Effect of Fuel Injection Pressure and Injection Timing on Performance and Emissions of Diesel Engine Using Nanoadditive Blends

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Nomenclature: MB30: Diesel blended with 30% Mahua biodiesel, MB50: Diesel blended with 50% Mahua biodiesel MB100 Pure Mahua biodiesel (100%), BTH: Brake thermal efficiency,BSFC: Brake specific fuel consumption, HC: Hydrocarbon, CO: Carbon monoxide,Knox: Oxides of nitrogen

ABSTRACT

In the present work biodiesel derived from Mahua (B50) was used as an alternative fuel. Metal oxide Nano-particles were then added to mahua biodiesel to prepare novel hybrid fuel blends. Biodiesel-nanoparticles blends were prepared with the aid of an ultra-sonicator and the nanoparticles used in the mass fraction of 100 ppm. Experimental investigations were carried out on a single cylinder four stroke diesel engine fuelled with biodiesel-nanoparticle blends at different fuel injection pressures (200, 220 and 240 bar) and fuel injection (19°, 23° and 27° bTDC) timings to determine performance, and emission characteristics.

From the experimental results, it is found that injecting fuel at 240 bar and 19° bTDC will give better performance and emissions. Brake thermal efficiency and BSFC are improved by 21.8% and 12% respectively when compared to diesel. Emissions such as CO (%), HC (ppm) and Smoke opacity (%) are decreased by 52.94%, 62.22%, 28.22% respectively, whereas for NOX (ppm) is increased by 6.39% when compared to diesel.

INTRODUCTION

In the present energy scenario of increased energy demand and rapid depletion of high energy non-renewable energy resources like petroleum products the search for new renewable and alternative fuels has gained momentum. Increased pollution due to the excess use of such petroleum and diesel fuels for varied energy requirements is another important issue to be addressed. Due to their low emission characteristics and equivalent energy density biodiesel are becoming more useful in replacement for petroleum fuels.

Nano Additives

Nanoparticles because of their high surface-to-volume ratio, had an average diameter of 51 billionths of a meter—have more reactive surfaces, allowing them to act as more efficient chemical catalysts, thus increasing fuel combustion. The presence of the particles also increases fuel–air mixing in the fuel, which leads to more complete burning.

LITERATURE SURVEY

Conducted experiment on Kirloskar AV1, four stroke, single cylinder and water cooled diesel engine assisted by common rail direct injection system, the combustion characteristics and fuel properties of MME20. In order to better utilization of mahua methyl ester blend, fuel injection pressure increased from 22 MPa to 88MPa. High fuel injection pressure (88 MPa) exhibit higher

BTE and better combustion characteristics when compared to that of other injection pressures [1],

B20 blend of Mahua methyl ester(MME) was investigated using a single cylinder diesel engine at various nozzle opening pressures (NOP) (225, 250,275 bar) and static injection timings (19, 21, 23, 25, 27 bTDC). The performance of B20 mahua bio-diesel at 225 bar and 23 bTDC, NOP to 275 bar and to 21 bTDC, the stringent emission norms of Central Pollution Control Board (CPCB) stage I can be met with B20 mahua bio-diesel without compromising the performance against diesel [2].

As a renewable, sustainable and alternative fuel for compression ignition engines, biodiesel instead of diesel has been increasingly fueled to study its effects on engine performances and emissions in the recent 10 years. Therefore, the blends of biodiesel with small content in place of petroleum diesel can help in controlling air pollution and easing the pressure on scarce resources without significantly sacrificing engine power and economy [3].

Experimental setup consists of single cylinder, four stroke, air cooled, direct injection (DI), diesel engine NO emission decreases from 4.5 to 2.8%, and the smoke emission increased from 10 to 75% from no load to full load respectively. it is suggested that the 30% MPO(Mahua pyrolysis oil) blend can be considered as a potential candidate to be used as a fuel in compression ignition engines [4].

METHODOLOGY

Transesterification Process

The trans-esterification process can be defined as the process of reacting that is oil with an alcohol that may be methanol or ethanol in the presence of a catalyst like potassium hydroxide or sodium hydroxide, to chemically break the molecule of the oil into methyl esters or ethyl esters.

The following steps were used to complete the trans-esterification process.

