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Effect of Diametric ratio on Eigen Frequency of Functionally Graded Piezoelectric Round Disc

Trivedra Kumar Sharma[1], Prem Singh[2], Monu Gupta[3], Sanjay Choudhary[4]
[1, 2]*SKIT Jaipur 302017 (India)*

Abstract: Functionally graded piezoelectric material has very enormous application in the field of engineering and science. It is very useful for smart device like micro electric mechanical system, nano electro mechanical system. In the present work the effect of diametric ratio has been observed for functionally graded piezoelectric circular plate. d_{15} effect has been utilized for exited shear induced flexural vibration. Plate has been readily polarized and electric effect is applied along the thickness direction.
Keywords: Piezoelectric material, d_{15} effect, and power law

I. INTRODUCTION

Functionally graded piezoelectric materials is widely used material. Functionally graded material has been used in drone for making it self-powered. Functionally graded piezoelectric materials are using in gas litre and in gas stove for auto ignition. This plate can be use in crack detection in the pipes and rail wheel. Piezoelectric materials are used to measure change in pressure, acceleration.

II. MODEL DESCRIPTION

For analysis the effect of diametric ratio on functionally graded piezoelectric materials a circular plate of inner diameter of 1 mm and outer diameter of 24 has been consider. Thickness of the plate is 1mm. This plate has been radially polarized and electric field has been applied towards the thickness direction. Eigen frequency has been evaluated for free-free, fixed-free and for fixed-fixed boundary conditions.

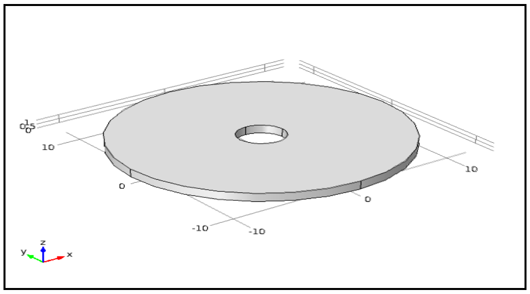

Figure 1 Functionally graded piezoelectric circular disk (D_o=24mm, D_i= 2mm, t=1mm)

III. GOVERNING EQUATIONS

$$\{S\} = [s^E]\{\sigma\} - [d]^T\{E\} \qquad (1)$$

$$\{D\} = [d]\{\sigma\} + [\varepsilon^\sigma]\{E\} \qquad (2)$$

Where σ the stress in (N/m2) and S is strain. ε^σ is the electric permittivity at constant stress in (F/m). E is the electric field. D is the elastic displacement vector. [d] are piezoelectric coupling coefficients [12].

IV. RESULT AND DISCUSSION

In this study, Eigen frequencies of functionally graded circular disks have been evaluated for free-free, fixed-free, and fixed-fixed boundary conditions. Hare the meaning of free-free boundary conditions is that inner surface of the plate is free and outer surface of the plate is also free, fixed free means that inner surface of the plate is fixed while outer surface of the plate is free. Fixed-fixed means that plate is fixed from inner and outer surface of the plate. Power law is used to vary the property in thickness direction. Upper surface of the plate is PZT-4 rich while inner surface of the plate is PZT-5H rich. Properties of the plate constantly varying.

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A. Analysis of Eigen frequency of FGPM disk for measuring the effect of diametric ratio for free-free boundary condition

Table 1 shows the effect of natural frequency of FGPM disk for free-free boundary conditions. From this table it can be observed that the natural frequency of the disc is decreasing when the diametric ration is increases. ‘n’ denotes nodal diameter, ‘s’ denotes nodal circle hare, N is the power law index. Power law index N is 0.5 in this analysis. Thickness of the plate is 1 mm and outer diameter of the plate is 24 mm while inner diameter is varying constantly.

Table 1 NATURAL FREQUENCY (kHz) FOR A FREE- FREE FGPM DISC, D=24, h=1mm, N=0.5

d/D N=0.5	(n, s) (2,0)	(n, s) (0,1)	(n, s) (4,0)	(n, s) (0,2)
2/24	5.058	8.981	20.714	39.718
3/24	5.000	8.873	20.634	40.923
4/24	4.934	8.459	20.671	41.715
5/24	4.863	8.306	20.659	44.199
6/24	4.548	7.625	20.018	47.833

1) Graphical Representation of natural frequency when the diametric ratio increases for free-free boundary conditions

From figure 2 it can be observed that natural frequency of FGPM disc increasing for zero nodal diameter and two nodal circle. And natural frequency is decreasing for 2 nodal diameters and for zero nodal circle, natural frequency is decreasing for zero nodal diameter and for 1 nodal circle and natural frequency also decreasing for 4 nodal diameter and zero nodal circle.

