Study of performance and emission parameters of a single cylinder four stroke diesel engine in dual fuel mode using rice bran biodiesel with CNG

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Abstract

The continuously increasing cost of petroleum along with their rising pollution levels from diesel engines has caused an interest in finding alternate fuels to diesel. Emission control and engine efficiencies are the important parameters in current engine design. This paper studies the effect of CNG gas induction on the performance of CNG biodiesel operated dual fuel engine for both CNG and Rice bran oil ethyl esters (ROEE) on combustion of manifold inducted compressed natural gas (CNG) blended with ROEE in a dual-fuel engine. The use of Compressed Natural Gas (CNG) is experimented to improve the performance of a dual fuel compression ignition (CI) engine running on Rice bran oil ethyl ester blends. Diesel is used as the base fuel for the dual fuel engine results. During experimentation, the engine performance was measured in terms of brake thermal efficiency and brake specific fuel consumption. Results showed that using Rice bran biodiesel blends has improved the CI engine performance with a reduction in HC and NOx emissions.

Keywords: Rice bran oil, CNG, diesel engine, dual fuel mode.

I. INTRODUCTION

Petroleum resources are finite and therefore search for their alternative fuels for IC engines is continuing everywhere. Alternative gaseous fuels are used widely all over the world. Use of gaseous fuels is prompted by its cleaner nature of combustion compared to the usual liquid fuels. Natural gas has relatively high octane number and is suitable for engines with higher compression ratios [1-3]. CNG has a good potential because of its very low emissions. The use of CNG as an alternative fuel results in better economical as well as environmental impacts. It is safer than other fuels such as motor fuels in the case of a fuel spill, where natural gas is lighter than air, so it disperses quickly when leaked. Biodiesel is referred to as the mono-alkyl-esters of long-chain-fatty acids derived from renewable fatty acid sources. The principal advantages of biodiesel is that it minimizes the formation of sulphur dioxide, CO, HC, and Particulate Matter emissions during the combustion process due to low sulphur and the presence of oxygen-containing compounds. In addition, biodiesel has good ignition ability in engine due to its relatively high cetane number compared to that of conventional diesel fuel. It is found that the lower concentrations of biodiesel blends improve the thermal efficiency. As the parameters at which the engines are operating, a blend up to 20% of biodiesel with diesel works well without any modification in the engine. The potential benefits of using CNG in diesel engines are both economical and environment friendly. With reduced energy consumption, the dual fuel engine shows a significant reduction in smoke density and improved BTE. In the present study, the effect of biodiesel blends along with CNG induction over the performance and emission characteristics of a diesel engine in dual fuel mode was experimentally investigated.

II. CHARACTERIZATION OF RICE BRAN, ROEE AND CNG

In the present study, ROEE a biodiesel derived from the locally available rice bran oil is used as the injected pilot fuel and CNG as the inducted fuel. Rice bran oil is used as biodiesel when its viscosity is reduced by the method of trans-esterification. This oil was converted into its ethyl ester known as ROEE by the trans-esterification process. CNG is produced from gas wells. It is primarily made up of methane but contains some trace amounts of ethane, propane, carbon dioxide, and water vapor. Normally more than 90% of natural gas is methane. NG can be compressed, stored and used as CNG. The auto ignition temperature of NG is higher than that of gasoline and diesel. Properties of these fuels are listed in tables 1 and 2.

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Table 1. Properties of diesel, Rice bran oil and its ethyl ester [3]

Properties	Diesel	Rice bran oil	ROEE
Viscosity@40^0C (cst)	4.59	38.48	4.81
Flash point (^{0}C)	56	226	137
Calorific Value (KJ/Kg)	44585	41170	41382
Density (Kg/m^3)	830	898	872

Table 2.Properties of CNG [5]

Properties	CNG
Molecular Mass	16.01
Density at NTP (Kg/m^3)	147
Burning Velocity (cm/s)	45
Adiabatic Flame Temperature (K)	2148
Auto Ignition Temperature (K)	813
Calorific Value (MJ/Kg)	46.28

III. EXPERIMENTATION

The aim of the study is to establish a combination of biodiesel blends with gaseous fuel in dual fuel mode and to study the performance and emission characteristics of the engine with CNG as the gaseous fuel.

