



IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 Issue: XII Month of publication: December 2020 DOI: https://doi.org/10.22214/ijraset.2020.32150

www.ijraset.com

Call: 🕥 08813907089 🔰 E-mail ID: ijraset@gmail.com



# Impact of Modal Frequencies of Cavity on Acoustic Performance for Variational Bellow Diameter (d) to Cavity Diameter (D)

Praniket Palkondwar<sup>1</sup>, Assoc. Prof. A. A. Panchwadkar<sup>2</sup> <sup>1</sup>PG Student, PCCOE, <sup>2</sup>Associate Professor, PCCOE

Abstract: Helmholtz Resonator is widely known as the phenomenon of air resonance in the cavity. The intent of this paper is to find out the effects of various geometric parameters of the cavity models. The main objective of this work piece is to investigate the effect of acoustic natural frequency on structural natural frequency for the given cavity model.

The design of experiment method is chosen to investigate the relation. It was found that variation in the cavity diameter will not much affect the acoustic performance. The noise cancellation signal which consisting of acoustic and structural frequency, their peaks are apart by quite long span, providing vary broad width of the band of frequencies for noise cancellation or attenuation. Index Terms: Helmholtz Resonator, Acoustic Performance, Cavity Design, Design of Experiment, Normal Modal Analysis, Longitudinal Vibration, Acoustics.

# I. INTRODUCTION

The noise is pollution can cause adverse effects on the both mental and physical health of the animals. According to studies, it is observed that the noise pollution is associated with faster cognitive decline. The current need of the industry is to reduce the instrumental noise. There are different ways to control noise depending upon application and the costs associated with it are the major constraints. There are different techniques to control the noise transmission, such as use of barriers, reactive silencers and costlier active noise control devices.

The noise can be effectively reduced by the use of HR. There are versatile usages of the HR in order to mask, reduce or suppress the acoustic pressure inside any defined volume. The main problem associated with HR is that it can attenuate only single one designed frequency. In real life world, the resonant frequencies of the machines will vary according to its operating conditions. In such cases traditional HR becomes ineffective. For instance, if we have designed HR for a specific resonance frequency of blower, then it will only induce one peak to attenuate the noise for that specific frequency only. Further, if there is speed variation in the blower due to load variation, then the conventional HR will not be useful. In order to rectify this limitation associated with classical HR, the new approach was suggested by changing the neck shape in order to reduce the noise in real life applications.

The general design parameters for HR are Cavity Diameter and Cavity Length, while for the general design of Metallic Bellow involves Neck Diameter, Neck Length & Convolution Pitch.

# A. The broad objectives of the Study

- 1) Study of existing Cavity volume to find the structural natural frequency.
- 2) To find the dominant set of parameters for the cavity volume design by design of experiments.
- *3)* To study and investigate relation between the acoustic resonance frequencies and the structural frequencies of the cavity model design.

During the literature study, it was found that the work implementation of this topic covers a specific direction like "Acoustic Performances or Resonances", so there is need to study and summaries the interaction of acoustic and structural performances. The proposed work of this paper discusses about relation between the structural natural frequencies of cavity frame and acoustic natural frequencies of cavity. This will be helpful understand the required cancellation frequency signal to attenuate the noise.

The scope of this paper is limited to the variable Cavity to Bellow Diameter (D/d ratios) under different conditions mentioned below:

- *a)* Keeping "d" Constant and varying "D"
- b) Keeping "D" Constant and varying "d"

International Journal for Research in Applied Science & Engineering Technology (IJRASET)



ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429 Volume 8 Issue XII Dec 2020- Available at www.ijraset.com

# **II. LITERATURE**

Helmholtz resonator consists of different parameters on which noise attenuation phenomenon can be tested. Cavity Volume design is an essential part of this study, also considered while designing Helmholtz resonator.

Akira S. et al.; [1] discusses the method in which he had proposed two-degree-of-freedom HR, to enhance the effect of the sound absorber which can enable the HR to work in wide frequency range. In its arrangement, the resonator is fixed with the panel in the cavity region, so whenever the sound wave will incident on this panel will vibrate and resonator acting as 2-dof system. Further the respective arrangement is done in order to spit the resonant frequency peak into two.

