

# Effect of Intake Manifold Inclination on Performance and Emission Parameters of 4-Stroke Single Cylinder C.I. Engine : A Technical Review

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## Abstract

The main problem related with the combustion in C.I. engine is to get the homogeneous mixture of fuel and air. Air motion in CI engine influences the atomization and distribution of fuel injected in the combustion chamber. This air-motion and all other subsequent in-cylinder flow field structure developed are greatly influenced by the design and orientation of the Intake Manifold. Here, the review is given on how the design and orientation of the intake manifold influence the Performance and Emissions characteristics of diesel engine. From literature survey, it will be shown that the in-cylinder flow field structure is greatly influenced by varying the orientation of the Intake Manifold which will directly affect the performance and emission of the engine and certain orientation of the intake manifold can be optimized for the enhancement of performance with least emissions.

**Key words-** Intake Manifold Orientation, Single Cylinder 4-stroke Diesel Engine, In-Cylinder flow-field structure.

## 1. 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 aluminum 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].

## 2. 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].

### 2.1 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:

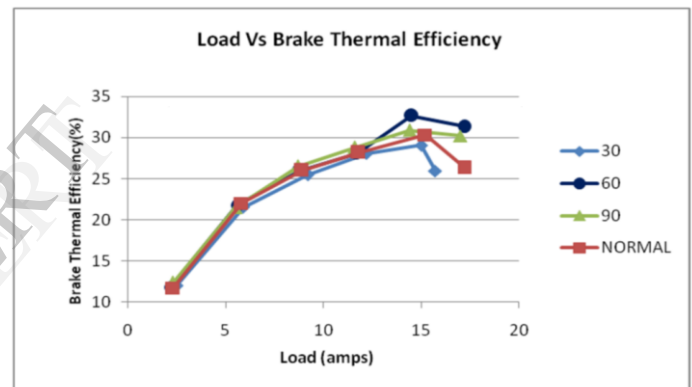
1. **Swirl Motion:** The geometrical configuration of the inlet ports and the valves, and their opening schedule creates organized rotational motions about the cylinder axis within the cylinder; this motion is termed as "Swirl". It is generated by constructing the intake system to give a tangential component to the intake flow as it enters the cylinder.
2. **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".
3. **Squish Motion:** As the piston approaches TDC, the gas mixture occupying the volume at the outer radius of the cylinder is forced radially 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].

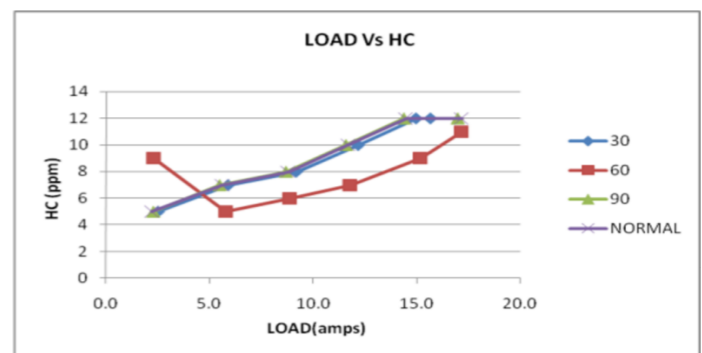
### 3. Literature Survey

M.L.S Deva Kumar, et al. [1] studied the effect of the fuel injection pressure on performance and emission of the single cylinder diesel engine at different intake manifold inclinations. A single cylinder 4-stroke water-cooled diesel engine having 5 HP as rated power at 1500 rpm was used for the research work. In this work, the inlet manifolds were manufactured with different angle of inclinations using mild steel. The manifolds were manufactured with angles 30°, 60°, 90° w.r.t. normal manifold and a normal intake manifold. In the investigation, they studied the effects of injection pressure on the performance and emission of the engine, in fixed engine speed-variation engine loads and the fuel injection pressures were setting at 160, 180 & 200 bar turn by turn.

It was found that at 60° intake manifold inclination, at 180 bar gives the maximum brake thermal efficiency (Fig.1) and also emission levels were considerably reduced (Fig.2). This work improves both performance and fuel economy with optimum emission levels. By increasing fuel injection pressure, pollution levels reduce due to complete combustion of fuel. Emissions were reduced at 200 bar with different manifold inclinations compared to other pressures.



