Experimental Analysis of Single Cylinder 4-Stroke Diesel Engine For the Performance and Emission Characteristics at Different Inclinations Of The Intake Manifold

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Abstract— In the present days, most of the countries over the world wide have enforced the strict emission norms in order to reduce emission levels from the engine exhaust to curb the problem of pollution. The main problem in connection with the combustion in C.I. engine is the intimate mixing of fuel injected and air. Air motion in CI engine influences the atomization and distribution of fuel injected in the combustion chamber and also supplies fresh air to the interior portion of the fuel drops and thereby ensures complete combustion. The design and orientation of the Intake Manifold has a major influence on the air flow-field generated within the Diesel Engine Cylinder which in turn directly influence the Performance and Emissions characteristics of the engine. In this present work, the orientation of the Intake Manifold was changed by inclining it at several different angles viz. Normal Intake Manifold, Intake Manifold at 25° inclination, 50° inclination and 75° inclination w.r.t. Normal Intake Manifold Position and then the effects of these different orientations of the Intake Manifold on the Performance and Emission parameters of the Single Cylinder 4-Stroke naturally aspirated Diesel Engine were analyzed and then comparisons of the computed results were made with those of the Normal Intake Manifold. From the experimental research work, it is found that the BSFC reduces, brake thermal efficiency increases and there is an improvement in the exhaust gas emissions as orientation of the Intake Manifold is changed from Normal Manifold Position to 50° inclination w.r.t. Normal Manifold Position.

Keywords: Intake Manifold Orientation, Single Cylinder 4-stroke Diesel Engine, In-Cylinder flow-field structure.

I. INTRODUCTION

In the present days, most of the countries over the world wide have enforced the strict emission norms in order to reduce emission levels from the engine exhaust to curb the problem of pollution. Due to this, all automobile and engine manufacturing companies have to make such an engine that satisfy the strict environmental constraints and fuel economy standards in addition to meeting the competitiveness of the world market. Diesel engine plays a dominant role in the field of power, propulsion and energy. The diesel engine is a type of internal combustion engine; more specifically it is a compression ignition engine in which the fuel injected by fuel injection system is ignited solely by the high temperature created by compression of the air during the compression stroke. There are various factors that influence the performance of engine such as compression ratio, atomization of fuel, fuel injection pressure, and quality of fuel, combustion rate, air fuel ratio, intake temperature and pressure and also based on piston design, inlet manifold, and combustion chamber designs etc. Growing demand on reduction of internal combustion engine fuel consumption with increase of its performance new designs and optimization of existing ones are introduced [1]. An inlet manifold or intake manifold is the part of an engine that supplies the fuel/air mixture (in case of SI engine) or only fresh air (in case of CI engine) to the engine cylinder. The primary function of the intake manifold is to evenly distribute the combustion mixture (or just air in a direct injection engine) to each intake port in the cylinder head(s). The intake manifold has historically been manufactured from aluminium or cast iron but use of composite plastic materials is gaining popularity. The intermittent or pulsating nature of the airflow through the intake manifold into each cylinder may develop resonances in the airflow at certain speeds. These may increase the engine performance characteristics at certain engine speeds, but may reduce at other speeds, depending on manifold dimension and shape. Engineers discovered that pulsating flow can be used to force additional air into the engine making it more efficient. Air motion in CI engine influences the atomization and distribution of fuel injected in the combustion chamber and also supplies fresh air to the interior portion of the fuel drops and thereby ensures complete combustion. By way of complete combustion and reduced excess air supply, it increases the thermal efficiency of the engine. In other words, reduces specific fuel consumption of the engine [8].

