Design and Analysis of Muffler for Two-wheeler

[1]Tejas J. Kalange, *P. G. Student, Department of Mechanical Engineering, SKNSITS, Lonavala, Maharashtra, India.*

[2]Samir L. Shinde, *Prof., Department of Mechanical Engineering , SKNSITS, Lonavala, Maharashtra, India.*

ABSTRACT

Noise from automobiles is one of the components for noise pollution to environment. Exhaust noise is one of the main source of vehicle and exhaust systems are developed to attenuate noise meeting required levels and sound quality emissions based on environment norms. Muffler is important part of engine system and commonly used in exhaust system to minimize sound transmission caused by exhaust gases. So to deal with this problem, muffler should be modified. But again there is one problem that is selection of type of muffler either reactive or absorptive. Absorptive muffler has more weight than reactive type as it is consisted of wound material over perforated pipes. So in this study reactive type muffler is modified for 110 cm^3 *four stroke engine of two wheelers. But maximum noise reduction affect backpressure of engine. Also pressure drop is one of the parameter which influences backpressure of engine as minimum pressure drop indicates minimum backpressure. Depending on space availability for muffler on vehicle body, external dimensions of new muffler are kept same as that of existing one. In this paper, a muffler is analyzed for varying porosity of pipes and it's effect on pressure drop by simulation.*

Keyword : - *Acoustic Analysis, Backpressure, Muffler, Noise Reduction, Transmission Loss.*

---

1. INTRODUCTION

Mufflers are main components found in automotive exhaust system. The primary purpose of this component is to reduce noise level of exhaust stream in any vehicle. The muffler is engineered as an soundproofing device designed to reduce the loudness of sound pressure created by engine by way of acoustic quieting. The majority of sound pressure produced by engine is emanated out of vehicle using same piping used by silent exhaust gases absorbed by series of passages and chambers lined with roving fibreglass insulation and resonating chambers harmonically tuned to cause destructive interference wherein opposite sound waves cancel out each other.

Sudarshan Pangavhane et al [1] have studied the effect of different porosity on backpressure value of engine. He concludes that as porosity has been doubled backpressure get reduced sharply. Also slight change in size of hole diameter also affects backpressure of engine is shown by him in his paper. S. Krishnan et al [2] have downsized the original muffler in his paper. He has got good result with reducing backpressure by only changing porosity of pipes and shortening baffle plates’ spacing. S. S. Mane [3] has analyzed muffler with different geometries by cfd simulation and experimentally and have result that change in hole diameter and number of holes has significant effect on backpressure of engine. Xiaofeng Shi and Cheuk-Ming Mak [4] have studied wave propagation in micro perforated tube mufflers by theoretically, numerically and experimentally. Its high acoustic resistance and low mass reactance provide good sound attenuation. The parallel arrangement of different micro perforated panel absorber has given broader absorption bandwidth than single one. In compared with dissipative muffler this structure gives better attenuation. The periodic distance of perforation has greater impact on sound attenuation for certain frequency range. In this paper Yoha Hwang et al [5] have proposed new method for exhaust noise control of IC engine. In this method, U shaped bypass pipe has been attached to original pipe. But this configuration reduces noise in higher range frequency than passive muffler and not efficient for lower frequency range. K.Suganeswaran et al [6] have suggested different design criteria and studied on different internal parts in this paper. Also this paper has analyzed muffler by simulation and experiments for passenger car which says that without varying absorptive material density better results can be achieved by varying internal parts' parameters.

1.1 Transmission Loss

Transmission loss is a key quantification of effectiveness of muffler for engineering application. It indicates how much sound energy is prevented from travelling through a muffler. Transmission loss is difference in sound power level between incident wave entering and transmitted wave exiting muffler when muffler termination is anechoic. It is property of muffler only. Possible calculation methods are transfer matrix method, finite element method, boundary element method and computational fluid dynamics.

1.2 Insertion Loss

The insertion loss is sound pressure level difference at a point usually outside system without and with muffler present. Though insertion loss is very useful to industry, it is not so easy to calculate since it depends not only on muffler geometry itself but also on source impedance and radiation impedance.

1.3 Noise Target

The noise target for different vehicles is as mentioned in table 1. The allowable noise target in India for two wheeler of 110 cm^3 is 77 dB(A).

Table 1. Noise limit value of vehicle in India

Type of vehicle	Noise Limits dB(A)
1) Two wheeler	
Displacement upto 80 cm^3	75
Displacement of 80 cm^3 - 175 cm^3	77
Displacement more than 175 cm^3	80
2) Three wheeler	
Displacement upto 175 cm^3	77
Displacement more than 175 cm^3	80

1.4 Size

The available space has great influence on size and type of muffler that may be used. A muffler may have its geometry designed for optimum attenuation however if it does not meet space constraints, it is useless. For performance vehicle every gram saved is crucial to its performance, especially when dealing with light race vehicles. So a small light weight muffler is desirable.

