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Study of Back Pressure in Chambered Exhaust Muffler

KEYWORDS: muffler, exhaust gas, flow simulation

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ABSTRACT *The essential function of an exhaust muffler is to facilitate the exhaust gases from the exhaust manifold while reducing the noise produced 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 enhances the fuel economy 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. Virtual simulation for backpressure testing was performed by Computational Fluid Dynamic analysis using 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. The findings are tabulated to conclude the best exhaust muffler.*

INTRODUCTION

A muffler is a device for decreasing the amount of noise emitted by the exhaust of an IC engine. They are installed within the exhaust system of most IC engines. Due to increased environmental concerns requiring less noise emissions combined with reduced emission of harmful gases, it is becoming very crucial to carefully design the exhaust system mufflers for road transport applications. Exhaust gas emitted from vehicles contains many components that contribute to air pollution, namely carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NOx). Regarding the design of chambered muffler, it consists of series of passages and chambers to reduce sound pressure which is produced from the engine. An unavoidable side effect of muffler use is an increase of backpressure. Gas cannot flow against increased pressure. This is because the engine exhaust must share the same complex exit pathway built inside the muffler as the sound pressure that the muffler is designed to mitigate.

Most muffler designs in the automotive industry is accomplished by using cut and try methods which rely on what has worked in the past. Now at present, new computer software like Solid works, CFD (computational fluid dynamics) is aimed at muffler design and analysis which shortens the design cycle process and yields more effective results.

LITERATURE

The function of exhaust system is to collect and dispose the exhaust gases discarded by the engine with a maximum reduction in exhaust noise and minimum effect on the power output, life and maintenance of the engine [1]. Diesel engine causes emissions in the environment, some of them are harmful for human being. Exhaust systems including catalytic converter, muffler and resonator in diesel engine reduce the engine emissions [2, 3]. Increase in exhaust back pressure decreases nitric oxide, due to the increased exhaust gas remaining in the cylinder. Hydrocarbon emissions are also reduced as exhaust back pressure is increased [4]. Long term application of the system causes significant effect on engine performance and emissions. Particulate matter and other exhaust product adhere with flow passage of exhaust systems and the passage is reduced and backpressure is building up on the engine. The performance and emissions of a diesel engine can control by backpressure [2]. Excessive backpressure in the exhaust system create excessive heat, lower engine power and fuel penalty in the engine cylinder, that may cause damage of the engine parts and poor performance [5]. Hence, backpressure can be used up to a certain level to improve the engine performance and reduce emissions. In this point of view the exhaust system is installed with muffler. Various designs are in existence to meet the requirements of the performance of the engine.The essential function of a muffler is to route the exhaust gases from the engine exhaust manifold while reducing the noise and backpressure. Noise reduction is an emerging concern in the automotive industry, and reduction in backpressure enhances the fuel economy of the engine [6]. One important characteristic of muffler is how much backpressure they produce. Backpressure usually refers to the pressure exerted on a moving fluid by obstructions against its direction of flow [7]. The word back may suggest a pressure that is exerted on a fluid against its direction of flow indeed, but there are two reasons to object. First, pressure is a scalar quantity, not a vector quantity, and has no direction. Second, the flow of gas is driven by pressure gradient with the only possible direction of flow being that from a higher to a lower pressure. Gas cannot flow against increasing pressure. It is the engine that pumps the gas by compressing it to a sufficiently high pressure to overcome the flow obstructions in the exhaust system. At increased back pressure levels, the engine has to compress the exhaust gases to a higher pressure which involves additional mechanical work and/or less energy extracted by the exhaust turbine which can affect intake manifold boost pressure. This can lead to an increase in fuel consumption, PM and CO emissions and exhaust temperature. The increased exhaust temperature can result in overheating of exhaust valves and the turbine. An increase in NOx emissions is also possible due to the increase of engine load [8].

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Other effects on diesel combustion are possible, but depend on the type of engine. Increased back pressure may affect the performance of the turbocharger, causing changes in the air-to-fuel ratio usually enrichment which may be a source of emissions and engine performance problems [9]. The magnitude of the effect depends on the type of the charge air systems. Increased exhaust pressure may also prevent some exhaust gases from leaving the cylinder (especially in naturally aspirated engines), creating an internal exhaust gas recirculation (EGR) responsible for some NOx reduction. Slight NOx reductions reported with some DPF systems, usually limited to 2-3% percent, are possibly explained by this effect [10].

MATERIALS & METHODOLOGY

MATERIALS

The materials mostly used in exhaust systems are cast iron, stainless steel, mild steel / carbon steel. Recent trends towards light weight concepts, cost reduction and better performance, designers are progressing towards sheet metals. Mild steel or carbons steel are used for mufflers.

