Backpressure Investigation and Design Modification to Reduce Noise Level of Silencer Used for Single Cylinder Water Cooled Diesel Engine through CFD Simulation

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Abstract- *This research paper concentrates on investigation of backpressure of silencer used for single cylinder water cooled diesel engine through CFD simulation. The main objective of silencer is to attenuate a sound by reducing exhaust gas pressure, but it causes back pressure which effects on engine efficiency. The exhaust system being a critical system of any engine plays the role of improving its work quality by attenuating the noise from the engine without deteriorating the engine performance by ensuring an optimum value of back pressure. The major concern for a designer is to ensure that the backpressure should as minimum as possible. This work is mainly concerned with the simulation of flow through the silencer followed by the prediction of the exhaust back pressure of the silencer using computational fluid dynamics (CFD). The comparison of backpressure between two different designs of silencer is carried out with the help of CFD simulation method. The diesel engine silencer is simulated at different velocities, the flow field of a given geometry of silencer is simulated and the total back pressure inside the silencer is calculated. It is resulted out that the arrangement of perforated plate or baffle plate inside the silencer is the most critical parameter from back pressure point of view.*

Key Words: CFD simulation, silencer, backpressure.

1. INTRODUCTION

Internal combustion engine should be always equipped with exhaust silencer to reduce the acoustic pulses generated by the combustion in the engine. The pressure wave generated by the combustion process inside the cylinder propagates along the exhaust. The pulse repeats the firing frequency of the engine i.e. at every exhaust stroke of the engine. As the engine RPM increases the pressure fluctuations also increases; Therefore, the sound emitted has high frequency. Exhaust silencers are designed to reduce sound levels at these frequencies. It is well known that the acoustic performance of silencing elements decreases with increase in exhaust gas flow through it. If the high pressure exhaust gases were allowed to enter atmosphere directly from the exhaust manifold, a loud unpleasant noise will be heard like firing of a gun. This noise is due to the large difference in pressure between the exhaust gases and the atmosphere. For quite operation of the engine, it is desirable to reduce this noise as much as possible. This is done by using a silencer in the exhaust system. So, the silencer is connected at the exhaust of the engine.

There is no any investigation on the effect of baffle arrangement on both transmission loss and back pressure in the exhaust silencers. This investigation highlights the effect of geometrical baffle configurations associated with following main parameters; baffle cut ratio, number of holes, holes distribution and baffle spacing. Excessive exhaust gas flow restriction and backpressure can adversely effect on engine performance, resulting in reduction of output power and increased fuel consumption, exhaust temperatures and emissions. It is imperative that exhaust backpressure is kept within specified limits for those engines subject to emissions legislation.

In this work, a single cylinder water cooled diesel engine experimental set up is selected, having a silencer. The main aim of this study is to minimize the back pressure with reduced noise level of the silencer and hence to improve the efficiency of the engine. The flow field of the silencer is simulated using CFD and computed.

1.1 EXHAUST BACKPRESSURE

Engine exhaust backpressure is defined as the exhaust gas pressure that is produced by the engine to overcome the hydraulic resistance of the exhaust system in order to discharge the gases into the atmosphere. The silencer's performance is mainly dependent on the values of backpressure. As backpressure increases; the specific fuel consumption of engine also increases which effects on its efficiency. Pressure minimization of exhaust system includes losses due to piping, silencer, muffler and termination. A high backpressure is commonly caused by one or more factors such as exhaust pipe diameter too small, excessive number of elbows especially the sharp bends in the exhaust system, exhaust pipe is too long or too high resistance inside the silencer. Backpressure has a significant effect on performance of an engine particularly in single cylinder water cooled diesel engine which is used for this study. The backpressure is measured with the help of U-tube manometer.

2. PROBLEM STATEMENT

Maximum amount of backpressure can cause a reduction in engine efficiency or increase in fuel consumption, overheating, and may result in a complete shutdown of the engine. At increased backpressure levels, the engine has to compress the exhaust gases to a higher pressure which involves additional mechanical work on the engine. It is required to reduce the exhaust backpressure of the engine without changing noise level to increase its efficiency.

Also high noise level of engine is harmful for the operator; therefore it is required to reduce the noise level of engine by modifying the silencer with minimum backpressure.

3. OBJECTIVES

The main objectives of this study are as follows:

1. To reduce the backpressure of engine with modifying the design of silencer.
2. To reduce the noise level of the engine on the arrangement of baffle without affecting on its efficiency.