1.5 Backpressure

Backpressure refers to pressure exerted on a moving fluid by obstructions against its directions of flow. The effects of increased backpressure are more fuel consumption, increase in CO emissions and exhaust temperature.

1.6 Problem Statement

Though noise reduction is main purpose of muffler but it increases backpressure of engine too. This backpressure depends on pressure drop directly. So minimizing pressure drop surely reduces backpressure. And this can be achieved by varying some parameters like porosity, shape of pipes, position of baffle plates.

1.7 Objective

The objective of this paper is to study effect of varying porosity of pipes on pressure drop value.

2. METHODOLOGY

Primarily, external parameters of existing muffler are measured and its transmission loss value is calculated theoretically as transmission loss of muffler is main parameter for mathematical modeling. So by keeping same parameters, new muffler is designed with less and more porosity and is simulated on Ansys CFD software. Then results of new model are compared with model in [1].

3. MATHEMATICAL MODELLING

3.1) The parameters like total length of muffler body, diameter of pipe and body are kept same. The input values for further calculations are as follow.

1) Total length of muffler = L= 280 mm

2) Pipe diameter = D_1 = 18 mm

3) Body diameter = D_2 = 110 mm

4) Pipe Thickness = t_1 = 1 mm

5) Body thickness= t_2 = 2 mm

6) Frequency Range = 300 - 600 Hz

3.2) Calculation of transmission loss for existing muffler

Now $\alpha = 1 + 0.25 * (m-1/m)^2 * (\sin(K_1L))^2$ (1)

where α = Transmission loss coefficient

m = Ratio of cross-section areas

K_1= Wave number (m^{-1})

L = Length of chamber (m)

So Transmission Loss = $10 * \log(\alpha)$ (2)

Now we have to design the muffler having more transmission loss. But higher transmission loss also lengthen the muffler with single expansion chamber so here considered three chambered muffler for design and length of first chamber is kept maximum so that more transmission loss can be achieved and next two chambers are equally spaced. All chambers are separated by two baffle plates, one having centered hole and other having off-center hole for positioning pipes. So for maximum transmission loss length of first expansion chamber is calculated as 120 mm and next one is 80mm each.

For design of perforated pipe different parameters are calculated as below

1) *Resonant frequency* = $f_0 = \sqrt{(f_1 * f_2)}$ (3)

2) *Damping parameter* = $B = 10^{(TL/20)}$ (4)

3) *Cross section area* = $S = 3.14 * D_1^2 * 0.25$ (5)

4) *Acoustic Resistance* = R_a = Density * C/(2 * S * (B-1)) (6)

5) *Acoustic quality factor* = $Q_a = (f_0 * B)/(((f_2-f_1) * \sqrt{(B^2-2)})$ (7)

6) *Acoustic mass* = M_a = Ra * $Q_a/(2 * 3.14 * f_0)$ (8)

Now

$a = 3 * 3.14/16 *(M_a * R_s/R_a * density-t_1)$ (9)

Hole diameter = $d_h = 2* a$

After putting all values in above equations, we get value of hole diameter for both pipes is 5 mm. As we have lowered the porosity in middle section so hole diameter is kept 3 mm in intermediate tube and again 5 mm towards outlet pipe to higher porosity.

3.3) Calculation of Porosity

The porosity is calculated as,

Porosity = $0.25 * 3.14 * (d_h)^2/(C_a * C_c)$ (10)

Where C_a = axial distance between center to center

C_c = circumferential distance between center to center

For different pipes porosity is maintained as 23%, 12%, and 47%. The 3D model is created in Catia V5 using data as given below.

Table 2 : Dimensional Data

Sr No.	**Entity**	**Dimension (mm)**
1	Body length	280
2	Body diameter	110

3	Inlet pipe diameter	18
4	Inlet pipe length	180
5	Outlet pipe diameter	18
6	Outlet pipe length	80
7	Intermediate pipe diameter	18
8	Intermediate pipe length	40
9	No. Of holes in Inlet Pipe	72
10	No. Of Holes in Intermediate pipe	12, 16