Chenzhi Cai et al. [2] In this paper the focus is given on the improvement of overall acoustic performance by increasing noise attenuation of HR operating at low frequencies where the space is constraint. The suggestions related to shape have been proposed to study and analyze the acoustic performance.

The spiral neck and extended neck were proposed instead of conventional neck of HR. In the overall process the performance was studied by theoretical and numerical approach. The respective changes have been carried out by converting it to one dimensional approach by introducing equivalent straight neck. There is reasonable accuracy in the results by theoretical and numerical analysis method.

Final, outcome of this experiment suggests that resonance frequency of HR system by increasing extended or spiral neck length and without changing cavity volume.

Mohammad Kurdi et al. [3] describe a simulation based design process which is capable of producing a small volume HR which can provide the higher value of transmission loss across a specific range of frequencies. The design of HR with the flexible plate at the end was achieved by multi-objective optimization formulation. Pareto curve was referred to quantify the tradeoff between the objectives of the optimization. Finally, gradient based approach was used to get optimum design solution.

M.B. Xu et al. [4] presented dual-HR.

The construction of such dual HR consists of two back to back HR connected in series. The arrangement is such that cylindrical shape neck and cavity volume are connected to another neck and cavity volume of the HR. The respective attempt was made in order to improve the performance related to attenuation of sound.

An attempt was made in order to form a relationship between resonance frequency range and transmission loss of this 2 dof by following lumped mass approach. Post 2D analytical approach, experimentation and simulation by BEM methods shows an acceptable agreement.

The effects of constituents of HR like neck and cavity volume have been studied; the resonance frequency can be decreased by following parameters (a) increasing the overall cavity volume (b) increasing neck length (c) decreasing neck radius, whereas the changes shape changes in second cavity volume remains infinitesimal. It has been observed that multiple solution paths can be achieved for the same acoustic performance

Amit Panchwadkar et al. [5] paper implements HR principle for the reduction of noise along the transmission path. The resonator frequency range can be determined by the by using design parameters. The paper explains the use of metallic bellow acts like the inertial mass in the HR setup.

The transmission loss was found by the metallic bellow in combination with resonator. Similarly, the FFT in combination with microphone yielded to find the operating frequency. Further the acoustic behavior of metallic bellow was studied by the numerical analysis of bellow and the resonator with help of earlier calculated operating frequency. The paper concludes that there is scope for parametric variations in the dimensions and modifications in the shapes to get the desired acoustic performance.

# A. Literature Summary

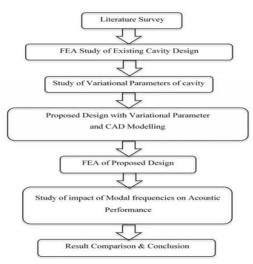
From the literature survey we came to know the importance of Metallic Bellow in Helmholtz resonator. There are few major finding which are found by above literature survey.

- 1) The Classical HR principle can be implemented by using Newton's Second law to give single resonance frequency and a corresponding attenuation peak. This method is available for single dof system.
- 2) Extended neck cavity models can be used to reduce the resonance frequency instead of increasing volume.
- 3) The geometric modifications like extended neck length and overall shape can be one of the effective methods to control resonance frequency of HR for the same cavity volume.
- 4) Dimension and shape modifications can be implemented to get the desired acoustic performance of the bellow & system.



# III. METHODOLOGY

The respective block outlines the work in the respective stages:



#### IV. ACOUSTIC NATURAL FREQUENCY OF CAVITY

The acoustic natural frequency of the Cavity is the HR is determined by the simple formula illustrated below:

$$f = \frac{C}{2\Pi} \sqrt{\frac{S}{VL}}$$

The above equation can be simplified for the ease of the calculation:

$$\mathbf{f} = \frac{C}{2\Pi} \sqrt{\frac{\Pi r^2}{\Pi R^2 L l}}$$

$$\mathbf{f} = \frac{c}{2\pi} \sqrt{\frac{r^2}{R^2 L l}} \dots \dots 1$$

Where,

C = Speed of the sound, (m/sec) S = Neck cross Section area, (m^2) L = Cavity Length, (m) l = Neck Length, (m) V = Volume of the Cavity, (m^3)

#### A. Existing Cavity Volume CAD Model

The dimensional study of the existing model is conducted in order to form 3D model. The measurements were taken from the original (existing) model by using various metrological instruments. The prime dimensions which were required for modeling 3D CAD model are cavity diameter, bellow neck diameter, length of cavity, length of the neck & thickness.

