Effect of hole size and plate thickness on natural frequency of isotropic annular Plate

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Abstract: *The aim of the present paper is to investigate the effect of hole size and plate thickness on the vibration frequencies of annular plate. The finite element software COMSOL (version 4.2) is used to obtain the natural frequencies of isotropic annular plate under clamped-clamped boundary condition. The effect of plate thickness and inner radii on different mode shapes are also reported.*

Keywords: Isotropic Material; Annular Plate; COMSOL multiphysics (version4.2); Three-dimensional (3D) Vibration Analysis

I .Introduction

Annular plates are extensively used as mechanical structures in manufacturing of missiles, aircraft, ships, automobiles etc. in order to minimize the weight of the whole structure. In general the natural frequencies and mode shapes of any circular plate is affected by the presence of the hole in it. Hence, the modal analysis study of the vibrational behaviour of circular plate with a hole is the great importance in engineering. Therefore, in this present paper the effects of the hole size and plate thickness on vibration modes of an isotropic annular plate is investigated. Also, modal analysis on a clamped-clamped (C-C) annular plate is carried out and find that the results are in good agreement with those obtained by numerical analysis.

II. Literature Survey

An annular element is derived by Kirkhope et al. [1], they applied finite element method to the free transverse vibration of circular and annular plates of varying thickness. Soni et al. [2] investigated free axisymmetric transverse vibrations of annular plates of linearly varying thickness on the basis of the classical theory of plates. C. F. Liu et al. [3] determined three dimensional vibrations of thick circular and annular plates by a finite element method. Further, vibration frequencies under different combinations of boundary conditions, wave numbers and finite element meshes are examined and some mode shapes are also shown graphically. Gupta et al. [4] investigated the effect of non-homogenity and thickness variation on natural frequencies of vibration for the first three modes of vibration. Experimental modal analysis on a clamped-free annular like plate using the finite element analysis code Nastran is investigated by Cheng et al. [5]. Wong et al. [6] investigated the sensitivity of changes in displacement mode shape of annular plates relative to the hole size by using mode subtraction method. The generalized differential quadrature method is applied to the free vibration analysis of solid circular plates by Wu et al. [7]. There work mainly deals with the free vibration of solid circular plates with radially variable thickness. Exact element method is used to solve the equations of motion using the first – order shear deformation theory by Efraim et al. [8]. Exact vibration frequencies and modes are also calculated for various combinations of boundary conditions.

ISSN: 2454-4248
186 – 191

III. Results and Discussion

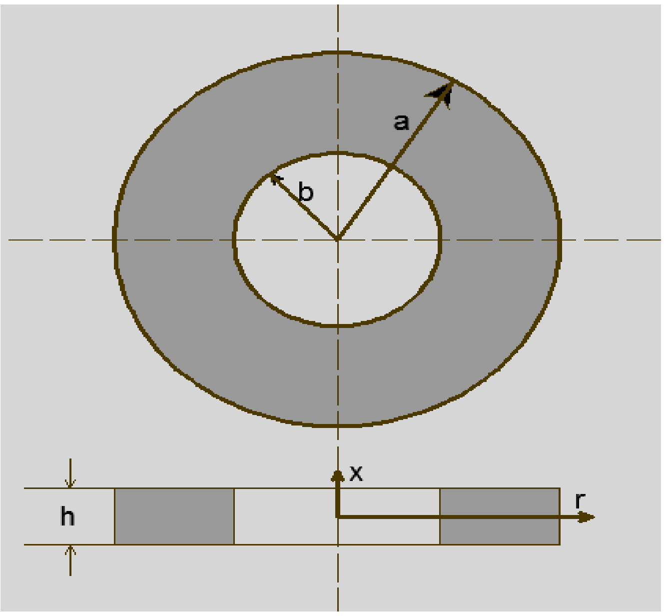


Figure 1: Isotropic annular plate

The geometry of isotropic annular plate is given in Figure 1. The material used is steel. The E, ν, ρ are representing Young's modulus, Poisson ratio, Mass density respectively. h is the thickness of the plate. b and a is the inner and outer radius of annular plate respectively.

A. Validation Study

Initially to validate the results, the modal analysis of Isotropic annular plate (inner radius (b) = 0.1 m, outer radius (a) = 0.6 m, E = 200 x 10^9 (N/m^2), ν = 0.3, ρ = 7.8 x 10^3 (kg/m^3) is presented. The results are obtained using three-dimensional finite element software COMSOL.

