Experimental Investigation of Performance and Exhaust Emission Characteristics of Diesel Engine by Changing Piston Geometry

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***Abstract* - Extensive research is going on to improve the combustion efficiency of CI Engine. Combustion efficiency of CI Engine can be increased by creating turbulence, by designing intake system, by designing combustion chamber. A good swirl promotes fast combustion to improve the efficiency. So in this present work a study about influence of air swirl in the combustion chamber upon the performance and emission of a diesel engine is presented. In order to achieve different swirl intensity to improve combustibility of combustible mixture in the cylinder, three different configurations of piston i.e. in the order of number of grooves 4, 8 and 12 are used to intensify the swirl for the better mixing of fuel and air and their effect on the performance and emission are recorded.**

***Index Terms* - Diesel Engine, Air Swirl, Cylinder, Efficiency and Emission**

I. 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 [7].

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 [1].

Swirl, considered as a two-dimensional solid body rotation, persists through the compression and combustion processes [1]. Many researchers have demonstrated that the decay of swirl in an engine cylinder during the compression process is relatively small so that the overall angular momentum of the swirl vortex is almost conserved [4].

Internal combustion engines have been a relatively inexpensive and reliable source of power for applications ranging from domestic use to large scale industrial and transportation applications for most of the twentieth century [2]. DI Diesel engines, having the evident benefit of a higher thermal efficiency than all other engines, have served for both light- duty and heavy-duty vehicles [5].

The combustion efficiency in the combustion chamber depends on the formation of homogeneous mixture of fuel with air. The formation of homogenous mixture depends on the amount of swirl created in the combustion chamber. This further increases the thermal efficiency of the engine. This investigation leads to improvement in performance, combustion and emission characteristics of a D.I diesel engine through methods enabling improvement in ignition characteristics of the fuel by generating turbulence in the cylinder, for the achievement of better fuel air mixing [3].

Air motion plays a significant role in fuel — air mixing, combustion and emission processes. Along with air motion, spray characteristics, spray angle, injection pressure and injection timing also have a significant role in diesel engine combustion. Also 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 [1].

A combustion chamber design layout of grooves or channels or passages formed in the squish band to further enhance turbulence in the charge prior to ignition as compared to existing designs with squish bands or hemispherical layouts in I.C. Engines [8]. These grooves or channels or passages after ignition direct the flame front to cause multipoint ignition during the combustion cycle resulting in the following distinct advantages over existing designs in practice. First, quicker and complete clean burn combustion; second, lower operating temperatures due to the higher flame velocities; third, enhanced torque and power through the entire range resulting in better fuel economy with lower Emissions; and fourth, smoother engine operation through the entire range enhancing engine life [6]. These grooves or channels or passages cause rapid progressive complete combustion in the shortest possible time resulting in lower build-up of temperatures in the combustion chamber, piston crown, and cylinder walls. The lower combustion chambers temperature greatly reduces emissions of nitrous oxide [9]. Existing combustion chamber greatly fall short in controlling excessive temperature build ups resulting in pinging, detonation and auto-ignition.

II. AIM

The main aim of the present investigation is to find the effect of the different piston geometry for the complete burning of diesel in the conventional CI engine. The total experiment consists of the following segments.

1. Preparation of different piston geometries.
2. Methods of conducting the investigations with different piston inserts.
3. Results and discussions.

