Performance and Analysis of Single and Twin Spark Plug Direct Injection Engine: Gasoline Fuel

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Abstract

This paper describes some results of the research in the area of multiple spark ignition engines In the single spark plug engine there is a high exhaust emission and low break thermal efficiency because of incomplete combustion .To overcome this problem new dual spark plug engine is developed. Dual spark ignition system has proved their potential in improving the performance of the engines and improved emissive characteristics as compared with the single spark plug ignition system. Recently a new type engine has been introduced which uses triple spark plugs at different location, controlled by an advanced electronic control unit. This advanced electronic control unit uses three different ignition timings with variable spark plug number. Experiments were conducted at different load conditions and different types of engines has proved that dual spark plug ignition engines are surely better than a single spark plug engine ,but triple spark ignition engines has proved their potential .It is experimentally investigated that in the single spark plug mode the centrally located spark plug is most effective and gives best performance. In the dual ,triple and four spark plug mode if the central location of the spark plug is not possible because of the design of the engine than spark plugs were considered to be located diametrically opposite to each other on cylinder head axis symmetrically. According to Dimensionless distance from the cylinder centre to spark plug location on cylinder head, rsd = rs/R, five locations (rsd = 0, 0.25, 0.50, 0.75, and 1.0) were considered. Inevitably rsd = 0 corresponds to the single spark arrangement that the plug is located at the centre. To comparison, single-spark plug configurations were also considered for other selected spark plug locations. Current paper investigate the effect of multi spark plug to the single spark plug on the basis of the performance of engine and emissive characteristics of engine. The result shown that the considerable improvement in the performance of engine output and considerable reduction in BSFC,HC and Co emission in multi spark plug mode **Keywords: Performance Analysis,Two Spark Plug, Four Spark Pluk, Optimisation of Location Spark Plug**

I. INTRODUCTION

The direct injection system introduces the fuel directly in the combustion chamber, which means that only air enters the cylinder through the manifold and the mixture of air and fuel takes place inside the combustion chamber. This system has the possibility of running in the premixed mode previously described if the injection of the fuel is done during the admission stroke, and in a mode called stratified if the fuel is injected at the end of the compression stroke which means that the fuel burns while being injected.
Stratified combustion has the advantage of avoiding knock, since there is no air-fuel mixture in the front of the flame. Gasoline needs to have a special property of anti ignition to avoid knocking when the pressure inside an engine's combustion chamber is very high, but in the case of stratified combustion it is not needed; even more, different kinds of fuels can be used by the same engine. A second advantage of stratified combustion is that, since the front of the flame doesn't reach the cylinder wall, less amount of heat is transferred to them, increasing the work transferred to the piston. The third advantage of this type of injection is that the combustion can be controlled by the amount of fuel being injected, living the opportunity of not using a throttle valve at all and to reduce significantly pump losses. This also gives better control of the flame in the combustion chamber than premixed mode, as in premixed mode the flame propagation depends heavily on the air movement inside the combustion chamber which is not always the same, and in stratified mode the flame is always near the injector and controlled by the injection of the fuel and the shape of the piston. As for the two stroke engine the big advantage is that, since the fuel is being injected when the exhaust port is closed, the short circuit problem is totally overcome. This characteristic is very important since this problem has not permitted the two stroke engine to be further used in the automotive industry due to the high emissions it produces.

Another big and important difference between both combustion modes is that flame propagation is faster in premixed mode than in stratified. This makes that premixed mode can reach higher engine speeds, developing higher power than stratified mode. This difference makes that, in practical applications, an engine needs to use both combustion modes. Stratifying at low and mid revs makes that the operation of the engine is smoother and the fuel consumption is improved. Premixing at high revs will develop a higher power the final difference to be mentioned in this work is the fuel pressure the injector needs to have on each injection type. Indirect injection runs on premixed mode, and in this mode the gasoline have time enough to mix with the air. Direct injection runs also in stratified mode, in which the gasoline has to mix with the air very fast to be able to ignite when going out from the injector. This requires the direct injector to produce a thinner spray than the indirect injector (smaller drops of fuel in the jet spray). To achieve this, the direct injection system needs a higher pressure in the fuel rail, and thus a high pressure fuel pump, which increases energy consumption, weight and cost. There are some other strategies to implement a direct injection system, like a dual fluid injector, or a hammer type of injector.

