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DESIGN VALIDATION OF THE EXISTING MUFFLER'S TRANSMISSION LOSS RESULTS WITH ACOUSTIC SIMULATION TOOL

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Abstract

Muffler is an important noise control setup for reduction of machinery exhaust noise. Mufflers are typically arranged along the exhaust pipe as the part of the exhaust system of an internal combustion engine to reduce its noise. Noise from an automotive application is the major source of noise pollution. Researcher Abdullah A. Dhaiban et.al. suggested that a three-dimensional finite element analysis has been implemented to predict the transmission loss of an elliptic expansion chamber muffler for a given frequency range. Finite element models have been established by ANSYS 12.0.1 [1]. Results obtained from the model were compared with both experimental data obtained from previous work. Further this research work is implemented by Comsol tool which shows the capability of simulation tool for the acoustical transmission loss measurement. The main aim of this paper is to design validation of the existing muffler transmission loss results with Comsol acoustic module.

Introduction

Recently the phenomenal global growths of automobile vehicle are in increasing trend. Obliviously the noise pollution has become more Challenging of the major environmental concerns and human concern in present scenario. Experimentally Two-load method is commonly used to predict the transmission loss of an Acoustic muffler. Finite Element Method is also used to show the comparative study of Transmission Loss of Muffler. 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) [4]. 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. The numerical methods are allowing the analysis of all types of acoustic mufflers. Finite Element Analysis tools may not be full proof due to many reasons such as modeling and patching errors, meshing errors including aspect ratio. It also incorporate with certain assumptions while solving the mathematical partial differential equations, insufficient boundary conditions, insufficient constraints, types of meshing elements, size of meshing. 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 previous researcher Abdullah A. Dhaiban et. al. suggested that a three-dimensional finite element analysis has been implemented to predict the transmission loss of an elliptic expansion chamber muffler for a given frequency range.[1] The measured transmission losses are compared with Finite Element Analysis simulation tool Comsol. Also muffler is simulated by Finite Element Analysis tool Ricardo Wave – 1D is used to predict muffler's transmission loss performances and validated with existing results. As well Muffler's Transmission loss also predicted by Two Load Method. 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. [6] [7] Reactive silencers, which are commonly used in automotive applications, reflect the sound waves back towards the source and prevent sound from being transmitted along the pipe. Reactive silencer design is based either on the principle of a helmholtz resonator or an expansion chamber, and requires the use of acoustic transmission line theory [2] [3].

Build up of an experimental set up based on two load method

By Two Load method, Two Loads should be kept different to keep results more stable. Generally, two loads can be two different length tubes. In this research paper two loads were achieved by outlet tube with and without absorbing material which is shown in Figure 1. The two load method is based on the transfer matrix approach. Using the transfer matrix method, one can readily obtain transmission loss of any muffler by using four pole equations from the four positions of microphones [3]. For evaluation of transmission loss of muffler the volume of Expansion chamber is keeping constant then changing the expansion ratio of muffler. 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. An Experimental Test Rig Setup is established to achieve Transmission Loss of Single Expansion Muffler. Setup consists of a noise generation system by ahuja speaker, noise propagation system and measurement of sound. The setup has following main component like noise source with I & II Stage Amplifier, Impedance tube, Sound Analyzer & Microphone.

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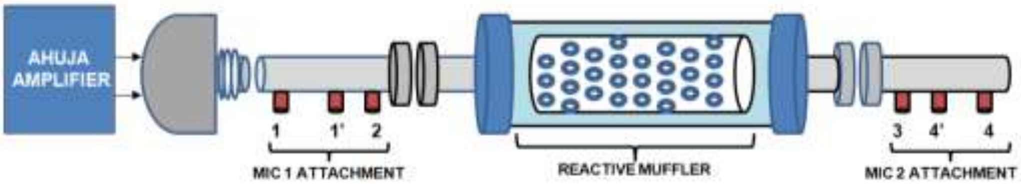

Fig.1: Schematic Layout of Two Load Method

In our setup sound analyzer consists of two assemblies one for input signal (Green Color) and another for output signal (Red Color) appeared while it will attach with computer system. The differences of FFT of these two signals are analyzed in Matlab based sound spectrum software which is developed by author Dr. Amit Kumar Gupta. This provides Noise (dB) versus frequency plot of different frequency components present in the signal. Our circuit provided the sensitivity, frequency and range selection facility [5].