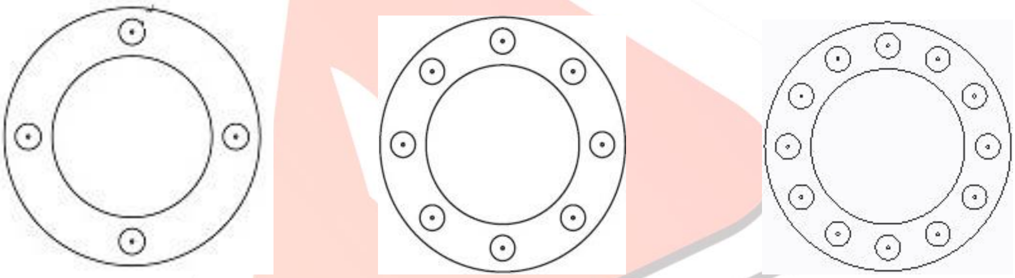
III. EXPERIMENT WORK

In the present work the effects of air swirl in combustion chamber are experimentally studied on performance of single cylinder light duty direct injection diesel engine. The experiments were 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. Rope brake dynamometer was used for the tests. V-grooves are prepared on the piston crown (fig. 1). The experiments are conducted on a diesel engine by varying number of grooves on the crown of piston.

Table1: Specification of diesel engine used for experiment

Specification	***Item***
3.68KW	Engine Power
80 mm	Cylinder bore
110 mm	Stroke length
1500 rpm	Engine speed
17:1	Compression ratio
553 cc	Swept volume

It is observed from fig. 1 that the V- grooves on the piston crown have a significant effect on air flow motion in the piston bowl, when the piston approaches the top dead centre [TDC]. This results in increasing the rate of evaporation, swirl motion of fuel &air and combustion efficiency.



NP 4 NP 8 NP 12

NP 4 – Normal Piston with 4 grooves
NP 8 – Normal Piston with 8 grooves
NP 12 – Normal Piston with 12 grooves

Fig. 1 Different types of configurations of piston crowns

IV. RESULTS AND DISCUSSIONS

A long term experimental study has been conducted on a single cylinder 4-stroke, water-cooled 5 BHP Kirloskar diesel engine by changing piston crowns.

A. Performance Parameters

1) **Fuel Consumption**

The variations of fuel consumption with power output for the piston with various configurations are shown in figure 2. As the power increases no doubt the fuel consumption also increases. It is observed that NP 12 configuration has the lowest fuel consumption 6.8% when compared to normal engine. This is because of the complete combustion of charge in the combustion chamber by liberating maximum energy due to the inducement of enhanced air swirl in the combustion chamber.

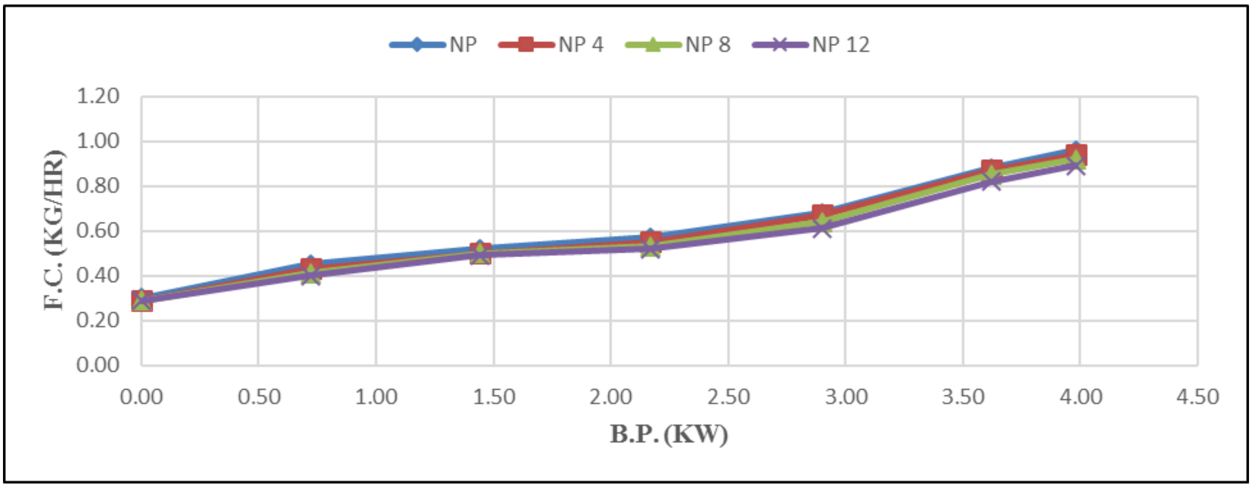


Fig.2. Comparison of fuel consumption with different configurations of grooved piston

