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Acoustic analysis and modelling of Reactive muffler to reduce noise of the System.

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Abstract— as per the new rules and regulations set by the government to minimize emission it is necessary to automobile makers to work on exhaust system for minimizing emission and noise of the system.So now we see that industry adopt new BS6 norms for minimizing emission.
Muffler is the device which is used for minimizing noise and back pressure of the system. Muffler plays and important role in minimizing transmission loss, because all these parameters affects the fuel efficiency of the system.
Typically three types of muffler is used 1.reactive muffler.2 Absorptive muffler. 3. Combination of both. Most of automotive mufflers are reactive type. Absorptive type of mufflers working on principle of absorption of energy.
This paper study the acoustic analysis of reactive muffler with various placements of baffle plates in chamber. The purpose of study this paper is that, effect of different placement of outlet chamber on transmission loss with the help of numerical analysis.
We used COMSOL Multiphysics for numerical analysis because of better compatibility for acoustic analysis and transmission loss

Index Terms— Reactive muffler, baffle plates, Numerical Analysis, Comsol Multiphysics, Transmission Loss, Chamber.

1 INTRODUCTION

T Muffler is a device which is used for noise reduction. Noise is harmful for us as well as environment also in engine noise is created due to various friction of the components. As per the government norms it should not be reached more than 80db.

Above 130db noise need to be ear protection. Muffler plays an important role in noise reduction
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[1] In this paper conventional muffler of Wagnor model taken for the reference and new muffler is design with the help of this muffler. Author uses water manometer in experimental setup to calculate the pressure drop. Sound intensity measured with SLM. Five different experimental models presented analysis done with help of ANSYS software. This paper indicates that Twin muffler design gives us better pressure loss.

[2] Dr M.V.Kulkarni. This paper presents FEA of double expansion chamber reactive muffler. Numerical analysis done by comsol & mean flow of the muffler is ignored. Analysis done within frequency range of 1-1600HZ.In this paper different types of model compare with placement of side outlet in different locations. It is observe that model 1 shows an optimum performance because it achieved maximum transmission loss. It shows COMSOL multiphysics is best for numerical analysis & acoustic performance of the reactive muffler. In model 1 outlet of double expansion chamber of reactive muffler placed at L/2 distance from the end plate.
[3] Prof .Lagdive H.D. In This paper two load method is used for measuring transmission loss. Experimental setup consist of series of rigid tube, OAS, amplifier & sound measuring microphones. Three methods for measuring transmission loss is discussed in this paper .Muffler size is large which is need to be minimize ,it reduces the cost of the system and also gives more optimum results.

2 .MODELLING

Modelling of reactive muffler done using three different placements of baffle plates. Design considerations of model 1 is given as bellow

Name	Expression	Unit	Description
P_in	intop_inlet (p0^2/(2*acpr.rho*acpr.c))	W	IP
P_out	intop_outlet	W	OP

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Name	Expression	Unit	Description
	(p*conj(p)/(2*acpr.rho*acpr.c))		
TL	10*log10(P_in/P_out)		TL

Transmission loss is calculated by using numerical simulation for this we used COMSOL Multiphysics, in which the mean flow of the muffler is not taken. The geometry & Meshing of the muffler is done using same program. Given muffler is meshed using tetrahedral elements & Sound pressure P is calculated by using of Helmholtz equation.

$$\nabla.\left(\frac{1}{\rho_0}\nabla_p - q\right) + \frac{k^2}{\rho_0}p = 0$$

Here, $k=2\pi f c0$ is the wavelength, $\rho 0$ is the density of the fluid, $c0$ is the velocity of sound, q is the two pole source term which means acceleration per unit volume and equals to 0 . With this equation, a solution on frequency domain can be found using parametric solver. The TL of the muffler is calculated using following equation

$TL=10\ log\ pin/pout$ (2) Where, pin and $pout$ indicates the acoustic effects at inlet and outlet. Which is calculated as

$$p_{in} = \int_\Omega^1 \frac{p_0{}^2}{2\rho c_0} dA$$

$$p_{out} = \int_\Omega^1 \frac{|p_c|^2}{2\rho c_0} dA$$

The inlet pressure value $p0$ is taken as 1 bar this analysis is Carried out at the frequency range of 1-1600 Hz. It uses sound hard wall boundary conditions at the solid boundaries.

Here we study three different types of acoustic models to get the maximum transmission loss.

Temperature keeping constant as= 298[K]

Absolute pressure = 1[atm]

Speed of sound =343 m/s

Density= 1.5 kg/$m3$.

