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Experimental verification and CFD analysis for single cylinder four stroke CI engine exhaust manifold system

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ABSTRACT

The present review paper is on the performance improvement of IC engine by using backpressure reduction in the exhaust manifold and their CFD analysis of Single Cylinder Four Stroke C.I. Engine. It is found that the development of an energy-efficient exhaust manifold system is possible by minimization of backpressure on the engine, due to an increase in brake thermal efficiency. Effective utilization of energy from exhaust manifold can be achieved by designing for backpressure reduction by energy-efficient exhaust manifold system. The exhaust manifold system design with reduced back pressure requirements is an important factor for upgrading engine performance. It is analysis by CFD on reduction in the backpressure of the exhaust manifold system to increase the efficiency.

Keywords— *Computational Fluid Dynamics (CFD), Single Cyl. Compression Ignition Engine, Exhaust Manifold System (EMS)*

1. INTRODUCTION

To reduce the exhaust emissions from C.I. engines, it is very important to understand the overall effects of devices installed in the exhaust system. Effective utilization of exhaust energy is economically possible to reduce exhaust emissions from old engines instead of engine and fuel modifications. More efforts are required on the development of the after-treatment devices, by further study of the theory of operation for diesel engines. Favorable operating parameters providing in the after-treatment devices during the whole operating range of the engine requires proper design of after-treatment devices by considering overall effects of its installation, in the exhaust system. Obtaining economically, maximum conversion efficiency of the pollutants without adversely affecting the engine performance with durability is the ideal requirement from the after-treatment devices.

Backpressure on engine cylinder is completely dependent on exhaust system design, its operating condition and atmospheric pressure (that is almost constant). During the exhaust stroke when the piston moves from BDC to TDC, pressure rises and gases are pushed into the 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 below 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.

2. LITERATURE REVIEW

This work on the application of reduced backpressure of an exhaust manifold of single cylinder CI engine. To minimize the backpressure of the exhaust manifold by decrease in pressure drop and utilize the total power during power stroke. With the help of this utilization of energy in minimum fuel consumption. In the fuel supply line diesel particulate is the main important factor to increase the backpressure so minimize the fuel particulate, filter is used to minimize the back pressure. So in the present work, at first critical study of exhaust subsystem design aspects with alternatives available is done, then experimental study of the effect of back pressure generated on the C.I. engine, with and without the use of a specially designed diesel particulate filter is done. By monize the backpressure, an efficiency of engine is increased in small amount also increase the life of engine. [4]. In this paper the study of EGR system to minimize the backpressure by reducing the NOx parameter from exhaust gases. EGR is introduced by some effects that is Depletion of oxygen in the intake charge, increased intake temperature due to mixing with EGR, Increased specific heat of intake charge, recycling of unburned hydrocarbons.

In this study, the venturi type EGR system was used. The experimental investigation is given that by using the diesel with canola oil ethyl ester in single cylinder 4S engine. By using EGR system the brake thermal efficiency decrease by both net diesel and COEE blends. The brake thermal efficiency is decreased due to by EGR ratio. If the higher the specific heat capacity of CO2 and H2O, high flow rate of EGR reduces the combustion temperature, resulted to brake thermal efficiency to reduce the EGR flow rates. In consideration of NO2 when decrease the EGR ratio the increase in NOx due to this minimize the peak combustion temperature. In case of unburned hydrocarbons these unburned gasses is recirculated and burned in succeeding cycle this is the effect that increases the intake temperature and increases in EGR ratio.in the condition of carbon monoxide Increasing EGR flow rates to high levels resulted in considerable rise in CO emission for both net diesel fuel and COEE blends. [14].

The objective of this work is to provide an estimate of the potential effect of substrate and exhaust system backpressure on engine performance. Parameters include fuel consumption, CO_2 emissions, and horsepower. Results were obtained on an engine test and statistical analysis was used to understand the relationships between variables. Trade-offs between catalyst substrate selection and engine performance for the particular engine used in this study are described. Finally, the potential impact of exhaust system backpressure on real-world driving conditions is discussed [5].

