Modal analysis of an elliptical plate clamped along its boundary

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Abstract - ***The first four natural frequency parameters of a clamped elliptical plate have been obtained using ANSYS. The plate is considered to have uniform thickness. Modal analysis of the plate is carried out in ANSYS 14.0. Results are tabulated for different aspect ratios. It has been observed that the natural frequency parameter of the plate decreases as the aspect ratio increases. Mode shapes of the clamped elliptical plate are plotted for the aspect ratio of 0.5. The results obtained are in good agreement with those provided in the literature. Finite element method serves as a good means to solve simple to complex engineering problems, the near to accurate results of which can be obtained by ensuring a proper mesh of the component that depends on the type, size and the number of element.***

Key Words: *Elliptical plates, mode shapes, modal analysis, natural frequency, aspect ratio.*

1. INTRODUCTION

Knowledge of mode shapes and natural frequencies is required to design the structural components like plates, shells and beams that are often subjected to vibration. Vibration of plates has been the study of importance due to its wide engineering applications in aerospace, marine, and ship industries. Especially in aerospace and ship industries, the plates of various shapes do occur.

An extensive work on the vibration of plates can be seen in the well known monograph by Leissa[1]. Rough estimates of the first few frequencies for elliptical plates of uniform thickness are available in many research works. Mcnitt [4] studied the free vibrations of a clamped elliptical plate using an ordinary product solution and Galerkin method and computed the lowest fundamental natural frequency parameters of a clamped elliptical plate for different aspect ratios. Singh B and Chakraverty S [3] have found the frequencies of the first five modes of elliptical plates subjected to transverse vibration using orthogonal polynomials in the Rayleigh Ritz method.

Saleh M. Hassan [6] has obtained the first four frequency parameters of elliptical plates with variable thickness for different aspect ratios and for various non-uniform boundary conditions. Axi-symmetric vibrations of circular plates of linearly varying thickness have been studied in Prasad et al.[7] Lam et al.[14] have studied the free vibration of circular and elliptical plates using orthogonal polynomials and reported the first six natural frequencies and plotted the two dimensional mode shapes. Rajalingham et al. [11] have determined the vibrations of clamped elliptical plates using exact modes of circular plates as shape functions in Rayleigh Ritz method.

Analytical methods like Rayleigh-Ritz method, Galerkin method or orthogonal polynomials have been extensively used in many research works to obtain the natural frequencies of vibration of plates of various shapes with different boundary conditions but very little is available in the literature regarding the vibration analysis of elliptical plates using ANSYS.

The present work focuses on investigating the natural frequency parameters of the clamped elliptical plates for various aspect ratios using ANSYS. Although the above mentioned analytical methods yield good accuracy in their results, they are time consuming. CAE software packages like ANSYS, NASTRAN and ADINA etc can be used to get the results with good accuracy in less time. ANSYS 14.0 workbench is used in the present work. To increase the accuracy of the results, we need to decide the number, size and type of element as per the geometry and its applications. Comparison of the results obtained in ANSYS is made with those of Chakraverty [3], [10], Hassan [6], Mcnitt [4] and Narita [15].

2. OBJECTIVES OF THE PRESENT WORK

- To carry out modal analysis of an elliptical plate with its edge clamped.
- To determine the natural frequency parameters of the elliptical plate for different aspect ratios.

3. FINITE ELEMENT METHOD

Finite Element Method is a piecewise approximation method in which a continuous system is divided in to finite elements that are inter-connected by finite points namely nodes. Principal steps involved in FEA are listed below:

Pre-processing: In Pre-processor, the element type is selected followed by defining the material properties. After selecting the element type, geometry of the model is created and mesh of the model is generated.

Solution: In this processor, we can choose the type of analysis that is needed and its options. Boundary conditions are also specified in this phase and finally the solution is obtained.

Post-processing: Results are shown in the post-processor in the form of graphs, lists, nodal solution, element solution, DOF solution, deformed shape and contour lines etc.

3.1 MODELING

Dimensions of the elliptical plate are 60mm x 30mm for the aspect ratio of 0.5 where semi major axis is 60mm and semi-minor axis is 30mm. Thickness of the plate is 1mm. An elliptical plate with its semi major axis and semi minor axis ('a' and 'b' respectively) is shown in Figure 1.