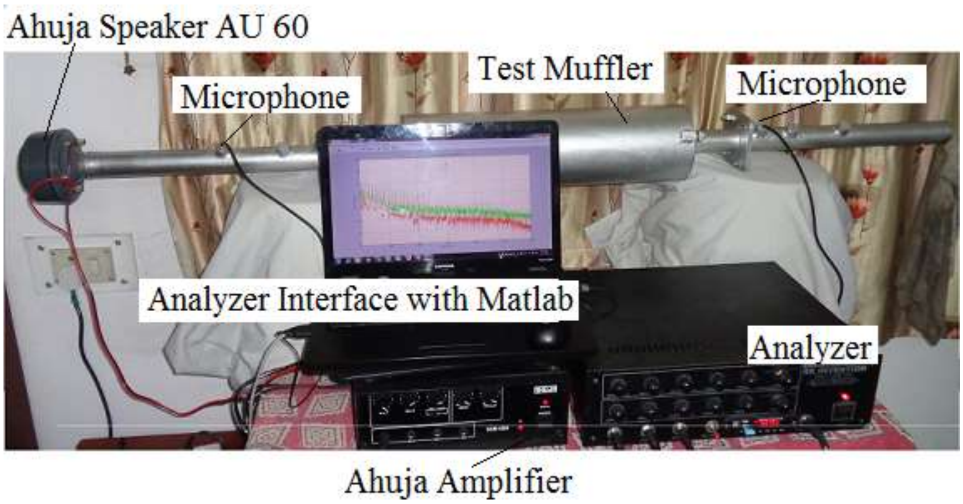

Fig.2: Development of an Experimental Two Load Method Setup [5]

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. 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. The experiment is performed for frequency range of 10 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 shown in figure 1[3]. 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 [3][6]. Two microphones are used for measurement, which are sufficient for measurement of transfer function between sound pressures measured at two locations. All other locations except locations where microphone are inserted are sealed with rubber cap to avoid sound leakage. The sound leakage is tested muffler is leak proof.

Validation of setup with acoustic module wave 1-D

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 circular expansion chamber by keeping 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.

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5. Modeling of circular expansion chamber by keeping the length of Inlet tail pipe and Outlet tail pipe as 100 mm.

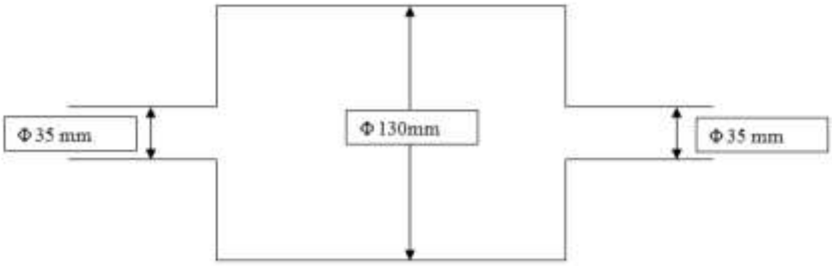

Fig.3: Test Muffler Dimensions

Following boundary condition are applied to muffler [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 and outlet boundary condition shown in figure 3.

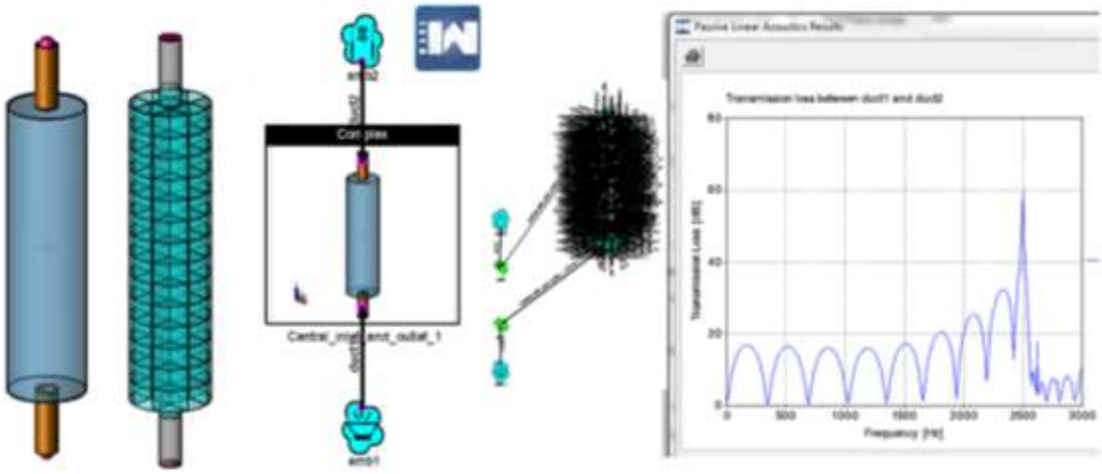

Fig. 3: Post Processing by Wave 1-D

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.