Table 1: Comparison of natural frequency (Hz) of an isotropic annular plate under clamped-clamped boundary condition.

h	Mode	COMSOL	Ref.[9]	% Diff
0.02	(1,0)	450	468	3.8
	(2,0)	533	552	3.4
0.06	(1,0)	1223	1260	2.9
	(2,0)	1449	1486	2.4

Table 1 shows the comparison of natural frequency (Hz) of an Isotropic annular plate under clamped-clamped boundary condition for modes (1,0) and (2,0) for different plate thickness. Here, the first digit represents number of nodal diameter and second term denotes the number of nodal circle. It may be seen from the Table 1 is that the results obtained by present work (COMSOL) are agree well with the results obtained by previous published work. Some of the mode shapes are also given in Figure 2.

The percentage difference is given by -

$$\% \text{ Diff.} = \frac{[(\text{Ref.})-(\text{COMSOL})]}{(\text{Ref.})} \text{ x } 100$$

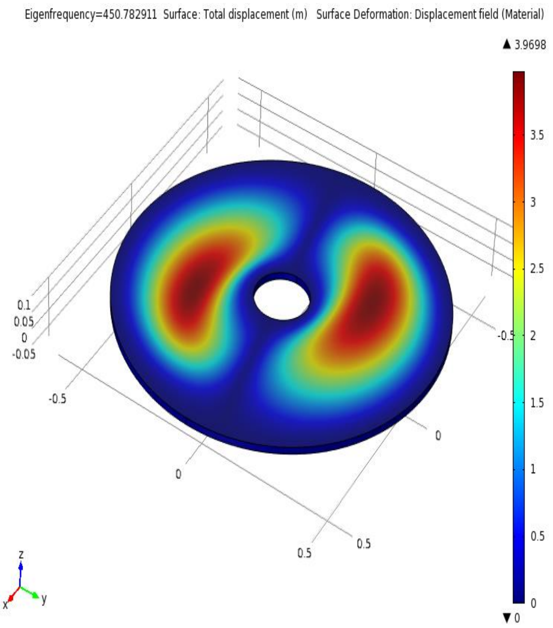
Table 2: The non-dimensional frequencies of an isotropic annular plate (h = 0.02, a = 0.6) with different inner radii (b) for clamped-clamped (C-C) boundary condition.

Inner radii (b)	Modes	
	(1,0)	(2,0)
0.1	450	533
0.12	487	562
0.14	528	597
0.16	575	638
0.18	628	687
0.2	690	745

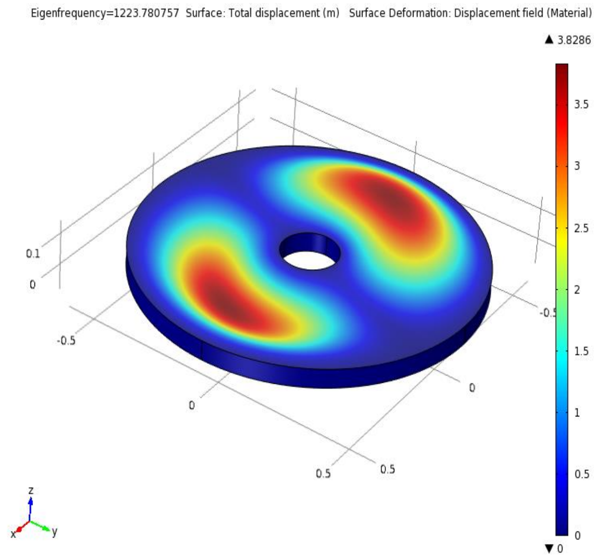
From Table 2, it is observed that the value of non-dimensional frequency increases by increasing the value of inner radii (b) for modes (1,0) and (2,0). While the values of plate thickness and outer radii remains constant.