The exhaust gas coming out from the single cylinder water cooled diesel engine has maximum pressure. The noise is generated due to the pressure difference between the exhaust gas from the engine and atmosphere. The more noise level is harmful for the operator. High noise level can lead not only physiological but also psychological ailments. Therefore the role of noise reduction is become more vital and competitive. The noise can be reduced by modifying the existing design of the silencer on the arrangement of the baffle plates. When baffle is fitted in the path of the exhaust gas inside the silencer, it attenuates the noise at certain level. Baffle creates backpressure to the engine. The increase in amount of backpressure effects on engine efficiency. The main objective of this study is to reduce the backpressure of the engine with minimized noise level to improve its efficiency.

4. METHODOLOGY

The numerical results of diesel engine silencer are calculated with the help of CFD simulation software. The existing design of silencer modeled in CATIA in 3D model. Before further modification in the silencer, first of all the study is carried out on the existing silencer. For this reason it is modeled in CATIA and analysis is carried out in the CFD simulation software.

Present work of CFD simulation has been carried out in the following steps:

1. Study of existing silencer used for single cylinder water cooled diesel engine.
   A. CAD modelling.
   B. Mesh generation.
   C. CFD analyses.
2. Develop new design of silencer and follow these steps again to examine the results.
3. Compare the numerical and experimental results.

The present work of design modification of silencer has been carried out in these steps. In this study the new modified design of silencer is developed in CATIA. The CFD simulation is carried out on it. The comparative study between existing silencer and new modified design of silencer is presented in the following steps.
After getting model in CATIA it has been analyzed in ANSYS fluent. To analyzed in the fluent there should know the input parameters which are exhaust velocity of the gas coming out of the engine, exhaust gas temperature and backpressure produced by the silencer. In these parameters any two are known, and then third parameter can be easily calculated by the finite element method using ANSYS. In this way the exhaust velocity coming out of the engine can be calculated by using CFD flow analysis.

For the calculation of velocity in CFD simulation, four different velocities of exhaust gas of single cylinder water cooled diesel engine are considered by referring the paper of Mr. S.S. Mane et al. of titled "Back pressure analysis of an engine muffler using cfd and experimental validation". These velocities range from 20 m/s to 80 m/s, and these are 20 m/s, 40 m/s, 60 m/s and 80 m/s. These velocities are given as inlet boundary conditions in CFD simulation.

The CFD analysis is carried out, for these velocities as inlet to the silencer temperature as 450^{0}C. Here different velocities are assumption made to get the real velocity of the exhaust manifold also the gas assumed as the exhaust gas properties taken from material library of the ANSYS fluent which is actual condition of the exhaust gas. The outlet pressure is given as atmospheric pressure outside of the silencer. From this CFD simulation analysis the inlet and exhaust gas pressure and velocity profiles are studied from which real exhaust velocity of the engine is calculated. By knowing the values of inlet and exhaust pressures the backpressure is easily calculated. The engine backpressure in this study is calculated experimentally by using U-tube manometer.

A. CAD modelling.

Computational fluid dynamics (CFD) study of the silencer starts with the construction of desired geometry and mesh for modeling the dominion. The existing and modified designs of silencer are modeled in CATIA as shown in Fig. - 01 and Fig. - 02 respectively. These two models are developed as a fluid geometry flowing inside the silencer.

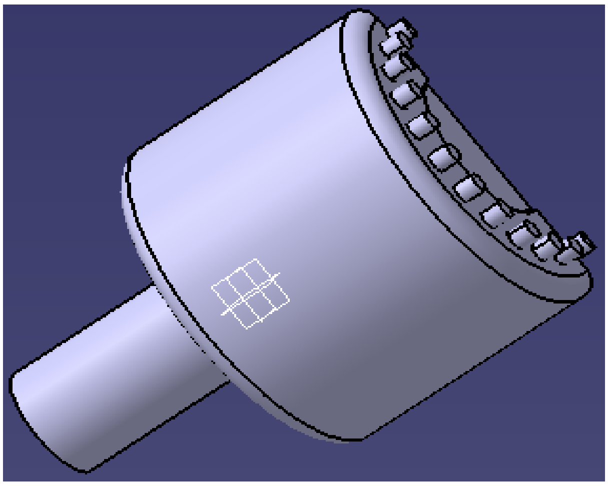

Fig.-01: Existing design of silencer.

