Investigation of Diffuser Concept for Four Strokes C.I. Engine Exhaust System Development

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Abstract— The global warming and air pollution are big issue now a days in the world. The major part 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. To minimize the exhaust emissions from C.I. engines, it is very important to study the overall effects of Devices attached in the exhaust system. Back pressure on engine is found as an important parameter having a strong influence on engine efficiency and it need to be minimized for maximum fuel efficiency. This work deals with the investigation of exhaust system through experimentation and CFD (Fluent), a compromise between two parameters namely, increase in brake thermal efficiency with limited back pressure was aimed at. In experimental analysis, different convergent divergent exhaust diffuser system (EDS) models with different angels are analyzed. The back pressure variations in six models and the flow of the gas in the substrate are discussed . Finally, 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

To get less fuel consumption energy efficient exhaust system development is required and to reduce the exhaust emissions maximum utilization of exhaust energy is to be required and also for effective waste energy recovery system such as in turbocharger, heat pipe etc. from C.I. engine. To analyze the exhaust energies obtainable at different engine operating conditions then to improve an exhaust system for maximum utilization of available energy at the exhaust of engine cylinder is studied. After the end of power stroke and the exhaust stroke starts when the piston changes from bottom Dead Centre to top Dead Centre, pressure increases and the engine performance should not be affected poorly for this purpose the design of every device shall have least pressure drop through the device gases are pressed into exhaust pipe. Therefore the power essential to drive exhaust gases is called exhaust stroke loss and rise in speed increases the exhaust stroke loss. The total work output per cycle from the engine is reliant on the pumping work spent, which is directly relative to the backpressure. To reduce the pumping work, backpressure must be as minimum as possible. The back-pressure is directly related to the exhaust diffuser system design. The profile of the inlet cone of exhaust diffuser system contributes the backpressure. This increment in backpressure causes rise in fuel consumption. Actually, an amplified pressure drop is a very key challenge to overwhelmed (Heywood, 1988), (Silvers et al, 1991).This work treat with the study of flow of an exhaust diffuser system. Computational fluid study is carried to conclude the pressure profile. Computational fluid study is done using two software CATIA V5 and ICEM CFD are used to prepare the model and mesh it and ANSYS FLUENT 14.5 is used to do the velocity, temperature and pressure analysis. This total investigation is called as Computational fluid dynamics analysis. Before carrying out the analysis it is vital to have an outline of what fluent is and how it works (Navale et al, 2014)

II. LITERATURE REVIEW

Since last 3 to 4 decades after treatment techniques are being increasingly utilized and research work is well under progress. Effective after treatment system, specifically for I.C. engines, requires critical analysis of the overall effect of backpressure on each particular I.C. engine performance. More efforts are required for the analysis of the after treatment System, by further study of the theory of operation of each device related to I.C. engines. Search on diesel particulate filters as a modern technology is very active because particulate matter is designated as a major cancer material. Regeneration phenomenon in after treatment devices is a subject of special concern for design and development of particulate matter emission control actions. The Backpressure acting on engine is most significant factor which mostly depreciates the engine and emission control performance. In the present work, dimensional analysis method is used for finding out the relationship between operating variables of internal combustion engines, then validation of the effect of back-pressure generated on a C.I. engine, with and without the usage of a particularly designed diesel particulate filter is done (Modak et al, 2010). To offer an estimation of the potential effect of substrate and exhaust system backpressure on engine performance is the objective of this work. Factors contain fuel consumption, CO_2 emissions, and HP. Results were gained on an engine test standpoint, and then statistical analysis was used to know the relations between variables.

