ISSN: 2349- 5197
Impact Factor (PIF): 2.138

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

PREDICTION OF TRANSMISSION LOSS FOR CYLINDRICAL EXPANSION CHAMBER HAVING CENTRAL-OUTLET AND SIDE-OUTLET CONFIGURATION BY TRANSFER MATRIX METHOD

Amit Kumar Gupta[1*], Neha Mathur[2]
[1*]Mechanical Engineering Department, IET-Devi Ahilya University, INDORE
[2]Student ME (Design & Thermal), IET-Devi Ahilya University, INDORE
Correspondence Author:gupta.ak4@gmail.com

Keywords: Transfer Matrix Method, central inlet-central outlet expansion chamber muffler, central inlet-side outlet expansion chamber muffler, Transmission loss.

Abstract
In this paper, the acoustic performance of a simple Expansion chamber Muffler for center inlet-center outlet and center inlet-side outlet is analyzed. Muffler is the most common device used for suppression of sound. Transmission loss (TL) of a Central inlet – Side outlet muffler is predicted by Transfer Matrix method for different positions of outlet. TL for both muffler configurations having different outlet position with same volume has been analyzed. The influence of different side outlet positions 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. Finally it is shown that by adopting suitable design of the muffler it is possible to improve acoustic performance of muffler.

Introduction
Acoustic filters are widely used for exhaust noise attenuation in vehicles, machinery and other industrial elements. Modeling procedures for accurate performance prediction had led to the development of new methods for practical muffler components in design [1]. An acoustic filter consists of an acoustic element or a set of elements inserted between a source of acoustic signals and the receiver, like atmosphere. Plane wave based models such as the transfer matrix method (TMM) can offer fast initial prototype solutions.

The transfer matrix method is based on plane wave (1-D) acoustic behavior (at component junctions). Three performance criteria were considered. These criteria were noise reduction (NR), insertion loss (IL), and transmission loss (TL). TL is the most commonly used parameter to evaluate the performance of simple expansion chamber muffler. Transmission loss is independent of the source and presumes (or requires) an anechoic termination at the downstream end. It is defined as the difference between the power level incident on the muffler proper and that transmitted downstream into an anechoic termination [2]. TL equals 20 times the logarithm (to the base 10) of the ratio of the acoustic pressure associated with the incident wave (in the exhaust pipe) and that of the transmitted wave(in the tail pipe), with the two pipe having the same cross-sectional area and the tail pipe terminating anechoically. There are so many tools available for calculating transmission loss of a muffler. They vary in terms of complexity and assumptions. However analytical method(transfer matrix method) gives accurate result. It can be very useful to evaluate performance of the muffler for relative comparison of design alternatives at design stage. [3][4][5]

