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Original Article

A Case Study on Exhaust Muffler Backpressure Optimization

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Abstract: *A silencer is a component that reduces the noise that a machine makes. The silencer needs backpressure to operate effectively. Backpressure, which is the difference between mean exhaust pressure and ambient pressure, is caused by the decrease in stagnation pressure that occurs through various perforated element and area discontinuities. A maximum permitted engine backpressure has been established by the engine manufacturer for all engines. Sometimes it can be excessive, which could harm engine performance, limit power production, and eventually increase fuel consumption. The Computational Fluid Dynamics analysis of these silencer models is carried out in the ANSYS FLUENT programme using the CATIA V5 software and the Computational Fluid Dynamics analysis. These new modelled mufflers' backpressure findings will be compared to those of current ones using this software. We have chosen the most advantageous model from a set of four models based on the various boundary conditions utilised for CFD analysis.*

Keywords: *CFD, Back pressure, Muffler, Limit conditions.*

I. Introduction

A muffler is a device that is used to reduce machine noise. In order to reduce exhaust noise, an exhaust pipe connects the engine exhaust to a component known as a silencer. The silencer is a crucial component in the reduction of exhaust noise. Internal combustion engines frequently have exhaust mufflers fitted in order to block out the audible pulse created during combustion. Although to varied degrees, all internal combustion engines produce noise. The intensity and loudness of the noise will vary greatly depending on the engine type, such as naturally aspirated or turbocharged, horse power produced, ways of scavenging, kind of fuel used, number of cycles, such as two cycle or four cycle engine, etc. The principal sources that make up the The two primary sources of engine noise are the intake and exhaust systems. In order to reduce airborne noise in engines, mufflers are typically utilised at the intake and exhaust. A maximum permitted engine back pressure has been established by the engine manufacturer for all engines. When it is high, the diesel engine may occasionally encounter different effects. Therefore, reducing the back pressure in the exhaust silencer is the aim of this research. Utilising the computational fluid dynamics (CFD) programme will reduce the back pressure. Then the silencer will be built.

II. PROBLEM FORMULATION

The main factor affecting an exhaust muffler's performance is the backpressure value. The engine will have a number of detrimental effects if the back pressure increases, such as increased pumping work, lower intake manifold boost pressure, cylinder scavenging and combustion effects, turbocharger difficulties, etc. Therefore, lowering backpressure will lead to good engine efficiency. This project's main objective is to reduce the backpressure on the silencer. There are several engine problems as a result of the increased backpressure in the currently in use exhaust silencer. As a result, CATIA software is used to produce four different kinds of models, which are then examined using computational fluid dynamics (ANSYS FLUENT) software in order to lessen backpressure. Based on analytical results, a comparison of backpressure between various existing mufflers and newly modelled mufflers will be conducted. Following comparison, the best-performing silencer model will be one with limiting backpressure.

III. SELECTION FACTORS FOR MUFFLER

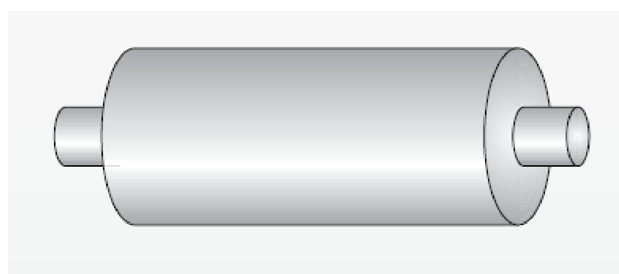


Figure 1: Muffler

A. Execution in the Acoustic:

The acoustical performance criterion, which is normally provided as IL values for each octave band as well as an overall predicted noise reduction value, specifies the minimal insertion loss (IL) of the Muffler. Using the free-field sound pressure levels of the silent and unsilenced systems measured at the same relative locations with regard to the outlet, the insertion loss is determined.