1.1. Direct injection methods:

There are two ways of direct injection 1) direct injection of liquid fuel and 2) direct injection of premixture

injection. Direct injection of liquid fuel: it is a high pressure fuel injection system in which liquid fuel is directly

injected into the engine cylinder. The fuel injection pressure should be sufficiently higher than cylinder pressure in

the range of 4Mpa- 15Mpa which is sufficient to produce well atomize spray. Direct injection of air fuel premixture:

It is a low pressure injection system in which mixture is formed outside the cylinder by injecting fuel (Pressure

range 0 .6 Mpa) in the part of air (Pressure 0.55 MPa). The premixture is transformed into combustion chamber by

mechanical valve with mechanical control or by solenoid with electronic control. Short duration needed for the

complete mixture formation diluting premixture in the engine cylinder results complete combustion and less

emissions. [5, 6, 7].

Nomenclature

GDI Gasoline direct injection

PFI Port Fuel Injection

UBHC unburned hydrocarbon

SI spark ignition

BSFC Brake specific fuel consumption

CFD computational fluid dynamics

2. Novel approaches towards GDI from PFI

Mixture formation strategies make difference between PFI and GDI engine. In PFI engine fuel injected on the

back of inlet valve when the valve is in closed position. Liquid film formation on the back of the inlet valve and fuel

wall wetting in the intake port are the major problems in the PFI engine which Results in the disadvantages like

metering error, fuel delivery delay. The time lag between fuel injection and induction into the cylinder may cause

misfire and significant increase in UBHC. Most of the problems associated with PFI are overcome in GDI by

injecting fuel directly into the cylinder; it avoids the wall wetting in the port, reduction in the fuel transport time,

more accurate control over fuel quantity entering into the cylinder and offer potential for leaner combustion and low

emissions. The better atomization of fuel entering into the cylinder due to high fuel injection pressure increases

vaporization rate and hence overcome cold start problems this can be explained by comparing the quantity of the

fuel to start GDI and PFI engine [8, 20]. Other advantages of the GDI are the fuel cut-off in deceleration and the

cooling of the inducted charge. The evaporation of the fuel droplets cools the air and this allows higher compression

ratios and lowers the octane requirement of fuels, and, in addition, if the injection occurs during the induction event

also the volumetric efficiency can be enhanced. Another limitation of PFI is the use of throttling for load control

Here we are taking four spark plug at three different location and find out the best location of all four spark plug.

For this project work three locations chosen 1) Randomly located all four spark plug.

2) All four spark plugs are mid radius located.
3) Three spark plugs are radial and one is at centrally located.

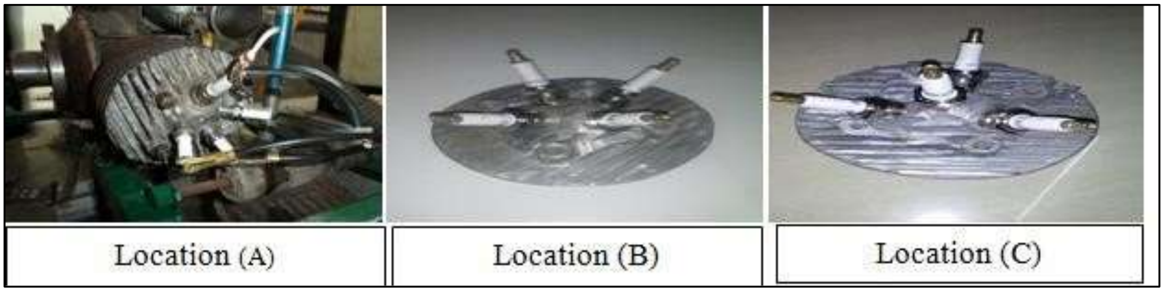

Fig. 1: Location Four Spark Plug on Cylinder Head

II. GRAPHICAL ANALYSIS OF ENGINE PERFORMANCE PARAMETERS

Graphical analysis of variation in various performance parameters with respect to brake power is shown in subsequent graphs.