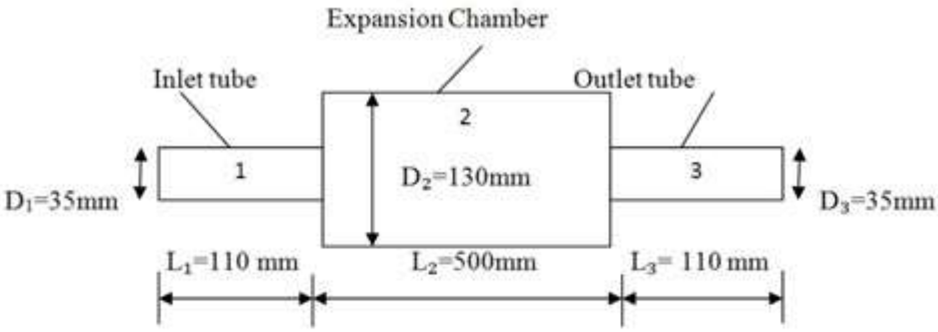

Figure1: Center inlet - Center outlet muffler

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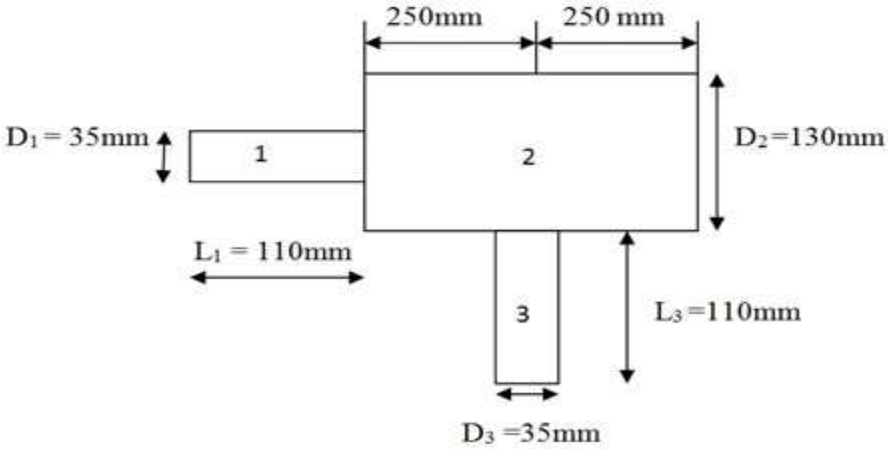

Figure2: Center inlet – Side outlet muffler

The muffler shown in Figure 1 & Figure 2 is 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 having 130 mm diameter and 500mm length. In Figure 2 the position of outlet is changed to side in place of center. The TL for both the cases is calculated and also different outlet position of side outlet is considered.

Methodology

The transfer matrix method (TMM) consists in multiplying the transfer matrices of sudden expansion, expansion chamber (a uniform tube) and sudden contraction, successively in order to obtain the overall transfer matrix[6]. The TL for the central inlet and central outlet expansion chamber shown in Figure 1 and TL for the central inlet and side outlet expansion chamber shown in Figure 2 was measured by transfer matrix method. The numerical analysis is carried out using Mat lab program [7][8]. 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 1 Hz. The volume of muffler is considered of .00663325 m^3.

This method is easy to use on computer to obtain theoretical values for the transmission loss of a muffler. The transmission loss gives a value in dB that corresponds to the ability of the muffler to dampen the noise. 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.

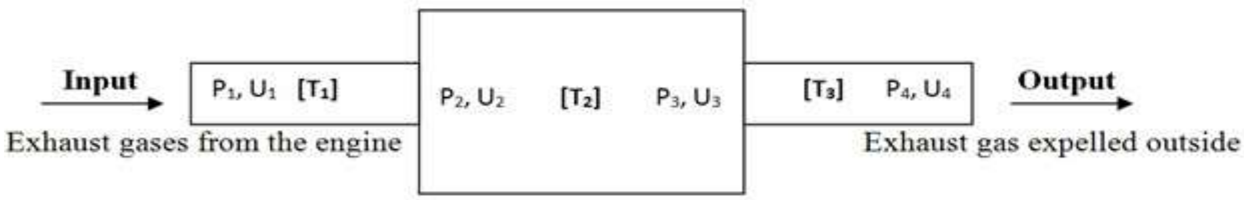

Figure 3: Acoustic filter

where,

P stands for Pressure [Pa] and U stand for volume velocity [m^3/s]

$[P1U1]=[T1][P2U2]$, $[P2U2]=[T2][P3U3]$

and $[P3U3]=[T3][P4U4]$

So,

finally: $[P1U1]= [T1][T2][T3][P4U4]$

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 $T=T_1*T_2*T_3$, it is the multiplication of all transfer matrix for individual element. For example, the muffler shown in fig.3 includes uniform tube, sudden expansion, uniform tube, sudden contraction and a straight tail pipe.

