

Effect of Induction Swirl and Piston Configuration in a Constant Speed Four Stroke Diesel Engine

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Abstract

New strategies and optimization in present techniques are introduced in increasing the demands of consumption of fuel in I.C engines. Movement of air within the combustion chamber effects the formation of air and fuel mixture with fine spraying of fuel. Complete combustion and reduction in knocking will be obtained by better mixing of air and fuel. For this purpose C.I with four stroke, working power 5KW and with the speed 1500rpm is used to analyze the engine characteristics. For betterment of the engine, air swirl motion technology is used as the optimized parameter. A nozzle of convergent divergent, inlet valves, exhaust valves, piston modification are incorporated for increasing the velocity of air and for better mixing of air – fuel mixture for better combustion. This may leads to increase in velocity and generates the turbulence at the outlet of the inlet manifold which leads to the better combustion. By making the above modifications in three methods, the characteristics performance of the engine and the emission parameters are evaluated.

Keywords: convergent divergent, inlet valves, exhaust valves, piston modification

I. Introduction

Out of all internal combustion engines, comparatively diesel engines more effective utilization of coal-thar and petroleum products which consumes more liquid fuels such as diesel, which is not used in other type of engines. For Some uses this engine is replacing gas and gasoline engines, but most important duty will be to replacing gas and gasoline engines, but it's most important duty will to be replacing the wasteful consumption of fuel oil in steam engines. Not only a wider use of the Diesel engine relieves the demand, but it will result in more power being obtained from the same consumption of fuel oils. In spite of these advantages, comparatively few Diesel engines are in use in the United States.

A C.I engine is one among different types of heat engine falls in the category of IC(Internal Combustion) engines utilizes heat developed due compression for the initiation of combustion process in which chemical reaction of air-fuel takes place in the combustion chamber in the compression final stage. Of all types of engines such as internal and external combustion engines having high compression ratio, diesel engine will have more thermal efficiency [3]. Fuel is plainly injected into the cylinder where

air Is compressed and mixes with the fuel, based on the motion of the air, in the inner part of the combustion chamber. The main factor for controlling the process of combustion is the way of passing the air into the cylinder from the inlet manifold, which causes the mixing of fuel and air in proper proportions for betterment of the combustion [5].

From the intake manifold the air enters into the cylinder of engine with the motion of swirl which increases the velocity, this causes increasing in the kinetic energy which give better result in mixing of air and fuel, causes the increase in turbulence, which in turn results in effective reduction in the temperatures of cylinder and by minimizing losses of heat to environment. During process of suction, heat associated with the walls of cylinder is dissipated to the air there by reducing the period of delay, by improving engine thermal efficiency. In the present work, the method involves three process, first one is the threaded manifold by varying pitches, second one is three frustum of cones with 2mm depth of cut and final stage is that the inlet and exhaust valves are re-designed by keeping the pitch 2mm, thread depth of cut is 4mm with 3 threads per inch to improve the

swirl motion in the combustion as well as to improve efficiency. In the current test we considered mono cylinder 4-stroke liquid cooled engine with diesel as fuel exhaust valves are re-designed.

II. Literature Review

It is found in the literature that the increase in airflow into an IC engine may increase the brake power, efficiency and reduce emissions of engine. To increase overall performance of engine induction convergent-divergent nozzle is used in this experiment [5]. With the literature studied, observations made are, major work involved in implementing helical threads in the inlet manifold with variation of pitch for creating the air swirl motion inside the cylinder during entering. By developing helical grooves with the variation of pitches in the inlet manifold, the turbulence was achieved by varying in the sizes of 3mm depth and 4mm width[1]. This variation can be done by altering the helical threads with steps of 5mm from 10mm to 25 mm in the intake manifold. The speed is maintained at 1500rpm, for calculation process. The performance characteristics can be calculated by varying the nozzle throat in the manifold at 15mm, 17mm, 19mm and 21mm. At 19mm nozzle throat diameter, the engine gives better performance when compared with helically threaded manifold with conventional manifold. To increase the efficiency of the combustion process, turbulence was generated by knurling on the head of the piston[2]. Hence with a minute increase in turbulence ends with higher performance of the engine. The turbulence generated due to the knurling machined on piston head causes effective mixing air with fuel. Hence the turbulence will be intensified with many suitable means like varying geometry of head of cylinder, manifold for inlet, piston crown and combustion chamber. The air swirl experiment was done to compute emissions and performance [4] of mono-cylinder direct diesel injection engine is presented. By cutting the trapezoidal grooves on piston, required turbulence is generated in the combustion chamber. With varying configuration of trapezoidal grooves on the piston head at the rate of 2 grooves are utilized for finer amalgamation of air-fuel, increases performance. From the experimental work Trapezoidal Grooved Piston (TGP) by modifying the piston head with TGP 2, TGP 4 & TGP 8 respectively.

