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Optimization of Backpressure for Exhaust Muffler

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Abstract: The muffler is defined as a device for reducing the amount of noise emitted by a machine. Backpressure is essential for the performance of muffler. Backpressure is the difference between the mean exhaust pressure and the ambient pressure and is due to drop in stagnation pressure across various perforated element and area discontinuities. All engines have a maximum allowable engine backpressure specified by the manufacturer of the engine. Sometimes it will be high so that may cause negative effect on engine efficiency resulting in a decrease in power output and therefore increasing the fuel consumption. By using CATIA V5 software and the Computational Fluid Dynamics analysis of these muffler models are carried in the ANSYS FLUENT software. By using this software, results of the backpressure of these new modelled mufflers will be compared with existing one. Based on the various boundary conditions used for CFD analysis we have selected the optimum model between four models.
Keywords: Computational Fluid Dynamics, Back pressure, Muffler, Boundary conditions.

I. INTRODUCTION

The muffler is defined as a device for reducing the amount of noise emitted by a machine. To reduce the exhaust noise, the engine exhaust is connected via exhaust pipe to Muffler called muffler. The Muffler makes a major contribution to exhaust noise reduction. Internal combustion engines are typically equipped with an exhaust muffler to suppress the acoustic pulse generated by the combustion process. All internal combustion engines produce noise, some more or less than the others. The intensity and magnitude of the noise will vary greatly depending upon engine type i.e. naturally aspirated or turbocharged, horse power developed, means of scavenging, type of fuel used, number of cycles whether two cycle or four cycle engine etc. Among the pre-dominant sources that make up the engine noise are the engine intake and exhaust. For the purpose of noise control on engines, it is common practice to use Mufflers at intake and exhaust for treating the airborne noise. All engines have a maximum allowable engine back pressure specified by the engine manufacturer. Sometimes it will be high so that may cause some effects on the diesel engine. So this project is aimed to reduce the back pressure in the exhaust Muffler. By using the software computational fluid dynamics (CFD) the back pressure will be reduced. Then the muffler will be fabricated.

II. PROBLEM STATEMENT

An Exhaust muffler's performance is mainly dependent on value of backpressure. If the back pressure increased then there are several adverse effects such as pumping work increases, intake manifold boost pressure reduces, cylinder scavenging and combustion effects and turbocharger problems etc. arises in engine. Therefore if the backpressure is reduced then engine efficiency will be high. This project is mainly for reducing the backpressure of the muffler. For the existing exhaust muffler the backpressure is more and therefore it creates many problems in engine. Therefore for reducing the backpressure four different types of models are modelled by using CATIA software and analysis of these models done by using the Computational Fluid Dynamics (ANSYS FLUENT) software. From the analysis results, comparison of backpressure between existing muffler model and newly modelled muffler will takes place. After comparison the muffler model with limiting backpressure will be chosen as an optimum muffler model.

III.MUFFLER SELECTION FACTORS

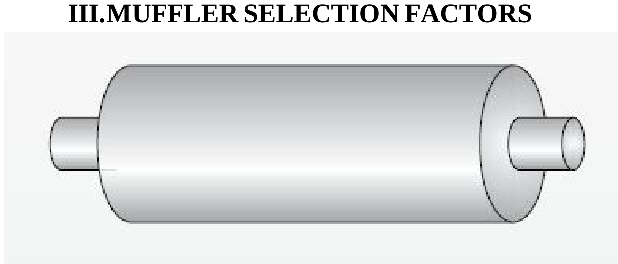

Fig. 1 Muffler

A. Acoustical Performance

The acoustical performance criterion specifies the minimum insertion loss (IL) of the Muffler, and is usually presented in IL values for each octave band as well as an overall expected noise reduction value. The insertion loss is determined from the free-field sound pressure levels measured at the same relative locations with respect to the outlet of the unsilenced and silenced systems.

B. Mechanical Performance

The Mechanical performance criterion specifies the material properties of the exhaust system to ensure that it is durable and requires little maintenance when incorporated into service. Material selection is especially important in cases involving high temperature or corrosive gases. Traditional carbon steels will typically be sufficient for the majority of applications using Diesel fuelled generators. Natural Gas engines will traditionally run at an elevated temperature above their Diesel counterpart, and may require a graded carbon or stainless steel that can maintain an element of structural performance at elevated temperatures.

C. *Structural performance*

The Structural performance criterion can specify the geometric restrictions and/or maximum allowable volume/weight of the Muffler that can substantially influence the Muffler design process. Secondary loading outside of the weight of the Muffler can also affect the design and cost of the exhaust system. A standard engine Muffler is not traditionally designed to absorb substantial loads due seismic activity, wind or thermal growth of adjacent piping. Mufflers that are specifically incorporated as an element of an exhaust "stack" should be designed to accommodate the loads that will be absorbed due to potentially high wind loads as well as seismic activity.

IV. BACK PRESSURE

It is essential to the performance of a generator set that the installed exhaust system does not exceed the engine manufacturer's maximum exhaust backpressure limit. Pressure drop of exhaust system includes losses due to piping, silencer, and termination. High backpressure can cause a decrease in engine efficiency or increase in fuel consumption, overheating, and may result in a complete shutdown of the generating system potentially causing significant damage .Back pressure caused by the exhaust system of an automotive four-stroke engine has a negative effect on engine efficiency resulting in a decrease of power output that must be compensated by increasing fuel consumption.

A. Measuring Backpressure

Exhaust backpressure is measured as the engine is operating under full rated load and speed conditions. Either a water manometer or a gauge measuring inches of water may be used. Backpressure is commonly caused by one or more of the following factors

1) Exhaust pipe diameter too small.
2) Excessive number of sharp bends in the system.
3) Exhaust pipe too long.
4) Muffler resistance too high.