II. IN-CYLINDER FLOW-FIELD STRUCTURE

In-cylinder flow field structure in an internal combustion (I.C) engine has a major influence on the combustion, emission and performance characteristics. The fluid motion in an internal combustion engine is induced during the induction process and later modified during the compression process. Intake charge enters the combustion chamber through the intake manifold of an I.C engine with high velocity. Then the kinetic energy of the fluid resulting in turbulence causes rapid mixing of fuel and air, if the fuel is injected directly into the cylinder. In-cylinder fluid motion governs the flame propagation in spark-ignition engines, and controls the fuel-air mixing and premixed burning in diesel engines. With optimal turbulence, better mixing of fuel and air is possible which leads to effective combustion [2].

III. AIR-MOTION INSIDE THE ENGINE CYLINDER

It includes air, fuel, and exhaust gas motion that occurs within the cylinders during the compression stroke, combustion, and power stroke of the cycle. It is important to have this motion to speed evaporation of the fuel, to enhance air-fuel mixing, and to increase combustion speed and efficiency. In addition to the normal desired turbulence, these motions include:

A. Swirl Motion:

The geometrical configuration of the inlet ports and the valves, and their opening schedule creates organized rotational motions about the cylinder axis within the cylinder; this motion is termed as "Swirl". It is generated by constructing the intake system to give a tangential component to the intake flow as it enters the cylinder.

B. Tumble Motion:

The geometrical configuration of the inlet ports and the valves, and their opening schedule creates organized rotational motions orthogonal to the cylinder axis within the cylinder; this motion is termed as "Tumble".

C. Squish Motion:

As the piston approaches TDC, the gas mixture occupying the volume at the outer radius of the cylinder is forced radically inward as this outer volume is reduced to near zero. This radial inward motion of the gas mixture is called "Squish". It adds to other mass motions within the cylinder to mix the air and fuel, and to quickly spread the flame front. Maximum squish velocity usually occurs at about 10°before TDC [10].

Due to the high velocities involved, all flows into, out of, and within engine cylinders are turbulent flows. The exceptions to this are those flows in the corners and small crevices of the combustion chamber where the close proximity of the walls dampens out turbulence. As a result of turbulence, thermodynamic transfer rates within an engine are increased by an order of magnitude. Heat transfer, evaporation, mixing, and combustion rates all increase. The inlet jet itself is turbulent, and in addition much of the directed (non-turbulent) energy of the inlet jet is converted to turbulence, resulting in a very high turbulence level during the intake stroke. Turbulence in a cylinder is high during intake, but then decreases as the flow rate slows near BDC. It increases again during compression as swirl, squish, and tumble increase near TDC. Swirl makes turbulence more homogeneous throughout the cylinder. The high turbulence near TDC when ignition occurs is very desirable for combustion. It breaks up and spreads the flame front many times faster than that of a laminar flame. The air-fuel is consumed in a very short time, and self-ignition and knock are avoided [8].

IV. EXPERIMENTAL SET-UP

A single cylinder, four strokes, naturally aspirated, diesel engine was used to carry out experimental investigations. The experimental set-up consists of a Single Cylinder 4-Stroke Diesel Engine along with several measuring instruments. The test set-up is as shown in fig. 1below:

The engine was then coupled to a D.C. Electrical dynamometer through universal joint type coupling. Necessary provisions were made to measure the flow rates of fuel and air flowing into the engine cylinder. The engine was first tested with Normal Intake Manifold (without any modification) and diesel as a fuel and was to be run for 20 minutes before each sets of reading were taken to get stabilization. The load on the engine is varied from no load to 16%, 32%, 48% and up to 64% of the full rated load. The engine speed was kept constant for the each set of readings to be taken through fuel control lever. The readings were taken at the speed of 1200, 1500 and 1800 rpm respectively for each loading condition. Then, the orientation of the Normal Intake Manifold was changed by inclining the Intake manifold at three different angles of Inclination w.r.t Normal Intake Manifold Position in the Vertical Plane and the same set of readings were taken for each orientation of the manifold.