2) Mechanical Efficiency

The variations of mechanical efficiency with power output for the piston with various configurations are shown in figure 3. As the power increases no doubt the mechanical efficiency also increases. It is observed that NP 12 configuration has the highest mechanical efficiency 14.8% when compared to normal engine. This is because of the complete combustion of charge in the combustion chamber by liberating maximum energy due to the inducement of enhanced air swirl in the combustion chamber.

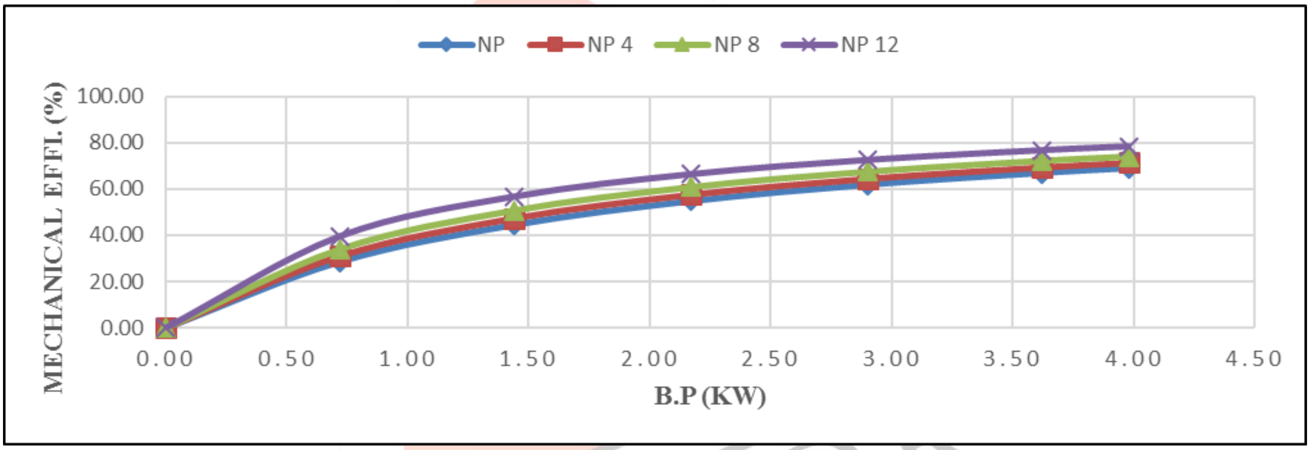


Fig.3. Comparison of Mechanical Efficiency with different configurations of grooved piston

3) Brake Thermal Efficiency

The variations of brake thermal efficiency with power output for the piston with various configurations are shown in figure 4. The brake thermal efficiency for normal engine at full load is 35.81%. It can be observed that the engine with NP 8 and NP 12 give thermal efficiencies of 37.08% and 38.43%. It is observed that with NP 12 configuration has higher thermal efficiency. It is also observed that there is a gain of 7.2% with NP 12 compared to normal engine. This increase in brake thermal efficiency might be due to enhanced mixing rate carried by the turbulence in the combustion chamber.

