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EFFECT OF NOZZLE GEOMETRY ON THE PERFORMANCE OF DUEL FUEL ENGINE OPERATED ON RBOME AND PRODUCER GAS

CHETAN PAWAR
Assistant Professor, Dr. D.Y.Patil Institute of Engineering, Management & Research, Akurdi Pune p.chetan0408@gmail.com

PARESH KULKARNI
Assistant Professor, Dr. D.Y.Patil Institute of Engineering, Management & Research, Akurdi Pune p.chetan0408@gmail.com

AMRUTA ADWANT
Assistant Professor, Dr. D.Y.Patil Institute of Engineering, Management & Research, Akurdi Pune p.chetan0408@gmail.com

ABSTRACT

Experimental investigation were carried out on a single cylinder four stroke direct injection diesel engine operated in duel fuel mode using rice bran oil methyl ester (ROME) and coconut shell derived producer gas. ROME is used as a pilot injected fuel which ignites the producer gas and air mixture when subjected to higher compression ratio. In order to study the effect of nozzle geometry on the performance of dual fuel engine an effort has been made to enhance the performance of a dual fuel engine utilizing different nozzle orifice. In this present work injector nozzle (3, 4 and 5 hole injector nozzle, each having 0.2, 0.25 and 0.3 mm hole diameter and injection pressure (varied from 210 to 240 bar in steps of 10 bar) was optimized. The HC, CO and smoke emission was less with the use of 4 hole injector compared to three and five hole injectors used for fuel injection.

Key words: Biodiesel, Rice bran oil methyl ester, Emissions, Nozzle geometry.

INTRODUCTION

Power production from diesel engines are getting more popular because of their higher brake thermal efficiency, power output, reliability, less fuel consumption, lower emissions and durability as well. Hence diesel engine technology plays a vital role in transportation, agricultural and power generation applications. In the present energy scenario, life of conventional fossil fuels has become limited, while the demand for energy is growing at a faster rate. Due to rapid depletion of conventional fuels, increasing prices of crude petroleum and stringent environmental legislations, use of environment friendly fuels (biofuels) in partial or complete replacement for diesel engine applications is the need of the hour. Major emissions from diesel engines include nitric oxide (NOx) and smoke. These pollutants can be overcome by dual fuel concept. However, a diesel engine using biodiesel-producer gas combination operating on dual fuel mode results in a higher hydrocarbon (HC) and carbon monoxide (CO) emissions [1,2] Some of modern diesel engines use micro-orifices having various orifice designs and affect engine performance to a great extent. Several investigators have investigated the effect of dynamic factors on injector flow spray, combustion and emission levels from a diesel engine Utilization of gaseous fuel along with injected fuel in a dual fuel engine leads to combustion with more complexity because it involves two fuels with different properties and is burnt simultaneously inside the engine cylinder. Therefore, heat release rate of dual fuel combustion is the result of three combustion stages [3,4]. In case of dual fuel engine, injection of liquid fuel is performed with an in-cylinder injection system. These engines can operate un throttling, with load regulated by admitting gaseous fuel along with air through induction manifold. Substantial research on producer gas fueled dual fuel engine and its effect on performance and emission levels has been reported in the literature [5,6]. Dual fuel engines are known for good liquid fuel saving with decreased smoke and nitric oxide (NOx) emissions. Some of the investigators have reported lower performance, increased HC/CO and lower NOx/smoke levels under producer gas dual-fueling [7]. Some researchers have reported decreased power output of engine, whereas others have not mentioned. Loss of thermal efficiency compared to diesel operation has been reported in the literature. In view of this, several investigators have made an effort for achieving comparable efficiencies Experimental studies involving the effects of nozzle orifice geometry on global injection and spray behavior has been reported [8,9]. Smaller injector nozzle hole diameter produces smaller droplet size and results into reduced spray tip penetration due to the low spray momentum [10]. Air and fuel mixing depends on the number of nozzle holes and diameter. Adverse effect on combustion and emissions has been reported when number of holes exceeds a certain threshold value. This could be due to lack of the air entrainment required for the achievement of a stoichiometric mixture

The main objective of the present work is to

1. Production of biodiesel from rice bran oil by using conventional transesetrification process.
2. To conduct performance and emission characteristics of CI engine in dual fuel mode using ROME and Producer gas with different types of nozzle geometry

TRANSESTERIFICATION SETUP:

