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Research Article

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Effect of Tangential Grooves on Piston Crown of Diesel Engine with Preheated Cotton Seed Oil

C .V. Subba Reddy*
Dept of Mechanical Engineering
P. B. R VITS, Kavali,
AP, India

K. Hemachandra Reddy
Dept of Mechanical Engineering
JNTUCE, Anantapur,
AP, India

C. Eswar Reddy
Dept of Mechanical Engineering
SVU College of Engineering
Tirupati, AP, India

Abstract --- The world's rapidly dwindling petroleum supplies, their rising cost and the rapid growing of automobile pollutions from fossil petroleum fuels have led to an intensive search for alternative fuels to replace diesel fuel. Direct injection diesel engines are in service for both heavy duty vehicles, light duty vehicles not only in the fields of agriculture and transport sectors, but also stationary engines consume maximum percentage of petroleum based fuels and have the evident benefit of a higher thermal efficiency than all other engines. However, the direct injection diesel engine emits significant amount of pollutants such as CO, UHC, NOx, smoke etc. which are harmful to the environment. There is a wide variety of alternative fuels available as renewable fuels to replace diesel fuel. Vegetable oils, their properties being close to diesel fuel, may be a promising alternative for use in diesel engines. The high viscosity and low volatility of these vegetable oils are the major problems for their use in diesel engines. Such problem can be solved by the process of preheating of vegetable oils. In the present work experiments are conducted on D I diesel engine with tangential grooved piston, using cotton seed oil. The effect of tangential grooves on piston crown on the performance and emission characteristics of preheated cotton seed oil are studied and compared with diesel fuel and cotton seed oil (CO). Brake specific energy consumption decreases and thermal efficiency of engine slightly increases when operating on preheated cotton seed oil (PCO) with tangential grooves on piston crown.

Keywords --- Diesel engine, Cotton seed oil (CO), Preheated Cotton seed oil (PCO), Grooved Piston, Emissions.

I. Introduction

It is well known that in DI diesel engines swirl motion is needed for proper mixing of fuel and air. Moreover, the efficiency of diesel engines can be improved by increasing the burn rate of fuel air mixture [1]. This can be achieved in two ways; one by designing the combustion chamber in order to reduce contact between the flame and the chamber surface, and two by providing the intake system so as to impart a swirl motion to the incoming air [1,2]. The swirl ratio and resulting fluid motion can have a significant effect on air-fuel mixing, combustion, heat transfer, and emissions. During compression stroke, swirl ratio decreases with the decrease of angular momentum. When the piston moves close to the top dead center [TDC], the variation of swirl ratio depends on the shape of the combustion chamber [5]. For combustion chamber bowl-in piston, the gases are squished in to the piston bowl when the piston moves close to TDC. The momentum of inertia of gases decreases abruptly, leading to the increase of swirl ratio [Belair et al.,1983]. This increase in large scale flow speed contributes to the fuel spray being spread out which accelerates the processes of the fuel-air mixing and rate of combustion in diesel engines. The effect of swirl on combustion and emissions of heavy duty-diesel engines has been investigated by Benajes et al [8].and suggested that optimum level of air swirl that minimizes soot depends on engine running conditions. Timothy [7] has recognized that over-swirling causes centrifugal action which directs the fresh air away from the fuel, resulting in complete combustion and there by soot formation. The interaction between the swirl motion and the squish flow induced by compression increases the turbulence levels in the combustion bowl, promoting mixing and evaporation of fuel. In diesel engine, fuel is injected at the end of compression stroke, followed by the entry of compressed air tangentially into the injected fuel spray and then it mixes with air. The combustion of fuel depends on evaporation and mixing of fuel with compressed air. The effect of tangential grooves on piston crown on performance of the diesel engine with preheated cotton seed oil (PCO) is studied. Considering various vegetable oils but the preheated cotton seed oil is not considered with base line engine with tangential grooved piston [14].

