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Sound Quality Performance of Pure Reactive and Pure Absorptive Muffler by Simulation

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Abstract: Paper shows the sound quality performance of pure reactive and pure absorptive muffler by using wave 1-D simulation tool. Pure reactive muffler and pure absorptive 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 Wave 1-D tool to simulate sound quality performance as well as an 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. CFD 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 prototyping. Finally absorptive muffler gives good performance.

Keywords: Transmission Loss (TL), Sound Quality, Wave 1-D.

1. INTRODUCTION

An experimental approach of two-load method is commonly used to predict the transmission loss of an acoustic filters like muffler, resonator etc. Here the finite element analysis is used to show the comparative study for sound quality of muffler.[2] Hatti, proposed the application of these advanced CAE methods used in the development of our new small Gas Turbo Direct Injection Eco-Boost engines and DCT transmissions. These new powertrains have achieved impressive levels of quietness and smoothness. [8] 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. [1] [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.[4][5] In this paper, muffler is simulated by CFD tool like Ricardo Wave –1D which is used to predict muffler's sound quality performances as well transmission loss. Also the result of Wave 1-D is validated by experimental two load method.

2. MODELLING

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.

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.

Then simulation is performed for pure reactive and pure absorptive muffler with packing density 60 kg/mm^3.

3. 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.

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.

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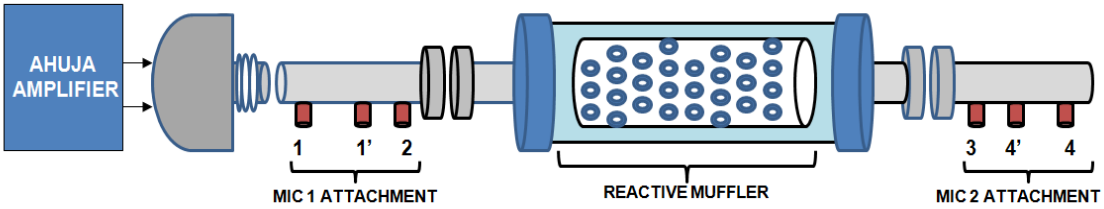

