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Performance and Emission Characteristics of Diesel Engine by Semi Ellipsoidal Arc Grooves on Piston Crown

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Abstract: **Direct injection diesel engines are very useful in heavy duty vehicles as well as light duty vehicles. Direct injection diesel engine emits significant amount of pollutants such as HC, CO, NOx and soot etc., which are harmful to the environment. These pollutants formed due to improper combustion in combustion chamber. In the present experimental attempt is made to study the performance and emission characteristics of diesel engine by adding the semi ellipsoidal arc grooves on piston crown. The tests are performed at two, three and five groves on piston crown of diesel engine [2EGP,3EGP and 5EGP]. The grooves on the piston crown creates turbulence and proper mixing of air and fuel in combustion chamber which helps to create proper combustion and leads to decrease the formation of pollutants as compared to normal diesel engine. From the experimental investigations, it is concluded that three ellipsoidal grooves arc pistons [3EGP] has less emissions and high performance than that of other type of pistons.**

Index Terms: **Ellipsoidal arc grooves, Piston crown, Diesel engine, Performance and Emissions**

I. Introduction

It is well-known that in DI diesel engines swirl motion is required for proper mixing of fuel and air. Moreover, the efficiency of diesel engines is often improved by increasing the burn rate of fuel air mixture. This can be achieved in two ways, one by designing the combustion chamber and two by providing the intake system so it can create a swirl motion to the incoming air.

In this experimental work is conducted on single cylinder 4-stroke DI diesel engine with semi hemispherical bowl [1],[2],[8] in the piston to study the effect of groves on fluid flow and on the engine performance.

Experiments are carried out to measure the performance and emission characteristics of two, three and five ellipsoidal groves on piston crown. The result of grooves on piston head and optimum number of grooves for better performance is discussed. It is observed from the experiments, is that three ellipsoidal grooves (3EGP) is better than two and five ellipsoidal grooves (2EGP, 5EGP) for conventional engine.

II. Literature Survey

J.Li et.al [1] has conducted simulation work using CFD on different types combustion chamber i.e. hemispherical combustion chamber (HCC), shallow depth combustion chamber (SCC) and omega combustion chamber (OCC).This project conclude that at low speed SCC is favorable and at high speed hemispherical combustion is favorable.

Nimesh. A. Patel et al [2] has conducted test on direct diesel engine by varying injection pressures and piston bowl geometry to reduce the emissions and performance of engine. In this study, hemisphere combustion chamber with circular arc on the periphery of the piston crown at 120^0 is used for test and compared these results with hemispherical open type combustion chamber. The results show that Break thermal efficiency, exhaust gas temperature and No_x is increased and break specific fuel consumption, HC emissions and CO emissions are decreased.

Venkata Ramesh Mailla et al [3] has conducted experiment on direct injection diesel engine by changing the combustion chamber design by using different blends of Jathropa Mythyl ester as alternative fuel and results are shown.

Md Nurun Nabi et al [5] has studied the performance of diesel engine and production of biodiesel from linseed oil. The performance characteristics like thermal efficiency, break thermal efficiency and emissions characteristics like CO, HC and NO_x are calculated and shown in results.

A Swayamkumari et al [6] has done research on direct injection diesel engine for calculating the performance and emissions characteristics by using sunflower oil as biodiesel and the results are shown.

Sk. Gouse Ahamed et al [7] has conducted experiment on direct injection diesel engine by using apricot seed oil as bio diesel. Mechanical efficiency break thermal efficiency, CO, NOx and HC emissions are calculated and shown in results.

Banapurmath NR et al [8] has calculated the emissions characteristics and performance characteristics of direct injection diesel engine by changing the different shapes of piston geometry using mahua and neem oil as biodiesel.

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B Naveen Kumar et al [9] has conducted experiment on diesel engine by changing the piston shape as toroidal using olive oil as biodiesel and results are calculated.

Y Shyamala et al [10] has conducted experiment on four stroke direct injection diesel engine by changing the combustion chamber as shallow depth combustion chamber using olive oil as biodiesel and results are calculated.

