



Reduction of Emissions by Enhancing Air Swirl in a Diesel Engine with Trapezoidal Groove on Piston Crown

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ABSTRACT

Diesel engines plays prominent role in the power generation, transportation, marine applications etc. Intensive research efforts are ongoing for improving combustion efficiency, fuel consumption and exhaust emissions from diesel engines. To increase the combustion efficiency, turbulence plays a very important role in the combustion phenomenon of C.I engine. Hence even a small increase in the combustion efficiency will result in greater advantage. The turbulent motion of the mixture intensifies the better mixing. The turbulence can be increased by suitable designing of combustion chamber, which involves the geometry of cylinder head, inlet manifold and piston crown. In the present work, the experimental investigation of air swirl in the cylinder upon the performance and emission of a single cylinder direct injection diesel engine is presented. Turbulence is created in the engine cylinder by cutting trapezoidal grooves on the piston crown, different configurations of the piston i.e., in the order of 2 grooves, are used to intensify the swirl for better mixing of air and fuel. A series of experiments are conducted on four stroke single cylinder direct injection diesel engine with grooved piston and compared with that of normal piston. Performance parameters such as brake power, specific fuel consumption, and thermal efficiencies are calculated based on the experimental analysis of the diesel engine. Emissions such as carbon dioxide, carbon monoxide, unburnt hydrocarbons, and NO_x are measured.

Keyword: Trapezoidal Grooved Piston(TGP), single cylinder 4-stroke diesel engine, Air swirl, Piston crown

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. It is well known that in DI diesel engine swirl motion is required for proper mixing of air and fuel. However, the efficiency of the diesel engines can be increased by increasing the burn rate of fuel air mixture. The swirl can be generated in the diesel engine by modifying the 3 parameters in engines, they are the cylinder head, the piston i.e., modification of the combustion chamber and the inlet manifold. 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.

When the piston moves close to the top dead centre [TDC], the variation of swirl depends on the shape of the combustion chamber. The effect of swirl on combustion and emission of heavy duty- diesel engines has been investigation by Benajes et al. And suggested that the optimal level of swirl that minimizes soot depends on engine running conditions.

To reduce the emissions coming the engines exhaust, manufacturer try to design the best combustion chamber and other level. At the design of combustion chamber geometry to reduce

the NO_x many researchers studied the different piston bowl geometry. Cao Li et al reported NO and CO emissions are lower for changing the piston geometry as comparison to normal piston geometry.

K.HemachandraReddy, C.EswaraReddy, C.V.Subba Reddy et.al. (2012): "effect of tangential grooves on piston crown of direct injection diesel engine with blends of cotton seed oil methyl Ester". This paper presents about direct injection diesel engines are in service for both heavy duty vehicles, light duty vehicles not only in the field of agriculture and transport sectors, but also stationary engines consume maximum percentage of petroleum based fuels and have the evident benefit of higher thermal efficiency than all other engines. In this, experiments are conducted on D.I diesel engine with three different tangential grooved pistons and cotton seed oil methyl esters blended with diesel in various proportions. The effect of three different sizes of tangential grooves on piston crown on the performance and emission characteristics are studied.

C R Rajashekhar, Sudeep Kumar, Veeresh M Kodekal, : "Studies on induced turbulence combustion on performance and combustion characteristics of bio-diesel fuelled C.I engine" this paper presents about the effects of modification of piston in C.I engine. For inducing the turbulence in the combustion chamber, a rotating blade had been placed on the piston crown. The oscillation of the connecting rod causes the blade to rotate by an

angle of 60°. This arrangement induces the turbulence in combustible mixture during combustion, by which better combustion can be achieved.

Vaibhav C.Bhatt , V.Y.Gajjar ,K.K.Araniya et.al.(2014): “A review on performance and exhaust emission characteristics of a diesel engine by changing piston geometry” this paper gives the basic idea about the effects of air swirl in the cylinder on its performance and exhaust emission of single cylinder direct injection diesel engine. In order to achieve the different swirl intensities in the cylinder, three design parameters have been changed i.e., the cylinder head, piston crown and inlet duct.

S.L.V.Prasad, V.Pandurangadu et al. (2011)made investigated experimentally the factor that the effected performance of diesel engine. It is quite well known that a properly designed intake manifold is vital for the optimal performance of an I.C.Engine. This a method of increasing the performance of a Diesel engine without any major modification. This paper aims at studying the effect of air swirl generated by directing the air flow in intake manifold on engine performance. The turbulence was achieved in the inlet manifold by grooving the inlet manifold with a helical groove of size of 1mm width and 2mm 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. In this paper clearly observed the results are compared with normal engine (without helical groove). The results of test show an increase in air flow, increases the brake thermal efficiency, mechanical efficiency and decrease in HC and Co emissions.