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Results & discussion

The TMM analysis was performed for center inlet- center outlet muffler and center inlet- side outlet muffler using the MATLAB code. The acoustic performance of simple expansion chamber muffler is expected to depend on the position of outlet. In the first configuration (refer Fig. 1) transmission loss of central inlet and central outlet muffler is obtained 12.14 dB (refer Fig. 4). In the second configuration (refer Fig. 2) in which the side outlet position is at 250 mm far from the starting of the expansion chamber, transmission loss of central inlet- side outlet muffler is obtained 14.94 dB (refer Fig. 4). Figure.4 shows that by changing the outlet position from center to side, the acoustic attenuation of muffler is improved. Two domes of center outlet is combined in to one bigger dome of side outlet in Fig.4, which drastically increases transmission loss at low and medium frequency range.
For different configuration, by changing the position of side outlet the results are shown in table 1. Result shows that when the distance of side outlet is increased from the inlet, the value of transmission loss will be decreased.

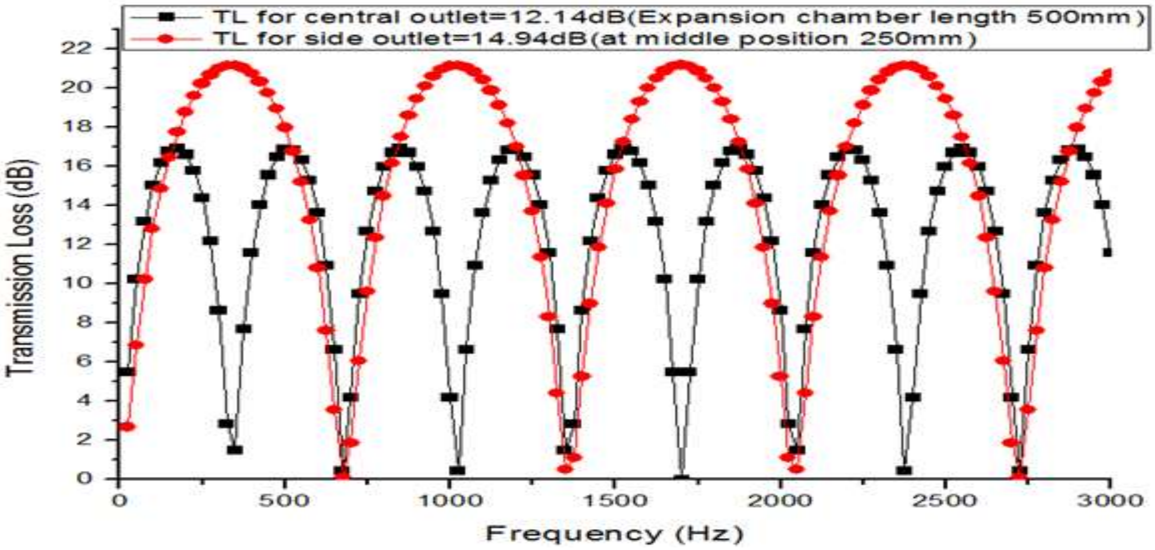

Figure 4 Comparison of Performance of central inlet-central outlet muffler with central Inlet -side outlet muffler

This result is compared by FEA acoustic module and validated. It's result is shown in figure 5.

