Optimization of Transmission Loss of Perforated Tube Muffler by using CAE Tool Ansys

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Abstract

Noise produced by exhaust of an IC Engine, is one of the main cause of noise pollution in today's environment. With the increase in vehicles at alarming rate, it has become necessary to have an effective noise-attenuating device to control this noise pollution. Muffler is one of such device that can be used for noise reduction. Transmission loss is the major performance parameter of muffler and it depends on the acoustic filters applied to it. This paper reveals the performance of transmission loss on using perforated tube as an acoustic filter. Different parameter of the perforated tube such as perforated whole diameter, porosity and dimension of the tube are considered for study. All the analysis for the evaluation of transmission loss is performed by using ANSYS which is one of the major CAE tool for simulation. The paper also reveals new models that have better sound attenuation capabilities than the conventional model especially at low to medium frequencies level.

Keywords- *ANSYS, COMSOL, Exhaust muffler, perforated tube, transmission loss*

I. INTODUCTION

A. *Introduction of Muffler*

Muffler commonly known as silencer or back box is an important element of the automotive exhaust system for attenuating sound produced by the exhaust. An unavoidable side effect associated with the use of muffler in the exhaust system is increase in backpressure. Increase in backpressure reduces the efficiency of the engine. To overcome this, a tube made of stainless steel with number of small holes drilled around its periphery is placed inside the muffler. The function of these tubes is to guide the flow and reduce the backpressure of the engine. Perforated tube offers resistance to the flow and hence converts the sound energy into heat energy which helps to minimize the sound produced by exhaust.

B. *Types of Muffler*

Broadly, there are two types of muffler (a) Reactive or reflective muffler and (b) dissipative or absorptive muffler.

1) *Reactive or Reflective Muffler*

Reactive muffler have engineered expansion chamber, perforated tube, and baffle plates. These muffles uses their geometry for canceling out sound wave. Reactive muffler is normally designed in such a manner that, they force the exhaust gases through small diameter passage and thereby, it produces backpressure on the engine. Therefore, main aim of the reactive muffler is to minimize the flow restriction.

2) *Dissipative or Absorptive Muffler*

Dissipative muffler works on the principal of converting sound energy into heat energy. These mufflers generally consists of expansion chamber, perforated tube, and absorption materials like glass wool.

3) *Perforated Tube:*

Perforated tube is tube generally made up of stainless steel and have holes punched or drilled around its periphery. These tubes are provided to guide the flow and hence their main function is to reduce the backpressure of the engine. However, with the appropriate design of perforated tube it ispossible to increase the transmission loss of the muffler.

C. *Explanation of Transmission Loss*

Transmission loss of the muffler is defined as the difference in the acoustical power of the forward travelling incident pressure wave at inlet to the forward travelling transmitted pressure wave at the outlet.

$$TL = 20Log\left(\left|\frac{P_{inc.}}{P_{trans.}}\right|\right) + 10Log\left(\frac{S_o}{S_i}\right) \quad (1)$$

Here, $S_o$and S_i are outlet and inlet area of the muffler which is generally identical and hence the above equation reduces to

$$TL = 20Log\left(\left|\frac{P_{inc.}}{P_{trans.}}\right|\right) \quad (2)$$

Transmission loss of simple expansion chamber can be calculated as

$$TL = 10Log[1 + \frac{1}{4}\left(M - \frac{1}{M}\right)^2 \sin^2 KL] \quad (3)$$

Where, M is the ratio of area of expansion chamber to the area of inlet tube.

K is the wave number

L is length of expansion chamber

D. Literature Review

First patent on "exhaust muffler of engines" was awarded to Milton O .Reeves and Marshall T. Reeves in 1897. Since from then numerous research has been done to improve the design and performance of the muffler.

