EFFECT OF TANGENTIAL GROOVES ON PISTON CROWN OF D.I. DIESEL ENGINE WITH BLENDS OF COTTON SEED OIL METHYL EASTER

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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 transesterification. In the present work 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. Brake specific energy consumption decreases and thermal efficiency of engine slightly increases when operating on blended fuel of 20% Cotton seed oil methyl ester (COME) and 80% diesel (20BD) than that operating on diesel fuel.

From the experimental investigations, it is found that 200 bar is the optimum injection pressure with 20BD blend of COME, which has resulted in better performance and emission characteristics among the biodiesel blends. Based on the results it is concluded that the base line engine with tangential grooved piston configuration(TGP-2) gives maximum performance in all aspects and reduces emissions.

Keywords: *D.I. Diesel engine, Cotton seed methyl ester, Tangential Grooved Pistons, Blended fuel, Pressure, Emissions*.

1. 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 centre [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 influence of the injection pressure on the performance of the diesel engine is studied. Considering various bio diesel blends but the cotton seed methyl ester blended fuel is not considered [GBR etc].

2. OBJECTIVE OF THE STUDY

The present study is to investigate the suitable tangential grooved piston configuration to increase swirl motion in the combustion chamber and vegetable oil blended fuel at 200 bar injection pressure for which the diesel engine delivers better efficiency with minimum pollutants and there by the suitable replacement for diesel oil. To achieve the better efficiency and low emission, the following experiments are carried out as explained below.

3.1 EXPERIMENTAL WORK

The piston crown of 80 mm diameter of base line engine is modified by producing four tangential grooves. In the present experiment, four tangential grooves of different widths of 5.5mm, 6.5mm and 7.5 mm were produced on three pistons of 80 mm diameter and maintaining constant depth of 2 mm in each piston. The experiments are conducted with these three different tangential grooved pistons and their performance and emissions are compared with base line piston of diesel engine (BLE). It is observed that the piston with tangential grooves of width 6.5 mm is found to give better results than those grooves of widths 5.5 mm, 6.5 mm, 7.5 mm and the effect of the geometry of the grooves shown in Figure-1 on combustion performance is analyzed in the study. The three different tangential grooved pistons for the experiments are shown in Figure-2

Figure-1(a): Tangential grooved piston.

