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Comparison of Noise Attenuation Level by Convergent and Divergent Cylindrical Duct with Space Constraints

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ABSTRACT

This paper shows the details of comparison of noise attenuation level by convergent and divergent cylindrical duct with space constraints by using Transmission loss parameter. Reactive muffler is noise reduction element on exhaust system. Two basic term is used for noise attenuation first is transmission loss (TL) and other is insertion loss (IL). The main aim of this paper is to use of TMM, FEA (Wave 1-D & Comsol) as well experimental method (two load method) for muffler's TL measurement for central inlet and side outlet position. Afterword to achieve by proven results analysis is done for convergent and divergent cylindrical duct. Also FEA based tool Comsol Multiphysics and Wave 1-D is used to validate and comparing the results. FEA tool is used for virtual prototyping which has already validated with various case studies. Also by comparing the experimental results by fabricated muffler with FEA results for central inlet and central outlet shows the validation of results. So the optimization can be achieved by using FEA tool by using virtual protyping.

Keywords: Transmission Loss (TL), Transfer Matrix Method (TMM), Wave 1-D.

I. INTRODUCTION

The experimental approach of two-load method is commonly used to predict the transmission loss of an acoustic filters like muffler, resonator etc. Here the TMM & finite element analysis is also used to show the comparative study of transmission loss of muffler. Muffler for an automobile is characterized by numerous parameters like insertion loss (IL), transmission loss (TL). The best used parameter to evaluate the sound radiation characteristics of muffler is transmission loss (TL). This is the one of the most frequently used criteria of muffler performance because it can be predicted very easily from the known physical parameters of the muffler. [1] Mufflers might also be used where it is directly access to the interior of a noise containing enclosure is required, but through which no steady flow of gas is necessarily to be maintained. For example, an acoustically treated entry way between a noisy and a quiet area in a building or factory might be considered as a muffling device. [2] [3] The measured transmission losses are compared with finite element analysis simulation. 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. In this paper, muffler is simulated by TMM and Finite Element Analysis tool like Ricardo Wave –1D and Comsol which is used to predict muffler's transmission loss performances as well transmission loss also it is validated by experimental two load method. The analysis of the performance of a silencer with one dimensional plane wave approach is very effective, although it is suitable for only below cut-off frequency. [4] For achieving higher TL, the expansion ratio must be correspondingly higher. However, higher expansion ratio introduces an upper frequency limit up to which the plane behavior is valid. [5] When better performance is desired in the mid to high frequency region, the central inlet and side outlet chambers are helpful. In this paper examine the performance of convergent and divergent cylindrical duct of reactive mufflers by using Wave 1-D.[7][8]

II. METHODS AND MATERIAL

1. Modeling

Here firstly validate the transmission loss measurement with experimentally and validate with the FEA result by using acoustical simulation tool which proves the compatibility of software. For evaluation of transmission loss of muffler the volume of Expansion chamber is keeping constant for cylindrical central inlet and outlet, Convergent duct and Divergent duct. Then simulation is performed for all this cases to achieve the transmission loss performance of muffler.

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

1. Volume of the Expansion chamber is kept constant for all the modeling and designing work.
2. Modeling of circular expansion chamber by keeping the length of expansion chamber as constant i.e., 500 mm.
3. Modeling of cylindrical central inlet and outlet, Convergent duct and Divergent duct by keeping the same volume. For the case of pure cylindrical duct the diameter of expansion chamber as constant i.e., 130 mm.
4. Modeling of circular expansion chamber by keeping the diameter of central inlet and central outlet tail pipe as constant i.e., 35 mm.
5. Modeling of circular expansion chamber by keeping the length of Inlet tail pipe and Outlet tail pipe as 100 mm.

2. Validation Experimental and Fea Acoustic Module Results

Sound analyzer consists of two assemblies one for input signal (Green Color) which refers to upstream and another for output signal (Red Color) which refers to downstream with computer interfacing. The differences of FFT of these two signals are analyzed in Matlab based sound spectrum software which is developed by the author Dr. Amit Kumar Gupta. The difference of upstream and downstream sound pressure level is calculated as transmission loss. Our circuit provided the sensitivity, frequency and range selection facility.

