DESIGN AND ANALYSIS OF MUFFLER TO REDUCE THE BACK PRESSURE

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ABSTRACT
The function of an exhaust muffler is to make the smooth path for flue gases emitted from the exhaust manifold while reduces the clam our build by the engine. Due to the twists and turns that the exhaust gas has to make to reach the atmosphere, there is a considerable amount of backpressure which restricts the free flow of the exhaust gases. It is necessary to reduce the backpressure as it reduces the fuel consumption of the engine. The major concern for a designer is to ensure that the backpressure is minimum. This project deals with four different models of chambered exhaust muffler and concludes the best possible design for least pressure drop. SolidWorks 2014 version was used to design the exhaust mufflers. Numerical analysis for backpressure testing was conducted by Flow Simulation of SolidWorks 2014. Heat balance test on single cylinder diesel engine was performed to know the mass flow rate of the exhaust gases. Flow trajectories are viewed to know the flow of exhaust gases through the muffler. The cut plots for pressure and exhaust gas velocity are viewed. Pressure drop is calculated across the exhaust muffler by viewing the pressure distribution.

Keywords *- Back pressure, CFD analysis, Diesel engine, Muffler*

I. INTRODUCTION

A muffler is a component, which is used to reduce the chaos produced by internal combustion engine. It is installed within the exhaust system. The exhaust sub-system is exposed to high temperatures as they form the passage for the hot gases released upon combustion of fuel to be released to the atmosphere. While there are other prominent areas to be focused during design phase, the uniform distribution of heat over the entire exhaust system (including the silencer) is of importance for ensuing enhanced life of the elements in the sub-system. The increase in world's industrialization results biggest ever global warming. Automobiles are the major contributors to environmental pollution. As pollution regulations are stringed among the countries, the automotive industry is being concentrated on reduction in exhaust emissions without affecting the performance of engine. The gases from vehicles contains many combustion products that contribute to air pollution, mainly carbon monoxide (CO), hydrocarbons (HC) and oxides of nitrogen (NOx). Muffler is the one of the device in reduction of adverse affects from internal combustion engine. In this work the design of muffler is modified in such a way that it reduces the backpressure and noise. The design of chambered muffler consists of series of passages and chambers to reduce sound pressure that produced from the engine. Exhaust gases cannot flow out to atmosphere properly as back pressure is increased as the exhaust system shares the same complex of exit path built inside the muffler. The automotive industry is making the muffler designs by using cut methods which depend on what has been worked in the previous experiments. This difficulty has been accomplished by numerical methods, which helps to perform the tests on replica under number of operating conditions there by reducing the time and money. A new computer software, like Solid works flow simulation, FLUENT, CFX are some of the methods used to analyze the muffler.