II. Experimental Work

In the present study, four tangential grooves of different widths were produced on a piston of 80 mm diameter and their performance compared with each other. The tangential groove depth is kept constant at 2 mm. It is observed that groove of width 6.5 mm is found to give better results than those grooves of widths 5.5, 6.5, 7.5 mm. It is observed from Fig.1 (a) that the four tangential grooves on the piston crown have a significant effect on air flow motion in the piston bowl, when the piston approaches the top dead center [TDC]. This results in increasing the rate of evaporation, swirl motion of fuel &air and combustion efficiency. The combustion efficiency in the combustion chamber depends on the formation of homogeneous mixture of fuel with air. The formation of homogenous mixture depends on the amount of turbulence created in the combustion chamber. It is observed from the Fig.1 (b), as the piston approaches the TDC, the part of compressed air enters the bowl through four tangential grooves and forms a swirl ring in the combustion bowl. The effect of the geometry of the grooves on combustion performance is analyzed in the study.

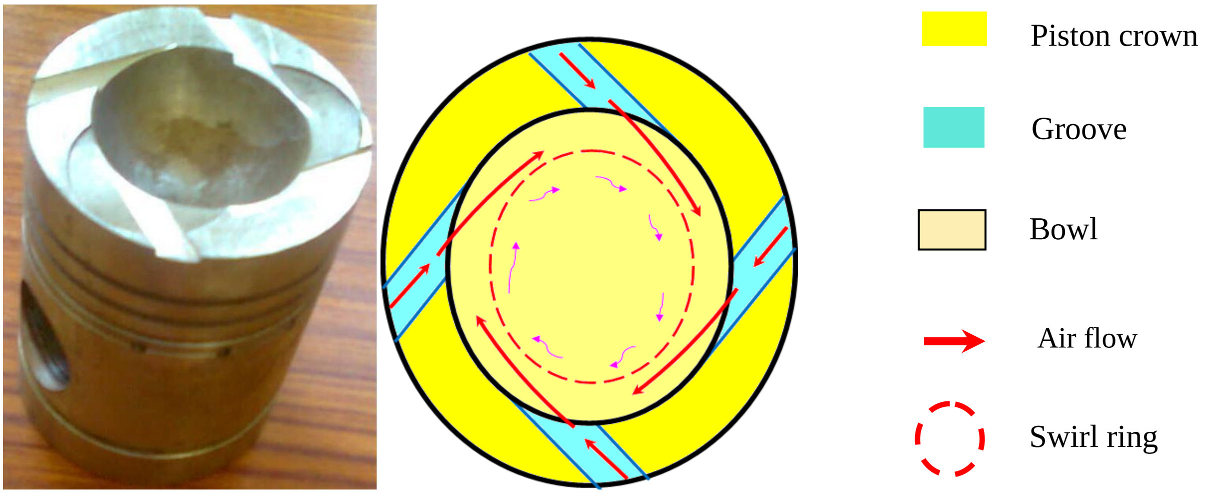


Fig.1 a). Tangential grooved piston. *Fig. b) Swirl motion in Tangential grooves*

A. Fuel Preheating Setup

The high viscosities of vegetable oils are not conducive for direct use into the engines. Preheating is one of the simple methods of reducing the viscosity of a fuel. Fig.2 shows a fuel tank fabricated in the laboratory for heating the fuel. It is basically a steel container fitted with an electric heater, stirrer, thermostat and temperature sensor. A small hole is provided at the bottom of the container to supply the fuel to the engine with the help of a hosepipe. During heating of the fuel by using the electric heater and mechanical stirrer works simultaneously, when input supply is added. The temperature of the fuel is displayed on a digital temperature indicator that is connected to a temperature sensor. The temperature sensing element is placed in the fuel such that it is not touching the walls of the container. The purpose of thermostat is to control the temperature of the fuel to be heated. It can be set at any desired temperature. Thermostat cuts–off the input supply to the heater when required temperature is reached. It again gives supply when the temperature of fuel goes down below the pre-set value.

