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Effect of Piston Bowl Geometry to Study the Performance Characteristics Emission and Parameters in DI Diesel Engine

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ABSTRACT:

To investigate the performance characteristics and emission parameters of diesel engines, the effect of piston bowl shape was investigated. A study of the swirl in the cylinder performance and emission of a diesel engine direct injection to the engine cylinder is now a day's job. From the cylinder head to the piston crown, the varied swirl strengths in the cylinder parameter vary. In this method, the combustion chamber's piston crown is adjusted to improve turbulence in the cylinder. This spiraling of the swirl is accomplished by cutting a hole in the piston's crown. In this work, swirling a piston with a 2 mm diameter hole is more efficient than combining fuel and air for performance and emission reduction.

KEYWORDS: Piston crown, Cylinder head, Swirling, Emission, Hole diameter.

I.INTRODUCTION

Internal combustion engines are energy-producing engines that burn fuel inside them. Direct injection diesel engines are the most important of all the engines since they have higher thermal efficiency than the others. Light-duty and heavy-duty cars can both benefit from them. Because fuels are nonrenewable energy sources, the most efficient use of the energy available from them must be attained. The efficient burning of the fuel, i.e., combustion of the fuel, is required in internal combustion engines to boost the engine's efficiency. The fuel injected must be spatially effectively distributed throughout the entire space in order to achieve efficient combustion. To make optimum use of gas flows, the fuel sprays must be matched to the geometry of the combustion chamber. Here, air is swirled to improve the mixing of fuel and air, resulting in a faster rate of mixing and a shorter combustion time. Higher swirl decreases soot emissions at the expense of increased NOx levels.

One of the most significant aspects in managing the combustion process in internal combustion engines is in-cylinder fluid motion. It controls the mixing of air and fuel in diesel engines, as well as the pace of combustion. As a result, a better understanding of fluid motion is essential for developing engines with the best operating and emission characteristics. The thermal energy of the fuel transformed into power after losses through the engine exhaust, coolant, and radiation is referred to as indicated power, or ip. Through the piston rod, this indicated power is transferred to the crank shaft. There are energy losses in this transmission due to bearing friction, pumping losses, and other factors. Frictional power, or fp, is the sum of all of these losses given in units of power.
The residual energy is known as brake power, or bp, and is used to generate useful mechanical energy.
IP − FP = BP
One of the efficiencies that determines how efficient an engine is is brake thermal efficiency. The ratio of brake power to input fuel energy is what it's called.
Three design elements were adjusted to achieve the varying swirl intensities in the cylinder: the cylinder head, piston crown, and inlet duct. We alter the piston bowl and make a hole in it in this way to examine the engine performance and emission characteristics with a regular piston.

II. LITERATURE SURVEY

[1] Santhoshkumar et al investigated the impact of in-cylinder air swirl on diesel engine performance and emissions. The turbulence inside the cylinder can be improved by modifying the piston crown design. Also, grooves are constructed to improve the swirl strength for better fuel and air mixing. Swirling the air minimizes soot emissions at the expense of increased NOx levels. The increased thermal efficiency of the brakes could be attributed to the increased mixing rate carried by the turbulence in the combustion chamber.

[2] By altering piston shape, Vaibhav Bhatt and Vandana Gajjar evaluated the performance and exhaust emission characteristics of a diesel engine. To improve the combustibility of the combustible mixture in the cylinder, three different piston configurations (NP 4,NP 8,NP 12) are utilized to intensify

the swirl for better mixing of fuel and air, and their influence on performance and emission is documented. When compared to a standard engine, the NP 12 design has the lowest fuel usage of 6.8%.

[3] K.K.Araniya et al looked at the performance and emissions of a diesel engine with a modified piston. The research looks at how air swirl in the cylinder affects its performance and emissions. A review of the literature on the effect of air swirl in the cylinder on the performance and emissions of single cylinder direct injection diesel engines is offered in this paper. In comparison to a standard piston in a diesel engine, modifying piston shape enhances turbulence, which results in better air-fuel mixing.

[4] The effect of air swirl in a diesel engine was elucidated by S.L.V. Prasad et al. The piston crown is adjusted in this fashion, i.e. the combustion chamber is altered to increase turbulence in the cylinder. Swirl intensification is achieved by carving grooves in the piston's crown. At full load, the braking thermal efficiency for a typical piston is 28%. When comparing the G P 9 engine to a standard engine, a 10% gain is noticed. G P 9 has a lower exhaust gas temperature due to the redesigned piston's increased range turbulence in the combustion chamber.

[5] Using FEA, Avinash M. Wankhade and Praful R. Sakharkar performed a thermal analysis of an IC engine piston. The piston's piston is made of Al alloy, and the piston's piston is made of Al alloy. The stresses in a piston of an internal combustion engine are studied using finite element analysis. The highest stress develops on the top end of the piston, according to the investigations, and stress concentration is one of the main causes of fatigue failure.