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.

Table:1 VERT Maximum recommended Exhaust Backpressure

ENGINE SIZE	BACKPRESSURE LIMIT
Less than 50kW	40 kPa
50-500kW	20 kPa
500kW and above	10 kPa

DESIGN OF CHAMBERED EXHAUST MUFFLER

Design 1:

CAD modelling has been done using SolidWorks 2014 version. The dimensions required to design were taken from a muffler manufactured by Flowmaster.

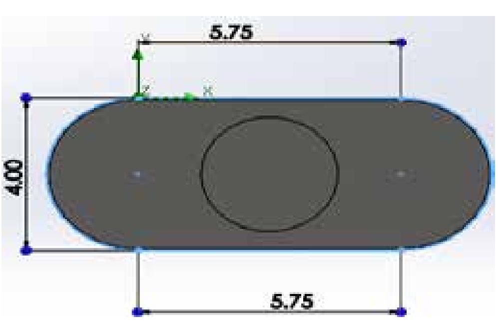

Fig.1 Front View of Design-1 with inlet position

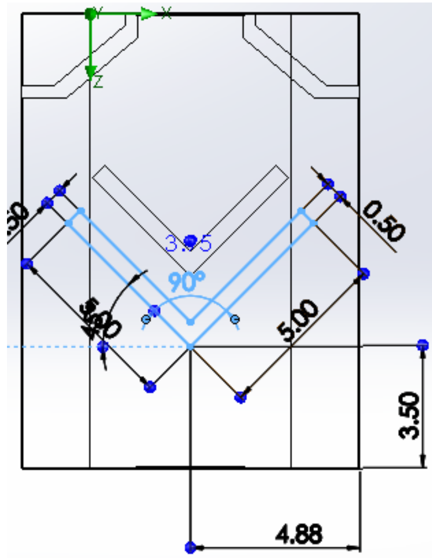

Fig.2 Top view of Design-1

Design 2:

In Design 2, the inlet position has been placed at an offset 2.00 inch from the centre.

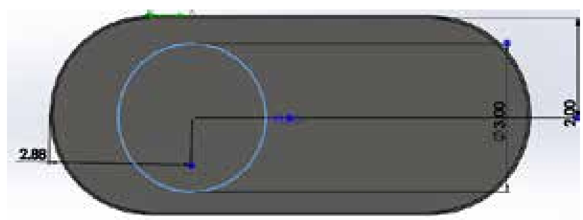

Fig. 3 Front view of Design-2 with inlet position

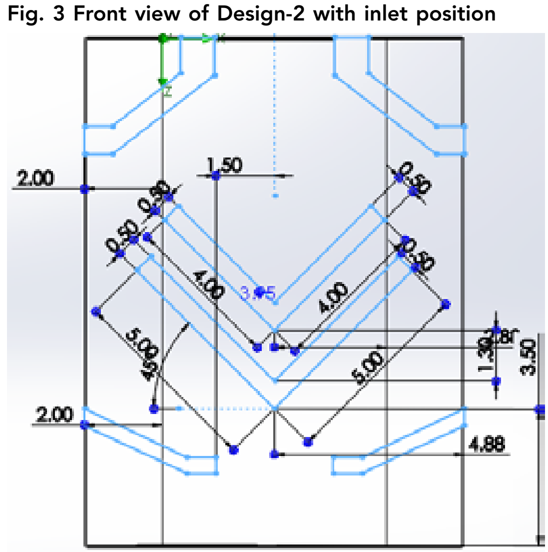

Fig. 4 Top view of Design-2

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

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that depict how the exhaust mufflers are meshed by the software.

