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Design of Muffler of Three Cylinder Four Stroke Engine for Car for Reducing Backpressure

[1]Amit Galphade (M.E. Design Engineering 2nd Year)

[2]Prof Avinash Patil (H.O.D., Mechanical Department)

[1,2]Shree Sant Gadge Baba College of Engineering and Technology

Abstract: *Automobiles are the one of the major sources of noise pollution in modern times. Mufflers are used to reduce the noise from engine. However, due to the path provided, there is increase in the backpressure in the muffler which in turn increases the load on the engine. This paper explores the idea of perforation in the pipe and chamber plate and analyses the result of this introduced perforation*.

I. INTRODUCTION

Noise is defined as any unwanted sound. In any vehicle the prime suspects of the noise are engine and exhaust gases. Exhaust gases which are produced during the fourth stroke of the petrol engine are released by exhaust valve. However, instead of releasing them straight way to atmosphere, they are passed through the exhaust system comprising primarily of the exhaust manifold, catalytic convertor, muffler and exhaust pipe.

A muffler is an important noise control element for reduction of machinery exhaust noise, fan noise, and other noise sources involving flow of a gas. In general, a silencer may be defined as an element in the flow duct that acts to reduce the sound transmitted along the duct while allowing free flow of the gas through the flow passage.

There are many regulations put forward by both international organizations like WHO as well as national government organizations for control of noise. The mufflers are primarily designed for reduction noise. Thus mufflers are definitely reducing the noise pollution, but at the same time, there is increase in the back pressure which results in reducing the efficiency of the engine. This further results in heavy fuel consumption which leads to another problem of wastage of now highly deflated non-renewable energy sources like petroleum.

Automobile manufacturers are more concerned to meet the standards set by the different regulatory bodies because they have to. Hence we are able to get the relatively silent vehicles than before but this is also resulting into having vehicles with less engine efficiency. This actually puts new challenge for the engineers. In other words, this means redesigning the muffler which is the most critical component of exhaust system wherein the back pressure is created due to the flow of the exhaust gases through the exhaust pipes.

This calls for the balancing and challenges the engineers to create the exhaust system which will not only reduce the noise level but also will result in the fuel efficient engine. The balance needs to be stroked between the engine noise and engine efficiency such that it will give both fuel efficient as low in noise engines.

The aim of this project to study the existing muffler for the three cylinder petrol engine, then design the new muffler, installing it in the existing vehicle and then comparing and verifying the results with the existing and new values respectively.

Existing Muffler:

The existing muffler contains three chambers. The particulars for the muffler are as tabulated below

Muffler		
Sr. No.	**Particular**	**Dimensions (mm)/Number**
1	Length	304
2	Internal Diameter	130
3	Outer Diameter	134
Chamber 1		
4	Length	95
5	Pipe 3 Outlet Diameter	30
6	Length of Pipe 3 in Chamber 1	34
Chamber 2		
7	Number of Perforated Holes	16
8	Hole Diameter	7
9	Horizontal Distance Between Two Holes	4
10	Vertical Distance Between Two Holes	22
11	Length of Chamber	40
Chamber 3		

12	Length of Pipe 3 in Chamber 3	38
13	Number of Perforated Holes of Outlet Pipe	16
14	Hole Diameter	3
15	Horizontal Distance Between Two Holes	32
16	Vertical Distance Between Two Holes	21

Table 1: Dimensions of Existing Muffler

The design of existing muffler is as given below:

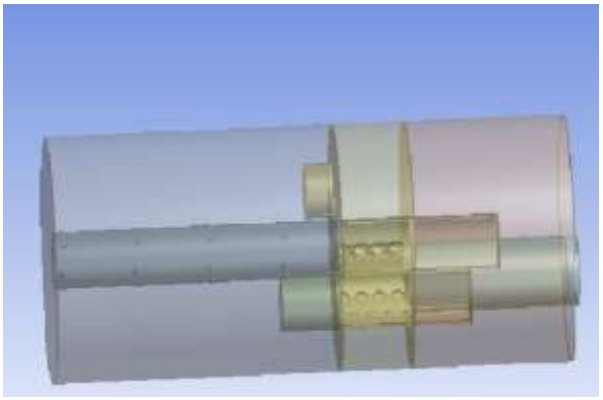

Fig 1: Existing Muffler

Design of Muffler for the 4-Stroke 3-Cylinder Petrol Engine

The conventional muffler is an enclosed metal tube packed with sound deadening material. An exhaust muffler is an acoustic filter except that waves are transmitted downstream by the moving medium. Inside a muffler, it contains a deceptively simple set of tubes with some holes in them. These tubes and chambers are actually designed to reflect the sound waves produced by the engine in such a way that partially cancels them out. Most conventional mufflers are rounded or oval-shaped with an inlet and outlet pipe. Some mufflers contain partitions to help reduce noise.

Muffler design is traditionally a trial and error process. However there are several guide lines suggested by several organizations but one main system that is followed is the one that is suggested by ASHRAE Technical Committee.

