Numerical Study of Loudspeaker Diaphragm Geometries

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INTRODUCTION: This work was aimed to study the Dynamics of the Loudspeaker Diaphragm Geometry subjected to Geometry Modifications using Numerical Techniques. Geometry modification is achieved by segmentation of a 2D geometry that is shown in the below figure. This work provides an opportunity to study dynamic responses of different cases shown in the table 1 also the influence of acoustical domain on the dynamic response of given cases. The mass distribution on the radial direction also helps in observing the Eigen Frequency pattern changes.

Cases	Geometry-Distribution of thickness	Stiffness [N/mm]
Case 1	0.5 mm Uniform	0.04856
Case 2	2.2638mm; 0.2705mm	0.08564
Case 3	0.5 mm; 1.3751 mm; 0.3110 mm	0.08675
Case 4	0.5 mm; 1.23395 mm; 0.1739 mm	0.12847
Case 5	0.4 mm; 1.12719 mm; 0.35630 mm	0.04806
Case 6	0.4mm; 0.4 mm; 0.78524 mm	0.04592
Case 7	0.77351 mm; 0.3 mm; 0.67826 mm	0.06473

Table 1. Geometries

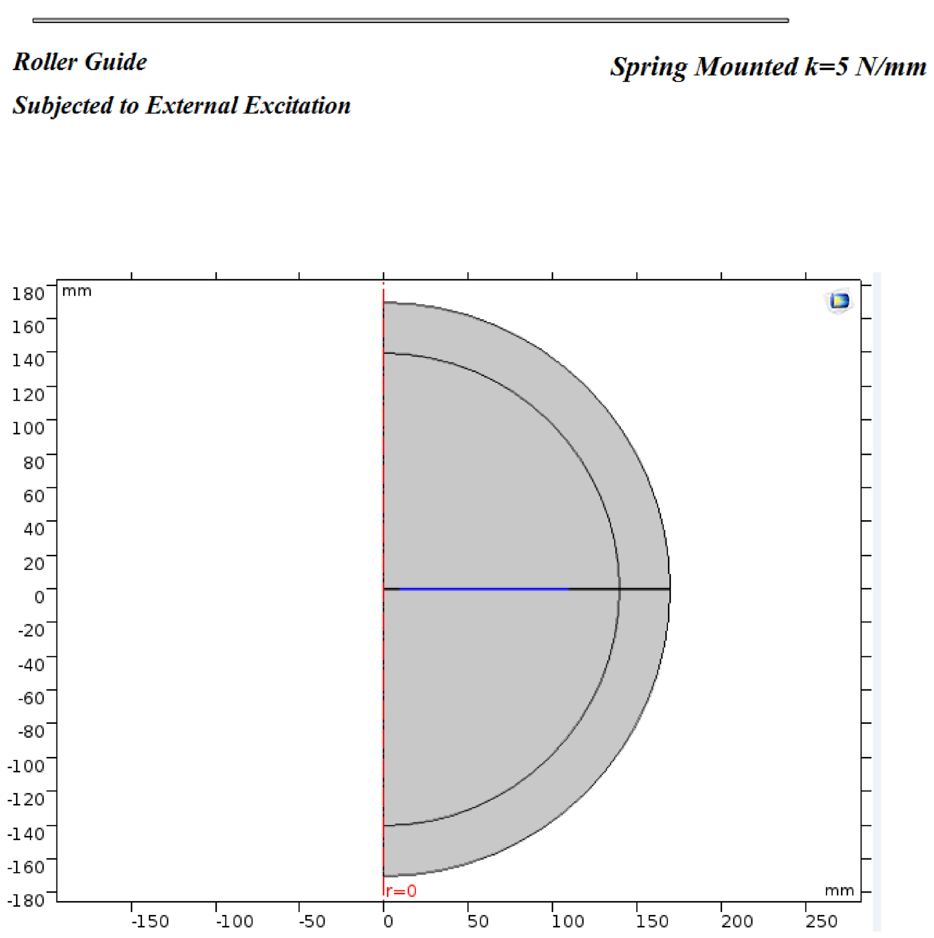

Figure 1. Geometry – Acoustic interaction

GEOMETRY MODIFICATION & COMPUTATIONAL METHOD: Cross section of the loudspeaker diaphragm in 2D axisymmetric coordinates is considered for the simulation. The model initially subjected to Eigen frequency analysis to study the modal performance of the different cases and the model further subjected to Frequency Domain and Influence of the acoustics interaction studies. Mass of the plate is kept constant and this is achieved by the controlling the volume of the each segment in the radial direction. Below are the mathematical functions used to control the volume of the segments.