[6] M.V.Mallikarjun et al. used a ceramic crown to analyze a diesel engine piston. High temperature and pressure are produced when combustion occurs in a heavy diesel engine cylinder. The piston will fail as a result of the tremendous thermal and structural strains produced.

[7] Dr.P.Manoj Kumar and his colleagues looked into it. The goal of this research is to look into the process of making straight grooves in the cylinder head to increase air swirl, as well as to analyze the performance and emissions of a single cylinder direct injection diesel engine. At 3/4 of rated load, the brake thermal efficiency for a typical engine is 26.1 percent. When comparing a CH3 engine to a conventional engine, a gain of 6.9% is seen.

[8] The Effect of Tangential Grooves on Piston Crown of D.I. Diesel Engine with Retarded Injection Timing was investigated by C.V.Subbareddy et al. The tests are carried out at three different fuel injection timings before TDC: 230, 200, and 170. Under all test conditions, the delayed injection time of 230 to 170 reduces emissions of nitrogen oxides and carbon monoxide and boosts thermal efficiency when compared to the regular injection timing of 230.

[9] Bhanupratap Patel et al investigated the effect of spiral grooves in the piston bowl on diesel engine exhaust emissions. To lower NOx, HC, CO, and CO2, a modification to the piston bowl was made by carving three spiral grooves on the inner surface of the hemispherical bowl and slightly increasing the bowl diameter. The spiral grooves boost air capacity while also lowering the compression ratio and ensuring that air and fuel are mixed evenly.

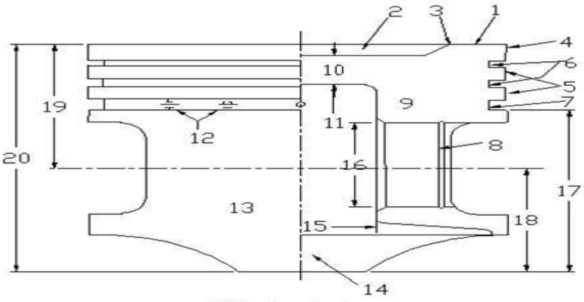
[10] High swirl inducing piston bowls in small diesel engines for pollution reduction were explained by B.V.V.S.U.Prasad et al. The current research looks at the impact of swirl caused by re-entrant piston bowl geometries on emissions in a diesel engine, with a single cylinder, 7.5 kW constant-speed engine as the emphasis. The in-cylinder air motion was then investigated in a variety of combustion chamber shapes, with the maximum in-cylinder swirl and Turbulence Kinetic Energy (TKE) near the compression top dead center (TDC) being discovered.

III. PISTON GEOMETRY

3.1 Piston Geometry

A piston is a cylindrical plug in the engine cylinder that moves up and down. It has a piston pin that connects it to the connecting rod's small end. It has a little smaller diameter than the cylinder bore. The piston clearance is the distance between the piston and the cylinder wall. This gap exists to prevent the piston from seizing in the cylinder and to create a lubricating coating between the piston and the cylinder wall. Because different metals have varying rates of contraction and expansion when cooled and heated, the amount of clearance varies on the size of the cylinder bore and the piston material.

3.2 Parts of piston



3.2 Parts of piston

3.3 Parts of piston

1. Crown,
2. Dish (or bowl),
3. Bowl lip,
4. Top land,
5. 2nd and 3rd ring lands
6. Compression ring grooves,
7. Oil ring groove,
8. Pin retainer ring groove
9. Pin boss,
10. Crown thickness,
11. under crown surface,
12. Oil return or drain holes,
13. Skirt,
14. Skirt tail,
15. Boss spacing,
16. Pin bore diameter

Selection for aluminium

The type of aluminum utilized to make the piston was chosen. Because the thermal and mechanical piston loads in the combustion chamber are so great that engine designers are concerned the lightweight material may eventually break, high-performance, highly-charged passenger vehicle diesel engines are typically considered as the touchstone for Al pistons. Cracks usually start on the rim of the bowl. As a result, the first reasonable step is to strengthen this area.

Because the piston is constructed of an aluminum alloy, it creates less inertia forces, allowing the crankshaft to rotate more smoothly. Aluminum's heat conductivity is three times that of cast iron, and this, along with the need for larger thickness for strength, allows an aluminum piston alloy to operate at significantly lower temperatures than cast iron. As a result, carbonized oil does not accumulate on the piston's underside, and the crank case remains clean at all times. The following is the SAE-recommended composition.
SAE 300:Heatresistant aluminum alloy with the composition, Cu 5.5 to 7.5%,Fe 1.5%,Si5.0to6.0%,Mg0.2to0.6 %,Zn0.8%,Ti0.2%, otherElements0.8%.
SAE321:LowexpansionAlloyhavingthecomposition,Cu0.5to1.5%,Fe1.3%,Si11to13%,Mn0.1%,Mg 0.7to1.3%,Zn0.1%,Ti0.2%
,Ni2 to3%, OtherElements0.05%.