Since the last 3 to 4 decades after treatment techniques are being increasingly utilized and research work is well under progress. The 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 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 interest for design and development of particulate matter emission control activities. The Backpressure acting on engine is most important factor which basically deteriorates the engine and emission control performance. In the present work, dimensional analysis technique is used for determining 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 use of a specially designed diesel particulate filter is done.[1].

3. METHODOLOGY

In the analysis select three exhaust manifold system of modified design having inlet cone angle for EMS-1 with 0^0 inlet cone angle, second EMS-II has 30^0, and EMS-III have 75^0 inlet cone angle in the experimental work shows that the brake thermal efficiency increases due to reduction in backpressure of engine. These results are compiled with CFD analysis.

4. EXPERIMENTAL RESULT AND DISCUSSION

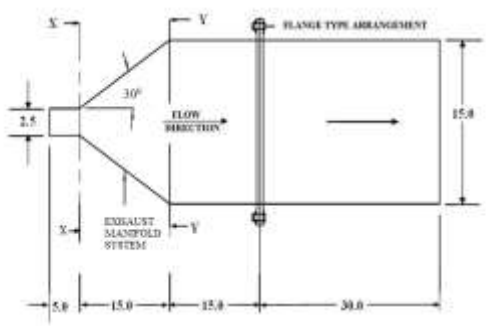

Fig. 1: Exhaust Manifold System

The experimentation was done on single-cylinder four-stroke CI engine with EMS-I, EMS-II, and EMS-III. According to these readings plotted the graph of brake thermal efficiency and back pressure on engine.

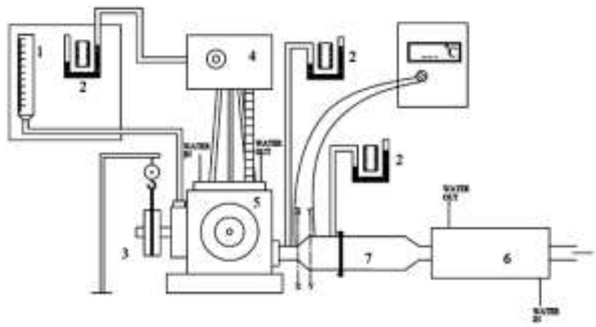

Fig. 2: Schematic view of experimental set up

1 Fuel Flow Measurement
2 U- Tube Manometers
3 Dynamometer
4 Air Flow Meter
5 C.I. Engine
6 Exhaust Gas Calorimeter
7 Exhaust Manifold System
X-X: Inlet to Exhaust Manifold System
Y-Y: Outlet to Exhaust Manifold System

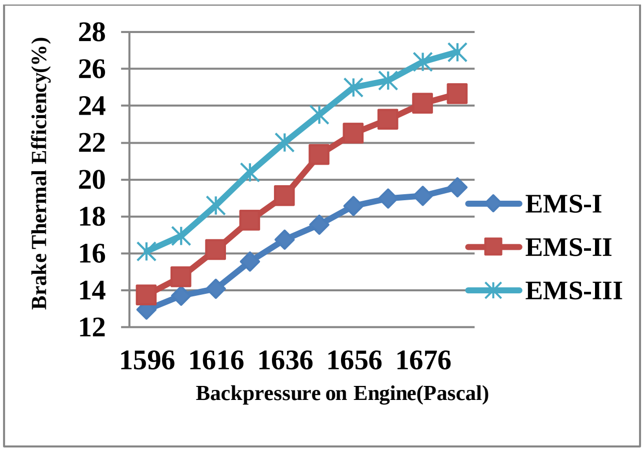

Fig. 3: Variation in brake thermal efficiencies vs. backpressure on the engine for different load conditions using Exhaust Manifold Systems

Figure 3 shows that for different load from 0.5kg to 5 kg at constant load the brake thermal efficiency is increased as backpressure decreases. The brake thermal efficiency increases from 9 to 13%.