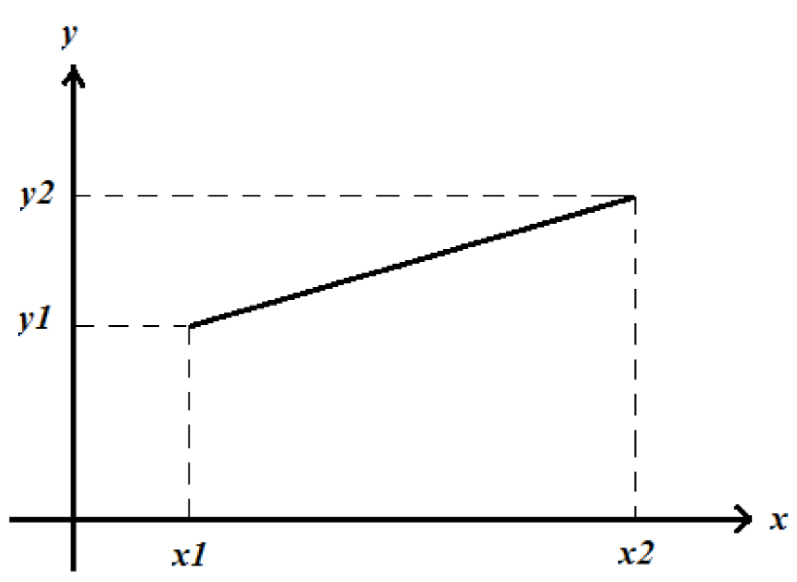

Figure 2. Segmented Geometry – Line Function

$$V = \int_{\theta_1}^{\theta_2}\int_{r_1}^{r_2}\left(\left(\frac{(y_1-y_2)}{(x_1-x_2)}\right)r + y_1 - x_1\frac{(y_1-y_2)}{(x_1-x_2)}\right) r\,dr\,d\theta$$

$$y_2 = y_1 - \left[\frac{\frac{180V}{\pi} - y_1\left(\frac{r_2^2-r_1^2}{2}\right)}{\frac{r_2^3-r_1^3}{3} + x_1\left(\frac{r_1^2-r_2^2}{2}\right)}(x_1-x_2)\right]$$

$$y_1 = \frac{\frac{180V}{\pi}(x_1-x_2) + y_2\left[\frac{r_2^3-r_1^3}{3} + x_1\left(\frac{r_1^2-r_2^2}{2}\right)\right]}{\frac{r_2^3-r_1^3}{3} + x_1\left(\frac{r_1^2-r_2^2}{2}\right) + (x_1-x_2)\left(\frac{r_2^2-r_1^2}{2}\right)}$$

The segments are modeled as shown in the figure 2 above and the Volume of the segment in polar coordinates is modeled as V in above formula. y2 and y1 are the height control variables of the 2D segmented geometry. Note that the integrand function is only depends on r not Theta. Figure 2 representing the geometry in XY coordinate for the ease of understanding of the integrand formation.

COMSOL® Solid Mechanics module is used for finding Eigen values of the each cases and same module further used for Dynamic Analysis and finally acoustic coupled model is solved for studying the acoustical domain influence on the structure. FEM and BEM methods are used for calculations. BEM is used for calculating the far field pressure response which is not considered for this study. Far field calculations for each cases will be compared in future studies.

RESULTS: Modal performances of the each cases is studied at first and modal patterns were carefully observed and the it is possible to notice that there was an increase and decrease of values and this study helps in understanding the reason behind the such happenings!