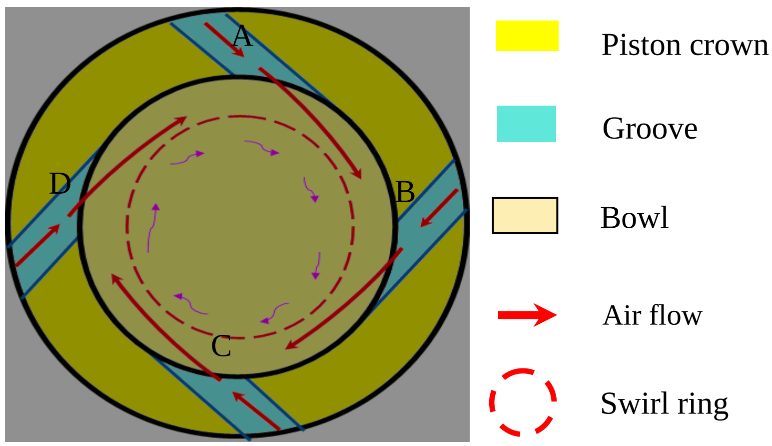


Figure-1(b): Swirl motion in tangential grooves

Tangential Grooved Pistons for Experiments

Figure-2(a).TGP-1

Figure- 2(b) TGP-2

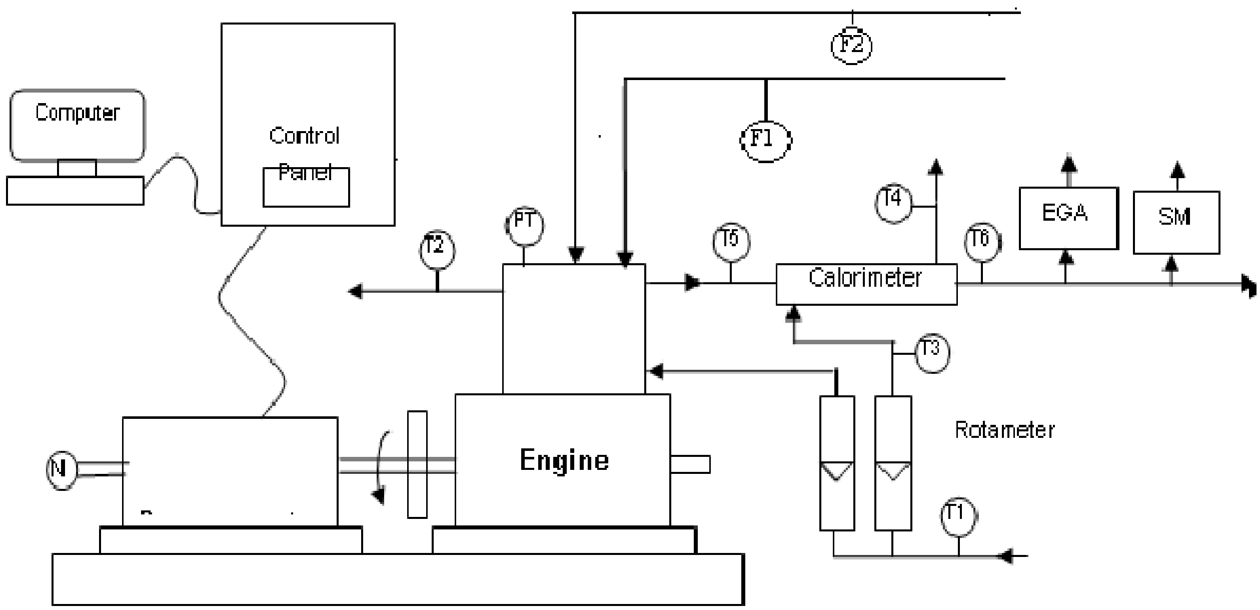
Figure-2(c) TGP-3

3.2. EXPERIMENTAL SETUP

The experimental setup is shown in Figure-3 with accessories and measuring instruments. A Kirloskar make single cylinder four stroke, naturally aspirated, direct injection, water-cooled diesel engine test rig of 3.72 kW(5BHP) with 1500 RPM, is directly coupled to an eddy current dynamometer. The engine and the dynamometer are interfaced to a control panel, which is connected to computer for automatic recording the experimental observations such as fuel flow rate, temperatures, air flow rate, loads, water flow rate, etc., are measured. Data such as exhaust gas temperature, water inlet and outlet temperature, fuel consumption rate, air flow rate, brake power, torque, smoke opacity, UHC, CO are recorded at these conditions .

Table-1: Blends of Cotton Seed Oil Methyl Ester with Diesel fuel

S.NO	Blends	Cotton Seed Oil Methyl Ester (COME) (%)	Diesel (%)
1	0 BD	0	100
2	10 BD	10	90
3	20 BD	20	80
4	30 BD	30	70
5	100 BD	100	00



T_1, T_3=Inlet Water Temperature.
T_4 = Outlet Calorimeter Water Temp.
T_6 = Exhaust Gas Temp. Outlet to Calorimeter
F_2= Air Intake DP unit
EGA = Exhaust Gas Analyzer
T_2 = Outlet Engine Jacket Water Temperature.
T_5 = Exhaust Gas Temp. Inlet to Calorimeter.
F_1 = Fuel Flow Measuring unit.
PT = Pressure Transducer
SM= Smoke Meter

Figure-3: Experiment Setup

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

1. BLE-1: Base line engine with diesel fuel (0% COME +100% Diesel)
2. BLE-2: Base line engine with 20BD (20%COME + 80% Diesel)
3. BLE-3: Base line engine with tangential grooves size of width 5.5 mm and depth 2 mm on the piston crown [TGP-1], 20BD (20%COME + 80% Diesel)
4. BLE-4: Base line engine with tangential grooves size of width 6.5 mm and depth 2 mm on the piston crown [TGP-2], 20BD (20%COME + 80% Diesel)
5. BLE-5: Base line engine with tangential grooves size of width 7.5 mm and depth 2 mm on the piston crown [TGP-3], 20BD (20%COME + 80% Diesel)

For the experimentation, diesel and 20BD are used as base line fuels at 200 bar injection pressure. The steady state engine performance testing was carried out with diesel fuel and its blends.

