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STUDY OF THE EFFECT OF IN CYLINDER AIR SWIRL ON DIESEL ENGINE PERFORMANCE AND EMISSION

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ABSTRACT

Internal combustion engines in now a days is the best available reliable source of power for all domestic, large scale industrial and transportation applications. The major issue arises at the efficiency of these engines. Every attempt made to improve these engines tends to attain the maximum efficiency. The study is about the effects of air swirl in the cylinder on its performance. Here a single cylinder direct injection diesel engine is used for study. For obtaining different swirl intensities the following design parameters have been changed the piston crown, cylinder head and inlet duct. By changing the piston crown design the enhancement in the turbulence inside the cylinder is achieved. Also grooves are made to achieve the increase in swirl intensity for better mixing of fuel and air.

Key words: Diesel engine, air swirl, cylinder, efficiency, emissions

1. INTRODUCTION

Internal combustion engines are the engines which burn the fuel inside it and produce the energy. Of all the engines the direct injection diesel engines have their own importance because of their higher thermal efficiencies than all the others. They can be used for both light-duty and heavy-duty vehicles.

Fuels are non-renewable resources of energy therefore the maximum usage of energy available from them is to be achieved. In internal combustion engines the efficient burning of the fuel i.e.., combustion of the fuel is required to increase the efficiency of the engine. To obtain efficient combustion the fuel injected is to be spatially well distributed throughout the entire space. This requires matching of the fuel sprays with the geometry of the combustion chamber to effectively make use of gas flows. Here air is made to swirl for better mixing of fuel and air which increases rate of mixing and reduces the combustion duration. The higher swirl reduces the soot emission at the cost of higher NO_x level.

The in-cylinder fluid motion in internal combustion engines is one of the most important factors in controlling the combustion process. It governs the air-fuel mixing and rate of burning in diesel engines. Therefore better understanding of fluid motion is critical for designing the engines with the most desirable operating and emission characteristics.

The heat energy of the fuel which is converted into power after the losses through the engine exhaust, to the coolant and due to radiation is called indicated power, *ip*. This indicated power is transferred to the crank shaft through the piston rod. In this transmission there are energy losses due to bearing friction, pumping loses etc.., The sum of all these loses expressed in units of power is termed as frictional power, *fp*. The remaining energy is the useful mechanical energy and is termed as brake power, *bp*.

$$bp = ip - fp$$

Brake thermal efficiency is one of the efficiencies which determine how much efficient the engine is. It is defined as the ratio of brake power to the input fuel energy.

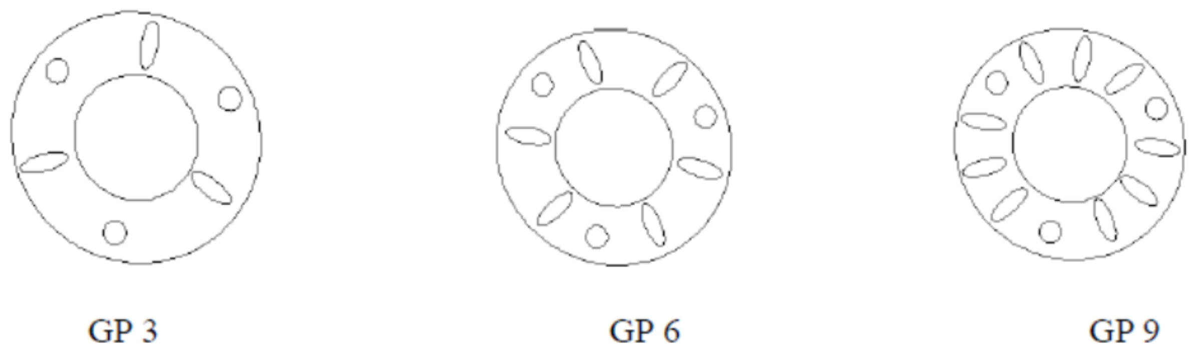
2. EXPERIMENTAL SETUP AND PROCEDURE:

Experimental studies were carried out on how the air swirl affects the performance of direct injection diesel engine. The experiments were conducted on a single cylinder kirloskar make direct injection four stroke diesel engine. Water cooled eddy current dynamo meter was used for the tests. In addition to the above the engine is equipped with the following

- Equipped with electro-magnetic pick up.

- Piezo-type cylinder pressure sensor.
- Thermocouples to measure the temperature of water, fuel and air.
- Rota meter for measuring water flow rate.
- Manometer for measuring air and fuel flow rates.
- Bosch smoke meter to measure smoke density.

