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Research Article

REDUCTION OF EMISSIONS BY INTENSIFYING AIR SWIRL IN A SINGLE CYLINDER DI DIESEL ENGINE WITH MODIFIED INLET MANIFOLD

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ABSTRACT
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. 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. Therefore, it is very much essential to understand the in-cylinder fluid motion thoroughly in order to optimize the combustion chambers of the I.C engines.
This paper aims at studying 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 are 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 are done at constant speed of 1500 rpm. The results are compared with normal engine (without helical groove). The results of test show an increase in performance and decrease in emission

Key Words: *Diesel Engine, Air Swirl, Intake Manifold, Efficiency, Emissions*

INTRODUCTION
In-cylinder flow field structure in an internal combustion engine has a major influence on the combustion, emission and performance characteristics. Fluid flows into the combustion chamber of an I.C engine through the intake manifold 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. With optimal turbulence, better mixing of fuel and air is possible which leads to effective combustion. A good knowledge of the flow field inside the cylinder of an I.C engine is very much essential for optimization of the design of the combustion chamber for better performance (B. Murali Krishna, 2010).
Previously, Heywood (1998) has stated that generating a significant swirl and/or tumble motion inside the engine cylinder during the intake process was one of the promising ways to obtain high in-cylinder turbulent intensity. Valentino et al (1993), Reeves et al (1999),Li et al (2001), Yasar et al (2006) and Stansfield et al (2007) have conducted PIV measurements on various engines and reported that the flow structure changes substantially along the cylinder length due to the geometry of the intake valve port and the tumble motion was generated during induction process. Also, reported that the increase in the air flow rate at higher engine speed causes the vortex center to move right-upwards compared to the lower engine speeds.
In general, the presence of a swirl in the cylinder of an internal combustion engine improves the homogenization of the air - fuel mixture, and consequently, enhances fuel combustion. The aim of this work is to analyse the effect of the swirl on the combustion and emission by modifying the inlet manifold

MATERIALS AND METHODS
In the present work the effects of air swirl in intake manifold are experimentally studied on performance of single cylinder light duty direct injection diesel engine. The experiments are

conducted on a single cylinder Kirloskar make direct injection four stroke cycle diesel engine. The general specifications of the engine are given in Table-1. Water cooled eddy current dynamometer is used for the tests. The engine is equipped with electro-magnetic pick up , piezo-type cylinder pressure sensor, thermocouples to measure the temperature of water, air and gas, rotameter to measure the water flow rate and manometer to measure air flow and fuel flow rates, the smoke density is measured with a Bosch Smoke meter

The configurations tested on diesel engine

MM 2	Modified manifold of helical groove of pitch 2 mm
MM 4	Modified manifold of helical groove of pitch 4 mm
MM 6	Modified manifold of helical groove of pitch 6 mm
MM 8	Modified manifold of helical groove of pitch 8 mm
MM 10	Modified manifold of helical groove of pitch 10 mm
NE	Normal Engine

Table 1. Specifications of Diesel Engine Used for Experimentation

Item	**Specification**
Engine power	3.68 kW
Cylinder bore	80 mm
Stroke length	110 mm
Engine speed	1500 rpm
Compression ratio	16.5:1
Swept volume	553 cc

RESULTS AND DISCUSSION

Brake Thermal Efficiency

The brake thermal efficiency with brake power for different configurations is compared with the normal engine and is shown in fig.1. The brake thermal efficiency of normal engine at 3/4 of rated load is 26.1%. It can be observed that the engine with MM8 and MM6 give thermal efficiencies of 32.8% and 31.8%, respectively, at 3/4 of rated load. It is observed that there is a gain of 25.6% with MM8 compared to normal engine. The thermal efficiencies of MM10 and MM2 are lower compared to that MM8. From Fig, it is inferred that the brake thermal efficiencies are increasing with an increase in brake power for configurations that are under consideration. Even though the brake thermal efficiencies are not vary too much between MM8 and MM6 configurations, these configurations are found to offer better thermal efficiencies than the normal engine. This might be due to the enhanced evaporation and mixing rate in the case of MM8 carried by swirl in the combustion chamber.