ISSN: 2454-4248
186 – 191

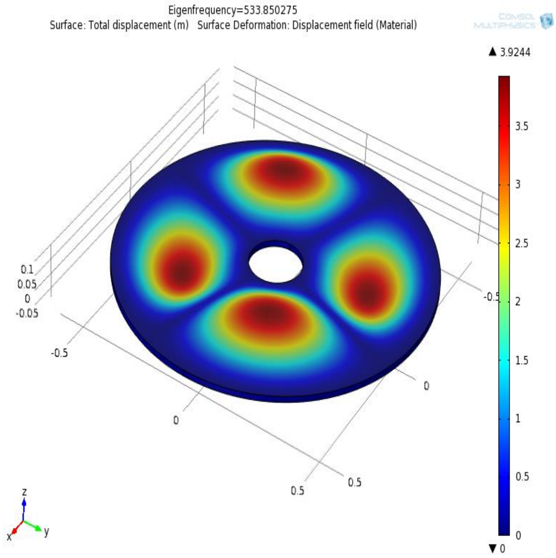
Mode (1,0) h = 0.02 m



Mode (1,0) h = 0.06 m



Mode (2,0) h = 0.02 m



Mode (2,0) h = 0.06 m

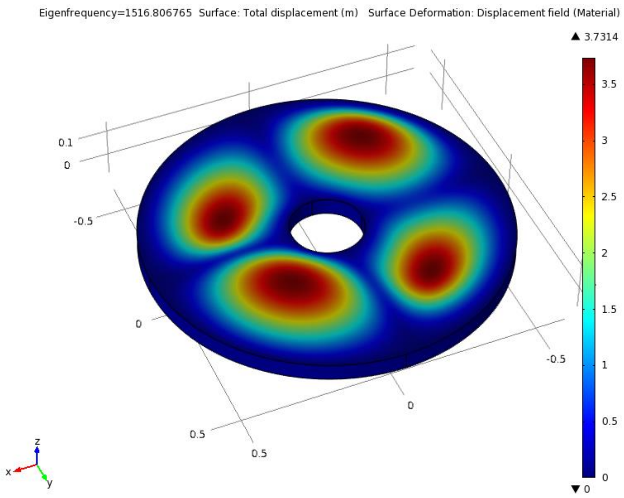


Figure 2: Mode shapes of isotropic annular plate under clamped-clamped boundary Condition.

ISSN: 2454-4248
186 – 191

B. Parametric Study

In this study, three dimensional Isotropic annular plate with different values of inner radii (b), outer radii a = 0.6 m, and plate thickness h = 0.06 m, is used to obtain the non-dimensional frequency of annular plate for (1,0) and (2,0) modes.

Table 3: The non-dimensional frequencies of an isotropic annular plate (h = 0.06, a = 0.6) with different inner radii (b) for clamped-clamped boundary condition.

Inner radii (b)	Modes	
	(1,0)	(2,0)
0.1	1232	1449
0.12	1316	1516
0.14	1418	1518
0.16	1533	1695
0.18	1663	1810
0.2	1809	1943

From Table 3, it is observed that the value of non-dimensional frequencies increases by increasing the value of plate thickness for modes (1,0) and (2,0) under clamped-clamped boundary condition. Some of the mode shapes for isotropic annular plate are shown in Figure 3.

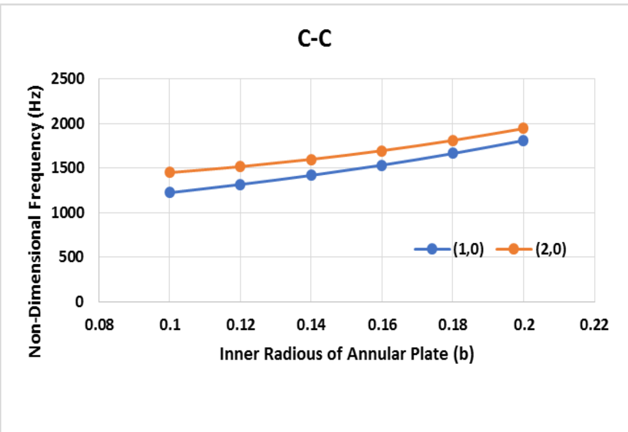
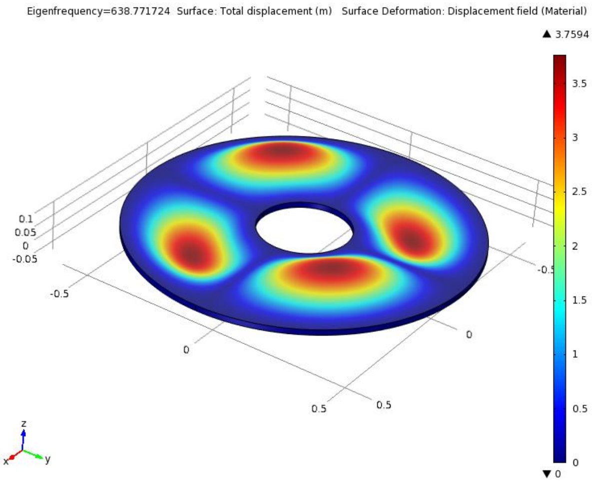
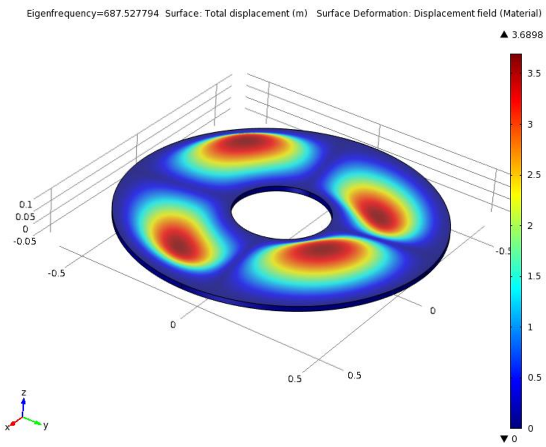