- Initially 200 ml methanol and 7.5 g KOH were mixed.
- After that the 1 lit of esterified mahua oil was heated up to a temperature of 100 °C to remove water particles and then cooled to 50 °C.
- Methanol and KOH were mixed with mahua continuously stirring at constant temperature of 55 °C.
- In this way continuously heating this mixture up to 1-2 hrs.
- After that mahua methyl ester and glycerine were separated in conical flask after 8-12 hrs.
- Then removed the free fatty acids and glycerine from the flask.
- The trans-esterified oil was collected from the conical flask.

Preparation of Biodiesel Blends

Initially 500 ml of Mahua biodiesel is taken in a flask and heated to a temperature of 40°C.Using the magnetic stirrer, the biodiesel is stirred and 480 ml diesel is added to it.Add 20 ml of surfactant in the fuel. Continue stirring for about 20 mins until both the fuels are properly mixed to obtain B50 biodiesel blend.Measure 0.1 g of Al_2O_3 nanoparticles and add them to B50 biodiesel blend. Pour this fuel in an ultra-sonicator for 10 mins, to obtain homogeneous nanoadditive biodiesel blend (Figures 1 and 2) [5-9].

Figure 1: Magnetic stirrer with Ultrasonicator.

Table 1: Mahua biodiesel blends and properties.

Fuel property	DIESEL	B50	B100	B50+100 Al_2O_3
Kinematic viscosity @40°C in cSt	3.2	5.25	8.95	6.75
Flash point (°C)	58	53	158	57

Fire point (°C)	62	58	168	68
Calorific value(KJ/kg)	43400	36349	34210	39167
Density @15°C in	840	871	900	878.8

EXPERIMENTAL SETUP

Figure 2: Experimental setup.

Table 2: Engine specifications.

S.No	Particulars	Description
1	Type	Kirloskar TV1
2	No. of cylinders	One
3	No. of strokes	Four
4	Bore	87.5 mm
5	Stroke	110 mm
6	Compression Ratio	17.5:1
7	Rated Power	5.2 kW at 1500 rpm
8	Dynamometer	Eddy current
9	Type of Cooling	Water cooled
10	Type of injection	Mechanical pump-nozzle injection
11	No. of nozzle holes	3
12	Fuel injection starts	23° bTDC

In the present work mahua biodiesel blend (B50) is prepared by mixing mahua oil and diesel. This B50 blend is then used to prepare B50+100AL_2O_3 in an ultra-sonicator. Then experiments are conducted on Kirloskar TV1 engine at different loads to obtain performance and emissions. The experiments are done at different injection pressures (200, 220 and 240 bar) and injection timings (19°, 23° and 27° bTDC).

RESULTS AND DISCUSSION

Effect of Fuel Injection Pressure

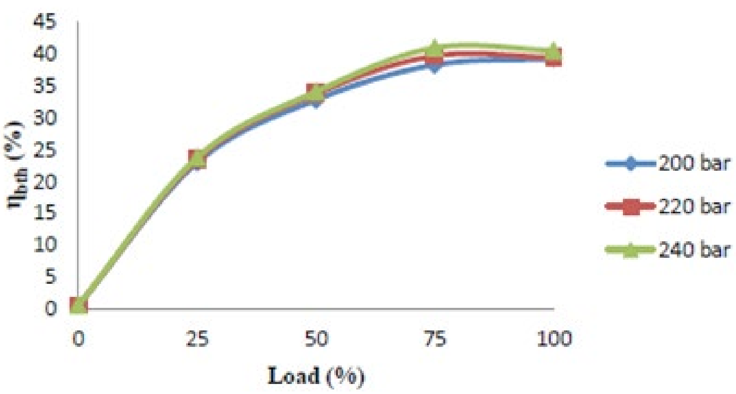

Figure 3: Load *vs.* BTE.

Figure 3 shows brake thermal efficiency variations for B50+100AL_2O_3 for fuel injection pressures 200, 220 and 240 bar at different load conditions[11,12]. The BTE increases with increase in load. With increase in injection pressure, the brake thermal efficiency (BTE) is increased due to the reduction in the viscosity, improved atomization and better combustion. At full load conditions BTE for B50+100AL_2O_3 at injection pressures of 200, 220 and 240 bar are 39.26%, 39.46% and 40.53% respectively. There is almost 3.23% increment in brake thermal efficiency using B50+100AL_2O_3 at 240 bar compared to 200 bar.