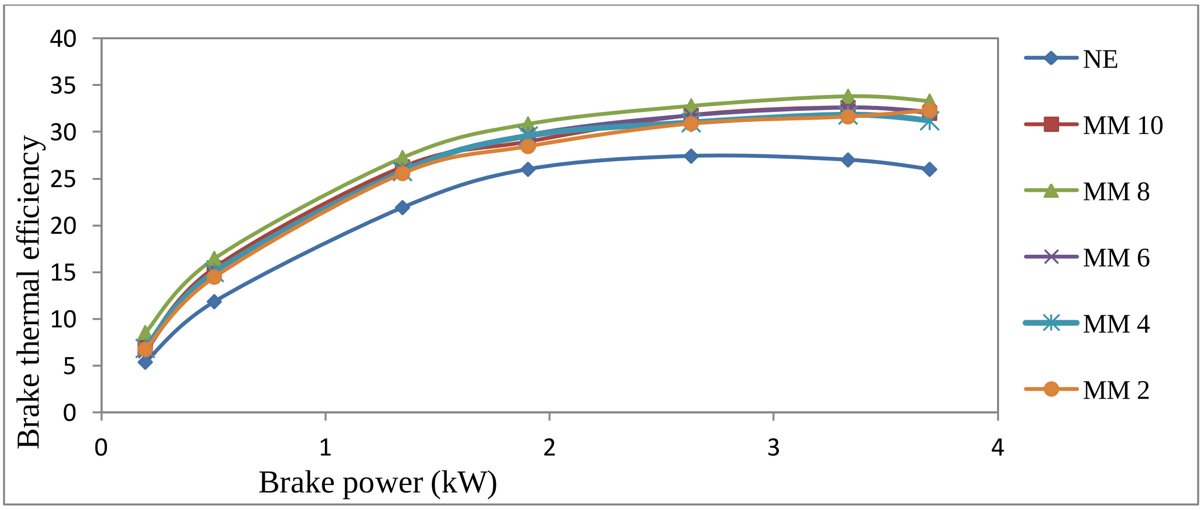

Figure 1: Comparison of Brake thermal efficiency with different configurations of inlet manifold.

Brake Specific Fuel Consumption

The variations of brake specific fuel consumption with brake power for different configurations are shown in fig 2 The brake specific fuel consumption for normal engine at 3/4 of rated load is 0.34 kg/kW-hr. It can be observed that the engine with MM8, MM6 configurations brake specific fuel consumption are 0.26 kg/kW-hr and 0.27 kg/kW-hr respectively, at 3/4 of rated load. From fig 2, it is inferred that the brake specific fuel consumption are increasing with an increase in brake power for configurations that are under consideration. It is also observed that the MM8 has the lowest fuel consumption of 23.5% when compared with normal engine. This due to the quick and complete combustion of the charge in the combustion chamber by the enhanced air swirl.