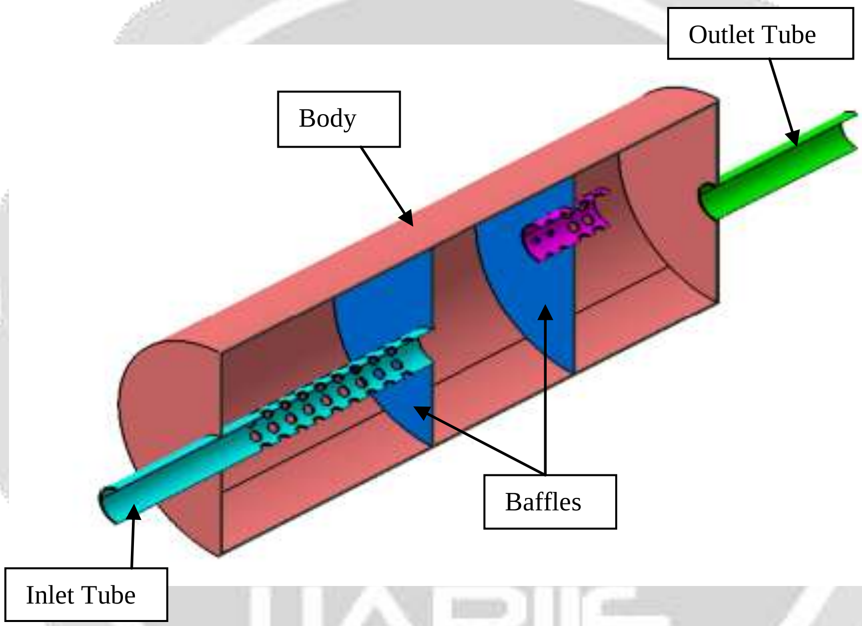

Fig.1 Cut Section Of Muffler

Fig. 2. CAD model of referred Muffler

The above figure shows finalized model from [1] with higher porosity which is selected for further experimental testing.

4. ANALYSIS OF MODEL

To give input data for analysis some assumptions are considered here as below,

- The flow is assumed to be steady and non-uniform.
- The flow is assumed to be incompressible.

From above assumptions and as referred from [1] following data is considered for analysis.

Table 3 : Input Parameters

Sr.No.	Property	Value	Units
1	Inlet Temperature	500	^0C
2	Inlet Pressure	121325	Pa
3	Inlet velocity	30	m/s
4	Density	0.4575	Kg/m^3
5	Specific heat capacity	1093	J/Kg.K
6	Thermal Conductivity	0.027	W/m.K
7	Viscosity	$2.23x10^{-5}$	Pa.s
8	Mass flow rate	0.0406	Kg/s

Then we have analyzed model in Ansys CFD and following results are obtained. The mesh analysis is given in tables below.

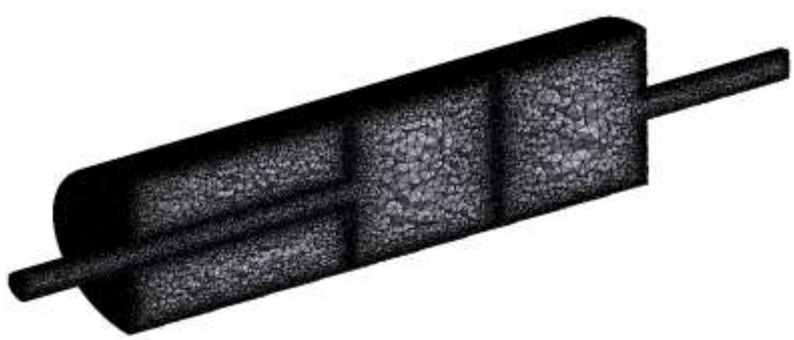

Fig.3. Meshed model of muffler

Table 4: Mesh Input Details

Minimum Size	2 (mm)
Maximum Size	10 (mm)
Mesh Method	Tetrahedron (Patch Conforming)

Table5: Mesh Output Details

Total Mesh Elements	6631884
Average Mesh Quality	0.82
Minimum Mesh Quality	0.11
Maximum Mesh Quality	1