Comparison of the results

The 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 [11]. 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.

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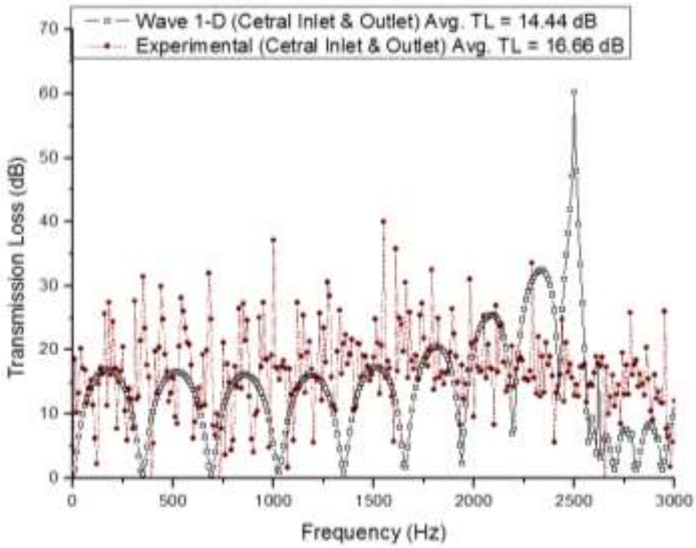

Fig. 4: Result comparison of TL by two load setup and wave 1-D

Validation of transmission loss measurement with existing system

This research paper shows that transmission loss of single expansion chamber muffler experimentally measured and also verified by simulation 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 small deviation in TL of 2 dB with the comparison of two methods may be due to leakage of sound, roughness of impedance tube, and problems in generating pure white noise in experimental setup. Abdullah A. Dhaiban, M-Emad S. Soliman, and M.G. El-Sebaie used a simple circular expansion chamber having dimension radius of the pipe is 0.6 m (60 mm) while for the simple elliptical expansion chamber is 0.42 m (420 mm) long while the pipes are 0.05 m (50 mm) long and the ovality ratio is 2.15.[1] The dimensions are shown in figure 5 and figure 6 .