T.W.Wu et.alstudied the effect of perforated tube diameter and the tube thickness on the transmission loss of the muffler. They found that perforated hole diameter and thickness of perforated tube has pronounced effect on the transmission loss [1].Balasubramanian and Datchanamourty considered three different perforated tube and each tube differs in the perforation pattern. They performed their analysis by using detailed holemethod andCAE Tool SYSNOISE. From the results obtianed they concluded that SYSNOISE results matches the experimental results at low frequencies[2]. Potente and Daanielcompared the curve of transmission loss of reactive muffler and absorptive muffler and concludes that transmission loss of absorptive muffler is more consistent than that of reactive muffler. Also at higher frequencies, the transmission loss of the reactive muffler increases dramitacally[3].Zhenlin Ji and Wenping Zhang analyzed the effect of length of concentric perforated tube on acoustic attenuationperformance of muffler. From the results obtained they concludes that number of domes obtained in transmission loss curve dependes on the length and porosity of the tube[4]. Haluk Erol and Ozcan Ahmetoglu stuided the effect of amount of perforation on the transmission loss of the muffler.He found that at low frequencies transmission loss is independent of porosity of the tube but at higher frequencies transmission loss increases with decrease in porosity of the tube[5].Taylor W. Le Roy in his research work concluded that perforated tubes in the mufflers are efficient especially when the expansion chamber is not used effectively. Perforated tubes are used to guide the flow in the ideal directions to maximize the available space. Perforated tubes can also be used to reduce the noise generated from the turbulent flow[6]. Nouby M. Ghazaly studied the various research trends in sound transmission loss of muffler. They concluded that more research is required for complete optimization of transmission loss[7]. Rahul et. al studied the effect of various shape of the muffler. From their work they stated that double chamber muffler gives better result than single expansion chamber muffler[8]. Guo ying et. al investigated a plug flow muffler and an eccentricmuffler for their acoustic properties. From their experimental work they showed that the over all frequencies range uniform flow gives better results. The results obtained from eccentric muffler shows shifting of higher mode effect to low frequencies values when porosity of the pipe decreases[9]

II. DESCRIPTION OF MODELS

Model 1: Simple expansion chamber

Length of expansion chamber	250 mm
Diameter of expansion chamber	164 mm
Diameter of inlet and outlet	76 mm
Length of inlet and outlet	100 mm

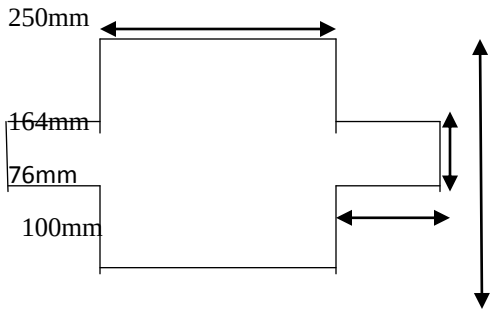

Figure1:2-D Model of Simple Expansion Chamber

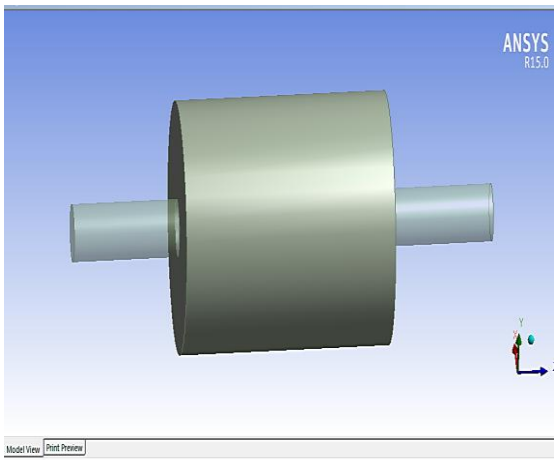

Figure2: ANSYS Model of Simple Expansion Chamber

Model 2: Cylindrical perforated tube muffler

Length of expansion chamber	250 mm
Length of perforated tube	250 mm

Diameter of perforated tube	76 mm
Diameter of perforated hole	4 mm
Number of holes	342

Model 3: Designed elliptical perforated tube muffler

Length of expansion chamber	250 mm
Length of perforated tube	250 mm
Major axis of tube	76 mm
Diameter of perforated hole	4 mm
Number of holes	342

III. MESHING OF MODELS

Meshing is done in ANSYS by taking element size of 0.01. Meshing method taken is Tetrahedral, which represents fluid 221 as working fluid.