From this research work TGP2 gives superior performance of engine correlated with usual engine and reduced in the emissions.

III.

Experimental Setup

3.1. Technical Specifications

Table 1. Engine Specifications

Engine	4 Stroke Single Cylinder Diesel
Capacity	5kW
Fuel Capacity	10cc
Speed	1500 rpm
Current	230V Single Phase Generator
Loading Unit	Eddy Current Dynamometer
Dia of the bore	0.095m
Length of cylinder & bore	0.110m & 0.080m

3.2. Procedure

The performance of the C.I engines are increased by the movement of air motion within the cylinder was shown in the experimental setup, which controls the air fuel mixture. With the modification of the inlet manifold about 90 mm, 30mm the convergent section and the length of the 45mm divergent section gives the better mixing of fuel-air mixture. The performance can be evaluated.

- i. By varying the inside diameter 34 mm.
- ii. The modification is done on the head of the piston by knurling with 2mm depth of cut and with 3 frustum of cones.

The emission levels and performance of the engine can be obtained by the better mixing of fuel-air mixture[7]. Another last method for modification in the engine is made by changing inlet and exhaust valve for having effective air-fuel mixing. The diameter of Inlet valve is 36mm and with valve stem diameter 9.5mm and the exhaust valve diameter is 28mm with variation in pitch with the rate of 2mm and 4mm depth of thread cut. All these modifications are done to build-up the swirl of air motion as well as turbulence leads to effective cooling of surfaces of the cylinder by decreasing the surroundings heat loss. In suction, the air absorbs heat from the cylinder walls which reduces the delay period, in-turn leads to escalate the combustion efficiency in

the engine operation. By modifying piston cavity shape, intake system shape etc., causes the change of the fluid flow in the combustion chamber.

IV. Results & Discussions

The observations from the experiments suggest that convergent and divergent nozzle, inlet and exhaust manifold and piston crown designed with ¾ rated loads and correlated with usual engine. Piston with this 3 frustum of cones with 2mm depth of cut gave the best result compared with other techniques.

4.1. Brake Thermal efficiency

The BTHE (brake thermal efficiency) variation in respect with BP output exhibited with Figure 1. The BTHE (brake thermal efficiency) for usual engine at 75% of designed load is 28.94%. It can be observed that the variations in the convergent and divergent Nozzle and 3 frustum of cones with 2mm depth of cut and variations in inlet and exhaust valve diameters with 3 threads for every inch 2mm depth in cut give thermal efficiencies of 28.7%, 32.65% and 32.67%, at 75% of designed load. It is realized that BTHE increases with increase in BP for different configurations that are considered. It also noted from the figure that there is gain of 12.8% with 3 frustum of cones with depth in cut 2mm, compared with usual engine. This may be due to enhanced air swirl in combustion chamber, resulted for finer amalgamation of fuel-air and also effective combustion of charge in chamber of combustion.