A. Effect of Four Spark Plugs and Its Location on Fuel Consumption:

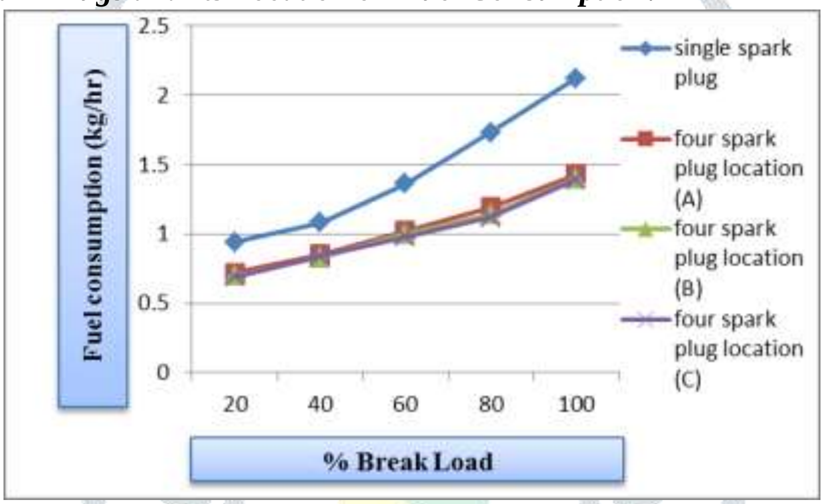

Fig. 2: Variations in Fuel Consumption With Break Load

Figure 1.1 shows the variation of FC with Brake power for single plug mode of operation and four spark plugs mode of operation. From above graph it is observed that FC increases with load and was minimum at low load in both modes of operation. This confirms that maximum efficiency is attained. Also it shows wider gap in FC values between single and four plug modes at higher loads.

B. Effect Of Four Spark Plug And Its Location On BSFC:

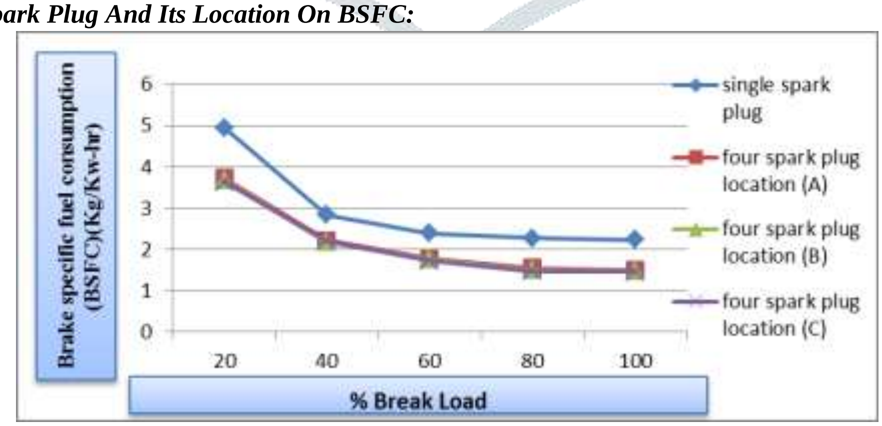

Fig. 3: Variations in BSFC with Break Load

Figure 1.2 shows the variation of BSFC with Break power for single plug mode of operation and shows the comparison with four plug mode of operation. It shows that BSFC decreased with load and was minimum at full load in both modes of operation, which confirms the maximum efficiency is attained. It is also observed that wider gap in BSFC values between single and four plug modes at lower loads.