Chemical composition of aluminium alloy

The chemical composition of aluminium alloy used for manufacturing of piston sa sfollows,

Material : [P-AL-003]{(LM-6)(2285)(IS-7793-1975}

Chemical composition (%):

Table 3.1 Properties of Aluminium (P- Al-003)

ELEMENT	REQUIRED	ELEMENT	REQUIRED
SILICON	0.6Max	COPPER	3.5-4.5
MANGANESE	1.2-1.8	MAGNESIUM	1.2-1.8
ZINC	0.2Max	NICKEL	1.7-2.3
TIN	0.05Max	TITANIUM	0.2Max
IRON	0.7Max	LEAD	0.05Max
		ALUMINIUM	Reminder

Table 3.2 Properties of Aluminium (p – Al -001)

ELEMENT	REQUIRED	ELEMENT	REQUIRED
SILICON	11.0-13.0	COPPER	0.8-1.5
MANGANESE	0.2Max	MAGNESIUM	0.8-1.5
ZINC	0.35Max	NICKEL	0.8-1.5
TIN	0.05Max	TITANIUM	0.2Max
IRON	0.5Max	LEAD	0.05Max
		ALUMINIUM	Reminder

Material:[P -AL-002]{(LM-28)(4928A)(IS-7793-1975)}

Chemical composition (%):

Table 3.3 Properties of Aluminium (P – Al -002)

ELEMENT	REQUIRED	ELEMENT	REQUIRED
SILICON	17.0-19.0	COPPER	0.8-1.5
MANGANESE	0.2Max	MAGNESIUM	0.8-1.3
ZINC	0.2Max	NICKEL	0.8-1.3
TIN	0.05Max	TITANIUM	0.2Max
IRON	0.5Max	LEAD	0.05Max
		ALUMINIUM	Reminder

IV.METHODOLOGY

Problem identification

Internal combustion engines are the most reliable source of power available today for all domestic, large-scale industrial, and transportation applications. The main problem is that these engines are inefficient. Every effort made to develop these engines is aimed at maximizing their efficiency. Poor combustion is caused by a lack of air swirl and inappropriate mixing of the air-fuel mixture. Diesel engines are thought to be more fuel efficient and more durable than gasoline engines. However, they emit large amounts of toxic pollutants such as nitrogen oxides (NOx), particulates, unburned hydrocarbons, smoke, and carbon monoxide (CO).

4.1 Objective

Various procedures, such as fuel modification, engine design changes, exhaust gas treatment, and so on, have been tried to improve the performance and minimize emissions from diesel engines. To improve combustion efficiency and reduce emissions, the air swirl is intensified. Air swirl enhancement is used to induce turbulence in the combustion chamber for better air-fuel mixture mixing. To achieve varying swirl intensities, the piston crown, cylinder head, and inlet duct design characteristics were adjusted. The turbulence inside the cylinder can be increased by modifying the piston design. Also, holes are drilled to improve the swirl intensity for better fuel and air mixing.
This method is utilized to improve the engine's performance while lowering emissions.

V.EXPERIMENTAL SETUP

5.1 Experimental setup

The effect of air swirl on the performance of direct injection diesel engines has been studied experimentally. The tests were carried out on a single cylinder direct injection four stroke diesel engine made by Kirloskar. The experiments were conducted using a water-cooled eddy current dynamometer. A good swirl encourages rapid combustion, which increases efficiency. Three design elements were altered to achieve the swirl intensities in the cylinder: the cylinder head, piston crown, and inlet duct. The piston crown is modified in this fashion. By drilling holes in the piston crown, the air swirl is intensified. The hole diameter of 2 mm is employed in this work to strengthen the air swirl for improved fuel and air mixing, and the effects on performance and emission are recorded. In addition to the foregoing, the engine has the following features:

1. Electromagnetic pickup is included.
2. Cylinder pressure sensor with a piezoelectric element
3. Thermocouples for measuring water, fuel, and air temperatures
4. A rota meter is a device that measures the rate of water flow.
5. Air and fuel flow rates are measured with a manometer.
6. A Bosch smoke meter is used to determine the density of smoke.

In this experimental setup the no of holes & degree of angle are produced in the piston crown is calculated as shown in below.
The piston crown angle =360^0
No of holes produced in the piston crown =6
Angle of degree to produce the hole = 360 / 6= 60^0
Therefore the holes are produced in the piston crown with the angle of 60^0.