Figure 3: Effect of inner radii on the non-dimensional frequencies (Hz) of an isotropic annular plate for clamped-clamped (C-C) boundary condition (h = 0.06 m)

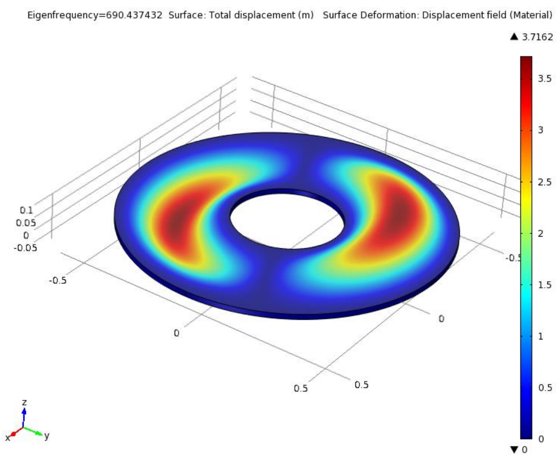
Mode (2,0) b = 0.16 m



Mode (2,0) b = 0.18 m

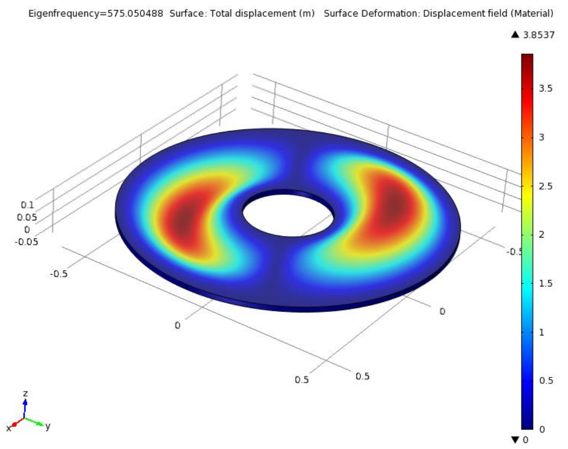


Mode (1,0) b = 0.16 m

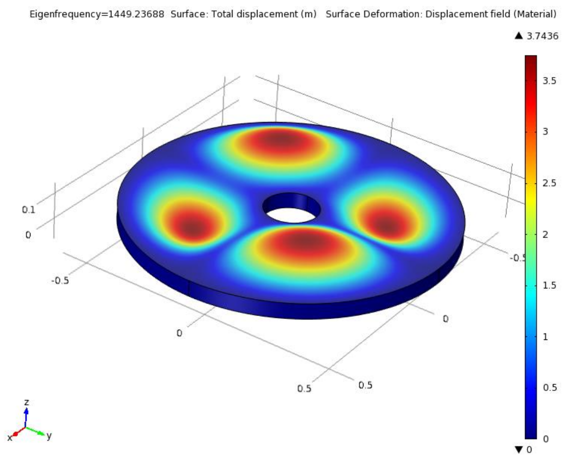


ISSN: 2454-4248
186 – 191

Mode (1,0) b = 0.18 m



Mode (2,0) b = 0.20 m



Mode (1,0) b = 0.20 m

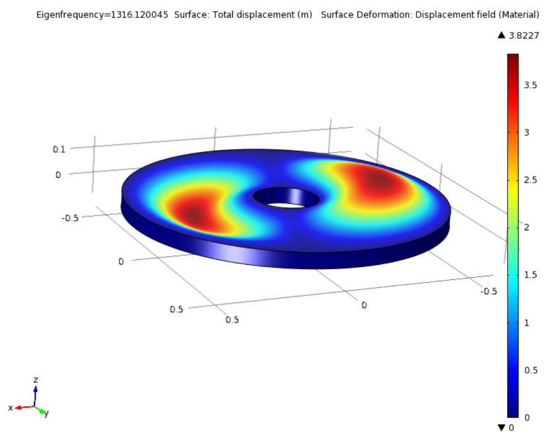


Figure 4: Mode shapes of isotropic annular plate under clamped-clamped boundary Condition (For Inner Radius)

IV. CONCLUSION

Modal analysis of isotropic annular plate is reported. It can be observed here that with increase in thickness to diameter ratio i.e. with increase in thickness the natural frequencies increases continuously for clamped-clamped (C-C) boundary condition. Also, 3-D vibrations of annular plates are analysed with the finite element software COMSOL (version 4.2). Effect of hole size and plate thickness is also investigated. The conclusions of this study can be summarized are as follows:

1. With the increase in inner radius of annular plate, the non-dimensional frequencies increases for modes (1,0) and (2,0).
2. With the increase in plate thickness, the non-dimensional frequency increases for modes (1,0) and (2,0).

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ISSN: 2454-4248
186 – 191

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