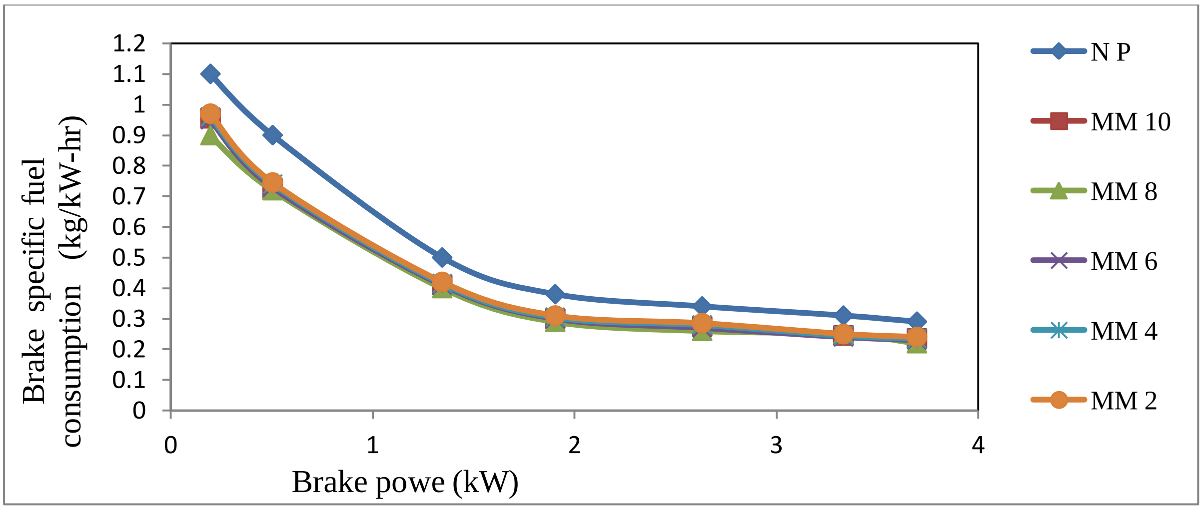

Figure 2: Comparison of Volumetric efficiency with different configurations of inlet manifold.

Ignition Delay

The variation of ignition delay with brake power for different modes of combustion is shown in Fig. 3. It is inferred that ignition decreases with an increase in brake power for almost all configurations. With an increase in brake power, the amount of fuel being burnt inside the cylinder gets increased and subsequently the temperature of in- cylinder gases gets increased. This may lead to reduced ignition delay in all configurations. However, the ignition delay is lower i.e 9.5 ^{o}CA under MM 8 than the normal engine at 3/4 of rated load. The reduction in the ignition delay of MM8 is about 13.6% at 3/4 of rated load when compared to normal engine. This is due to the high angular momentum created by the helical groove inside the manifold compared to the other configurations.

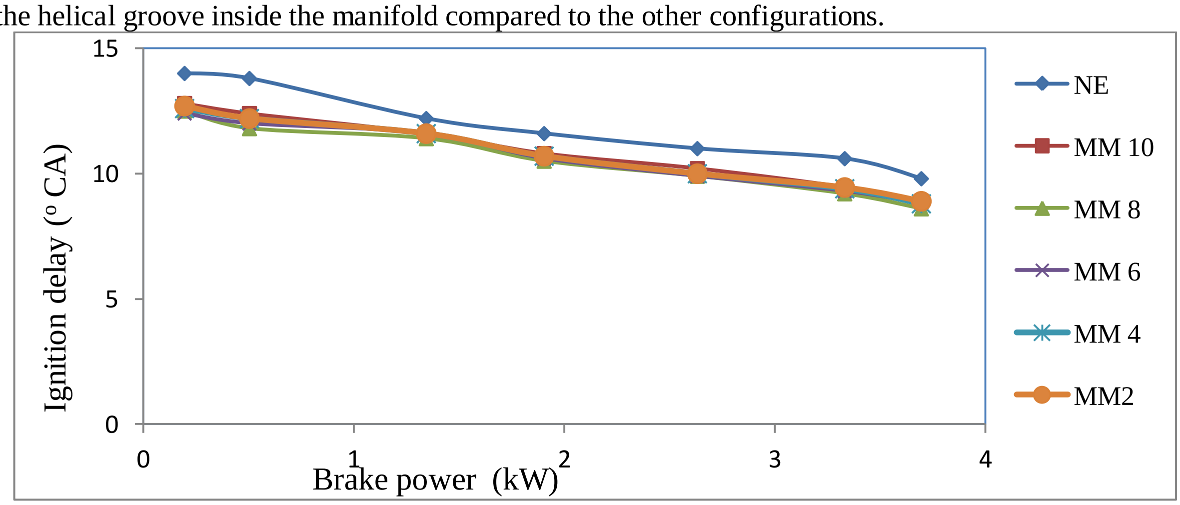

Figure 3: Comparison of Ignition delay with different configurations of inlet manifold.

