International Journal of Engineering Research and General Science Volume 3, Issue 3, May-June, 2015
ISSN 2091-2730

EFFECT OF PERFORATED TUBE ON TRANSMISSION LOSS OF MUFFLER- A REVIEW

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Abstract – Noise pollution produced by engines becomes a vital concern especially for residential areas or in the areas where noise creates hazard. The main source of noise produced by an engine is the exhaust noise. With the increased use of industrial machinery and automobiles, it is necessary to have an effective noise attenuation device. Muffler is such a device used for reducing the amount of noise produced by an IC Engine. Noise attenuation quality of muffler depends on the used materials and its internal geometry. Perforated tube is used in muffler to reduce backpressure as well as to increase transmission loss of muffler. There are many methods for evaluation of transmission loss of muffler such as analytical method, computational method using FEM and BEM and experimental method. This paper discuss the effect of various parameters of perforated tube on transmission loss.

Keywords – muffler, expansion chamber, perforated tube, transmission loss, FEM, BEM, backpressure

1. INTRODUCTION

A muffler well known as silencer in British English or in Irish English as a back box is a device used in automobiles for attenuating the amount of noise emitted by the exhaust of an internal combustion engine. An unavoidable side effect associated with muffler use is decrease in engine efficiency because of an increased backpressure. Therefore, to improve the performance of the engine perforated tube which is a tube made of stainless steel with a number of small holes drilled around its periphery is placed inside the muffler. These metal tubes guide the flow inside the muffler in order to reduce the backpressure. As the flow passes through small holes, these tubes converts the sound energy into heat energy and hence increases the transmission loss of muffler So perforated tube are used to provide happy intermediate solution between performance and quietness of the engine.

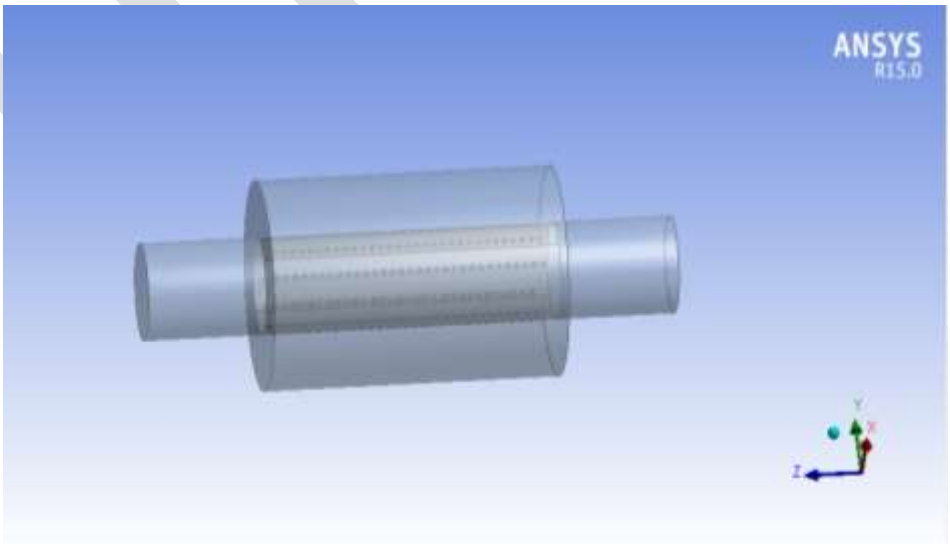

Figure1: muffler and perforated tube

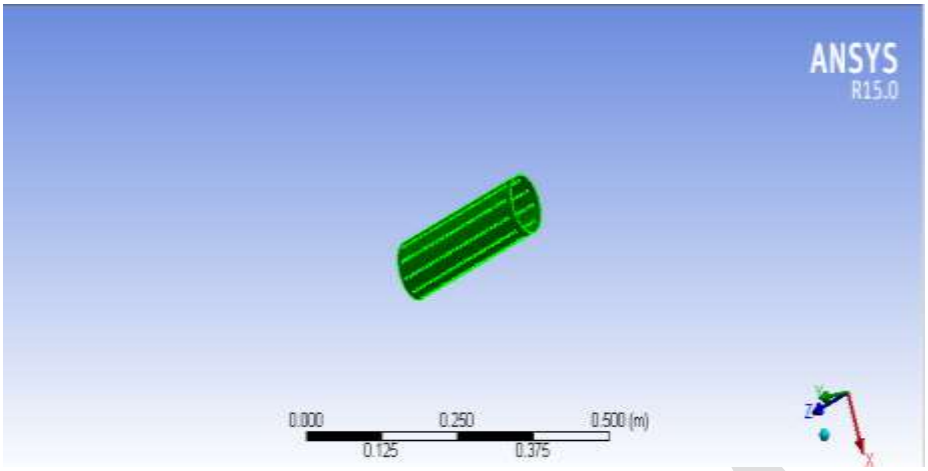

Figure2: Perforated tube

Types of muffler

Typically mufflers are classified under two categories, dissipative and reflective.