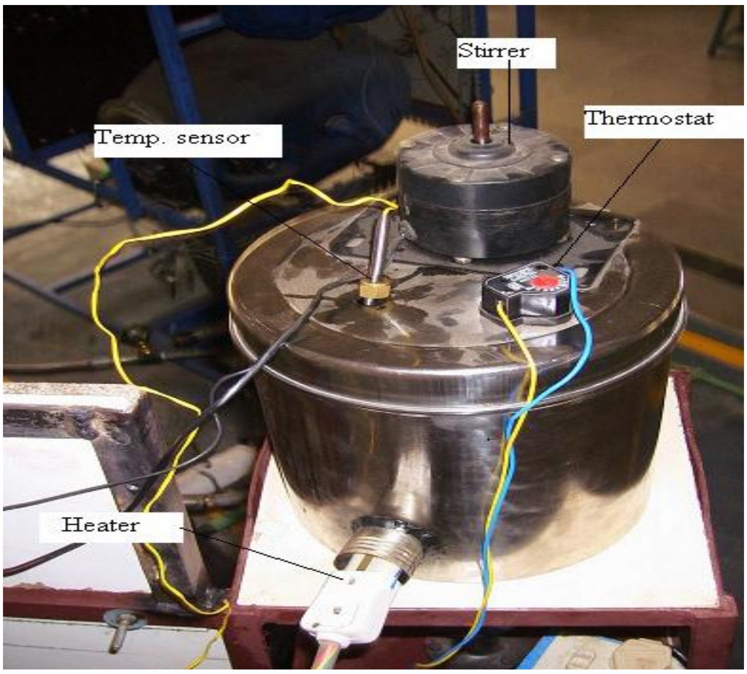
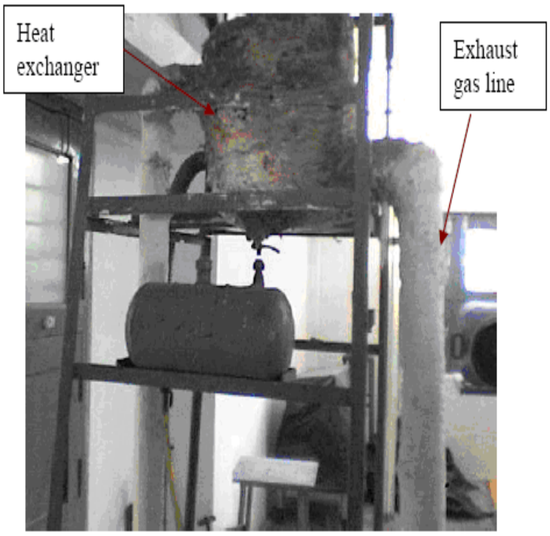


Fig.2 Fuel Tank for pre-heating of fuel

In order to utilize the heat of exhaust gases, a small heat exchanger has been fabricated. It is a typical shell and tube heat exchanger where fuel flows in tubes and exhaust gases in the shell. The setup made for this purpose is shown in Fig.3 (a) and Fig.3 (b) shows its layout. The exhaust gas pipe line and the heat exchanger are insulated to minimize the heat losses. The fuel is made to flow through the heat exchanger by gravity, while with the help of small quantity of exhaust gases flowed due to pressure difference. At higher loads the fuel could be heated up to 55^{0}C in this heat exchanger.



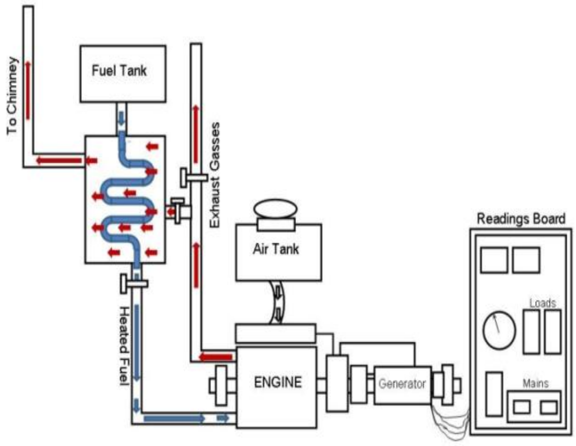


Fig. 3 a) Experimental setup for preheating *b). Schematic diagram for fuel pre-heating of oil with exhaust gases*

III. Equipmentand Test Procedures

A. Engine Setup

The experiments are conducted on a 5 H.P single cylinder, direct injection diesel engine. The engine is coupled with an A.C alternator for loading it. The engine can be loaded from zero to maximum value in 6 steps with the help of hand operated electrical switches as shown in Fig. 4(a). The specifications of D. I. Engine are shown in table.1