MODEL 1: Modelling of Extended inlet outlet with single baffle plate of muffler.

a) Design considerations model 1 is listed below.
b) Diameter of the chamber=60mm
c) Length of the chamber=560mm
d) Inlet & outlet tube diameter =22mm
e) Length of the tube=95mm
f) Outer diameter of baffle plate=60mm
g) Inner diameter of baffle plate=22mm

Name	Expression	Value	Description
p0	1Pa	1 Pa	I/P amplitude

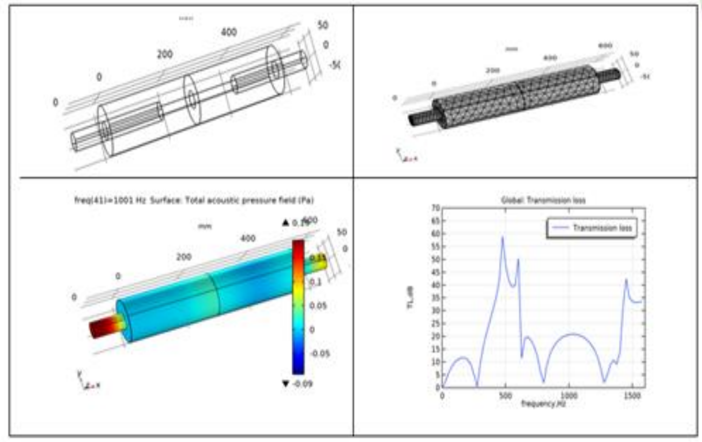

FIG NO 1: MODELLING OF EXTENDED INLET OUTLET WITH SINGLE BAFFLE PLATE OF MUFFLER.

MODEL 2: Modelling of reactive muffler with double baffle plates

a) Design considerations model 2 is listed below.
b) Diameter of the chamber=60mm
c) Length of the chamber=560mm
d) Inlet & outlet tube diameter =22mm
e) Length of the tube=95mm
f) Outer diameter of baffle plate=60mm
g) Inner diameter of baffle plate=22mm
h) Circumferential Diameter of plate= 5mm

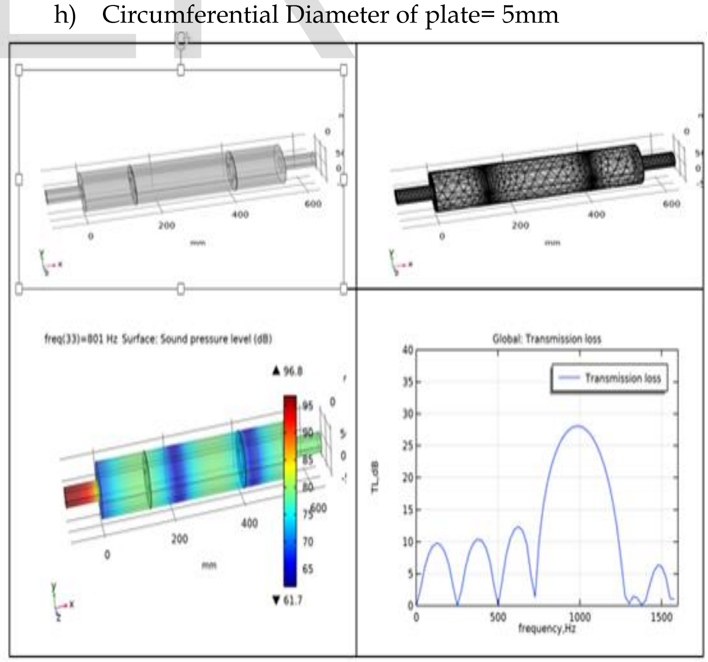

FIG NO 2: MODELLING OF REACTIVE MUFFLER WITH DOUBLE BAFFLE PLATES.

h) **MODEL 3: Modelling of reactive muffler with three baffle plates with different circumferential diameter.**

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i) Design considerations model 3 is listed below.
j) Diameter of the chamber=60mm
k) Length of the chamber=560mm
l) Inlet & outlet tube diameter =22mm
m) Length of the tube=95mm
n) Outer diameter of baffle plate=60mm
o) Inner diameter of baffle plate=22mm
p) Circumferential Diameter of plate= 5mm

In this model we use three baffle plates to optimize acoustic pressure and noise level of the muffler.