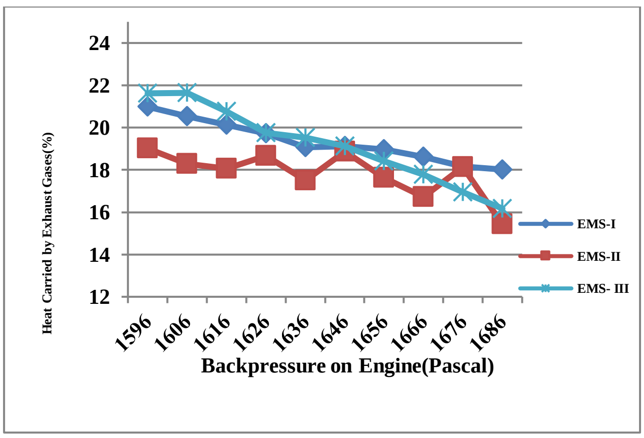

Fig. 4: Variation in heat carried away by exhaust gases in percentage vs. backpressure on the engine for different load conditions using Exhaust Manifold Systems

Figure 4 shows that for different load from 0.5kg to 5 kg at constant load the heat carried away by exhaust gases decreases as backpressure decreases. The heat carried away by exhaust gases decreases near about 4%.

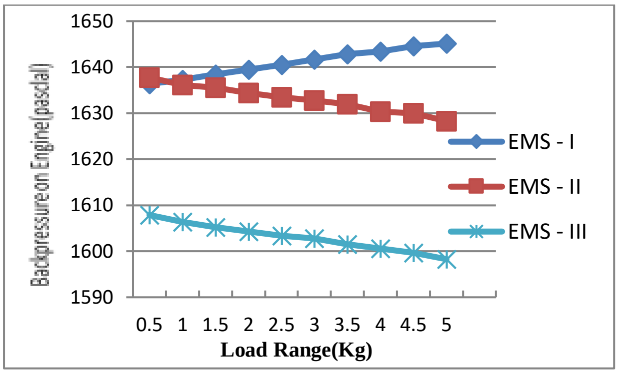

Fig. 5: Variation in backpressure on the engine during experimentation vs. different load conditions for Exhaust Manifold Systems

Figure 5 shows that for different load from 0.5kg to 5 kg at constant load the backpressure by exhaust gases is decreased. The backpressure on engine decreases with increase in brake power on engine for EMS-I to EMS-III

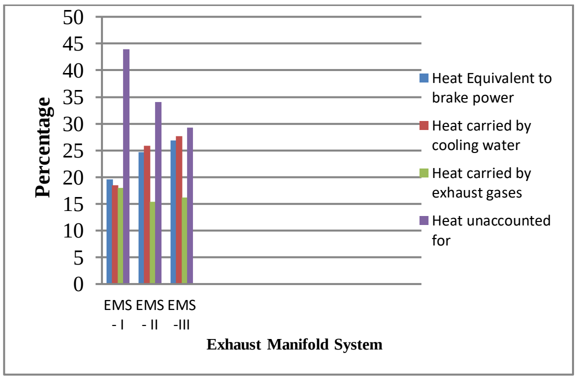

Fig. 6: Heat balance sheet for Exhaust Manifold Systems at constant load 5 Kg

The fig. no.6 shows that Heat balance sheet for different Exhaust Manifold systems at constant load of 5 kg. When the exhaust manifold systems vary from EMS - I to EMS – III the heat equivalent of brake power increases and heat carried by exhaust gases decreases. After experimental evaluation showed that around 30 to 40%of fuel energy is wasted, this is the important factor to concern to maximize utilization of exhaust energy.

5. METHODOLOGY OF CFD

This exhaust manifold models implemented in ANSYS-FLUENT to evaluate the effect of backpressure on engine performance.

5.1 Modeling and Meshing

The geometry of the CFD model has tetrahedral mesh and have mesh quality 0.4. The first mesh is checked for unconnected vertices and smoothened the mesh by smoothing tool after that file is imported in ANSYS-FLUENT. The K-ε turbulence models used for analysis of Exhaust Manifold System.

5.2 Boundary conditions

Boundary conditions used at inlets mass flow rate of fluid is applied and at outlets static pressure is applied. Domain surface is used as a wall with 'No-Slip Condition' and heat transfer coefficient of 45 w/m^2 °k and wall surface roughness as 0.00508 mm is used.