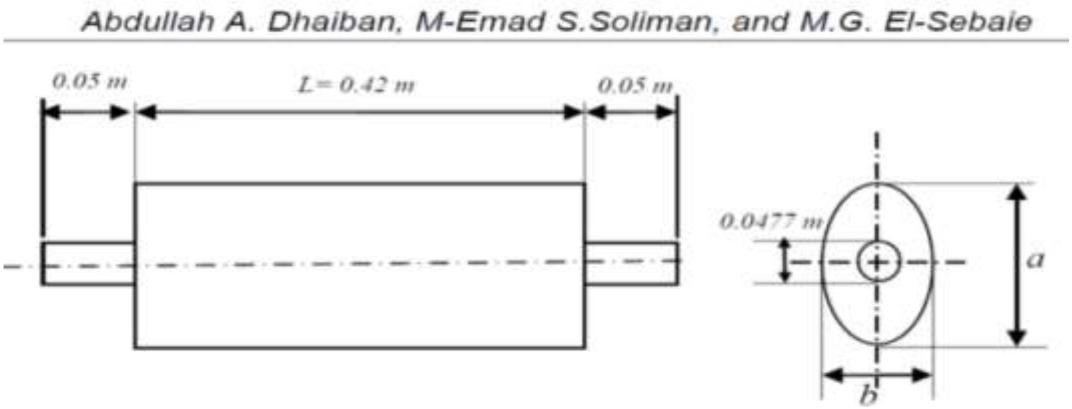

Fig. 5: Existing geometry of a simple elliptic expansion chamber

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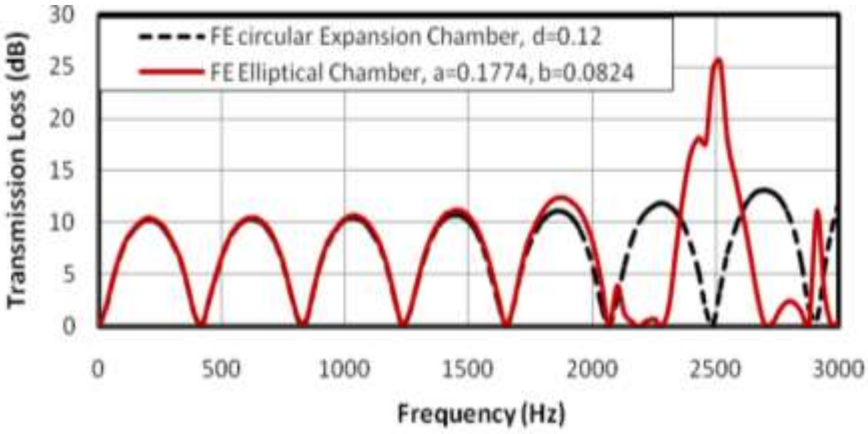

Figure 6: Existing Results of Transmission loss of muffler

Transmission Loss Measurement by FEA Acoustic Module Comsol shown in figure 7.

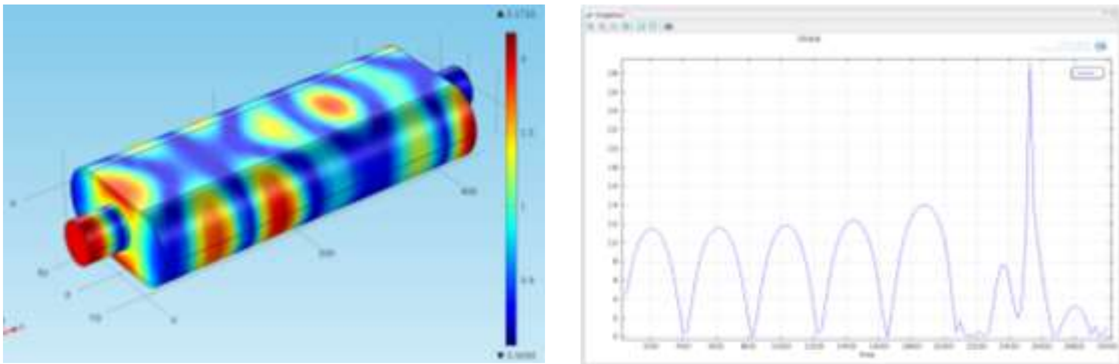

Figure 7: Result of Transmission loss of muffler with FEA

Transmission Loss measurement compared with FEA with existing same dimensions:

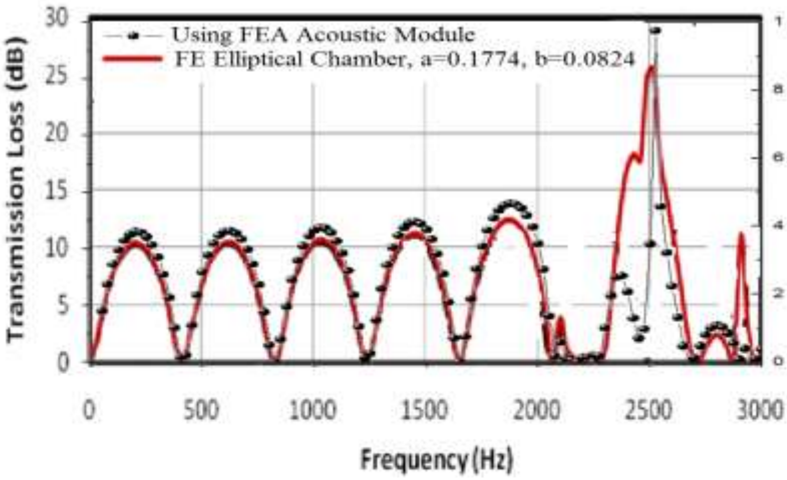

Figure 8: Result comparison for Transmission loss of muffler

Figure 8 shows that the result finding by earlier researcher is comparable with Comsol simulation tool. So that we can say Comsol is a proven software which is capable to calculate Transmission Loss of any complicated shape of mufflers.

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