Trade-offs among catalyst substrate selection and engine performance for the particular engine used in this study are labeled. Lastly, the potential impact of exhaust system backpressure on actual world driving situations is deliberated (Jonathan et al, 2009). To find out the optimum geometry for decreasing emissions work is done on CFD analysis of exhaust manifold of multi-cylinder S.I. engine, The most critical components of an I.C. engine is exhaust manifold. The designing of exhaust manifold is a complex process and is reliant on various parameters viz. back pressure, exhaust velocity, mechanical efficiency etc. Liking for any of this parameter varies as per designer's desires. Generally fuel economy, emissions and power requirement are three separate thought about exhaust manifold design. The study widely analyses 8 separate models of exhaust manifold and then determines the best likely design for minimum emissions and complete combustion of fuel to ensure least pollution (Rajagopal et al, 2013).It is well known that a accurately designed intake manifold is important for the optimal performance of an I.C. engine. This work will present 3-D simulation of a 1.6L MPFI engine intake manifold by using the FLUENT code and the results will be talk over. Both steady and unsteady state simulations have been consummate for this case. For validation steady state simulation results are compared with flow bench rig data. From 1-D WAVE code boundary condition for unsteady state simulation was found. Lastly according to the results of steady and unsteady simulations, some ideas are recommended to advance the performance of this intake manifold (Nasirtosi et al ,2003).During the investigation on optimization of exhaust systems, the abstract is given here. Some design optimization work of automotive exhaust systems are taken out using numerical simulation. This numerical simulation includes computational fluid dynamics for fluid flow and temperature distribution and finite element analysis (FEA) for following structural analysis. The importance is given to optimization associated to exhaust system design parameters such as shape and shape of manifold, catalyst inlet tube, inlet cone, exit cone, and exit tube under a given exhaust gas conditions. Numerous cases of optimization including study of design parameters on the index of flow evenness and backpressure are explained. Another part of this study includes finite element calculation of stresses and strains. In structural analysis due to high temperatures involved in the exhaust system both material and geometric non-linearity are measured. Precisely, the work involves the calculation of material response behavior under numerous thermal cycles, every cycle involving a heating and a cooling stages, and finally comparative study of suitability of cast steel and fabricated steel for exhaust manifolds are debated (Keck Et al, 2002).During the investigation in the result of intake manifold runners length on the volumetric efficiency by 3D CFD Model, the abstract is given here. It is quite known that a correctly designed intake manifold is important for the optimal performance of an I.C. engine. 3-D Simulation of a XU7 engine intake manifold is to be studied in present work and the results will be debated. Boundary condition for unsteady state simulation was gained. From 1-D WAVE code With the help of 3D CFD models at separate speeds are analyzed in the current investigation of the effect of length of runners on the volumetric efficiency .Three hypothetical models have been prepared that all of their runner's length is increased to 110,120 and 130% of initial value. In the model with 20% extended runners, the volumetric efficiency rises at 3500 rpm and 4500 rpm. Lastly according to the results of steady and unsteady simulations, some suggestions are suggested to progress the performance of this intake manifold (Negin et al,2006)

III. METHODOLOGY

The study has been done out on six designs a current one that is EDS – I with 0° inlet cone angle besides a improved one that is EDS – VI by 90° inlet cone angle, outcomes are afterward compared. It was observed that the brake thermal efficiency enriched drastically upon modification in exhaust geometry. Physical models of the similar these two systems are afterward manufactured and exhaustive experiments are done on them. The outcomes gained through CFD analysis are experimentally checked. For analyzing its performance using CFD the Exhaust system data for the same engine output condition that is at 0.5 to 5 kg load at ten levels and 1500 rpm is given. The EDSEDS – I to EDS – VI are developed .The major objective of analyzing such a systems are to determine the pressure drop across the exhaust diffuser system geometry using experimentation and CFD analysis.