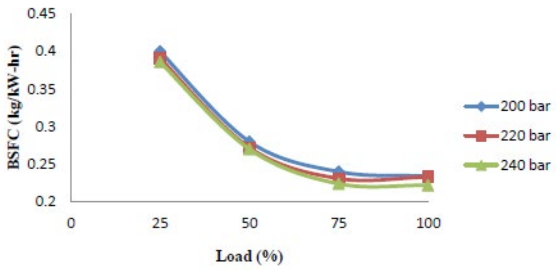

Figure 4: Load *vs.* BSFC

Figure 4 shows BSFC variations for B50+100AL_2O_3 for fuel injection pressures 200, 220 and 240 bar at different load conditions. The BSFC decreases with increase in load. This may be due to the fact that, as injection pressure increases the penetration length and spray cone angle increases, so that at optimum pressure, fuel air mixing and spray atomization will be improved. At full load conditions BSFC for B50+100AL_2O_3 at injection pressures of 200, 220 and 240 bar are 0.234 kg/kW-hr, 0.233 kg/kW-hr and 0.222 kg/kW-hr respectively[13,14]. There is almost 5.13% decrement in BSFC using B50+100AL_2O_3 at 240 bar compared to 200 bar.

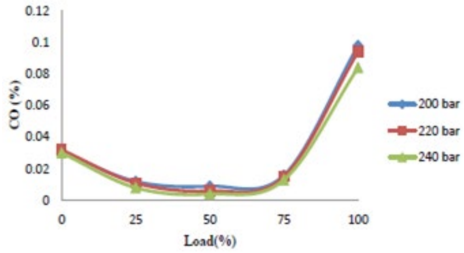

Figure 5: Load *vs.* CO.

Figure 5 shows CO variations for B50+100AL_2O_3 for fuel injection pressures 200, 220 and 240 bar at different load conditions. This may be due to proper mixing of fuel particles with air, less penetration of fuel particles and effective combustion of the blend at these pressures. At full load conditions CO% for B50+100AL_2O_3 at injection pressures of 200, 220 and 240 bar are 0.098, 0.094 and 0.084 respectively. There is almost 14.29% decrement in CO using B50+100AL_2O_3 at 240 bar compared to 200 bar.

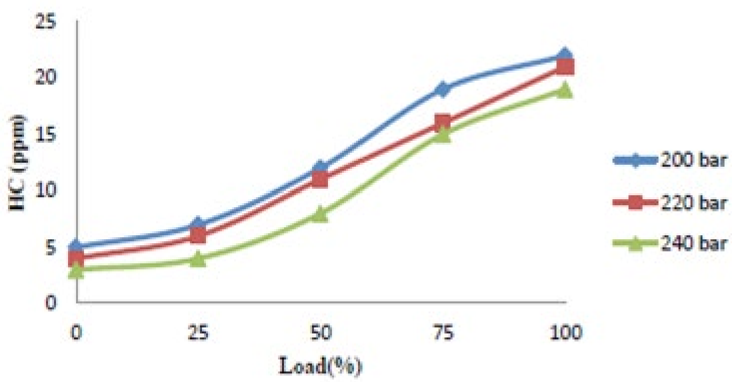

Figure 6: Load *vs.* HC.

Figure 6 shows HC variations for B50+100AL_2O_3 for fuel injection pressures 200, 220 and 240 bar at different load conditions. There seems to be a decrement in HC emissions which may be because of finer fuel spray and results in momentum and penetration of the droplets resulting complete combustion. At full load conditions HC for B50+100AL_2O_3 at injection pressures of 200, 220 and 240 bar are 22 ppm, 21 ppm and 19 ppm respectively. There is almost 13.64% decrement in HC using

$B50+100AL_2O_3$ at 240 bars compared to 200 bar [15,16].

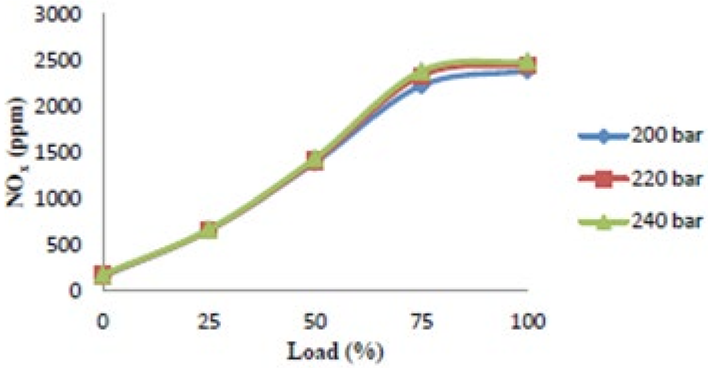

Figure 7: Load *vs.* NOx.