B. Effects Of Backpressure

Increased exhaust pressure can have a number of effects on the diesel engine, as follows:

1) Increased pumping work
2) Reduced intake manifold boost pressure
3) Cylinder scavenging and combustion effects
4) Turbocharger problems

These are the problem arises in the engine. So the backpressure will be reduced the engine efficiency will be high.

V. 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.

A. 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

B. Calculation of Muffler volume -

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

Volume Considered for Calculation = (n) * VS /2
= 1 * 0.395 /2
Volume = 0.1975 Lit.
Silencer Volume = Factor * Considered volume
= 0.1975* 17
Silencer Volume = 3.335 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 m

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

VI. MUFFLER MODELS

Below figure shows the existing model of muffler which is modelled in the CATIA V5. The material used for the manufacturing of these mufflers is mild steel chromium based material. This model consists of chamber, inlet, outlet, front and back baffle, Holes on back baffle. In this assembly three pipes are connected on front and back baffle as shown in model. Below the full assembly model various parts of the exhaust muffler are shown 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

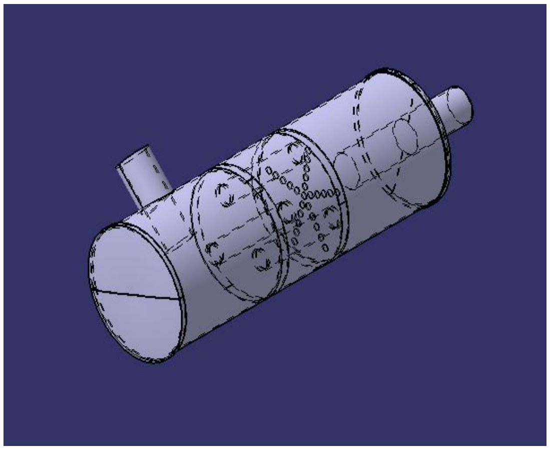

Fig. 2 CAD Model of Existing Muffler

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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.

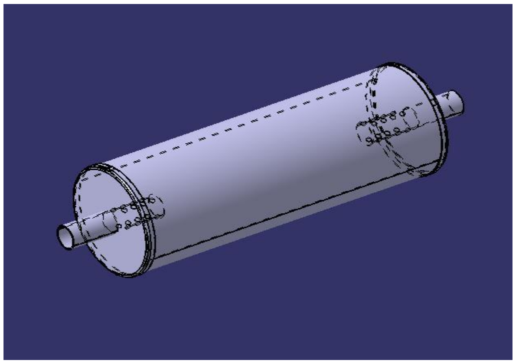

Fig. 3 - CAD Model of Muffler 1

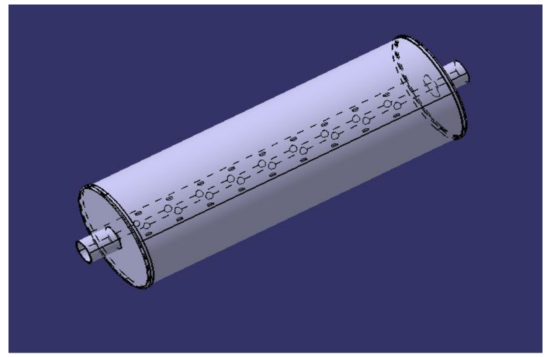

Fig. 4 - CAD Model of Muffler 2

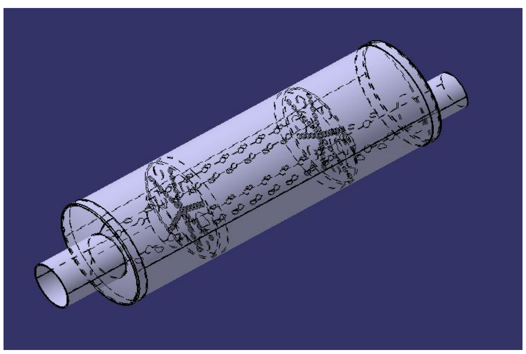

Fig. 5 - CAD Model of Muffler 3

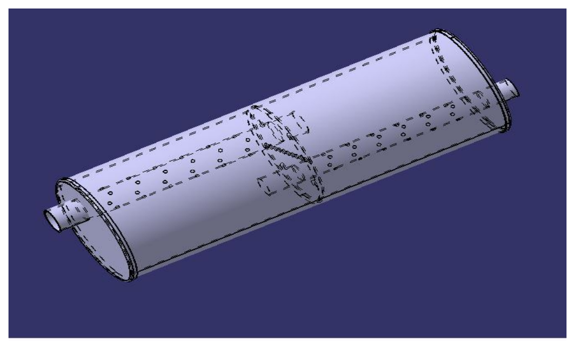

Fig. 6 - CAD Model of Muffler 4

VII. ANALYSIS OF MUFFLER MODEL

A. Comparison of Meshing

The 3 D meshing of the all above muffler models is done by using the ANSYS FLUENT software. For meshing of all the models, settings used in fluent meshing are Physical preference - CFD , Solver preference - Fluent , Element size - Default . From comparison of all meshing models it is seen that the models which contains more perforated holes has more number of nodes and elements. The elements used in meshing are the Quad and Tetra elements in all muffler models. Below table shows the nodes and elements of the all muffler 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

VIII. CONCLUSION

From the CFD analysis (Ansys Fluent) results it is seen that the value of backpressure of muffler model-4 is less than existing muffler and this shows optimized backpressure value. After analysis, these results are compared with experimental results. From all the analysis and experimental results we will choose the muffler with optimum backpressure.

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