B. Mechanical Efficiency

The mechanical performance criterion specifies the material characteristics of the exhaust system in order to ensure its durability and minimal maintenance requirements once it is in service. The selection of materials is especially important when there are caustic gases or high temperatures present. Conventional carbon steels are often appropriate for the majority of applications requiring diesel-fueled generators. Because natural gas engines normally operate at higher temperatures than their diesel counterparts, a graded carbon or stainless steel that can maintain some structural performance at high temperatures may be required.

C. *Structural performance*

The structural performance requirement may specify the geometric restrictions and/or maximum allowable volume/weight of the Muffler, which may have a significant impact on the Muffler design process. Secondary loading, which is distinct from the weight of the silencer, may also have an impact on the design and cost of the exhaust system. A typical engine silencer is not frequently designed to support substantial stresses due to earthquake activity, wind or thermal expansion of adjoining pipe work. If mufflers are specifically included as a part of an exhaust "stack," they should be engineered to resist the loads that will be absorbed due to the likelihood of strong wind loads and seismic activity."

IV. BACK PRESSURE

A. For the generator set to function effectively, the installed exhaust system must not exceed the maximum exhaust backpressure limit stipulated by the engine manufacturer. The pressure drop of the exhaust system includes losses from the termination, silencer, and pipework. High backpressure can cause overheating, decreased engine efficiency or higher fuel consumption, as well as a complete shutdown of the producing system, all of which could cause significant harm. Back pressure in the exhaust system of a four-stroke vehicle engine degrades engine performance, reducing power output and requiring increased fuel consumption to make up for the lost power.

B. Measuring Backpressure

Exhaust backpressure is measured at full rated load and speed for the engine. You can use a gauge that measures inches of water or a water manometer. Backpressure is often caused by one or more of the following factors.

The exhaust pipe is too long, the muffler resistance is too high, the diameter of the exhaust pipe is too tiny, and the system has too many abrupt bends..

C. Effects Of Backpressure

Several consequences of increased exhaust pressure on the diesel engine include the following:

- Increased pumping effort
- Decreased boost pressure in the intake manifold
- Cylinder scavenging and combustion impacts
- Turbocharger difficulties

These are the engine issues that have developed. As a result, the engine efficiency will be high and the backpressure will be decreased.

MODELLING OF MUFFLER

The modelling of the all muffler by using given dimensions is done by using CATIA V5 software. The various modules used for the modelling purpose are Sketcher, Part design, Surfacing and assembly design. After the modelling these models are saved in .stp format for the analysis purpose.

D. Design of Muffler

Following are the parameters of the Engine for which this exhaust muffler is used.

Number of Strokes - 2
Fuel used - Diesel
Power - 7.5 HP
Number of Cylinder (n) - 1
Bore (D) - 86 mm
Stroke (L) - 68 mm

E. Calculation of Muffler volume -

$$\text{Swept volume (VS)} = ((\pi*D^2*L))/4$$
$$VS = 3.14*862*68$$
$$VS = 0.395 \text{ Lit.}$$

$$\text{Volume Considered for Calculation} = (n) * VS/2$$
$$= 1 * 0.395/2$$
$$\text{Volume} = 0.1975 \text{ Lit.}$$
$$\text{Silencer Volume} = \text{Factor} * \text{Considered volume}$$
$$= 0.1975 * 17$$
$$\text{Silencer Volume} = 3.335 \text{ Lit.}$$

Diameter of Muffler Calculated as, l - Length of Muffler (m)

$$Vm = ((\pi*d^2*l))/4$$

d - Diameter of Muffler (m)

$$0.0033 = 3.14 * d2 * 0.335/4$$
$$d = 0.113 \text{ m}$$

Therefore the Length and Diameter of the muffler is taken as 335 mm and 113 mm for further modelling.

V. MUFFLER MODELS

The figure below shows the current muffler's CATIA V5 model. These mufflers are constructed of mild steel, with chromium serving as the main material. This model consists of a chamber, an inlet, an outlet, front and rear baffles, and holes on the back baffle. On the front and back baffles of this assembly, three pipes are connected, as shown on the model. Below the model of the full system, several parts of the exhaust silencer are depicted separately.

