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Measurement of Sound Transmission Loss on Straight and Zigzag Perforated Concentric Tube Muffler with Constant Porosity

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ABSTRACT: Noise is unwanted sound. Muffler plays a vital role to reduce the noise level. Noise reduction on muffler is generally predicted by the term transmission loss (TL) and insertion loss (IL). Expansion chamber is generally used as silencing elements in exhaust systems. The main aim of this paper is to focus on FEA Tool (Wave 1-D) capability as well experimental method for muffler's transmission loss measurement for straight and zigzag perforated concentric tube muffler with constant porosity. For this purpose experimental setup which is based on two load method is used for prediction of transmission loss. Also FEA is used to validate and comparing the results. Generally FEA tool is used for virtual prototyping. So it saves the substantial amount of time and resources. By the comparison with straight and zigzag perforated pattern on concentric tube the transmission loss is more in case of zigzag pattern in both the case perforation is constant. Also by comparing the experimental results with FEA results shows the validation of results.

Keywords: Transmission Loss (TL), Perforation Pattern, Wave 1-D.

I. INTRODUCTION

In present situation the growths of automobile vehicle are in increasing trend. Noise pollution has become more challenging of the major environmental concerns and human concern in present scenario. The two-load method is commonly used to predict the transmission loss of an acoustic filters like muffler, resonator etc. Acoustic mufflers are basically of reactive muffler and absorptive muffler, combination of both the muffler. Here the finite element analysis is also used to show the comparative study of transmission loss of muffler. Reactive mufflers are used to reduce noise level related with internal combustion engine exhausts, compressors and fans. With increasingly stringent regulations for controlling noise pollution of automotive vehicles, mufflers are important part of engine system and commonly used in exhaust system to minimize noise caused by exhaust gases. 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. 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. Numerical methods are very useful for optimization of model of having complicated shapes and also where the cost is involved. But in the cases of complicated model of muffler the formation of numerical method is too difficult. Obviously 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 [1]. The measured transmission losses are compared with finite element analysis simulation. It describes 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 Finite Element Analysis tool Ricardo Wave – 1D simulation tool is used to predict muffler's transmission loss performances as well it is also predicted by two load method to verify the results. Now result concluded that the experimental measurements and Finite Element Analysis bt Eave 1-D results can employed to any shape and size of muffler [2]. In this paper mufflers with perforated tubes are analyzed by modeling the simple geometry. The locations of straight and zigzag holes on the concentric tubes introduced having diameter 5 mm.

II. MODELING OF CONCENTRIC TUBE MUFFLER

A concentric-tube resonator consists of an external cylindrical tube and a perforated internal tube located co-axially. The two ends of the external cylinder are covered by circular flanges which are mounted on the internal tube. The external tube is 500 mm long and 130 mm diameter and the internal tube has a diameter of 35 mm shown in Fig. 1.

Two different perforated tubes are considered in this paper and each tube differs in the perforation of pattern as shown in Fig. 2. Tube 1 & Tube 2 has porosity (flow percentage) of 4.908 % and 130 holes with a hole diameter of 5 mm. Tube 1 and tube 2 share the same hole diameter and the same length of 500 mm but difference is in the flow pattern of holes.

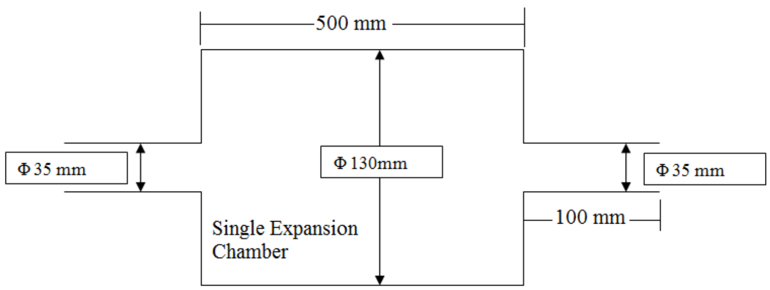

Fig. 1. Geometry of Single Expansion Chamber Test Muffler.