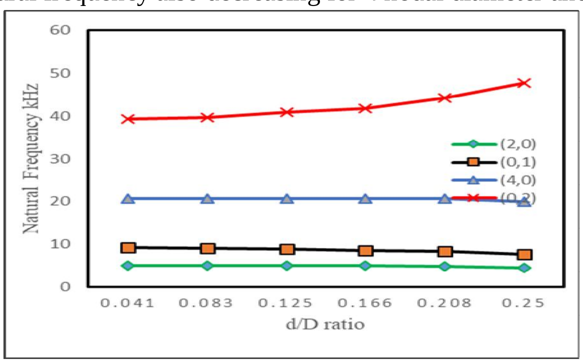

Figure 2 Variation of natural frequency with d/D ratio for free-free annular plate

2) Mode shape of natural frequency when the diametric ratio increases for free-free boundary conditions

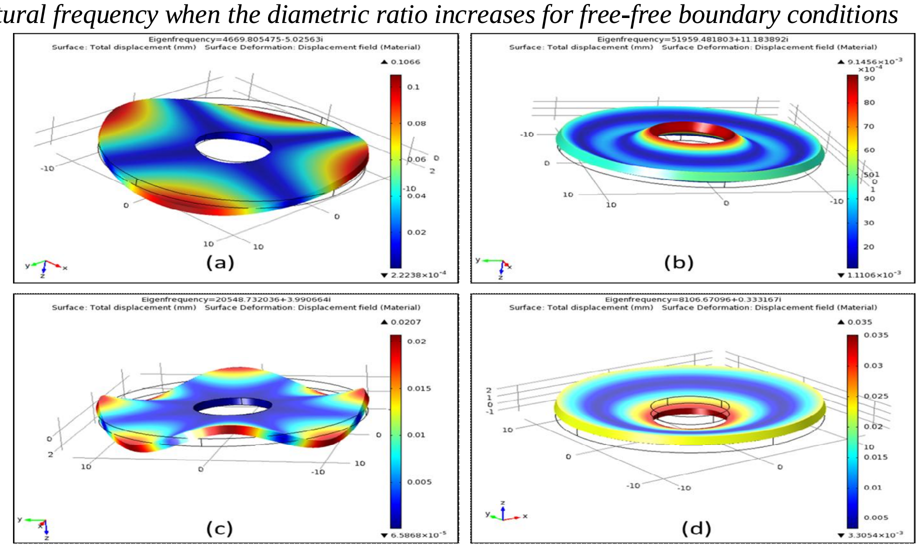

Figure 3 Mode shape of the free-free annular FGPM plate (D=24mm, d=7mm, and h=1mm): (a) (2, 0) mode at 4.669 kHz, (b) (0, 2) mode at 51.959 kHz, (c) (4, 0) mode at 20.548 KHz, (d) (0, 1) mode at 8.106 Kh

B. Analysis of Eigen frequency of FGPM disk for measuring the effect of diametric ratio for fixed-free boundary condition

From table 2 in can be observed that natural frequency of the circular disc increases when the inner and outer diameter ratio increases. Natural frequency of one nodal diameter and zero nodal circle increase in greater diameter. For the engineering application it is very good to find more flexible plate so this results can be utilized for developed more new engineering applications.

Table 2 NATURAL FREQUENCY (kHz) FOR A FIXED-FREE ANNULAR FGPM PLATE WITH VARATION IN OUTER TO INNER DIAMETER RATIO d/D, D=24 mm, h=3 mm, N=0.5.

d/D, N=0.5	(n, s) (1,0)	(n, s) (2,0)	(n, s) (3,0)	(n, s) (4,0)
6/24	14.878	18.325	33.044	53.513
8/24	19.488	22.056	34.447	53.964
10/24	25.634	27.720	37.561	55.240
12/24	35.976	36.364	43.749	58.791

1) Graphical Representation of natural frequency when the diametric ratio increases for free-free boundary conditions

It can be observed from figure 4 that natural frequency for 1 nodal diameter and zero nodal circle increases, natural frequency for two nodal diameter and zero nodal circle increases, natural frequency of three nodal diameter and zero nodal circle increase and natural frequency of 4 nodal diameter and zero nodal circle also increases**.**

