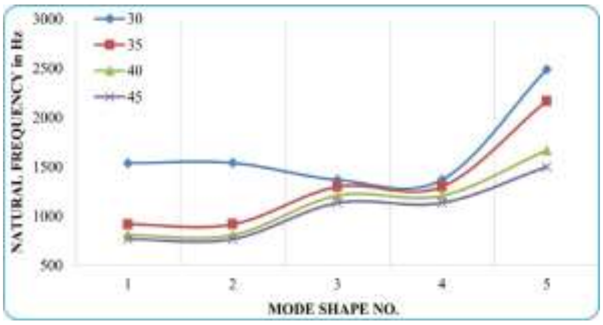


Fig. 5: Variation of the frequency w.r.t. D/t ratio for a cylindrical shell with CF boundary condition

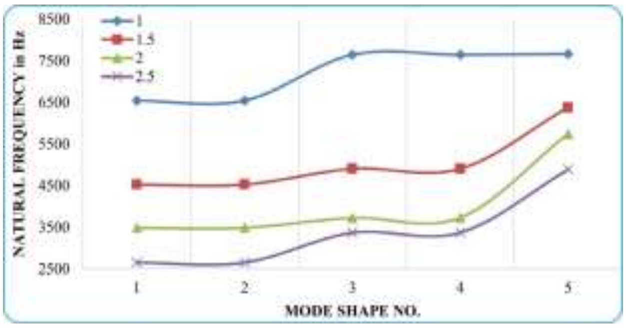
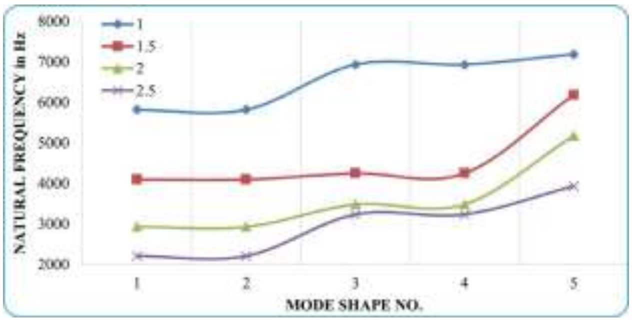


Fig 6: Variation of the frequency w.r.t. the L/D ratio for a cylindrical shell with CC boundary condition.



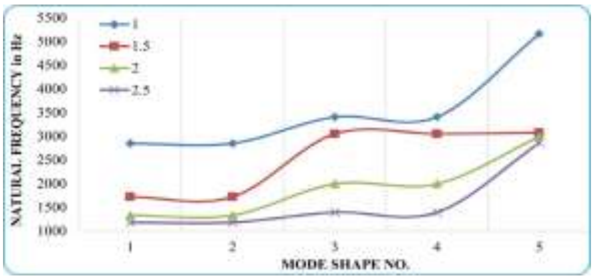


Figure 7: Variation of frequency w.r.t. the L/D ratio for a cylindrical shell with CS boundary condition.

Figure 8: Variation of frequency w.r.t. L/D ratio for a cylindrical shell with CF boundary condition

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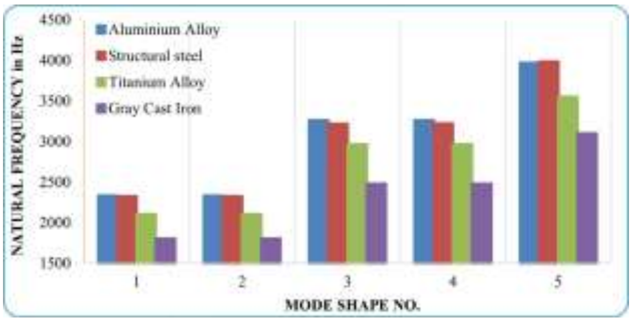

Figure 9: Graphical representation natural frequencies vs mode shape no. of different material with CC boundary condition.

III. Conclusion

In order to solve the problems of diminishing arable land and the rising demand for food brought on by an expanding global population, improved and more effective methods of crop production are required. Everyone should make it a priority to educate themselves on the importance of food security in relation to environmentally responsible agriculture. The proliferation of new technology that may boost agricultural yields and encourage inventive young people to take up farming as a respectable vocation are two positive outcomes of this trend. This article stressed the role that many of the technologies now employed in farming, notably IoT and AI, play in making agriculture smarter and more successful so that it can meet the demands of the future. Scholars and engineers might benefit from taking notice of the present issues confronted by the sector as well as the future potential. Because of this, every acre of farmland should be used to its full potential in order to maximize agricultural output. This may be accomplished by using environmentally friendly sensors and communication systems that are powered by artificial intelligence and the internet of things.

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