The Dimensions of the Existing Muffler are given below,

Length of Chamber - 335 mm
Diameter of Chamber - 113 mm
Thickness of Chamber - 1.2 mm
Inlet Diameter - 35mm
Outlet Diameter - 40 mm

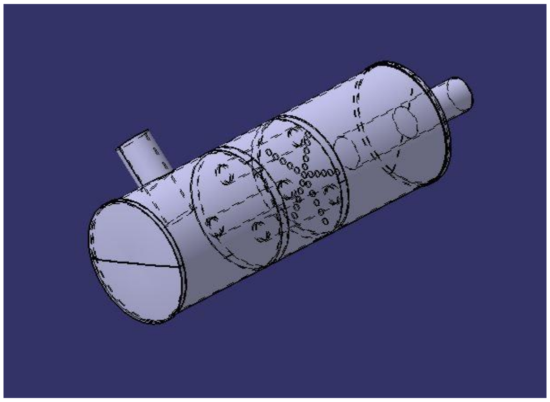
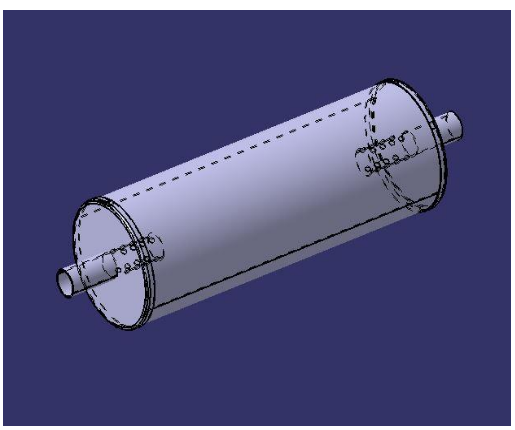


Fig. 2 CAD Model of Existing Muffler

Newly Designed Muffler Models -

The dimensions of all muffler models are given below,
Length of Chamber - 335 mm
Diameter of Chamber - 113 mm
Thickness of Chamber - 1.2 mm
Inlet Diameter & Outlet Diameter –Different for each models.
Number of perforated holes - Different for each models.



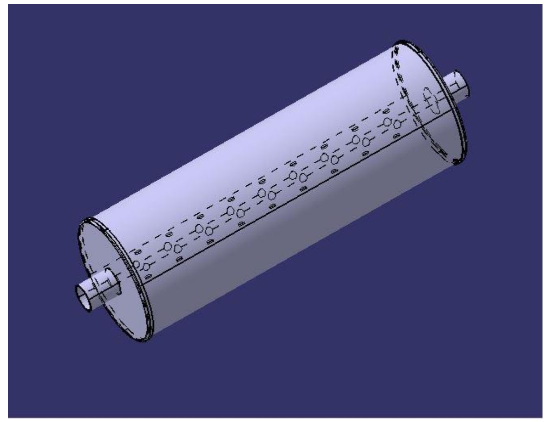
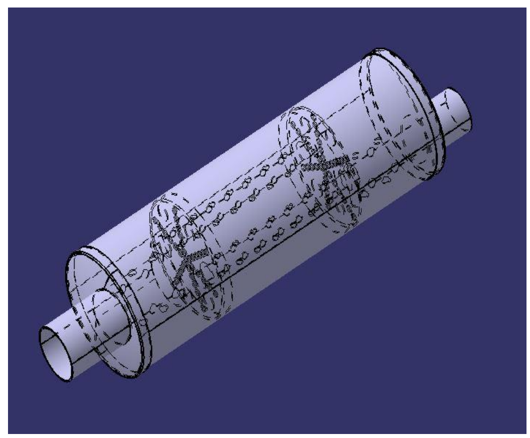


