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Design, Analysis of Flow Characteristics of Exhaust System and Effect of Back Pressure on Engine Performance

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***Abstract**: Now a days the global warming and air pollution are big issue in the world. The more amount of air pollution is due to emissions from an internal combustion engine. Exhaust system plays a vital role in reducing harmful gases, but the presence of after treatment systems increases the exhaust back pressure.*

This paper deals with the exhaust system designed and through CFD (Fluent) analysis, a compromise between two parameters namely, more maximization of brake thermal efficiency with limited back pressure was aimed at. In CFD analysis, two exhaust diffuser system (EDS) models with different angels are simulated using the appropriate boundary conditions and fluid properties specified to the system with suitable assumptions. The back pressure variations in two models and the flow of the gas in the substrate are discussed in. Finally, the model with limited backpressure was fabricated and Experiments are carried out on single cylinder four stroke diesel engine test rig with rope brake dynamometer. The performance of the engine and the exhaust diffuser systems are discussed.

***Keywords**: Exhaust Diffuser system (EDS), Computational Fluid Dynamics (CFD), Backpressure, Fuel Consumption.*

I. Introduction

Energy efficient exhaust system development requires minimum fuel consumption and maximum utilization of exhaust energy for reduction of the exhaust emissions and also for effective waste energy recovery system such as in turbocharger, heat pipe etc. from C.I. engine. To analyses the exhaust energies available at different engine operating conditions and to develop an exhaust system for maximum utilization of available energy at the exhaust of engine cylinder is studied. Design of each device should offer minimum pressure drop across the device, so that it should not adversely affect the engine performance.

During the exhaust stroke when the piston moves from BDC to TDC, pressure rises and gases are pushed into exhaust pipe. Thus the power required to drive exhaust gases is called exhaust stroke loss and increase in speed increases the exhaust stroke loss. The network output per cycle from the engine is dependent on the pumping work consumed, which is directly proportional to the backpressure. To minimize the pumping work, backpressure must be low as possible. The backpressure is directly proportional to the exhaust diffuser system design.

The shape of the inlet cone of exhaust diffuser system contributes the backpressure. This increase in backpressure causes increase in fuel consumption. Indeed, an increased pressure drop is a very important challenge to overcome. [1], [2]

II. Diesel Exhaust Systems

Backpressure on engine cylinder is completely dependent on exhaust system design, its operating condition and atmospheric pressure (i.e. almost constant). The exhaust system routes exhaust gas from the engine and then exhaust it into the environment, while providing noise attenuation, after treatment of the exhaust gas to reduce emissions and energy recovery. One of the most important sources of vehicle noise, the noise associated with exhausting combustion gases from the engine, is controlled using mufflers. A number of sound reduction techniques are employed in mufflers, including reactive silencing, resistive silencing, absorptive silencing, and shell damping. Exhaust gas properties which are important for the exhaust system design include its physical properties; exhaust gas temperature, which depends on the vehicle duty and/or test cycle and the exhaust gas flow rate. Exhaust system materials are exposed to a variety of harsh conditions, and must be resistant to such degradation mechanisms as high temperature oxidation, condensate and salt corrosion, elevated temperature mechanical failure, stress corrosion cracking, and inter granular corrosion. Engine performance improvement by developing energy efficient exhaust diffuser system requires understanding of integrated component performance aspects to achieve overall system improvement to increase fuel efficiency and to reduce the engine exhaust emissions. The exhaust system design with minimum back pressure requirements is the key factor for upgrading engine performance [3]

III. Methodology

The analysis has been carried out on two designs an existing one that is EDS – I with 0° inlet cone angle and a modified one that is EDS – I with 90° inlet cone angle, results are subsequently compared. It was observed that the brake thermal efficiency improved drastically upon modification in exhaust geometry. Physical models of the same these two systems are subsequently manufactured and exhaustive experiments are carried out on them. The results obtained through CFD analysis are experimentally confirmed.
In CFD analysis two major flow characteristics (back pressure and engine performance) are studied.