3.1 Construction of the Model

The coordinates are shown for the development of the 2D model of the exhaust system. Then the model is rotated about 360^0 to get the 3D profile. The diffuser can be seen as an assembly of three distinct sections operating in series a short parallel section and the diverging section for design solution. The short parallel section of the system to the engine acts as a casing. To reduce the non-uniformity of flow the straight portion of the diffuser helps and the pressure recovery takes place in the diverging section. The geometrical specifications of the diffuser have selected somewhat arbitrarily. Diameter of diffuser inlet is 0.0254 m and diameter of the engine outlet is 0.15m. The model of exhaust diffuser system is shown in Fig.1

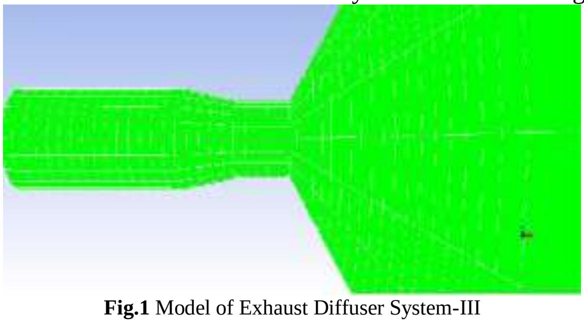

Fig.1 Model of Exhaust Diffuser System-III

Then all the parts are well-defined i.e. inlet is defined as Inflow, outlets as Outflow, and wall**.**

IV. THREE DIMENSIONAL CFD STUDY

A 3D model of exhaust diffuser system is made in CFD Fluent for the study.

4.1 Modeling and Meshing

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

4.2 Boundary Conditions

Boundary conditions used are applied at inlets mass flow rates and temperatures of fluid and at outlets pressure outlet is applied. Domain surface is used as a wall with 'No Slip condition' and heat transfer coefficient of 45 w/m2^{0}k and wall surface roughness as 5.08 micron is used (Anderson, 1995).

V. CFD RESULTS & DISCUSSION

The main aim of this CFD analysis is to invent out the correct form of system for the exhaust system which can offer least back-pressure [6].

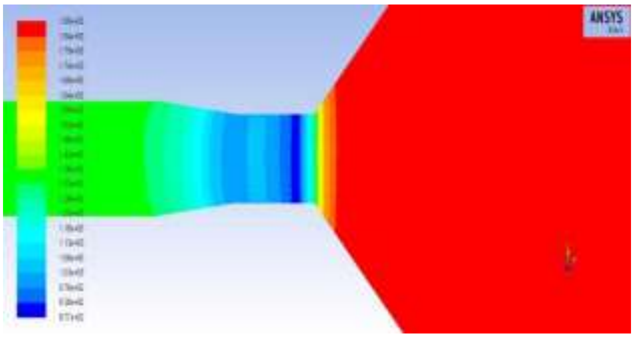

Fig.2 Shows the Pressure Contour which indicates the change of Pressure along the X- Axis for EDS – III at Continuous Load of 5 Kg.

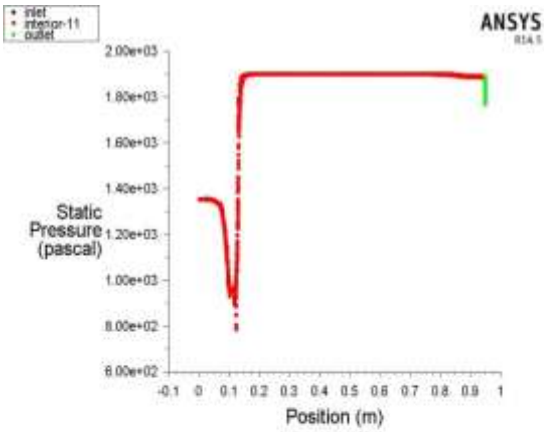

Fig.3 Shows that variation in backpressure on engine during the flow through EDS – III along its length at Constant Load 5 Kg

It is seen that the back pressure at inlet of EDS- III is found to be 1618.781 Pa, as shown in Fig.2 and In Fig.3 the back pressure is found to be rise with the increase in length of EDS for the similar inlet pressure. Likewise the back pressure study is done for further EDS. The back pressure is found to be reducing with the rise in inlet cone angle of EDS for the similar inlet pressure (Navale, 2014).