Fig. 3 - CAD Model of Muffler 1
Fig. 4 - CAD Model of Muffler 2



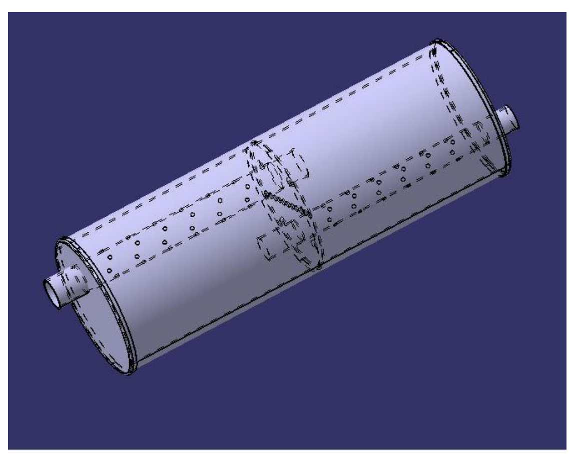


Fig. 5 - CAD Model of Muffler 3
Fig. 6 - CAD Model of Muffler 4

VI. Analysis Of Muffler Model

A. *Comparison of Meshing*

The three-dimensional meshing of all the aforementioned silencer models is performed using the ANSYS FLUENT software. Physical preference - CFD, Solver preference - Fluent, and Element size - Default for meshing all models are the settings for fluent meshing. A comparison of all meshing models shows that the models with the most perforated holes have the most nodes and elements. The Quad and Tetra elements are employed in the meshing process for all silencer kinds. The table below shows all of the nodes and parts for the silencer models.

TABLE I

Muffler Models	***No. of Nodes and Elements***
Existing Muffler	Nodes - 11237 Elements - 24997
Muffler Model – 1	Nodes - 112352 Elements - 380522
Muffler Model – 2	Nodes - 8658 Elements - 44657
Muffler Model – 3	Nodes - 45951 Elements - 225873
Muffler Model – 4	Nodes - 58106 Elements - 159980

B. *Comparisons For Pressure(From Ansys Fluent Results)*

TABLE II

Muffler Models	***Values of Backpressure (Kpa)***
Existing Muffler	44
Muffler Model – 1	178
Muffler Model – 2	916
Muffler Model – 3	13
Muffler Model – 4	35

VII. **CONCLUSION**

The results of the CFD analysis (Ansys Fluent) show that the muffler model-4 has an optimal backpressure value since it has a lower backpressure value than the current muffler. These results are compared to those of the experiment after analysis. Based on all of the analyses and experimental results, we will choose the silencer with the best backpressure.

References

M. Rahman, T. Sharmin, A F M E. Hassan, and M. Al Nur, "Design and Construction of a Muffler for Engine Exhaust Noise Reduction", Proceedings of the International Conference on Mechanical Engineering, 2005.

Yunshi Yao, Shaodong Wei, Jinpeng Zhao, Shibin Chen, Zhongxu Feng and Jinxi Yue, "Experiment and CFD Analysis of Reactive Muffler", Research Journal of Applied Sciences, Engineering and Technology, 2013,Volume 6, ISSN: 2040-7459.

Mr. Paritosh Bhattacharya, Rajsekhar Panua, Dr. Prabir Kumar Bose, Dr. Bankim Bihari Ghosh ,"Design of Reactive Muffler for Study on the Noise Level and Performance of a Two Cylinder Four Stroke 16 H.P Diesel Engine", SAE International, 2007

Zeynep Parlar, Sengil Ari, Rifat Yilmaz, Erdem Ozdemir, and Arda Kahraman, "Acoustic and Flow Field Analysis of a Perforated Muffler Design", world academy of science ,engineering and technology, 2013, vol.7 .

Mr.Amit Mahadeo Asabe, Prof. Pravin P Hujare.,"Performance Enhancement of Automotive Silencer Using Finite Element Analysis"., International Journal of Engineering Science, Volume 3, PP.14-22, 2014.

Potente, Daniel, "General Design Principles for an Automotive Muffler", www.daydesign.com, 2005.

Shital Shah, Sai sankaranarayana K, Kalyankumar S., Prof. D. G., "A Practical Approach towards Muffler Design, Development and Prototype Validation",SAE International, 2010.

Rajasekhar Reddy M., Dr.Madhava Reddy.," Design And Optimization Of Exhaust Muffler In Automobiles ", International Journal Of Engineering Vol. 2, pp.395-398, 2012.

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