The following are the different piston configurations tested in diesel engine



N P	-	Normal Piston ;	GP 3	-	Piston with 3 grooves
GP 6	-	Piston with 6 grooves;	GP 9	-	Piston with 9 grooves

Fig. 2.1 Different types of configurations of piston crowns

Source: S.L.V. Prasad et al. 2011

Table 1: Specifications of the diesel engine

<u>Specifications of Diesel Engine Used for Experimentation</u>

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

3. RESULTS AND DISCUSSIONS:

3.1 Brake thermal efficiency:

For different piston crown configurations the brake thermal efficiency with brake power are compared. The table below gives the data

Table 2: Brake thermal efficiencies of different configurations

Type of configuration	**Brake thermal efficiency**	**Type of load**
GP 9	31.80%	Full
GP 6	30.80%	Full
GP 3	-	Full
NP	29.80%	Full

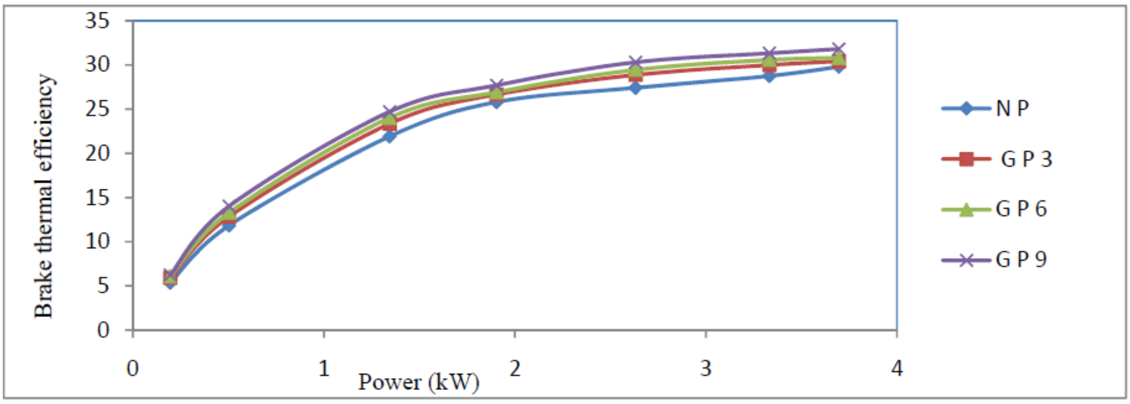


Fig. 3.1 Comparison of brake thermal efficiency with different configurations of piston

Source: S.L.V. Prasad et al. 2011

It is observed that the piston crown with GP 9 configuration has higher thermal efficiency. It is also observed that there is a gain of 6% with GP 9 compared to normal engine. GP 6 and GP 3 have lower thermal efficiencies than GP 9. From fig. 3.1 it was inferred that the brake thermal efficiency increases with the increase in brake power for the configurations considered. This increase in brake thermal efficiency might be due to enhanced mixing rate carried by the turbulence in the combustion chamber.

3.2 Exhaust gas temperature:

At no load and full load conditions the exhaust gas temperatures are taken for different configurations. The table shown below gives the data

Table 3: Exhaust gas temperatures

Type of configuration	**Exhaust gas temperature (°C)**	
	No load	Full load
GP 9	120	380
GP 6	131	400
GP 3	135	410