TABLE. 1. The specifications of D.I.Diese1engine

Make	Kirloskar
Type	4 stroke, Direct injection, Water cooling
Number of Cylinders	One
Bore	80 mm
Stroke	110 mm
Compression Ratio	16.5:1
Capacity	5 H.P
Speed	1500 rpm(constant)
Injection timing	23^0 BTDC
Type of loading	Electrical resistance

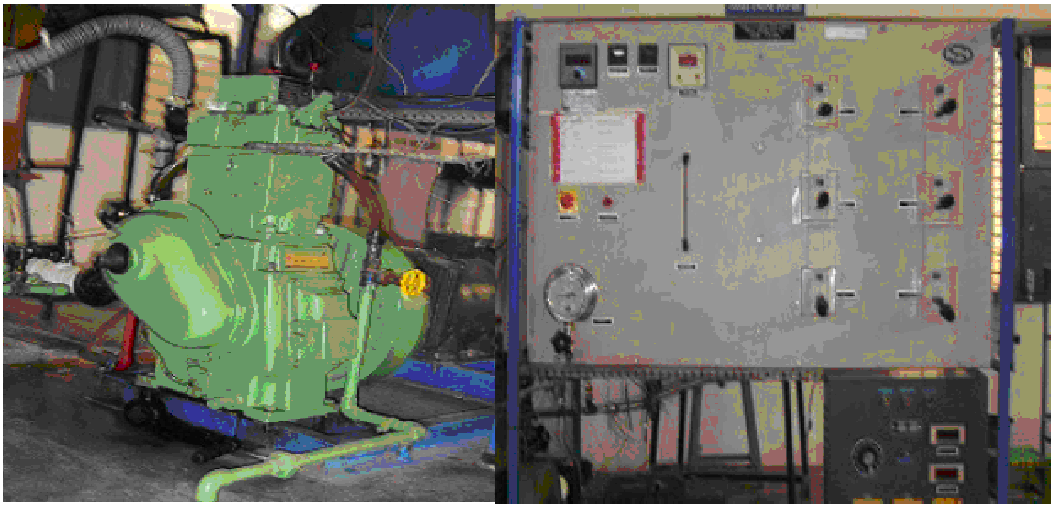


Fig. 4 Test Engine

Experiments are conducted on D.I. Diesel engine with four configurations. Emissions and performance characteristics of diesel engine with tangential grooved piston configurations are compared with that of the base line engine [BLE].

- BLE-1: Base line engine with diesel fuel
- BLE-2: Base line engine with cotton seed oil (CO)
- BLE-3: Base line engine with preheated Cotton seed oil (PCO)
- BLE-4: Base line engine with tangential grooves piston(TGP) and Preheated cotton seed oil (PCO)

The engine is started with diesel as base line fuel and run the engine with cotton seed oil (CO) and preheated cotton seed oil. For the experimentation, the fuel injection system at 200 bar is used for the fuels of diesel, cotton seed oil (CO) and preheated cotton seed oil (PCO). In summary, the base line engine with configuration-4 (BLE-4) enhances the turbulence and hence results in better air-fuel mixing process among all four configurations in DI diesel engine. As a result, soot emissions are reduced, although the NOx is slightly increased due to better mixing and a faster combustion process. Since the reduction of soot [which is of global concern today] is more than the increase of NOx, it can be concluded that the diesel engine with configuration-4 (BLE-4) is the best option in terms of performance and emissions. The steady state engine performance testing is carried out with diesel fuel.

IV. Results And Discussion

The experiments are conducted on D. I. Diesel engine with three fuels of diesel, cotton seed oil at room temperature (CO) and pre-heated cotton seed oil (PCO) at injection pressures of 200 bar ester. And also observed the effect of tangential grooves on piston crown of diesel engine preheated cotton seed oil (PCO). The results thus obtained are compared with that of diesel fuel at different load conditions.

