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Acoustical Performance of Pure Reactive Muffler with Central Inlet and Central Outlet Configuration

Amit Kumar Gupta[#1], Neha Mathur [*2]
[1,2]Mechanical Engineering Department, Institute of Engineering & Technology - Devi Ahilya University, Indore (MP),INDIA

Abstract*— This paper investigates the acoustic performance of a simple Expansion chamber Muffler for different dimensions by taking same volume. Muffler is the most popular device used to reduce exhaust noise. The acoustic wave Propagates outwards from the source the intensity of the signal is reduced with increasing range due to: Spreading and attenuation.. Transmission loss (TL) of a silencer is predicted by Transfer Matrix method. TL for Five muffler configurations of different dimensions, with same volume has been analyzed. The influence of different structure dimensions of the simple expansion chamber muffler on its acoustic performance was studied. In this paper, the principles of TMM for calculating the transmission loss (TL) of a muffler are used. Results show that by adopting suitable dimensions of the muffler it is possible to improve acoustic performance of mufflers.
Keywords*—Transfer Matrix Method, Simple expansion chamber muffler, Transmission loss

I. INTRODUCTION

Noise from automobile is the one of the major source of noise pollution to the environment. There are different parameters that describe the acoustic parameters of muffler. These include the noise reduction (NR), the insertion loss (IL) and the transmission loss (TL). Noise Reduction (NR) is defined as the sound pressure level difference between two points in a system. Insertion loss (IL) is the loss of signal power resulting from the insertion of a device in a transmission line [1]. Transmission loss (TL) is the accumulated decrease in acoustic intensity as an acoustic pressure wave propagates outwards from a source. Transmission loss (TL) is the most important criterion used for the evaluating the performance of muffler because I can be calculated easily from the known dimensions of the muffler.[2] A muffler is an important noise control element for reduction of machinery exhaust noise, fan noise and other noise sources involving flow of a gas. Basically, muffler is designed for two reasons: 1) High noise attenuation performance, a basic necessity of a muffler. 2) Minimum back pressure, it represents the extra static pressure acted by the muffler on the engine. Mufflers are of two types: the reactive type and absorptive type. Reactive mufflers work on the principle of impedance mismatch by use of sudden changes in the area of cross-section, perforated elements, resonators etc. Absorptive filter have absorptive material lined on the inside of the ducts. The linings absorb acoustic energy and convert them to heat. It does not alter the sound produced by the source [3]. To design a complete muffler is a very complex task because every element of its is selected by considering its acoustic performance and its effect on the complete system of simple expansion chamber muffler for predicting the acoustic performance of muffler.

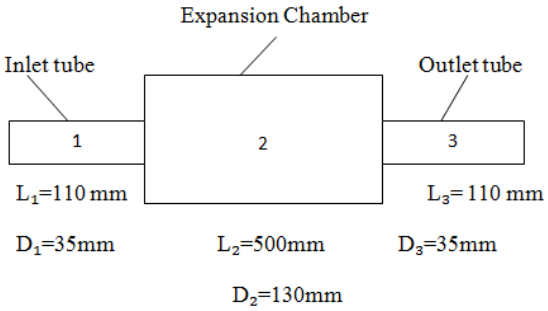

Fig. 1 Central inlet and Central outlet muffler

The muffler shown in Figure 1- consists of expansion chamber, inlet tube and exhaust tube. The diameter of inlet and outlet tube is 35 mm, both are having equal length of 110 mm. expansion chamber is a circular cross section of 130 mm diameter and 500mm length. The exhaust gases enter through the inlet tube and exit through the right pipe [4]. Acoustic performance of a

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simple expansion chamber muffler is represented by the repeating dome shaped transmission loss curve.

II. METHODOLOGY

The transfer matrix method (TMM) use the transfer matrix of a muffler element as a function of the element geometry, state variables of the medium, mean flow velocity, and properties of duct liners, if any [5]. The TL for the central inlet and central outlet expansion chamber shown in Figure 3 was measured by transfer matrix method. The numerical analysis is carried out using Matlab program. The air density and speed of sound are taken as $1kgm^{-3}$ and 340 $msec^{-1}$ respectively. In these cases a frequency of maximum frequency of 3000 Hz is considered with a frequency resolution of 2 Hz. The volume of muffler is considered of .00663325 m^3. By taking same volume, dimensions have to be varied in this research work. This transfer matrix approach allows the calculation of the acoustic performance of a pipe with multiple elements by forming a transfer matrix for each individual element and then successively multiplying by a cumulative total matrix. The TMM approach takes the muffler system under study and separates it into individual components (subsystems) consisting of straight pipes, an expansion, and a contraction, which is shown below in Fig.2.