Transesterification was carried out in a system which is shown in the figure 1.1. Three necked flat bottomed glass flask of 2liter capacity was used for transesterification reaction. A double coiled reflux condenser was fitted to a neck of the glass flask for condensing methanol vapors during the reaction. Water was circulated through coils of the condenser. A plate heater with a magnetic stirrer was used for uniform heating of the contents of the flask. Rice bran oil, methanol and NaOH were transferred through the third neck of the flask. In the transesterification process triglycerides of Rice bran oil react with methyl alcohol in the presence of a catalyst (NaOH) to produce fatty acid ester and glycerol. In this process 1000 gm of Rice bran oil, 200 gm methanol and 8 gm sodium hydroxide were taken in a round bottom flask. Figure 1.2 show items required for transesterification process such as Rice bran oil, Methanol, Sodium hydroxide containers. All the contents were heated up to 65^{0}C to70^{0}C and stirred by the magnetic stirrer vigorously for one hour when the ester formation begins. The mixture was transferred to a separating funnel and allowed to settle down under gravity for overnight. The upper layer in the separating funnel forms the ester and the lower layer being glycerol was removed from the mixture (figure 1.3). The separated ester was mixed with 250 gm of hot water and allowed to settle under gravity for 24 hours. Water washing removes the fatty acids and catalyst dissolved in the lower layer and was separated. Fatty acids and dissolved catalyst were removed by using a separator funnel.

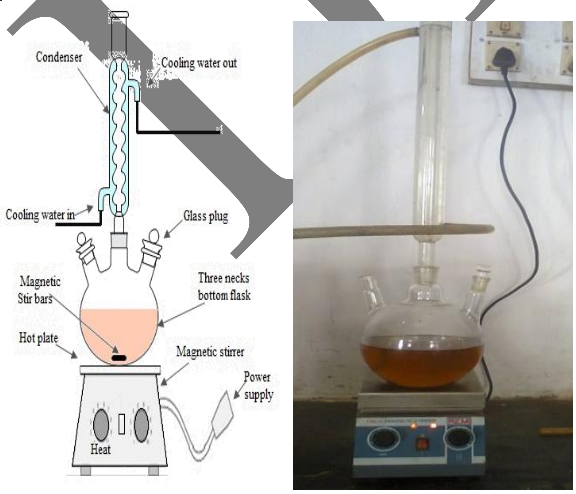

Figure 1.1: Transesterification setup

Figure 1.2: Rice bran oil, Methanol, Sodium hydroxide

Figure 1.3: Separation of glycerol and Rice Bran oil Methyl Ester (ROME).

EXPERIMENTAL SETUP FOR DUAL FUEL OPERATION:

The engine tests were conducted on a four stroke single cylinder water cooled direct injection compression ignition engine with a displacement Volume of 662 cc, compression ratio of 17:1, developing 3.7 kW at 1500 rev/min as shown in Figure 1.4. The engine was always operated at a rated speed of 1500 rev/min. The engine had a conventional fuel injection system. The governor of the engine was used to control the engine speed. The engine was provided with a hemispherical combustion chamber with overhead valves operated through push rods. Cooling of the engine was accomplished by circulating water through the jackets on the engine block and cylinder head. A piezoelectric pressure transducer was mounted with the cylinder head surface to measure the cylinder pressure. A carburetor was fitted in the inlet manifold to supply Producer gas obtained from a down draft gasifier for the dual fuel operation.

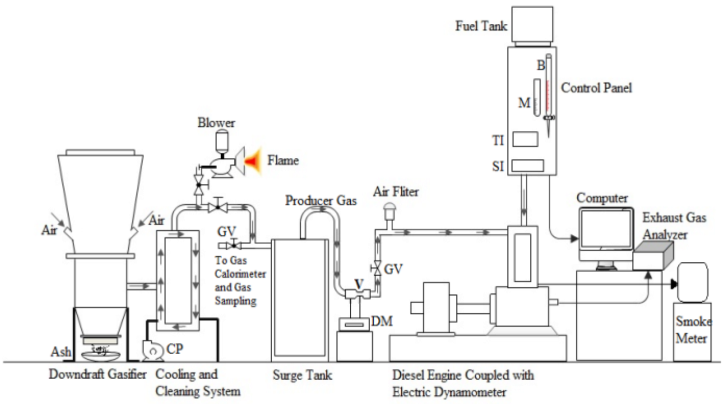

Figure 1.4: Dual Fuel Engine Experimental Setup

V-Venturimeter, GV-Gate valve, DM-Digital Manometer, CP-Centrifugal pump, M-Manometer, TI-Temperature Indicator (^{0}C), SI-Speed Indicator (rpm), B- Burette

Table 1: Specification of CI Engine

Sl No	Diesel engine	
	Parameters	Specification
1	Type of engine	Kirlosker Single cylinder four stroke direct injection diesel engine
2	Nozzle opening pressure	200 to 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

CHARACTERIZATION OF FUELS USED:

In the present study ROME was used as injected liquid fuels and their properties are listed in Table 2.