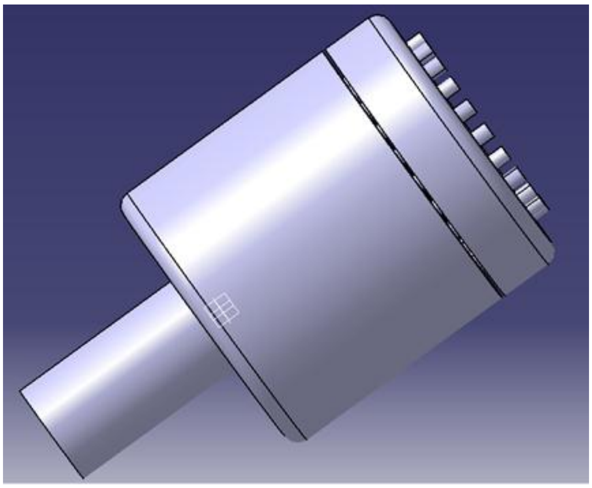

Fig.-02: Modified design of silencer.

These geometries of silencer are imported in the ANSYS FLUENT software to conduct the CFD simulation. The steps involved in the CFD simulation are described in the following points.

B. Mesh generation.

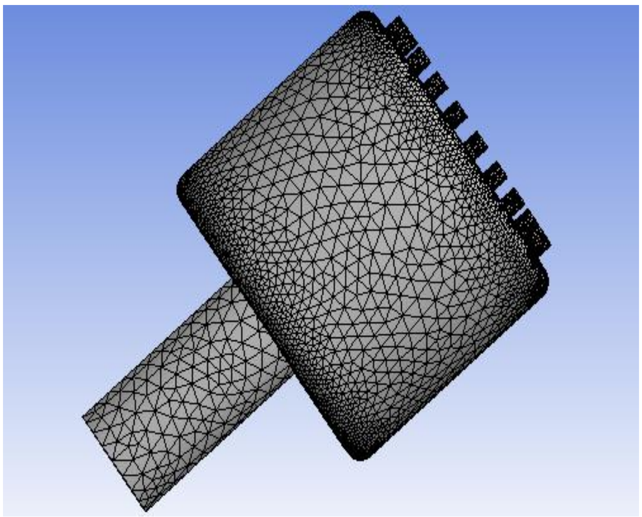

Fig.-03: Meshing on existing silencer.

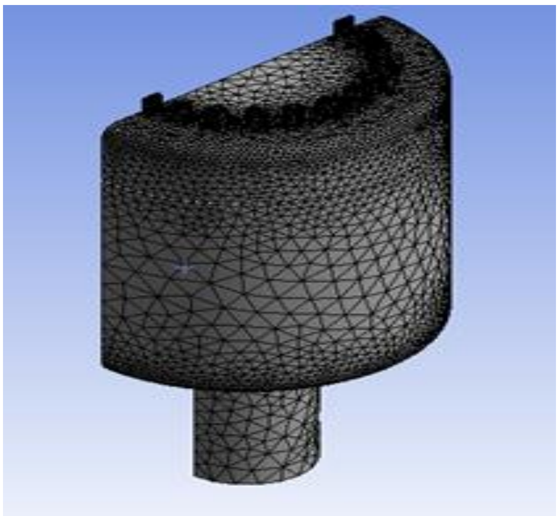

Fig.-04: Meshing on modified silencer.

Mesh generation is the discretization of the domain into small volumes where the equations are solved with the help of iterative methods. In this step, meshes are generated on both silencers as shown in Fig. -03 and Fig. -04.

C. CFD Simulation

Silencer modeling starts with the describing of the boundary and initial conditions for the dominion and leads to modeling of the entire system. Inlet and outlet boundary conditions are decided and CFD simulation is carried out on both silencers. The CFD simulation results are shown in the following figures.

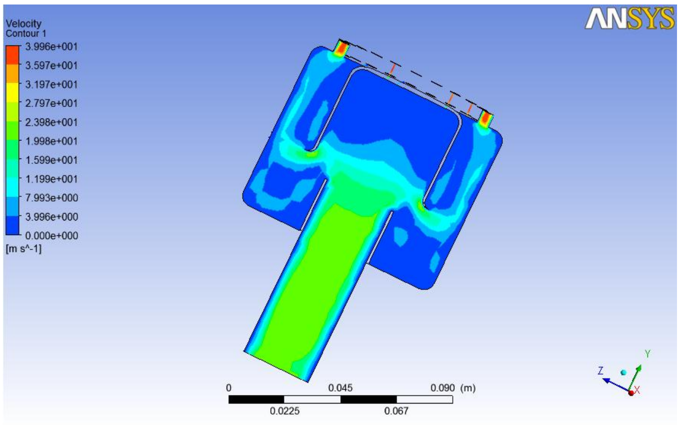

Fig.-05: Velocity contour of existing silencer.