C. Effect of Four Spark Plugs and Its Location on BSEC:

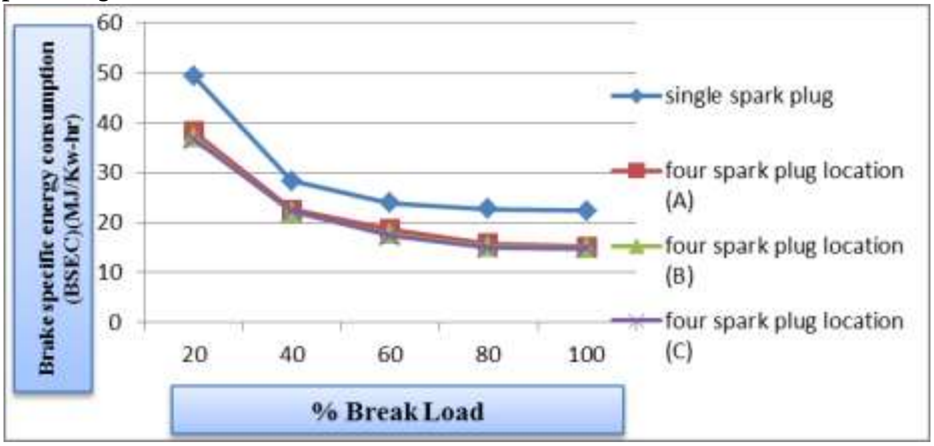

Fig. 4: Variations in BSEC with Break load

Figure 1.3 shows the variation of Brake specific energy consumption with Brake for single plug mode of operation and shows the comparison with four plug mode with different location. It shows that Brake specific energy consumption decreased with load and was minimum at full load in all modes of operation, which confirms that maximum efficiency is attained at full load condition. It is also observed that wider gap in Brake specific energy consumption values between single and four plug modes at all loads.

D. Effect of Four Spark Plugs and Its Location on Brake Thermal:

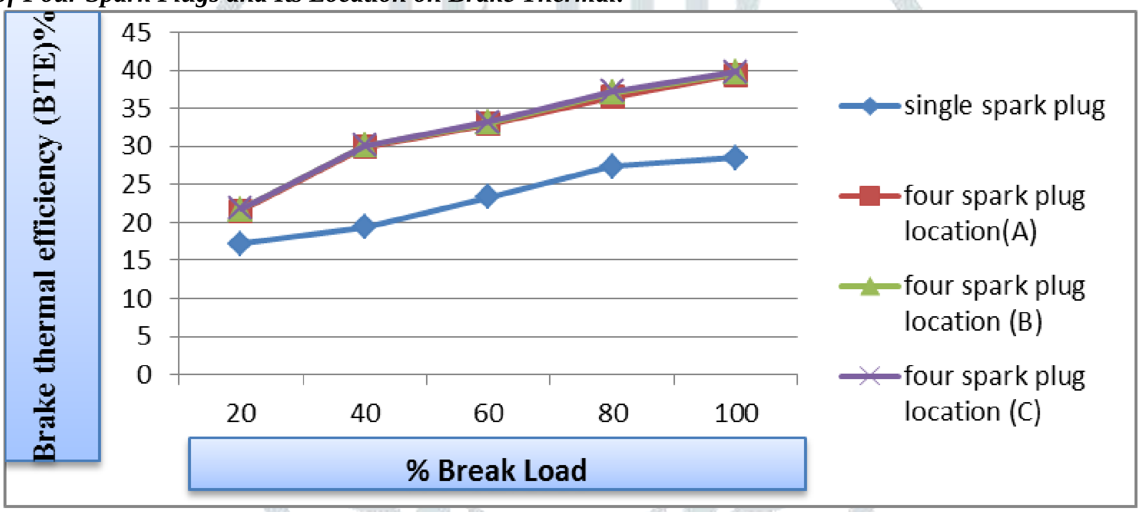

Fig. 5: Variations In Brake Thermal Efficiency With Brake Load

Figure 1.4 shows the variation of Brake thermal efficiency with break load for single plug mode of operation and shows the comparison with four plug mode of operation. It shows that Brake thermal efficiency increases with load and was maximum at full load in both modes of operation, which confirms the maximum efficiency is attained at full load condition. It is also observed that wider gap in Brake thermal efficiency values between single and four plug modes at all loads. This is due to the fact that the combustion of the unburned mixture is equally shared by the four plugs at the optimum ignition timings.