Study I: In study I, the change in pressure of structure was studied. This study offered to find the change in pressure difference in inlet and outlet of exhaust diffuser system. The models which produce the higher pressure difference are selected for further studies.
Study II: In study II, the models which had the higher pressure difference are studied for the flow pattern. The back- pressure characteristics of the models are modeled and the model having the lesser backpressure was taken for experimental study of engine performance. [4]

IV. THREE DIMENSIONAL CFD STUDY

A three- dimensional model of exhaust diffuser system is generated in CFD Fluent for the analysis.

A. ***Modelling and Meshing:***

The geometry of the element is made as tetrahedral mesh, with a refined mesh near the wall. The K-E turbulence model is used, with standard wall functions for near-wall treatment for analysis of Exhaust system.

B. ***Boundary Conditions:***

Boundary conditions used at inlets mass flow rates and Temperatures of Fluid are applied and at outlets pressure outlet is applied. Domain surface is used as a wall with 'No Slip condition' and heat transfer coefficient of 45w/m2 ºk and wall surface roughness as 0.00508 mm is used [5].

V. CFD RESULTS & DISCUSSION

The primary aim of this CFD analysis is to find out the right shape of catalytic converter for the exhaust manifold which can offer minimum back pressure.[6]

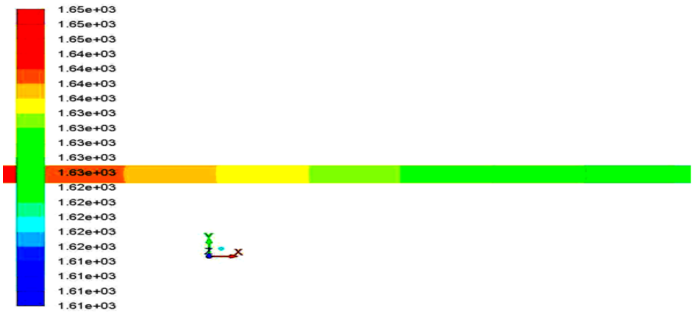


Figure 1: This depicts the Pressure Contour which indicates the change on Pressure along the X- Axis for EDS – I at Constant Load 5 Kg.

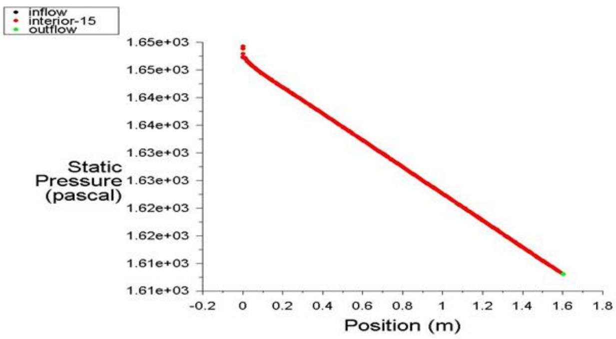


Figure 2: This depicts that variation in backpressure on engine during the flow through EDS – I along its length at Constant Load 5 Kg

It is observed that the back pressure at inlet of EDS- I is found to be 1659 Pa, as shown in Figure 1and 2. The back pressure is found to be increase with the increase in length of EDS for the same inlet pressure.

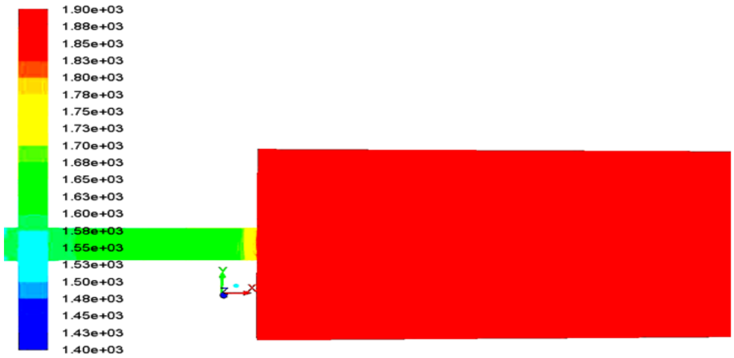


Figure 3: This depicts the Pressure Contour which indicates the change on Pressure along the X- Axis for EDS – II at Constant Load 5 Kg.