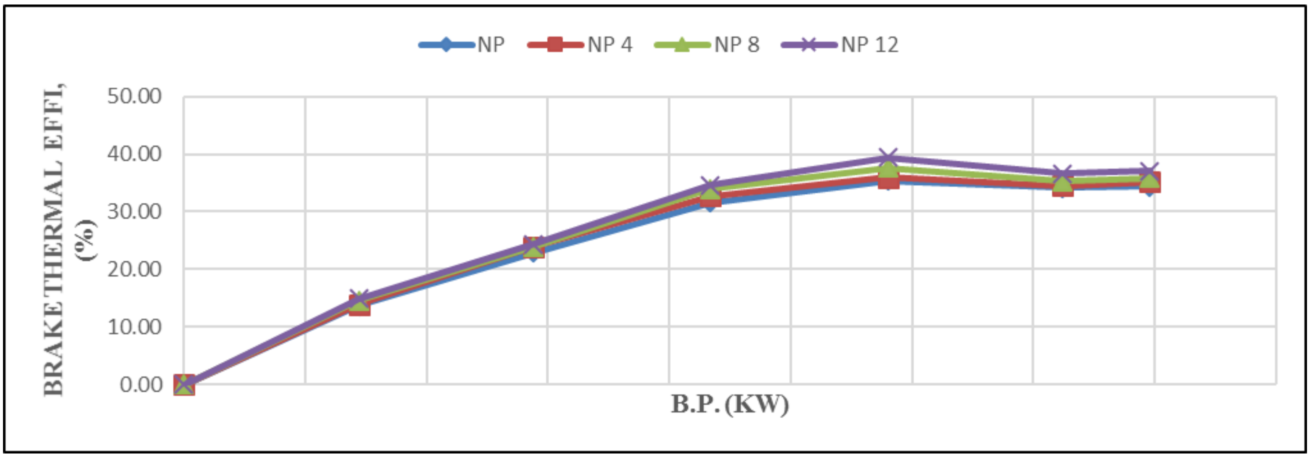


Fig.4. Comparison of Brake Thermal Efficiency with different configurations of grooved piston

4) Brake Specific Fuel Consumption

The variations of brake specific fuel consumption with power output for the piston with various configurations are shown in figure 5. The brake thermal efficiency for normal engine at full load is 0.243 kg/kW-hr. It can be observed that the engine with NP 4, NP 8 and NP 12 give brake specific fuel consumption of 0.240 kg/kW-hr, 0.234 kg/kW-hr and 0.226 kg/kW-hr. It is observed that NP 12 configuration has the lowest brake specific fuel consumption 6.9% when compared to normal engine. This is because of the complete combustion of charge in the combustion chamber by liberating maximum energy due to the inducement of enhanced air swirl in the combustion chamber.

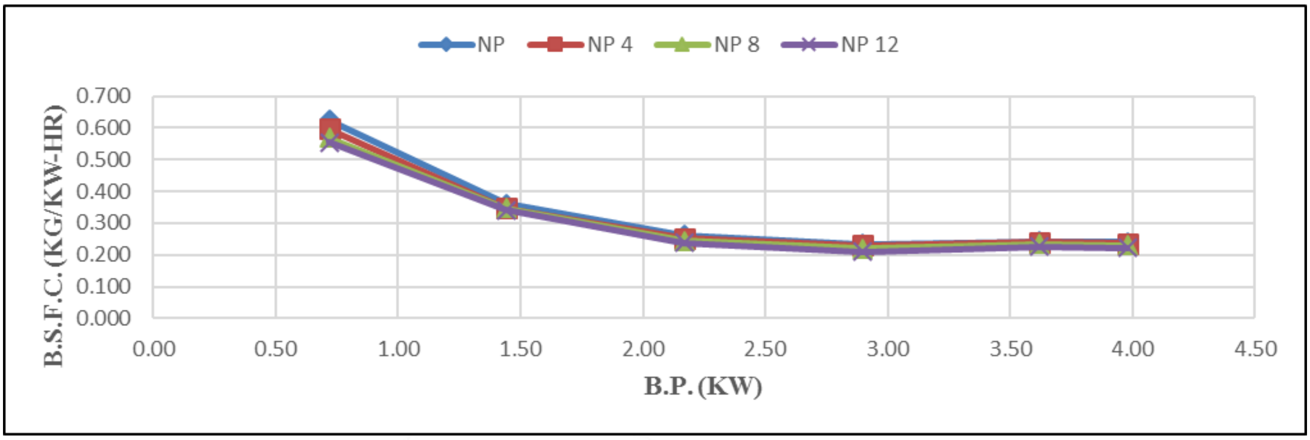


Fig.5. Comparison of Brake Specific Fuel Consumption with different configurations of grooved piston

B. Emission Parameters

The emission parameters like exhaust gas temperature, Nitrogen Oxide Emissions, Hydrocarbon Emissions, Carbon monoxide Emissions are discussed below.

