NOISE ATTENUATION MEASUREMENT FOR VARIOUS OVALITY PARAMETERS OF AN ELLIPTICAL CHAMBER MUFFLER

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ABSTRACT

The paper shows the measurement of the sound transmission loss of elliptical chamber muffler having different ovality parameters. 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 used as a simulation tool. This paper is investigating the shape of muffler which is capable to reduce noise level. A silencer is an important noise control element for reduction of exhaust noises 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).

Keywords: *Elliptical Cross Section Muffler, FEA Acoustic Module- Comsol, Sound Transmission loss,*

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1. INTRODUCTION

The UK based term muffler (silencer in US, or back box in Irish English) is a device for reducing the amount of noise emitted by the exhaust of an internal combustion engine [1]. In recent scenario growths of automobile vehicle are in increasing day by day. Basically a 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). 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 performance of a muffler. [5] 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] Finite Element Method is also used to show the comparative study of Transmission Loss of Muffler. Muffler Designing is a complex function that affects the noise characteristics and fuel efficiency of the vehicle. In this paper, muffler is simulated by Finite Element Analysis tool Comsol is used to predict muffler's transmission loss performances. As well Muffler's Transmission loss also predicted by Two Load Method [12]. Firstly evaluation of Transmission loss for cylindrical muffler is compared with 1-D Wave simulation, Comsol and Two Load method than after transmission loss is evaluated with various ovality ration of elliptical cross section muffler.

2. OBJECTIVES AND MODELLING

For evaluation of transmission loss of muffler the volume of Expansion chamber is keeping constant like cylindrical muffler then changing the cross section of muffler with rectangular and square cross section. Than the FEA result simulate by using acoustical simulation tool wave 1-D, comsol 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. Modeling of elliptical cross section muffler by keeping the constant gas volume throughout the chamber.

3. ACOUSTIC MODULE WAVE 1-D MODELLING

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.

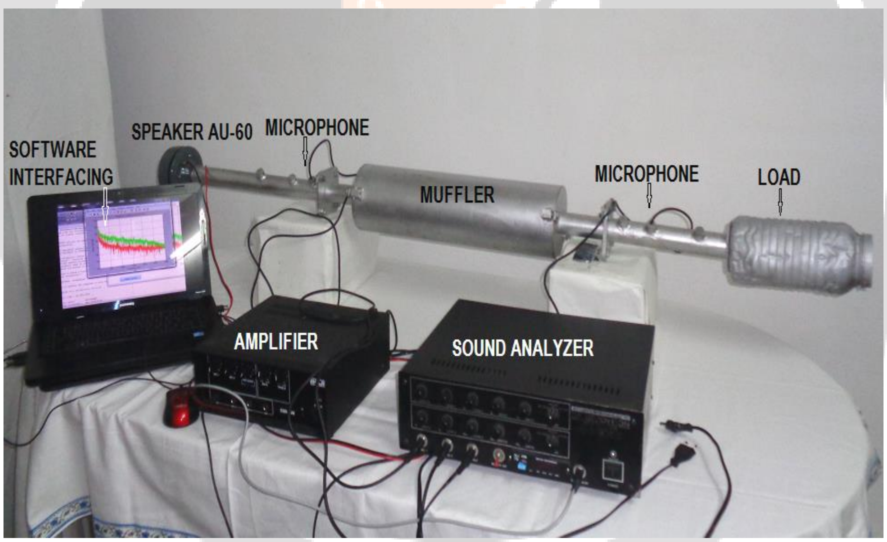

Fig. 1: Layout of Actual Experimental Test Rig Setup

4. 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 mm^3.
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.