Smoke Density

Fig. 4 shows the comparison of smoke level with brake power for different configurations. It can be observed that smoke increases with increase in brake power. The higher turbulence in the combustion chamber results in better combustion and oxidation of the soot particles, which reduces the smoke emissions. Due to the complete combustion of fuel with excess air, the smoke emissions are marginal. At 3/4 of the rated load, the smoke emissions of MM 8 are reduced by about 26.9% compared to normal engine. It is seen that the reduction in the smoke emissions of MM 6 is 22.7% and for MM 4, it is 19.5% compared to normal engine.

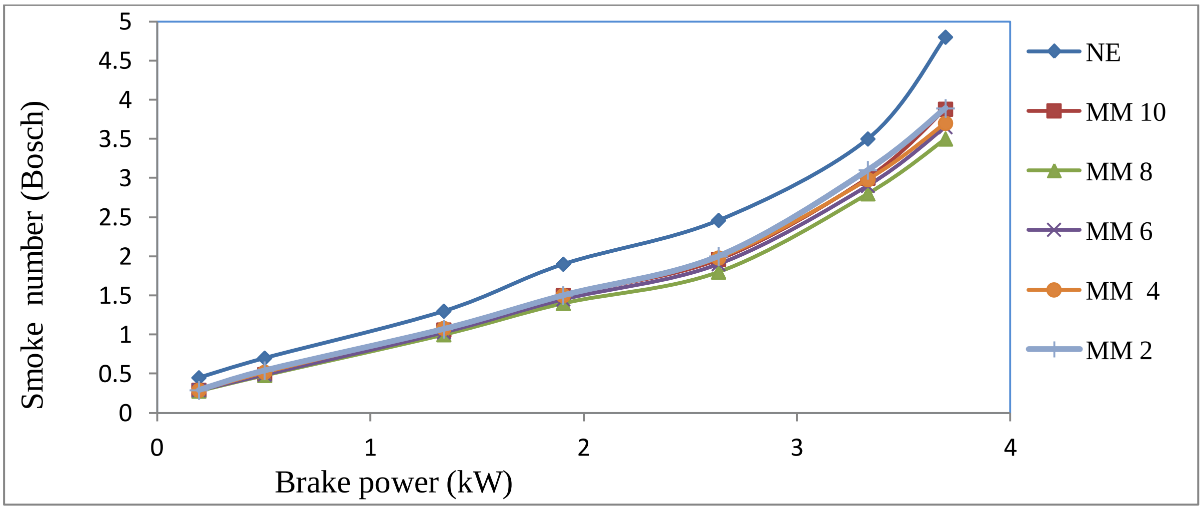

Figure 4: Comparison of Smoke densities with different configurations of inlet manifold.

No_x Emission

Fig. 5 shows the comparison of NOx emission with brake power for different configurations. The NOx emissions for MM8 configuration is 525ppm and whereas for normal engine it is 562ppm. NOx emissions are lower for MM8 when compared to normal engine at 3/4 of rated load. This is due decrease in the operating temperature in the cylinder by the air swirl inside the cylinder and leads to less NOx formation. Therefore, the NOx formation is lower with MM8 and is about 6.6% than normal engine at 3/4 of rated load, when compared with normal engine. The decrease in NOx emissions for MM 10 and MM6 are 4.2 % and 5.6% at 3/4 of rated load respectively.