1) Exhaust Gas Temperature

The variations of exhaust gas temperature with power output for the piston with various configurations are shown in figure 6. The exhaust gas temperature for normal engine at full load is 365˚C. It can be observed that the engine with NP 4, NP 8 and NP 12 give exhaust gas temperature of 351˚C, 335 ˚C and 327˚C. It is observed that with NP 12 configuration has the lowest exhaust gas temperature 10.4% when compared to normal engine. Lower exhaust gas temperature for NP 12 can be attributed due to low operating temperature in the combustion chamber resulted by the swirl created in the combustion chamber.

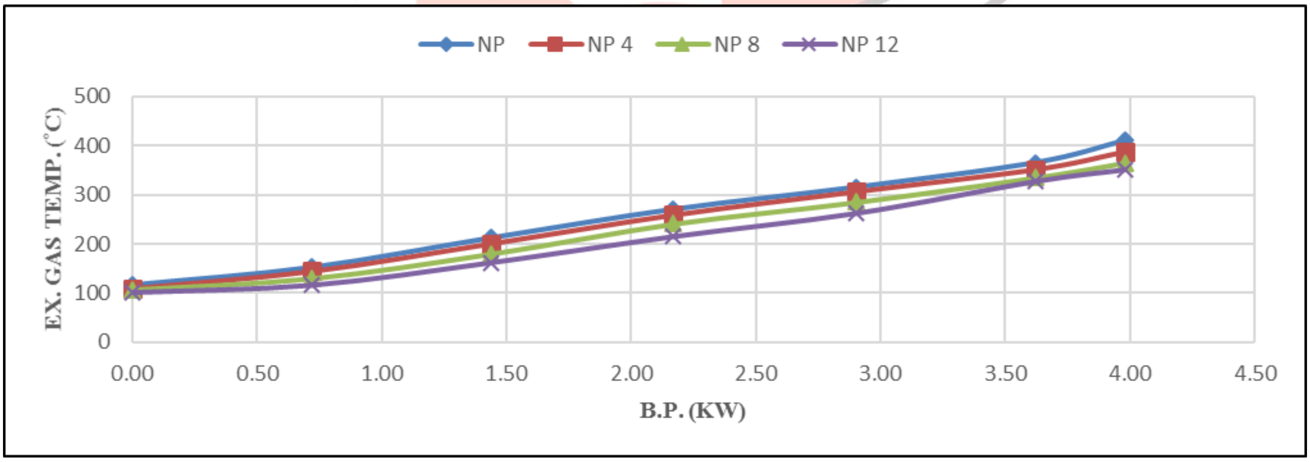


Fig.6. Comparison of Ex. Gas Temperature with different configurations of grooved piston

2) Nitrogen Oxide Emissions

The comparison of NO_x emission with brake power for different configurations is shown in Figure 7. It can be observed from the figure that NO_x emission increases with increase in turbulence in the cylinder because of high temperature. The NO_x emissions for NP 4, NP 8 and NP 12 are 563 ppm, 559 ppm and 556 ppm respectively, whereas for normal engine it is 565 ppm. The NO_x emissions are lower of 1.5 % for NP 12 when compared to normal engine at full load. This may be due to decrease in combustion duration; the residence time for the gas in the combustion chamber is too short to form the NO_x at normal level.

