Effect of nozzle geometry on the performance and emission characteristics of C.I. Engine Operated on Palm Oil Methyl Ester

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Abstract*—As more and more fossil fuels are depleting day by day, it is very necessary to switch to alternative source of energy as a fuel for internal combustion engines. The internal combustion engines used in Propulsion, Transportation and marine applications, will leads to socio economical growth of any country. The emissions from the fossil fuels leads too many environmental problems like green houses effect, ozone depletion etc. This present work investigates the effect of varying the nozzle geometry on the performance of a diesel engine using POME fuel and its blends. Experimental investigations were carried out on single cylinder 4 stroke direct injection compression Ignition (CI) engine and comparison was made between 3 holes base line nozzle geometry (base line nozzle geometry) and 5 holes nozzle geometry (modified nozzle geometry). Blends like B20, B40, B60, B80, B100 and standard diesel were used in engine and studied the performance and emission characteristics without altering the compression ratio of the engine. The experimental results showed that higher Brake thermal efficiency (BTE) for baseline nozzle geometry up to B40 POME blend, but BTE for modified nozzle geometry improved up to B60 blend of POME blend. Also significant improvement in reduction of oxides of Nitrogen (NOX) was observed for modified nozzle geometry. However carbon monoxide and unburnt hydrocarbons (HC) were slightly higher for modified nozzle geometry as compared to baseline nozzle geometry at full load condition.

Keywords: Nozzle geometry, Engine, Emission, POME (Palm oil Methyl Ester).

I. INTRODUCTION

The fossil fuels are depleting day by day with uncontrolled rising of price of fossil fuels. Because of this reason, alternative fuels usage has got more importance in the diesel engine application. These fuels are more suitable for the engine application with slight modification in the engine parameters. Hence modification of nozzle of holes geometry makes changes in the performance and emission characteristics. Many research works have been carried on the biodiesel fuels in the diesel engine. Alternative fuels received more focused due to its ability to replace fossil fuels. Moreover, fossil fuels are creating more problems on the environment, hence alternative fuel are more encouragement in the diesel engine application [1]. The main drawback of vegetable oils was their high viscosity, 15–20 times greater than the mineral diesel fuel. Researchers have been suggested various techniques to reduce viscosity of the vegetable oils as micro-emulsification with ethanol, thermal cracking, and transesterification process. Among these, transesterification process is most widely used [2–5]. It usually accepted that 20% blends of biodiesel in diesel without modification of diesel engine. Many researchers have shown that biodiesel fuel showed the similar properties as mineral diesel fuel in terms of physical, chemical and thermodynamic properties [6, 7]. However, some properties like viscosity, calorific value, density and isothermal compressibility of biodiesel change from mineral diesel fuel. All required properties strongly affect on injection pressure, number of the holes of injector and air fuel mixture in a diesel engine. The diesel engine operated with Chicha oil methyl ester (COME) gave higher performance and reduction of emissions like CO & HC emissions with increased in CO_2 & NO_x emissions as compared to diesel [8]. The diesel engine operated with neem methyl ester (NOME) blend gave better performance, combustion and reduced emission characteristics [9]. Ten holes nozzle geometry exhibits better atomization and reduced of oxides of nitrogen in diesel engine at full load condition [10]. The NOx emission has been increases as increase in the number of holes increase in injector in biodiesel fuelled diesel engine [11]. The diesel engine operated with HOME showed 4 holes nozzle geometry gave the higher performance and reduced emission as compared to 3 and 5 holes injector at retarded injection timing and 230 bar IOP [12]. The increasing the number of holes leads to increase in the performance and reduced emissions, when engine was powered with COME as biodiesel fuel [13]. 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 [14].

The research work has been scantly done with modification of nozzle geometry in the base line diesel engine operated with POME biodiesel fuel. Hence current work has been carried with 5 holes nozzle geometry in engine with different blends of POME and compared same with 3 holes nozzle geometry in terms of performance and emission characteristics. The main objective of our work is to increase the performance and reduces the emission characteristics by using the POME as a alternative fuel with modification of nozzle geometry. The experiments are conducted on diesel engine with keeping constant engine parameters like 17.5 CR, 23° BTDC and 205 bar IOP.