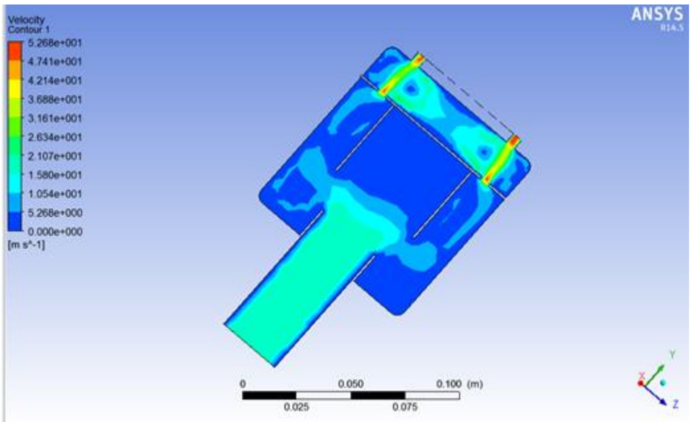

Fig.-06: Velocity contour of modified silencer.

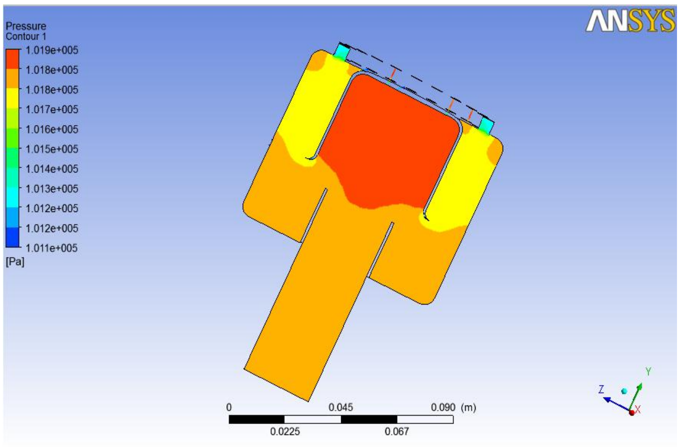

Fig.-07: Pressure contour of existing silencer.

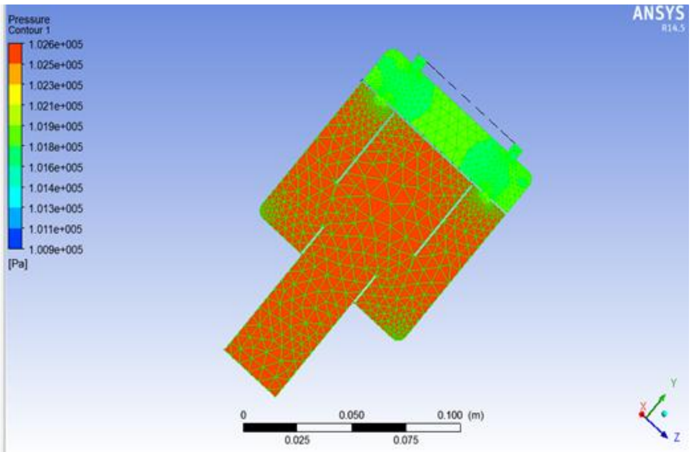

Fig.-08: Pressure contour of modified silencer.

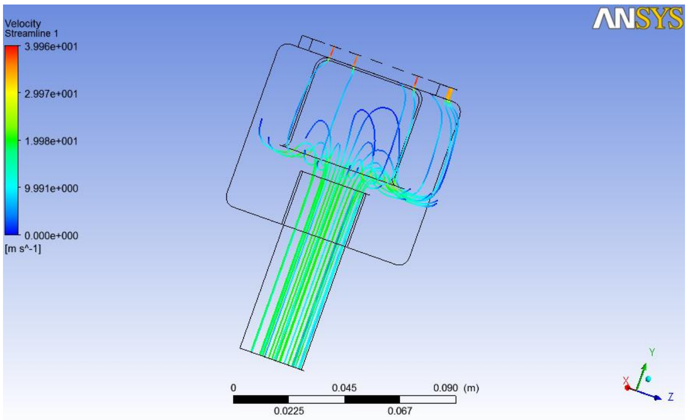

Fig.-09: Streamlines in existing silencer.