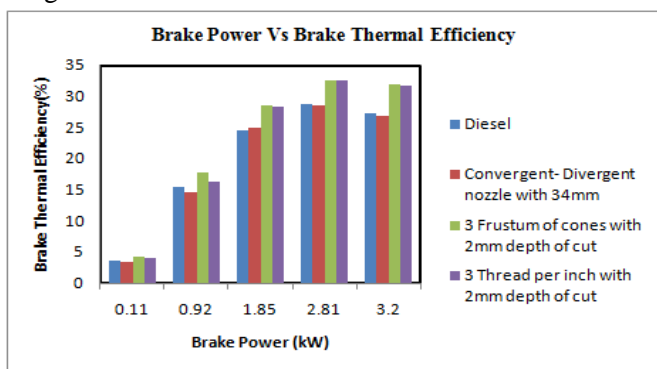


Fig. 1. Variation of Brake Power Vs Brake Thermal Efficiency

4.2. Brake Specific Fuel Consumption

Variations in BSFC with BP with varying load configurations are shown in Figure 2. The BSFC which is nothing but the conversion of the content of the chemical energy into useful work. At maximum speed of the engine the air and

fuel mixes effectively results for superior combustion. While at the 75% of designed load the fuel consumption is reduced to 0.24kg/kWh as compared to the diesel engine at 0.31kg/kWh. At maximum cylinder temperatures, the combustion is greater because of higher loads.

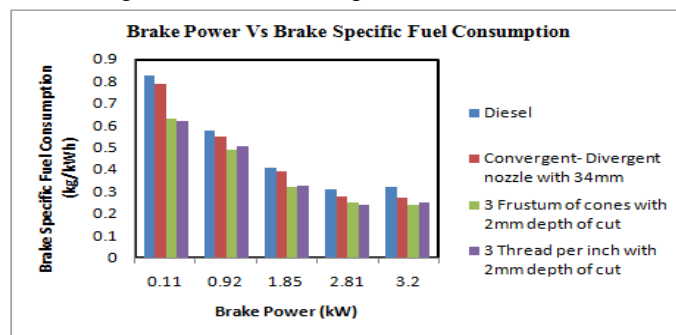


Fig. 2. Brake Power Vs Brake Specific Fuel Consumption

4.3. Exhaust Gas Temperature

Changes in EGT with BP for different load configurations are displayed with Figure 3.

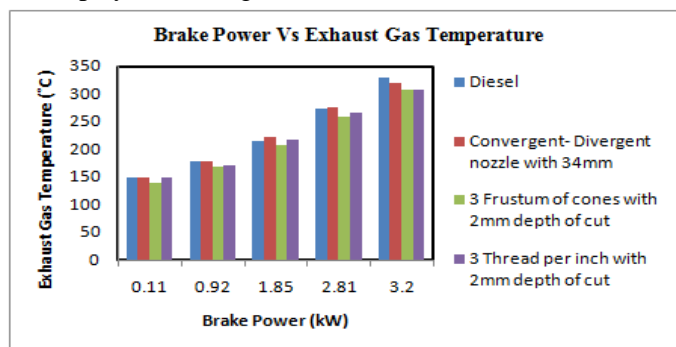


Fig. 3. Brake Power Vs Exhaust Gas Temperature.

EGT is decreased to three frustum of cones with 2mm depth of cut as compared to normal diesel engine is 5.26%. The ratio of fuel-air amalgamation in a volume Proportioned 75% of designed load and it is forced in to the cylinder where meeting at a high air temperature ,it automatically ignites and burns.

4.4. HC (Hydro Carbon Emissions)

Changes in Hydro Carbon Emissions (HC) with BP at varying load configurations are shown in Figure 4. Due to heterogeneous mixture, combustion process in C.I engine is complex where the un burnt gases and vapor of air and fuel mixes and combustion takes place simultaneously. At above 600°C in the presence of oxygen the hydrocarbon continues its reaction process in the outlet manifold, so from the tail pipe line HC emission is considerably less than the HC leaving form the cylinder through outlet manifold. The HC Emissions are decreased to 3frustum of cones with 2mm

depth of cut compared to usual engine is 17%.