Formula for calculating element size

$$Element\ size = \frac{speed\ of\ sound\ in\ medium}{2\pi f} \quad (4)$$

Where, f is frequency

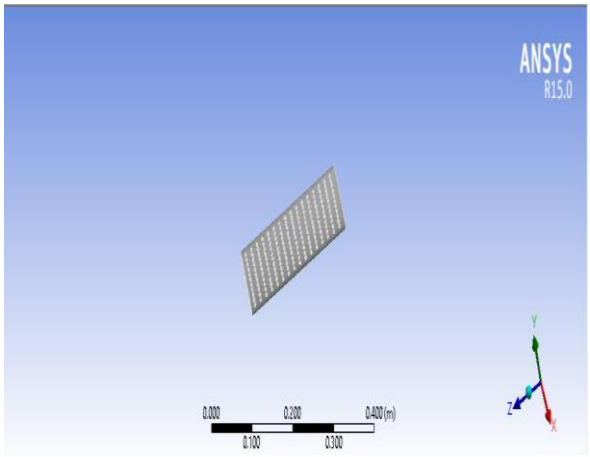

Figure3: Ansys Model of Elliptical Perforated Tube

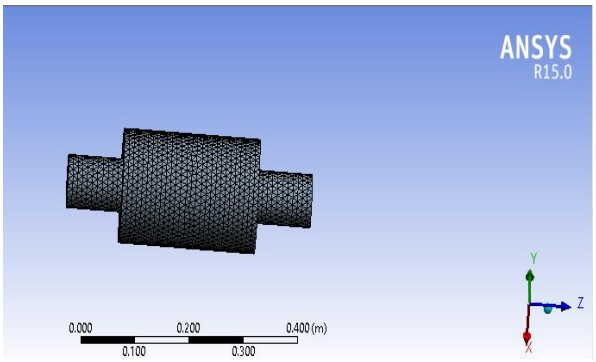

Figure4: Mesh model in Ansys Workbench

IV. RESULT AND DISCUSSUION

A. *Comparison of Mathematical & Simulation Transmission Loss*

Here analysis are performed under the frequency range of 2 Hz to 2500 Hz. Figure 5 shows the transmission loss of simple expansion chamber produced by mathematical and simulation methods. Mathematically calculated value of transmission loss is obtained by using equation (3). The transmission loss is calculated numerically in ANSYS & COMSOL.

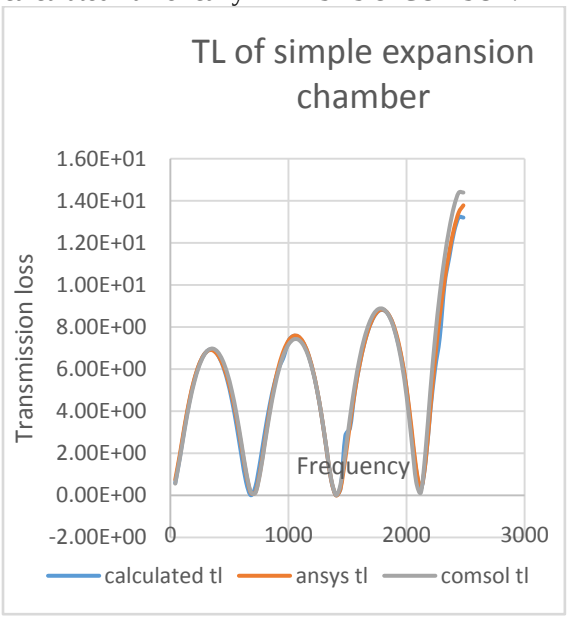

Figure5: Comparison of Transmission Loss of Simple Expansion Chamber by Various Methods