(a)Dissipative Muffler:-A dissipative muffler is based on the principle of converting the exhaust noise energy caused by fluctuating pressure waves into heat.

(b)Reflective Muffler:-This type of muffler uses the geometry of the complex muffler components to create impedance mismatches with the incoming exhaust stream in an attempt to cancel out the progressive pressure wave.

Muffler performance parameter

Transmission loss, insertion loss, and level difference are three performance parameters of the muffler, out of which transmission loss (TL) is most commonly used performance parameter.

Transmission loss

Transmission loss is defined as the difference in the acoustical power of the forward travelling incident pressure wave at the inlet of the muffler to the forward travelling transmitted pressure wave at the outlet [1]

The equation for calculating transmission loss is

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

$$=20\text{Log}\left(\left|\frac{P_1+\rho c v_1}{2p_2}\right|\right) + 10Log\left(\frac{S_o}{S_i}\right)$$

Where;

ρc −Characteristic impedance of the medium.

V_1-applied particle velocity at inlet.

Si, So-cross sectional area of inlet and outlet respectively, which is usually identical.

2. RELATION BETWEEN TRANSMISSION LOSS AND BACK PRESSURE

Use of perforated tube in the muffler reduces the back pressure to improve the performance of the engine and so have the direct effect on the transmission loss of the engine. A.K.M Mohumuddin in his research paper concludes that relation between noise level and back pressure is inversely proportional [2]. So from his research work it was found that transmission loss and back pressure are proportional to each other i.e. when back pressure increases, transmission loss also increases.

3. APPROACHES FOR CALCULATING TRANSMISSION LOSS IN MUFFLER USING PERFORATED TUBES

There are many methods to calculate the transmission loss in the mufflers, out of which few are as discussed below

(A) EXPERMINTAL APPROACH

There are three methods for calculating transmission loss under this approach.

I. Calculation of TL by acoustic measurements.

Equipment used for measuring transmission loss are

1.4-channel FFT Analyzer

2. Pressure type microphone

3. Power amplifier

4. Adapter and connection pipes

5. Sound source

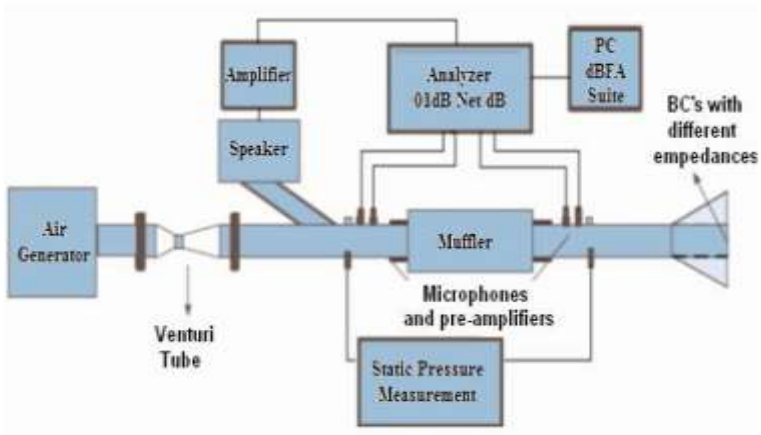

Figure3: experimental setup

In the experimental approach, noise signal produced by analyzer is transmitted to the source of the sound in order to generate the needed sound by amplifier. Noise generated by the source is sent to the muffler. With 4 microphones placed in inlet and outlet of the muffler, sound pressure signal are collected during a period of time and these signals are converted to frequency domain with FFT after being amplified and as a result auto spectrum and cross spectrum values are obtained. These data taken from analyzer is processed by computer and the transmission loss curves are obtained. [3]

II. Two Load Method

The two load method consist of four microphones. Two microphones are placed both in inlet and outlet piping to determine both the reflective and progressive waves. This technique is used to determine 4-pole parameters of the muffler and then using equation

$$TL=20Log_{10}\left(\left|\frac{1}{2}\left[A+\frac{B}{\rho_o c}+(\rho_o c)c+D\right]\right|\right)+10Log_{10}\left(\frac{S_o}{S_i}\right)$$

Transmission Loss can be calculated.Here A, B, C, D are 4 pole parameters.