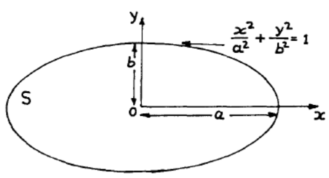

Fig -1: Geometry of an Elliptical Plate

3.2 MATERIAL PROPERTIES

Meshing of the elliptical plate is done in ANSYS Mechanical which resulted in 12280 nodes and 1701 elements.

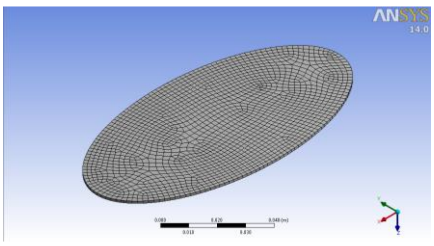

Fig -2: Meshing of elliptical plate

3.3 BOUNDARY CONDITIONS

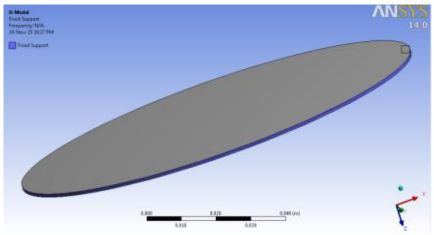

Fig -3: The edge of the elliptical plate is fixed

Natural frequency parameter of the plate, λ^2 is given by

$$\lambda^2 = \omega a^2\sqrt{\rho h/D}$$

where, $D= Eh^3/12(1- \nu^2)$,

h=thickness of the plate

a=semi major axis of the plate

b=semi minor axis of the plate

ω= natural frequency in rad/s

ν= Poisson's ratio of the material of plate

Modal analysis of a structure gives us the specific information on its vibration characteristics, the frequency at which it will absorb all the energy applied to it and the mode shape corresponding to this frequency.

The values of aspect ratio (b/a) taken into account in the present work are 0.2, 0.5, 0.8 and 1. Natural frequencies have been obtained for each aspect ratio. All the other parameters are considered to be constant.

4. RESULTS AND DISCUSSION

Results of the first four natural frequencies have been obtained for different values of aspect ratio. Poisson's ratio, ν has been taken as 0.3 for all the calculations in the present work.

Table 1-3 gives the comparison of our results for the first four natural frequency parameters of a clamped elliptical plate with those of Hassan [6] and Chakraverty [3] for aspect ratios 0.2, 0.5 and 0.8 respectively.

Table 4 gives the comparison of our results with those of Chakraverty [10] and Narita[15] for b/a=1 i.e., circular plate. Table 5 gives the comparison of our results of fundamental natural frequency parameters of a clamped elliptical plate for various values of a/b with those of Mcnitt[4].

Table -1: First four natural frequency parameters of a clamped elliptical plate for b/a=0.2

Mode	Chakraverty[3]	Hassan [6]	Present
1	149.66	149.6368	150.556
2	171.10	170.9924	171.603
3	198.55	195.9039	196.069
4	229.81	224.4718	224.043

Table -2: First four natural frequency parameters of a clamped elliptical plate for b/a=0.5

Mode	Chakraverty[3]	Hassan [6]	Present
1	27.377	27.377	27.446
2	39.497	39.4974	39.557
3	55.985	55.9757	55.996
4	69.858	69.8580	69.865

Table -3: First four natural frequency parameters of a clamped elliptical plate for b/a=0.8

Mode	Chakraverty[3]	Hassan [6]	Present
1	13.229	13.229	13.261
2	24.383	24.3826	24.423
3	30.322	30.3217	30.368
4	39.972	39.9709	40.002

Table -4: First four natural frequency parameters of a clamped elliptical plate for b/a=1

Mode	Narita [15]	Chakraverty[10]	Present
1	10.2144	10.216	10.238
2	21.2613	21.260	21.291
3	34.8808	34.878	34.905
4	39.7656	39.773	39.801

Table -5: Fundamental natural frequency parameters of a clamped elliptical plate

a/b	Mcnitt [4]	Present
1	10.217	10.238
1.5	17.025	17.172
2	27.746	27.447
3	58.693	56.927
5	158.85	150.556