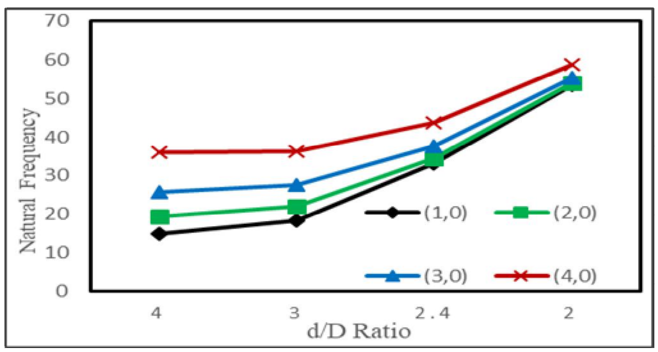

Figure 4. Variation of natural frequency of fixed-free FGPM annular plate with d/D ratio

2) Mode shape of natural frequency when the diametric ratio increases for fixed-free boundary conditions

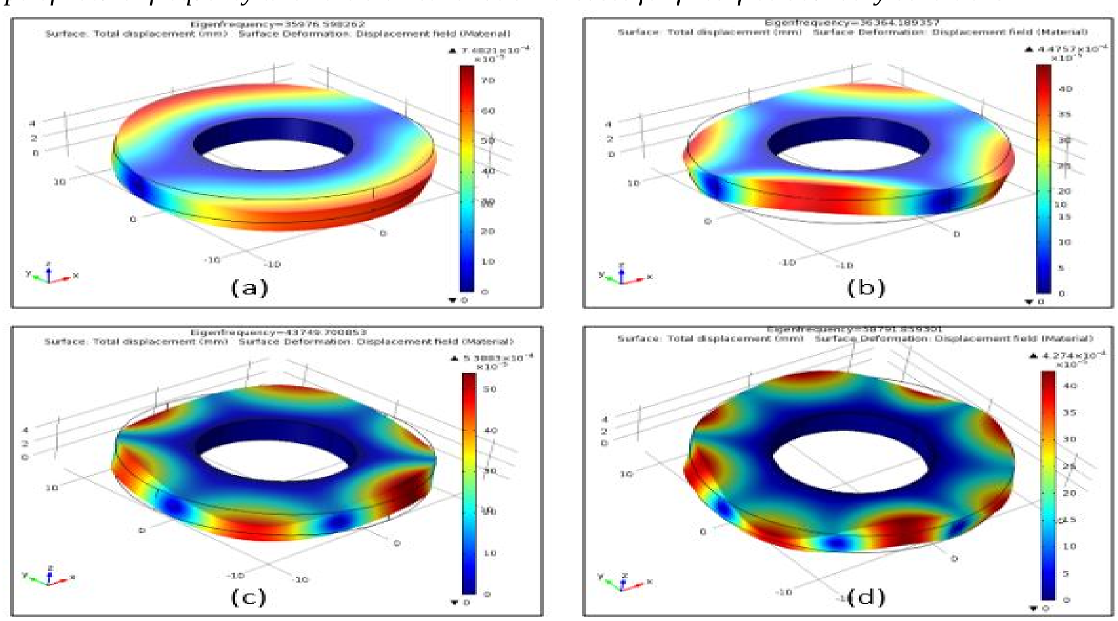

Figure 5 Mode shapes of the fixed-free annular FGPM plate (D=24 mm, d=4 mm, and h=3 mm, N=0.5) (a) (1, 0) mode at 35.976 kHz, (b) (2, 0) mode at 36.364 kHz (c) (3, 0) mode at 43.749 kHz, and (d) (4, 0) mode at 58.791

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C. Analysis of Eigen frequency of FGPM disk for measuring the effect of diametric ratio for fixed-free boundary condition

It can be observed from table 3 that natural frequency increase when diameter ratio increases. Second column of this table show zero nodal diameter and zero nodal circle third Colum show the natural frequency for the one nodal diameter and zero nodal circle and forth column show result for two nodal diameter and zero nodal circle and similarly fifth, sixth and seventh column show the result for three, four and fifth nodal diameter.

Table 3. Natural frequency (kHz) for a fixed- fixed annular FGPM plate with variation in inner to outer diameter ratio d/D, D=24 mm, h=3 mm, N=0.5.