Figure 7 shows NOX variations for $B50+100AL_2O_3$ for fuel injection pressures 200, 220 and 240 bar at different load conditions. There seems to be a increment in NOX emissions. Due to the better combustion at high injection pressure, at high temperatures N2 reacts with oxygen and produce more amount of NOX emissions. At full load conditions NOX for $B50+100AL_2O_3$ at injection pressures of 200, 220 and 240 bar are 2390 ppm, 2456 ppm and 2495 ppm respectively [17]. There is almost 4.39% increment in NOX using $B50+100AL_2O_3$ at 240bar compared to 200 bar.

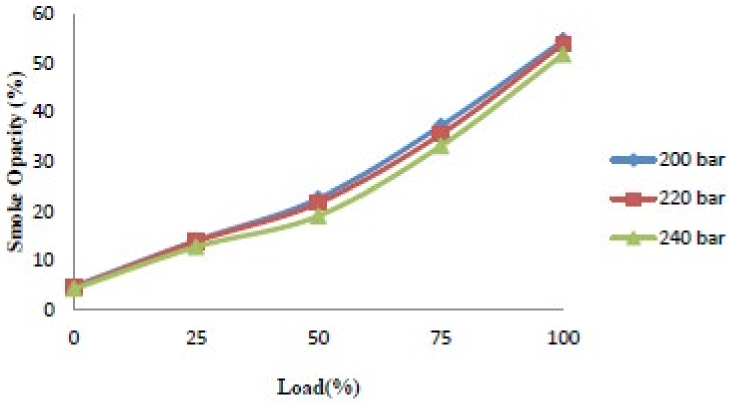

Figure 8: Load *vs.* smoke opacity.

Figure 8 shows smoke opacity variations for $B50+100AL_2O_3$ for fuel injection pressures 200, 220 and 240 bar at different load conditions. There seems to be a decrement in smoke opacity. The presence of oxygen in the blends in addition to good atomization of fuel at higher pressure may be the reason for lower opacity at higher injection pressures. At full load conditions smoke opacity for $B50+100AL_2O_3$ at injection pressures of 200, 220 and 240 bar are 54.6%, 53.9% and 51.8% respectively. There is almost 5.13% decrement in smoke opacity using $B50+100AL_2O_3$ at 240 bar compared to 200 bar.

Effect Of Fuel Injection Timing

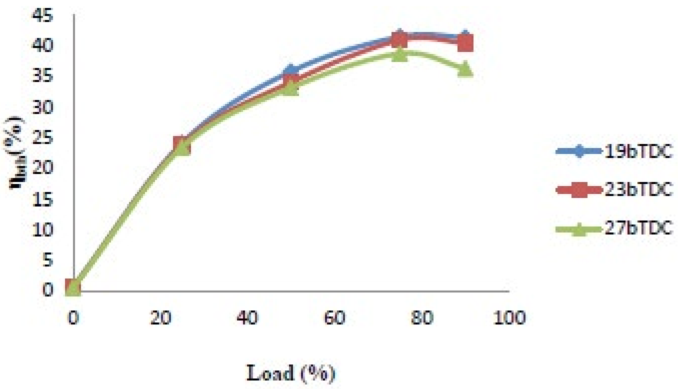

Figure 9: Variation of BTE with load.

Figure 9 shows brake thermal efficiency variations for B50+100AL$_2$O$_3$ for fuel injection timing 19°, 23° and 27° bTDC at different load conditions. The BTE increases with increase in load. At full load conditions BTE for B50+100AL$_2$O$_3$ at injection timing 19°, 23° and 27° bTDC are 41.43%, 40.53% and 36.32% respectively. There is almost 2.22% increment in brake thermal efficiency using B50+100AL$_2$O$_3$ at 19° bTDC compared to 23° bTDC.

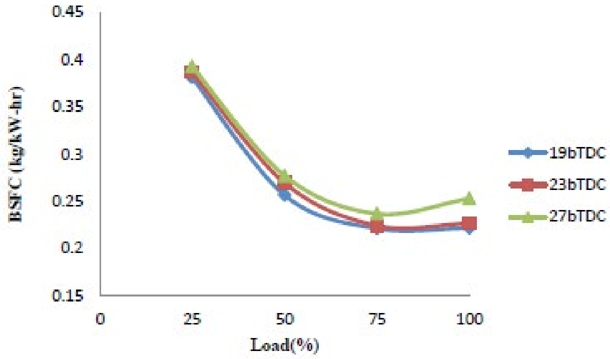

Figure 10: Variation of BSFC with load.