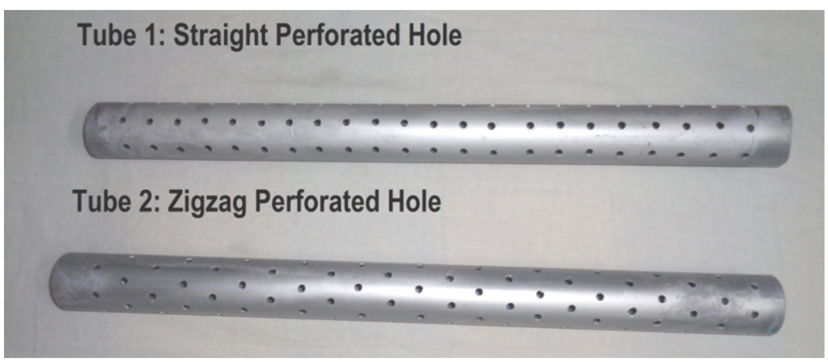

Fig. 2. Pattern of hole on tube 1 (Straight) & tube 2 (Zigzag).

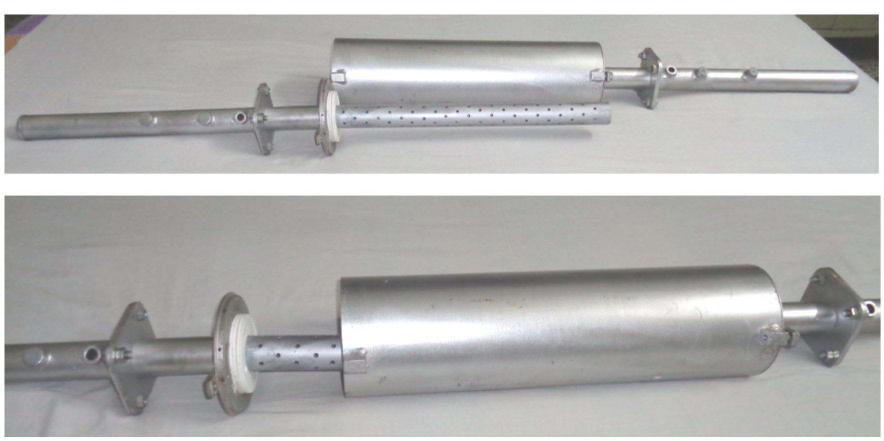

Fig. 3. Assembly of perforated tube with expansion chamber.

Tube 1 having straight pattern & tube 2 having zigzag pattern and assembly of muffler shown in Fig. 3. Now both the tubes are introduced into single expansion chamber simultaneously to observe the transmission loss performance.

III. EXPERIMENTAL SETUP

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 autors Amit Kumar Gupta and Dr. Ashesh Tiwari.

The difference of upstream and downstream sound pressure level is calculated as transmission loss. Our circuit provided the sensitivity, frequency and range selection facility shown in Fig. 4. 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 transmission loss is measured by transfer function method. This setup has following main component like noise source with i & ii stage amplifier, impedance tube, sound analyzer, load & microphone. Load consist surroundings of absorptive material.

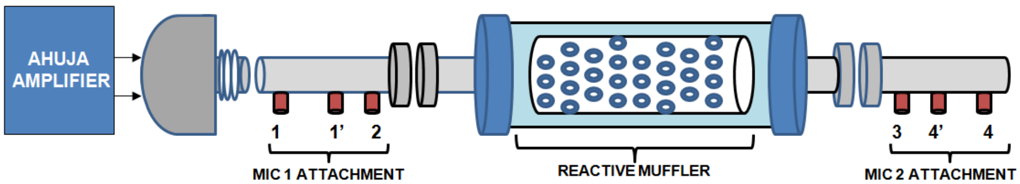

Fig. 4. Schematic Layout of Test Rig.