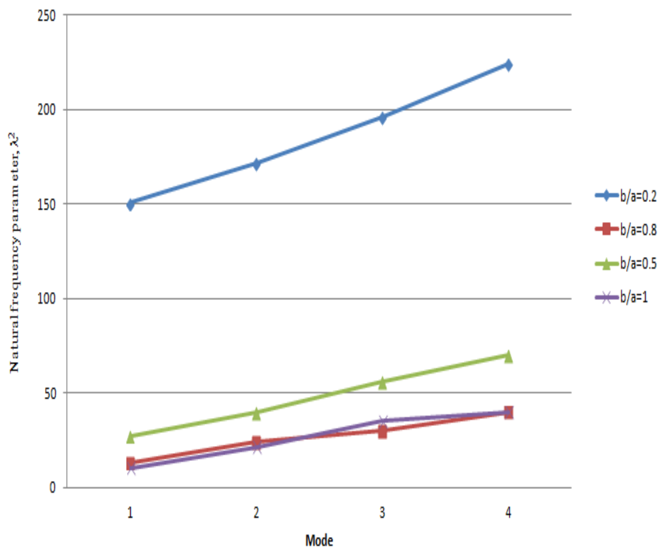

Fig -4: Natural frequency parameters for different aspect ratios

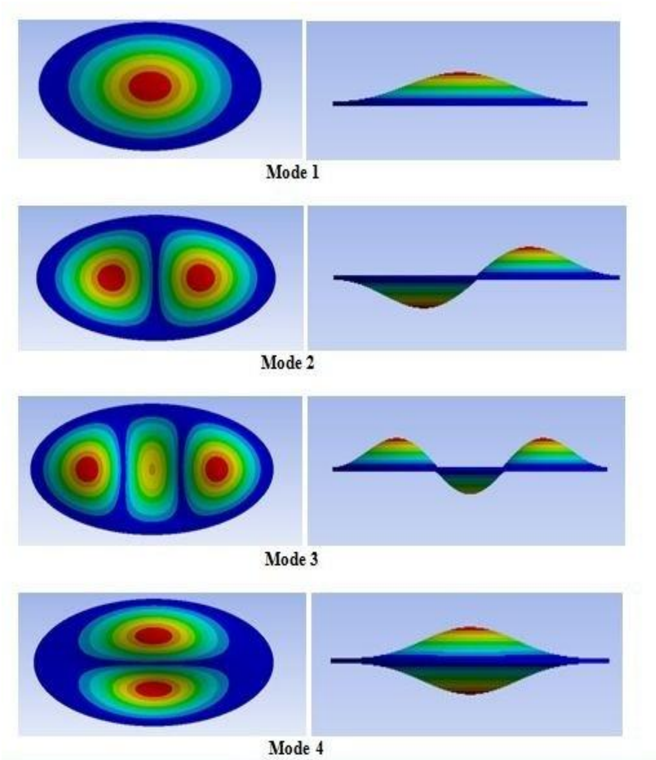

Fig -5: Mode shapes of a clamped elliptical plate for b/a=0.5

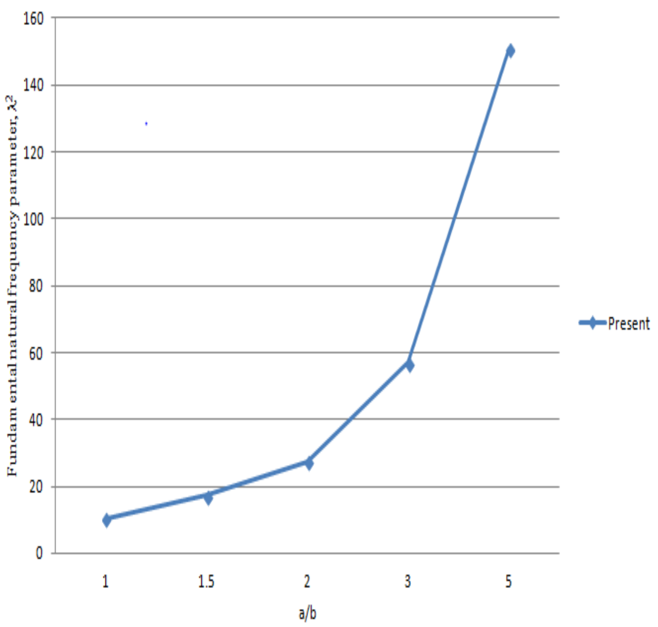

Fig -6: Fundamental natural frequency parameters for various values of a/b

5. CONCLUSIONS

Elliptical plates with uniform thickness have been investigated in ANSYS 14.0 and its first four natural frequency parameters have been determined.