BhanuPratap Patel , I J Patel , G P Rathod et al. (2014): “effect of spiral grooves in piston bowl on exhaust emissions of direct injection diesel engine”.in present time developed country are used from small to largest diesel engine as a power plant for different purpose like generation electricity and transportation. These engines consume in heavy quantity fuel per hour, where these engines produce the bulk power as well as there also produce the different types of toxic gases that harmful our human beings and environment. At this time both type of country try to reduce the harmful gases from diesel engine. In present scenario many technology are used to reduce the toxicity of exhaust gases EGR(exhaust gas recirculation) is one of them. Where EGR reduces the toxicity of exhaust gases and fuel consumption as well as reduce the power of the engine which is not good at any level. In this present experimental to reduce the NOx, HC, CO, and CO₂ some modification has been done in piston bowl by cutting three spiral grooves on inner surface of hemispherical bowl and slight increasing in bowl diameter. The spiral grooves increases the capacity and slight reduce the compression ratio as well as make homogeneous mixing of air and fuel.

MODIFIED PISTON



Fig 1: TGP 2

TGP 2- TRAPEZOIDAL GROOVED PISTON WITH 2 GROOVES

Above showed pistons are the modified pistons with trapezoidal grooves on the piston crown. figure 1 shows that the making of 2 grooves i.e., TGP 2 and similarly fig 2 & fig 3 shows the TGP 4 and TGP 8 respectively. the trapezoidal grooves are placed on the piston crown for homogeneous mixing of air and fuel by enhancing air swirl within the combustion chamber which decreases the compression ratio and its effects on performance and emissions are observed.

EXPERIMENTAL WORK

Experiment is carried out in diesel engine with the following engine specifications as shown in table 1

TABLE I: Engine Specifications:

Specifications	Item
A V 1	Kirloskar Diesel Engine Model
3.68kW	Engine Power
80 mm	Cylinder bore
110 mm	Stroke length
1500 rpm	Engine speed
16.5:1	Compression ratio
Rope Brake Type	Dynamometer



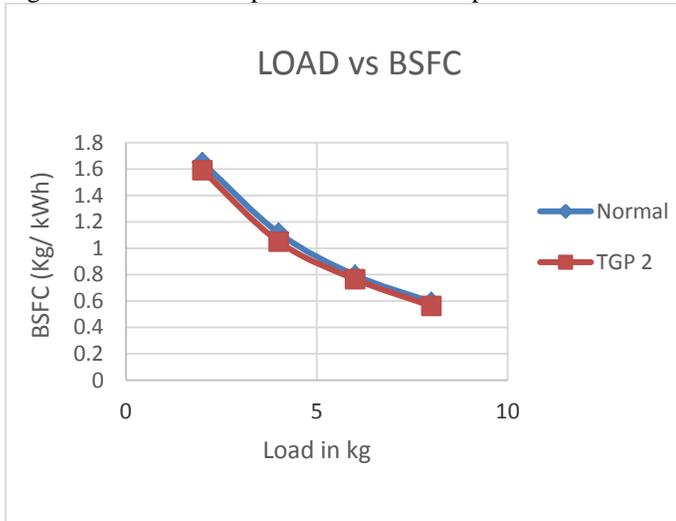
PROCEDURE:

The experiments are performed on D.I. diesel engine at constant speed 1500rpm by using pure diesel. In the first phase data recorded with standard piston and in the second phase data recorded by changing the modified piston (TGP 2, TGP 4 & TGP 8) respectively. The power of the engine is measured by using the rope brake dynamometer that is coupled with engine and engine exhaust emissions are measured by gas analyzer at different load. The performance and emission characteristics are compared with standard piston results.

RESULTS AND DISCUSSIONS

Load vs Brake specific fuel consumption

Fig: 2 Load vs Brake Specific Fuel Consumption



The variations of brake specific consumption with load as shown in fig 2. The brake specific consumption for TGP 2 at max load are 0.562kg/kW-hr, whereas for normal piston it is 0.592 kg/kW-hr. It is observed that the TGP 2 has lowest brake specific consumption 0.05% when compared to normal piston. This is because of complete combustion of charge in the combustion chamber due to the enhancement of air swirl.