B. *Effect of Perforated Tube on Transmission Loss of Muffler.*

Transmission loss of model 2 is calculated and compared with the transmission loss of model 1. The results of two transmission loss is shown in figure 6.From the figure it is found that when perforated tube is fitted in the simple expansion chamber, it improves the sound attenuation capacity of the model. The nature

of variation of transmission loss with respect to frequency for both the models is same.

C. *Comparison of Transmission Loss of Model 2 and Model 3.*

Here the model 2 is compared with the newly designed muffler i.e. model 3. The boundary conditions for this muffler is taken similar to the existing model and analysis is performed.

From the analysis, it is found that the new design produces better transmission loss than the existing muffler (model 2). Thus it is predicted that this new model would be most effective forlow and medium frequencies range.

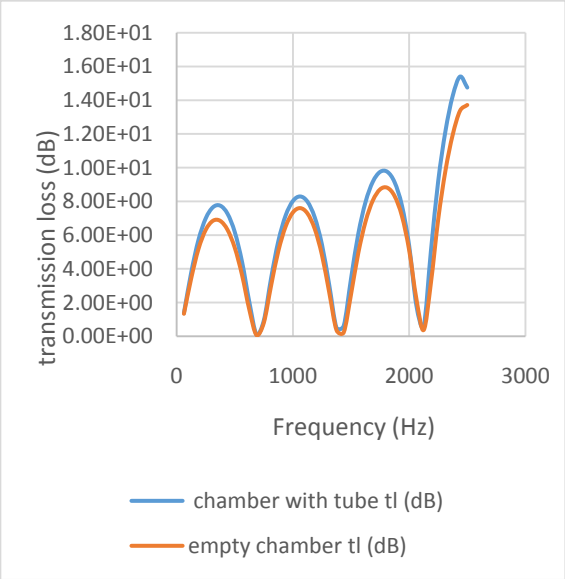

Figure6: Comparison of Transmission Loss of Simple Expansion Chamber and Perforated Tube Muffler

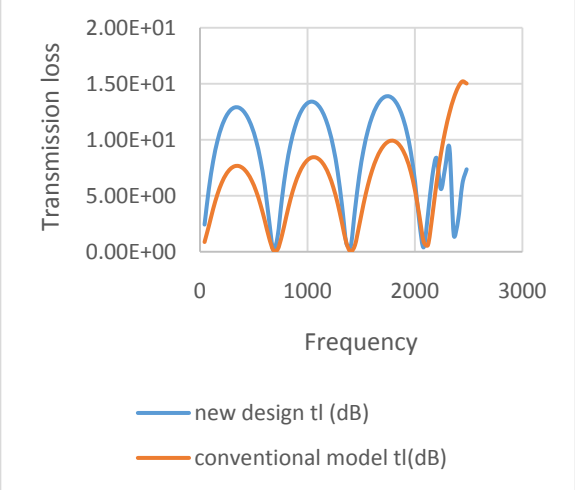

Figure8: Comparison of New Design Muffler and Existing Perforated Tube Reactive Muffler

V. CONCLUSION

The muffler with perforated tube produces better transmission loss result than simple expansion chamber at all frequencies. So, it can be concluded that it is required to place a perforated tube inside the muffler. Newly designed muffler with elliptical perforated tube is superior to cylindrical perforated tube muffler for sound attenuation up to frequency 2100 Hz. It is found that for new proposed muffler transmission loss increases by 7-9 dB .After 2100 Hz cylindrical perforated tube muffler have higher sound absorbing capacity.So, conventional cylindrical tube muffler could be better choice for higher frequencies but for low to medium frequencies range elliptical tube muffler could be used.

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