It has been observed that the natural frequency decreases with the increase in aspect ratio of the elliptical plate. It has been found that the fundamental natural frequency of a clamped elliptical plate increases as the value of a/b increases. The special case of the elliptical plate for a=b i.e., the case of circular plate has also been covered in the present work. Finite element method can be employed for various engineering problems of vibration of structures.

REFERENCES

[1] Leissa AW. Vibration of plates. NASA SP -160, Washington, DC: US Government Printing Office: 1969.
[2] Singh B, Chakraverty S, On the use of orthogonal polynomials in the Rayleigh-Ritz method for the study of transverse vibration of elliptic plates. Computers and Structure 1992-43 (3); 439-44.
[3] Singh B, Chakraverty S, Use of characteristic orthogonal polynomials in two dimensions for transverse vibration of elliptic and circular plates with variable thickness. Journal of Sound and Vibration 1994: 173 (3): 289-99.
[4] McNitt RP, Free vibrations of a clamped elliptic plate. Journal of Aerospace Science 1962: 29:1124.
[5] Hassan Saleh M, Makary M. Transverse vibrations of elliptical plate of linearly varying thickness with half of the boundary clamped and the rest simply supported. International Journal of Mechanical Science 2003: 45 950: 873-90
[6] Hassan Saleh M. Free Transverse vibration of elliptical plates of variable thickness with half of the boundary clamped and the rest free. International Journal of Mechanical Sciences 2004; 46: 1861-1862.
[7] Prasad C, Jain RK, Soni SR, Axisymmetric vibrations of circular plates of linearly varying thickness. ZAMP 1972: 23: 941.
[8] Singh B, Chakraverty S, Transverse vibration of completely free elliptic and circular plates using orthogonal polynomials in the Rayleigh-Ritz method. International Journal of Mechanical Sciences 1991: 33(9): 741-51.
[9] Singh B. Chakravaerty S, Transverse vibration of simply supported elliptical and circular plates usng boundary characteristic orthogonal polynomials in two variables. Journal of Sound and Vibration 1992: 152 (1): 149-55.
[10] Chakraverty S, M. Petyt, Natural frequencies for free vibration of non homogeneous elliptic and circular

plates using two dimensional orthogonal polynomials. Applied Mathematical Modelling 07/1997: 21(7-21): 399-417.
[11] Rajalingham C, Bhat R.B and Xistris G.D, Vibration of clamped elliptic plates using exact modes of circular plates as shape functions in Rayleigh-Ritz method. Int.J. of Mech. Sci. Vol.36, pp. 231-246 (1994).
[12] Leissa AW, Recent studies in plate vibrations, 1981-1985. Part I: classical theory. Shock and Vibration Digest 1987; 19(2): 11-8
[13] Leissa AW, Recent studies in plate vibration, 1981-1985. Part-II: complicating effects. The Shock and Vibration Digest 1987: 19(3):10-24
[14] Lam K.Y, Liew K.M and Choe S.T. Use of two dimensional orthogonal polynomials for vibration analysis of circular and elliptical plates. Journals of Sound and Vibration. Vol. 154 (2), pp. 261-269 (1992).
[15] Narita Y,Leissa AW. Flexural vibrations of free circular plates elastically constrained along parts of the the edge. Internal Jourrnal of Solids and Structutres 1981: 17: 83-92
[16] Singh B, Hassa S.M, Transverse vibration of a circular plate with arbitrary thickness variation. International Journal of Mechanical Sciences. 1998: 40(11): 1089-104.
[17] Singh B, Tyagi DK, Transverse vibrations of an elliptic plate with variable thickness. Journal of Sound and Vibration 1985: 99(3): 379-91.
[18] Singh B, Chakraverty S. Boundary characteristic orthogonal polynomials in numerical approximation. Commun. Num. Methods. Engg. 1994: 10, 1027-1-43.
[19] Chakraverty S and Chakrabarti S. C. Deflection of circular plate using orthogonal polynomials. ISIAM Conference, University of Roorkee, India, 1993.
[20] Chakraverty S, An efficient method for finding deflection of circular and elliptic plates. J. Inst. Engrs (India) 1996, 77, 7-11.
[21] SHIBAOKA Y,: On the transverse vibration of an elliptic plate with clamped edge. J. Phys. Soc. Japan, vol. 11, no.7, 1956, pp. 797-803.

BIOGRAPHIES

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