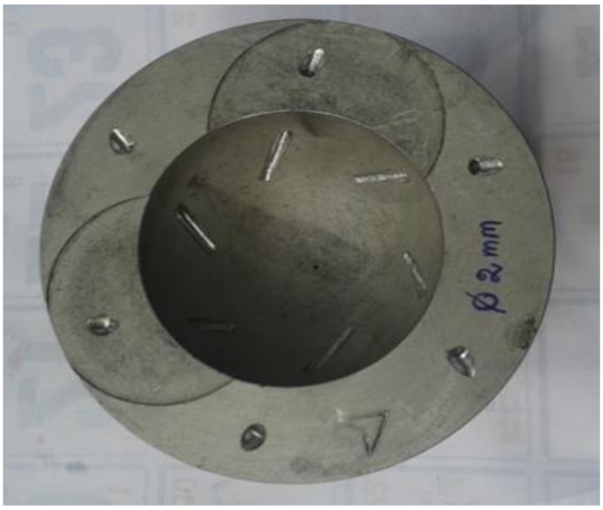


Fig 5.1 Top view of modified piston

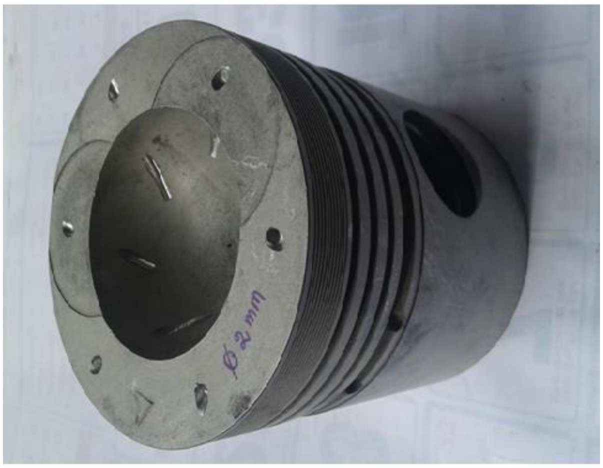


Fig5.2 Side view of modified piston

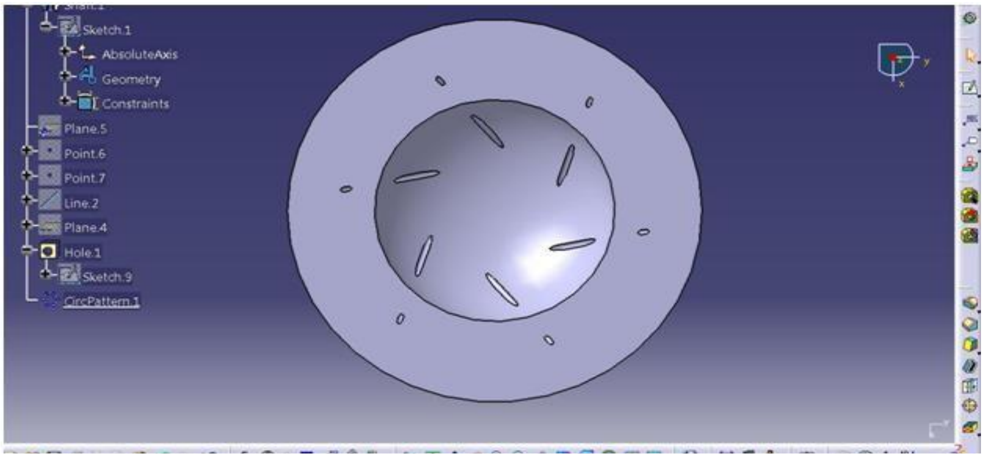


Fig 5.3 Top view of modified piston (using CATIA)