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 984 cc, compression ratio of 17.5:1, developing 7.45 KW at 1500 rpm. The specifications of the engine are given in Table 3. The engine runs at a constant speed of up to 1500 rpm. The injector opening pressure is 20.5 MPa and static injection timing is 23^0 bTDC as specified by the manufacturer. Cooling of the engine was accomplished by circulating water through the jackets on the engine block and cylinder head. A piezo-electric pressure transducer was mounted with the cylinder head surface to measure the cylinder pressure. The engine is coupled with an electrical dynamometer to measure the operating load. The inlet valve opens 4.5^0 bTDC and closes 35.5^0 aBDC. The exhaust valve opens 35.5^0 bBDC and closes 4.5^0 aTDC. The engine was modified to work in the dual fuel mode by connecting CNG line to the intake manifold with a flame trap, non-return valve, needle valve and mixing unit. Time taken for fuel consumption was measured with the help of a digital stopwatch. With help of a U tube manometer, measurement of air consumption of the engine was done. CO, NOx, particulate and unburned HC emissions were measured using a 5 gas analyzer.

Table 3. Specifications of the engine

Model & Make	Kirloskar DM10, Single cylinder, 4 stroke, constant speed, vertical, water cooled, direct injection compression ignition engine
Bore & Stroke	102 mm x 118 mm
Compression ratio	17.5:1
Rated Output	7.45 KW @ 1500 rpm
Rated Speed	1500 rpm
Opening pressure of injection nozzle	190-200 bars
Fuel injection timing	26^0 bTDC
Capacity	984 cc

The schematic representation of the experimental setup is shown in fig.1, The experimental procedure consists of the following steps.

Initially, engine was tested using the reference fuel diesel at all loads to determine the engine operating characteristics and pollutant emissions. The engine speed was maintained constant throughout the entire engine operation at 1500 rpm. The engine was tested using neat rice bran biodiesel for the same operating conditions. The same procedure was repeated in dual fuel mode with an optimum pilot fuel quantity of 7.6 mg/cycle diesel with CNG and 7.6 mg/cycle rice bran biodiesel with CNG. The injection timing was advanced 1^0 CA for dual fuel operation (27^0bTDC). The liquid fuel quantity was maintained constantly for the entire load range.

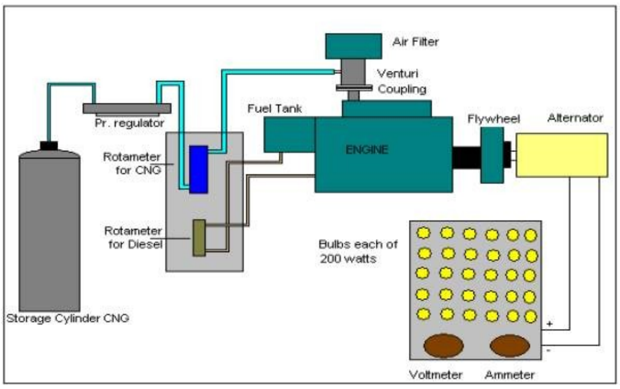

Figure 1. Schematic Representation of Engine setup

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IV. RESULTS AND DISCUSSIONS

The variations of performance and emission parameters of CNG fuelled direct injection compression ignition engine with rice bran biodiesel as the pilot fuel have been discussed in this section.

A) Engine performance

Brake specific fuel consumption

Figures 2 and 3 shows the variations of brake specific fuel consumption with brake power curves for diesel, biodiesel, biodiesel+CNG operation of the engine at 27 deg bTDC and 190bar, 200bar injection pressures respectively. BSFC of 0.87 Kg/KW hr, 0.74 Kg/KW hr were obtained at low loads of operation at 190bar, 200bar pressures. At higher loads the values are 0.29Kg/KW hr, 0.26Kg/KW hr respectively for 190bar, 200bar injection pressures respectively. BSFC at higher loads is even less than diesel operation at all pressures with advanced injection timings due to slow flame velocities and clean burning.

