# An Improvement of Transmission Loss on Reactive Muffler by using Helmholtz Resonator

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*Abstract*— The paper shows an improvement of acoustical transmission loss on single expansion chamber muffler by using Helmholtz resonator with same gas volume. A reactive muffler (silencer) is an important noise control equipment for reduction of exhaust noise and other noise source which involves the flow of gases. Mufflers are typically arranged along the exhaust pipe as the part of the exhaust system of an internal combustion engine to reduce its noise. Here basic term is used for noise attenuation namely transmission loss (TL). An experimental method for muffler's transmission loss (TL) measurement for central inlet and central outlet muffler shows the validation of result. Finite element analysis tools comsol multiphysics used to validate the results. The wave 1-D is also used to validate the results. This paper is involving an improvement of transmission loss on first cut off frequency by the modeling of Helmholtz resonator.

***Key words:*** Helmholtz resonator, FEA Acoustic Module-wave 1-D, Sound Transmission loss, Reactive Muffler

## I. INTRODUCTION

In current scenario the growths of automobile vehicle are in increasing day by day. Basically a muffler for an automobile is characterized by numerous parameters like Insertion Loss, Transmission Loss. The best used parameter to evaluate the sound radiation characteristics of muffler is Transmission loss .The United Kingdom based term muffler (silencer in USA) is a device for reducing the amount of noise emitted by the exhaust of an internal combustion engine [1]. Transmission Loss is defined as difference between power incident on muffler proper and that transmitted downstream into an anechoic termination. It is independent of source and presumes an anechoic termination at tail pipe. It describes the performance of a muffler. [5][8] Sound waves propagating along a pipe can be attenuated using either a dissipative or a reactive muffler. A dissipative muffler uses sound absorbing material to take energy out of the acoustic motion in the wave, as it propagates through the muffler. Noise levels of more than 80 dB are injurious for human beings [3]. Hence to reduce noise from internal combustion engines they are equipped with an important noise control element known as silencer or exhaust muffler which suppresses the acoustic pulse generated by the combustion processes [4]. This is only the one of the most frequently used physical parameters of the muffler. Numerical methods are very useful for optimization of model of having complicated shapes and also where the cost is involved. So that it is essential to optimize the model by Finite Element Analysis and validate it by experimental methods. Validation of experimental setup it is necessary to test the results of model of which analytical, numerical results are known [2]. It describe that the transmission losses can be determined reliably with the test rig setup. Many tools are available to simulate the transmission loss characteristics of a muffler. Experimentally Two-load method is commonly used to predict the transmission loss of an Acoustic muffler [6] [9]. Finite Element Method is also used to show the comparative study of Transmission Loss of Muffler. In this paper, muffler is simulated by Finite Element Analysis tool Wave 1D which is used to predict muffler's transmission loss performances. Firstly evaluation of Transmission loss for cylindrical muffler is compared with 1-D Wave simulation, Comsol and Two Load method. Than after an attempt is to improve transmission loss at cut off frequency.

## II. OBJECTIVES AND MODELLING

For evaluation of transmission loss of muffler the volume of Expansion chamber is keeping constant like cylindrical muffler then the transmission loss of this shape is evaluated by experimentally and FEA. The CFD tool wave 1D is used to modelling of Helmholtz resonator which is already proven software[10][11].

Following design conditions are applied to analyzing the transmission loss of the simple expansion chamber:

1) Dimensions of test muffler, the length of expansion chamber as constant i.e., 500 mm with diameter 130 mm which is validated with transfer matrix method, two load method, wave 1-D and comsol.
2) Volume of the Expansion chamber is kept constant for throughout the modeling and analysis.
3) The volume of Helmholtz resonator calculated based on first cut off frequecy.

## III. ACOUSTIC MODULE WAVE 1-D MODELLING FOR MUFFLER

A Sound Analyzer is a testing and measurement instrument which is used to quantify the audio performance of electronic and electro-acoustical devices. Audio quality measurements covers a wide variety of parameters like level gain, noise and inter modulation distortion, frequency response, and relative phase of signals. The circuit comprises of mike for taking audio input, mike interfacing assembly for sensitivity selection, low-noise mike preamplifier circuit with variable gain adjustment, bandwidth adjustment from more than one octave down to a tenth of an octave, frequency range selection from 20 Hz to 20 KHz in three bands selection. An NE5534 op-amp is used for the mike preamplifier stage because of its low input noise.[7][12] Noise level of 40 dB of gain is sufficient for most microphones, since the white noise will be played through the speakers at a moderately high level.