A. Brake Thermal Efficiency

Figure.5 shows the effect of preheating and tangential grooves on thermal efficiency of the engine. The efficiency of all test fuels increased with load. This may be because of reduced heat losses at higher load conditions. The efficiency of the engine for CO without heating is about 22% (relative percentage) lowers than that of diesel at 70% load. When the engine is run with preheated CO, the efficiency is increased by 8.75% compared to that of CO without heating. But when engine is run with configuration-4(BLE-4), the efficiency of engine is nearer to diesel at lower load and but increased by 18.5% at 70% load compared to diesel fuel and higher than preheated CO and CO (without heating) due to better combustion produced by tangential grooved piston.

B. Brake Specific Energy Consumption

Fig.6 shows the brake specific energy consumption of the three test fuels for four configurations of engine at different load conditions. It is the lowest for diesel fuel compared with CO and PCO fuels at all loads. However the engine is operated with tangential grooved piston for preheated CO, the energy consumption is same at lower loads and less than that of unheated CO and diesel at 70% load. These results showed that the base line engine with configuration-4, the performance of the engine is considerably improved.

C. Emission Parameters

1) *Smoke Emissions:* The variation of Smoke opacity at different load conditions for all test fuels is shown in Fig.7. It is observed that the smoke opacity level is increased with load. This may be because of local fuel rich mixtures at higher loads which results in incomplete combustion. Smoke opacity of both heated and unheated CO is more than that of diesel. But the smoke opacity of diesel engine with configuration-4(BLE-4) is found to be lower at70% load due to better mixing and evaporation of fuel. At higher loads, smoke opacity is less for preheated CO compared to unheated CO.
2) *NOx Emissions:* These emissions are generally more in diesel engines because of their high temperature operations and also availability of excess oxygen. As shown in Fig.8. NOx emissions are increased with load for all the fuels. This is because of higher in-cylinder temperatures that prevail at higher loads. NOx emissions are found to be the slightly low for CO and heated CO compared with diesel at all loads due to incomplete combustion. But the engine with configuration-4(BLE-4) shows that NOx emissions are lower at low load conditions and slightly higher at 70% load conditions due to better combustion during pre combustion stage compared with diesel and unheated cotton seed oil (CO).
3) *Carbon monoxide (CO) emissions: Fig.9* shows the emissions of carbon monoxide for these fuels of cotton seed oil (CO), preheated cotton seed oil (PCO) and diesel with different configurations. The effect of an increase in load on CO emissions for diesel fuel is found to be insignificant. But for the other two fuels it increased with load. The CO emission of preheated Cotton seed oil (PCO) is found to be less than that of unheated CO. In diesel engine, swirl motion of air plays a major role in the increase of fuel- evaporation and air-fuel mixing, thereby resulting in reduction of the combustion time and increasing of the combustion efficiency. With the higher turbulence in the combustion chamber, the oxidation of carbon monoxide is improved which reduces the CO emissions. The lowest carbon monoxide emission is with BLE-4 configuration compared to BLE-1 configuration and about 17.5% by volume at 70% load operation. It is observed from Fig.9 that the carbon monoxide emissions of unheated oil and preheated oil are higher than diesel.