	Sr. No.	Cavity Parameters	Dimensions			
	1	1 Cavity Diameter (D)				
	2	36 mm				
	3	Neck Diameter (d)	36 mm			
	4Nek Length (l)5Overall Modal Thickness (t)		28 mm			
			1.25 mm			

Table 1 – Cavity Dimensions



Acoustic frequency values of various Cavity Models are enlisted below in the Table 2 referring the formulation of the Equation 1 and Table 1 respectively.

Table 2. Acoustic Frequency of the Cavity Models							
	Acoustic Frequency of the Cavity Models						
Sr. No.	Parame	Acoustic Frequency, (Hz)					
1	For 100% Dime	522.397					
	Case 1 -	10% decrease in "d"	470.158				
2	Keeping "D"	20% decrease in "d"	417.918				
2	Constant &	30% decrease in "d"	365.678				
	Varying "d"	30% increase in "d"	Acoustic Frequency, (Hz) 522.397 470.158 417.918				
	Case 2 -	10% decrease in "D"	580.442				
3	Keeping "d"	20% decrease in "D"	652.997				
5	Constant &	30% decrease in "D"	746.282				
	Varying "D"	30% increase in "D"	401.844				

# Table 2: Acoustic Frequency of the Cavity Models

#### V. NUMERICAL ANALYSIS

# A. Model Building Activity

The model building activity is done by the market leading pre-processor. Model building activity is followed by quality checks which include the warpage, aspect ratio, minimum angle, maximum angle, Jacobian and skewness. This makes sure that the interpolation of the results will be accurate and smoother.

- 1) Element Type Quad4 Shell Element
- 2) Element Size 2 mm

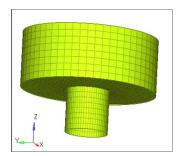


Fig. 1 - Meshed Model of the Cavity Model

#### B. Material

The existing Metallic Bellow is made up of SS 304 and the respective mechanical properties have taken in the study.

#### VI. SIMULATION APPROACH (OFFSET BARRIER)

Normal Modal Analysis (NMA) is carried out of the existing Cavity volume cover in order to find the mode shapes and the natural frequencies. To longitudinal mode shapes along with respective frequencies have taken to understand the behavior of existing bellow. The given table enlists longitudinal models with the frequency values -

Table 5 - First Three Longitudinal Modes				
Sr. No.	Longitudinal	Frequency		
SI. NO.	Mode No.	(Hz)		
1.	Mode 1	332.084		
2.	Mode 2	1000.501		
3.	Mode 3	3494.145		

Table 3 - First Three Longitudinal Modes



International Journal for Research in Applied Science & Engineering Technology (IJRASET)

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429 Volume 8 Issue XII Dec 2020- Available at www.ijraset.com

A. Proposed Parametric Models

- The proposed models are based on following Variational parameters -
- 1) Case 1: Keeping Cavity diameter (D) constant & Varying Neck diameter (d)
- a) Keeping Cavity Diameter Constant, D = 114 mm
- b) Varying Neck Diameter, by 10%, 20% & 30% of the original dimension.
- 2) Case 2: Keeping Neck Dia. (d) constant & Varying Cavity diameter (D)
- *a)* Keeping Neck Diameter Constant, d = 36 mm
- b) Varying Cavity Diameter, by 10%, 20% & 30% of the original dimension.

#### VII. RESULT DISCUSSION

The result table enlists the values of the Longitudinal Modes for both the cases. Further these values are represented on graphical scales as well in order to understand the behavior of cavity volume for various parametric changes.

