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Effect of Injection Pressure and Nozzle Geometry on the Performance and Emission Charcteristics of Diesel Engine Operated with Palm Oil Methyl Ester

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ABSTRACT
The experimental study has been massinly focused on effect of Injection Opening Pressure (IOP) and nozzle geometry operated on diesel fuel and blends of palm oil methyl ester (POME) fuel in diesel engine. The 3 holes nozzle geometry with 205 bar injection opening pressure (base line nozzle geometry) and 5 holes nozzle geometry with 240 bar injection pressure (modified nozzle geometry). The various blends like B20, B40, B60, B80, and B100 are prepared and experiments conducted on single cylinder 4 stroke diesel engine with keeping constant compression ratio and studied the performance and emission characteristics. The experimental results showed that higher Brake thermal efficiency (BTE) for baseline nozzle geometry up to B40 pome, but BTE for changed nozzle geometry improved up to B20 mix of POME blend. Also 32 % of reduction in oxides of element (NOX) was observed for modified nozzle geometry. However carbon monoxide and unburnt hydrocarbons (UBHC) emissions were slightly higher for modified nozzle geometry as compared to baseline nozzle geometry at full load condition.

Keywords: Nozzle geometry, Diesel Engine, Emission, Palm oil Methyl Ester.

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INTRODUCTION

The present situation of fossil fuels are decaying day by day, hence more focusing on the usage of sustainable energy resources in existed engine other than mineral diesel fuel. The drawback of the usage of the fossil fuel in existed engines emits high grade of pollutants to atmosphere. These emitted pollutants pollute the environmental aspects, which will effect on the living beings. Hence it is very essential matter to control the emission parameters of engine throughout the globally [1].The usage of biodiesel fuel blends in the existed diesel engine minimize pollutants, but true efficiency of the diesel engine decreases due to insufficient air fuel mixture formation and insufficient swirl. These are causes poor turbulence characteristics in the combustion chamber. To improve the entire air- fuel mixture, swirl and turbulence characteristics of combustion chamber, there is a very essential to modification of suitable nozzle geometry. Due to presence of higher viscosity in biodiesel fuel that leads to reduce the mixing quality of air and fuel [2]. The nozzle geometry with increase in the number of holes can inject more amount of fuel in combustion chamber which leads to participation of more fuel in the combustion chamber [3-5]. To improved atomization characteristics by higher amount of fuel with higher injection [6].

The diesel motor operated with HOME showed four holes nozzle geometry gave the upper performance and reduced emission as compared to 3- and 5-holes widget at backward injection timing and 230 bar IOP [7]. The increasing the number of holes leads to increase in the performance and reduced emissions, when engine was powered with COME as biodiesel fuel [8]. By increase in the number of holes in diesel engine that leads to better atomization, which is in turn increases efficiency of diesel engine and reduced emissions [9]. The investigators worked on the diesel engines reported that efficiency of diesel engine is higher than the bio fuelled diesel engine [10-12]. The diesel engine powered with rice brain biodiesel showed better BTE, minimum brake specific fuel consumption (BSFC), reduced 27.47 % of smoke, CO and UBHC emissions [13]. The diesel engine has declined in its BTE with higher blend ratio [14]. The harmful pollutants like CO, smoke and HC were minimized by addition of desulfurized tyre oils in diesel fuel (DF) [15]. The engine powered with jathropa oil methyl ester (JOME) and its blends found that slightly lower BTE and reduced emissions as compared to DF [16].

The research work has been scantly done with modification of nozzle geometry in diesel engine operated with POME biodiesel fuel. Hence current work has been carried with modified geometry in diesel engine with different blends of POME and compared same with base line geometry in terms of performance and emission characteristics. The main objective of our work is to improve the performance and minimize the emission characteristics by using the POME as an alternative fuel with modification of nozzle geometry at 240 bar injection opening pressure.

PROPERTIES OF FUEL

The properties of the POME fuel are measured with help of laboratory facility. The details of properties of POME are shown in the below Table 1.