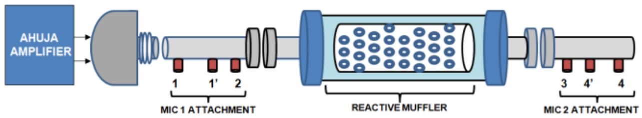

Figure 1 : Schematic Layout of Test Rig

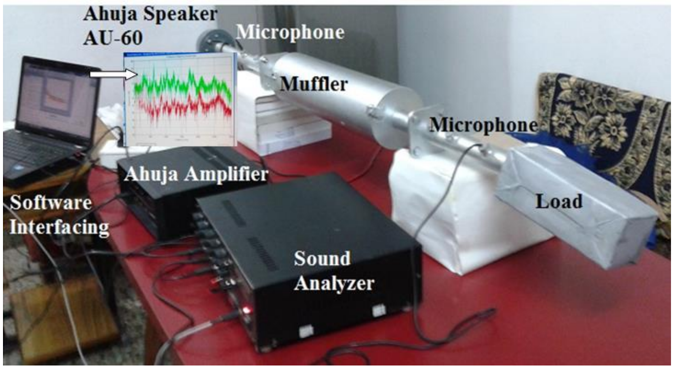

Figure 2: Muffler Transmission loss measurement setup with load

The experiment is performed for frequency range of 1 to 3000 Hz. The readings are taken in two slots with two locations 1-1' and 4-4' which is shown in figure respectively to achieve desired frequency range. The locations 1-2-3-4 are used for measuring pressure in frequency range 10-400 Hz, while the locations 1'-2-3-4' are used for measuring pressure in frequency range of 400-3000 Hz. Two microphones are used for measurement, which are sufficient for measurement of transfer function between sound pressures measured at two locations.[4] All other locations except locations where microphone are inserted are sealed with rubber cap to avoid sound leakage. [6].

Now, WAVE 1-D tool which is one-dimensional gas dynamics code based on finite volume method for simulating engine cycle performance. This tool is most popular to estimate transmission loss (TL).

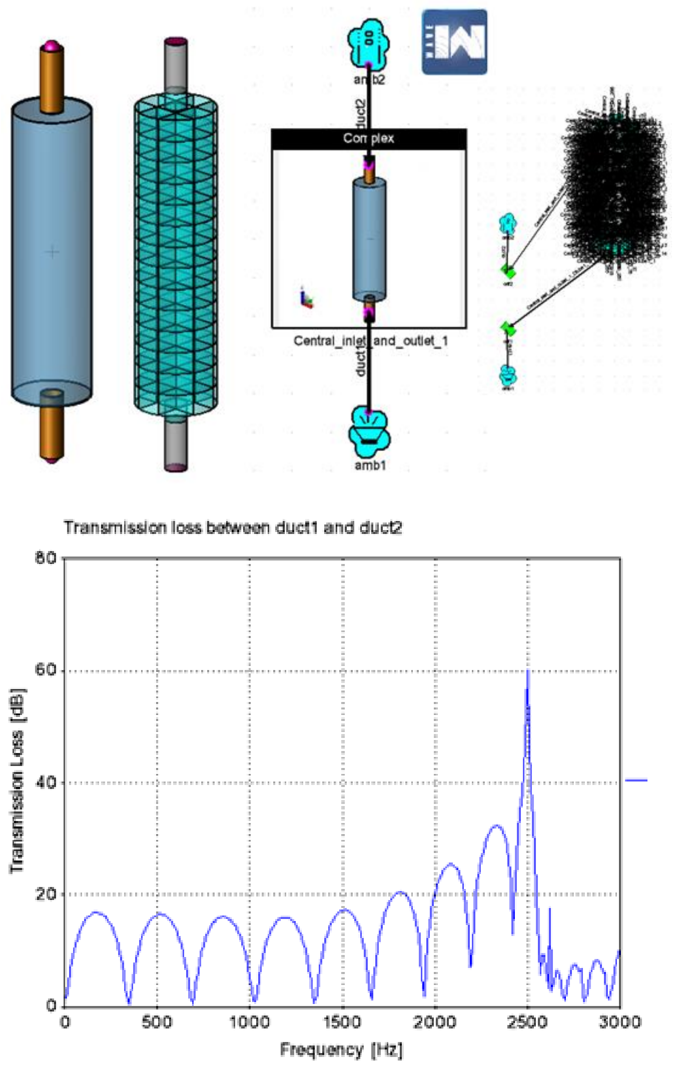

Figure 3: GUI for Post Processing of Wave 1-D.

3. Comparison of Experimental And Wave 1-D 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 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.