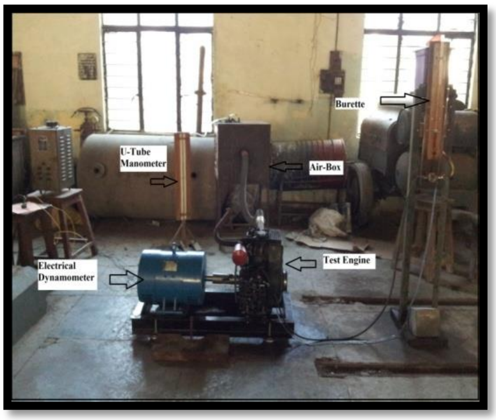

Fig. 1: Experimental Set-up

– At 25° w.r.t. Normal Intake Manifold Position.
– At 50° w.r.t. Normal Intake Manifold Position.
– At 75° w.r.t. Normal Intake Manifold Position.

V. PERFORMANCE AND EMISSION CHARACTERISTICS

A. Brake Specific Fuel Consumption:

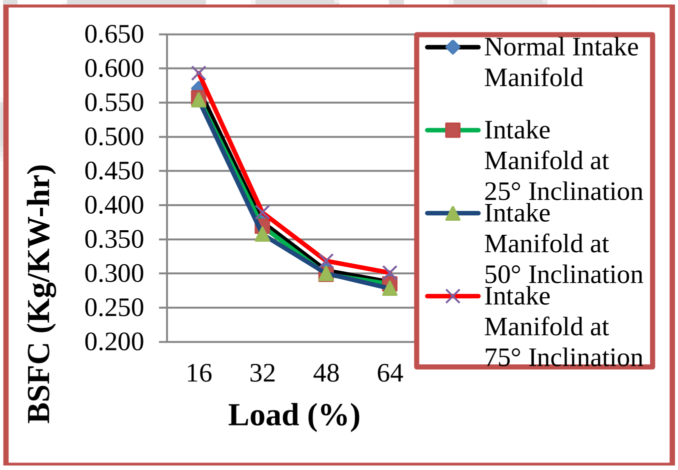

Fig. 2: Variation in BSFC with Load at 1800 rpm

As seen from the above fig. 2, one can say that at the same speed of the engine, BSFC is maximum for the Intake Manifold oriented at 75° Inclination w.r.t. Normal Manifold Position for all loading conditions. There was a marginal reduction in BSFC for the Intake Manifold oriented at 25° inclination as compared to Normal Intake Manifold. However, the least BSFC was encountered with 50° inclination of the Intake Manifold for all loading conditions and at the same speed of the engine.

B. Brake Thermal Efficiency:

As seen from the above fig. 3, it can be concluded that at the same speed of the engine, BTE is minimum for the Intake Manifold oriented at 75° Inclination w.r.t. Normal Manifold Position for all loading conditions. There was a little increase in BTE for the Intake Manifold oriented at 25° inclination as compared to Normal Intake Manifold.

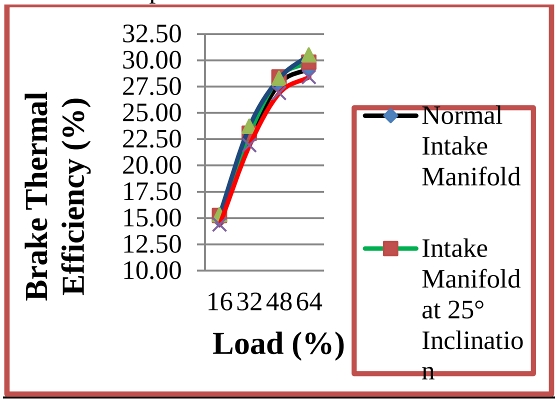

Fig. 3: Variation in BTEwith Load at 1800 rpm

However, the highest BTE was encountered with 50° inclination of the Intake Manifold for all loading conditions and at the same speed of the engine as compared to other Intake Manifold orientations.

