# INFLUENCE OF PISTON GROOVED AIR SWIRL ON COMBUSTION AND EMISSIONS IN DIESEL ENGINE

**K.L Srinivasulu[1],B .Ramanjaneyulu[2]A.V.N.S.Kiran[3]**

[1]*Assistant Professor, Department of Mechanical engineering, Santhiram Engineering College, Nandyal ,India,*

[2]*Research scholar, Department of Mechanical engineering, Annamacharya institution of technology and sciences, Rajampet, India.*

[3] *Assistant Professor, Department of Mechanical engineering, Sri venkateswaraUniversity, Tirupathi, India.*

***Abstract:*** *In the present work a study about influence of the air swirl in the cylinder upon the performance and emission of a single cylinder diesel direct injection engine by using diesel on volume basis is presented. The intensification of the swirl is done by cutting grooves on the crown of the piston. In this work three different configurations of piston i.e. in the order of number of grooves 6,9,12 are used to intensify the swirl for better mixing of fuel and air and their effects on the performance and emission are recorded.*

**Keywords:**Diesel Engine, Air Swirl, Cylinder, Efficiency, Emissions

## I. Introduction

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. 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.

The in-cylinder fluid motion in internal combustion engines is one of the most important factors controlling the combustion process. It governs the fuel-air mixing and burning rates in diesel engines. The fluid flow prior to combustion in internal combustion engines is generated during the induction process and developed during the compression stroke [1-2]. Therefore, a better understanding of fluid motion during the induction process is critical for developing engine designs with the most desirable operating and emission characteristics [3].To obtain a better combustion with lesser emissions in direct-- injection diesel engines, it is necessary to achieve a good spatial distribution of the injected fuel throughout the entire space [4]. This requires matching of the fuel sprays with combustion chamber geometry to effectively make use of the gas flows. In other words, matching the combustion chamber geometry, fuel injection and gas flows is the most crucial factor for attaining a better combustion [5]. In DI diesel engines, swirl can increase the rate of fuel-air mixing [6], reducing the combustion duration for re-entrant chambers at retarded injection timings. Swirl interaction [7] with compression induced squish flow increases turbulence levels in the combustion bowl, promoting mixing. Since the flow in the combustion chamber develops from interaction of the intake flow with the in -cylinder geometry, the goal of this work is to characterize the role of combustion chamber geometry on in-cylinder flow, thus the fuel-air mixing, combustion and pollutant formation processes. It is evident that the effect of geometry has a negligible effect on the airflow during the intake stroke and early part of the compression stroke. But when the piston moves towards Top Dead Centre (TDC), the bowl geometry has a significant effect on air flow thereby resulting in better atomization, better mixing and better combustion. The re-entrant chamber without central projection and with sharp edges provides higher swirl number than all other chambers [8-11]. This higher swirl number reduces the soot emission at the cost of higher NOx level. Characteristics are well comparable with that of diesel and also up to 50% with and without preheating can be used in diesel engines.

## II. Experimental Setup

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. Water cooled eddy current dynamometer was 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, Rotometer 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. An attempt is made in this work with variable number of grooves on the crown of the brass piston along with knurling on the face of the piston crown. Elliptical grooves of size 16 mm X 6 mm X 2 mm 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 brass piston.

Specification of Diesel Engine Used for Experimentation

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

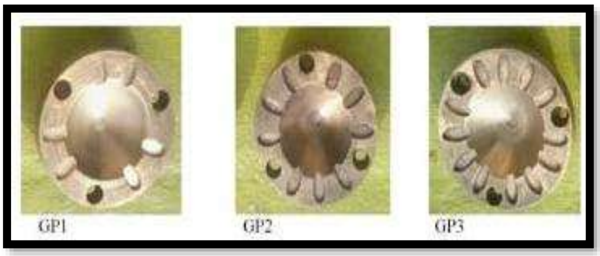


Fig. 1: Different Types of Configurations of Piston Crowns

N P - Normal Piston; GP1 - Piston with 6 grooves GP2 - Piston with 9 grooves;
GP3 - Piston with 12 grooves

## III. Results & Discussions

### A. Brake Thermal Efficiency

The variations of brake thermal efficiency with power output for the piston with different configurations are shown in Figure 1. The brake thermal efficiency for normal engine at 3/4 of rated load is 26.1%. It can be observed that the engine withGP1 GP2 and GP3 give thermal efficiencies of 27.9% and 27%, respectively, at 3/4 of rated load. From fig., it is inferred that the brake thermal efficiencies are increasing with an increase in brake power for configurations that are under consideration. It is also observed that there is a gain of 6.9% with GP2 compared to normal engine. This may be due to the enhanced air swirl in the combustion chamber which resulted in better mixing of fuel and air and as well as complete combustion of the charge in the combustion chamber.