4. RESULTS AND DISCUSSION

The results obtained from three different sizes of tangential grooved pistons of TGP-1, TGP-2 and TGP-3 respectively for all blends of cotton seed methyl ester with 0BD, 10BD, 20BD, 30BD and 100BD blends are analyzed. The results thus obtained are compared with that of base line diesel engine (BLE). Based on the output results, the discussions are presented in the following

The base line engine with configuration-4 (BLE-4) enhances the turbulence and hence results in better air-fuel mixing process among all five configurations in D.I. diesel engine. As a result, soot emissions are reduced, although the NOx is 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.

4.1 BRAKE SPECIFIC ENERGY CONSUMPTION (BSEC)

Figure-3: depicts the variation of BSEC with different bio diesel blends for 30%, 50%, 70% load of base line engine without and with tangential grooved pistons(TGP-2). It is observed that the BSEC has decreased with increase in load. The BSEC of BLE with tangential grooved piston is lower for 20BD at all load operations. It is found that the BSECs for 70% load operation of BLE without grooves and with tangential grooves (TGP-2) are 13.6 and 12.7 MJ/kW-hr respectively. At 70% load operation of BLE with configuration-4(BLE-4), the reduction in BSEC may be due to improved combustion with better evaporation and mixing of fuel with air is improved by 7.02% compared BLE without tangential grooves. It is also observed from the Figure-3 that the 20% blended fuel (20BD) shows low BSEC compared other blended fuels of 0BD, 10BD, 20BD, 30BD and 100BD.

4.2 Exhaust Gas Temperature

The turbulence produced in the combustion chamber depends on whirl motion of air during suction stroke and at the end of compression stroke which increases with number of tangential grooves on the piston crown. Exhibit- 3 shows the variation of exhaust gas temperature with brake power for different base line engine configurations. From the results, it is concluded that the exhaust gas temperature of base line engine [BLE] is lower than all other base line engines with different configurations over a wide range of operation. The base line engine with tangential grooves [BLE-4] shows maximum exhaust gas temperature due to effective combustion of fuel rated loads. It is observed that the temperature at 70% load for BLP-4 and BLE-5 with 20% blended fuel (20BD) is 9.2% and 6.7% more than base line engine without grooves (BLE-1).

4.3 Brake Thermal Efficiency

The variation of brake thermal efficiency with power output for base line engine with different configurations is as shown in Figure-4. The brake thermal efficiency of the diesel engine depends on the combustion efficiency of the engine. This further depends on the formation of homogeneous mixture with turbulence which increases with whirl motion of air in the combustion chamber. The brake thermal efficiency of the base line engine with TGP-2 configuration is increased by 7.6% for 70% load operation compared with base line engine. Similarly the brake thermal efficiency of BLE- 5 and BLE-3 are 6.2% and 3.68% more than BLE-1.

4.4 Volumetric Efficiency

The effect of base line engine with different configurations on the volumetric efficiency is depicted in Figure-5. The temperature generated in the combustion chamber depends on turbulence created by the tangential grooves on the piston crown. For base line engine with configuration-4 [BLE-4], the drop in volumetric efficiency is more and is about 1.59% as compared to BLE for 70% load operation. It is observed that the volumetric efficiencies of BLE-2 and BL-3 lie in between BLE and BLE-5. The fall in volumetric efficiency has an undesirable effect on power output. So the power output of DI diesel engine with configuration-4 (BLE-4) can be compensated by turbo charging.

4.5 Combustion Characteristics

The combustion duration increases with increase in power output with all the fuels. This is due to increase in the quantity of the fuel injected. The combustion efficiency in the combustion chamber can be enhanced with the turbulence in that. The combustion characteristics are explained as below.