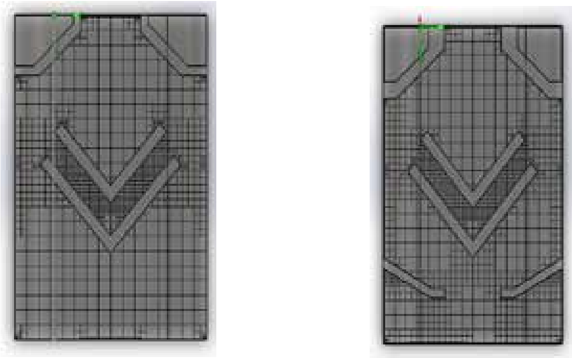

Fig. 5 Mesh of design 1 and 2

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

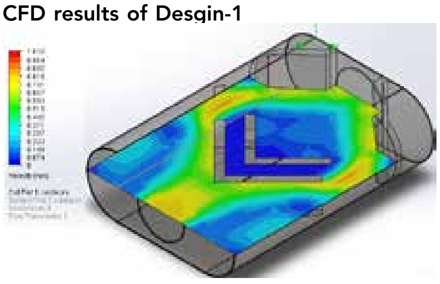

Fig. 6 Cut plot of Desgin-1 showing velocity distribution

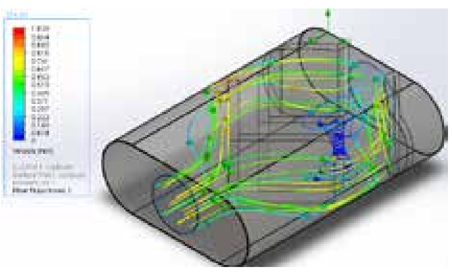

Fig. 7 Flow trajectories with velocity as parameter in Desgin-1

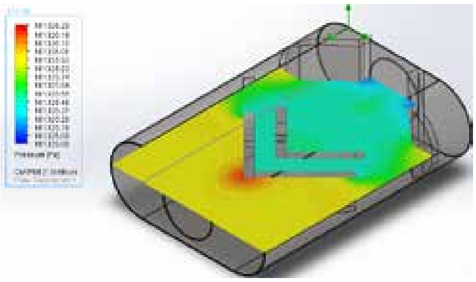

Fig. 8 Pressure distribution in Desgin-1

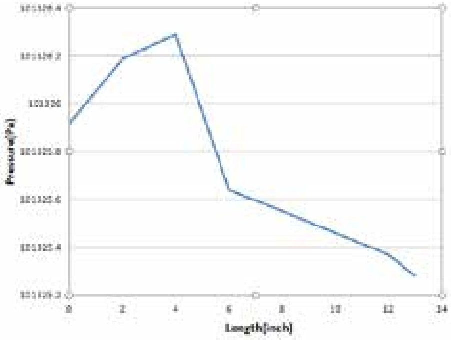

Fig. 9 Variation of Pressure with Length for design-1

CFD results of Desgin-2

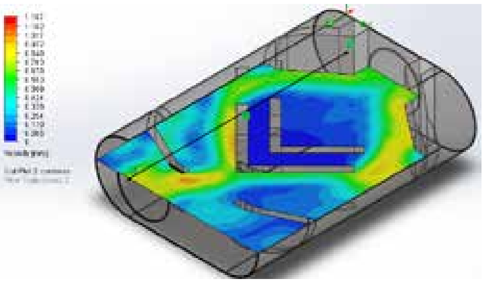

Fig. 10 Cut plot of Design-2 showing velocity distribution

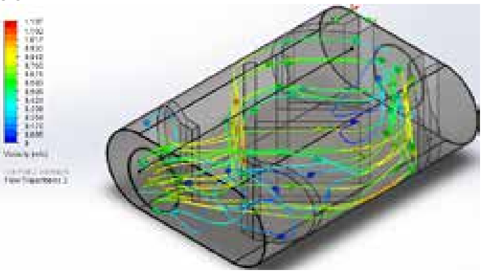

Fig. 11 Flow trajectories with velocity as parameter

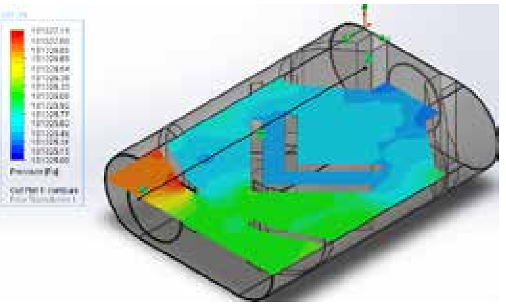

Fig. 12.Cut plot of Design-2 showing pressure distribution

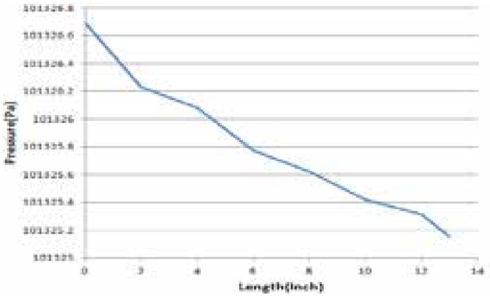

Fig.13Variation of Pressure with Length for design-2

Fig.13 showing that the pressure exerted on a moving fluid by obstructions against its direction of flow is reduced in muffler by modifying the design with plates at an angle.

Table 3 Pressure drop in both designs

Exhaust Muffler Design	Pressure Drop(Pa)
1	0.64
2	1.54

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

CONCLUSIONS

In the present work, study of two different chambered exhaust mufflers designs has been carried out to choose the design which can satisfy the flow conditions. After carrying out flow simulations, following conclusions are drawn

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