### B. Brake Specific Fuel Consumption

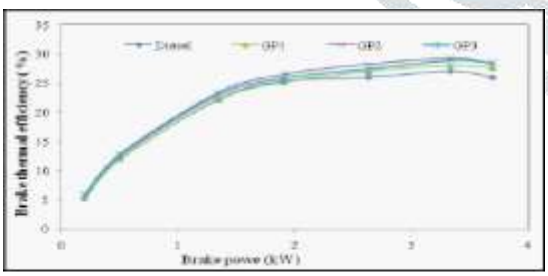

Fig. 2: Comparison of Brake Thermal Efficiency with

Different Configurations of Grooved Piston

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 GP1, GP2 and GP3 give brake specific fuel consumption of 0.31 kg/ kW-hr and 0.32 kg/kW-hr and 0.33 kg/kW-hr respectively, at 3/4 of rated load. From fig. 4.3, it is inferred that the brake specific fuel consumption is increasing with an increase in brake power for configurations that were under consideration. It is also observed that the GP2 has the lowest fuel consumption of 8.8% when compared with 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.

### C. Ignition Delay

The variation of ignition delay with brake power for different configurations is shown in Figure 3. It is inferred that ignition delay, 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 is increased and subsequently the temperature of in-cylinder gases is increased. This may lead to reduced ignition delay in all configurations. However, the ignition delay for diesel fuel was lower under GP1, GP2 and GP3 configurations than the normal engine. It is observed that the ignition delay of GP1, GP2 and GP3are 10.2o CA, 10.7o CA and 10.8o CA at 3/4 of rated load respectively. The reduction in the ignition delay of GP2 is about 7.3% at 3/4 of rated load when compared to normal engine. This is due to the fast and complete burn of the charge because of the flow of high velocity

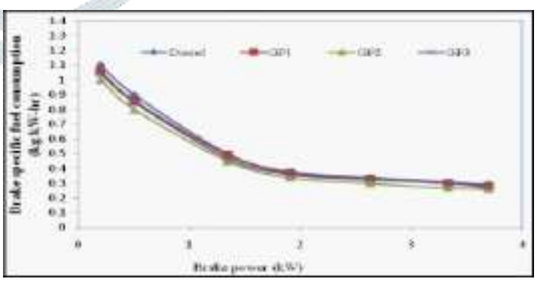

Fig. 3: Comparison of Brake specific fuel consumption Different Configurations of Grooved Piston

flames through the grooves in the piston of the

### D. Smoke Density

Smoke is solid soot particles suspended in exhaust gas. The comparison of smoke level with brake power is shown in fig. 4. It can be observed that smoke increases with increase in brake power. The smoke number for GP1, GP2 and GP3 are 2.32 BSU, 2.36 BSU and 2.4 BSU respectively, whereas for normal engine it is 2.46 BSU. This is because of higher turbulence in the combustion chamber which results in the better combustion and oxidation of the soot particles, which further reduces the smoke emissions. Due to the complete combustion of diesel with excess air, the smoke emissions are marginal. At 3/4 of the rated load, the smoke emissions for GP2 are reduced by about 5.7 % when compared to normal engine.

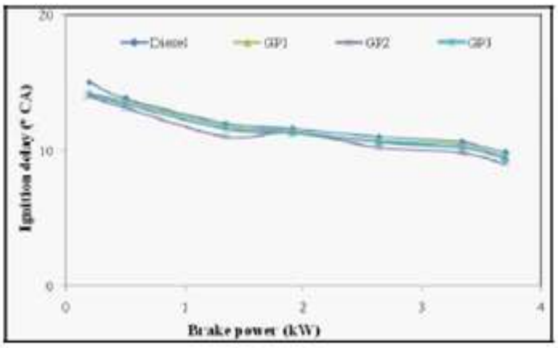


Fig. 4: Comparison of Ignition delay with Different Configurations of Grooved Piston

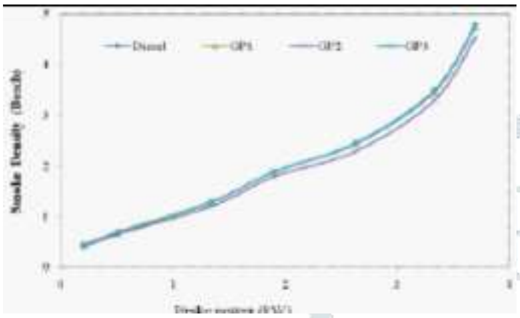


Fig. 5: Comparison of smoke delay with Different Configurations of Grooved Piston