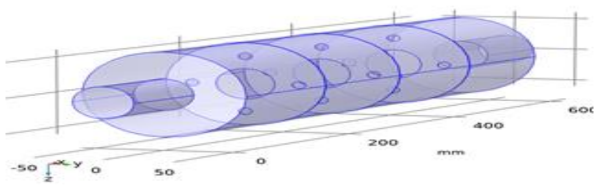

FIG NO 3: GEOMETRY OF MODEL 3

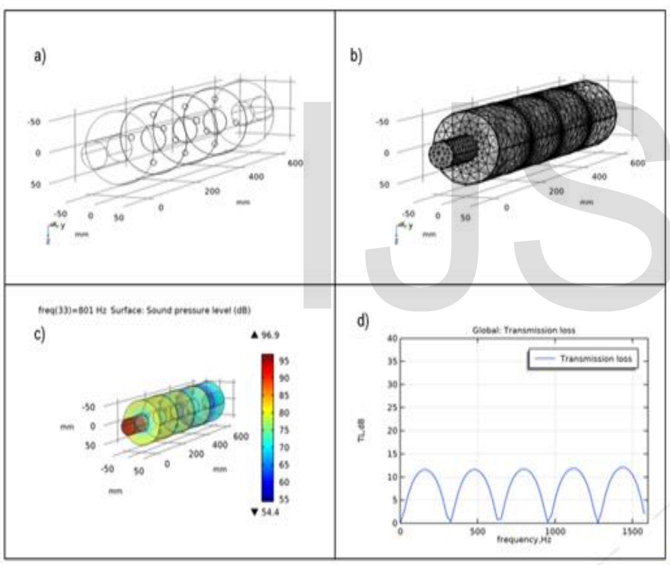

FIG NO 4: MODELLING OF REACTIVE MUFFLER WITH DOUBLE BAFFLE PLATES.

In above three different models figure a) shows Geometry of muffler, b) shows Meshing geometry, c) shows Acoustic sound pressure level in dB at frequency no 33 at 801Hz, d) shows Transmission loss plot.

3. EXPERIMENTAL ANALYSIS

Experimental Analysis carried out using two load method[4]. The experimental setup is given below

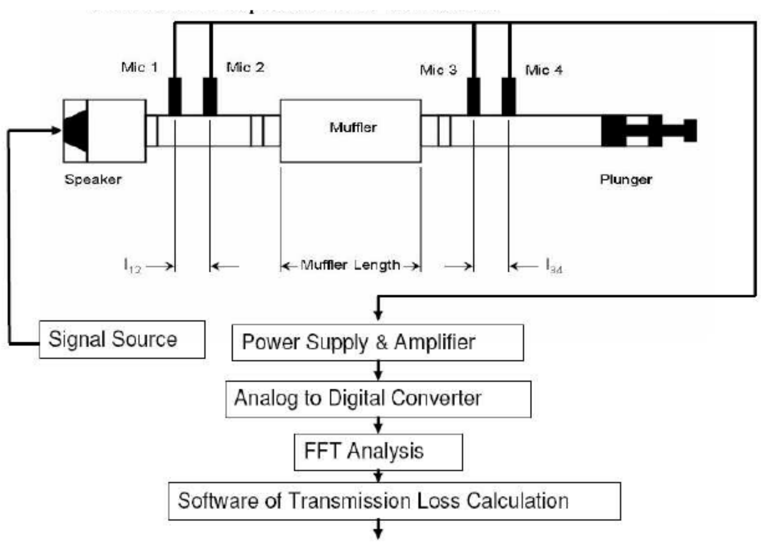

FIG NO 5: EXPERIMENTAL ANALYSIS SETUP

Experimental set up analysis consist of a) speaker or sound generation system, b) muffler,3)power supply & amplifier. 4) FFT Analyzer, 5) Sound measuring system.

The positions of microphones are shown in above setup. Microphones are connected serially to the impedance tube. At end of the impedance tube sound source is connected and test muffler is connected to the other end

Here we two impedance tubes are connected because we are interested in calculation of incident as well as transmission loss.

FFT analyzer collects the pressure data from microphones and give it to the data recording storage system.

Here we used high power sound source to generate sound equals to 120dB. To use Transfer function technique we utilized two microphones here.

4. TWO LOAD METHOD THEORY

In the research paper of Z. Tao published in 2003 ,He mention three measuring techniques for the experimental analysis in whch Two load theory describe here.