III. Piston Modification

A. *Piston Modifications*

The design of the combustion chamber and the fluid flow within the chamber are necessary for complete combustion. The main goal from the design of chamber geometry is to optimize the mixing of the fuel and air, before and during ignition, and to improve the flow of the exhaust products once combustion is complete.

The piston crown of 80 mm diameter of normal engine is changed by producing semi ellipsoidal arc grooves. In this work, two, three and five semi ellipsoidal arc grooves at 180^0, 120^0, 72^0 on the pistons [2] with different widths of 10mm, 8mm and 6mm were created on three pistons of 80 mm diameter and continuing the depth of 3 mm prepared by CNC machine**.** The experiments were carried out with these pistons and their performance and emissions are compared with normal diesel engine [4].

B. *Three types of semi-elliptical arc grooves*

a) Two groove elliptical piston

b) Three groove elliptical piston

c)Five groove elliptical piston

Figure 1. Two, Three and Five grooves elliptical piston

Fig.1 shows that two, three and five grooves elliptical pistons which are prepared by CNC machines used in diesel engine to find performance and emissions characteristics.

IV. Experimental setup

The experimental set up consists of KIRLOSKAR engine, DC alternator with resistance heaters, Rota meter, and digital RPM indicator fuel tank along with immersion heater, thermocouples, and manometer. The engine which is supplied by KIRLOSKAR make AV1 model diesel engine (crank started) of 5HP (3.7kW) capacity single cylinder water cooled diesel and the specifications are given in Table-II. For the measurement of emissions five-gas-analyzer is used. The fuel used for present work is diesel. The level of lubricating oil in the sump was checked periodically. Constant water flow was maintained through the engine to reduce the overheating of engine. All the readings were taken under steady running conditions.

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TABLE I.
ENGINE SPECIFICATIONS

Particulates	Specifications
Model	AV1
Make	KIRLOSKAR
Engine type	Single cylinder, four strokes, Water cooled Compression ignition engine
Bore	80 mm
Stroke	110 mm
Speed	1500 rpm
Rated power	5HP

Table I. Shows the Engine specifications which are used in this work.

A. Nomenclature

i. Normal: Normal piston with pure diesel.
ii. 2EGP: Two semi ellipsoidal arc groove piston with pure diesel.
iii. 3EGP: Three semi ellipsoidal arc groove piston with pure diesel.
iv. 5EGP: Five semi ellipsoidal arc groove piston with pure diesel.

V. RESULTS AND DISCUSSIONS

The performance of the engine is measured in the form of brake specific fuel consumption, brake thermal efficiency and mechanical efficiency. The exhaust emissions of the engine are measured in percentage of HC, NO_x, and CO [4]. The results acquired by the piston with grooves are compared with the normal piston.

A. Break Thermal Efficiency

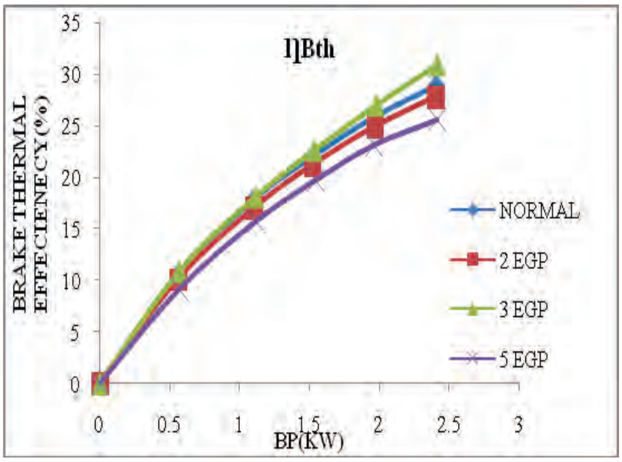

Figure 2. Brake power Vs Brake thermal efficiency with diesel

Fig.2 represents the variation of brake thermal efficiency with load for different Pistons with pure diesel. It is clear from the graph that 3EGP high break thermal efficiency as compared to other pistons. The brake thermal efficiency is found to increase by 6.27% for Normal piston with pure diesel of engine.