C. Volumetric Efficiency:

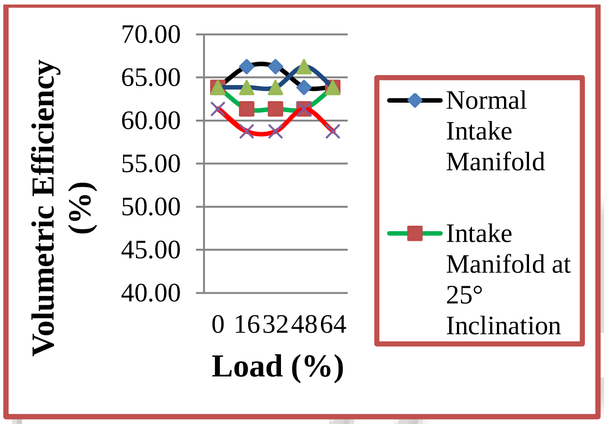

Fig. 4: Variation in Volumetric Efficiencywith Load at 1800 rpm

It is also clear from the fig. 4 that there was a very little variation in the volumetric efficiency for each Intake Manifold orientation for different loading conditions and at constant engine speed. The volumetric efficiency was found to be minimum for the Intake Manifold oriented at 75° inclination w.r.t. Normal Manifold at all engine speeds as compared to the other Intake Manifold orientations.

D. EXHAUST EMISSION:

From experimental data following analysis can be carried out when four stroke single cylinder diesel engine running with duel fuel at different ratio and load condition as a various emissions constitutes from engine exhaust are measured and compare with diesel.

E. Co Emission:

As seen from the fig.5 below, it can be concluded that the emissions of CO were the highest for the Intake Manifold oriented at 75° inclination and were the least for the Intake Manifold oriented at 50° inclination as compared to the other orientations of the Intake Manifold for all the speeds of the engine and at each loading condition.

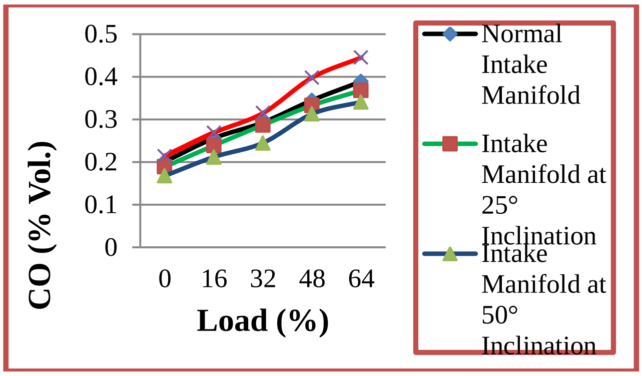

Fig. 5: Variation in CO emissions with load at 1800 rpm

F. HC Emission:

HC emission increases as the load on engine increases at all the engine speeds. Emissions of HC are generally the product of incomplete combustion of the charge. As seen from the fig. 6 below, it can be concluded that the emissions of HC were the highest for the Intake Manifold oriented at 75° inclination and were the least for the Intake Manifold oriented at 50° inclination as compared to the other orientations of the Intake Manifold for all the speeds of the engine and at each loading condition.

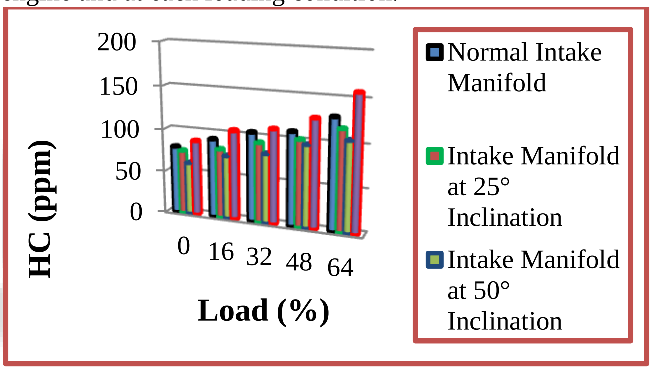

Fig. 6 Variation in HC emissions with load at 1800 rpm

G. CO_2 Emission:

As seen from the fig.7 below, it can be concluded that the emissions of CO2 were the highest for the Intake Manifold oriented at 50° inclination and were the least for the Intake Manifold oriented at 75° inclination as compared to the other orientations of the Intake Manifold for all the speeds of the engine and at each loading condition.