II. LITERATURE

Jianmin Xu et al. [1] analyzed the influence of the distance between the main and sub-muffler on the flow field of exhaust system. Yunshi Yao et al. [2] evaluated the performance of reactive muffler and how it effects the power loss of engine. The flow field inside the muffler was discussed. They used computational fluid dynamics simulation and compared with experimental results and the design of reactive muffler was optimized. The velocity field coincided with the pressure field which showed the optimized muffler has improved aerodynamic characteristics. Puneetha C G et al.[3] studied and analyzed four different models of exhaust muffler and concluded that the best possible design for least back pressure drop. Back pressure was obtained based on the flow pattern analysis and was also compared with all muffler design. In their work they used numerical simulation to observe the back-pressure. The model and mesh was generated using finite element and hyper mesh as the preprocessor. The function of exhaust system was observed and disposed the exhaust gases emitted by the engine with a maximum reduction in exhaust noise and minimum effect on the efficiency, life and maintenance of the engine [4]. A.K.M. Mohiuddin et.al. and Huang, L [5, 6], explained that the exhaust emissions from diesel engines are more harmful than petrol engines to environment, which adversely affects the human health especially on lungs, eyes and nerve system. Jay A. Bolt et.al. [7] performed a detailed study on various exhaust equipment, including catalytic converter, muffler and resonator in diesel engine which helps in reduction of engine emissions. Results showed that the increase in exhaust back pressure decreases nitric oxide, due to the exhaust gas remaining in the cylinder and un burnt hydrocarbon emissions because of reduction in exhaust back pressure. Mohd Rashidin Ideres et.al.[5] explained the performance and emissions of a diesel engine can be controlled by backpressure. The long term application of the muffler causes significant effect on engine performance and emissions. The backpressure is build due to particulate matter and other exhaust products in flow passage of exhaust systems there by reducing the gas path. J.E. Bennethum et.al.[8] elaborated on effect of excessive backpressure in the exhaust system. It creates extra heat, low engine power output and more fuel consumption in the engine cylinder, results the damage of the engine parts and poor performance. They concluded that the backpressure is one of the parameter to improve the engine performance and reduces emissions. In this point of view the exhaust system is installed with muffler. C.G.Puneetha et.al. [9] described the important function of a muffler. It creates a path to the exhaust gases from the engine exhaust manifold while reducing the noise and backpressure. In automotive industry the reduction in noise is an emerging concern. Reduction in backpressure enhances the fuel economy of the engine. Murari Mohon Roy et.al. [10] conducted experiments on effect of backpressure in compression engine, on performance and emissions. The pressure exerted on a moving fluid by obstructions against its direction of flow is called back pressure. They explained that the pressure is a scalar quantity, not a vector quantity, and has no direction. The gas flows in only one direction which is driven by pressure gradient. The flow obstructions in the exhaust system were overcome by engine that pumps the gas by compressing it to a sufficiently high pressure. Mayer, A., [11] explained that the engine must compress the exhaust gases to a higher pressure at the time of increased back pressure levels. This involves additional shaft work and/or low energy extraction by the exhaust turbine. This affects the intake manifold boostup pressure. These results in increased fuel consumption, more particulate matter & carbon monoxide emissions and higher exhaust temperatures. The increased exhaust temperature causes NOx emissions .

Peter Hield [12] evaluated the other effects of backpressure on diesel engine combustion. He observed that the performance of the turbocharger was affected by increased backpressure. It causes the change in the air-to-fuel ratio usually enrichment which is a source of emissions.

Pradyumna Saripalli et.al. [13] studied the effect of type of the air charging systems. Some of the exhaust gases leaving from the engine cylinder might prevented by increasing in exhaust pressure which creates exhaust gas recirculation. This EGR reduces some part of oxides of nitrogen by 2-3%.

III. MATERIALS & METHODOLOGY

To estimate the performance parameter that is pressure variation in muffler the following methods should be done:

- Flow pattern CAD model of muffler is created in Solidworks.
- Meshing.
- Calculating the mass flow rate of exhaust of single cylinder diesel engine.
- Analysis is carried out in Flow simulation with boundary conditions.
- Results are noted and compared to further change in designs of muffler.

These methods are carried out for study of backpressure in chambered exhaust muffler and results are discussed.

DESIGN OF CHAMBERED EXHAUST MUFFLER

The design of muffler was modified by changing the inlet position with respect to width of the system. It also incorporated with number of plates inside the object across the path of the exhaust gases. These plates are placed at different angles to observe which plate position results in optimum backpressure. Combination of inlet position and inclined plates studied using numerical simulation to get the detailed view of flow pattern in terms of pressure and velocity. Two different models were created and analyzed as shown in following.

IV. FIGURES AND TABLES

Design 1:
In Design - the length is changed from 13.00" to 10.25" CAD modelling has been done using SolidWorks 2014 version. The dimensions required to design were taken from a muffler manufactured by Flowmaster.