**Figure 1.** Effect of Intake manifold inclination on Brake Thermal Efficiency at 180 bar Fuel-Injection Pressure

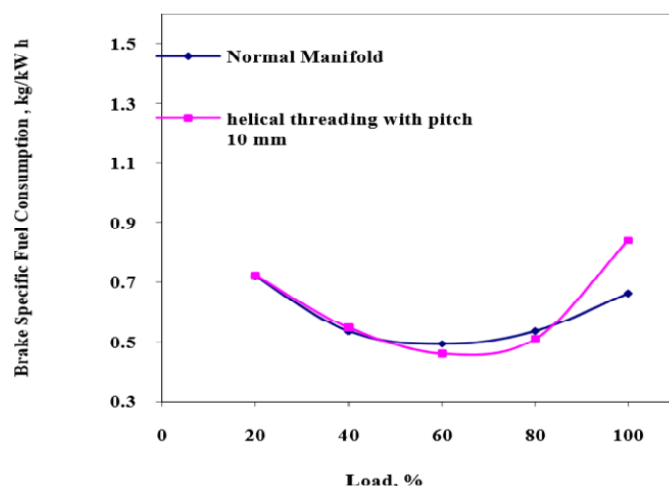


**Figure 2.** Effect of Intake manifold inclination on HC emission at 180 bar Fuel-Injection Pressure

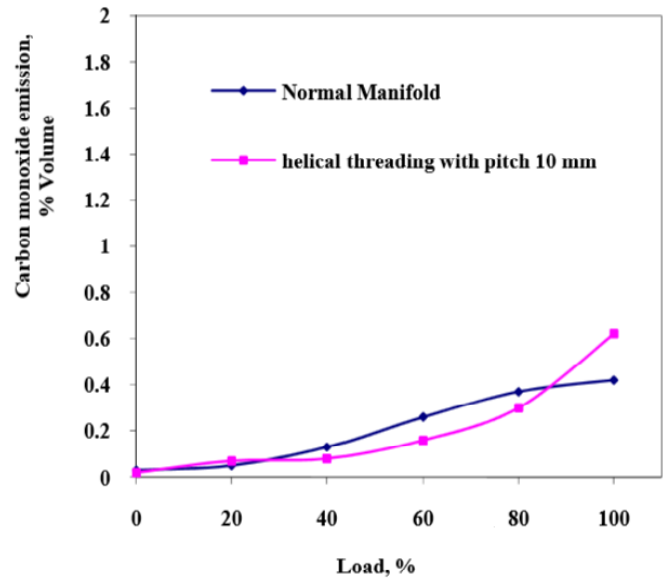
B. Murali Krishna, et al. [2] studied the in-cylinder fluid flow field characteristics of a single-cylinder engine to see the effect of intake manifold inclination at equivalent rated engine

speed using Particle Image Velocimetry(PIV) under various static intake valve lift conditions.To facilitate the PIV experiments, the metal cylinder of the engine was replaced by a transparent one. For every operating test condition, 50 image pairs were captured and processed using DAVIS software.Four intake manifolds with inclinations of 0°, 30°, 60° and 90° with respect to horizontal plane were fabricated.Then the intake valve was fitted on to the intake manifold. A screw arrangement was made to vary the intake valve lift. For all the intake valve lifts with 0° intake manifold inclination, air flow was in the form of jet near the intake valve exit, whereas for other manifold inclinations, jet formation is not common for all the lifts.They found that at 30° intake manifold inclination, large scale vortex below the intake valve at all intake valve lifts.They also found that at all the intake valve lifts with 60° manifold inclination, the maximum TKE was highest compared to all other manifold inclinations.

V.CVS Phaneendra, et al. [3]optimized the design of the inlet manifold by providing helical threads of variable pitches inside the manifold , which is a major factor effecting the performance of the engine. A four stroke compression ignition engine with power 9 H.P and rated speed 1500 rpm was selected for the present work to investigate the performance characteristics. The performance characteristics with normal manifold and helical threaded manifold were calculated and compared. The tests were carried with different configurations by varying the pitch of the helical threads from 10mm to 25 mm in steps of 5mm inside the intake manifold. The core diameter of the manifold was about 30 mm. By considering the thread, the outer diameter was 30 mm and inner diameter was about 24 mm.It was found from the experimental results that the 10mm pitch manifold showed better performance. The performance parameters were presented below at 4/5th of rated load (80%).