Figure 10 shows BSFC variations for B50+100AL$_2$O$_3$ for fuel injection timing 19°, 23° and 27° bTDC at different load conditions. The BSFC decreases with increase in load. This may be due to increase of ignition delay and the fuel may take longer time to burn completely to produce large amount of heat energy as a result there is an increase of fuel consumption [19]. At full load conditions BSFC for B50+100AL$_2$O$_3$ fuel injection timing 19°, 23° and 27° bTDC are 0.222 kg/kW-hr, 0.227 kg/kW-hr and 0.253 kg/kW-hr respectively. There is almost 2.2% decrement in BSFC using B50+100AL$_2$O$_3$ at 19° bTDC compared to 23° bTDC.

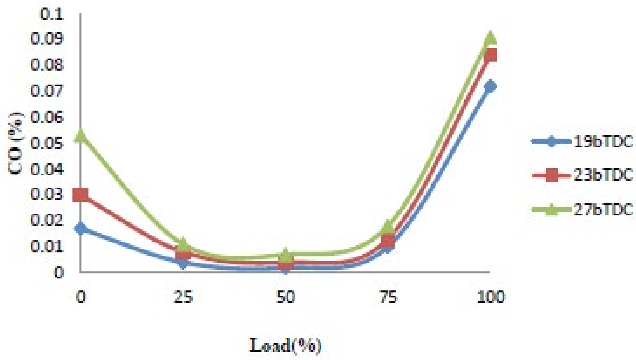

Figure 11: Variation of CO with load.

Figure 11 shows CO variations for B50+100AL$_2$O$_3$ for fuel injection timing 19°, 23° and 27° bTDC at different load conditions. This may be due to the oxygen concentration and cetane number. At full load conditions CO% for B50+100AL$_2$O$_3$ at fuel injection timing 19°, 23° and 27° bTDC are 0.072, 0.084 and 0.091 respectively. There is almost 14.28% decrement in CO using B50+100AL$_2$O$_3$ at 19° bTDC compared to 23° bTDC.

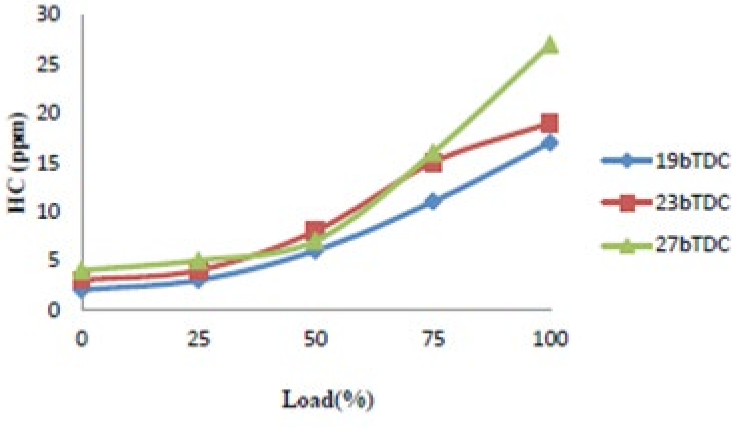

Figure 12: Variation of HC with Load

Figure 12 shows HC variations for B50+100AL_2O_3 for fuel injection timing 19°, 23° and 27° bTDC at different load conditions. There seems to be a decrement in HC emissions which may be because of finer fuel spray and results in momentum and penetration of the droplets resulting complete combustion. At full load conditions HC for B50+100AL_2O_3 at fuel injection timing 19°, 23° and 27° bTDC are 17 ppm, 19 ppm and 27 ppm respectively. There is almost 10.53% decrement in HC using B50+100AL_2O_3 at 19° bTDC compared to 23° bTDC.