N=0.5, d/D	(0, 2) (n, s)	(1, 0) (n, s)	(2, 0) (n, s)	(3, 0) (n, s)	(4, 0) (n, s)	(5, 0) (n, s)
1/24	57.361	62.054	80.319	105.667	132.623	160.253
2/24	68.154	71.267	84.217	106.44	132.680	160.16
3/24	80.410	82.674	92.044	109.907	133.747	160.427
4/24	95.797	97.517	104.109	117.775	137.764	162.091
5/24	114.810	116.049	120.881	131.187	146.956	167.693
6/24	140.488	141.694	144.840	152.441	164.442	181.02

1) Graphical Representation of natural frequency when the diametric ratio increases for free-free boundary conditions

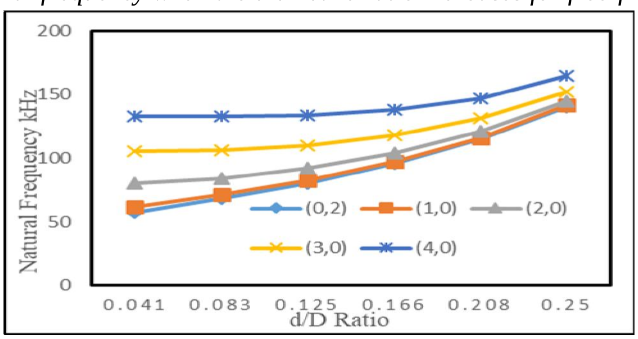

Figure. 6 Variation of natural frequency of fixed- fixed annular plate with d/D ratio increase

2) Mode shape of natural frequency when the diametric ratio increases for fixed-free boundary conditions

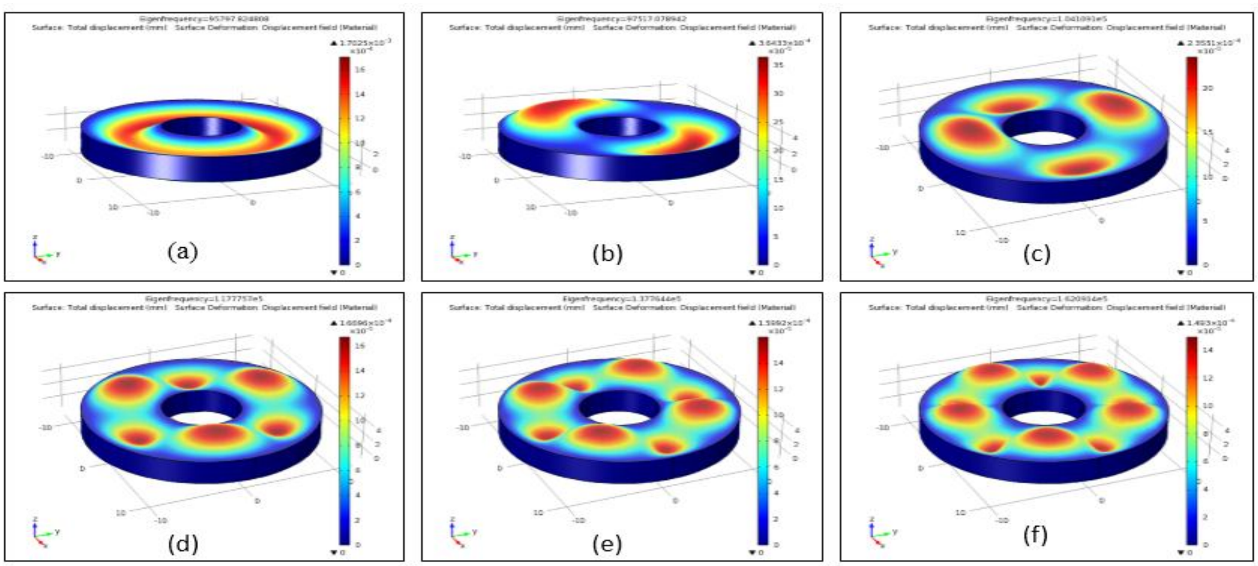

Figure 5.: Mode shapes of the fixed-fixed annular FGPM plate (D=24 mm, d=4 mm, and h=3 mm, N=0.5) (a) (0, 2) mode at 95.797 kHz, (b) (1, 0) mode at 97.517 kHz (c) (2, 0) mode at 104.109 kHz, and (d) (3, 0) mode at 117.775 kHz, (e) (4, 0) mode at 137.764 kHz (f) (5, 0) mode at 162.091 kHz

V. CONCLUSION

Eigen frequency for the FGPM plate has been evaluated, and a comparative study of different geometrical parameters has been conducted with power law variation. It is observed here that natural frequency slightly creases when the value of the power law index increases. This FGPM circular disk can be used in ultrasonic motors, drones, and many smart devices. Here, the natural frequency is higher for fixed-fixed boundary conditions than the free and fixed-free boundary conditions. The free-free plate's natural frequency is much less than the other boundary condition for the same nodal circle and nodal diameter. The natural frequency obtained here is believed to be useful for designing smart systems based on FGPM round disks by exited shear vibration. Shear-induced flexural vibration for varying power law index on the elastic foundation can be explored in future work.