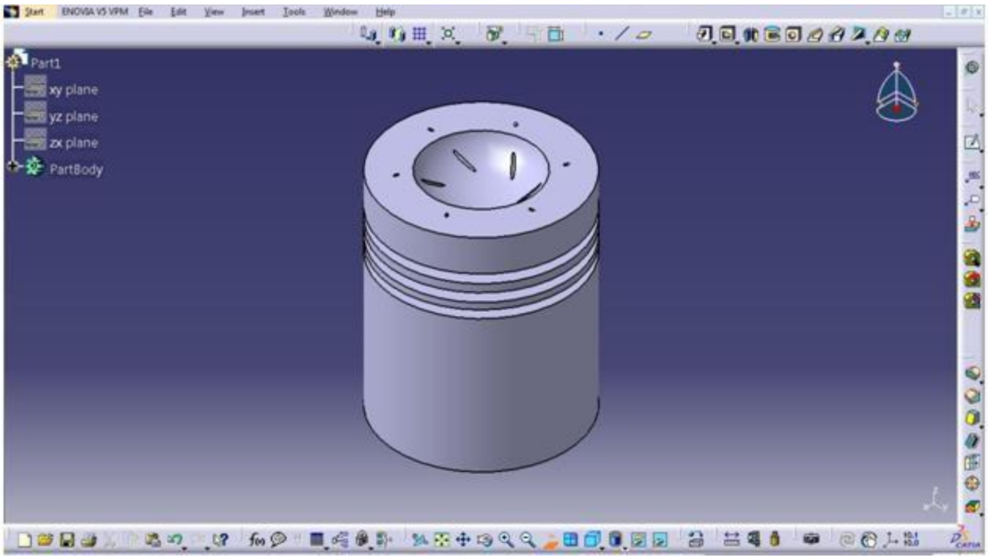


Fig5.4 Isometric view of modified piston (using CATIA)

5.2 Engine specification

Table5.1 Specification of engine

MAKER	**KIRLOSKAR AV 1**
TYPE	VERTICALCYLINDER,DI DIESELENGINE
SPEED	1500RPM
COMPRESSIONRATIO	17:1
COOLINGSYSTEM	WATER
FUEL	DIESEL
BOREANDSTOKE	87.5MM×110 MM
PISTON	NORMALAND MODIFIED PISTON
RATEDPOWER	5.2KW

Fig 5.5 Photographic View of Experimental Set

5.2 Procedure

- The filters of the engine are replaced and the injectors were cleaned and calibrated according to the desired specifications.
- The AVL gas analyzer and smoke meter were installed. The input to the gas analyzer was taken from the exhaust port of the engine.
- The fuel tank was then filled with diesel and the engine was run.
- The engine was run at various loads of the dynamometer–20, 40, 60, 80,100 kgs and respective readings were taken for fuel consumption/sec.
- The readings of gas analyzer and smoke meter were noted in each case.
- After all the readings were taken, the modified piston was fitted in the combustion chamber instead of normal piston.
- Same steps were taken and the readings were noted down for modified piston.
- After taking all the observations, graphs were plotted to compare the performance characteristics and emission characteristics of the engine in case of normal piston with modified piston.

V.RESULT AND DISCUSSION

A series of engine tests were carried out using diesel in normal piston and modified piston to find out the effect of various performance and emission characteristics of the engine. Investigations are carried out on the engine mainly to study the effect of specific fuel consumption, brake thermal efficiency, mechanical efficiency and emissions such as NOx, CO, CO2, and HC.

Comparative analysis of performance and emission characteristics modified piston and actual piston on normal engine.

6.1 Performance characteristics:

6.1.1. Variation of specific fuel consumption with brake power

Fig. 1 shows Brake specific fuel consumption variation brake power for the modified piston and actual piston. It is observed that the brake specific fuel consumption is found to decrease with increase in load. The minimum BSFC is observed as 0.36 for modified piston whereas for actual piston it was 0.37 at initial load of the engine. This may due to better combustion and an increase in the energy content of the blend. This is also due to lower calorific value of the actual piston as compared with modified piston.