[5] Here we used transfer matrix method approach, from this method we easily achieved transmission loss of any muffler by using four positions of microphones. This approach is obtain by two loads at outlet tube with and without observing material as shown in figure 6

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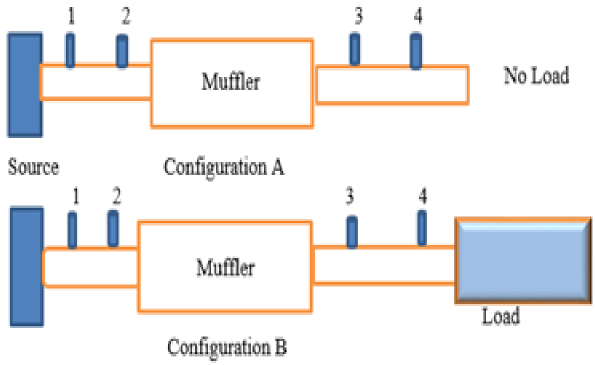

With the help of transfer matrix approach Transmission loss of the muffler is calculated by using four pole equations from four positions of microphones. Here we neglecting the flow of the air, the four poles for the elements 1-2 can be expressed as

$$\begin{bmatrix} A_{12} & B_{12} \\ C_{12} & D_{12} \end{bmatrix} = \begin{bmatrix} coskl_{12} & j\rho c\ sinkl_{12} \\ \frac{j\ sinkl_{12}}{\rho c} & coskl_{12} \end{bmatrix} \qquad ....1$$

The four poles for elements 2-3 can be expressed as

$$\begin{bmatrix} A_{23} & B_{23} \\ C_{23} & D_{23} \end{bmatrix} \qquad ....2)$$

Where,

$$A_{23} = \frac{\Delta_{34}(H_{32a}H_{32b} - H_{32b}H_{34a}) + D_{34}(H_{32b} - H_{32a})}{\Delta_{34}(H_{34b} - H_{34a})}$$

$$B_{23} = \frac{B_{34}(H_{32a} - H_{32b})}{\Delta_{34}(H_{34b} - H_{34a})}$$

$$C_{23} = \frac{(H_{31a} - A_{12}H_{32a})(\Delta_{34}H_{34b} - D_{34}) - (H_{31b} - A_{12}H_{32b})(\Delta_{34}H_{34a} - D_{34})}{B_{12}\Delta_{34}(H_{34b} - H_{34a})}$$

The four poles for elements 3-4 can be expressed,

$$\begin{bmatrix} A_{34} & B_{34} \\ C_{34} & D_{34} \end{bmatrix} = \begin{bmatrix} coskl_{34} & j\rho c\ sinkl_{34} \\ \frac{j\ sinkl_{34}}{\rho c} & coskl_{34} \end{bmatrix}$$

From above equations we get final equation as,

$$\begin{pmatrix} A_{14} & B_{14} \\ C_{14} & D_{14} \end{pmatrix} = \begin{pmatrix} A_{12} & B_{12} \\ C_{12} & D_{12} \end{pmatrix} \begin{pmatrix} A_{23} & B_{23} \\ C_{23} & D_{23} \end{pmatrix} \begin{pmatrix} A_{34} & B_{34} \\ C_{34} & D_{34} \end{pmatrix}$$

Transmission loss is calculated as,

$$TL = 20\log_{10}\left[\frac{1}{2}\left(\left|A_{14} + \frac{B_{14}}{\rho c} + \rho c C_{14} + D_{14}\right|\right)\right]$$

Transmission loss can be calculated experimentally using equation

PROCEDURE OF EXPERIMENTAL ANALYSIS

As per the IS standards (10534-2) the procedure of experimental analysis is done[6]. This experiment is carried out at frequency range of 1-2000 Hz. Locations 1-2-3-4 are used for measuring the sound frequency range 1-400 Hz, & Locations 1'-2-3-4' are used for frequency range 400 Hz to 2000Hz One microphone is placed at location 3 and other placed at location 1, 2 and 4 respectively to get transfer function H31, H32 and H34 with respected locations.[7]

FIG NO 6: ACTUAL EXPERIMENTAL SET UP

FIG 6 shows Actual Experimental setup. Reading taken for no load and with load conditions.

5. RESULTS:

- From above 3 different models it is conclude that model no 3 gives us an optimum acoustic performance then others
- Model 3 gives us maximum transmission loss up to 27dB and average transmission loss up to 16 db.
- In this project we are taking four different models with four different placements of reactive muffler.
- In 1st model we uses single baffle plate with extended inlet and outlet this placement gives us Transmission loss up to 58 dB
- In second model we used two baffle plates which is placed in chamber at two different locations it gives us TL up to27 dB
- In third model we used three baffle plates and placed equally in muffler chamber this model gives us TL up to 17 dB.
- Below chart shows comparison of these three models

6. CONCLUSION

- In this project, we used baffle plates and placed in Expansion Chamber of Reactive Muffler.
- The three models with different combinations are analysed using COMSOL Multiphysics.
- It is observed that out of three models, model-3 is providing broadband transmission loss over the frequency range of consideration.

We successfully reduce the overall size of the muffler with optimum performance.

Achieved average transmission loss up to 17dB

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