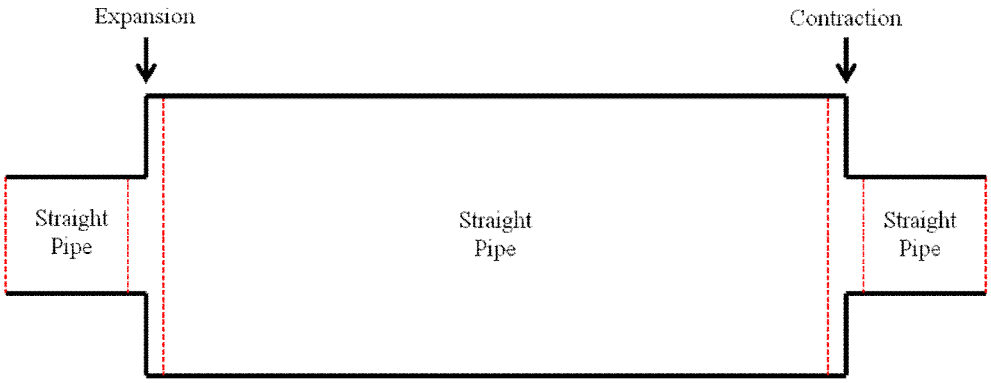

Fig. 2: Schematic of Subsystem Components Define Muffler System

As expressed in **Error! Reference source not found.**, these subsystem components can be described as 2x2 matrices in terms of the pressure and particle velocity at each boundary by taking into consideration plane wave theory and average flow velocity. Considering a muffler as shown in figure 2, the transfer matrices are

$$T_1=\begin{bmatrix}\cos(kLi) & i\sin(kLi)\\ i\sin(kLi) & \cos(kLi)\end{bmatrix},\quad T_2=\begin{bmatrix}1 & 0\\ 1 & Sc/Si\end{bmatrix},\quad T_3=\begin{bmatrix}\cos(kLc) & i\sin(kLc)\\ i\sin(kLc) & \cos(kLc)\end{bmatrix},$$

$$T_4=\begin{bmatrix}1 & 0\\ 0 & So/Sc\end{bmatrix},\quad T_5=\begin{bmatrix}\cos(kLo) & i\sin(kLo)\\ i\sin(kLo) & \cos(kLo)\end{bmatrix}$$

In several muffler elements, such as sudden expansion, sudden contractions, extended tubes and perforated tubes are connected together in series, then the overall transfer matrix of the entire system is given by the product of the individual system matrices. The total transfer matrix will be $T=T_1*T_2*T_3*T_4*T_5$, it is the multiplication of all transfer matrix for individual element. For example, the muffler shown in fig.2 includes uniform tube, sudden expansion, uniform tube, sudden contraction and a straight tail pipe.

III.RESULTS AND DISCUSSION

All paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified. The TMM analysis was performed using the MATLAB code. The acoustic performance of simple expansion chamber muffler is expected to depend on the geometric characteristics. In the first configuration (refer Fig. 1) transmission loss of central inlet and central outlet muffler is obtained 12.24 db (refer Fig. 3). For different configuration, by changing the dimensions with same volume the results are shown in table 1.

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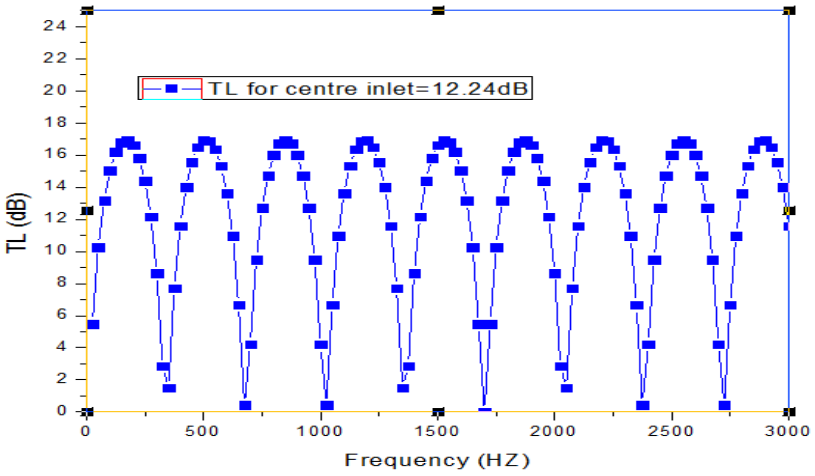

Fig. 3 Transmission loss of muffler

This figure shows that the transmission loss characteristic for muffler configuration is repetitive across the analyzed frequency range. I have compared this result by analytical as well as by FEA acoustic module also as shown in figure 4.