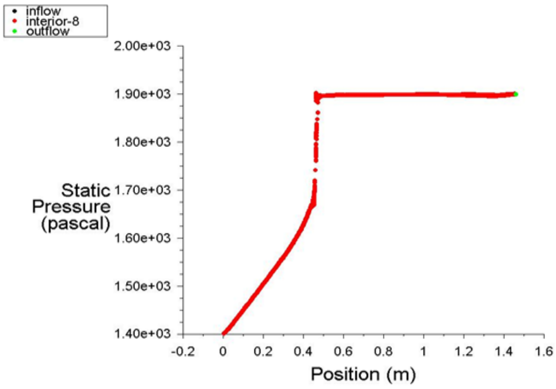


Figure 4: This depicts that variation in backpressure on engine during the flow through EDS – II along its length at Constant Load 5 Kg.

Similarly the back pressure analysis is carried out for other EDS – II is found to be 1585 Pa, as shown in Figure 3 and 4. The back pressure is found to be decrease with the increase in inlet cone angle of EDS for the same inlet pressure. [7] [10]

VI. EXPERIMENTAL RESULT & DISCUSSION

The experimentation was conducted with the EDS - I and EDS – II in single cylinder four stroke diesel engines. The exhaust system was fitted on the engine exhaust flange. Then the performance study was conducted and plotted against the brake thermal efficiency. [8], [9].

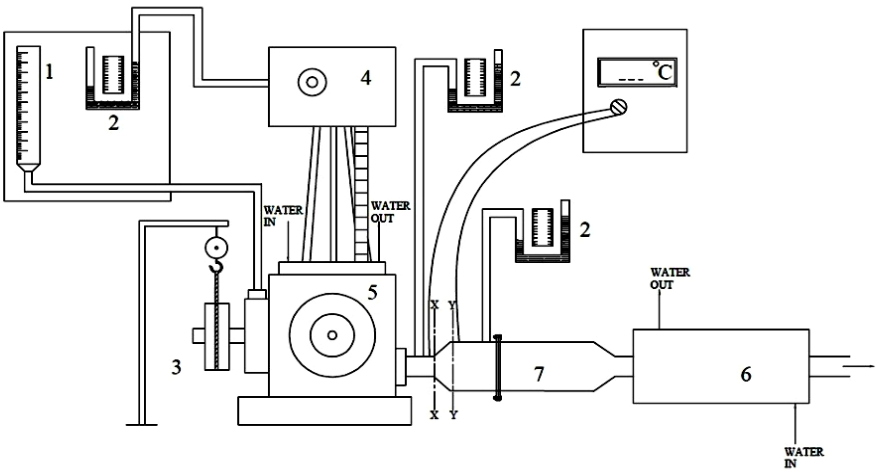


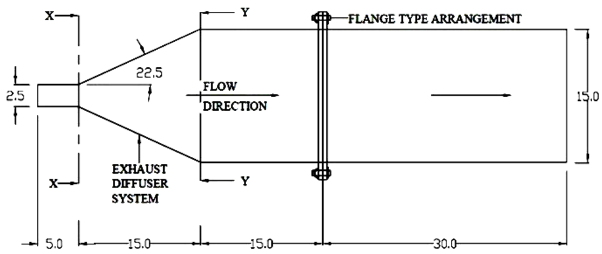
Figure 5 Schematic view of experimental set up