 

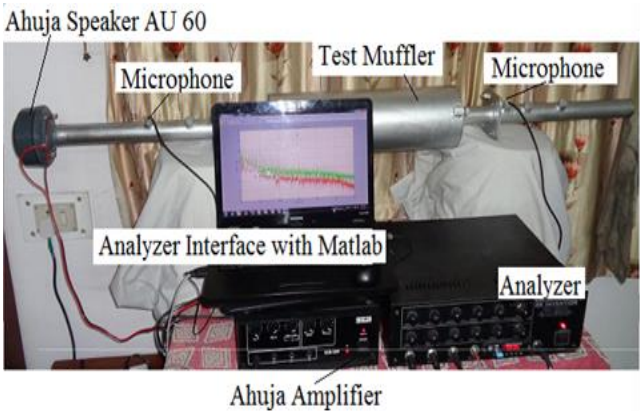


Fig. 1: Layout of Actual Experimental Test Rig Setup

## IV. POST PROCESSING BY USING WAVE 1-D AND COMSOL

WAVE is a 1-dimensional gas dynamics code which is based on finite volume method for simulating engine cycle performance. Tools using this one dimensional approach accurately predict all engine breathing characteristics. This enables engineers to Consider air system and combustion effects during analysis. A. F. Seybert model is used to compare the wave result. The working fluid was perfect air having following boundary conditions [8] [9]:

1) Gas Volume approximately: 6636500 mm3.
2) Exhaust gas Temperature: 300 K.
3) Exhaust Gas pressure: 1.0 bar.
4) Initial fluid composition: Fresh Air.
5) Upper frequency Limit: 3000 Hz.
6) Lower Frequency Limit: 25 Hz.

Model is prepared on wave build 3D with inlet & outlet boundary condition shown in figure 2.

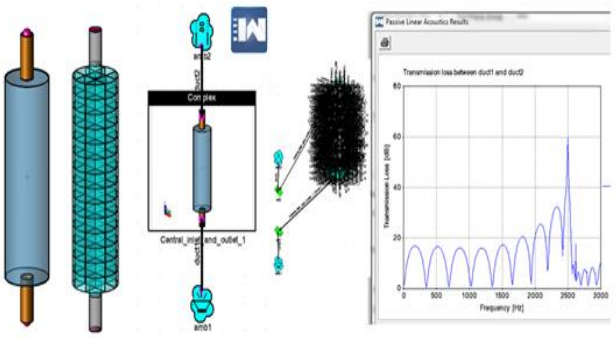

Fig. 2: GUI for Post Processing of Wave 1-D

The same dimension is simulated in Comsol tool the result shown in figure 3.

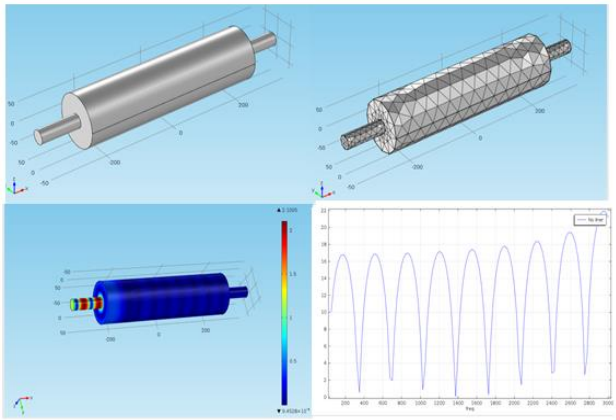

Fig. 3: GUI for Post Processing of Comsol

## V. COMPARISON OF EXPERIMENTAL AND ACOUSTIC TOOL RESULTS

Attenuation curves represent among two observations clearly shows that by the comparison with two results experimental (two load method) and FEA tools like Ricardo wave 1-D and comsol the transmission loss are equally are comparable. Small deviation is appeared with FEA tool is due to meshing parameter. Now any shape of muffler can be modeled to predict the TL measurement. In recent scenario so many complicated geometry where the practical analysis proves too expensive and complicated. Therefore the FEA Tool can be the best approach to achieve the expected outcomes regarding the transmission loss of Muffler shown in figure 4.