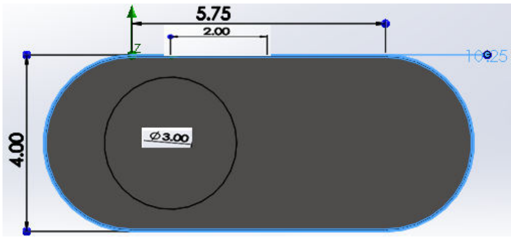

Fig.1 Front View of Design-1 with inlet position

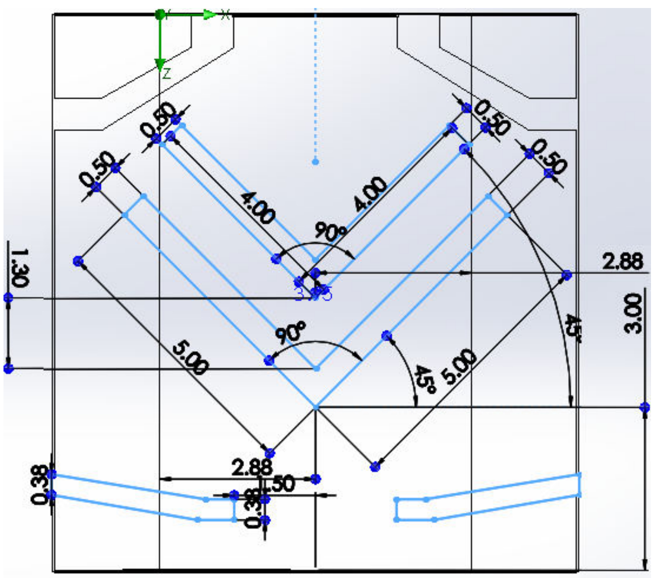

Fig.2 Top view of Design-1

Design 2:
In Design -2, the inlet position is changed from offset to centre by keeping the length constant. The dimensions are as given below:

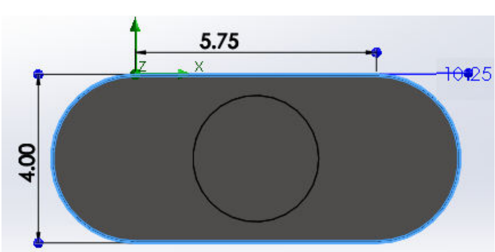

Fig. 3 Front view of Design-2 with inlet position

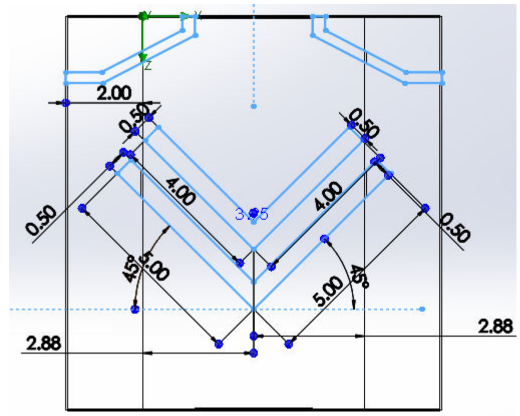

Fig. 4 Top view of Design-2

CFD ANALYSIS
CFD Analysis has been performed using Flow Simulation of SolidWorks 2014x64 edition.

Meshing:
Meshing is done automatically by the software. The element used by the software is Cubic. Below are the figures that depict how the exhaust mufflers are meshed by the software.

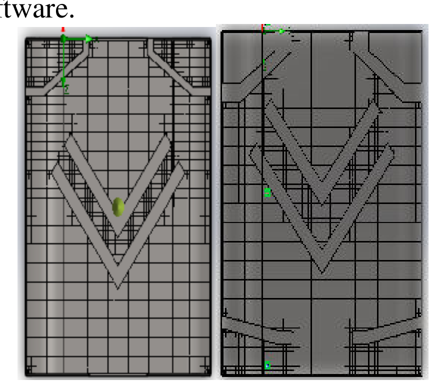

Fig. 5 Mesh of design 1 and 2

Boundary Conditions:
In this study, mass flow rate is given as the inlet boundary condition and atmospheric pressure as the outlet boundary condition.