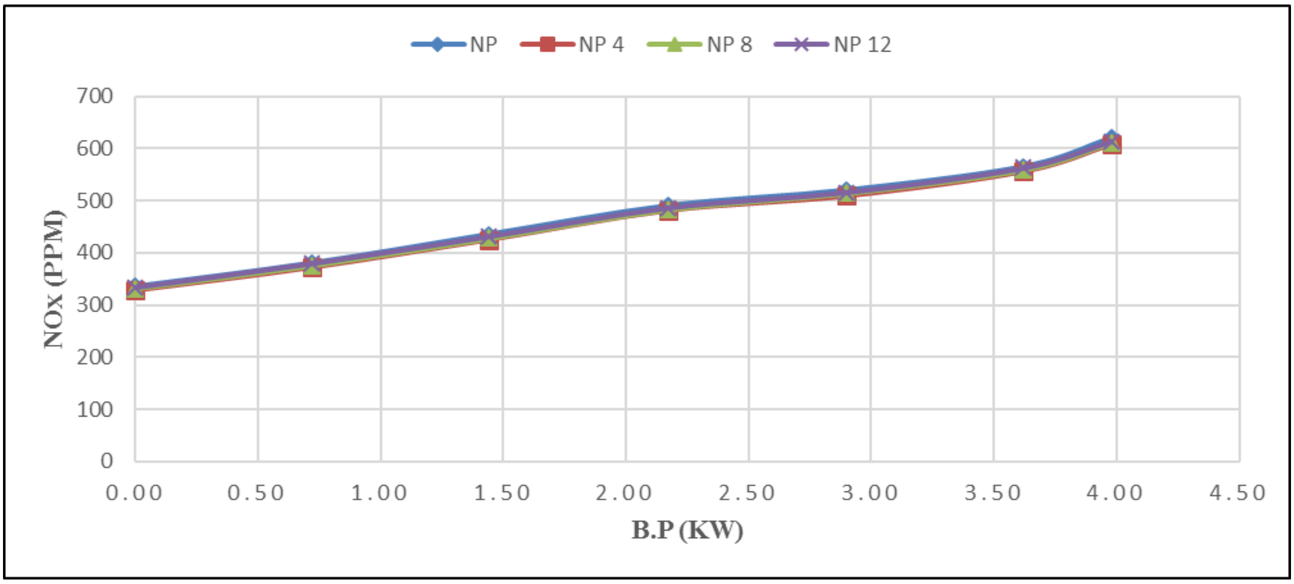


Fig.7. Comparison of NOx Emissions with different configurations of grooved piston

3) Hydrocarbon Emissions

The comparison of Hydrocarbon emission with brake power is shown in fig. 8. The HC emissions for NP 4, NP 8, and NP 12 are 94 ppm, 93 ppm and 92 ppm respectively, whereas for normal engine it is 95 ppm. The HC emissions are lower by 3.1% for NP 12 when compared to normal engine at full load. The Un-burnt 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.

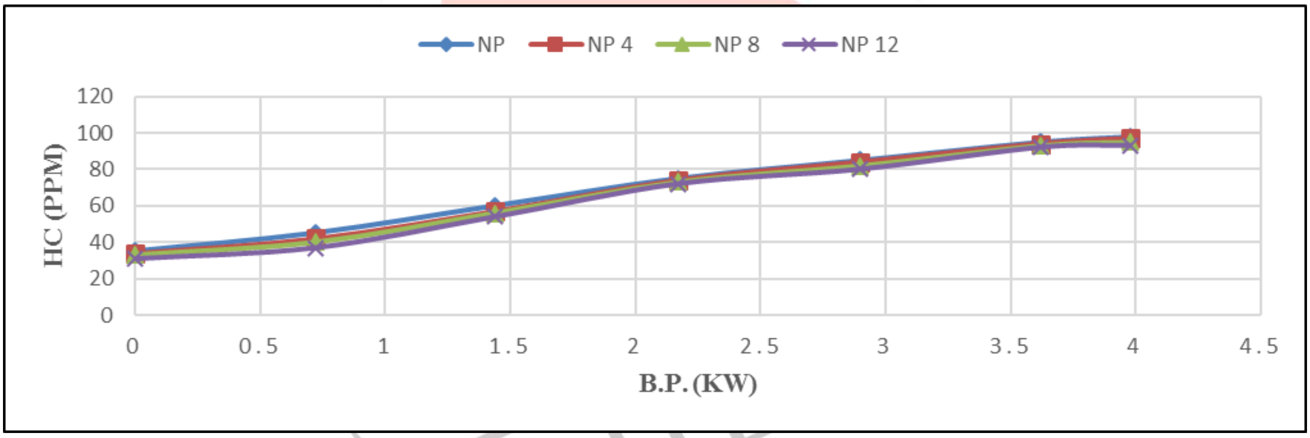


Fig.8. Comparison of Hydrocarbon Emissions with different configurations of grooved piston