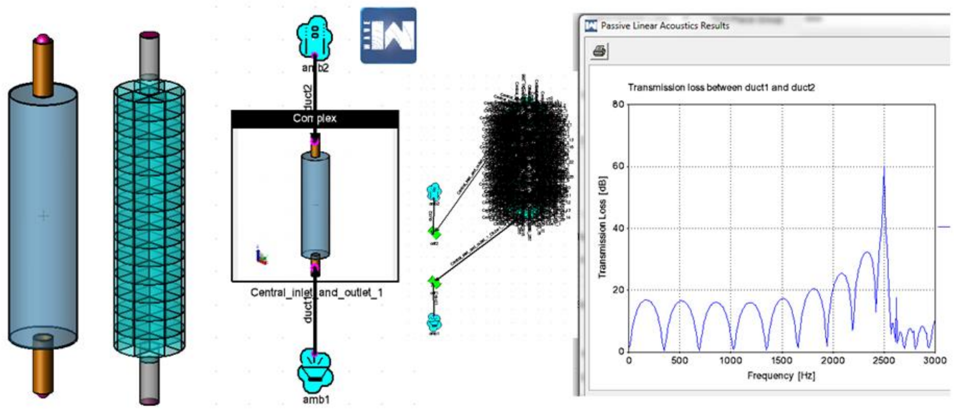

Fig. 2: GUI for Post Processing of Wave 1-D.

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

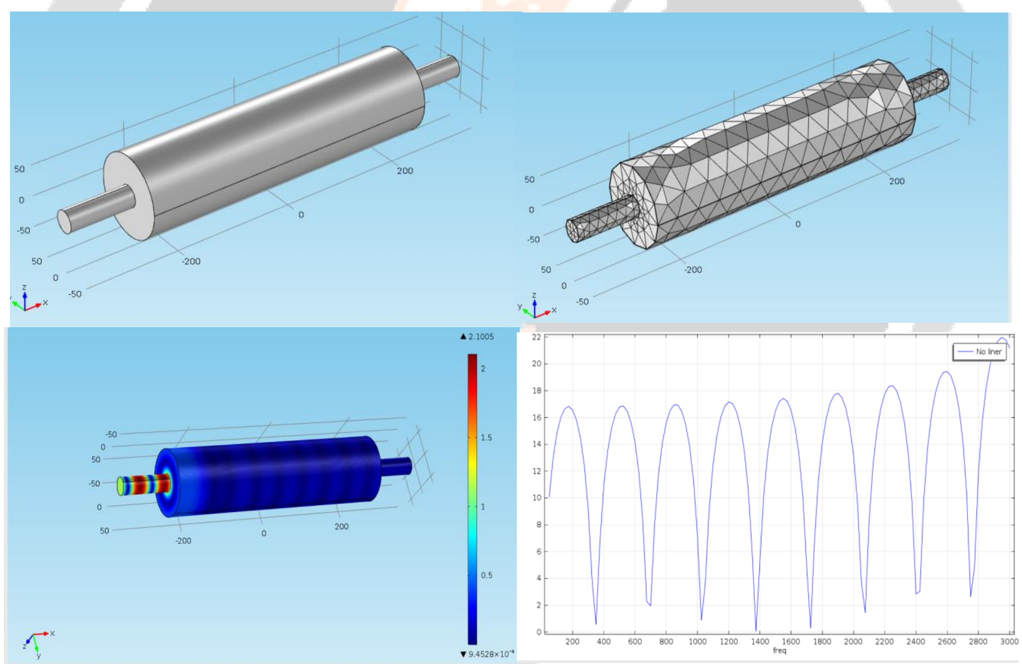

Fig. 3: GUI for Post Processing of Comsol

5. 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.