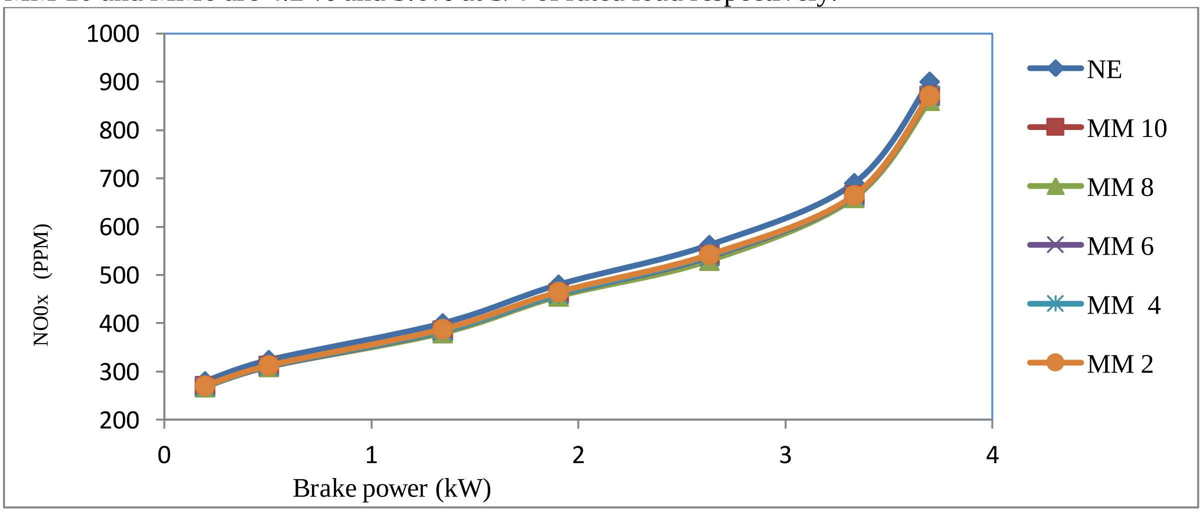

Figure 5: Comparison of NOx emissions with different configurations of inlet manifold.

Hydro Carbon Emission

The comparison of Hydrocarbon emission in the exhaust is shown in Figure 6. Unburnt hydrocarbon emission is the direct result of incomplete combustion. It is apparent that the hydrocarbon emission is decreasing with the increase in the turbulence which results in complete combustion. At 3/4 of the rated load with MM8 maximum reduction of hydrocarbon emission level is observed and is about 15.6% compared to normal engine. It is also observed that with MM 6 and MM 4 the reduction in hydrocarbon levels is about 14.3% and 13% compared to normal engine.

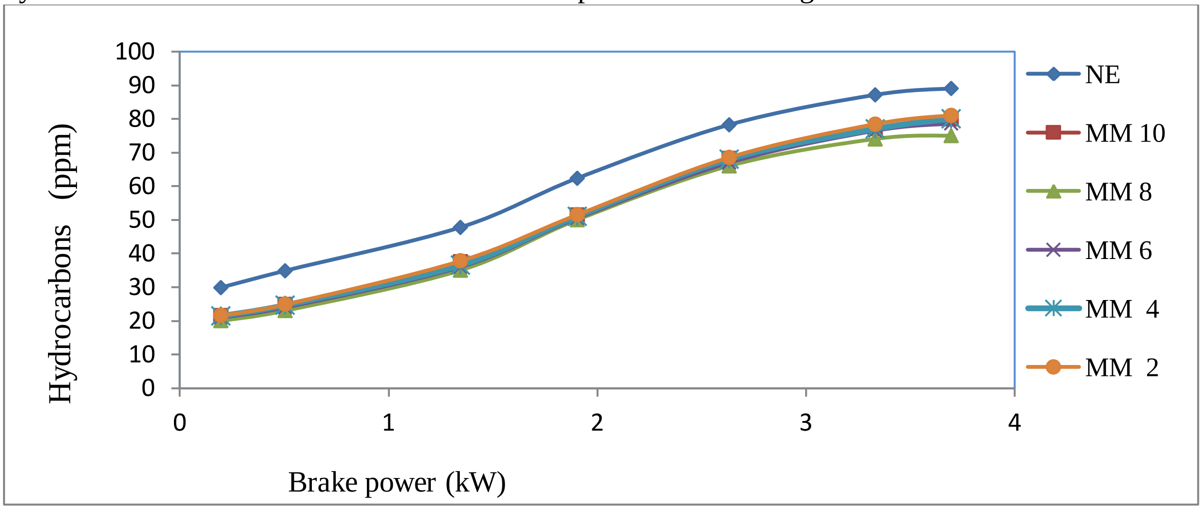

Figure 6: Comparison of Hydrocarbon emissions with different configurations of inlet manifold.