Fig.1 : Schematic Layout of Test Rig

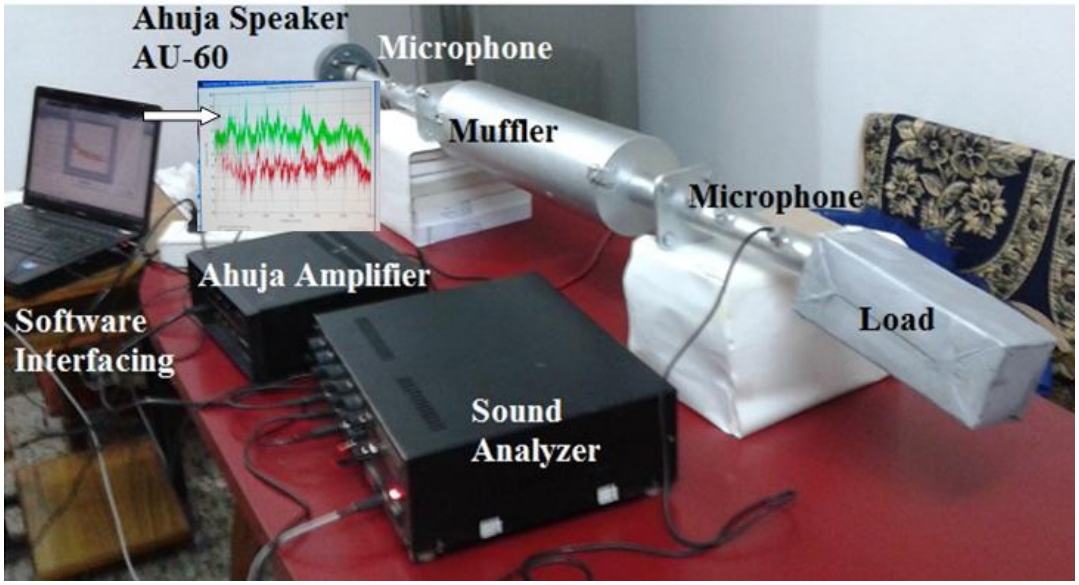

Fig. 2: Muffler Transmission loss measurement setup with load

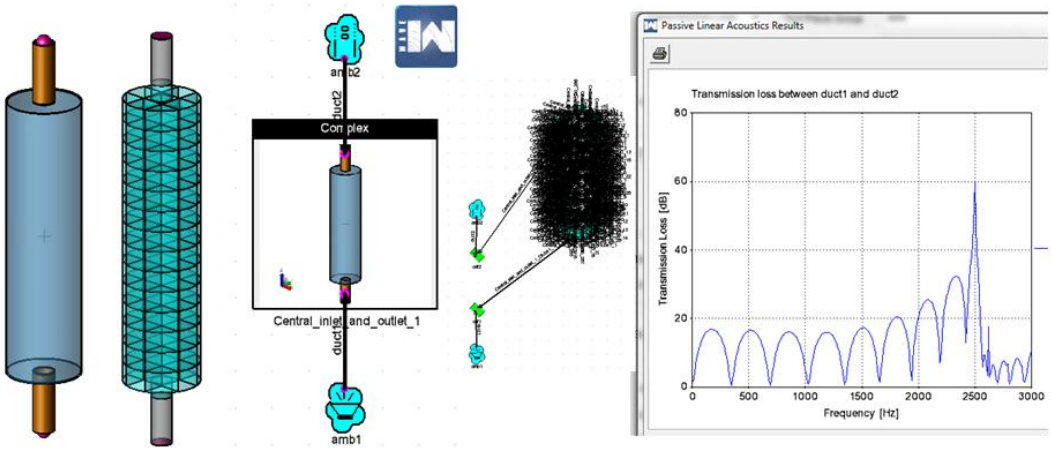

Fig. 3: GUI for Post Processing of Wave 1-D.

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).

4. 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.

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Therefore the FEA Tool can be the best approach to achieve the expected outcomes regarding the transmission loss of Muffler.

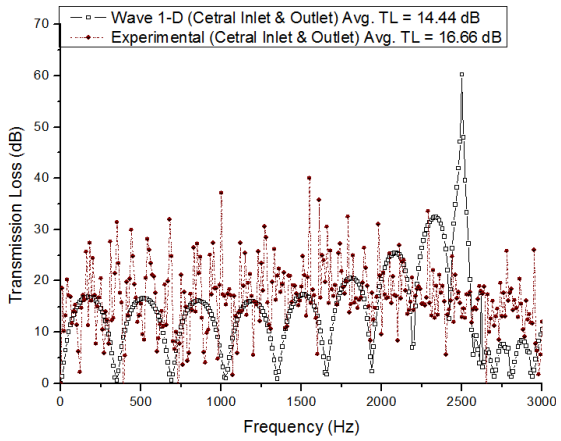

Fig. 4: Result comparison of TL for two methods

5. COMPARISON OF SOUND QUALITY FOR REACTIVE AND ABSORPTIVE MUFFLER

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.

Muffler noise levels required source information and may change based on source characteristics whereas TL (transmission loss) does not need the source information[6][7], in other words transmission loss is independent of the source characteristics. Using best design guidelines initial concepts are finalized and same will be verified virtually with help of readily available software packages with Wave 1-D.