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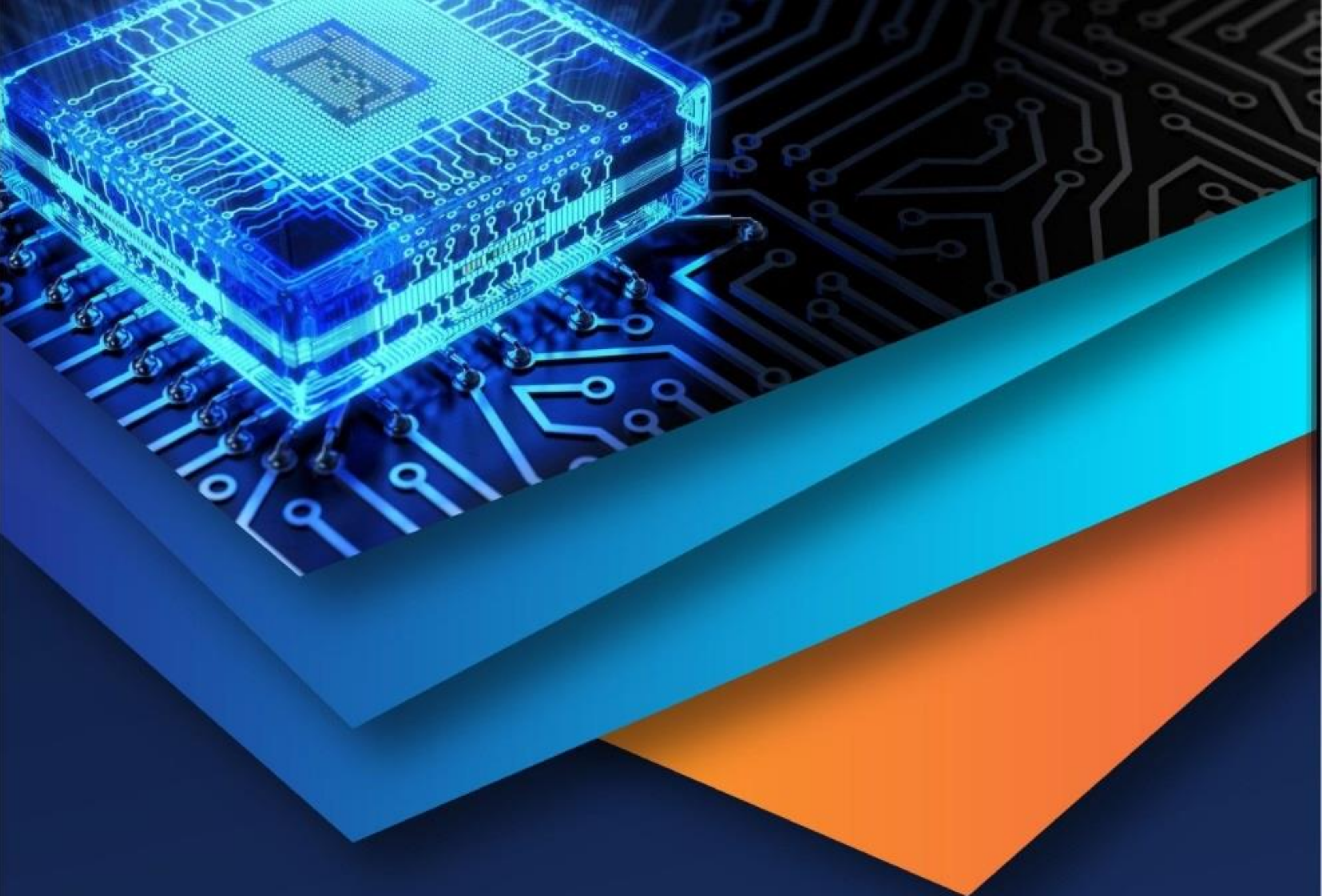

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