Load vs Brake thermal efficiency

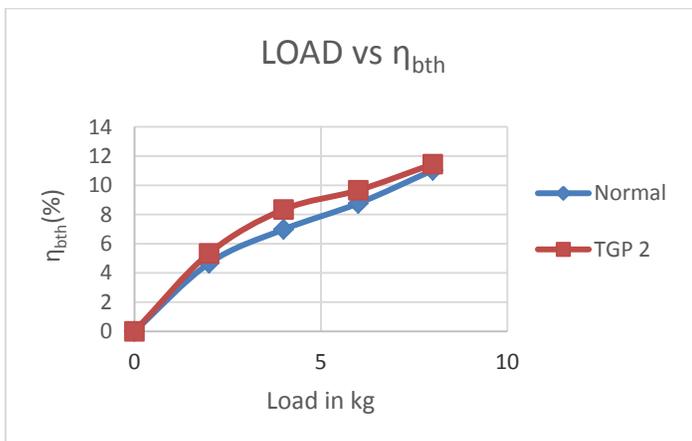


Fig: 3 Load vs Brake Thermal Efficiency

The variations of brake thermal efficiency with load as shown in fig 3. The brake thermal efficiency for TGP 2 at max load are 11.45% respectively, whereas for normal piston it is 11.03%. The brake thermal efficiency is increased by 0.03% for TGP 2 when compared to normal piston. This increase in brake thermal efficiency might be due to the turbulence created in the engine cylinder by enhancement of air swirl.

Load vs Mechanical efficiency

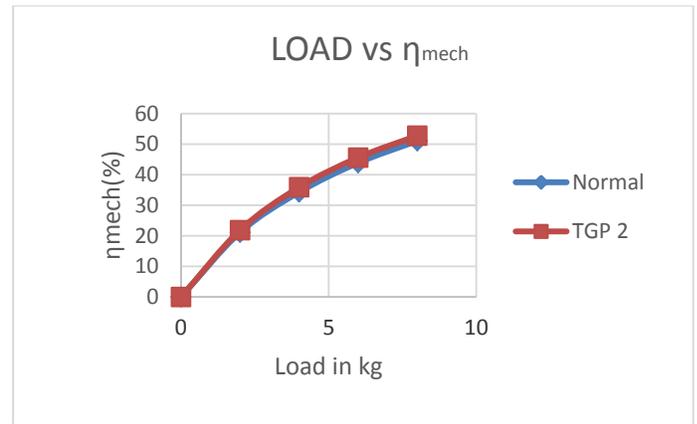


Fig: 4 Load vs Mechanical Efficiency

The variations of mechanical efficiency with load as shown in fig 4. The mechanical efficiency for TGP 2 at max load are 52.8% respectively, whereas for normal piston it is 51.08%. It is observed that TGP 2 has the highest mechanical efficiency of 0.033% when compared to normal piston. This is because of complete of charge in the engine cylinder by liberating maximum energy due to the enhancement of air swirl in the combustion chamber.

Load vs NO_x

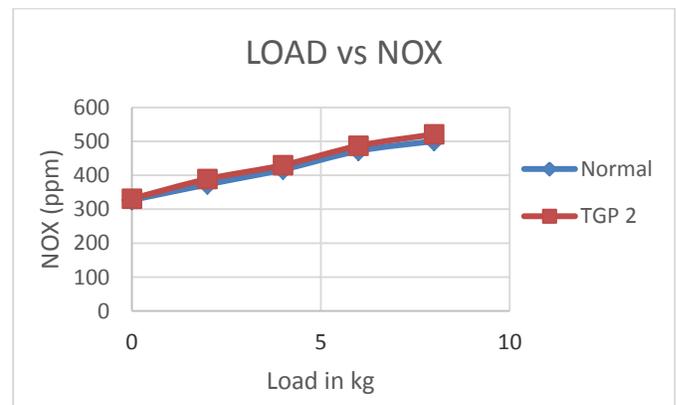


Fig: 5 Load vs NO_x

The comparison of NO_x emissions with load for different configurations of pistons as shown in fig 5.10. The NO_x emissions for TGP 2 at max load are 482ppm, whereas for normal piston it is 463ppm. The NO_x emission are higher of 0.039% for TGP 2 when compared to normal piston. This may be due to increase in the fuel lean mixture, i.e., fuel is less and air is more in the combustion chamber because of more amount of intensification of swirl is generated