Table 2 Boundary conditions

Mass flow rate at inlet	17.995 kg/hr
Atmospheric Pressure at outlet	101325 Pa

CFD results of Desgin-1
Velocity Distribution

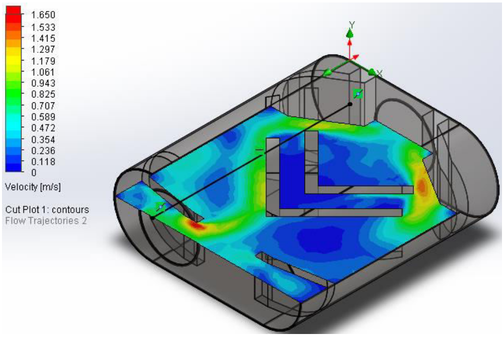

Fig. 6 Cut plot of Desgin-1 showing velocity distribution

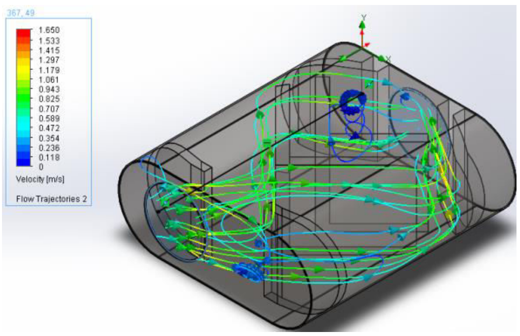

Fig. 7 Flow trajectories with velocity as parameter in Desgin-1

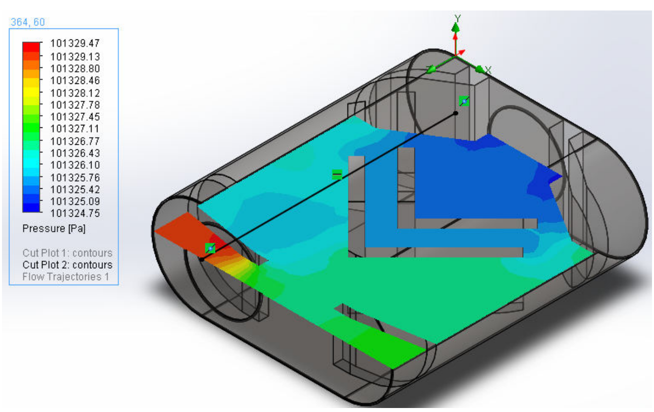

Fig. 8 Pressure distribution in Desgin-1

The fig. 6, 7, 8 and 9 exhibits the cut plot and the flow trajectories, pressure drop across the design-3. In the postprocessing, the total pressure is presented as gauge pressure. Showed the pressure drop as 3.71 Pa