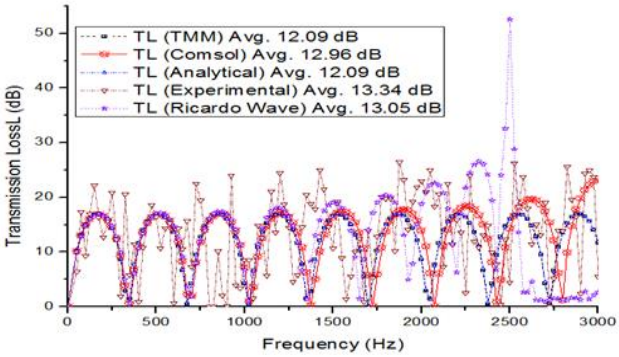


Fig. 4: Result comparison of TL for all methods

## VI. MODELING AND CALCULATION OF HELMHOLTZ RESONATOR

In the case of circular cross section expansion chambers, the dimensions of chambers are taken in such a way to observe complete wave propagation phemenon. The length to diameter ratio was also so chosen that one dimensional calculation becomes realistic for a sufficiently wide frequency range. in table 1. The first cut off frequency is shown in transmission loss curve.[2] The formula for cut off frequency is given by $f = \frac{C}{2L}$ [5]. To obtain the volume of resonator put the cut off frequency which is observed as 340 Hz shown in figure 2 and figure 4. Formula used to calculated volume of Helmoltz resonator

$$f_r = \frac{C}{2\pi}\sqrt{\frac{S_b}{L*V}}$$

C= Velocity of sound approx. 340m/s, $S_b$ = Neck area, by taking neck diameter d = 35 mm.

L= Length of neck. Assume 125 mm, V= Volume of

$$\text{resonator} = V_{resonator} = \frac{\pi}{4} * D^2 * L$$

Where the D is the diameter of Helmoltz resonator,

$$340 = \frac{340}{2\pi}\sqrt{\frac{\pi/4*(0.035)^2}{(0.0175)*(\pi/4*D^2*0.125)}}$$

With the calculation, D= 141.99 mm

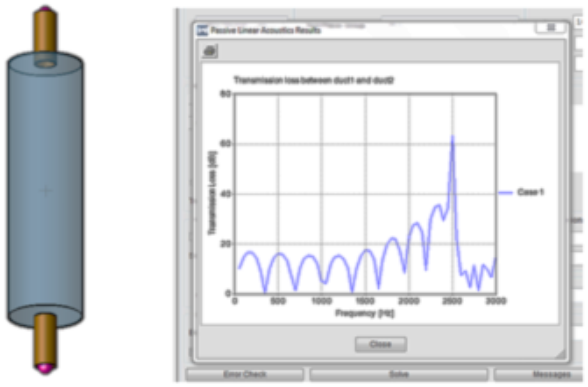

Fig. 5: TL for Pure Reactive Muffler

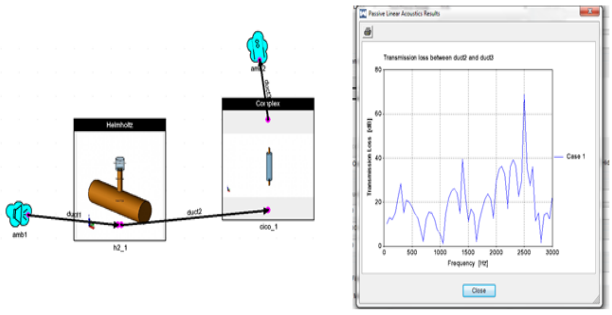

Fig. 6: TL for Pure Reactive Muffler With Helmholtz Resonator

By the comparison of figure 5 and figure 6 it appears that the first cut off frequency of 340 Hz attenuate approximately 17 dB with the combination of Helmholtz resonator.