Table 1. *Properties of POME*

Sl.No.	Properties	Diesel	PALM OIL	POME
1	Density (kg/m^3)	840	890	880
2	Calorific value (kJ/kg)	43,000	36,400	38,400
3	Viscosity at 40^o C(cSt)	2-5	43.28	3.94
4	Flash Point (^{o}C)	75	280.5	160
5	Cetane Number	45-55	-	64.6
6	Carbon Residue (%)	0.1	-	76.5
7	Pour point (^{o}C)	-5	-	15

EXPERIMENTAL METHODOLOGY

The diesel engine has been chosen to carry out experimentation shown in Figure 1. The engine operates with diesel, POME and its blends. The details of specification of engine are shown in the Table 2. The engine speed 1500 rpm, CR 17.5, injection pressure 205 bar and 23^o BTDC are maintained for base line nozzle geometry. The engine speed 1500 rpm, CR 17.5, injection pressure 240 bar and 23^o BTDC are maintained for modified nozzle geometry. The cooling of engine has maintained by passing the water through engine water jacket. The various POME blends like B20, B40, B60, B80 and B100 are prepared in the laboratory. The 3 holes and 5 holes nozzle geometries are selected for experiments with each 0.3 mm nozzle holes diameter shown in Figure 2. The experimentations are carried out various loads (0%, 25%, 50%, 75% and 100%) on the diesel engine operate with diesel, POME and its blends with using base line geometry. Similar, experiments are carried for the modified nozzle geometry. The emissions readings are measured with help of 5 gas exhaust analyzer. Finally the comparisons are made between base line geometry and modified geometry for diesel, POME and its blends in terms performance and emissions characteristics.

RESULTS AND DISCUSSIONS

The experiments are carried out on the diesel engine operate with diesel, POME and its blends for base line and modified nozzle geometries with various loads. The results are discussed here for base line and modified geometries at full load condition only.

Specific Fuel Consumption

Figure 3 reveled that that variation of SFC with BP for both nozzle geometries with diesel and POME blends. The SFC varies from 0.26 kg/kwh to 0.29 kg/kwh for diesel and B100 POME blend respectively in the baseline nozzle geometry. Similarly, The SFC varies from 0.29 kg/kwh to 0.34 kg/kwh for diesel and B100 POME respectively in the modified nozzle geometry. The minimum SFC was observed for the B40 (0.26 kg/kwh) POME blend in baseline nozzle geometry. Similarly, the minimum SFC was observed for the B20 (0.29 kg/kwh) in modified nozzle geometry. However, the maximum SFC was showed higher in the modified nozzle geometry as compared to baseline nozzle geometry due to poor mixing quality of air and fuel mixture in the combustion chamber.

Fig. 1. *Experimental test rig.*

Fig. 2. *Three hole and five hole nozzle geometries*

Table 2*: Engine specificationsss*

Sl. No	**Parameters**	**Specifications**
1	Type of engine	Kirloskar make Single cylinder four stroke direct injection diesel engine
2	Nozzle opening pressure	205 bar
3	Rated power	5.2 kW (7 HP) @1500 RPM
4	Cylinder diameter (Bore)	87.5 mm
5	Stroke length	110 mm
6	Compression ratio	17.5 : 1
7	Displacement volume	660cc
8	Arrangement of valves	Over head
9	Combustion chamber	Open chamber (Direct injection)
10	Cooling type	Water cooled
11	Loading	Mechanical type loading dynamometer