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 [2]. All other locations except locations where microphone are inserted are sealed with rubber cap to avoid sound leakage.

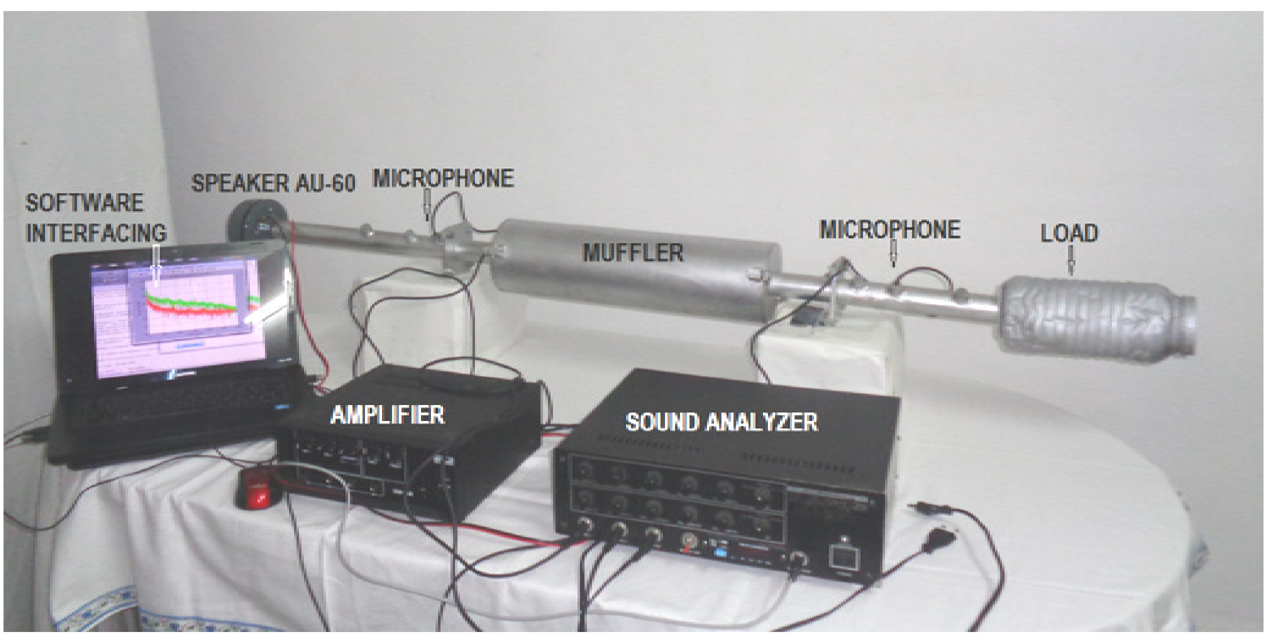

Fig. 5. Experimental Test Set Up.

IV. COMPARISON WITH FEA AND EXPERIMENTAL RESULTS

A. One-Dimensional Wave Approach

WAVE is a 1-dimensional gas dynamics code which is based on finite volume method for simulating engine cycle performance [3]. Tools using this one-dimensional approach accurately predict all engine breathing characteristics.

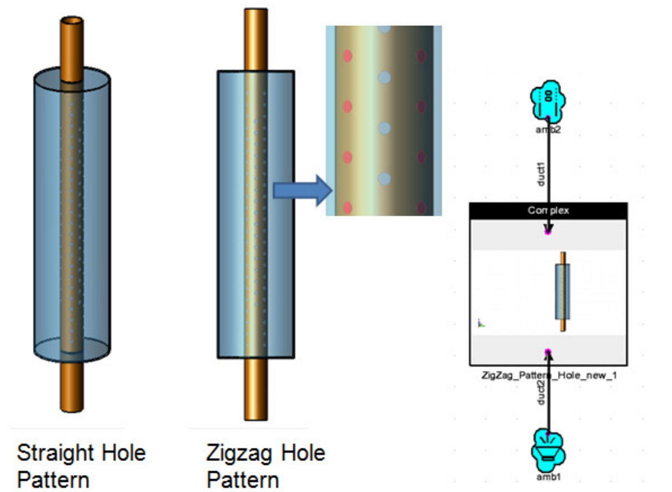

Fig. 6. Processing of Wave 1-D GUI

Now comparing the result of straight perforated tube with Experiment and Wave 1-D as followed