II. PROPERTIES OF FUEL

The properties of the POME fuel are flash point, fire point, density and calorific value of the fuel and measured in Energy conversion laboratory. The properties of POME are shown in the below Table I.

Table I. 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° C(cSt)	2-5	43.28	3.94
4	Flash Point (°C)	75	280.5	160
5	Cetane Number	45-55	-	64.6
6	Carbon Residue (%)	0.1	-	76.5
7	Pour point (°C)	-5	-	15

It is found that the viscosity and density are comparatively higher for POME than the diesel and also the calorific value is comparatively lesser than that of the diesel. The flash point and fire point are also higher for biodiesel than the diesel.

III. EXPERIMENTAL METHODOLOGY

The diesel engine has been chosen to carry out experimentation shown in "*Fig. 1.*" The engine operates with diesel, POME and its blends. The details of specification of engine are shown in the Table II. The engine speed 1500 rpm, CR 17.5, injection pressure 205 bar and 23° BTDC are maintained constant throughout the experiments. 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 "*Fig. 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 3 holes nozzle geometry with respect to performance and emissions characteristics. Similar experiments are carried for the 5 holes nozzle geometry. The emissions readings are measured with help of 5 gas exhaust analyzer. Finally the comparisons are made between base line geometry (3 holes) and modified geometry (5 holes) for diesel, POME and its blends in terms performance and emissions characteristics.

Fig. 1 Experimental test rig.

Fig. 2 Three hole and five hole nozzle geometries

Table II: Engine specifications

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

IV. RESULTS AND DISCUSSIONS

The experiments are carried out on the diesel engine operate with diesel, POME and POME blends for base line and modified nozzle geometries with various loads. The engine parameters are like speed 1500 rpm, CR 17.5 , IOP 205 bar and IT 23°BTDC are kept constant in the experiments. The results are discussed here for both nozzle geometries at full load condition only.

A. Specific fuel consumption

From "*Fig. 3,*" observed that that variation of SFC with BP for base line and modified nozzle geometries operate with diesel, POME and its 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 0.30 kg/kwh to 0.32 kg/kwh for diesel and B20 (0.26 kg/kwh) POME blend 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 B60 (0.27 kg/kwh) in modified nozzle geometry.

However, the maximum SFC was found higher in the modified nozzle geometry compared to baseline nozzle geometry due to insufficient mixing quality of air fuel mixture in the combustion chamber.

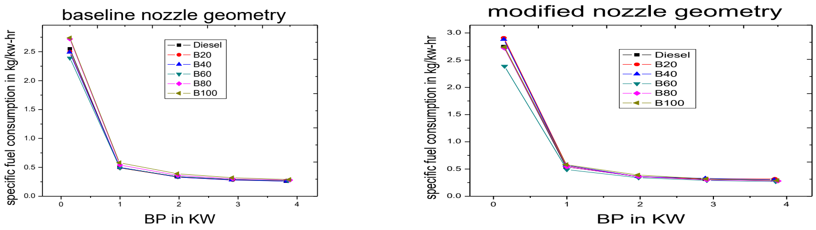

Fig.3 Variation of SFC with BP for baseline and modified nozzle geometries

B. Brake thermal efficiency

From “*Fig. 4*,” depicts that that variation of BTE with BP for base line and modified nozzle geometries operate with diesel, POME and its blends. 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 28.56 % to 34.50 % for diesel and B60 POME blend 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 B60 in modified geometry. However, slightly BTE has improved in the baseline than modified nozzle geometry due to improved diffusion combustion phase. Modified nozzle geometry impinges more amount of fuel in the combustion chamber and more availability of oxygen are leads to higher BTE for the B60 blend as compare to mineral diesel fuel.