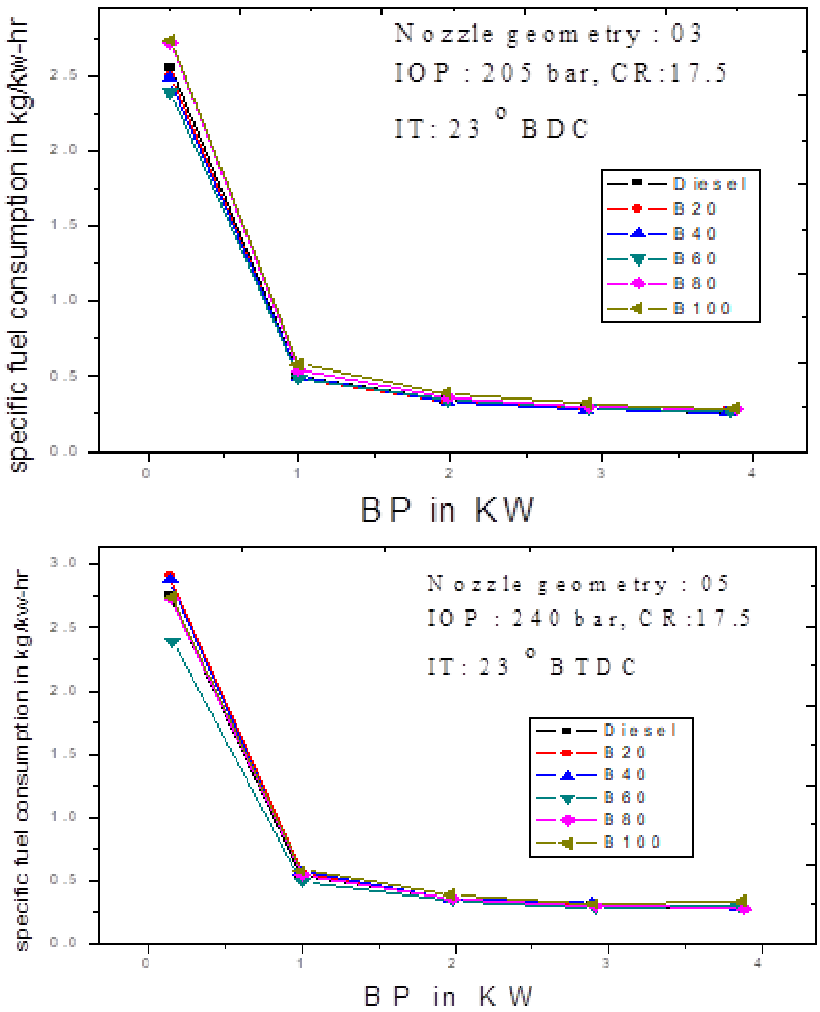


Fig.3. *Variation of SFC with BP for baseline and modified nozzle geometries*

Brake Thermal Efficiency

Figure 4 depicts that variation of BTE with BP for both nozzle geometries. The BTE varies from 32.83 % to 34.62 % for diesel and B40 POME blend respectively in the baseline geometry. Similarly, the BTE varies from 29 % to 32.73 % for diesel and B100 POME respectively in the modified geometry. The maximum BTE was observed for the B40 POME blend in baseline geometry. Similarly, the maximum BTE was observed for the B20 in modified geometry. However, slightly BTE has improved in the baseline than modified nozzle geometry due to improved combustion phase. The modified nozzle geometry impinges more amount of fuel in the combustion chamber and more availability of oxygen are leads to higher BTE for the B20 blend as compare to mineral diesel fuel.

Carbon Monoxide and Unburnt Hydrocarbon Emissions

Figure 5 showed that variation of CO and UBHC emissions with BP for diesel and biodiesel blend fuels. The CO varies from 0.225% to 0.262% for diesel and B100 POME blend respectively in the baseline geometry. Similarly, the CO varies from 7.9% to 11 % for diesel and B100 POME blend respectively in the modified geometry. The lower CO (0.009 %) emission was found for B40 POME blend in base line geometry as compared to modified geometry due to improve combustion process. But, UBHC varies from 483 ppm to 524 ppm for diesel and

B100 POME blend respectively in the baseline geometry. Similarly, the UBHC varies from 140 ppm to 820 ppm for diesel and B100 POME respectively in the modified geometry. The lower UBHC (49ppm) was for B40 POME blend. However, UBHC are also lower for the baseline geometry due to sufficient mixing quality of fuel and air in the combustion chamber. The both emissions are observed higher for the modified geometry due to poor atomization in the combustion chamber.

Oxides ff Nitrogen Emissions

The variation of NOx emissions with BP for both nozzle geometries operates with POME and its blends as shown in Figure 6. The NOx emissions vary from 2103 ppm to 2306 ppm for diesel and B60 POME blend respectively in the baseline geometry. Similarly, the NOx emissions vary from 1430 ppm to 1470 ppm for diesel and B100 POME respectively in the modified geometry. However, the 32 % of NOx emissions has been reduced in the modified nozzle geometry as compare to base line nozzle geometry. The modified nozzle geometry impinges more amount of fuel in to the combustion chamber that tends to decreases the rise in exhaust gas temperature. This is the reason to reduce the NOx emission in modified nozzle geometr.