ASHRAE has defined several grades for the muffler and dimensions for respective grades. According to ASHRAE, the requirement for the design of muffler for 3 cylinder engine can be taken as Critical length and accordingly, the numbers for this grade are:

Insertion Loss (IL) = 30 to 35 dBA

Body/Pipe = 3

Length/ Pipe = 8 to 10

Accordingly the formula is

$8 \times \text{pipe dia} \leq L \leq 10 \times \text{pipe dia}$
$8 \times 0.034 \leq L \leq 10 \times 0.034$
$0.272\text{m} \leq L \leq 0.340m$

The length of existing muffler is 304 mm and it falls under the above range. As the modification is to be done for the existing car, the length as well as the diameter are having constraint and hence both are kept as they are.

More the number of chamber, better is the attenuation. The important part is keeping the length of chambers is that it must not match with the wavelength of the wave of sound produced inside the chamber because this will result in the resonance. The number of chambers in the existing muffler is 3 which is adequate. Also the length is not matching the wavelengths related to frequency.

Now for good transmission loss, and better acoustic performance, it is better to have larger Area of Perforation.

Area of perforation is defined as the ratio of Area of perforation to the Area of the plain sheet. So to have higher Area of perforation, the number of holes should be higher.

In order to achieve this two areas are identified.

(a) The outlet of inlet pipe in the existing muffler: Here 16 holes are provided for the outlet of the gases. As there are 16 holes, each of 7 mm, the total area available is $16*(\pi*3.5^2)$ i.e. 615.75 mm^2.

In the new design, the proposed number of holes is 40. Hence the new are covered by holes will be 1539.38 mm^2. This increased area enables for easy outlet of gases from the inlet gases. Thus the gases will be easily coming out and hence, even if the load is increased on the car, the gases would still easily escape and the resulting back pressure on the engine will be quite less.

The cut section of new designed inlet pipe is as given below:

Fig 2: Cut Section of New Inlet Pipe

(b) Small pipe opening in outlet chamber: There is one small pipe of 16 mm length and 29 mm internal diameter opening in the outlet chamber. The area of this opening is 660.519 mm^2. Now the gases which are coming out of inlet pipe in the middle chamber move to the outlet chamber through this pipe. As area is less, this also results in the increase the back pressure. So to solve this issue, the holes of 7 mm diameter are introduced in the plate which separates the middle chamber from outlet chamber. The number of holes is 26. So the total area which is covered by holes is 1000.597 mm^2.

This two increased areas result in easy passing of gasses which helps in decreasing the back pressure.

The modified new plate that separates the middle chamber and the outlet chamber is as shown below:

Fig 3: New Modified Plate

Analysis

Once the CAD modeling was done, the analysis of both existing and new design was carried out using Ansys 14.5. The following two figures show the CFX results of existing and new design.

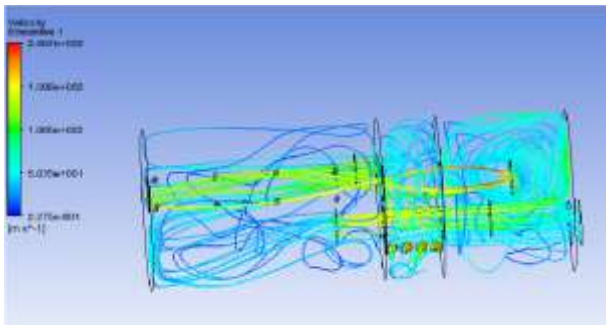

Fig 4: CFX Result of Existing Muffler

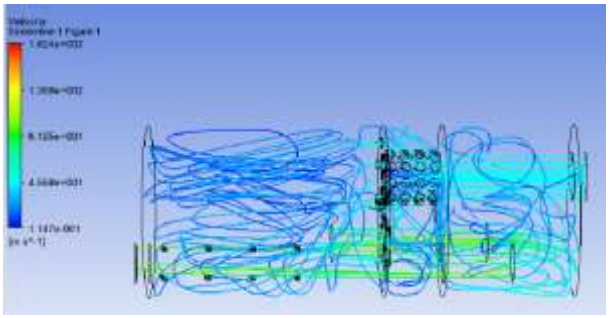

Fig 5: CFX Result of New Muffler

The above figures show that the flow is very smooth in the new muffler.

The CFX analysis was carried out in order to find out the back pressure that is created at the inlet chamber.The back pressure calculated is summarized in the following table:

Muffler	Max Pressure (Inlet) Pa	Max Pressure (Outlet) Pa	Back Pressure
Old	67751.2	194.137	67557.06
New	23698.3	214.124	23484.18

Table 2: Back Pressure Comparison

Conclusion

Backpressure is important parameter for designing the muffler yet is also the one which is mostly ignored by the automobile manufacturers. In the given project, the effort is made to reduce the backpressure so that the load that is developed on the engine due to exhaust can be reduced as much as possible. The analytical results show that the reduction in the back pressure is significant without compromising on the quality of the muffler.

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