Pressure Drop= Pressure at inlet- Pressure at outlet

Pressure at inlet= 101328.8Pa

Pressure at outlet= 101325.09Pa

Therefore, Pressure drop= 101328.8-101325.09=3.71Pa

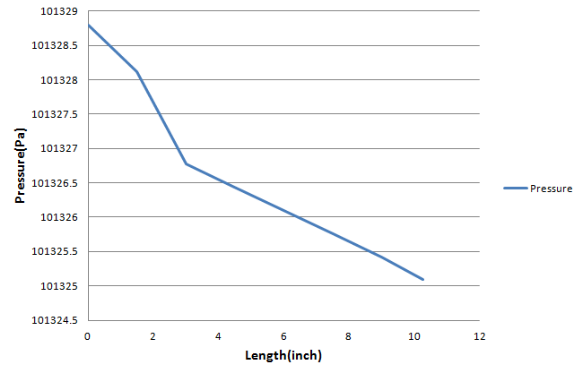

Fig. 9 Variation of Pressure with Length for design-1

CFD results of Desgin-2

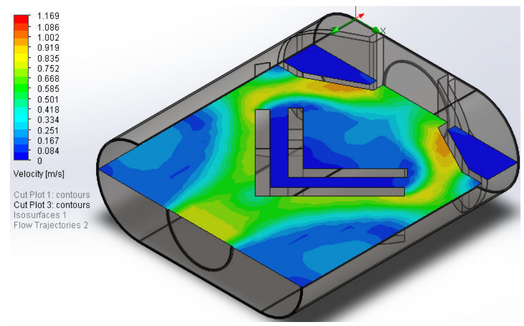

Fig. 10 Cut plot of Design-2 showing velocity

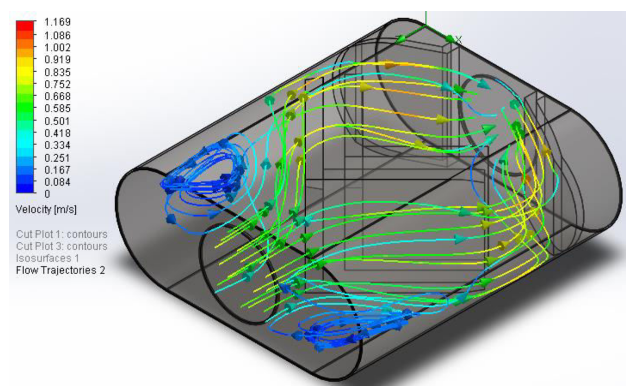

Fig. 11 Flow trajectories with velocity as parameter

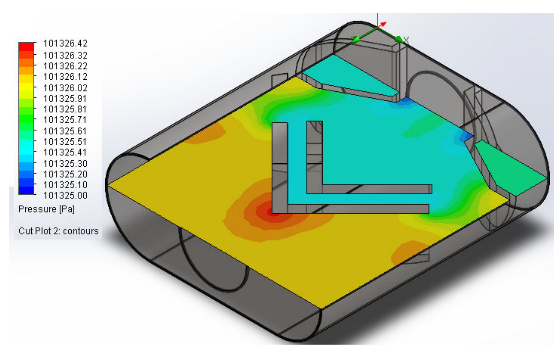

Fig. 12.Cut plot of Design-2 showing pressure distribution

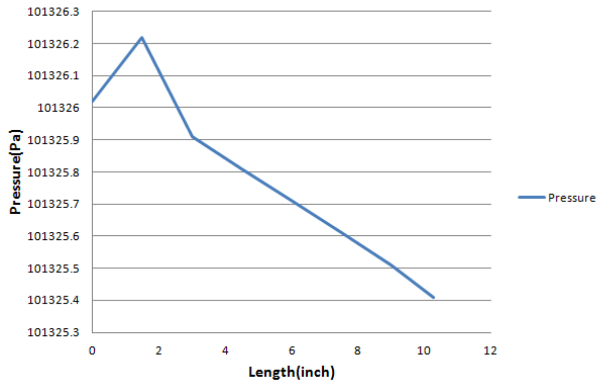

Fig.13Variation of Pressure with Length for design-2

From the above cut plot and the flow trajectories, pressure drop across the design-3 is calculated. The pressure drop due to plates placing at middle is 0.61 which is less than design -2. The plates have the ability to reflect the flow and split the flow.
Pressure Drop= Pressure at inlet- Pressure at outlet
Pressure at inlet= 101326.02Pa
Pressure at outlet= 101325.41Pa
Therefore, Pressure drop=101326.02-101325.41= 0.61Pa
It can be inferred from the above results that the exhaust velocity in all the designs increases and pressure decreases as the exhaust reaches the exit.

Table 3 Pressure drop in both designs

Exhaust Muffler Design	**Pressure Drop(Pa)**
1	3.71
2	0.61

The table. 3 has been showing the design-2 exhibits the better model in reduction of back pressure compared to other designs. This is due to placing the plates at middle and set of plates at inlet and outlet at an angle. From this study, it can be concluded that design-2 gives least pressure drop, which implies least resistance to the exhaust flow. Thus design-2 has least backpressure compared to other designs.

V. CONCLUSION

In the present work, study of four different chambered exhaust mufflers designs has been carried out to choose the design which can satisfy the flow conditions. After carrying out flow simulations, it is observed the design-2 has better performance than design-1 in reduction of back pressure. this is due to placing the plates perpendicular to inlet of muffler. The position of inlet is middle of the width of the muffler.

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