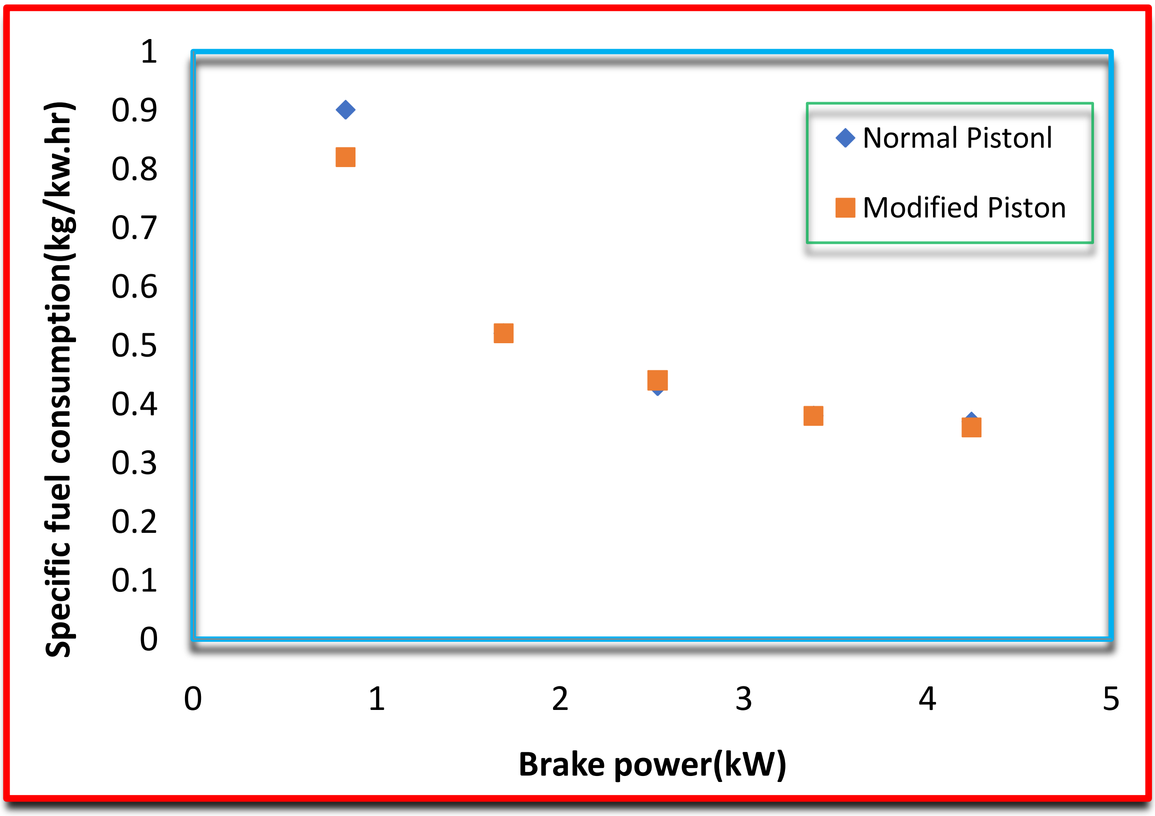


Figure 6.1. Variation of specific fuel consumption with brake power

6.1.2. Variation of mechanical efficiency with brake power

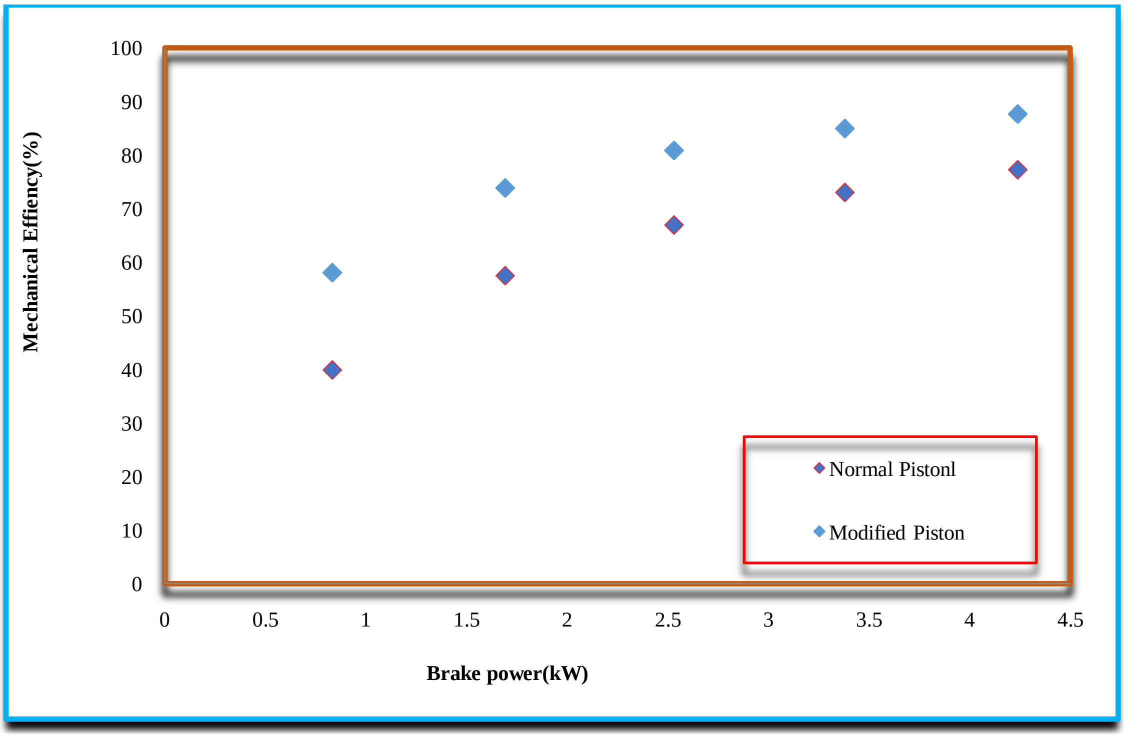


Figure 6.2. Variation of mechanical efficiency with brake Power

The variation of mechanical efficiency with brake power, for the altered piston and actual are as shown in figure.2. From the graph the mechanical efficiency is increase in the modified piston. At full load in DI has maximum efficiency of 77.23% this is due to fuel burning completely in DI engine due increased temperature in combustion chamber.