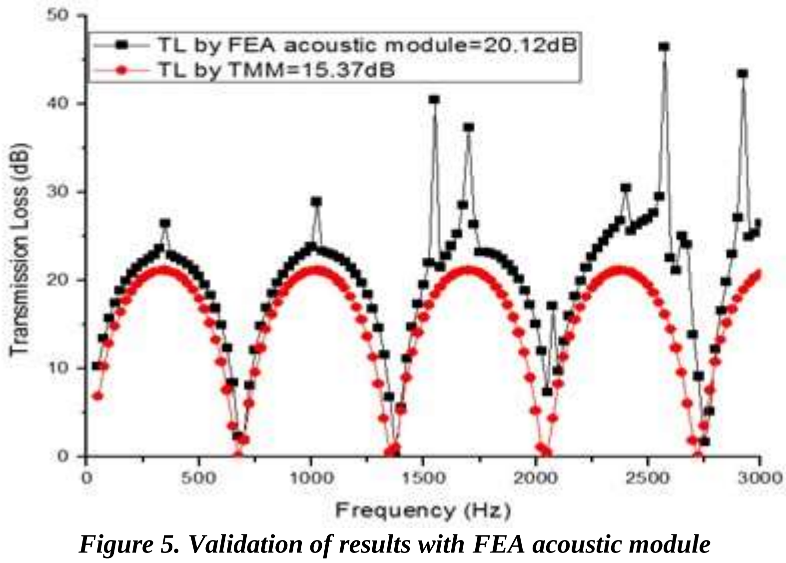

Figure 5. Validation of results with FEA acoustic module

This figure shows that the transmission loss characteristic for muffler configuration is repetitive across the analyzed frequency range. Additionally, this table is shown that changing the position of side outlet increases the maximum transmission loss for a

 ISSN: 2349- 5197
Impact Factor (PIF): 2.138

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given muffler configuration. The different outlet position considered are 150 mm, 200 mm, 250 mm and 300 mm length (refer Table 1). The value of maximum TL for side outlet position is at 150mm

Table 1. Side outlet position with transmission loss

S.No.	Side Outlet Position (in mm)	Average Transmission Loss (in dB)
1	150	15.37
2	200	15.11
3	250	14.94
4	300	14.85
5	350	14.80

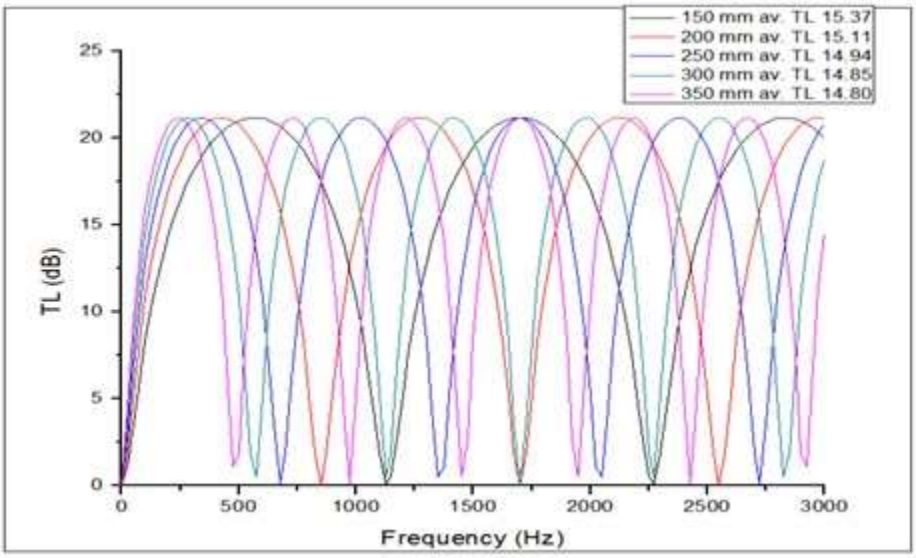

Figure 6. Comparison of TL for different positions of side outlet

Conclusions

The acoustic performances of proposed muffler were studied theoretically in the present research paper. Results showed that the attenuation performance is better for center inlet- side outlet muffler as compared to center inlet - center outlet muffler. For the given model transmission loss by using Transfer matrix method (TMM) has been calculated and compared with the FEA acoustic module for single chamber muffler which shows very good agreement. Five mufflers were employed to study the influence of side outlet position on their acoustic performance.

Attenuation curve represents that the high transmission loss can achieve by central inlet – side outlet muffler. By comparison the result obtained from the central inlet – side outlet muffler noise attenuation is more in case of side outlet having the position at 150 mm.

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ISSN: 2349- 5197
Impact Factor (PIF): 2.138

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

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