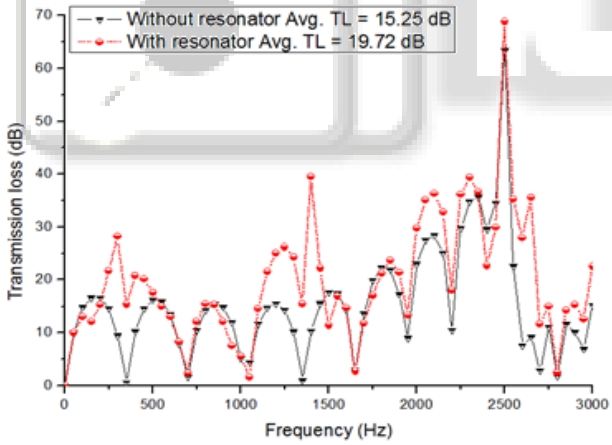


Fig. 7: TL comparison of muffler with and without resonator

## VII. Results and Discussion

This research paper shows that the results of Transmission loss of Single Expansion Muffler which are verified by experimental method as well with simulation CFD tool. The experimental results show good agreement with the numerical results. From this result it can be concluded that the developed experimental setup can measure the performance of Muffler's Transmission loss. The transmission loss is evaluated in the two cases with simple reactive muffler without resonator and with resonator, muffler having same gas volume in both the cases. The result shows that the Transmission Loss attenuated with first cut off frequency of 340 Hz as shown in figure 7 by using Helmholtz resonator. It attenuate the TL up to 17 dB at first cut off frequency. Also figure 6 shows that the resonator attenuate the noise level at low frequency zone. The avg. transmission loss is increased up to 4.47 dB by applying Helmholtz resonator.

## References

[1] Gupta A., Tiwari A.,"Improvement and validation of acoustic performance on reactive muffler with central inlet and side outlet position", National Journal of Technology, PSG, (Coimbatore), ISSN 0973-1334 Vol.11, No.3 pp 85-92, September, 2015.

[2] Yasuda T., Wu C., Nakagawa N., Nagamura K., "Studies on an automobile muffler with the acoustic characteristic of low-pass filter and Helmholtz resonator", Applied Acoustics, pp 49-57, (2013).

[3] Gupta A.K. and Tiwari A., "Comparison of Finite element analysis with an Experimental Validation on Transmission Loss Measurement for Acoustic Muffler", Journal of Automobile Engineering and Applications, Volume 1, Issue 2, pp 21-26, 2014.

[4] Amit Kumar Gupta, Dr. Ashesh Tiwari "Acoustic Characterization of Reactive Mufflers by Different Cross Sections Using One-Dimensional Analysis" Paripex - Indian Journal Of Research Vol 2 , Issue 3 , March 2013.

[5] Helmholtz H. V., On the Sensations of Tone, (1954).

[6] Gupta A.K. and Tiwari A.," Measurement of Sound Transmission Loss on Straight and Zigzag Perforated Concentric Tube Muffler with Constant Porosity", International Journal on Emerging Technologies, ISSN 2250–2459, Volume 6, Issue 1, pp 35-40, 2015.

[7] M.L. Munjal, "Acoustics of Ducts and Mufflers", John Wiley & Sons, (1987).

[8] Amit Kumar Gupta, Dr. Ashesh Tiwari "Modeling For Transmission Loss Prediction Of Different Shapes Of Acoustic Muffler With An Experimental Analysis " Journal Of Experimental & Applied Mechanics, Vol 6, No 1 (2015).

[9] Gupta A.K. and Tiwari A., "Performance of Transmission Loss on hybrid muffler by using rockwool and glass wool as a absorbing materials" International Journal of Advances in Materials Science and Engineering (Australia), ISSN: 2201-2311, Vol.4, No.4, pp -49-57, 2015.

[10] Lima K., Arcanjo Lenzi, Renato Barbieri, "The study of reactive silencers by shape and parametric optimization techniques", Applied Acoustics, pp 142-150, (2011).

[11] Gupta A.K. and Tiwari A. "Enhancement on Sound Transmission Loss for Various Positioning of Inlet and Outlet Duct of the Muffler", International Journal of Engineering and Manufacturing (Hong Kong), ISSN: 2305-5982, IJEM-V5- N4, 2015.

[12] International Standard (10534-2), Acoustics - Determination of sound absorption coefficient and impedance in impedance tubes.

 