B. Break Specific fuel consumption

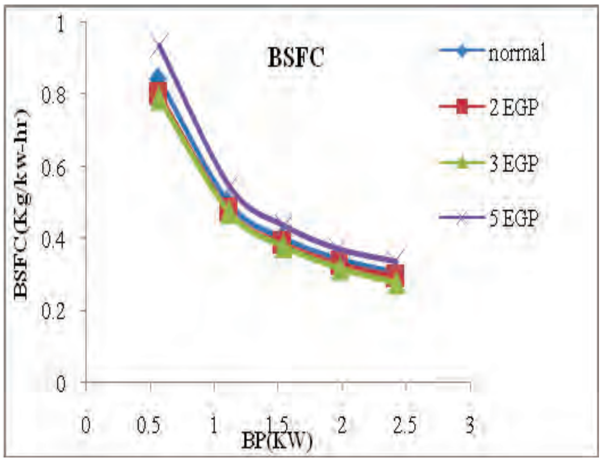

Figure 3. Brake power Vs Brake specific fuel consumption with Diesel

Fig.3 represents the variation of brake Specific fuel consumption with Diesel for different pistons of conventional engine. It is observed from graph that 3EGP has lower BSFC compare to other pistons. The BSFC is reduced about 10% compare to Normal piston.

C. Mechanical Efficiency

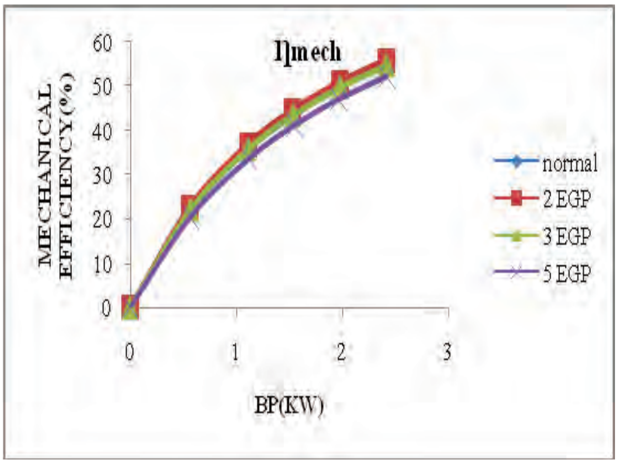

Figure 4. Brake power Vs Mechanical efficiency with Diesel

Fig.4 represents the variation of Mechanical efficiency with load for different Pistons. It is clear from the graph that 2EGP has slightly high mechanical efficiency compared to 3EGP piston in conventional engine.

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D. Hydrocarbons Emissions

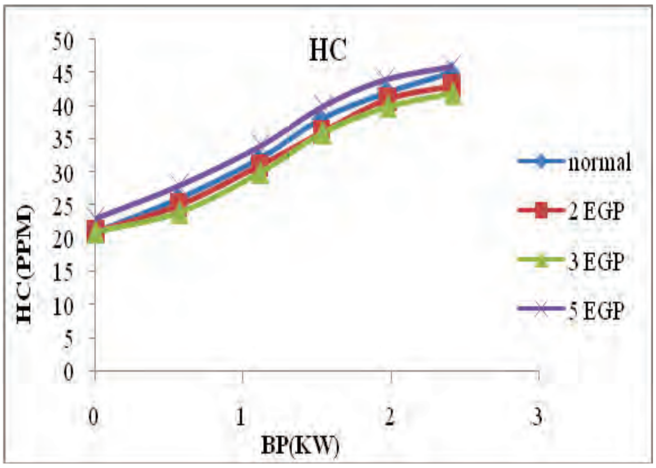

Figure 5. Brake power Vs HC emissions with Diesel

Fig.5 shows the HC emissions of diesel engine for different pistons. It shows that HC emission for 3EGP has less compare to other pistons because of proper atomization of fuel and air inside the combustion chamber.