**Figure 3.**Effect of different Intake Manifold Configurations on BSFC for various Engine Load Conditions

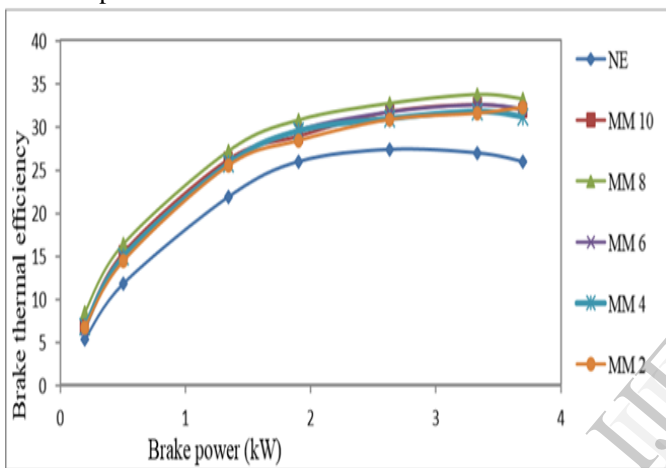


**Figure 4.**Effect of different Intake Manifold Configurations on CO emission for various Engine Load Conditions

Brake power was increased by 2.38%. Total fuel consumption was reduced by 2.91%. Brake Specific fuel consumption was reduced by 5.55% (Fig.3). Indicated power was increased by 4.27%. Mechanical efficiency was reduced by 1.81%. Brake thermal efficiency was increased by 5.13%. Volumetric efficiency was reduced by 11.3%. Exhaust gas temperature was reduced by 1.81%. Hydrocarbon emission was reduced by 12.5%. Carbon monoxide emission was reduced by 0.3% (Fig.4).

Benny Paul and V. Ganesan [4]studied the effect of helical, spiral, and helical-spiral combination manifold configuration on air motion and turbulence inside the cylinder of a Direct Injection (DI) diesel engine motored at 3000 rpm.Three-dimensional model of the manifolds and the cylinder was created and meshed using the pre-processor GAMBIT. The flow characteristics of these engine manifolds were examined under transient conditions using Computational Fluid Dynamics (CFD) code STAR-CD.The predicted CFD results of mean swirl velocity of the engine at different locations inside the combustion chamber at the end of compression stroke were compared with experimental results carried out by other researchers.They concluded that swirl ratio inside the cylinder and turbulent kinetic energy was higher for spiral manifold. Volumetric efficiency for the spiral-helical combined manifold was 10% higher than that of spiral manifold.Helical-spiral combined manifold creates higher swirl inside the cylinder than spiral manifold. Helical manifold provides higher volumetric efficiency. Helical-spiral combined manifold provides higher mean swirl velocity at TDC of compression.Hence, for better performance a helical-spiral inlet manifold configuration was recommended.

S.L.V. Prasad and V. Pandurangadu [5] studied the effect of air swirl generated by directing the air flow in intake manifold on engine performance. The turbulence is achieved in the inlet manifold by grooving the inlet manifold with a helical groove of size of 1 mm width and 2 mm depth of different pitches to direct the air flow. The tests were carried with different configurations by varying the pitch of the helical groove from 2 mm to 10 mm in steps of 2 mm inside the intake manifold. The measurements were done at constant speed of 1500 rpm. The results were compared with normal engine (without helical groove). Five different configurations of the intake manifold with different helical groove pitches were tested on the diesel engine. The Configuration MM8 (Modified Manifold with Helical Grooves of Pitch 8 mm) enhances the turbulence and hence results in better air-fuel mixing process among all the configurations of diesel engine. As a result, the brake thermal efficiency was increased (Fig.5) and SFC and soot emission were reduced. They concluded that MM8 is the best trade-off between performance and emissions.



**Figure 5.** Brake Power vs. Brake Thermal Efficiency for different Intake Manifold Configurations

#### 4. Conclusion

As observed from the above literature survey, it is concluded that in-cylinder flow field structure is greatly influenced by positioning the intake manifold at various inclinations or by modifying the intake manifold design. Air motion in CI engine influences the atomization and distribution of fuel injected in the combustion chamber. With optimal turbulence, better mixing of fuel and air is possible which leads to effective combustion.

Further, it can also be concluded from all above experimental and computational investigations for the enhancement of performance and reduction in emissions in a Diesel Engine by modifying the intake manifold of the Engine, carried out by various Researchers, one can say that it is possible to enhance the performance of the Single Cylinder Diesel Engine by providing certain inclination to the air-intake manifold. Moreover, it is comparatively easy to produce the air-motions within the engine cylinder by orienting the intake manifold at various inclinations other than its normal position.

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