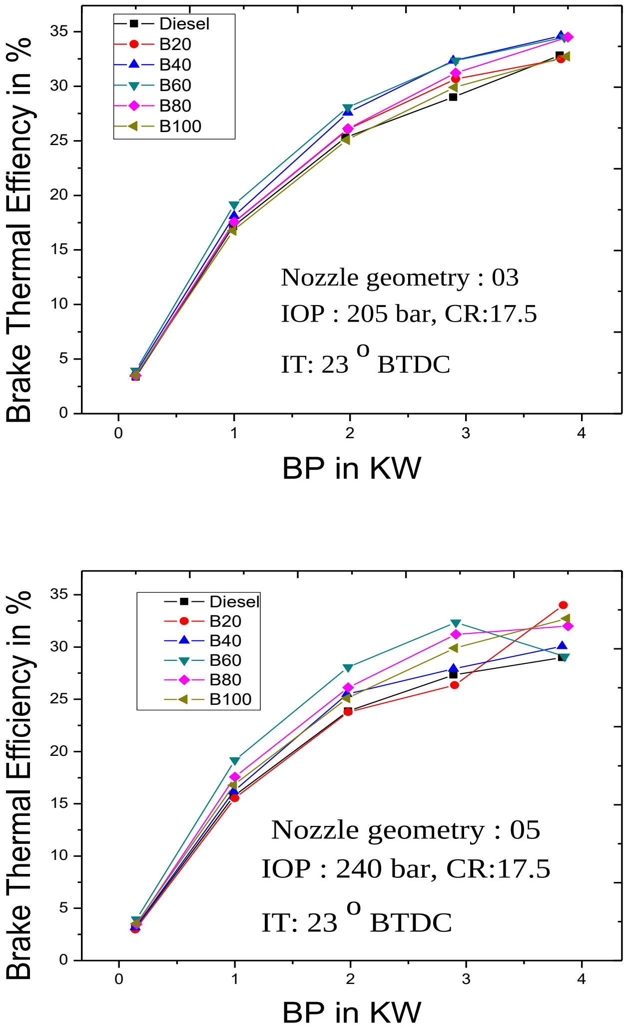
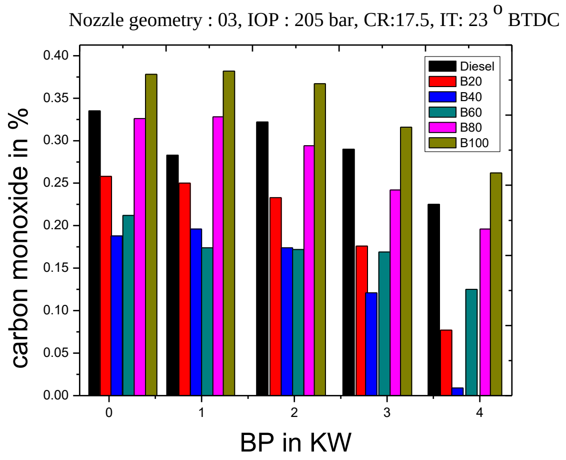
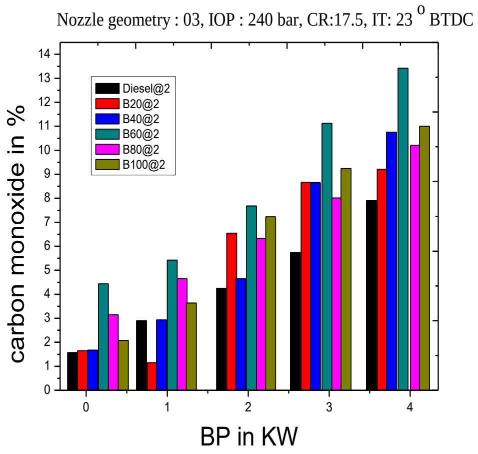
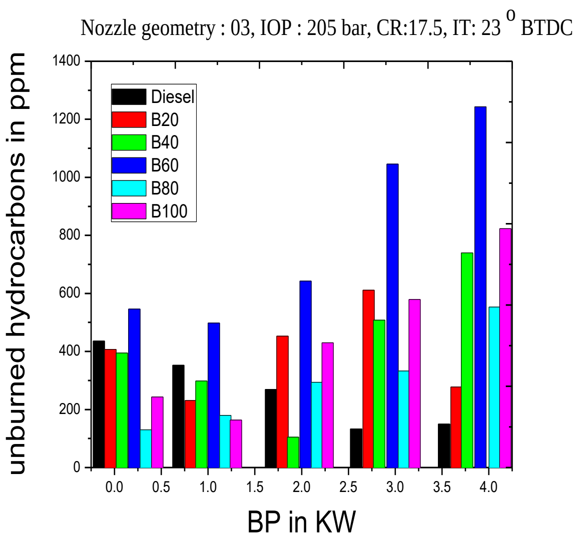