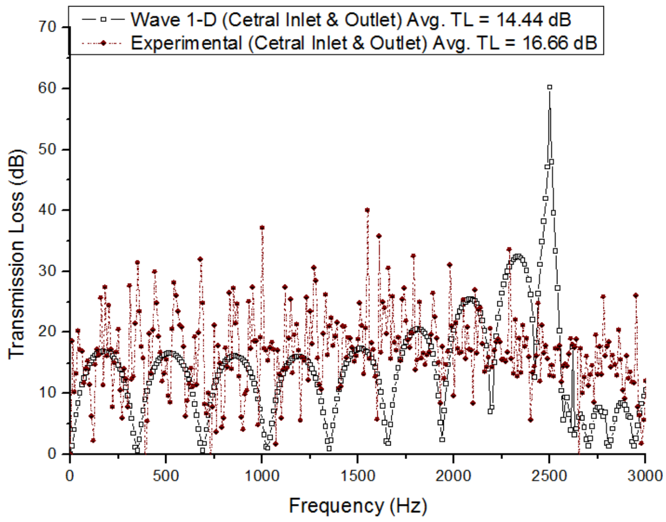

Figure 4: Result comparison of TL for two methods

4. Simulation of Convergent And Divergent Cylindrical Duct

In the case of expansion chambers, the dimensions of chambers are taken in such a way to observe wave propagation phemenon. The length to diameter ratio was also so chosen so that one dimensional calculation becomes realistic for a sufficiently wide frequency range. The transmission loss has been chosen as suitable magnitude representative of the frequency response of a given muffler. The volume of the duct is keeping constant 6636500 mm^3 in all the three case including cylindrical central inlet and outlet, Convergent duct and Divergent duct. In figure 5 amb1 (Acoustic Piston) shows the inlet point and amb2 (Anechoic Termination) for outlet point of the duct.

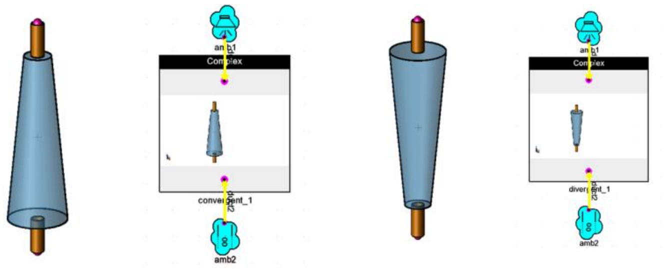

Figure.5: Convergent and Divergent Cylindrical Duct

Table 1: TL results of Circular, Convergent duct and Divergent duct

S No.	Types of Duct	Constant Gas Volume	Average Transmission Loss (dB)
1	Cylindrical Duct	6636500 mm^3	15.5 dB
2	Convergent Cylindrical Duct	6636500 mm^3	20.2 dB
3	Divergent Cylindrical Duct	6636500 mm^3	20.1 dB

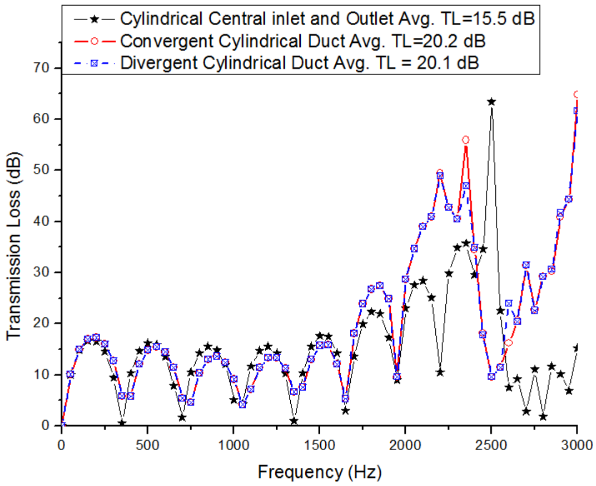

Figure 6: Transmission Loss for Convergent, Divergent and Cylindrical Duct

III. RESULTS AND DISCUSSION

The transmission loss is evaluated in the three cases of cylindrical central inlet and outlet, Convergent duct and Divergent duct which are having same gas volume. The result shows that the maximum Transmission Loss achieved in case of Convergent Cylindrical Duct (20.2 dB) as compared to another two cases. Attenuation curve shows clearly that the taper muffler can attenuate the noise level from medium to high frequency zone only. In low to mid frequency zone the behavior of all the here cases are same.

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