Cases(flat)	First Mode [Hz]	Second Mode[Hz]	Third Mode[Hz]	Fourth Mode[Hz]	Fifth Mode [Hz]	Sixth Mode [Hz]
Case 1	14.123	79.486	170.669	292.925	491.429	763.232
Case 2	13.754	86.679	207.931	383.703	623.410	941.675
Case 3	12.225	99.256	202.721	327.553	531.347	822.491
Case 4	17.945	89.407	248.723	364.446	612.664	878.376
Case 5	14.176	79.897	168.514	310.820	515.300	775.983
Case 6	14.111	72.514	151.886	252.332	441.292	706.329
Case 7	14.236	85.951	176.713	338.089	581.227	843.744

Table 2. Modal Performances of All Cases

For the ease of understanding the listed cases were split into groups. And now it is clear that there was increase and decrease of modal values can be seen in the below figures. This increase and decrease of modes are resulted by concentration of mass in radial direction.

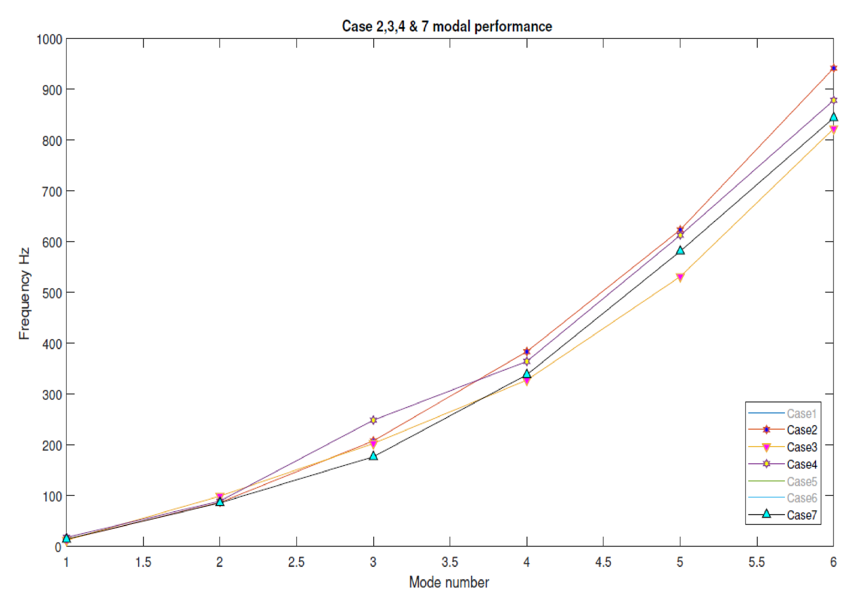

Figure 3. Modal Comparison 2,3,4,7

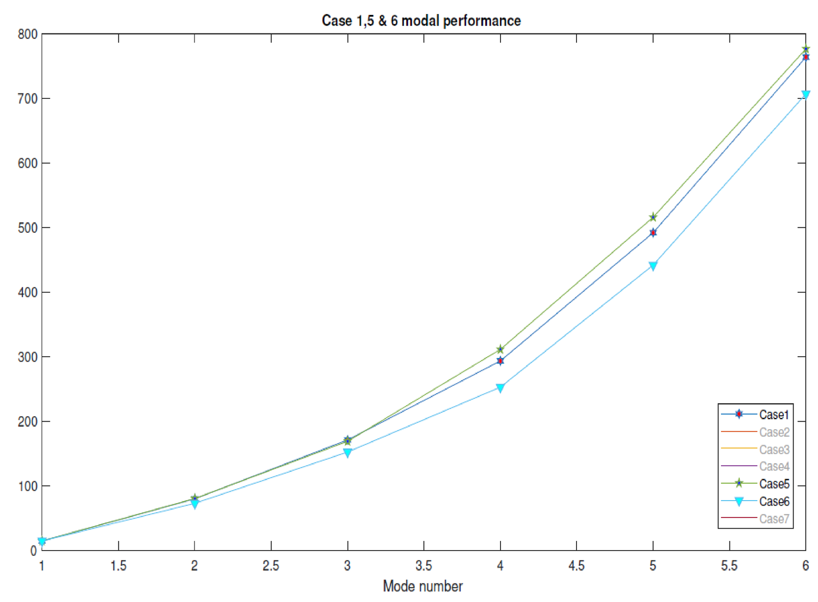

Figure 4. Modal Comparison 1,5,6

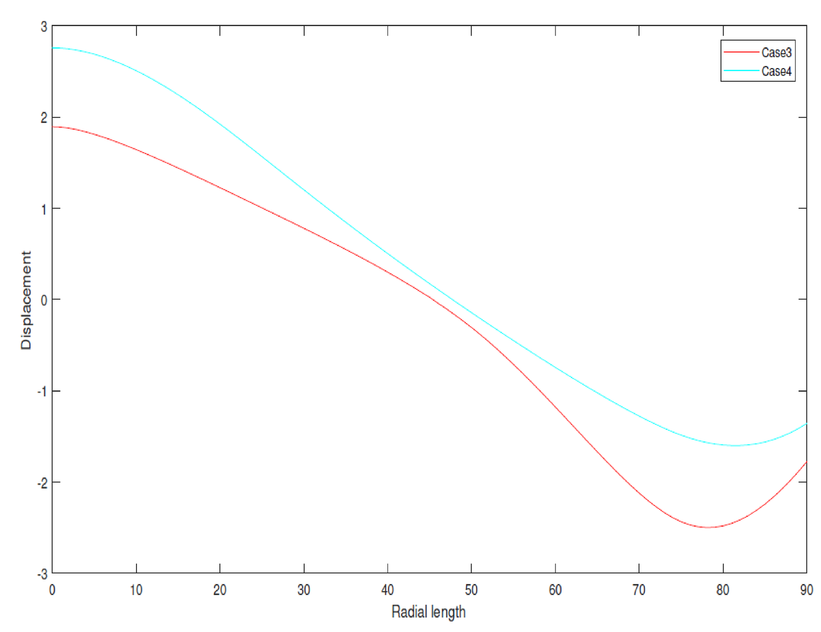

