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EXPERIMENTAL STUDIES ON MANIFOLD INJECTED CNG-BIODIESEL DUAL FUEL ENGINE

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ABSTRACT

The diminishing resources and continuously increasing cost of petroleum in association with their alarming pollution levels from diesel engines has caused an interest in finding alternative fuels to diesel. Emission control and engine efficiency are two of the most important parameters in current engine design. The impending introduction of emissions standards such as Euro IV and Euro V is forcing the research towards developing new technologies for combating engine emissions. This paper studies the effect of CNG gas induction as well as CNG gas injection on the performance of CNG Biodiesel operated dual fuel engine for both CNG and Honge oil methyl esters (HOME) on combustion of both manifold inducted and injected compressed natural gas (CNG) blended with HOME in a dual-fuel engine. From the experimental evidence it is found that combustion of HOME with CNG in a dual fuel engine operated with optimized parameters of injection timing of 27° BTDC and compression ratio of 17.5 results in acceptable combustion emissions and improved brake thermal efficiencies. The implementation of injection strategies for both CNG and HOME fuels results in increased brake thermal efficiency and considerably reduce combustion emissions such as smoke, HC, CO and NO_x.

Keywords: Honge Oil Methyl Ester; Dual fuel engine; Combustion; Compression Ratio; injection strategies; CNG; injector.

1. INTRODUCTION

Petroleum resources are finite and therefore search for their alternative non-petroleum fuels for internal combustion engines is continuing all over the world. The use of alternative gaseous fuels in diesel engines is increasing worldwide. The use of gaseous fuels is prompted by the cleaner nature of their combustion compared to conventional liquid fuels as well as by their relatively increased availability at attractive prices. Natural gas has high octane number and therefore is suitable for engines with relatively high compression ratio [1-8]. There is great potential for Compressed Natural Gas (CNG) because of its very low emissions. The use of CNG as an alternative fuel has far-reaching environmental and economic implications. It is much safer than other motor fuels in the event of a fuel spill as natural gas is lighter than air, so it disperses quickly when leaked or spilled.

Dual-fuel engines have drawn considerable research attention in the area of alternate fuels. Dual-fuel combustion system that utilizes combined diesel and natural gas fuel has been proposed in recent years [7, 8]. Due to a low cetane number, a CNG engine demands injection of diesel fuel as the pilot ignition fuel. Amenability of existing CI Engine to dual-fuelling, without any major modifications and flexibility of dual-fuel engines to switching back to the diesel mode as and when need arises, are the two main advantages of this concept. Dual-fuel combustion system that utilizes combined biodiesel and natural gas fuel also has been proposed in recent years [8-9]. Use of different biodiesels as injected fuels along with CNG induction in dual fuel mode has been reported in the literature [8, 9]. Dual fuel mode of operation employing CNG and plant oils like Honge and Jatropha oils is an attractive option as our country has a large agriculture base that can be a feed stock to this fuel technology and can ease the burden on the economy by curtailing the fuel imports.

Many investigators have studied the effect of CNG gas induction as well as CNG gas injection on the performance of CNG Biodiesel operated dual fuel engine. Advancing the injection timing resulting in better engine performance has been reported in the literature [10-12].

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Many investigators have studied the effect of compression ratio on the performance and emission characteristics of diesel engine running on natural gas in dual fuel mode. Advancing the injection timing resulting in better engine performance has been reported in the literature [13-14].EGR is an effective technique to reduce NO_x emissions in diesel engines. Many investigators have studied the effect of EGR on the performance and emission characteristics of diesel engine running on natural gas in dual fuel mode [15, 18].

In order to obtain a certain degree of mixture stratification up to the end of the compression stroke, a port injection has been proposed, in which CNG was injected near the inlet valves. The improvement of combustion at low loads, mainly in terms of HC and CO emission reduction, is one of the most important issues concerning port injection dual fuel engine operation [14].

2. CHARACTERIZATION OF HONGE, HOME AND CNG

In the present study HOME a biodiesel derived from the locally available honge oil is used as the injected pilot fuel and CNG as the inducted as well as injected fuel. The honge oil is popularly known as pongamia or karanja oil. Among the non-edible vegetable oils, the honge oil is considered as one of the better fuels for internal combustion engines [2,3,9]. It is also used as biodiesel when its viscosity is reduced by the method of trans-esterification. This oil was converted into its methyl ester known as HOME by the trans-esterification process [2-9].

