Int. J. Chem. Sci.: 14(2), 2016, 1069-1076
ISSN 0972-768X
www.sadgurupublications.com

DESIGN AND FABRICATION OF REACTIVE MUFFLER

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ABSTRACT

IC engines are one of the major sources of noise pollution. Mufflers are generally found with exhaust system. After the combustion the high intensity gas pressure through the muffler chamber and some of the gases reflected again passes through the combustion chamber it is called back pressure. It creates vacuum pressure in combustion chamber and decreases the engine performance. Reduction of weight, increasing the capability of noise absorption from the muffler with minimal back pressure can increase the performance of the engine. The objective of this study is to optimize noise level of engine and reduce back pressure. This project mainly targets on designing a muffler to reduce the noise and back pressure. Based on new muffler design parameters, a model is fabricated and tested.

Keywords: Muffler, Exhaust gas, Backpressure, Noise pollution.

INTRODUCTION

Since the invention of the internal combustion engine in the latter part of the nineteenth century, the noise created by it has been a constant source of trouble to the environment. Significantly, the exhaust noise in terms of pressure is about 10 times all the other noise combine. The design of muffler has been a topic of great interest for many years and hence a great deal of understanding has been gained Hence good design of muffler should give the best noise reduction and offer optimum back pressure for the engine.

The performance of an exhaust system is assessed by a different factors, the most important factors are backpressure and the insertion loss of the system. High backpressure in an exhaust system affects the performance of the engine, decreasing power and increasing fuel consumption. Exhaust noise can be classified into two categories pulsating noise from the engine, and flow noise from high speed exhaust gasses flowing though and exiting the exhaust system. Pulsating noise is generated when exhaust gases at high pressure are

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released from the engine cylinders through the exhaust valves. Flow noise is created by exhaust gas flow oscillating and impacting inside the exhaust system[1].

There are five different design criterion of mufflers design, they are acoustical criterion, aero dynamical criterion, mechanical criterion, geometrical criterion and economical criterion. The acoustical criterion specifies the minimum noise reduction required from the muffler as a function of frequency. The mechanical criterion specifies the materials from which the muffler is fabricated. So that it is durable and requires less maintenance.

The economical criterion is vital in the market place. A muffler must be inexpensive as possible while designing initial cost as well as operating cost must be considered[2]. The various dimensions of the muffler are varied keeping some dimensions constant and then the effect on Backpressure is observed. It can be seen that the backpressure varies nonlinearly and it cannot be predicted by any equation. It can be concluded that the backpressure value is high for small diameters as compare to bigger diameter holes even if the porosity is double[3].

Analysed muffler by changing the length of each expansion chambers to understand the effects to the flow characteristics of a cross-flowed perforated and 3-expansion-chambered reactive muffler. It is known that an increase in the total muffler axial length results in a better noise attenuation performance. The decrease in the length of middle chamber prevents the cross flow. Thus, a greater pressure loss occur at this model[4].

Muffler design

Generally an exhaust muffler is required to satisfy some basic requirements such as adequate insertion loss, low back pressure, muffler sizing, which could affect the cost and durability to withstand with rough use and extremely high temperatures. Automotive mufflers usually have a circular or elliptical cross section. A circular shaped cross section is the best suited in the vehicle as it is delays the onset of higher order modes.

Exhaust muffler grads

Design calculation of muffler

A muffler have been designed, which is of supercritical grade type of making the muffler calculations have to use the exhaust muffler grades shown in the Table 1.

Table 1: Exhaust muffler grades

Muffler grades	Insertion loss (IL)	Body/Pipe	Length/Pipe
Industrial/Commercial	15 to 25 dB	2 to 2.5	5 to 6.5
Residential grade	20 to 30 dB	2 to 2.5	6 to 10
Critical grade	25 to 35 dB	3	8 to 10
Super critical grade	35 to 45 dB	3	10 to 16

Input parameters

Max. Engine speed (N) = 3500 RPM

No. of cylinders (n) = 4

Inlet pipe diameter (d) = 45 mm

Maximum temperature at inlet of muffler = 350°C

Chamber design

Chamber length and diameter: according to ASHRAE Technical committee 2.6, design muffler grades and their dimensions, the requirement matches with the super critical grade.