6.1.3. Variation of brake thermal efficiency with brake power

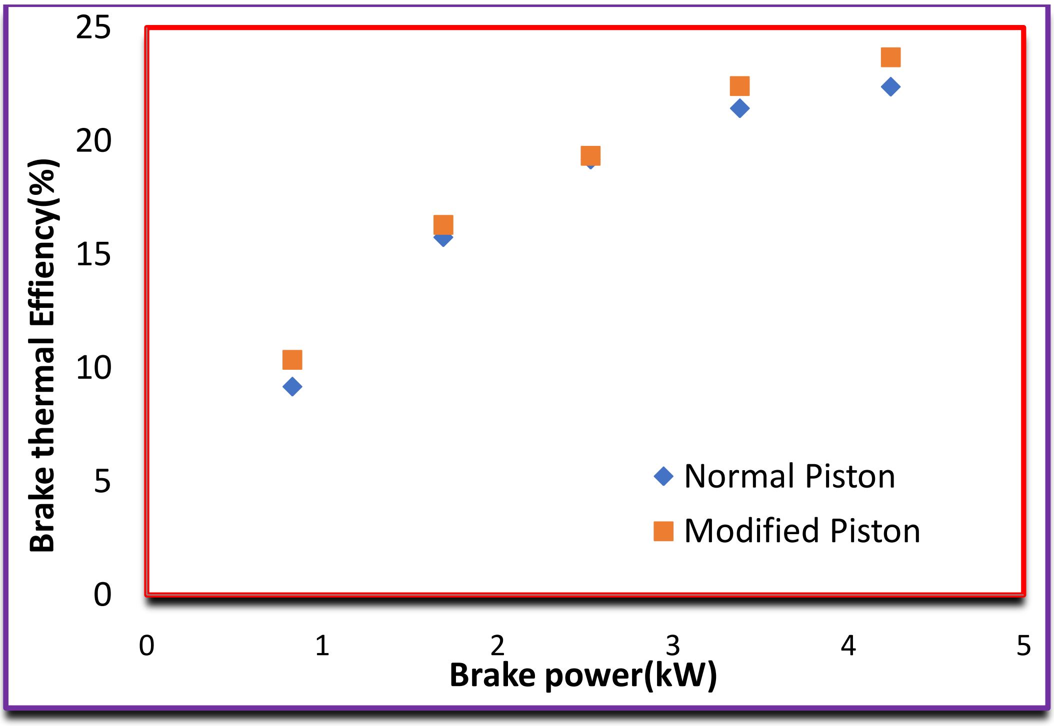


Figure 6.3 Variation of brake thermal efficiency with brake power

The brake thermal efficiency variation with brake power for the analysis are shown in figure3. It can be seen that in the beginning with increasing brake power of the engine the brake thermal efficiency were increased. The maximum brake thermal efficiency of the engine was 23.69 for modified piston at brake power 4.24 where it is 22.38 for actual. This is due to improved atomization fuel vaporization, better spray characteristics and improved combustion through mixture.

6.2 Emission characteristics:

6.2.1. Variation of hydrocarbon with brake power

The hydro carbons variation with brake power for altered piston and actual are shown figure-4.The hydro carbons are lower in altered compared with actual. The lowest value of HC was 21 at brake power 0.83 and it was 25 for actual.. This result depends on oxygen quantity and fuel viscosity, in turn atomization.