5.3 CFD Result and Discussion

CFD analysis shows that as the inlet cone angle of exhaust manifold increases, backpressure on engine reduced. It is observed that for EMS-I to EMS-III back pressure reduction from 1651.6 to 1614.122pascal.

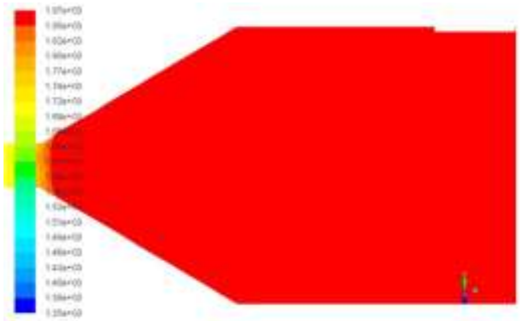

Fig. 7: The pressure contour for EMS – II at constant Load 5 Kg

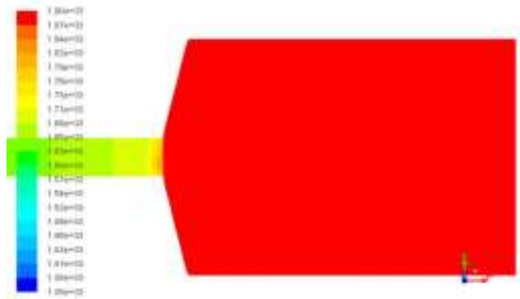

Fig. 8: The pressure contour for EMS – III at constant Load 5 Kg.

The above CFD analysis graph shows that at constant load 5 Kg contour static pressure difference at inlet and outlet of Exhaust Manifold System increases on the engine.

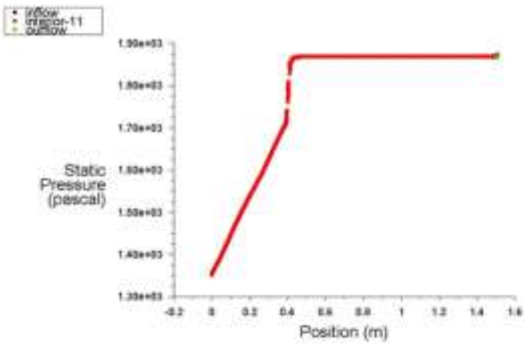

Fig. 9: Variation in backpressure on the engine during the flow through EMS – II at constant Load 5 Kg.

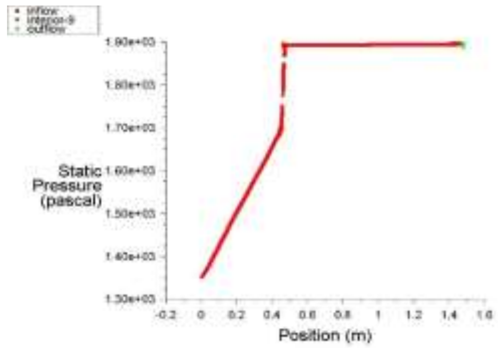

Fig. 10: Variation in backpressure on engine during the flow-through EMS – III at constant Load 5 Kg.

The above graph shows that the static pressure along with position to its length of Exhaust Manifold System increases on engine.

6. CONCLUSION

According to the experimental work as well as CFD analysis for Single Cylinder Four Stroke C.I. Engine Exhaust System for Backpressure Reduction the following conclusions appear to be justified.

- Exhaust Manifold System – III gives the highest brake thermal efficiency at different engine operating conditions. As an average the brake thermal efficiency increases by 5.44%, with the aid of EMS III.
- At the same operating conditions heat carried away by exhaust gases decreases with the decrease in backpressure.
- During studies it is found that the influence of term relating to geometric features of exhaust manifold System is crucial, so back pressure on engine could be controlled with the help of exhaust system design at the inlet section improvement specifically.
- Minimum values of backpressure on the engine is a response variable to get the best so as to design the energy-efficient exhaust system.

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