CNG is produced from gas wells or tied in with crude oil production. CNG is primarily made up of methane (CH_4), but frequently contains trace amounts of ethane, propane, nitrogen, helium, carbon dioxide, hydrogen sulphide and water vapour. Methane is the principal component of NG. Normally more than 90% of NG is methane. NG can be compressed, so it can be stored and used as CNG. The auto-ignition temperature of NG is higher than that of gasoline and diesel fuel. In addition NG is lighter than air and will dissipate up ward rapidly if a rupture occurs, Gasoline and diesel will pool on the ground, increasing the danger of fire. CNG is non-toxic and will not contaminate ground water if spilled. Properties of these fuels are listed in Tables 1and 2.

Table 1: Properties of CNG [14]

Properties	Diesel	Honge oil	HOME
Viscosity@40^{0}C (cst)	4.59	44.85	5.6
Flash point (^{0}C)	56	270	163
Calorific value (KJ/kg)	45000	35800	36010
Density (kg/m^3)	830	915	890

Table 2: Properties of diesel, Honge oil and its methyl ester [2, 3]

Properties	CNG
Molecular mass	16.01
Density at NTP (kg/m^3)	147
Normal boiling point (K)	.77
Flammability Limits in Air (%)	5-15
Burning velocity (cm/s)	45
Adiabatic Flame Temperature (K)	2148
Stoichiometric Composition (vol. %)	9.48
Min. Ignition Temperature (mJ)	.29
Auto Ignition Temperature (K)	813
Calorific Value (MJ/kg)	46.28
Quenching gap in air (cm)	.203
Normalized flame emissivity	1.7
Equivalence ratio	.7-4
% of thermal energy radiated	22-33

CNG composition: 2.18% - N_2, 92.69% - CH_4, 3.43% -C_2H_6 .52% - CO_2, .0.71% - Propane, 0.12% - iso-butane, 0.15% - n-butane, 0.09% - pentane, 0.11% - hexane

3. EXPERIMENTAL SETUP

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 17.5:1, developing 3.7 kW at 1500 rev/min. Fig. 1 shows the overall view of the test rig modified to operate on dual fuel mode. The specifications of the engine are given in Table 3. The engine was always operated at a rated speed of 1500 rev/min. The engine had a conventional fuel injection system. The injector had three holes each of 0.27 mm in diameter. The injector opening pressure and the static injection timing as specified by the manufacturer were 20.5 MPa and 230 BTDC respectively.

The governor of the engine was used to control the engine speed. The engine was provided with a hemispherical combustion chamber with over-head 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.

The different methods adopted to supply CNG into the engine cylinder are: inducting CNG in to the engine cylinder along with air through venture and CNG port injection. CNG port injection system has a separate CNG gas ECU and CNG Gas injectors to control the flow and quantity of the CNG. Gas injectors are installed very close to inlet valve in the inlet manifold.

Table 3: specification of CI engine

Parameters	Specification
Machine supplier	Apex Innovations Pvt Ltd. Sangli, Maharashtra
Type	TV1(Kirlosker make)
Nozzle opening pressure	20-22.5 MPa
Governor type	Mechanical centrifugal type
No of cylinders	Single cylinder
No of strokes	Four stroke
Rated power	3.7KW (5HP) @ 1500 RPM
Bore diameter	0.0875 m
Stroke length	0.11 m
Compression ratio	17.5:1

Fig 1.CNG/HCNG-HOME dual fuelled C I engine test rig

Table 4 and 5 shows specifications of exhaust gas analyzer and the smoke meter used for the emission measurements with measurement accuracies and uncertainties. Fig. 2 and fig 3 shows the overall view of the exhaust gas analyzer and smoke meter. The HC and NO_X are measured in PPM while CO and CO_2 were measured in percentage. The smoke is measured in HSU [Hartridge Smoke units].

Table 4: Specifications of the Smoke meter

Type	Hartridge Smoke Meter-4
Object of Measurement	Smoke
Measuring range opacity	0 – 100 %
Accuracy	+ / -2 % relative
Resolution	0.1 %
Smoke length	0.43 m
Ambient Temperature	-5^0 C to + 45^0 C
Warm up time	10 min. (self-controlled) at 20^0C
Speed of Response Time	Within 15 sec. for 90% response
Sampling	Directly sampled from tail pipe
Power Supply	100 to 240 V AC / 50HZ, 10 –16 V DC @15 amps
Size	100 mmX210 mmX50 mm.