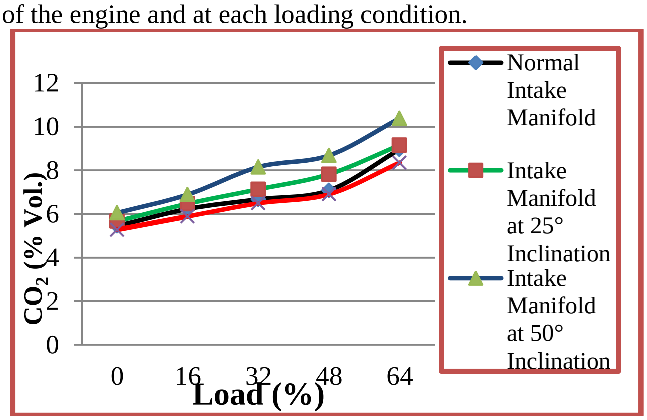

Fig. 7: Variation in CO_2 emissions with load at 1800 rpm

VI. Conclusion

- For 75° Intake Manifold inclination position, the BSFC was increased by 5.09% as compared to Normal Intake Manifold at 64% loading condition and 1800 rpm. Whereas at the same loading condition and speed for 25° Intake Manifold inclination position, the BSFC was decreased by 1.07% as compared to Normal Intake Manifold. Further, with Intake Manifold oriented at 50° inclination w.r.t. Normal Manifold Position, the BSFC was decreased by 5.92% as compared to Normal Intake Manifold.
- It can be concluded that for 75° Intake Manifold inclination position, the BTE was decreased by 3.12% as compared to Normal Intake Manifold at 64% loading condition and 1800 rpm. Whereas at the same loading condition and speed for 25° Intake Manifold inclination position, the BTE was increased by 2.10% as compared to Normal Intake Manifold while with Intake Manifold oriented at 50° inclination w.r.t. Normal Manifold Position, the BTE was increased by 7.49% as compared to Normal Intake Manifold.
- At 64% loading condition and 1800 rpm, the emissions of CO were decreased by 12.34% for the Intake Manifold oriented at 50° inclination as compared to the Normal Manifold while for the Intake Manifold oriented at 25° inclination, the CO emissions were reduced by 5.40% as compared to the Normal Manifold. Whereas at the same loading condition and speed, the emissions of CO were increased by 14.40% for the Intake Manifold oriented at 75° inclination as compared to the Normal Manifold.
- At 64% loading condition and 1800 rpm, the emissions of HC were decreased by 18.60% for the Intake Manifold oriented at 50° inclination as compared to the Normal Manifold. Whereas at the same loading condition and speed, the emissions of HC were increased by 21.71% for the Intake Manifold oriented at 75° inclination as compared to the Normal Manifold. The emissions of HC were also reduced for the Intake Manifold oriented at 25° inclination by 9.30% as compared to Normal Manifold.
- At 64% loading condition and 1800 rpm, the emissions of CO_2 were increased by 15.85% for the Intake Manifold oriented at 50° inclination as compared to the Normal Manifold. Whereas at the same loading condition and speed, the emissions of CO_2 were reduced by 6.81% for the Intake Manifold oriented at 75° inclination as compared to the Normal Manifold. The emissions of CO_2 were also increased for the Intake Manifold oriented at 25° inclination by 2.12% as compared to Normal Manifold.

Finally, from all the above results, analysis and comparisons, the conclusion was made that the Intake Manifold oriented at 50° inclination w.r.t. Normal Manifold Position is the best orientation of the Intake Manifold for the optimum Performance of the engine with the least emissions.

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