Figure 5. Mode Shape Comparison

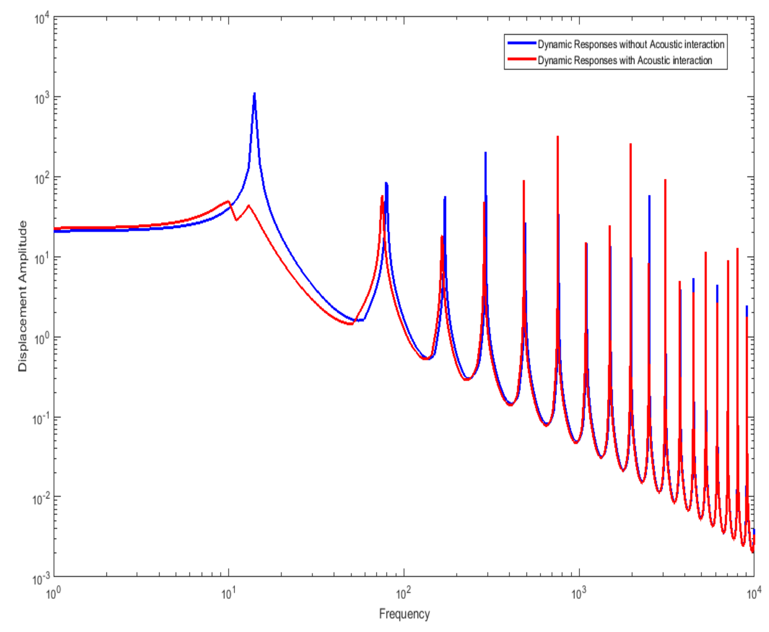

Figure 6. Dynamic Responses

First mode of the case 4 is the highest of all cases with 17.945 Hz While second mode is falling compared to the case 3 and case 3 has highest second mode value with 99.256Hz, this can be explained using figure 5 mode shape comparison. Note that the case 4 has mass concentrated at center while case 3 has concentrated mass shared between first two segments(Geometry has four segments).

CONCLUSIONS: 1. From the study it is possible to understand the modal performances of different geometries.

2. This Geometry designs exhibiting different modal characteristics and it is possible to be able control the modes of the structure by adding mass at appropriate locations.

3. This modal performances can be linked with acoustic pressure responses(Far Field) in the future and will be studied further.

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