Sl.No	Properties	Diesel	ROME
1	Viscosity @ 40 ^{0}C (cst)	4.59	44.850
2	Flash point ^{0}C	56	270
3	Calorific Value in kJ / kg	45000	35800
4	Specific gravity	0.830	0.915
5	Density Kg / m3	830	915
6	Type of oil	----	Nonedible

NOZZLE GEOMETRY:

The diesel engine operated in dual fuel mode had a conventional mechanical injection system with three hole nozzle with a constant diameter of 0.3 mm. To study the effect of nozzle geometry on performance of the dual fuel engine two more nozzles with 4 and 5 holes each having a constant diameter of 0.3 mm were selected. To determine the optimum nozzle for dual fuel operation, experiments have been conducted with above mentioned nozzles. Figure 1.5 shows the different nozzles

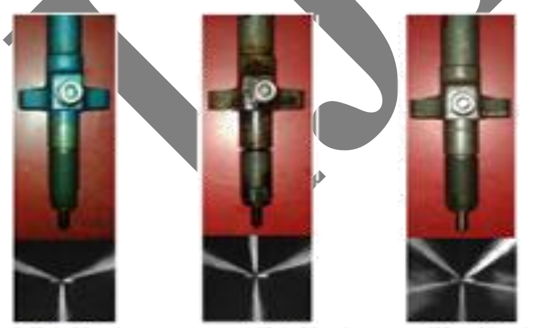

Figure 1.5: Multihole nozzle

RESULTS AND DISCUSSIONS:

This work involves the performance evaluation of ROME-producer gas dual fuel engine operation. The present work compares performance of the diesel-producer gas operation with ROME-producer gas and diesel-Producer gas operation. The tests were conducted with different load conditions. During the complete experimentation, engine speed was maintained constant. The injection timing, injection pressure and compression ratio were kept constant at 27^0 bTDC, 230 bar ROME-producer gas combinations and 17.5 respectively. However, for Diesel–Producer gas operation, injection pressure was changed to 205 bars.

PERFORMANCE CHARACTERISTICS:

Figure 1.6 shows the variation of brake thermal efficiency (BTE) with brake power for ROME–producer gas operation with different types of injectors. It is observed that over the entire power range, ROME-producer gas combination operates at a lower BTE compared diesel-producer gas mode of operation Producer gas being common, properties of the injected fuel has a major effect on the engine performance. The lower calorific value and higher viscosity of ROME in presence of slow-burning producer gas results in to lower BTE. Dual fuel operation with 4 hole injector resulted in higher thermal efficiency compared to 3 and 5 hole injector. It could be due to better mixing of the fuel combinations and better combustion. An important observation is that the better spray dispersion with proper fuel penetration for the 4 hole nozzle compared to the 3 and 5 hole nozzles. This is also due to the enhanced liquid breakup, which leads to smaller droplets and thus higher dispersion for the 4 hole nozzle. This can be a significant advantage for having 4 hole injector nozzles with 0.3 mm diameter hole. However, 4 hole orifice is required instead of 3 hole because to meet the desired mass flow rate. However, the operation with 5 hole injector, the decreased BTE was observed because higher mass flow rate of liquid fuel inside the combustion chamber. Whereas, 3 hole decreased performance was observed for 3 hole nozzle, it may be due to lower fuel injection rate and total fuel injection and decreased or insufficient fuel injection may leads to lower fuel in the air –fuel mixture. The BTE for diesel–producer gas and ROME-producer gas operation with 3, 4 and 5 hole injectors were found to be 18.65, 13.82, 15.85 and 17.14% respectively for 80% load.

EMISSION CHARACTERISTICS:

Emission Characteristics of an engine are important as for as environmental aspects is concerned. Combustion quality can be represented on the basis of emission levels from the engine. The emissions from the dual fuel engine is due to the variation of producer gas composition, type of liquid fuel used, engine design and operating parameters. The different emission parameters during the dual fuel mode of operation with different fuel combinations are discussed below.