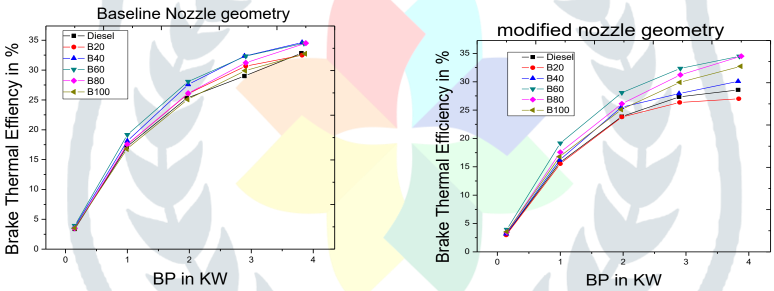

Fig.4 Variation of BTE with BP for baseline and modified nozzle geometries

C. Carbon monoxide and Unburnt hydrocarbon emissions

From “*Fig. 5*,” depicts that that variation of CO and UBHC emissions with BP for base line and modified nozzle geometries operate with diesel, POME and its blends. 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 0.525% to 3.64 % for diesel and B60 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 150 ppm to 1243 ppm for diesel and B60 POME blend 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 higher for the modified geometry due to presence of higher viscosity leads to poor atomization and spray characteristics of POME. As the number of holes increases, more amount of fuel entered in the combustion chamber, there were insufficient mixing characteristics leads to enhance the higher emissions in the modified nozzle geometry could be the reason.

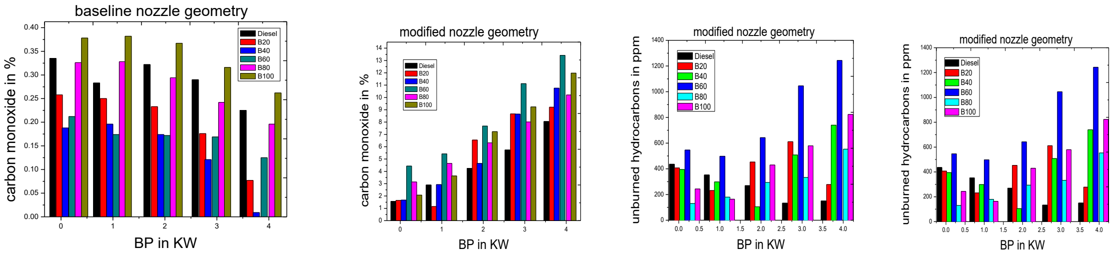

Fig.5 Variation of CO and UBHC emissions with BP for baseline and modified nozzle geometries

D. Oxides of nitrogen emissions:

From "*Fig. 6,*" depicts that that variation of NO_x emissions with BP for base line and modified nozzle geometries operate with diesel, POME and its blends. The NO_x varies from 2103 ppm to 2306 ppm for diesel and B60 POME blend respectively in the baseline geometry. Similarly The NO_x varies from 1422 ppm to 1466 ppm for diesel and B60 POME blend respectively in the modified geometry. However, the 36 % of NO_x 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 geometry.

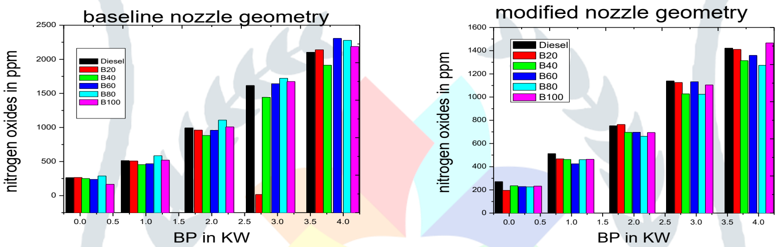

Fig.6 Variation of NO_x emissions with BP for baseline and modified nozzle geometries

V. CONCLUSIONS

The following conclusions are made for the base line and modified nozzle geometries at full load condition of diesel engine. The engine parameters 17.5 CR, 23° BTDC and 205 bar IOP are maintained constant for both nozzle geometries.

- The diesel engine operated with POME fuel gave the higher BTE up to B40 POME blend and reduced emissions (except NO_x) in base line nozzle geometry.
- The diesel engine operated with POME fuel gave the higher BTE up to B60 POME blend and slightly improved emissions (except NO_x) in modified nozzle geometry.
- The diesel engine operated with POME fuel gave 36 % reduction of NO_x emissions in modified nozzle geometry.
- In overall, the modified nozzle geometry operated with POME blend in engine has improved performance as compared to diesel fuel and also drastic reduction of NOx levels 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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