4.5.1 Ignition Delay Period

The general phenomenon is that with increasing the load the ignition delays are reduced. The variation in ignition delay with power output is illustrated in Figure -6. It is observed that the ignition delay of diesel engine of piston crown with different number of tangential grooves is lowered as compared with base line engine [BLE-1] due to higher swirl flow in the cavity of piston. The effect of this is to reduce the time lag for initiating combustion, bringing down delay periods. The diesel engine with TGP-2 (BLE-4) showed the lowest ignition delay among all the configurations tested and base line engine without grooves (BLE-1) shows marginally higher ignition delay. The reduction in the ignition delay of BLE-4 and BLE-5 are 5.2% and 4.95% for 70% load operation compared to BLE-1. The ignition delay of BLE-2 and BLE-3 lies between BLE-1 and BLE-5.

4.5.2 Rate of Pressure Rise

Figure-7: depicts the rate of pressure rise with power output. It is observed that the maximum rate of pressure rise is with BLE-4 and minimum for base line engine [BLE-1]. Due to high turbulence, complete combustion occurs and the combustion efficiency increases, consequently higher rate of pressure increases. At 70% load operation the rate of pressure rise is 10.4% and 9.76% for BLE-4 and BLE-5 compared to BLE-1.

4.5.3 Carbon monoxide

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. Figure-8. shows the variation of carbon monoxide with different configurations of engine. The lowest carbon monoxide emission is with BLE-4 configuration compared to BLE-1 configuration and about 9.75% by volume at 70% load operation. For the other configurations the values varies in between these two extremes.

4.5.4 Smoke Density

The variation of exhaust smoke emissions for different engine configurations is as shown in Figure-9: The higher turbulence in the combustion chamber results better combustion and oxidation of the soot particles which further reduces the smoke emissions. Due to the complete combustion of fuel with swirl motion of excess air the smoke emissions are marginal. At 70% load operation, the smoke emissions of BLE-4 are reduced by about 26.9% compared to base line engine [BLE-1]. It is seen that the reduction in the smoke emissions of BLE-5 is 26.54% and also diesel engine with configuration-3 and 2 reduce emissions by 14.97% and 8.2% compared to BLE-1.

4.5.5 Unburned Hydrocarbons

The variation of the hydrocarbon emissions for base line engine with different configurations is shown in Figure-10: The main sources of hydrocarbon emissions in diesel engine are wall quenching, lean mixing and the burning of lubricating oil. The hydrocarbon formation in the higher swirl motion engine is less compared to base line engine and this higher swirl motion in the combustion chamber is produced by the tangential grooves on the piston crown. At 70% load operation the BLE-4 gives a maximum reduction of hydrocarbon emission level is observed and is about 10.5% compared to BLE-1. It is also observed that with BLE-2, BLE-3 and BLE-5, the reduction in hydrocarbon levels are about 3.2% 5.86% and 7.2% compared to BLE-1.

CONCLUSIONS

Based on the experimental results for the base line engine with different configuration, the following conclusions are drawn:
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 Figure-1(b), as the piston approaches the TDC, the part of compressed air enters the bowl at points A, B, C & D through the tangential grooves and forms a swirl ring in the combustion bowl which increases combustion efficiency due to better evaporation and mixing of fuel with air

- The brake specific energy consumption diesel engine with configuration of TGP-2, 20BD (BLE-4) is decreased by 7.2% compared with base line engine with diesel fuel.
- The brake thermal efficiency of diesel engine with TGP-2 configuration (BLE-4) is increased by about 7.6% compared to base line engine [BLE-1] at 70% load operation.
- Due to higher swirl motion there is drop in volumetric efficiency of BLE-4 by 1.2% as compared to base line engine [BLE-1] at 70% load operation.
- With increase of mixing and evaporation of air and fuel due to higher turbulence motion in the combustion chamber the reduction in the ignition delay of BLE-4 is more by about 5.25% at 70% load operation compared to BLE-1.
- Due to the higher operating temperatures and with the oxygen present in the combustion chamber, the smoke, CO, UHC emissions are reduced 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 concluded that out of five different diesel engine configurations, the base line engine with TGP-2 configuration [BLE-4] proved to be better in all respects. At 200 bar with 20% COME (20BD), better efficiency and low emissions are obtained.