E. Effect on Hydrocarbon (HC) Emission Using Four Spark Plugs and its location As Compared To Single Spark Plug:

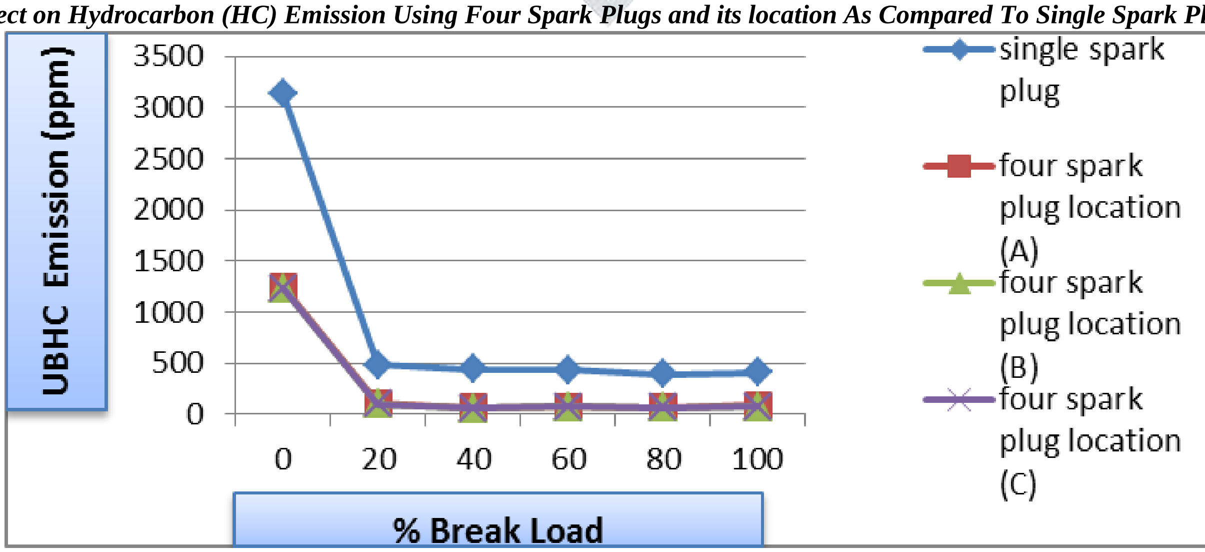

Fig. 6: Variations In HC Emission Versus Break Load

Figure 1.5 shows variations in HC emission with brake load. HC emission decreases with load starting from no load for all arrangement of spark plug. HC emissions are highest at no load for all fuels. The reason behind higher HC emissions at no or part load is lower cylinder temperature. Increase in brake power or load results in reduction in HC emissions for all arrangement of spark plug. The reason behind this is increase in cylinder temperature with rise in brake power or load. Unlike NOx emissions, HC emissions are highest at no load and decreases with increase in brake power or load. While using four spark plug configurations gives better results in reduced HC emissions at all load.

F. Effect on Carbon Monoxide (CO) Emission Using Four Spark Plugs and its location:

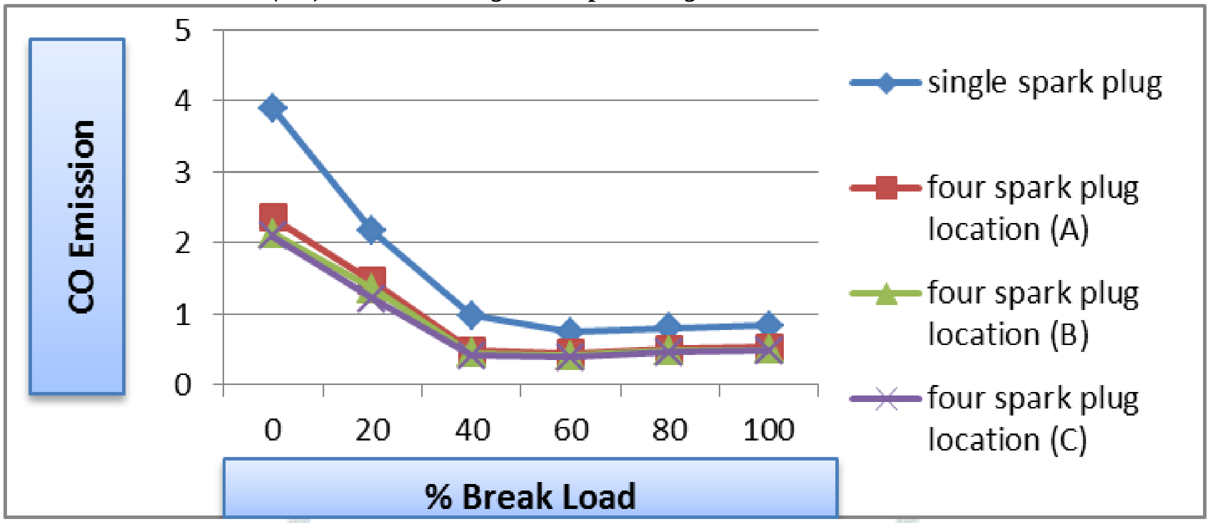

Fig. 7: Variations In Carbon Monoxide (CO) Emission Versus Brake Load

Figure 1.6 shows variations in CO emission with brake load. CO emission decreases with load starting from no load to full load condition for all configurations of spark plugs. After reaching minimum value, emission of CO increases again. This rise is continued up to the maximum brake power for all configurations of spark plugs. CO emission decreases with four spark plug configuration. The reason behind high emission of CO at no load may be lower cylinder temperature at no load. As load to brake power increases cylinder temperature also increases. Further increase in brake power results in higher emission of CO. While using four spark plug configurations gives better results in reduced CO emissions at all load.