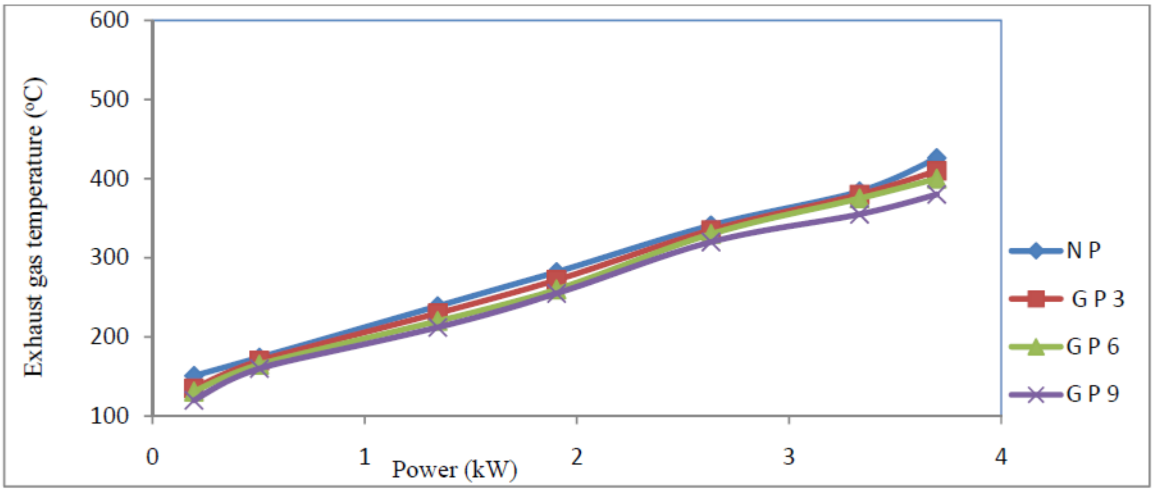


Fig. 3.2 Comparison of exhaust gas temperatures with different configurations of piston

Source: S.L.V. Prasad et al. 2011

It was observed that the exhaust gas temperatures are lower for GP 9 configuration. This might be due to high turbulence created in the combustion chamber by the modified piston.

3.3 Ignition delay:

Fig. shows the variation of ignition delay with brake power. It is inferred that the ignition delay is decreased with the increase in brake power. The reason for increase in brake power is the increase in the amount of fuel burnt inside the cylinder which in turn increases the temperature of in-cylinder gases. This may lead to reduction in ignition delay. It was observed that the ignition delay of GP 9 configuration with brake power varies from 12.5°CA at no load to about 8.8°CA at full load. A reduction of about 2.2% at maximum power in the ignition delay of GP 9 compared to normal engine is observed.

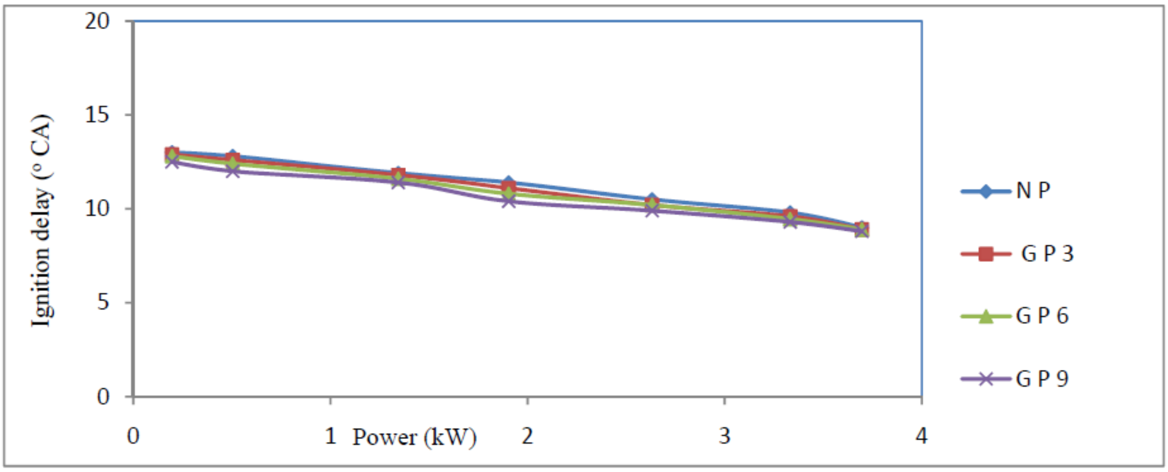


Fig. 3.3 Comparison of Ignition delay with different configurations of piston

Source: S.L.V. Prasad et al. 2011

3.4 Peak Pressure:

Fig. shows the variations of peak cylinder gas pressure with brake power for different modes of combustion.