Table 4 -	Proposed	Design	Result:	Cavity	Modeling	Case 1

Sr.	Longitudinal Modes, (Hz)		Keepi	ng ''D=Const'' & Varying ''d''		
No		100% Dim. (D=114mm,	10% Decrease	20% Decrease	30% Decrease	30% Increase
		d=36mm)	in ''d''	in ''d''	in ''d''	in ''d''
1	Mode 1	332.084	450.6336	605.892	865.781	431.64
2	Mode 2	1006.501	1235.453	1548.22	2003.97	1026.7
3	Mode 3	3494.114	4384.692	5541.93	7176.01	3988

Table 5 - Proposed Design Result: Cavity Modeling Case 2

	Longitudinal	For original	Keeping "d=Const" & Varying "D"			
Sr.	Modes, (Hz)	Dimension	10%	20%	30%	30%
No		100% Dim.	Decrease	Decrease	Decrease	Increase
		( <b>D=114mm</b> ,	in ''d''	in ''d''	in ''d''	in ''d''
1	Mode 1	332.084	450.6336	605.892	865.781	431.64
2	Mode 2	1006.501	1235.453	1548.22	2003.97	1026.7
3	Mode 3	3494.114	4384.692	5541.93	7176.01	3988

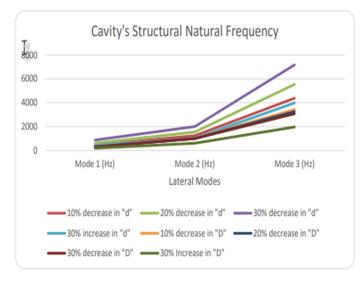


Fig. 2 - Graphical Representation of Results



Acoustic and Structural frequency Comparison					
	Acoustic	Structural			
Original Model	Mode,	Modes,			
Origimal Model	(Hz)	(Hz)			
	522.397	332.084			
Case 1 - Keeping "D" & Varying "d"					
10% Reduction in"d"	470.158	450.633			
20% Reduction in"d"	417.918	605.89			
30% Reduction in"d"	365.678	865.781			
30% Increase in "d"	679.117	431.638			
Case 2 - Keeping "d" & Varying "D"					
10% Reduction in"D"	580.442	326.904			
20% Reduction in"D"	652.997	306.97			
30% Reduction in"D"	746.282	288.846			
30% Increase in"D"	401.884	190.417			

# Table 6 - Acoustic and Structural Frequency Comparison Study of Cavity Models

#### VIII. CONCLUSION

The graphical indication states that the structural natural frequencies of the proposed cavity models are influenced by the variation in the neck diameter, for the cavity diameter its frequency band is narrow, so in order to attenuate a certain frequency signal any of the combination will serve the purpose.

Post comparison of the acoustic and structural frequencies, it has been found that the values of the frequencies are apart with quite huge margin indicating that in the noise cancellation signal there will be two different peaks which are separated by quite long span. It represents that the resultant signal can attenuate the noise with certain range of cancellation.

#### REFERENCES

- Akira Sanada and Nobuo Tanaka, "Extension of the frequency range of resonant sound absorbers using two-degree of freedom Helmholtz-based resonators with a flexible panel", Journal of Applied acoustics 2013, (74) pp. 509-516.
- [2] Chenzhi Cai, Cheuk-Ming Mak, Xiaofeng Shi, an extended neck versus a spiral neck of the Helmholtz resonator, Applied Acoustics, PP. 74–80, (2017)
- [3] Mohammad Kurdi, G. Duncan, S.S. Nudehi, "Optimal design of Helmholtz resonator with a flexible end plate", Journal of Vibration and Acoustics, June 2014, volume 136, pp. 1-8.
- [4] M.B. Xu, A. Selamet, H. Kim, Dual Helmholtz resonator, Applied Acoustics 71 (2010)
- [5] Amit A. Panchwadkar, Dr. Pradeep J. Awasare and Dr. Ravindra B. Ingle, "Experimental\_and\_Numerical\_analysis\_of\_Metallic\_Bellow for Acoustic Performance", IOP Conf. Series : Material Science and Engineering, 225 (2017), 012216
- [6] Saber M.Elsayed, Rahul A. Sarker, Daryl L.Essam, A new genetic algorithm for solving optimization problems, Engineering Applications of Artificial Intelligence 27 (2014)











45.98



IMPACT FACTOR: 7.129







# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 🕓 (24\*7 Support on Whatsapp)