G. Effect on Nitrogen Oxide (NOX) Emission Using Four Spark Plugs and its location:

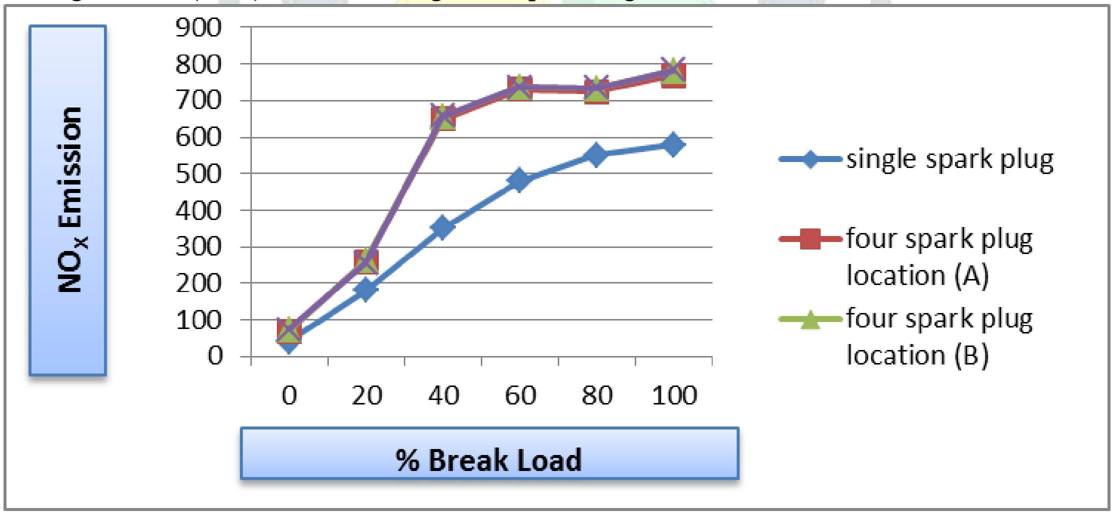

Fig. 8: Variations In Nox Emission Versus Break Load

Figure 1.7 shows variations in NOx emission with varying brake power. Emission of NOx increases with rise in brake load, percentage of NOx emissions also increase in four spark plug configuration versus single spark plug configuration. Rapid combustion of the fuel increases temperature inside the engine cylinder. At high temperature nitrogen reacts with oxygen to form its oxides. Hence at four spark plugs mode higher NOX emission was observed. At full load, the increase in F/A decreased NOx emission. While using four spark plug configurations gives raise in emissions of NOX at all load.

III. CONCLUSION

1) Two stroke engines deliver a good potential if four spark plug technology is applied.
2) Using the four spark plugs in two stroke gasoline engine combustion process have improved so the efficiency of the engine is improved.
3) By applying the four spark plugs in two Stroke Gasoline engine the problem of fuel economy will also be improved due to proper combustion inside the cylinder.
4) Carbon Dioxide (CO) emission is reduced significantly when four spark plugs are applied when compared single spark plug style. The CO emission is lower when compared to the Bharat stage IV Norms for the selected engine at all operated loads.
5) Unburned Hydro Cabin (UBHC) emission is reduced significantly when four spark plugs are used when compared single spark plug mode. The (UBHC) emission is lower when compared to the Bharat stage IV Norms for the selected engine at all operated loads.
6) Nitrogen oxides (NOx) emission is increased when four spark plugs are applied when compared single spark plug style. The (NOx) emission is lower when compared to the Bharat stage IV Norms for the selected engine at all operated loads.
7) The brake thermal efficiency of the engine is more with four spark plug configuration when compared single spark plug mode at 1500 RPM.
8) Brake specific fuel consumption is reduced four spark plugs are applied when compared single spark plug mode at all load conditions. .
9) More power can be generated from the same size engine by employing four spark plugs its mean improvement in power without changing other parameters.
10) Along with by comparing three different location of spark plug we can say that location in which three spark plug are mid radius located and one is centrally located gives best emission and performance parameter.

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