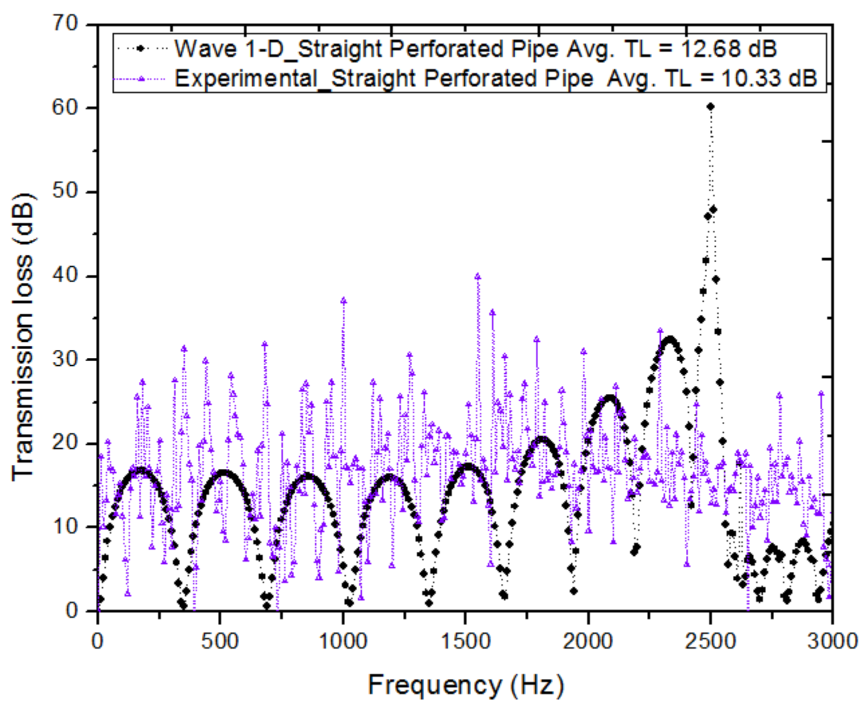

Fig. 7. TL measurement of straight perforated tube with Experiment and FEA.

Now comparing the result of Zigzag perforated tube with Experiment and wave 1-D as followed