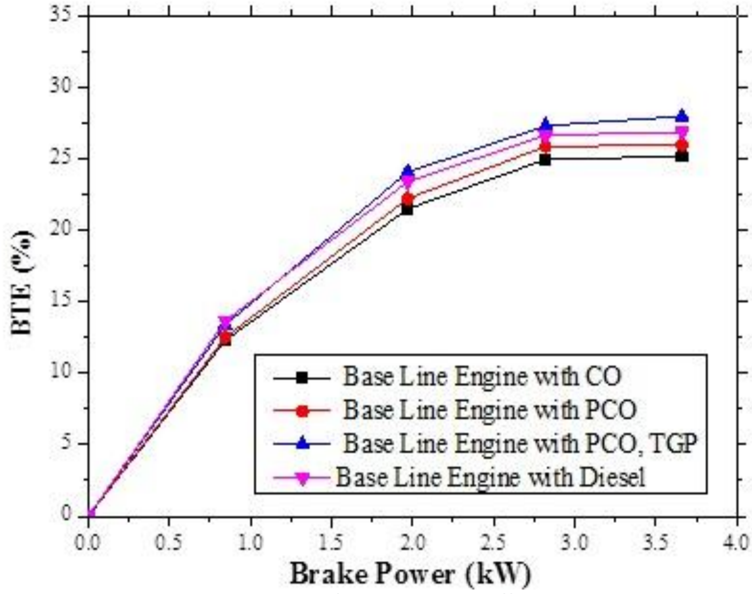


Fig. 5 Variation of Brake Thermal Efficiency with Brake Power

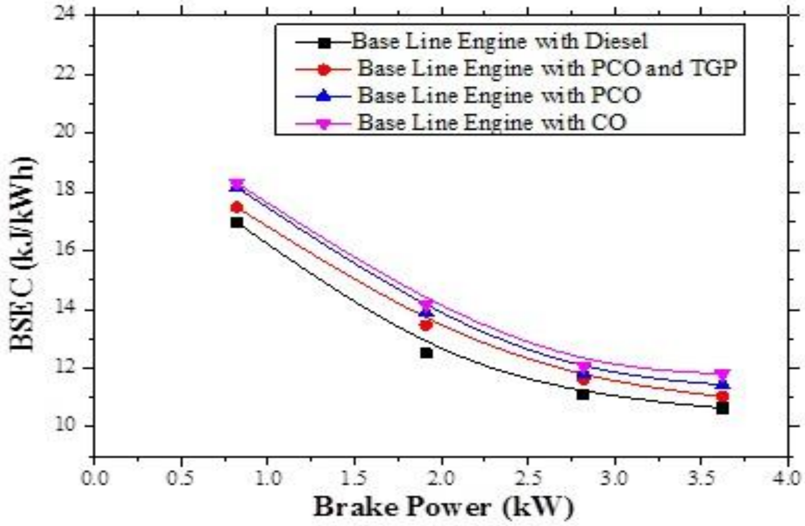


Fig. 6 Variation of Base Specific Fuel with Brake Power

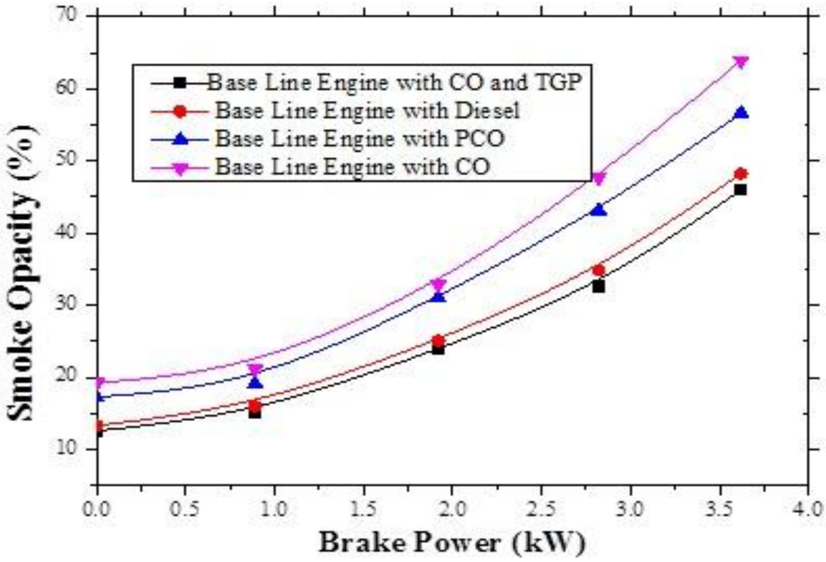


Fig. 7 Variation of Smoke Opacity with Brake Power

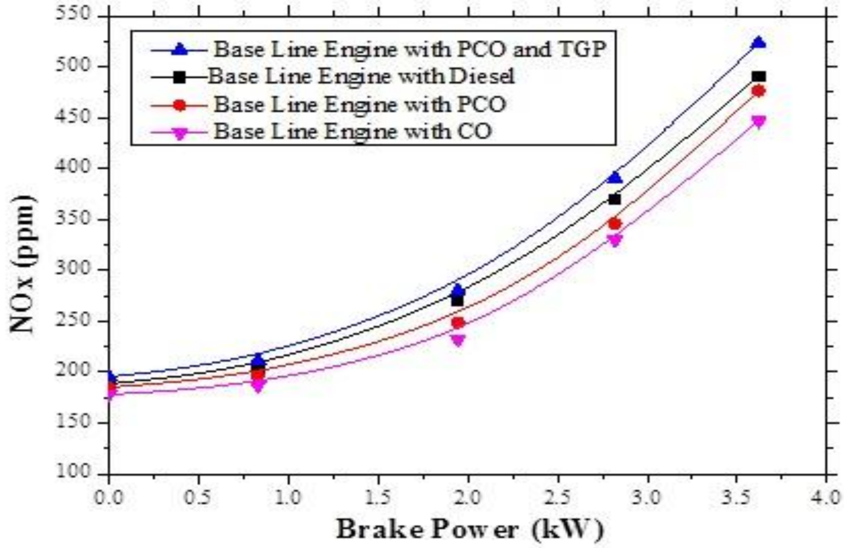


Fig. 8 Variation of NOx with Brake power

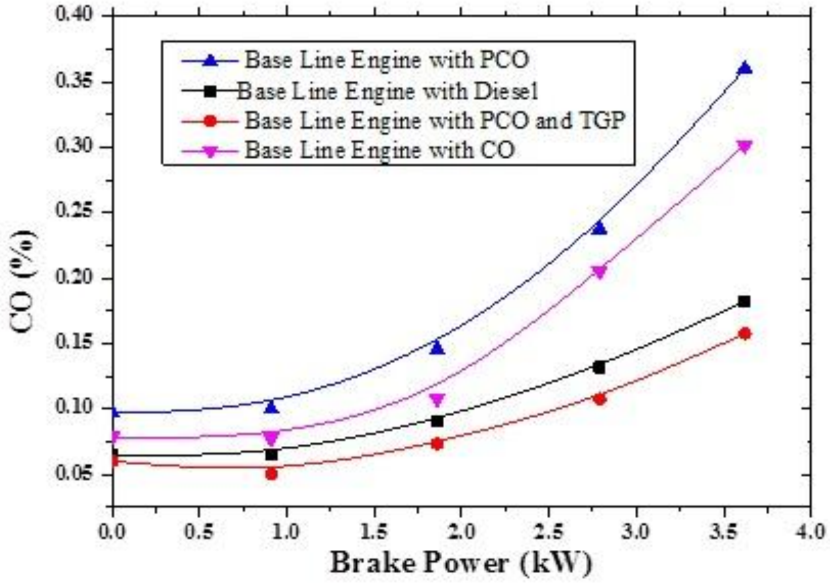


Fig. 9 Variation of Carbon Monoxide with Brake Power

V. Conclusion

Based on the experimental results for the base line engine with different configurations, the following conclusions are drawn:

- The brake thermal efficiency of diesel engine with configuration-4 (BLE-4) is increased by about 22% compared to base line engine [BLE-1] at 70% load operation.
- Due to higher swirl motion there is drop in carbon monoxide (CO) of BLE-4 (Base line Engine with Preheated cotton seed oil and tangential grooved piston) by 17.5% as compared to base line engine [BLE-1] at 70% load operation. It is observed that the tangential grooves on piston crown are more effective to reduce the carbon monoxide emissions.
- With increase of mixing and evaporation of air and fuel due to higher turbulence motion in the combustion chamber, the reduction in the smoke opacity of BLE-4 is low by about 7.25% at 70% load operation compared to diesel (BLE-1).
- Due to the higher operating temperatures and with the oxygen present in the combustion chamber, the NOx emission is slightly higher for the configuration-4 compared to base line engine at 70% load operation.
- With the grooves on the piston crown, the clearance volume in the combustion chamber increases and the compression ratio decreases further slightly. It is needed further investigation of engine with configuration-4 (BLE-4) about the effect of slightly decrease in compression ratio due to tangential grooves on piston crown.

It is concluded that out of four different configurations of base line diesel engine, the base line engine with tangential grooves and preheated cotton seed oil [BLE-4] proved to be better in all respects.

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