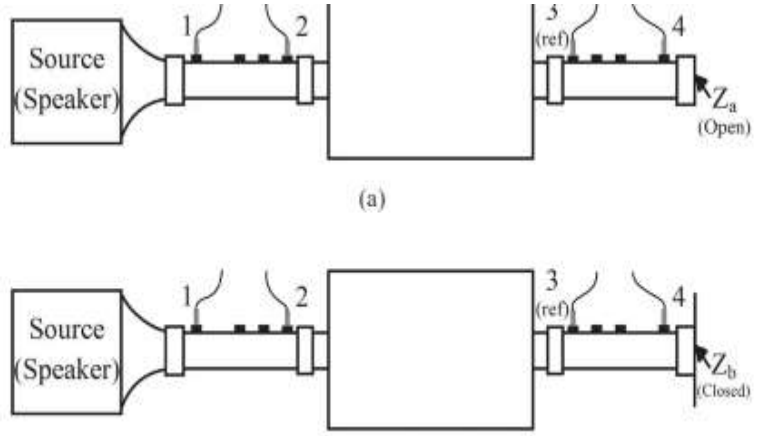

Figure5: Two load method in determining TL of muffler (a) step 1 when outlet is open to atmosphere and (b) step 2 when output is rigidly closed

The numbers in the figure represents the channel number of the microphone at that specific location. The major disadvantage associated with the method is if there are not substantial difference between the two loads attached at the termination, then the equation for Transmission loss breaks down. [4]

III. Two Source Location Method

In this method, the source is moved from inlet to outlet location. This technique is the most accurate and stable measurement and consists of microphones having variable spacing between them. Larger microphone spacing will more accurately lower frequency TL due to large wavelength and the shorter microphone spacing will more accurately calculate the higher frequency TL due to short wavelength. Here the frequency-microphone spacing combination should be avoided for accurate results. [4]

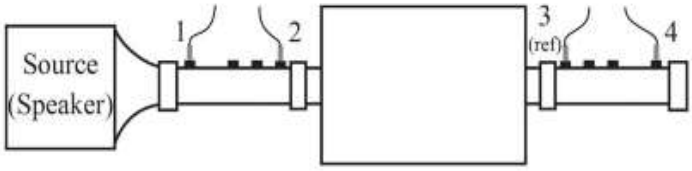

Figure6: Two source lcation method in determinig TL of the muffler

(B) Simulation approach

Under simulation approach there are following methods for calculating transmission loss.

I. 1-D linear and non-linear techniques

The transmission loss of the muffler can be calculated using 1-D software codes such as GT Power or wave. The 1-D package will solve a linear solution for the transfer matrix method.However, this type of method typically can not model complicated muffler components and only plane waves can exists in the model. The effects due to the 3-D waves can not be predicted which usually occurs in the middle to high end of the frequency spectrum.

II. BEM Method

The boundary element method consider the linear (frequency domain)approach which is based on the fundamental 3-D wave equation

$$\nabla^2 P + K^2 P = 0$$

The BEM is composed of two dimensional shell elements which make up all of the surfaces of the muffler.For the BEM,in order to determine state variable inside the muffler and exhaust tubes, field points need to be created. The state variables, are solved at these locations as a post processing step after BEM simulation and are determined by an integration technique from nearby nodes.Also plane waves must exist at a location of the field points for their state variables to accurately predicted.