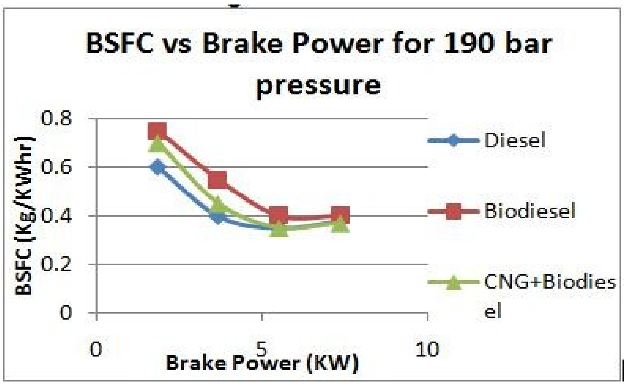

Figure 2. BSFC vs BP for 190 bar pressure

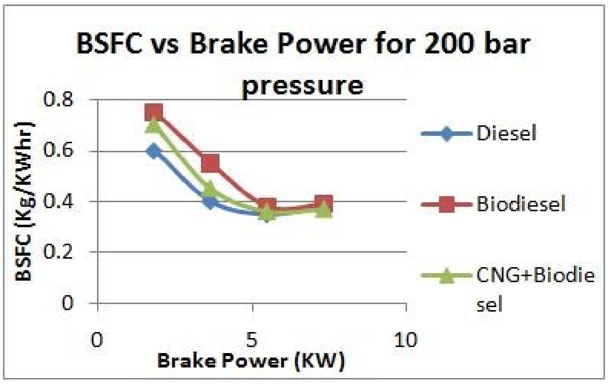

Figure 3. BSFC vs BP for 200 bar pressure

Brake thermal efficiency

Figures 4 and 5 shows variation of brake thermal efficiency with brake power curves for diesel, biodiesel and CNG+biodiesel operation of the engine at 27 deg bTDC and 190bar, 200bar injection pressures respectively.

An efficiency of almost equal to 9% is obtained at all the two injection pressures at low loads of operation, at higher loads an efficiency of 26.22, 27.42 is obtained at 190 bar, 200 bar respectively.

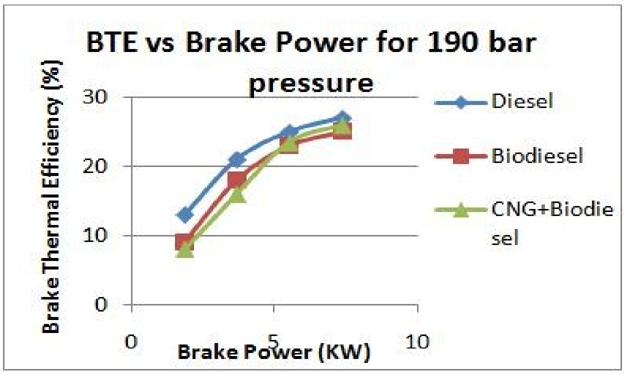

Figure 4. BTE vs BP for 190 bar pressure

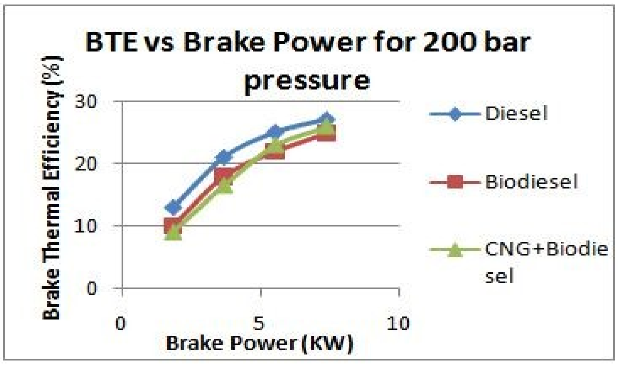

Figure 5. BTE vs BP for 200 bar pressure

B) Exhaust emissions

Figures 6 and 7shows variation of unburnt hydrocarbons with brake power curves for diesel, biodiesel and CNG+biodiesel operation of the engine at 27 deg bTDC and 190bar,200bar injection pressures respectively.