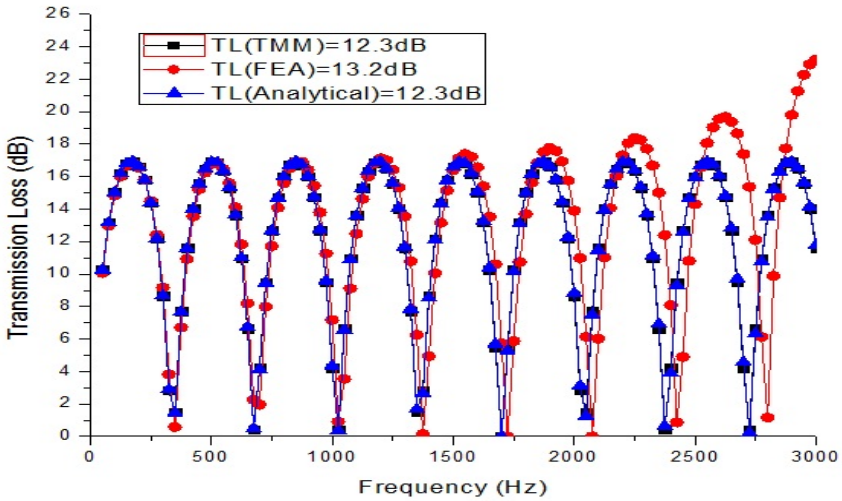

Fig. 4 Comparison of Result by analytical method and FEA acoustic module for Transmission loss of muffler

The value of transmission loss has been evaluated for different dimensions with same volume. Additionally, this figure 5 is shown that decreasing the chamber length, increases the maximum transmission loss for a given muffler configuration. The five different expansion chamber length 500 mm, 450 mm, 400 mm, 350 mm and 300 mm are considered. Expansion chamber of length having 300 mm has maximum transmission loss of 15.83dB. (Table 1).

TABLE I
DIFFERENT MUFFLER CONFIGURATION AND TRANSMISSION LOSS BY KEEPING CONSTANT VOLUME OF MUFFLER

S.No.	Length (mm)	Diameter (mm)	Average Transmission loss (dB)
1	500	130	12.24
2	450	137	12.86
3	400	145	13.59
4	350	155	14.59
5	300	168	15.83

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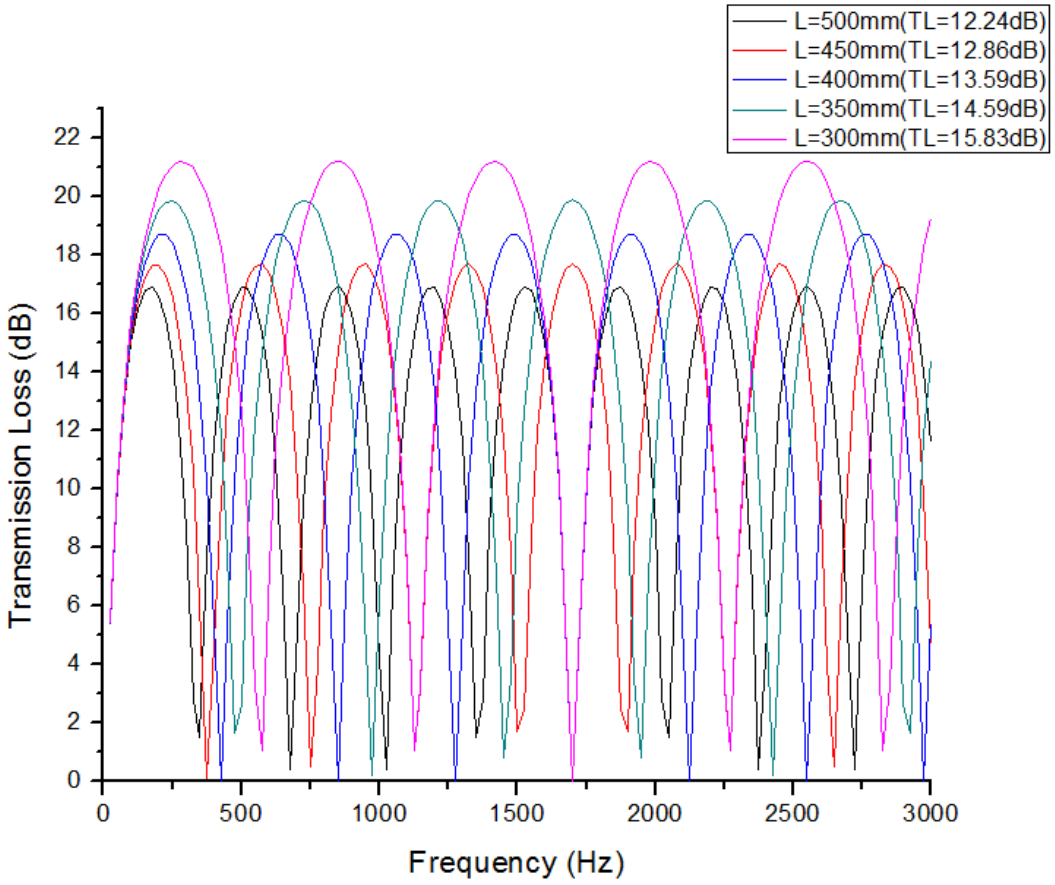