Figure 1.7 shows the variation of smoke opacity for diesel –producer gas and ROME–producer gas operation with different types of injectors. The smoke opacity with ROME- producer gas combination under dual fuel mode was found to be higher compared to diesel-producer gas combination. This could be attributed to lower calorific value, improper spray pattern due to higher viscosity of ROME in presence of slow-burning producer gas and free fatty acids with heavier molecular structure compared to diesel results in higher smoke levels. It is also due to insufficient availability of oxygen for combustion and high temperature of producer gas reduces the density, which in turn reduces the quantity of air required for complete combustion of fuel combination. The smoke levels for diesel–producer gas and ROME-producer gas operation with 3, 4 and 5 hole injectors were found to be 32, 61, 54 and 46 HSU respectively for 80% load.

Figure 1.8 and 1.9 shows the variation of hydrocarbon (HC) and carbon monoxide (CO) emission levels for diesel–producer gas and ROME–producer gas operation with different types of injectors. Both HC and CO emission levels are higher for ROME-producer gas operation compared to diesel-producer gas operation. It could be due to incomplete combustion of the ROME-producer gas operation. The incomplete combustion resulted in case of dual fuel mode of operation is due to presence of free fatty acids in a ROME and insufficient oxygen available for combustion. Also, lower calorific value of ROME and producer gas, lower adiabatic flame temperature and higher viscosity of ROME and lower mean effective pressure are responsible for higher HC and CO emission levels.

Producer gas being common, the ROME-producer gas dual fuel operation with 4 hole injector resulted in lower HC and CO emission levels compared to 3 and 5 hole injector. It could attributed to better combustion with 4 hole injector due to better mixing of the fuel combinations caused by better spray pattern and penetration. However, 5 hole injector resulted in higher HC and CO emission levels and it may be due to under-mixing of fuel injected and resulting in fuel-air ratios that are too rich for complete combustion.

The HC for diesel–producer gas and ROME-producer gas operation with 3, 4 and 5 hole injectors were found to be 38, 58, 49 and 41% respectively for 80% load. The CO for diesel–producer gas and ROME-producer gas operation with 3, 4 and 5 hole injectors were found to be 0.31, 0.72, 0.54 and 42% respectively for 80% load. It is observed that, with 3 and 4 hole injector for ROME-producer gas operation, higher HC and CO emission levels. It may be due to incomplete combustion caused by improper spray pattern.

The NOx emission levels were found to be higher for diesel-producer gas dual fuel operation compared to ROME-producer gas operation with different types injectors over the entire load range (Fig.5.10). This is because of higher heat release rate during premixed combustion phase occurs with diesel- producer combination compared to other fuel combinations. Compared to ROME– producer operation, ROME + bio ethanol–producer gas combinations resulted in slightly higher NOx emission levels. This could be due to slightly better combustion occurs in oxygen-rich region, resulting in slightly higher NOx emission levels with bio-ethanol added dual fuel operation. However, ROME-producer gas combination resulted in lower NOx emission levels compared to diesel-producer gas combinations. This is mainly due to the combined effect of incomplete combustion due to higher viscosity and lower energy density of ROME along with slow burning nature of producer gas. The ignition delay of 4-hole injection was shorter than that of 3 and 5-hole injection, which could be correlated with NOx formation behaviour. Higher cetane number and absence of aromatic hydrocarbon in the ROME improves fuel combustion and reduces HC, NOx and smoke levels in the exhaust. This is also responsible for lower NOx and PM emissions. However, it is observed that the NOx levels were found to be lower for 3 and 5 hole injector operation compared to 4 hole. It could be attributed to lower heat release rate due to incomplete combustion caused by improper spray pattern. The NOx levels for 3, 4 and 5 hole injector operation were found to be 110, 56, 85 and 82 ppm respectively for 80% load. The increase in hole number with reduced or smaller hole size may lead to efficient mixture preparation due to improved air utilization, which results in low PM, HC and CO emissions. However, NOx emission increases due to the rise of the combustion temperature