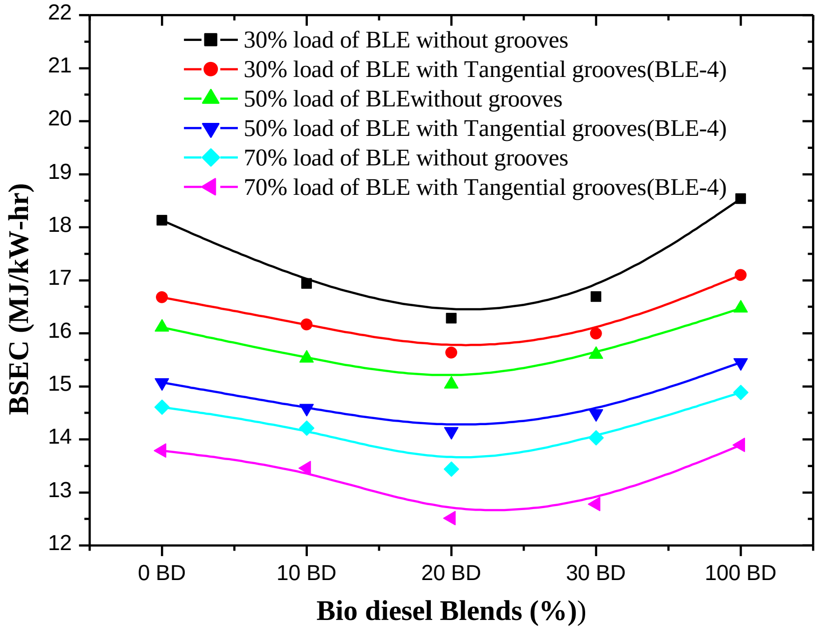


Figure-3: Bio Diesel Blends vs BSEC

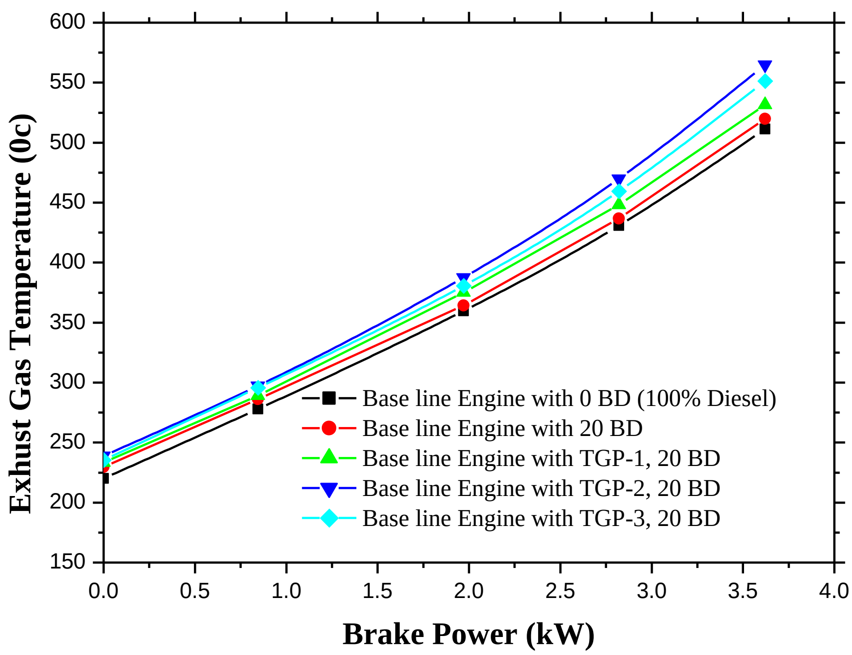


Figure-4: Brake Power vs EGT

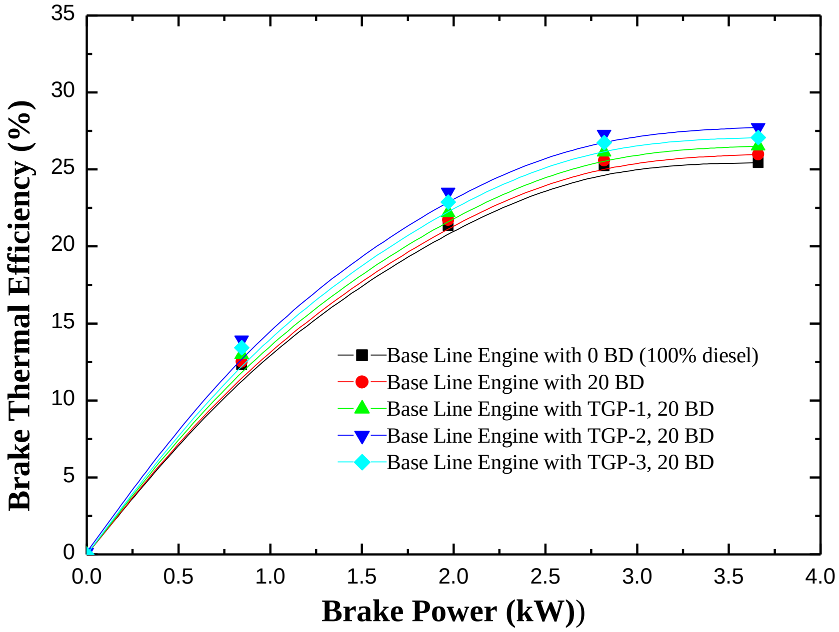