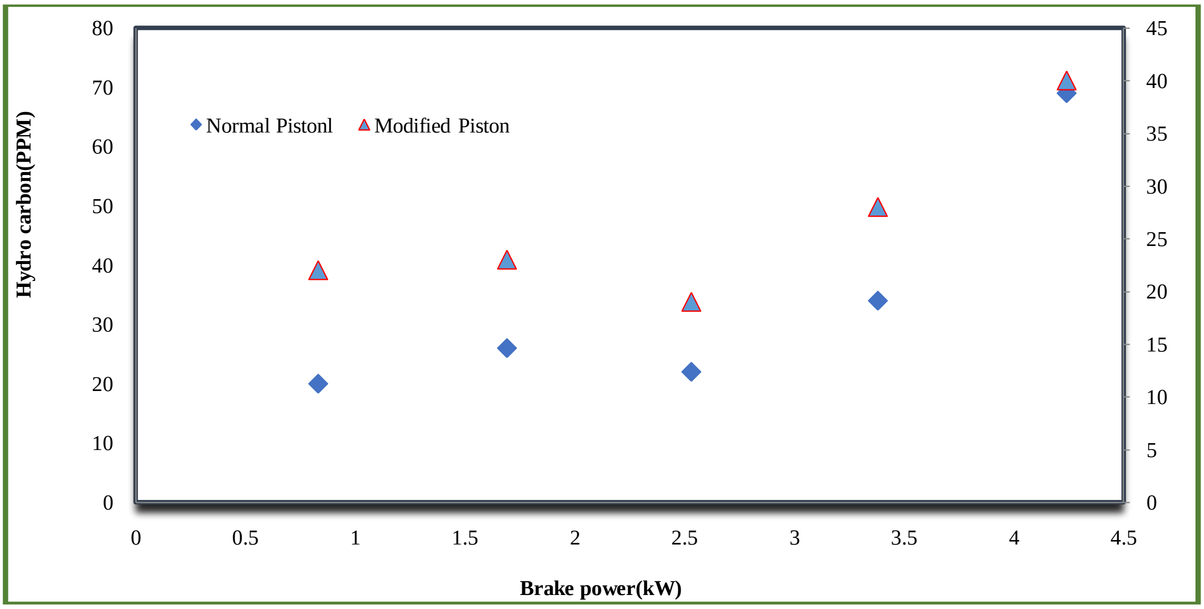


Figure 6.4 Variation of hydro carbon with brake power

8.2.2. Variation of NO_X with brake power

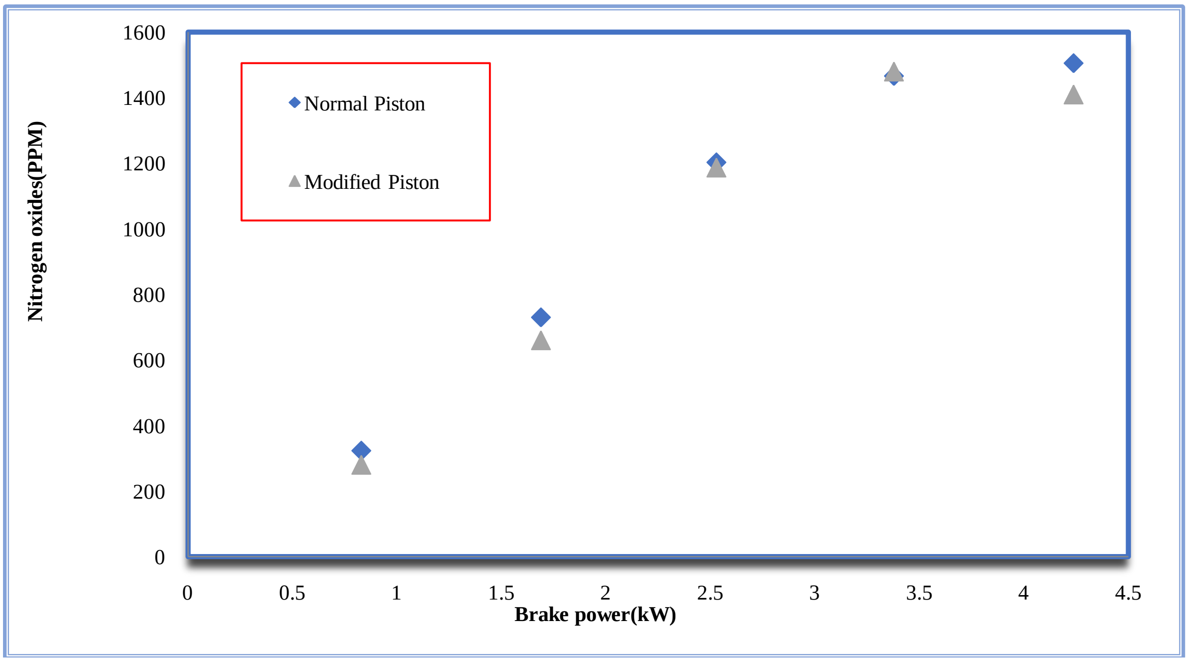


Figure 6.5 Variation of NO_X with brake power

The NO_X variation with brake power for the altered and actual piston are shown figure-5.The NO_X are lower for all the loads compared with actual. The lowest value of NO_X was 280 at brake power 0.83 and it was 324 for actual. This result depends on oxygen quantity and fuel viscosity, in turn atomization.

VI. CONCLUSION

The following conclusions were drawn from these investigations carried out on normal DI Diesel engine and altered engine for different loads. The conclusions of this investigating at are as follows.

- The maximum brake thermal efficiency 23.69% was observed with the modified piston as compared to normal engine at the brake power 4.24kw of the engine.
- The specific fuel consumption of the 0.36kg/kw-hr was observed with the modified piston the SFC is lower for above condition than that of normal engine.
- In the combustion analysis, the maximum cylinder pressure observed as 81bar for modified piston than normal engine at maximum brake power of the engine.
- The heat release rate is also higher for of altered engine than pure diesel engine.
- The CO2 percentage increased with increase of loads. The minimum value occurred at altered engine.
- The hydro carbons are also lower for modified than diesel.

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