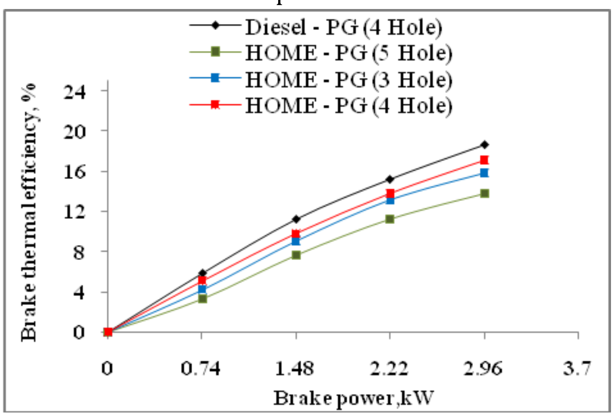

Figure 1.6 Variation of BTE with brake power

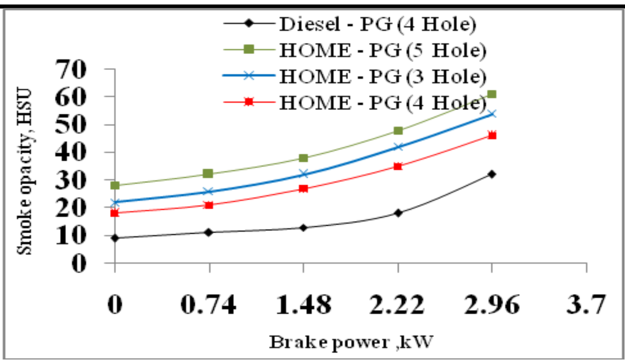

Fig.1.7 Variation of Smoke with Producer brake power

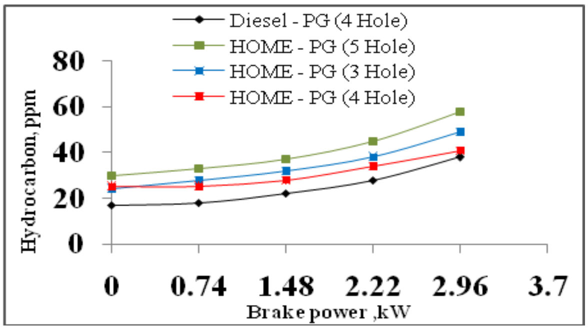

Figure.1.8 Variation of HC emission with brake power

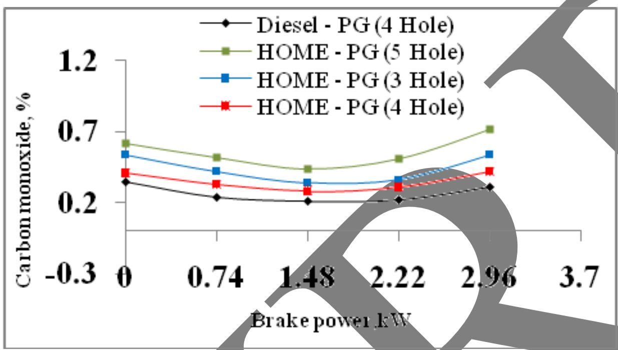

Figure.1.9 Variation of CO emission with brake power

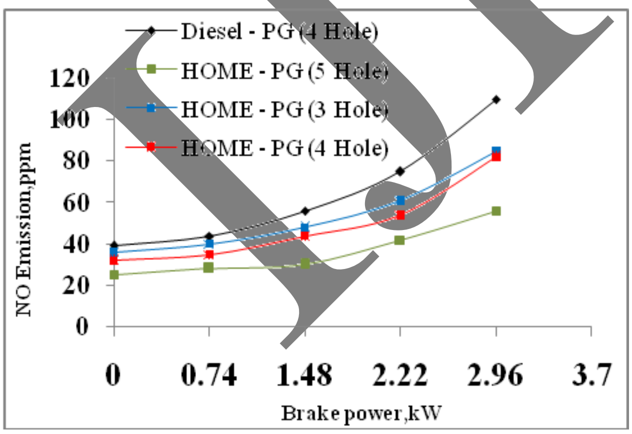

Figure.1.10: Variation of NOx emission with brake power

CONCLUSIONS

The following conclusions were made for the present study

1. The biodiesels can be used in dual fuel mode with producer gas induction and this feature does not require any major engine modifications.
2. The power de-rating in producer gas operated dual fuel engine is of the order of 20%. The power output of the engine used is 3.7 kW, and the engine is operated at less than 80% of the load.
3. The HC, CO and smoke emission was less with the use of 4 hole injector compared to three and five hole injectors used for fuel injection.

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