Figure-5: Brake Power vs Brake Thermal Efficiency

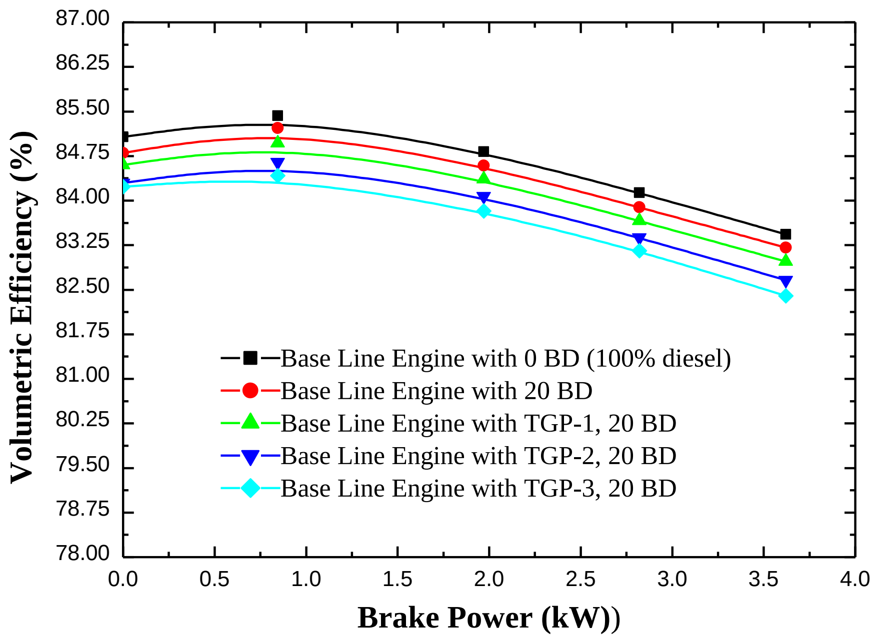


Figure-6: Brake Power vs Volumetri Efficiency

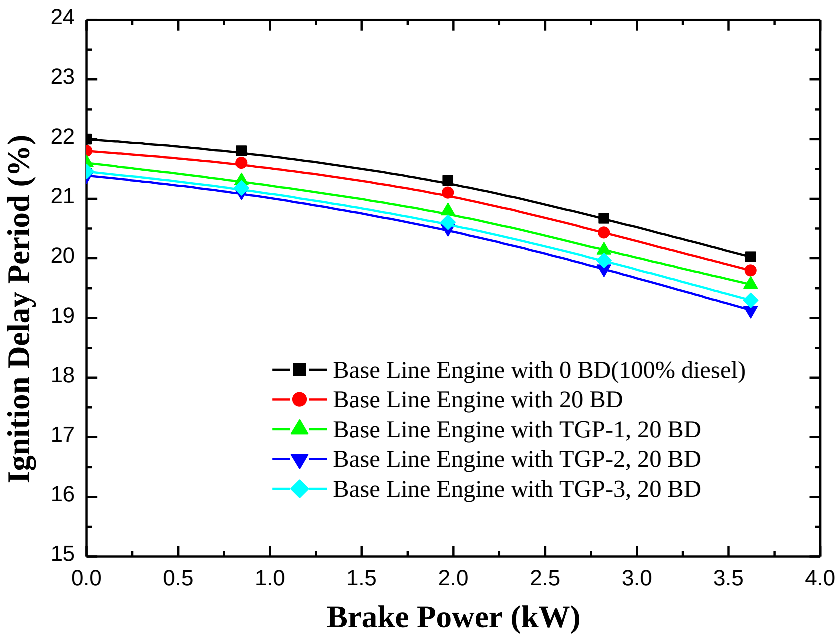


Figure-7: Brake Power vs Ignition Delay Period