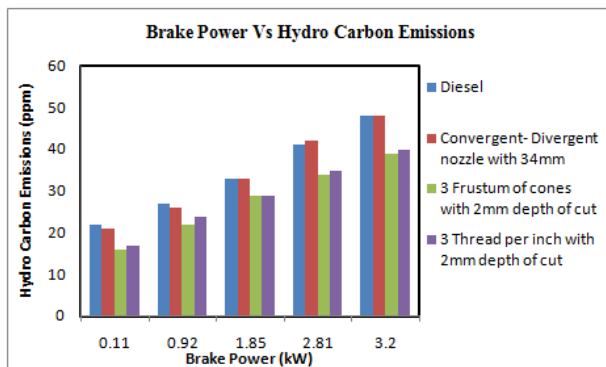


Fig. 4. Brake Power Vs Hydro Carbon Emissions

4.5. CO Emissions (Carbon Monoxide Emissions)

Changes of CO Emissions with BP with various configurations are in Figure 5. The reactants in the combustion process cannot be converted into CO₂ due to oxygen deficiency in air fuel mixture. The CO emissions are decreased for 3frustum of cones with depth of cut 2mm compared with conventional diesel engine is 20.9%.The CO Emissions are decreased by changing the piston crown, due to incomplete combustion.

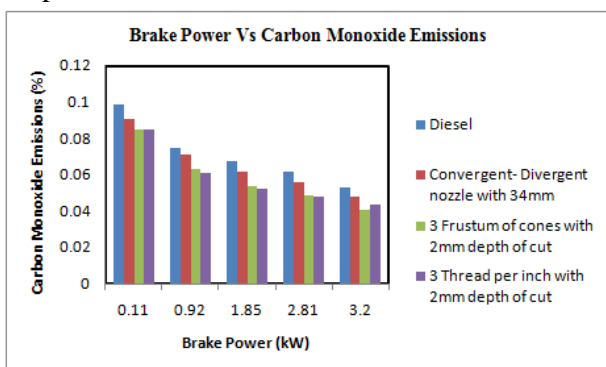


Fig. 5. Brake Power Vs Carbon Monoxide Emissions

4.6. NOx (Nitrogen oxide Emissions)

Change of NOx emissions with BP with various configurations are shown in Figure 6. The increase in the combustion of the temperature increases in the NOx amounts. Increasing The NOx Emissions are higher for 3frustum of cones with depth of cut 2mm as compared to conventional diesel engine is 25.8%.

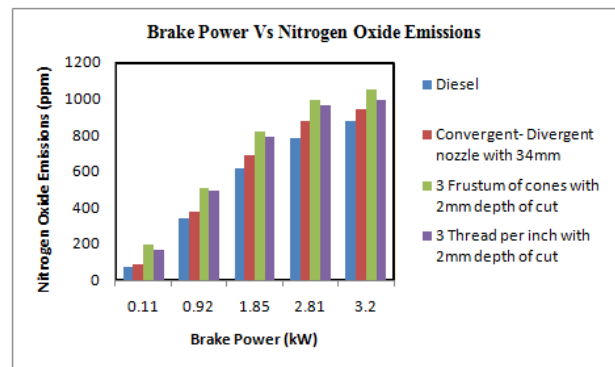


Fig. 6. Brake Power Vs Nitrogen Oxide Emissions

V. Conclusions

With the betterment of the air swirl motion in the inner part of the cylinder, at $\frac{3}{4}$ of the load, having 3 threads per inch, with depth of the cut 1.5mm, comparing with the conventional engine, the following outcomes are drawn.

- ❖ The BTH improves by 12.8%
- ❖ The BSFC is lowered by 22.5%.
- ❖ The EGT is lowered by 5.26%.
- ❖ The HC emissions are lowered about 17%.
- ❖ The CO emissions are reduced about 20.9%.
- ❖ The NOx emissions increase about 25.8%.

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Abbreviations

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- IC : Internal Combustion
- CI : Compression Ignition
- TGP : Trapezoidal Grooved Piston
- BTHE: Brake Thermal Efficiency
- BP : Brake Power
- BSFC : Brake Specific Fuel Consumption
- EGT : Exhaust Gas Temperature
- HC : Hydrocarbons
- CO : Carbon Monoxide

CO₂: Carbon Dioxide
NO_x : Nitrogen Oxide.

Availability of data and materials

The datasets supporting the conclusions of this article are included within the article.

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Competing interests

The authors declare that they have no competing interests.

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