5. RESULTS

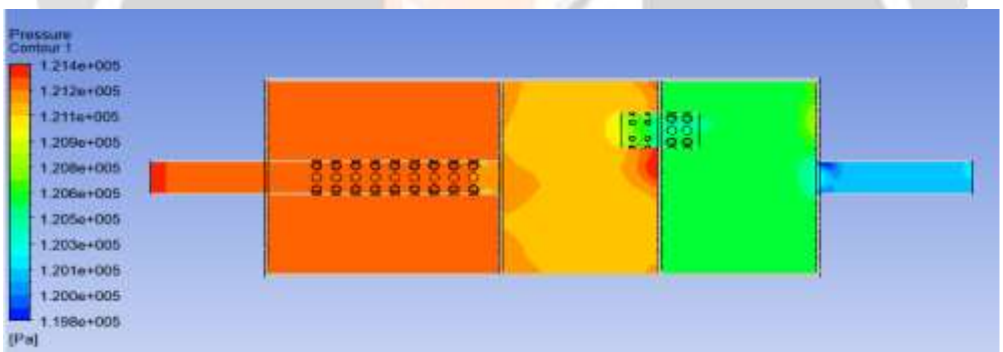

Fig.4. pressure contour of muffler

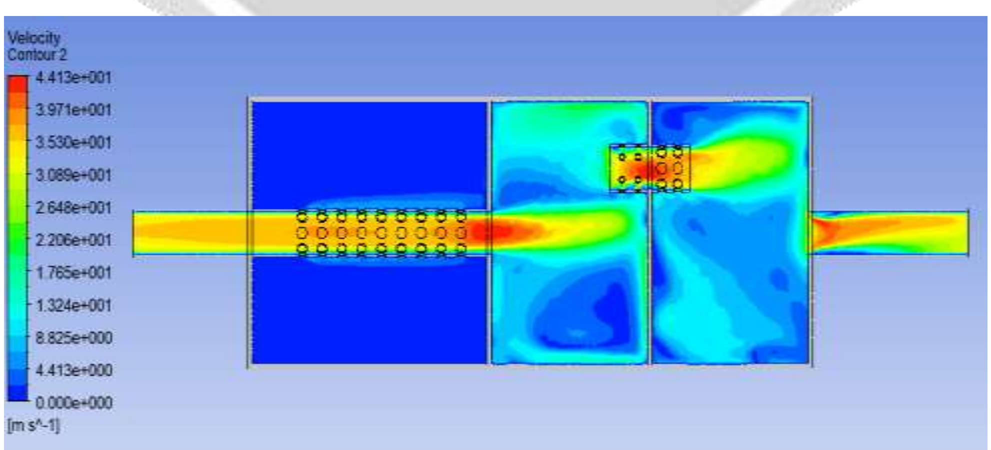

Fig. 5. Velocity contour of muffler

Fig. 6. Pressure Contours of referred Muffler Model

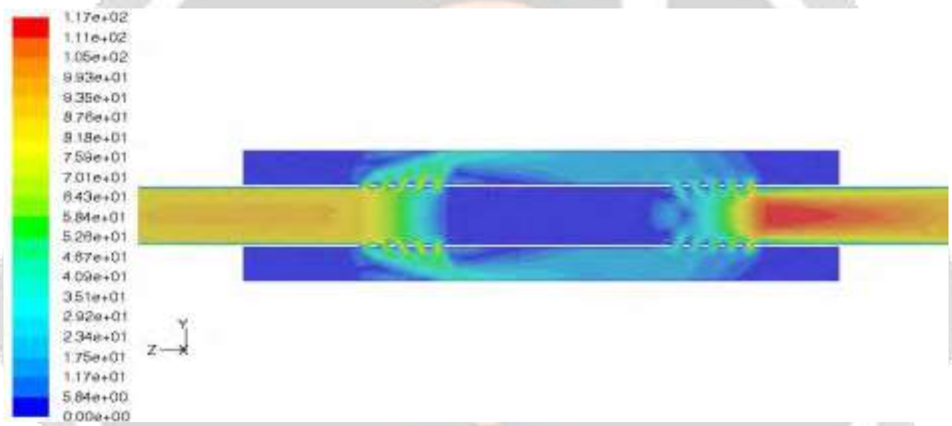

Fig. 7. Velocity Contours of referred Muffler

Table 6: Result for Pressure Drop

Parameter	Value	Unit
Pressure drop in new model	1185.8	Pa
Pressure drop in referred model	>4000	Pa

6. CONCLUSIONS

As we have designed muffler with variation in porosity for minimum pressure drop, maximum amount of pressure is distributed in first chamber then in next chamber such pressured gas is allowed to pass through less porous pipe. But as it passes through more porous region pressure is reduced so fast. According to velocity distribution, our new model has outlet velocity almost same as that of inlet but referred model has slightly higher outlet velocity which will create whistling sound on further throttling of engine. So it is better to vary porosity of pipe to get minimum pressure drop and uniform velocity distribution.

7. REFERENCES

[1] Sudarshan Pangavhane et al, " Experimental and CFD analysis of perforated inner pipe muffler for prediction of backpressure", in IJET Vol.5 No.5, pp. 3940-3950.

[2] S. Krishnan, " Exhaust System Muffler volume optimization of LCV by CFD simulation", in Proc. Materials Today 5, 2018, pp. 8471-8479.

[3] S.S. Mane, " Backpressure Analysis of engine muffler using CFD and experimental validation", in IERJ special issue , pp. 828-834.

[4] Xiaofeng Shi, Cheuk-Ming Mak, "Sound attenuation of a periodic array of micro-perforated tube mufflers", in *Applied Acoustics* 115, 2017, pp. 15-22.

[5] Yoha Hwang et al, "New active muffler system utilizing destructive interference by difference of transmission paths", in *Journal of Sound and Vibration* 262, 2003, pp. 175–186

[6] K. Suganeswaran et al , "Design and Optimization of Muffler for Manufacturing" , Volume 3, Special Issue 4, April 2014