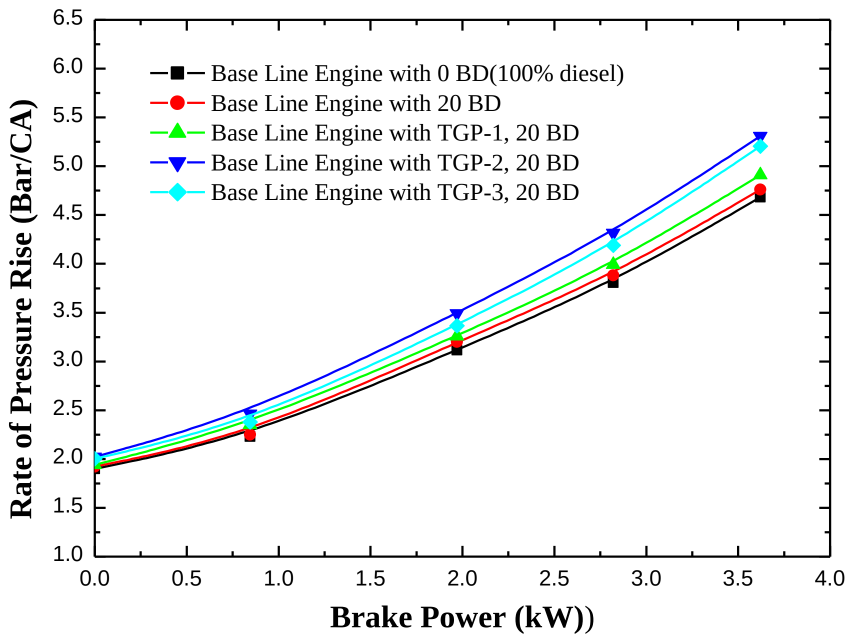


Figure-8: Brake Power vs Pressure Rise

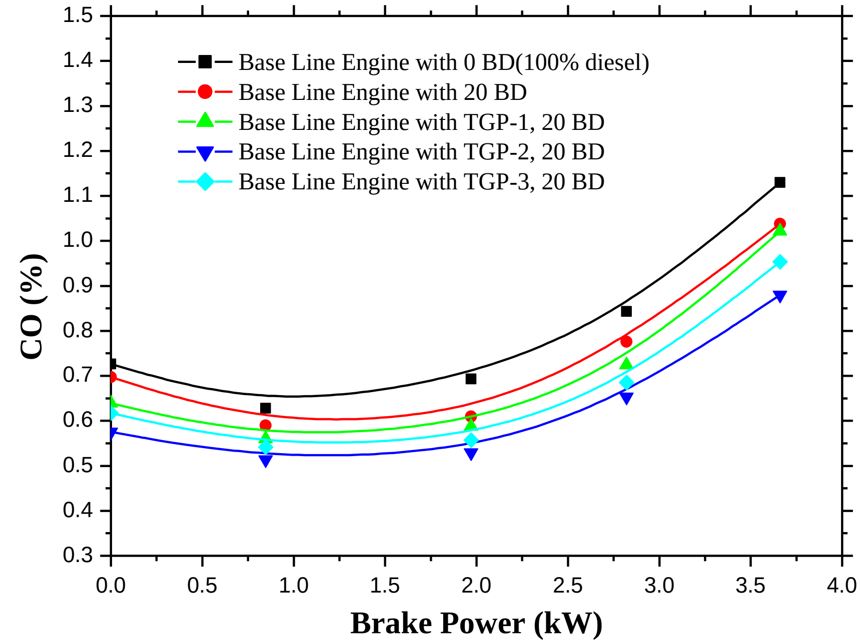


Figure-9: Brake Power vs Carbon monoxide

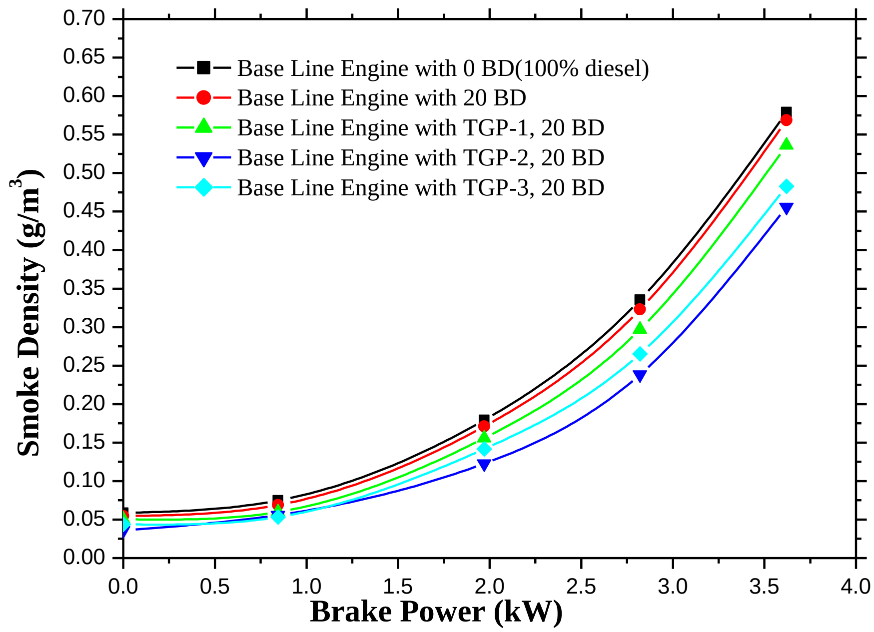