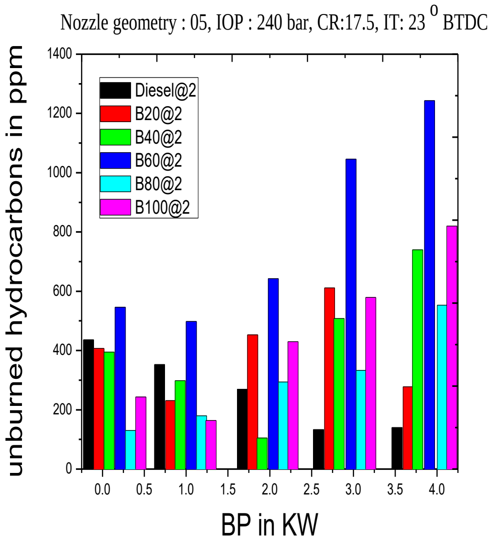
Fig.4. *Variation of BTE with BP for baseline and modified nozzle geometries*





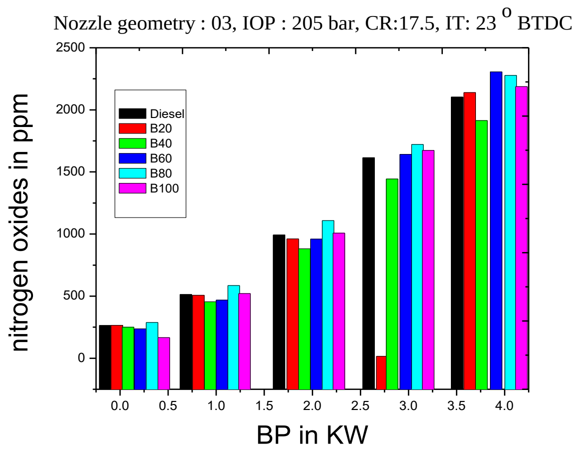
(a) *(b)*

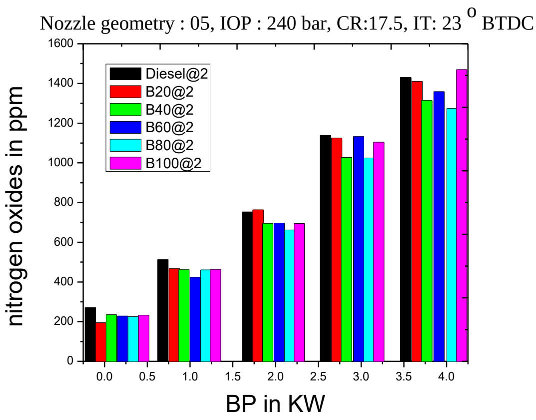




(c) *(d)*

***Fig.5**. Variation of CO and UBHC emissions with BP for baseline and modified nozzle geometries*





(a) *(b)*

***Fig.6.** Variation of NO_x emissions with BP for baseline and modified nozzle geometries*

CONCLUSIONS

The following conclusions are made for the base line nozzle geometry (3 holes, 205 bar IOP) and modified nozzle geometry (5 holes, 240 bar IOP) at full load condition of diesel engine.

- The diesel engine powered with POME fuel gave the higher BTE up to B20 POME blend and emissions (except NOx) are higher in modified nozzle geometry.
- The diesel engine powered with POME fuel gave the higher BTE up to B40 POME blend and emissions (except NOx) are reduced in base line nozzle geometry.
- The modified nozzle geometry showed 32 % of reduced oxides of nitrogen as compared to baseline geometry.
- In overall, the modified nozzle geometry powered with POME blend in diesel engine has improved performance as compared to diesel fuel and also drastic reduction of oxides of nitrogen emissions in the diesel engine. Hence POME fuel can be used as an alternative fuel in diesel engine to save huge amount of the fossil fuel requirement in our country and worldwide.

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