VI. EXPERIMENTAL RESULT & DISCUSSION

The experimentation was conducted with the six diffuser systems in single cylinder four stroke diesel engines. On the engine exhaust flange the exhaust system was fitted. Then the performance study was conducted and Figs are plotted against the brake thermal efficiency.

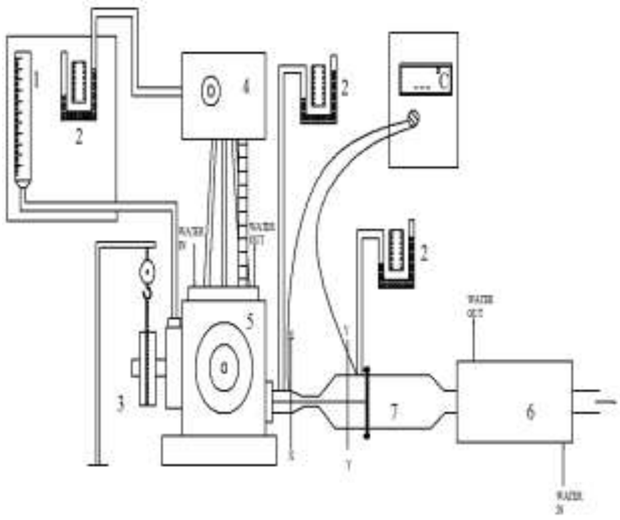

Fig.4 Schematic view of experimental set up

1 Fuel Flow Measurement
2 U- Tube Manometers
3 Dynamometer
4 Air Flow Meter
5 C.I. Engine
6 Exhaust Gas Calorimeter
7 Exhaust System
X-X: Inlet to Exhaust Diffuser System
Y-Y: Inlet to Exhaust Diffuser System.
All dimensions are in cm

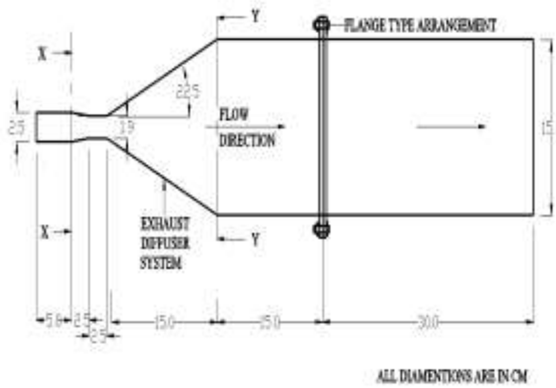

Fig.5 Schematic view of exhaust diffuser system

It is observed from the Fig.6 variations in brake thermal efficiency vs. backpressure on engine for different load conditions using EDS. It is found that when the load is kept constant load at different level viz. 0.5 kg to 5 kg the backpressure on engine reduces, brake thermal efficiency rises. The backpressure on engine reduces and brake thermal efficiency rises, because of rise in the brake power for EDS – I to EDS – VI. During the change of EDS – I to EDS – VI the rise in the brake thermal efficiency from 9 to 14% is observed by keeping all other parameters constant. The value of brake thermal efficiency and backpressure for EDS – I is rising, as load is increasing.