Figure-10: Brake Power vs Smoke Density

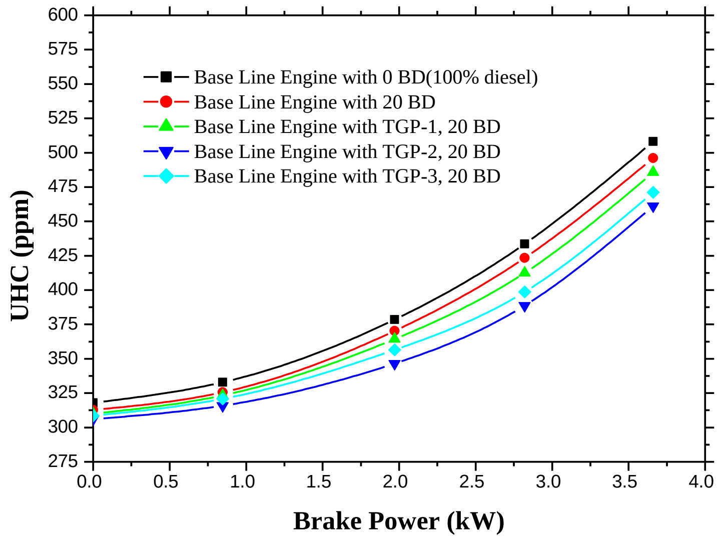


Figure-11: Brake Power vs Unburnt Hydrocarbons

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