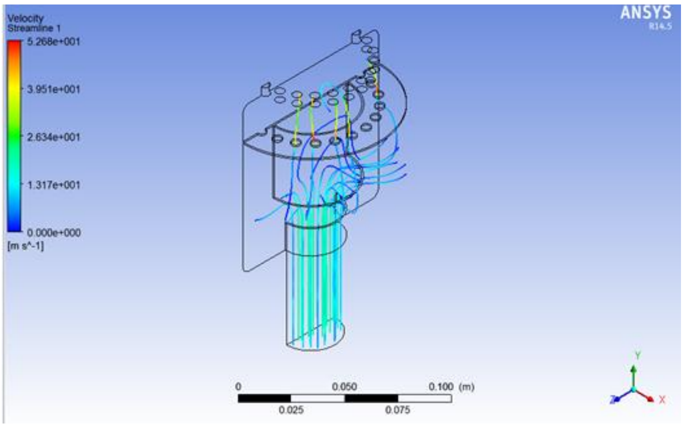

Fig.-10: Streamlines in modified silencer.

5. RESULTS:

Table -01: CFD Simulation results of existing silencer

PART	Sr. No.	PRESSURE (Pascal)		VELOCITY (m/s)	
Existing silencer		Inlet	Outlet	Inlet	Outlet
	A	101839.10	101325	20	30.54

	B	103350.20	101325	40	61.07
	C	105861.90	101325	60	91.596
	D	109408.80	101325	80	122.145
	Average	105115	101325	50	76.33

Table -02: CFD simulation results of modified silencer

PART	Sr. No.	PRESSURE (Pascal)		VELOCITY (m/s)	
Modified design of Silencer		Inlet	Outlet	Inlet	Outlet
	A	102303.99	101325	20	31.56
	B	105213.05	101325	40	69.05
	C	110046.88	101325	60	98.66
	D	117382.48	101325	80	127.93
	Average	108736.60	101325	50	81.80

From the CFD simulation results of both silencers, following parameters are identified and tabulated in the Table No.03.

Table -03: Numerical parameters between existing and modified silencers

Sr. No.	Parameters	Existing silencer	Modified silencer
01	Average pressure difference between inlet and exhaust of the silencer	3790 Pascal	7411.60 Pascal
02	Average velocity difference between inlet and exhaust of the silencer	26.33 m/s	31.80m/s

Table -04: Performance parameters of both silencers

Sr. no.	Exhaust silencer type	Test Hours	Exhaust Backpressure (cm of water)	Exhaust temperature (^{0}c)	SFC Kg/KWhr (norm 270)	Remark speed variation (RPM)
01	Existing silencer	01	23	458	273.1	2603-2640
02	Modified silencer	01	22	458	273.1	2603-2640

6. OBSERVATIONS

For CFD simulation of existing design of silencer and modified design of silencer velocity is used as inlet boundary condition whereas pressure is used as outlet boundary condition. The speed of exhaust gas changes due to varying loads on the engine, therefore different velocities of exhaust gas are assumed and average of the velocity is 50 m/s. The exhaust pressure is assumed as atmospheric i.e. 101325 Pascal. On comparing the results and performances of the two silencer models, it is observed that though both the models have similar design parameters, the modified design of silencer is more effective in reducing the exhaust pressure than the existing silencer. From the CFD simulation results, the observations are made as follows:

1. The average velocity at the inlet of existing silencer is 50 m/s and at its outlet 76.33 m/s; Also, the average velocity at inlet of modified silencer is 50 m/s and at its outlet 81.50 m/s. On comparing both silencers, the velocity is increased at outlet of modified design of silencer as compared to existing design.

2. The average pressure at the inlet of existing silencer is 105115 Pascal and at its outlet 101325 Pascal; Also, the average pressure at inlet of modified silencer is 108736.60 Pascal and at its outlet 101325. On comparing both silencers, the pressure loss is more in modified design of silencer as compared to existing design.

3. The pressure is inversely proportional to velocity. The velocity is increased at outlet of modified silencer as compared to existing design; also on comparing both silencers pressure loss is more in modified silencer. Therefore, the modified design of silencer is more effective to reduce noise level as compared to existing silencer.

7. CONCLUSIONS

In this work of 'Backpressure Investigation and Design Modification to Reduce Noise Level of Silencer used for Single Cylinder Water Cooled Diesel Engine through CFD simulation' two different models of silencer have been studied for the engine output and the flow has been simulated using ANSYS FLUENT. On comparing the performances of both silencer models conclusions are made as follows:

1. It is observed that though both the models have same similar design parameters, the modified design of silencer is more effective in reducing the exhaust pressure than the existing one because of its internal baffle arrangement.

2. As there is more pressure loss of exhaust gas inside the silencer, noise level of engine also reduced.

3. The CFD simulation software can be used as tool for design modification of silencer to reduce noise level.

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BIOGRAPHIES

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