III. FEM Method

Finite Element Method(FEM) also consider the linear (frequency domain)approach which is based on fundamental 3-D wave equation

$$\nabla^2 P + K^2 P = 0$$

In FEM approach,the location of the measurement points inside of the inlet and outlet tube is not affected by placement as in case of BEM.This method is most effective in determinig the the TL of the muffler when steady state condition are consider.The downfall of this method is whenever the source is non-periodic i.e. when determining the temperature pattern in a muffler as a function of time.The FEM is primaily used when only the interior acoustic field of geometry is to be computed. Two different approaches used in BEM and FEM Methods to calculate the transmission loss are 4 pole method and 3 point method. Based on certain criteria such as accuracy,computation time,and ease of use it is found that out of 4 pole method and 3 point method; 3 point method is the fastest method and easier to use then 4 pole method.[5]

Different software available to calculate transmission loss in perforated muffler

Different software available are SYSNOISE, GT POWER, ANSYS APDL, ANSYS WORKBENCH, FEMLAB, ABAQUAS, MSC. Nastran, MSC.Acrtan

4. LITERATURE REVIEW

Taylor W. Le Roy in his thesis has studied the effect of perforated tube on transmission loss of the muffler. He added a perforated tube to the single expansion chamber. From the results obtained he concluded that addition of perforated tube improves the transmission loss of muffler at higher frequencies. The addition of perforated tube increases the transmission loss by 4.5 dB to 6 dB. The perforated tube is beneficial especially when expansion chamber is not used effectively[6].

Haluk Erol and Ozcan Ahmetoglu studied the effect of amount of perforation and porous material thickness on the transmission loss of the muffler. They used two load method for calculation of transmission loss assuming plane wave propagation at inlet and outlet. They concluded that at lower frequencies transmission loss is independent of the number of perforated hole but at higher frequncies, the transmission loss incraeses with the increase in number of perforated holes[7].

F.D Denia et al. investigated the acoustic behavior of perforated dissipative circular mufflers. They considered the complex characteristic impedance, wave number, and perforation impedance to evaluate the axial wave number in the fibrous material and perforated pipe. From their work they showed that the use of empty extensions leads to quarter wave resonances which improved the acoustic performance of the muffler at low to mid frequencies. From their work they showed that the use of perforated tube leads to quarter wave resonances which improved the acoustic performance of the muffler at low to mid frequencies [8].

Ovidiu Vasile and Nicolae Enescu investigated the acoustic performance of reactive muffler by using numerical and experimental techniques. They had consider only the stationary and non dissipative mufflers. Their results shows that five lines of perforated holes of muffler configuration gives higher transmission loss in comparison to single line or three lines of perforated holes.[9].

Ayse Dincer in his thesis discussed the effect of perforated hole pattern on transmission loss of the muffler. He studied linear and staggered pattern of hole on the tube and concluded that pattern of holes do not have much effect on the transmission loss of the muffler [10].

Zhuoliang Li examined the effect of perforated tube on transmission loss of muffler. In his analysis He conclude that when perforated tube is replaced by solid tube, then transmission loss of the muffler reduces at all frequencies [11] **.** Fangsen Cui et.al studied the effect of porosity, length and diameter of perforated tube on the transmission loss of muffler. The results shows that transmission loss for large porosity is good for low frequency and small porosity is good for high frequency. Also the transmission loss increase with length of tube at high frequency but for small frequency effect of perforated tube length is not monotonous [12].

Nawaf H. Saeid performed the numerical simulation to investigate the effect of perforation on acoustical performance of muffler. He studied the effect of perforated hole diameter and length of perforated tube on transmission loss. In his work he considered three different perforated tube of hole diameter 6 mm, 9mm and 12 mm. He also varied the length of tube to analyze the effect of tube length on transmission loss. He concluded that transmission loss increases with increase in either perforated hole or length of perforated tube [13].

Nitin S. Chavan in his research paper shows the effect of length to diameter ratio of perforated tube on the transmission loss of muffler. His results shows that transmission loss increases as ratio of length to diameter of tube increases [14]

5. CONCLUSION

Different design of mufflers with different number of perforated holes, different perforated hole pattern and different operating conditions were studied. From the study, it has been observed that the number of holes and the size of the hole in the perforated tube affects the amount of transmission loss in the mufflers. Larger the diameter of the hole, lower will be the back pressure and hence lower will be the transmission loss which makes the vehicle more louder. Perforated muffler with the porous filling gives the higher value of transmission loss. Length of perforated tube also has a considerable effect on transmission loss and it increases with increase in length of tube. Transmission loss also increases with increase in length to diameter ratio of the perforated tube. Increase in porosity of the tube improves the transmission loss at low frequencies and vice versa.

Muffler having perforated central pipe with actual operating condition can be considered as a new research work for the calculation of transmission loss. Elliptical perforated tube can be considered for the analysis of transmission loss. Also, different shape of perforated hole such as elliptical and triangular holes can be considered for the analysis.

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