At low loads of operation all pressures nearly 210ppm again due to improper mixing and combustion higher loads it approximates to 55ppm.due to improved mixture formation and better combustion process.

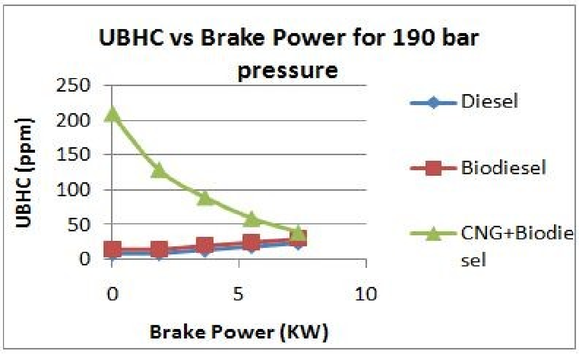

Figure 6. UBHC vs BP for 190 bar pressure

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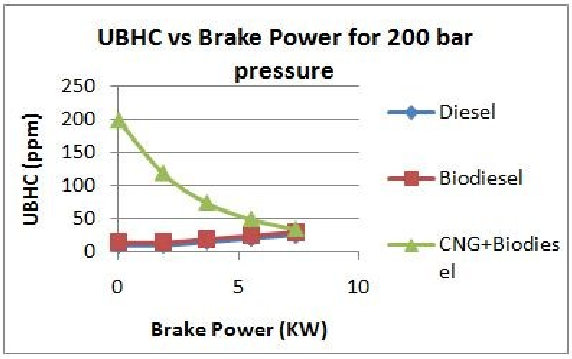

Figure 7. UBHC vs BP for 200 bar pressure

Figures 8 and 9 shows variation of oxides of nitrogen with brake power curves for diesel, biodiesel and CNG+biodiesel operation of the engine at 27 deg bTDC and 190bar, 200bar injection pressures respectively.

NOx emissions vary from 21 ppm to 145 ppm at two pressures measured. Pressure variation had slight effects on NOx emissions.

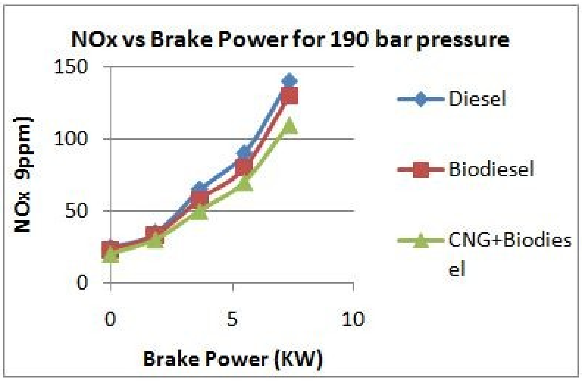

Figure 8. NOx vs BP for 190 bar pressure

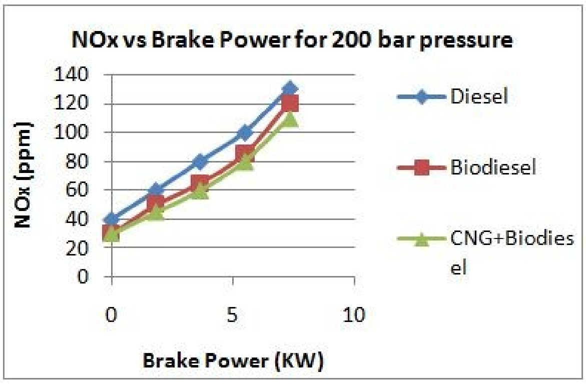

Figure 9. NOx vs BP for 200 bar pressure

V. CONCLUSIONS

CNG-biodiesel fueled dual fuel operation resulted in poor performance compared to diesel operation.

However, CNG inducted dual fuel operation resulted in improved overall performance compared to biodiesel operation.

The NOx emissions of CNG- biodiesel fueled mode resulted well while compared with diesel mode.

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