Carbon Monoxide Emission

Fig. 7 shows the comparison of Carbon monoxide emission with brake power. Generally, C.I engines operate with lean mixtures and hence the CO emission would be low. With the higher turbulence in the combustion chamber, the oxidation of carbon monoxide is improved and which reduces the CO emissions. The lowest carbon monoxide emission is with MM8 configuration when compared to normal engine is about 36.47% by volume at 3/4 of rated load. It is also observed that with MM6 and MM4 the reduction in CO levels is about 34.7% and 33.53% by volume at 3/4 of rated load when compared to normal engine.

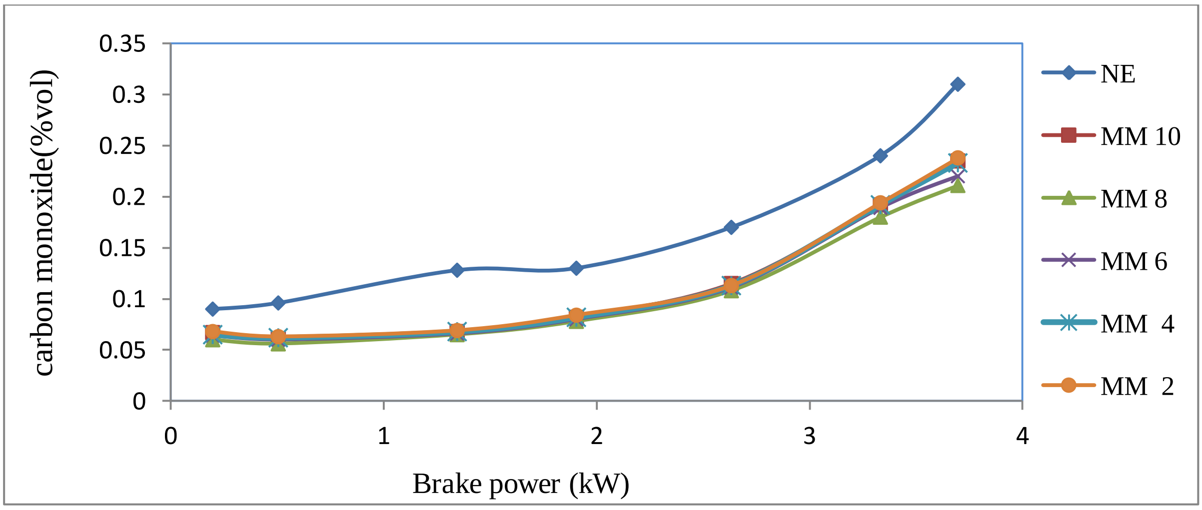

Figure 7: Comparison of Carbon monoxide emissions with different configurations of inlet manifold

Conclusions

The Configuration MM8 enhances the turbulence and hence results in better air-fuel mixing process among all the configurations of diesel engine. As a result, the thermal efficiency is increased and SFC and soot emission are reduced.. It can be concluded that MM8 is the best trade-off between performance and emissions.

Based on this investigation, the following conclusions are drawn:

- More power output is derived from the same given charge
- Lesser emission due to far more complete combustion is provided.
- Lesser carbon deposits in the combustion chamber, piston crown and exhaust system occur due to controlled complete combustion.
- There is no pinging or detonation or auto ignition due to reduced temperature in the combustion chamber and no residue of unburnt fuel.
- There is better fuel economy due to improved and complete combustion.

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