E. Nitrogen Oxides (NO_x)

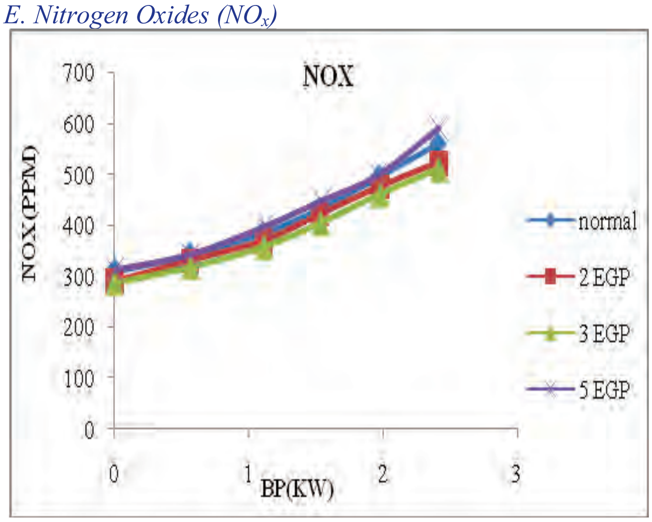

Figure 6. Brake power Vs NO_x emissions with Diesel

Fig.6 shows the variation of NO_x emissions with load for different pistons. It is clear from the graph that 3 EGP has low NO_x emissions compared to other pistons in conventional engine.

F. Carbon Monoxide(CO)

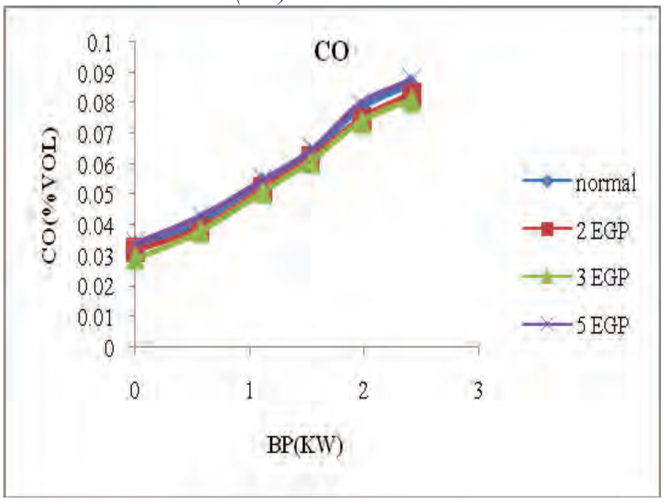

Figure 7. Brake power Vs CO emissions with diesel.

Fig.7 shows the variation of CO emissions with other pistons. It is observed that 3EGP is lower CO emissions than compared to 2EGP, 5EGP and normal piston.

TABLE II.
ENGINE PERFORMANCE CHARACTERISTICS

S.NO	Brake thermal efficiency (%)	BSFC (Kg/kw-hr)	Mechanical Efficiency (%)
Normal Piston	21.22	0.40	43.27
2 EGP	22.07	0.38	44.61
3EGP	22.64	0.36	43.43
5EGP	19.69	0.43	41.24

Table.II shows the comparison of characteristics of engine i.e. brake thermal efficiency, BSFC and mechanical efficiency using normal, 2EGP, 3EGP and 5EGP. It clearly shows that three ellipsoidal arc groove piston [3EGP] having high brake thermal efficacy and low BSFC as compared to other pistons, but the mechanical efficiency is slightly less than the two ellipsoidal arc groove piston.

TABLE III.
EMISSIONS CHARACTERISTICS

S.NO	HC (PPM)	NO_x(PPM)	CO (% Vol)
Normal Piston	38	432	0.063
2 EGP	36	422	0.062
3EGP	34	404	0.061
5EGP	40	422	0.065

Table.III shows comparing of engine emissions i.e. HC, NOx and CO using normal, 2EGP,3EGP and 5EGP.It clearly shows that three ellipsoidal arc groove piston has low HC, NOx and CO emissions compared to other type of pistons.

V. Conclusions

- Break thermal efficiency is increased by 6.27% by changing the normal piston with three semi elliptical arc groves piston.
- Break Specific fuel consumption is decreased by 10% for 3EGP piston compare to normal piston.
- HC emissions are reduced by 10.5% by changing the piston from normal to 3EGP.
- NO_x emissions are reduced 6.48% by changing the piston from normal to 3EGP.
- The CO emissions are reduced by 4% (3EGP) for modified pistons by compared to normal piston

From the above conclusions, three ellipsoidal grooves piston (3EGP) is better than the normal, two and five grooves piston (Normal,2EGP and 5EGP).

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