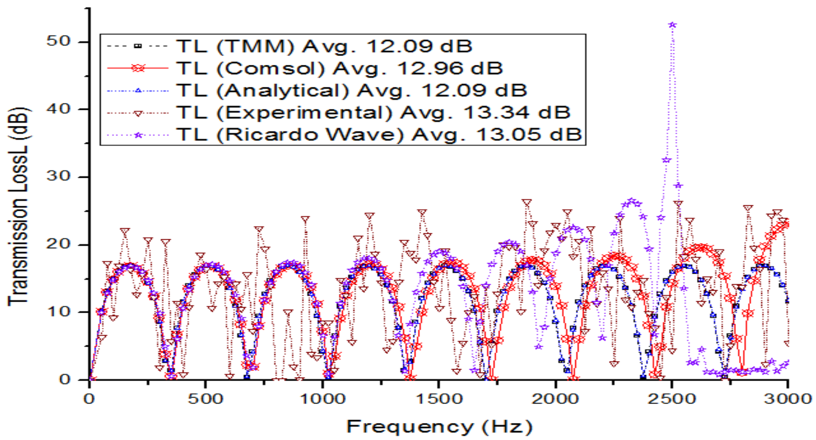

Fig. 4: Result comparison of TL for all methods

6. SIMULATION FOR ELLIPTICAL DUCT WITH DIFFERENT OVALITY PARAMETERS

In the case of elliptical cross section expansion chambers, the dimensions of chambers are taken in such a way to observe complete wave propagation phemenon. The ovality ratio is chosen that one dimensional calculation becomes realistic for a sufficiently wide frequency range in table 1. The transmission loss has been chosen as suitable magnitude representative of the frequency response of a given muffler shown in figure 5.

Table 1: Dimensional parameters of elliptical cross section duct

Case	Elliptical Expansion Chamber with major radius 'a' in mm	Elliptical Expansion Chamber with minor radius 'b' in mm	Ovality Ratio (a/b)
1	141.4	70.74	2
2	158.20	63.28	2.5
3	176.30	56.6	3
4	187	53.4	3.5