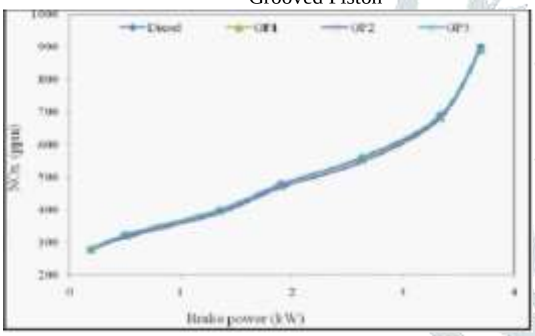


Fig. 3: Comparison of $NO_X$ Different Configurations of Grooved Piston

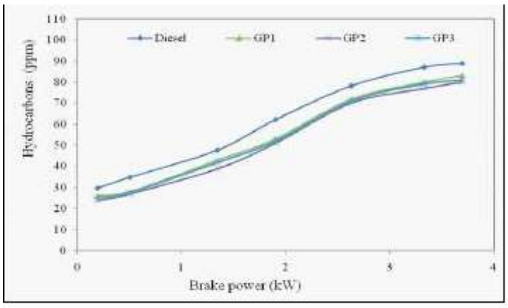


Fig. 3: Comparison of Hydro carbans Different Configurations of Grooved Piston

**E. Nitrogen Oxide Emissions**

The comparison of NOx emission with brake power for different configurations is shown in fig. 5. It can be observed from the figure that NOx emission increases with increase in turbulence in the cylinder because of high temperature. The NOx emissions for GP1, GP2 and GP3 are 552 ppm, 555 ppm and 559 ppm respectively.

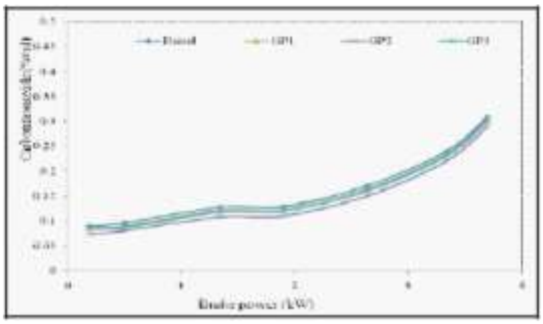

Fig. 3: Comparison of CO Different Configurations of Grooved Piston

## IV. Conclusions

From the investigation, it is evident that out of all pistons configurations tested in the single cylinder D.I diesel engine, piston with nine grooves i.e. GP2 gives better performance in all the aspects.

The following conclusions are drawn based on the effect of air swirl in the cylinder at 3/4 of the rated load when compared to normal engine.

- The brake thermal efficiency is increased by about 6.9%.
- The improvement in brake specific fuel consumption is about 8.8%.
- With higher turbulence in the combustion chamber, the reduction in the ignition delay is about 7.3%.
- The smoke emission in the engine is reduced by about 5.9%.
- The maximum reduction in NOx emissions is about 1.8%.
- The maximum reduction in HC emissions is about 2.83%.

The carbon monoxide emissions are found to be reduced by about 11.7%.

## References

[1] Xueliang H; ShuSong L,"Combustion in an internal combustion Engine", Mechanical Industry Press, Peking, 1990.

[2] Shaoxi S; Wanhua S,"Some new advances in engine combustion research", Trans CSICE 8, pp. 95-104, 1990.

[3] Wu Zhijun, Huang Zhen,"In-cylinder swirl formation process in a four-valve diesel engine Experiments in Fluids 31 (2001) 467 - 473 Springer-Verlag 2001.

[4] Arturo de Risi, Teresa Donateo, Domenico Laforgia, "Optimization of the Combustion Chamber of Direct Injection Diesel Engines", SAE2003-01-1064.

[5] Herbert Schapertons, Fred Thiele,"Three Dimensional Computations for Flow Fields in D I

Piston Bowls", SAE60463.

[6] Corcione. F. E, Annunziata Fusca, Gerardo Valentino, "Numerical and Experimental Analysis of Diesel Air Fuel Mixing", SAE 931948.

[7] Ogawa. H, Matsui. Y, Kimura. S, Kawashima. J,"Three Dimensional Computations of the Effects of the Swirl Ratio in Direct- Injection Diesel Engines on [NO.sub.X] and Soot emissions", SAE: 961125.

[8] Gunabalan, A., Ramaprabhu,"Effect of piston bowl geometry on flow, combustion and emission in DI diesel engine-a CFD approach", International Journal of Applied Engineering Research, Nov 2009.

[9] BRamanjanetylu et.al. International Journal of Engineering Research & Technology Published on "Performance Analysis on 4-S Si Engine Fueled With HHO Gas and LPG Enriched Gasoline"for publication in IJERT Vol. 2 Issue 8, August - 2013ISSN: 2278-0181

[10] K.L.Srinivasulu, et.al,.Journal of Mechanical and Civil Engineering (IOSR-JMCE) published on "Optimization of Air Filter in an Automobile Diesel Engine by Using CFD Analysis" for publication in IOSR-JMCE Volume 15, Issue 2, Oct 2012 page no- 17 to 25.

[11] P.Moulali, et.al., International Journal of ScientificEngineering and TechnologyResearch published on "CFD Analysis of Aerodynamic Trailer Devices for Drag Reduction of Heavy Duty Trucks"for publication in IJSETR Volume.05, IssueNo.18, July-2016, Pages: 3685-3695