Fig 3: Smoke Meter

Table 5. Specification of the exhaust gas analyzer

Type	DELTA 1600S
Object of Measurement	Carbon monoxide (CO), Carbon Dioxide (CO_2) and Hydrocarbons (HC)
Range of Measurement	HC = 0 to 20,000 ppm as C_3H_8 (Propane) CO = 0 to 10%, CO_2 = 0 to 16% O_2 = 0 to 21% , NO_X = 0 to 5000 ppm (as Nitric Oxide)
Accuracy	HC = +/- 30 ppm HC CO = +/- 0.2% CO , CO2 = +/- 1% CO2 O2 = +/- 0.2% O2 ,NOX = +/- 10 ppm NO
Resolution	HC = 1 ppm , CO = 0.01% V O2 = 0.1% Vol.,NO_x = 1 ppm
Warm up time	10 min. (self-controlled) at 20^0C
Speed of Response Time	Within 15 sec. for 90% response
Sampling	Directly sampled from tail pipe
Power Source	100 to 240 V AC / 50Hz
Weight	800 g
Size	100 mm x 210 mm x 50 mm

Fig 2: Exhaust Gas Analyzer

4. RESULTS AND DISCUSSIONS

The experimental investigations were carried out on a single cylinder four stroke CI engine test rig made to operate on dual fuel mode. The engine tests were conducted with dual fuel using CNG and HOME for both 80% and 100% load conditions. The tests were conducted on CNG Biodiesel operated dual fuel engine to study the performance of dual fuel engine operation with CNG gas induction as well as CNG gas injection.

4.1 BRAKE THERMAL EFFICIENCY

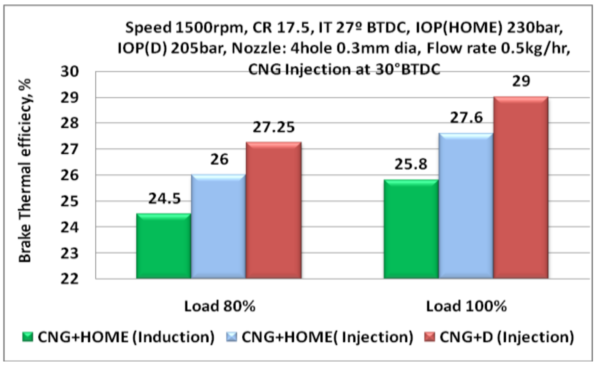

Fig4: Variation of BTE at 80% and 100% load

Figure 4 shows the variation of BTE for Diesel-CNG, HOME-CNG induction /CNG injection dual fuel operation at 80% and 100% load respectively. Higher brake thermal efficiency of 26% was observed with HOME-CNG port injection dual fuel operation with biodiesel as pilot fuel. The reason for this increase in brake thermal efficiency is due to better combustion taking place inside the engine cylinder due to timed manifold injection. The higher calorific value of CNG is also responsible for this trend. Complete burning of the injected liquid fuel as well as injected gaseous fuels leads to better combustion and hence brake thermal efficiency also increased.

4.2 SMOKE OPACITY

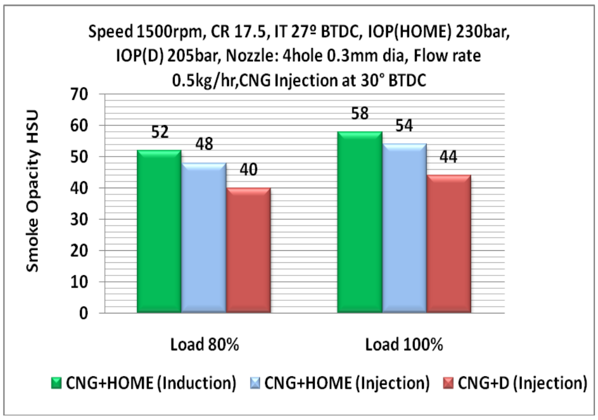

Fig 5: Variation of Smoke at 80% and 100% load

Figure 5 shows the variation of smoke for CNG-Diesel, HOME-CNG induction /CNG injection dual fuel operation at 80% and 100% load respectively. The inducted CNG-Biodiesel dual fuel results in higher smoke emission than injected CNG-Biodiesel fuel combination. Biodiesel being common, the property of the gaseous fuels used is responsible for this trend. Heavy reduction in smoke is observed with CNG injection. This is because the faster burning velocity of CNG facilitates quick burning of HOME droplets [26,30]. The high viscosity of HOME leads to higher smoke compared to that of diesel-CNG operation.