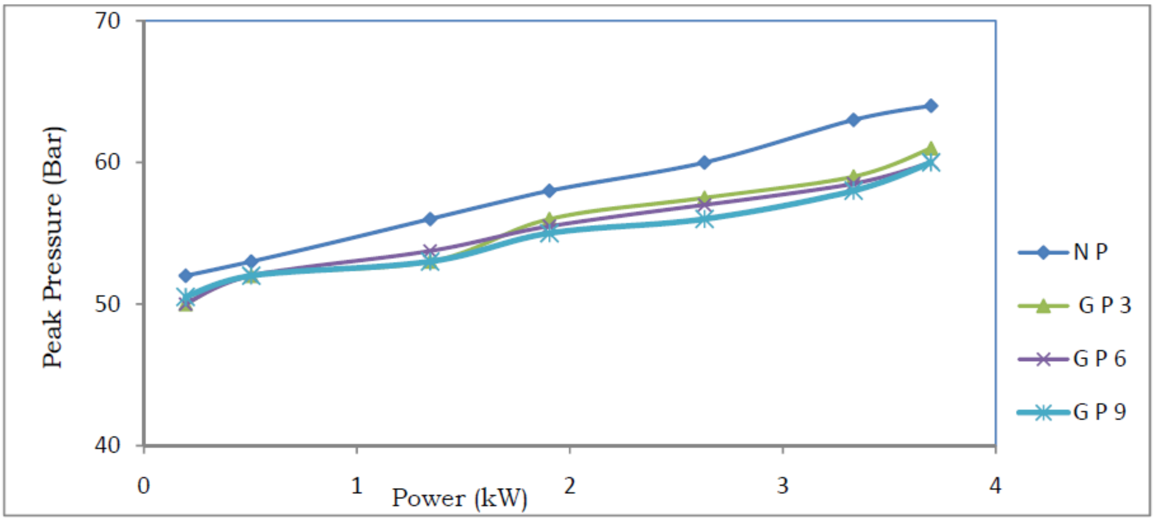


Fig. 3.4 Comparison of Peak pressure with different configurations of piston

Source: S.L.V. Prasad et al. 2011

It is observed that the lowest peak pressure is under GP 9 and maximum peak pressure is under NP configuration. The lowest peak pressure in GP 9 configuration might be due to the entire ignition and simultaneous burning of fuel air mixture. This entire ignition might be due to the angular momentum created by the grooves in piston crown of GP 9. A decrease of about 6% is observed in GP 9 when compared to NP configuration.

3.5 Hydrocarbon and Carbon monoxide emissions:

Hydrocarbon emission is a result of incomplete combustion. If the combustion takes place efficiently then the level of hydrocarbon emission decreases. It can be said that the hydrocarbon emission directly depends on the extent of combustion.

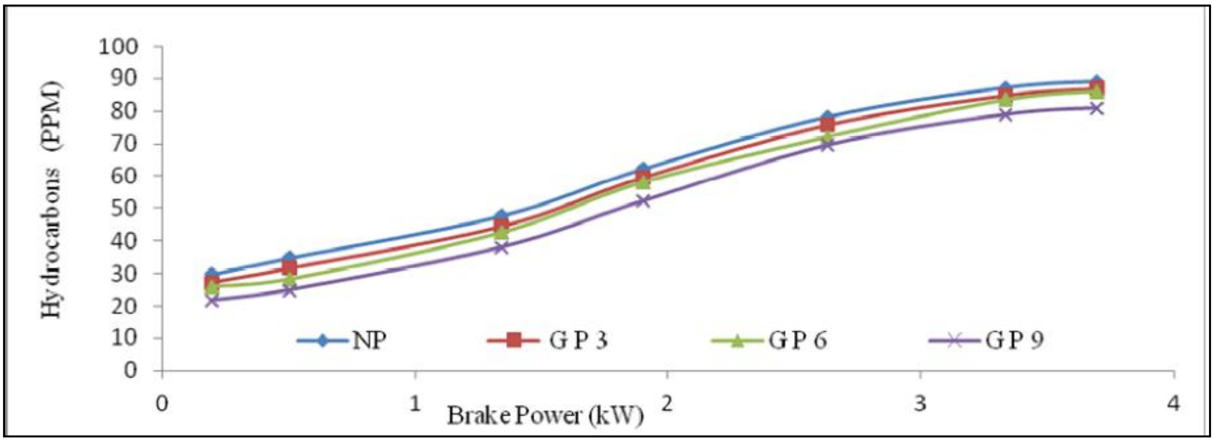


Fig. 3.5 Comparison of hydrocarbons with different configurations of piston

Source: Bharathi et al. 2011

Fig. shows the plot of hydrocarbon emission Vs brake power. It is observed that at rated load the GP 9 configuration has maximum reduction in hydrocarbon emission levels. The reduction in hydrocarbon levels is about 10.9% in GP 9, 7.8% in GP 6, 3% in GP 3 configurations when compared to normal engine.