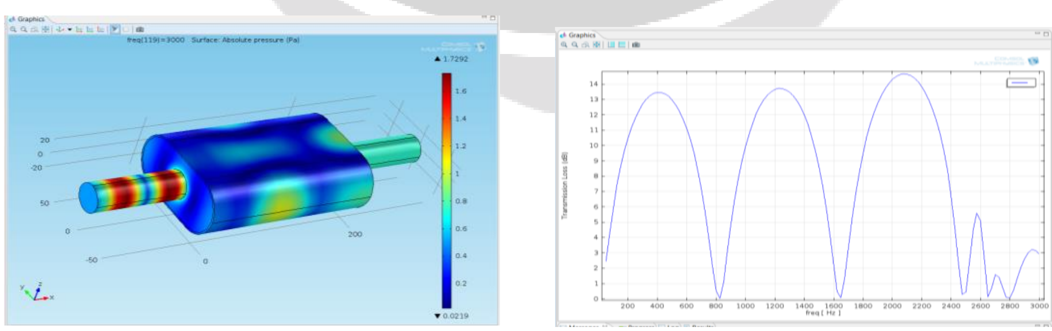

Fig.5: For case 1

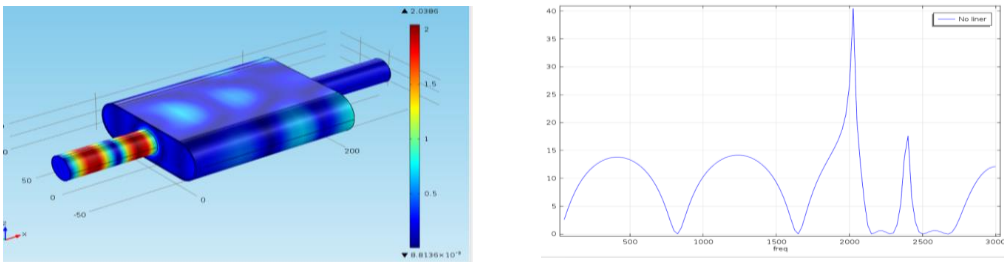

Fig.6: For case 2

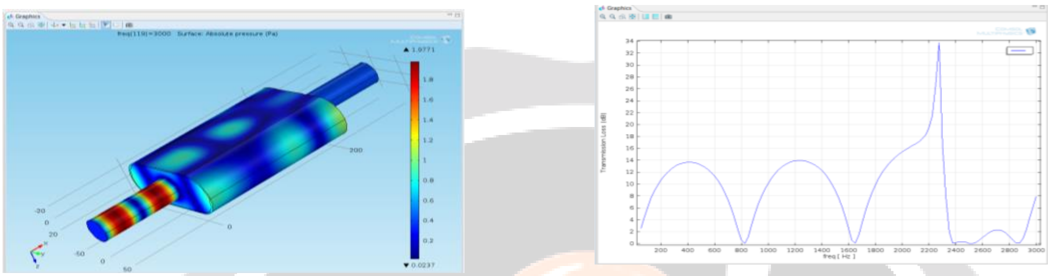

Fig.7: For case 3

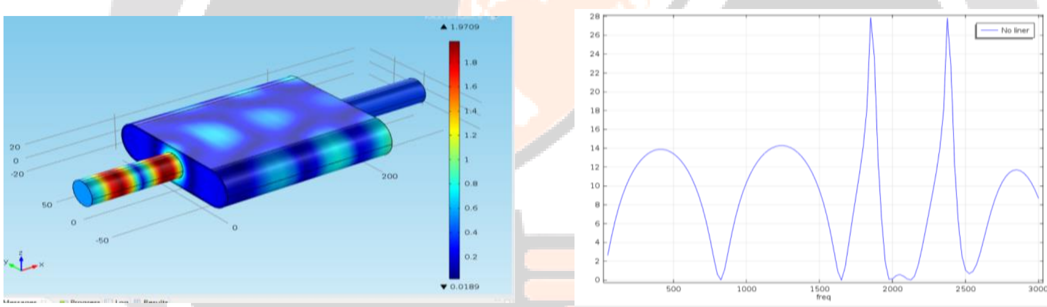

Fig.8: For case 4

Table 2: TL evaluation of elliptical cross section duct with different ovality parameters

S No.	Elliptical Expansion Chamber withmajor radius a in mm	Elliptical Expansion Chamber withminor radius b in mm	Ovality Ratio	Average Transmission Loss (dB)	Average Acoustic Pressure (Pa)
1	141.4	70.74	2	8.367781	1.72
2	158.20	63.28	2.5	8.819668	1.97
3	176.30	56.6	3	8.722845	2.03
4	187	53.4	3.5	9.074405	1.97

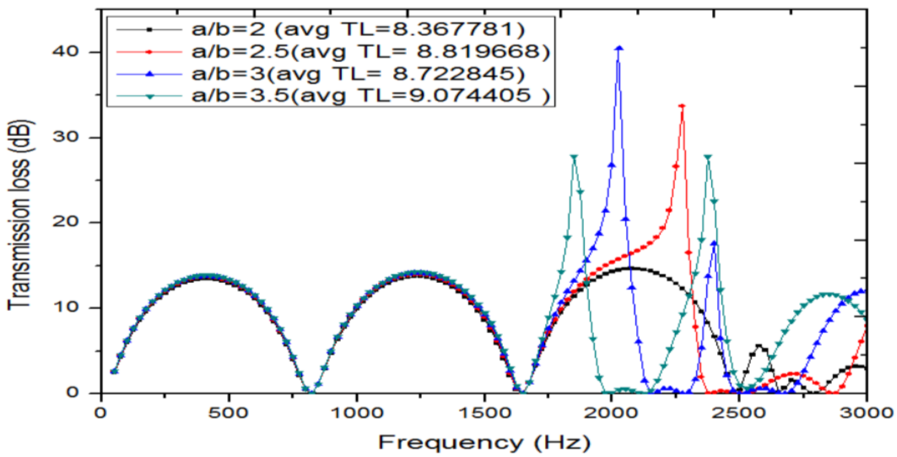

Fig.9: TL vs Frequency curve different ovality ratio of elliptical chamber muffler

7. RESULTS AND DISCUSSION

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 of square and rectangular cross section expansion chambers which are having same gas volume. The result shows that the maximum Transmission Loss achieved in case of higher ovality ratio 3.5 (9.07 dB) as compared to ovality ratio of 2. Attenuation curve shows clearly that high ovality ratio can attenuate the noise level only from low to medium zone.

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