4.3 HC emissions

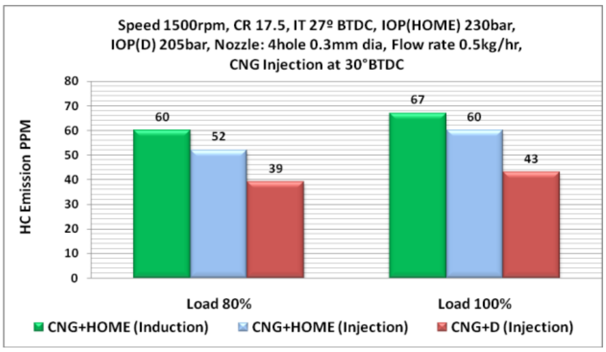

Fig 6: Variation HC Emissions at 80 and 100% load

4.4 CO emissions

Figure 6 and 7 shows the variation of HC and CO for CNG-Diesel, HOME-CNG induction /CNG injection dual fuel operation at 80% and 100% load respectively. With injection of CNG drastic reduction in HC, CO were observed. This is because timed manifold injection of CNG results in complete combustion. Optimized timed manifold injection in the suction stroke ensures better mixing of air and CNG and this could be the reason for the better combustion and may also be due to higher premixed combustion associated with high peak pressure and heat release rate. At 80% load smoke emission for port injected dual fuel operation is 48 HSU compared to 60 HSU for CNG induction method. For different combinations of the engine operating parameters, a port injection inlet configuration set up is always associated to the lowest HC levels, demonstrating the effectiveness of this methane supply method to reduce the unburned hydrocarbons concentrations at the engine exhaust [16,26,27,30].

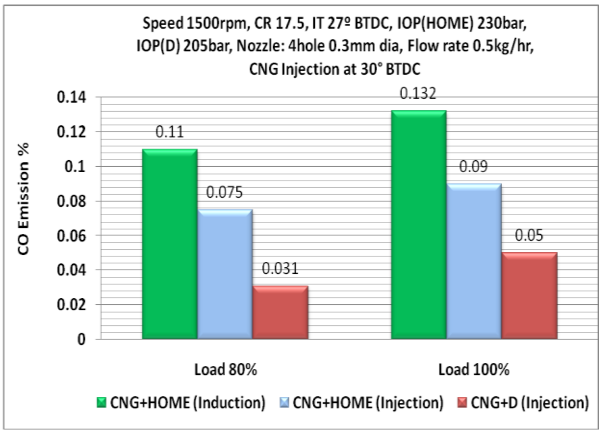

Fig 7: Variation CO Emissions at 80 and 100% load

4.5 NO_X Emission

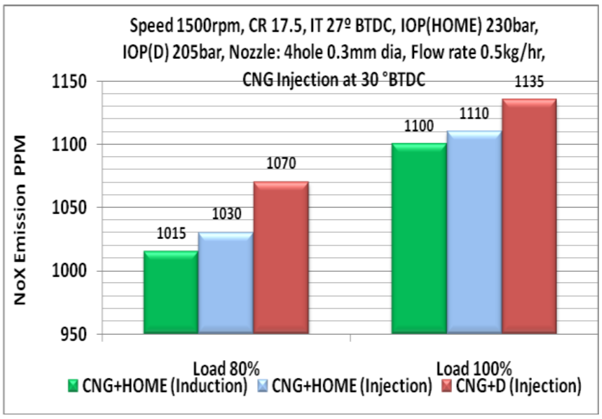

Fig 8: Variation NO_x Emissions of various Gaseous fuel at 80 and 100% load

Figure 8 shows the variation of NO_x for CNG-Diesel, HOME-CNG induction /CNG injection dual fuel operation at 80% and 100% load respectively. Higher NO_x emission is observed for CNG-Diesel dual fuel operation than injected and inducted CNG –Biodiesel dual fuel operation. This is because of very high temperature prevailing in the combustion chamber that leads to NO_x[23]. However this can be controlled with the introduction of suitable EGR.

5. CONCLUSIONS

CNG – biodiesels fueled dual fuel operation in both induction and injection modes resulted in poor performance compared to diesel operation.
However, CNG injected dual fuel operation resulted in improved overall performance compared CNG inducted operation. It can be stated that port injection, as a methane supply method for dual fuel engines, is a very effective method to reduce unburned hydrocarbons and nitric oxides emissions. Shifting from homogeneous to port injection method, HC levels tend to decrease while NO_x increase.

From the injection method, it was observed that, BTE was increased by 0.5 % compared to induction method. The emission levels were obtained were smoke 7.69%, HC decreased by 13.33%, CO decreased by 31.81%, NO_X increased by 1.45%.

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