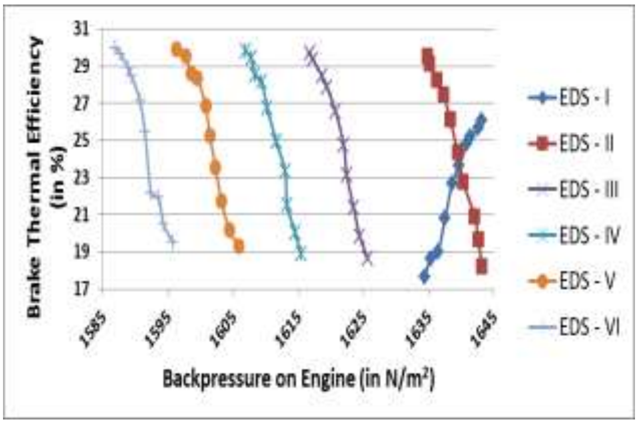

Fig.6 Brake thermal efficiencies vs. backpressure on engine

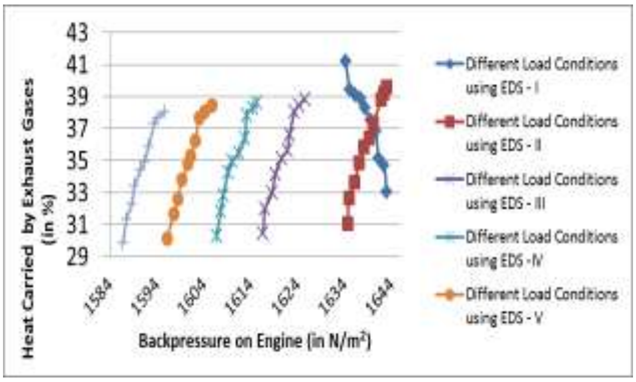

Fig.7 Heat carried by exhaust gases vs. backpressure on engine

It is observed from the Fig.7, variation in heat carried by exhaust gases verses back-pressure on engine for different load conditions using EDS shows that when the load is kept constant at separate level viz. 0.5 to 5 kg the backpressure on engine reduces and heat carried away by exhaust gases decreases. It is also observed that during the change of EDS – I to EDS – VI backpressure on engine reduce and heat carried away by exhaust gases also reduces. Heat carried away by exhaust gases cuts approximately 4 percentages for EDS – VI system as compared to EDS – I. Value for heat carried away by exhaust gases for EDS – I is reducing, as load is rising .

It is observed from the Fig.8, heat balance sheet for different EDS at constant load 5 kilogram; the heat balance sheet parameters that are heat equivalent of brake power, heat carried by the jacket cooling water, heat carried by exhaust gases and heat unaccounted for. When the EDS are varies during the change from EDS - I to EDS - VI the heat equivalent of brake power increases and heat carried by exhaust gases reduces. After testing it is observed that around 30 to 40 % of fuel energy is wasted, this part is of great concerned so as to maximize consumption of exhaust energy.

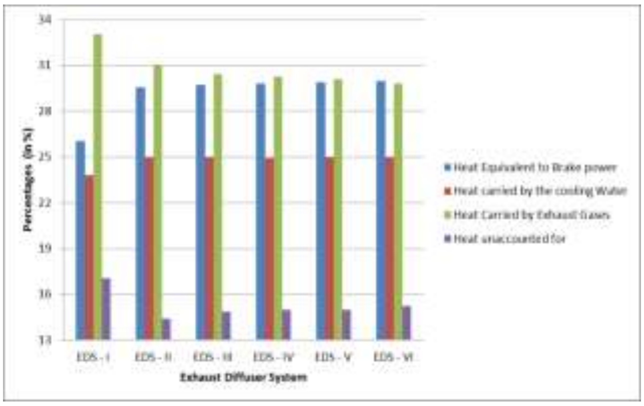

Fig.8 Heat balance sheet at constant load 5 Kg

It is important to utilize the exhaust energy through proper exhaust system design. Optimum energy utilization means that the fuel energy which is otherwise going to be wasted must be utilized in such a manner that it must not affect the engine performance adversely, which basically occurs because of increase in back pressure on the engine. The variation in the exhaust energy carried away by exhaust gases is found to be directly proportional to backpressure on the engine.