Load vs HC

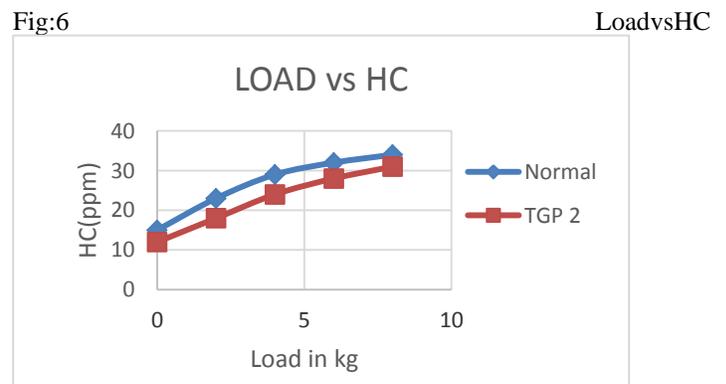


Fig:6

LoadvsHC

The comparisons of hydro carbon emissions with load as shown in fig 5. The HC emissions for TGP 2 at max load are 31ppm, whereas for normal piston it is 34ppm. The HC emissions are lowered by 0.08% for TGP 2 when compared to normal piston. It is obvious that hydrocarbon emission decreases with increase in turbulence.

Load vs CO

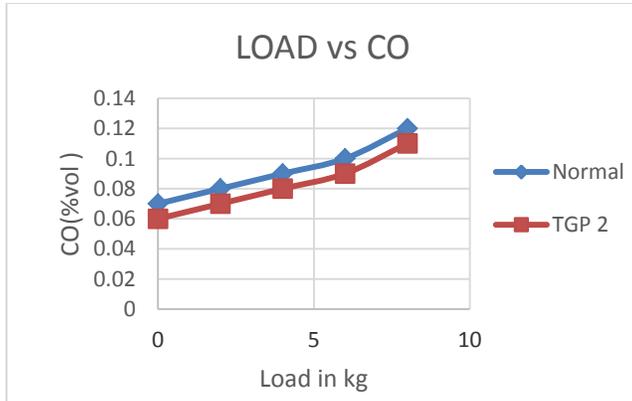


Fig: 7 Load vs CO

The variations of CO with load as shown in fig 4. The CO emissions for TGP 2 at max load are 0.11% by volume, whereas for normal piston it is 0.12% by volume. The CO emissions are lowered by 0.083% for TGP 2 when compared to normal engine. By increasing the turbulence in the combustion chamber the oxidation of CO is improved which in turn reduces the CO emissions.

Load vs CO₂

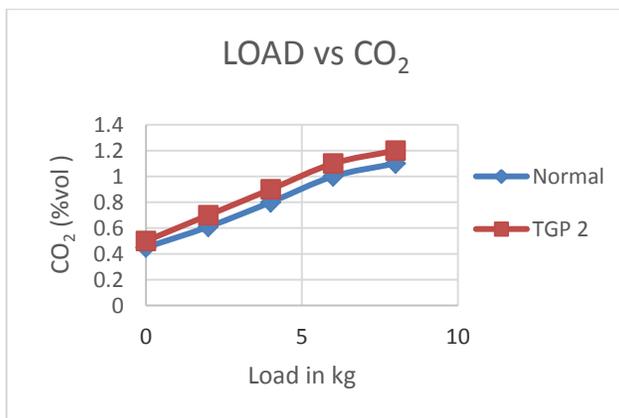


Fig: 8 Load vs CO₂

The variation of carbon dioxide emission with respect to load for normal piston and piston with grooves operation can be observed. From the results, it is observed that the amount of CO₂ produced while using piston with grooves is higher than normal piston at all load conditions. Carbon dioxide from the exhaust gas for the normal piston is 1.1% vol., and TGP 2 are 1.2% vol. It is also observed that there is a gain of 0.09% for TGP 2 when compared to normal piston. As a general rule, the higher the carbon dioxide reading, more efficient the engine is operating.

CONCLUSION

From the investigation, it is clear that out of normal pistons configurations tested in single cylinder direct injection (DI) four stroke diesel engine, piston with grooves i.e. TGP 2 gives better performance. The following conclusions are drawn at max load i.e. at 8kg load when compared to normal engine.

- ❖ The brake thermal efficiency is increased by 0.38%
- ❖ Fuel consumption for TGP 2 configuration is lowest among normal piston configuration.
- ❖ The improvement in mechanical efficiency is about 0.033%.
- ❖ The reduction in CO emissions is about 0.083%.
- ❖ The hydrocarbon emissions are reduced by 0.08%.
- ❖ The increase in NO_x emissions is about 0.039%.
- ❖ The increase in carbon dioxide is about 0.09%.

SCOPE OF FUTURE WORK

The present work can be extended by varying the number of grooves on the piston crown and the engine can be tested for better performance with various alternative fuels also.

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