Length of muffler chamber is L = 10*0.045 m to 16*0.045 m, L = 0.45 m to 0.72 m

Chamber diameter is $D_1 = 3*d = 3*0.45$ m = 0.135 m

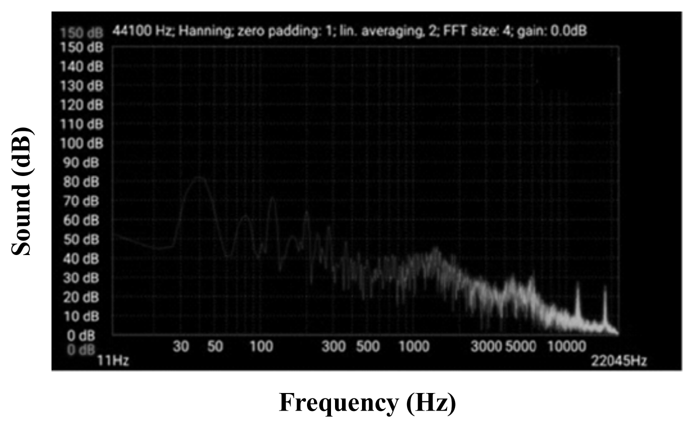

Fig. 1: Sound Vs frequency

Experimental peak low level frequencies are found from the above Fig. 4 are 40 Hz, 70 Hz, 125 Hz, 200 Hz, 250 Hz, 300 Hz, 370 Hz, 470 Hz and 550 Hz.

Resonance method

Where λ is the wavelength of sound (m). And n = 1, 3, 5… (Odd integers). But for economical consideration we take n = 1. And the reference value of speed of sound Vs is taken as 330 m/s. The length miscalculated for frequencies 370 Hz, 470 Hz and 550 Hz (other frequencies are either very short or very long chamber length) so that the length of the chamber method is satisfied. The wavelength λ is calculated for different frequencies.

Maximum attenuation occurs when $L = n\lambda/4$…(1)

Table 2: Wave length λ is calculated

Wave length	Sound velocity (Vs)	Frequency (Hz)	Vs/f
λ_1	330	370	0.891 m
λ_2	330	470	0.702 m
λ_3	330	550	0.6 m

Table 3: Calculated length of chambers

Chamber wave length	$\lambda_1/4$, $\lambda_2/4$, $\lambda_3/4$	Length of chamber
λ_a	0.891/4	0.222
λ_b	0.702/4	0.175
λ_c	0.6/4	0.150

We choose the length of chambers are 0.222 m for I chamber and II & III Chamber are 0.175 & 0.150 m Total length of chambers is taken as $\lambda_a + \lambda_b + \lambda_c = 0.222 + 0.175 + 0.150 = 0.547$ m

Dimensions of chamber

Diameter of chamber D_1 = 135 mm

Total length of chamber L_c = 547 mm

Length of I chamber = 222 mm

Length of II chamber = 175 mm

Length of III chamber = 150 mm

Diameter of perforated holes:

$$d_1 = 1.29 \sqrt{N} = 3 \text{ mm} \quad \ldots(2)$$

Baffle pipes design

Diameter of pipes inside the baffles are so that the cross section area doesn't reduce. So the Area of inlet pipe = Total area of baffle pipe, 2 pipes for the baffle are considered. So the diameter d_2 is calculated as:

$$d_2 = [\pi/4*d^2 = 2*(\pi/4*d_2^2)] \quad \ldots(3)$$

Design dimensions of muffler

Reactive muffler has been designed in SOLID WORKS using the above data in Table 4.