4) Carbon monoxide Emissions

The comparison of Carbon monoxide emission with brake power is shown in fig. 9. The CO emissions for NP 8 and NP 12 are 0.78% and 0.74% by volume respectively, whereas for normal engine it is 1% by volume. The CO emissions are lower by 10% for NP 12 when compared to normal engine at full load. Generally, C.I engines operate with lean mixtures and hence the CO emission would be low. With the higher turbulence and temperatures in the combustion chamber, the oxidation of carbon monoxide is improved and which reduces the CO emissions.

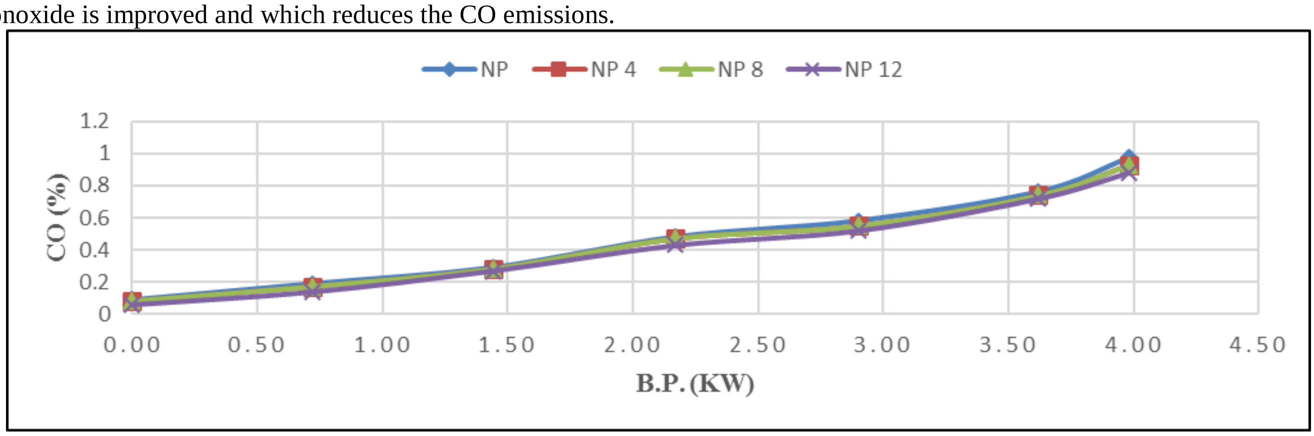


Fig.9. Comparison of Carbon monoxide Emissions with different configurations of grooved piston

V. CONCLUSION

From the investigation, it is evident that out of all pistons configurations tested in the single cylinder D.I diesel engine, piston with grooves i.e. NP 12 gives better performance in all the aspects. The following conclusions are drawn based on the effect of air swirl in the cylinder at full load when compared to normal engine.

- Fuel consumption for NP 12 configuration is lowest among all piston configurations.
- The improvement in mechanical efficiency is about 14.8%
- The brake thermal efficiency is increased by about 7.2%.
- The improvement in brake specific fuel consumption is about 6.9%.
- The maximum reduction in exhaust gas temperature is about 10.4%.
- The maximum reduction in NOx emissions is about 1.5%.
- The hydrocarbon emissions are found to be reduced by about 3.1%.
- The Carbon monoxide emissions are found to be reduced by about 10%.

VI. ACKNOWLEDGMENT

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