Fig. 5. Transmission Loss for different muffler configurations

IV. CONCLUSIONS

By comparing the results obtained from the Central inlet – Central outlet muffler having circular cross section noise attenuation is maximum in case of maximum diameter. The attenuation curve represents clearly that the high transmission loss can achieve by reducing the length of expansion chamber. Result shows that the TL of muffler increases with the increase of expansion ratio. For the given model transmission loss by using transfer matrix method (TMM) has been calculated and compared for different configuration. It can be concluded that the TMM is an effective tool in order to estimate the TL of a muffler.

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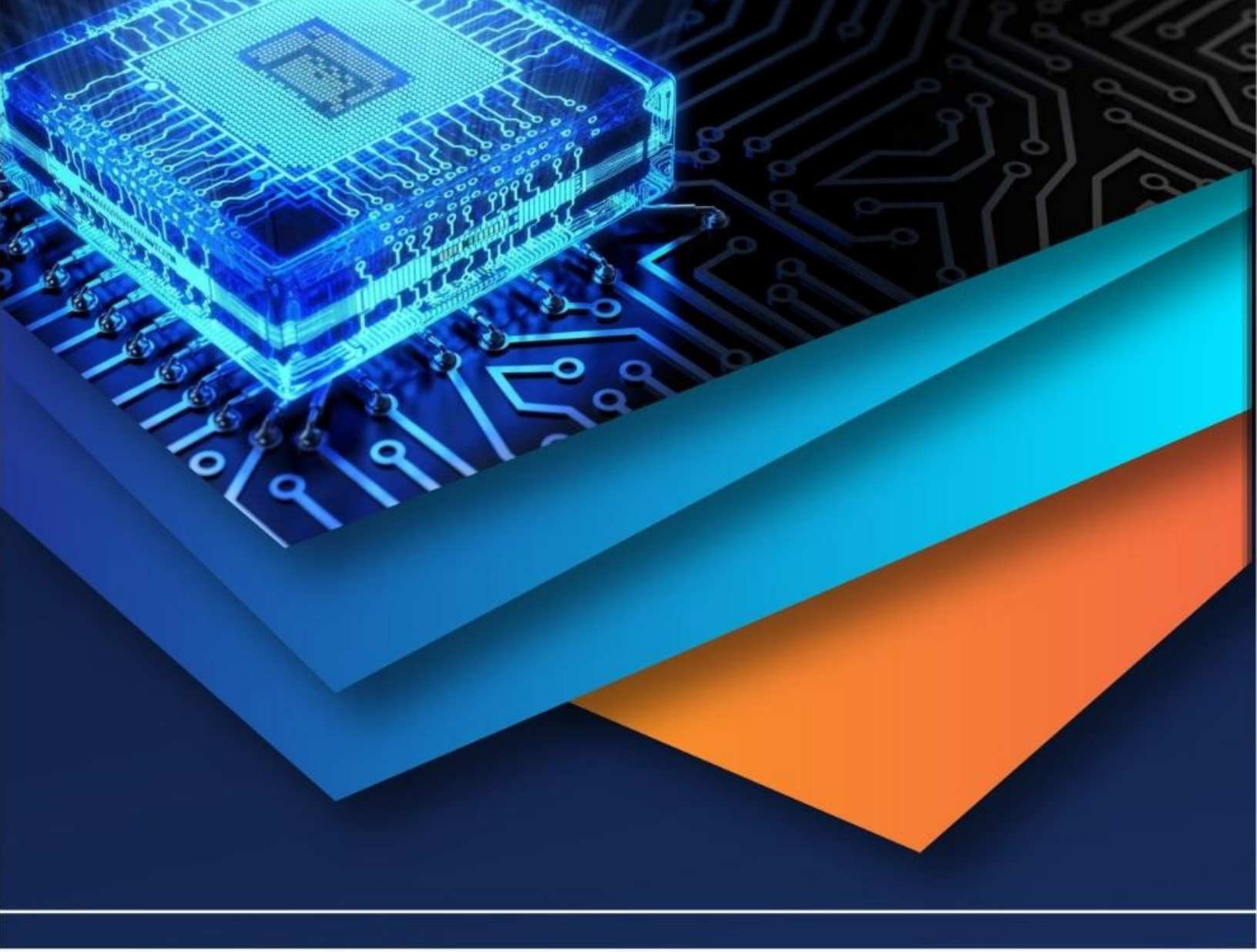

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