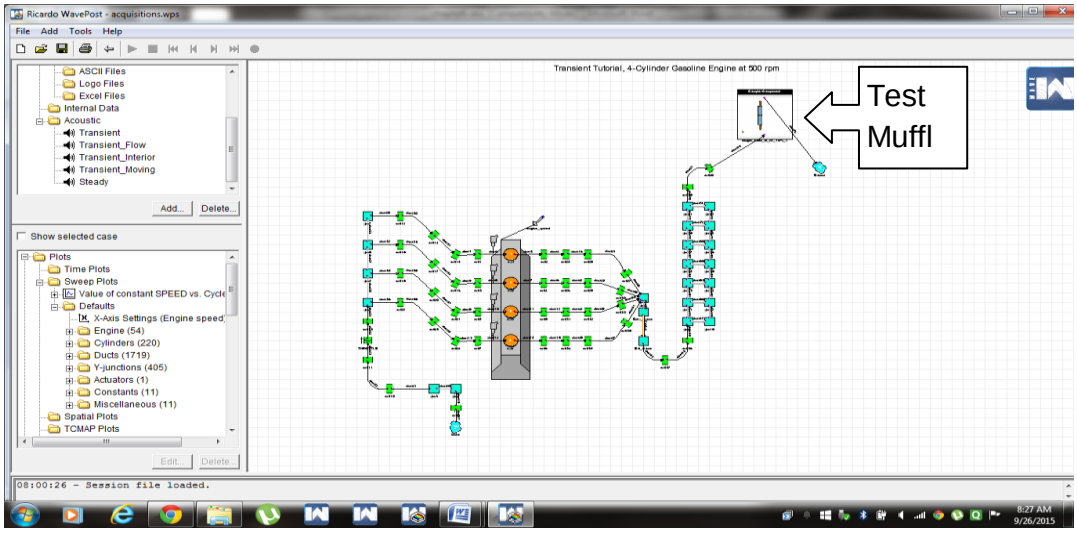

Fig.5: Test muffler with engine interface

5.1 Test muffler having single expansion Chamber

(a) Campbell diagram for Steady state condition

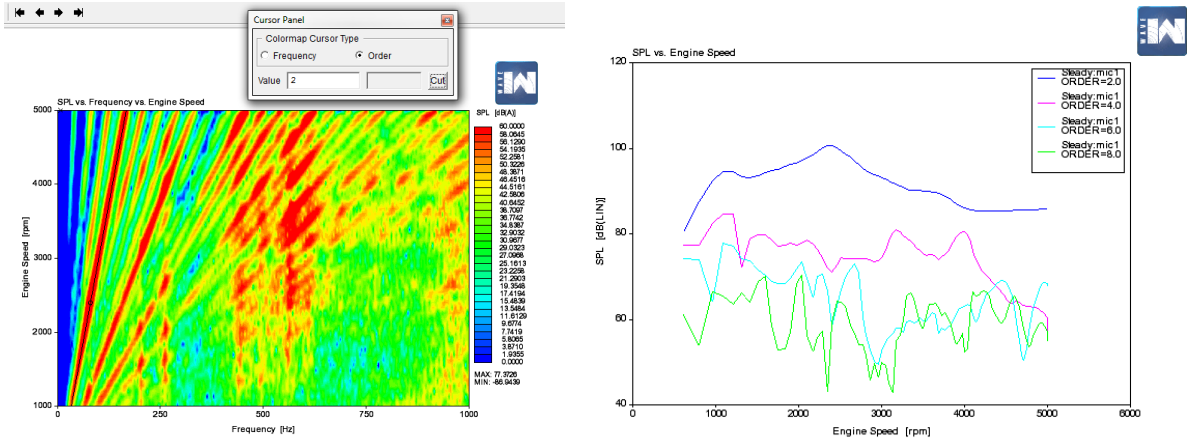

Fig.6: SPL vs. Engine speed for order 2,4,6 and 8 for test muffler

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5.2 Test hybrid muffler filled with glass wool of packing density (60kg/m^3)

(a) Campbell diagram for Steady state

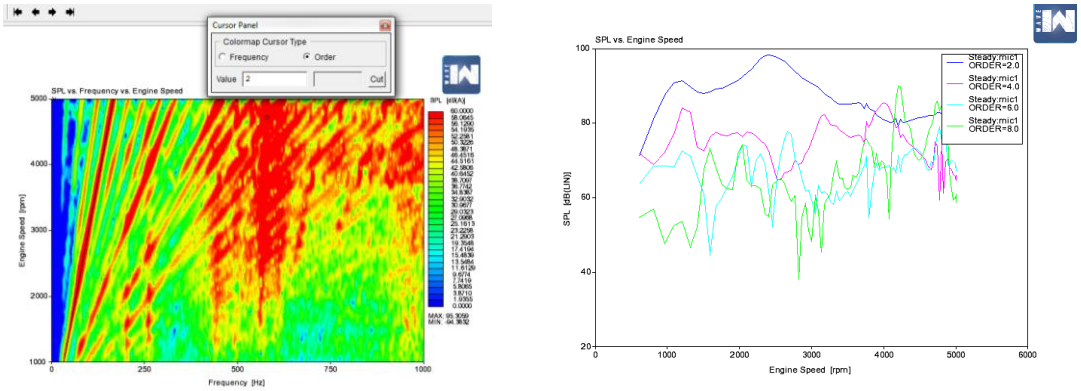

Fig.7: SPL Vs engine speed for order 2,4,6 and 8 for hybrid configuration

5.3 Comparison between test muffler and modified hybrid muffler

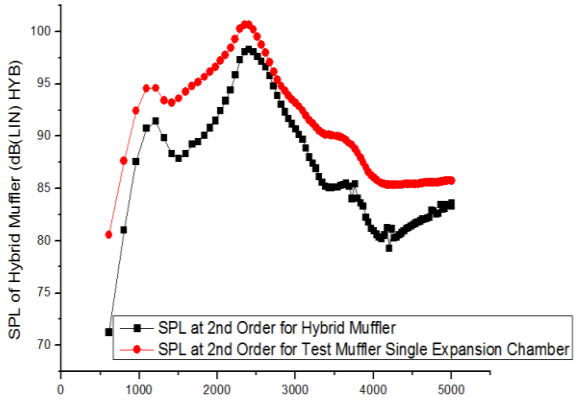

Fig.8 SPL vs. engine speed for order 2 for with and without hybrid configuration

With the comparison of both the results Hybrid muffler shows the low sound pressure level as compared to test muffler shown in figure 8.

6. RESULTS AND DISCUSSION

Vehicle sound quality measurement is essential part in view of growing economy, increased market requirement and aspirations of the customer. Now a day's government rules and norms are stringent about vehicle noise pollution. Here virtual prototype plays an important role to achieve the desired sound quality of vehicle. Figure 4 shows the validation of results. The comparison of empty muffler and empty muffler filled with rock wool from figure 6 and figure 7 shows the low sound pressure level can be achieved in case of hybrid muffler for 2nd order .

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