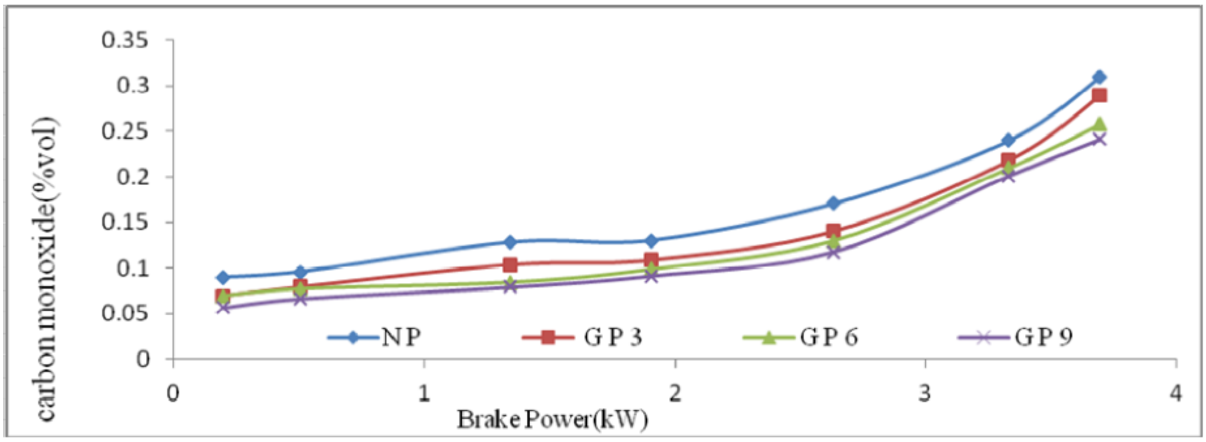


Fig. 3.6 Comparison of Carbon monoxide with different configurations of piston

Fig. shows the comparison of carbon monoxide emission with brake power. The GP 9 configuration has the lowest carbon monoxide emission compared to normal engine and is about 30.6% by volume at rated load. Due to high turbulence and high temperatures in the combustion chamber there is an improvement in carbon monoxide oxidation and thus CO emission is reduced. The reduction in CO levels of GP 6 and GP 3 are about 29.4% and 17.7% respectively compared with normal engine.

3.6 Smoke Density:

Solid soot particles suspended in exhaust gas is called smoke. The comparison of smoke level with brake power is shown in fig.

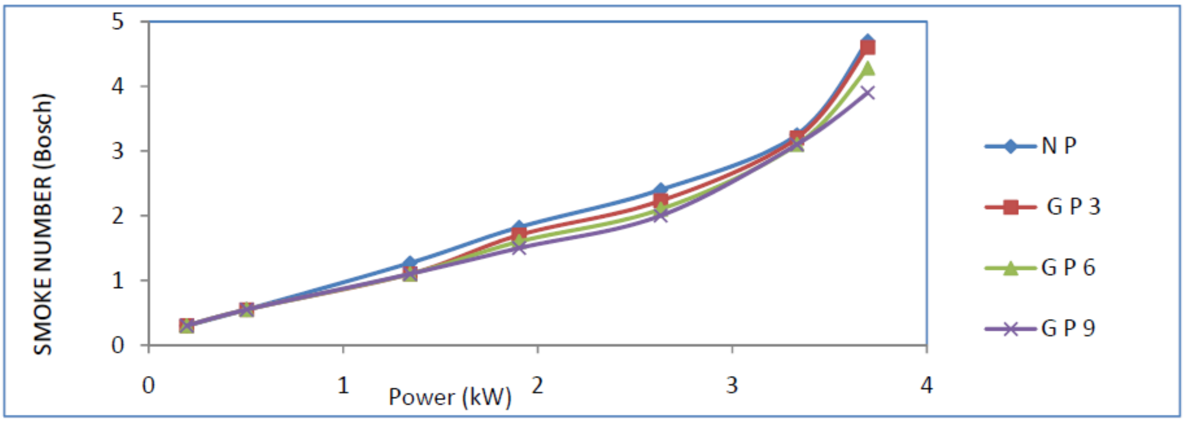


Fig. 3.7 Comparison of smoke densities with different configurations of piston

Source: S.L.V. Prasad et al. 2011

Smoke levels increases with increase in brake power. Because of high turbulence and temperature in the combustion in the combustion chamber combustion and oxidation of soot particles takes place efficiently leading to reduction in smoke emission. The smoke emission of GP 9 was reduced by 17% compared to normal engine at rated load.

4. CONCLUSIONS:

The GP 9 piston crown configuration is the best in performance and lower in emission. Due to increase in number of grooves the turbulence is enhanced and hence results in better fuel-air mixing. As GP 9 configuration has more no of grooves its performance is higher when compared to other configurations. Also the thermal efficiency is increased & SFC and soot emissions are reduced.

Based on the observations, the following are concluded for GP 9 configuration

- For the given charge and compression ratio more power output is obtained compared to other configurations.
- Smoke emission reduced because of complete combustion.
- Low exhaust gas temperature due to quicker flame propagation.
- Complete and improved combustion led to better fuel economy.
- Increase in the cylinder pressure due to effective combustion

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