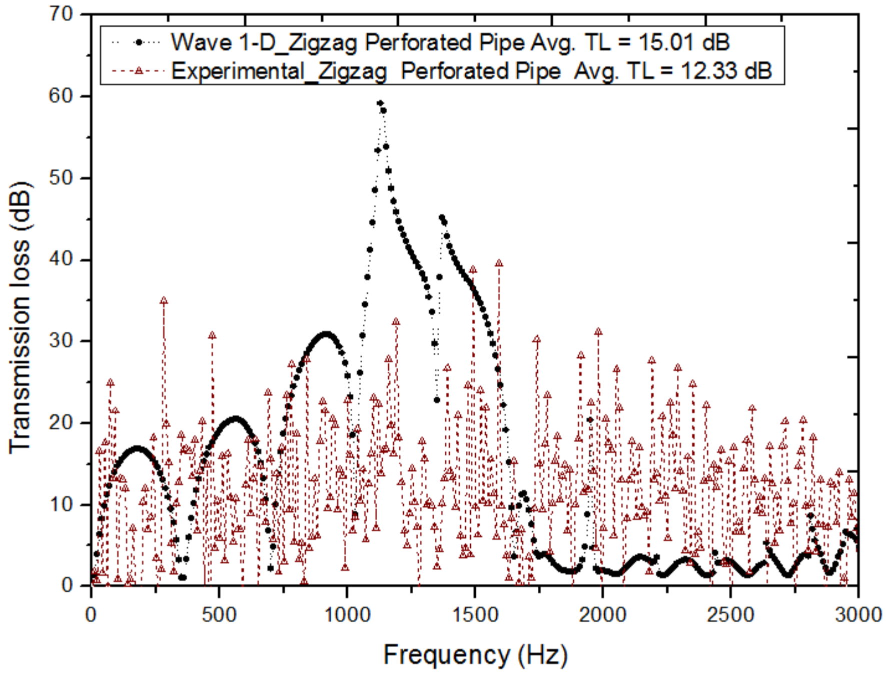

Fig. 8. TL for zigzag perforated tube with Experiment and FEA.

Now comparing the result of both the results of perforation pattern compared with wave 1-D

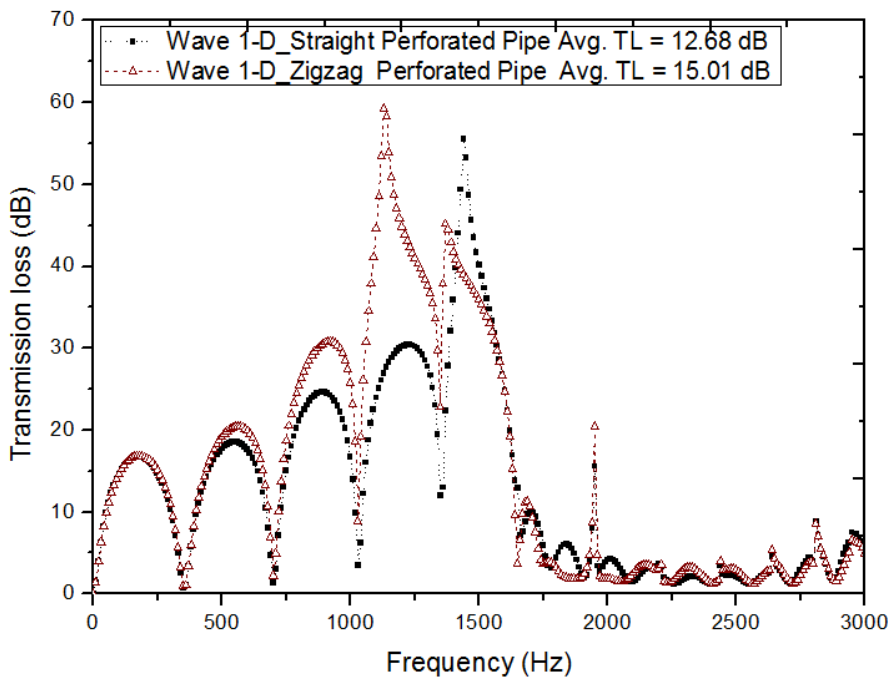

Fig. 9. TL comparison for straight and zigzag perforated tube with wave 1-D

Table 1: Average TL Results upto 3000 Hz.

Straight perforated tube with Experiment (Avg. TL)	Straight perforated tube with FEA (Avg. TL)	Zigzag perforated tube with Experiment (Avg. TL)	Zigzag perforated tube with FEA (Avg. TL)
10.33 dB	12.68 dB	12.33 dB	15.01 dB

CONCLUSIONS

Attenuation curves represent among four observations clearly shows that the high transmission loss can achieve by zigzag perforated tube muffler by experimental as well. Small deviation is appeared between FEA & Experimental results might be due to leakage of air in expansion chamber. Now it is observed that pattern of zigzag perforation is more effective in reducing the noise as aimed as it have a soothing effect in solving the noise reduction.

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