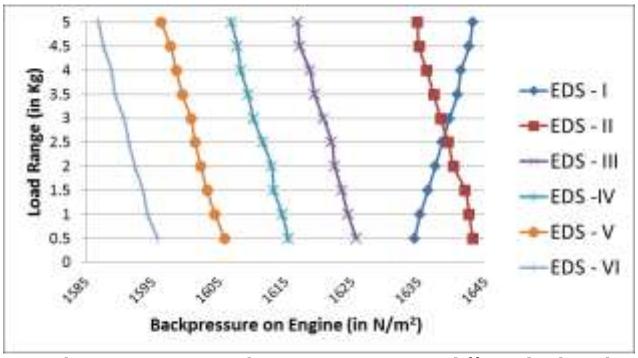

Fig.9 Back-pressure on engine by experimentation vs. different load conditions

As observed from the Fig.9 variation back-pressure on engine using values observed during experimentation verses different load conditions with EDS; when the load is kept constant load at separate levels viz. 0.5 to 5 kg the backpressure on engine reduces. It is also found that when the exhaust diffuser system is varied during the change of EDS – I to EDS – VI backpressure on engine reduces. Backpressure on engine reduces which results raise in brake power of engine. Value for backpressure on engine for EDS – I is rising, as load is increasing. The back pressure is found to be increased with the decrease in length of taper for the same inlet conditions. It is observed from the Fig 10 variation of backpressure on engine using CFD Fluent analysis vs. different load conditions with EDS, when the load is kept constant at different level viz. 0.5 to 5 kg the backpressure on engine reduces. It is also found that when the exhaust diffuser system is varied during the change of EDS – I to EDS – VI, backpressure on engine reduces. Value for backpressure on engine for EDS – I is increasing, as load is increasing

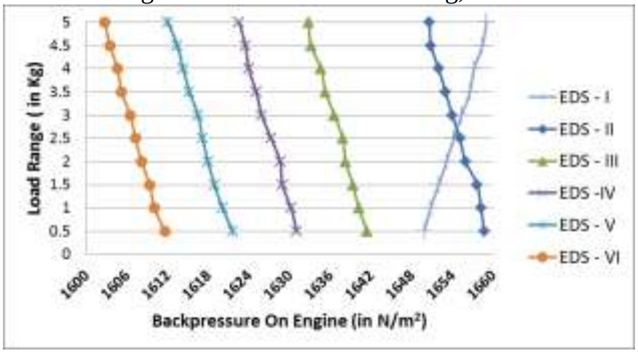

Fig.10 Back-pressure on engine by means of CFD vs. different load conditions.

By means of observed from the Fig.11, pressure difference using EDS. It is found that during the change of EDS – I to EDS – VI pressure difference using exhaust systems on engine increases. The load on engine is varied at different level viz.0.5 kg to 5 kg, the pressure difference using exhaust systems on engine increases for EDS – I to EDS – VI. At EDS – I i.e. inlet cone angle 0° the volume is 0.000076285 m3 and EDS – VII i.e. inlet cone angle 90° the volume is 0.002660452 m3. Change in volume because of diffuser angle change is the basic cause of reduction in backpressure on engine.

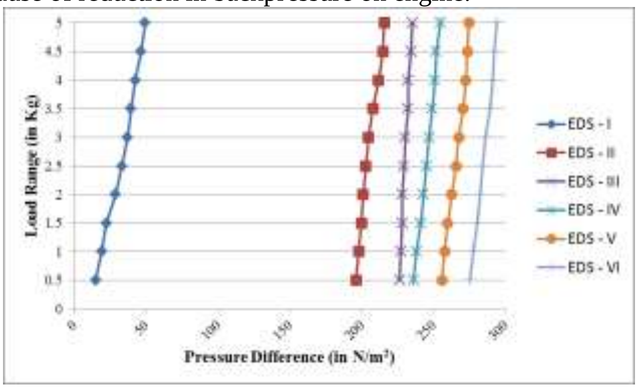

Fig.11 Load range vs. Pressure difference

VII. CONCLUSIONS

The following conclusions is be drained from the present study. The Exhaust system is effectively designed using diffuser concept. By CFD analysis using ANSYS FLUENT 14.5, the backpressures of EDS are learned. The decrease in inlet cone angle increases the velocity of the flow which leads to increase circulation at after treatment section. The increase in outlet cone angle of diffuser raises the pressure of the flow which leads to reduce the recirculation zones. Installation of the EDS – VI increases the brake thermal efficiency and decreases the backpressure.

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