1 Fuel Flow Measurement	5 C.I. Engine
2 U- Tube Manometers	6 Exhaust Gas Calorimeter

3 Dynamometer 7 Exhaust System

4 Air Flow Meter

X-X: Inlet to Exhaust Diffuser System Y-Y: Inlet to Exhaust Diffuser System



All dimensions are in CM

Figure 6: Schematic view of exhaust diffuser system

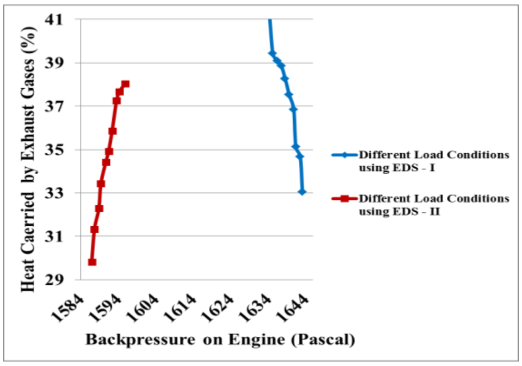


Figure 7: Variation in brake thermal efficiencies vs. backpressure on engine for different load conditions using Exhaust diffuser systems.

The figure 7 shows that the variations in the brake thermal efficiency. Considerable increase in brake thermal efficiency is observed while using the EDS – II. There is 9 to 14% of brake thermal efficiency increased.

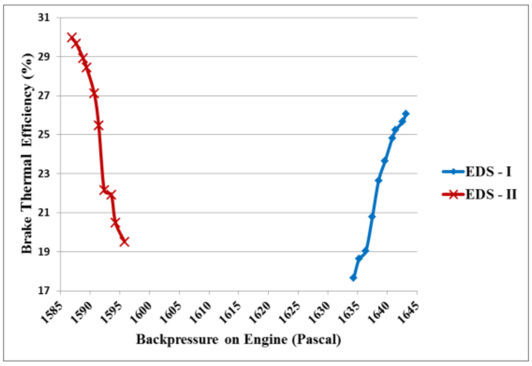


Figure 8: Variation in heat carried away by exhaust gases in % vs. backpressure on engine for different load conditions using exhaust diffuser systems.

The figure 8 shows that the variations in heat carried away by exhaust gases Vs. backpressure on engine for different load conditions using exhaust diffuser systems depicts that when the load is kept constant load at different level viz. 0.5 to 5 kg the backpressure on engine decreases and heat carried away by exhaust gases decreases. Value for heat carried away by exhaust gases for EDS – I is decreasing as load increasing. It is also found that for EDS – II backpressure on engine decreases and heat carried away by exhaust gases decreases. Heat carried away by exhaust gases decreases approximately 4% for EDS – II system as compared to EDS – I.

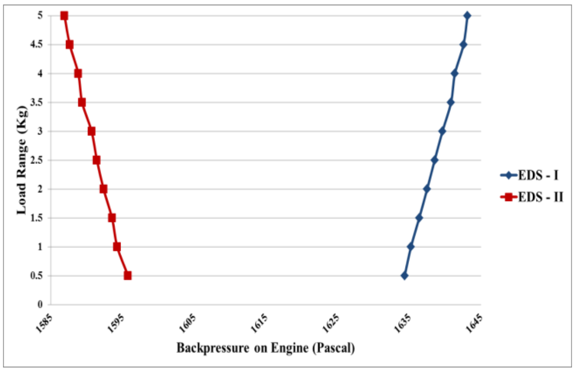


Figure 9: Variation in backpressure on engine using experimentation vs. different load conditions for exhaust diffuser systems.

The figure 9 shows that the variations back pressure on engine using values observed during experimentation Vs. different load conditions with exhaust diffuser systems; when the load is kept constant load at different level viz. 0.5 to 5 kg the backpressure on engine is decreases. Value for backpressure on engine for EDS – I is increasing as load increasing. It is also found that for EDS – II backpressure on engine decreases. Backpressure on engine decreases which results increase in brake power of engine.

VII. CONCLUSION

The following conclusions may be drawn from the present study. The Exhaust system is successfully designed. Through CFD analysis, the backpressures of various Exhaust diffuser systems are studied. The increase in inlet cone angle increases the pressure of the flow which leads to reduce the recirculation zones. Installation of the EDS – II increases the brake thermal efficiency and decreases the backpressure.

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