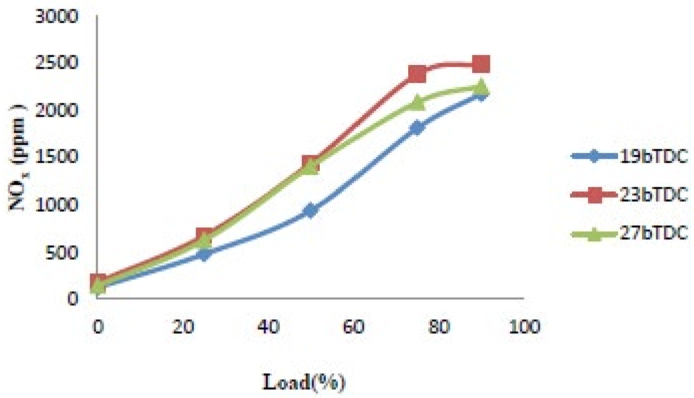

Figure 13: Variation of NOx with Load

Figure 13 shows NOX variations for B50+100AL_2O_3 fuel injection timing 19°, 23° and 27° bTDC at different load conditions. The NOX emission for 23° bTDC is more than 19° and 27° bTDC. At 19 ° bTDC, ignition delay is highest which causes more fuel to get accumulated and burnt lately during the expansion stroke followed by reduced local temperatures. At full load conditions NOX for B50+100AL_2O_3 at fuel injection timing 19°, 23° and 27° bTDC are 2180 ppm, 2495 ppm and 2262 ppm respectively. There is almost 12.63% decrement in NOX by using B50+100AL_2O_3 19° bTDC compared to 23° bTDC.

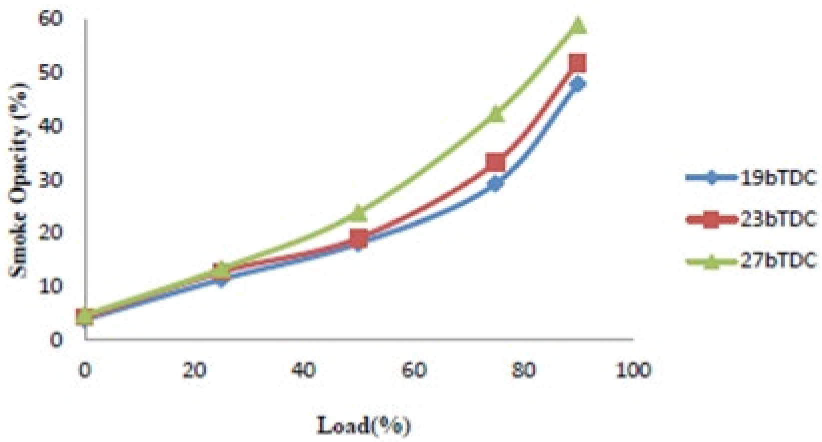

Figure 14: Variation of smoke opacity with load.

Figure 14 shows smoke opacity variations for B50+100AL_2O_3 for fuel injection timing 19°, 23° and 27° bTDC at different load conditions. There seems to be a decrement in smoke opacity. This is due to the lower combustion duration and higher levels of oxygen. At full load conditions smoke opacity for B50+100AL_2O_3 at fuel injection timing 19°, 23° and 27° bTDC are 47.8%, 51.8% and 58.9% respectively. There is almost 7.72% decrement in smoke opacity using B50+100AL_2O_3 at 19°bTDC compared to 23° bTDC.

CONCLUSIONS

In this study, the single cylinder diesel engine was tested with B50+100AL_2O_3 blend of Mahua bio diesel by varying injection parameters like fuel injection pressure (200, 220 and 240 bar) and injection timing (19°, 23° and 27° bTDC).

Based on experimental results, the following conclusions are drawn

The optimum injection strategy for the better performance and emission of the nanoadditive biodiesel blend for the single cylinder diesel engine is 240 bar and 19° bTDC.

At full load the brake thermal efficiency for diesel and B50+100AL_2O_3 at 240bar and 19° bTDC are 34% and 41.43% respectively. There is almost 21.8% increment by using B50+100Al2O3 than diesel.

At full load the BSFC for diesel and B50+100AL_2O_3 at 240bar and 19° bTDC are 0.25 and 0.22 kg/kW-hr respectively. There is almost 12% decrement by using B50+100Al2O3 than diesel.

At full load the CO% for diesel and B50+100AL_2O_3 at 240 bar and 19° bTDC are 0.153 and 0.072 respectively. There is almost 52.94% decrement by using B50+100AL_2O_3 than diesel.

At full load the HC ppm for diesel and B50+100AL_2O_3 at 240 bar and 19°bTDC are 45 and 17 respectively. There is almost 62.22% decrement by using B50+100AL_2O_3 than diesel.

At full load the NOX ppm for diesel and B50+100AL_2O_3 at 240 bar and 19°bTDC are 2049 and 2180 respectively. There is almost 6.39% increment by using B50+100AL_2O_3 than diesel.

At full load the smoke opacity for diesel and B50+100AL_2O_3 at 240 bar and 19°bTDC are 66.6 and 47.8 respectively. There is almost 28.22% decrement by using B50+100AL_2O_3 than diesel.

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