Table 4: Dimensional data

S. No.	Description	Dimensions (mm)
1	Shell length and diameter	547 and 135
2	Inlet pipe length and dia	100 and 45
3	Outlet pipe length, dia	100 and 45
4	Perforated pipe diameter	32
5	Perforated hole diameter	3
6	Shell thickness	1.5

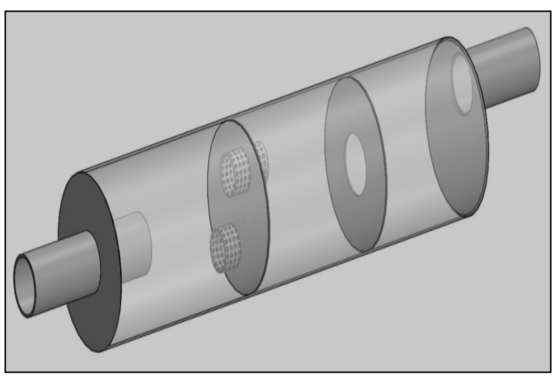

Fig. 2: Model of a muffler

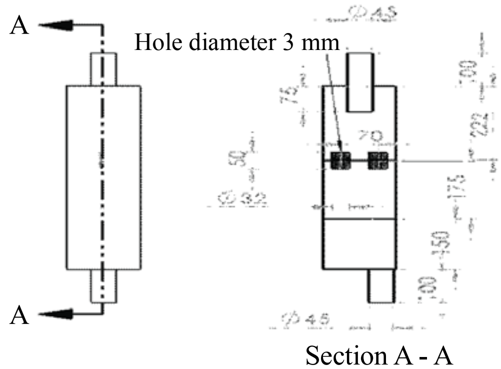

Fig. 3: Cut section view of muffler

RESULTS AND DISCUSSION

Mufflers are used to minimize sound transmission caused by exhaust gases. To optimized noise level of engine and reduce back pressure as possible. This can be achieved by new muffler designed. In designing there are different parameters, which have to be taken into consideration and designed the model is shown in the Fig. 2 it is a circular shaped muffler with inlet and outlet pipes. Inside a muffler, it contains a simple set of perforated tubes and baffle plates. Muffler is fabricated by stainless steel (SS-304). The fabricated muffler is show in the Fig. 4

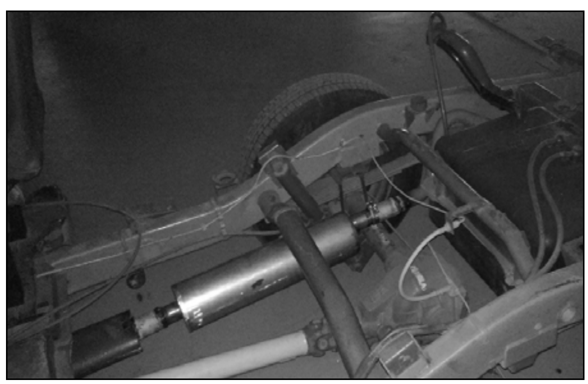

Fig. 4: Fabricated muffler

Design fabricated muffler is connected to the engine. Exhaust noise measurement were made at 0.5 m and 45 degrees angle from the end of the exhaust outlet with the precision sound level analyzer at the exhaust outlet level. Sound level is measured old and new muffler installed at different speeds Table 5.

Table 5: Insertion loss at different engine speed

S. No.	Engine speed (rpm)	Sound level (dB)		Insertion loss
		Old muffler	New muffler	
1	1000	80.8	66.6	14.2
2	1500	83.2	71.2	12.0
3	2000	85.3	74.5	10.8
4	2500	87.5	76.8	10.7
5	3000	90.3	78.5	11.8
6	3500	96.7	80.5	16.2

CONCLUSION

Amuffler was designed that meet the requirements likely adequate insertion loss, minimal backpressure, space constraints and durability, produce the minimal sound. Hence good design of the muffler should give the best noise reduction. The insertion loss in maximum at 3500 rpm with 16.2 dB. The maximum sound level of new muffler installation is 80.5 dBA at 3500 rpm as the position of install muffler. The variation of old and new muffler minimum insertion loss is 10.7 dBA at 2500 rpm. The designed muffler is capable to attenuate high as well as low frequency noise. The muffler attenuate low frequency noise, which lies between 200 Hz to 500 Hz. By replacing the muffler to existing model sound has been reduced compared to Mahindra maxx Mdi 3200 Di.

ACKNOWLEDGMENT

The successful completion of task would be in complete without dimension of these people who made it possible with constant guidance and cooperation. My grateful thanks to Mr. N. Prakash, Asst. Professor, Department of automobile engineering, Hindustan University, Chennai (TN), India.

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Accepted : 20.05.2016