



Experimental Studies of Compression Ignition Diesel Engine Using CNG and Pongamia Biodiesel in a Dual Fuel Mode

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Abstract: The rapid depletion of energy resources and continuous increasing cost of petroleum based fuels with their pollution from diesel engine to environment has caused an interest to search for new alternate fuels such as vegetable oils, gaseous fuel. The main objective of this work is to evaluate performance and emission characteristics using CNG (compressed natural gas) and POME (Pongamia oil methyl ester) in a dual fuel mode where pongamia biodiesel used as a pilot fuel to ignite CNG gas. The engine tests were carried out for neat pongamia biodiesel, CNG flow rates of 0.3 kg/hr and 0.6 kg/hr with pongamia biodiesel in a dual fuel mode and obtained results are compared with diesel. In a dual fuel mode CNG flow rate of 0.6 kg/hr gives similar performance compared to diesel. The brake thermal efficiency for 0.6 kg/hr CNG-POME is 26.7% against 28.6% diesel at 75% of the load. In a dual fuel mode CO, CO CORR and hydro carbon emissions are higher at low load and at full load with increase in percentage of CNG CO, CO CORR and HC emissions are completely reduced to a certain extent. In a dual fuel mode CO₂ emission, smoke and NO_x emission also reduced compared to diesel and pongamia biodiesel. From comparison of all tested fuels CNG flow rate of 0.6 kg/hr with biodiesel is optimum having lower emissions with very little reduction in brake thermal efficiency.

Keywords: CI Engine, CNG, Dual Fuel, POME

1. Introduction

In the world wide demand for conventional fuels such as petrol and diesel has been increasing day by day. Due to increased usage of these conventional fuels, reserves of these resources are being depleting. Increase in environmental pollution, global warming, ozone layer depletion, toxic emissions, rising costs of these non-renewable resources have caused the researches to investigate and search for clean burning alternate fuels in internal combustion engines [1-2]. Many of the researchers and scientist found that for a short term engine tests using edible and non edible oil in internal combustion engine were very promising but for a long term engine tests results lubricating oil contamination, higher carbon built up which results in engine failure. Finally researches concluded that using edible and non edible oils, either blend with diesel or chemically altered or by using a

dual fuel engine will prevent the engine failure [3-5]. Majority of the alternate fuels are applied correctly but their availability in the global energy market is as for now became quite small, so the research have been made in search of new promising alternative fuels such as (Compressed natural gas) CNG, (Liquified petroleum gas) LPG, dimethyl ether and hydrogen fuels. Among new alternative fuels compressed natural gas has major advantages for low particulate and NO_x emissions. Diesel engines are stringent emission regulation particularly of NO_x and smoke in their exhaust. This disadvantage will be overcome by operating diesel engine in a dual fuel mode. Compressed natural gas, diesel or biodiesel in a dual-fuel mode is regarded as the best ways to control emissions from compressed ignition diesel engines. Dual fuel engine is a diesel engine which burn either diesel or gaseous fuel or both at the same time [6-7]. In a dual fuel operation the compressed natural gas is mixed with the air intake manifold and this mixture is compressed during a

compression stroke. At or near the end of compression stroke, pongamia biodiesel is injected. After a certain time i.e short ignition delay or ignition lag the combustion of pongamia biodiesel occurs first, igniting the CNG gas and the flame propagation begins. The introduction of Compressed natural gas along with intake air changes the properties of the mixture in the cylinder and thus the quantity of pongamia biodiesel and concentration of Compressed natural gas in the intake air have important effects on the performance and emission characteristics of a dual fuel engine [8]. An experiment was conducted on a CI engine using CNG and Jatropa biodiesel in a dual fuel mode by [9], performance and emission characteristics are evaluated. The experiment is carried out at three injection pressures of 180, 200 and 220 bar. From the results they concluded that CNG with jatropa oil methyl ester will give better performance at 220 bar. An experiment was conducted on a CI engine using CNG and neem oil in a dual fuel mode by [10], the performance and emission parameters are evaluated. The experiments are carried out for five different CNG flow rates. From

comparison of results they concluded that 4% CNG + 96% Neem oil, 8% CNG + 92% Neem oil, 12% CNG + 88% Neem oil are found optimum. An experiment was conducted on CI engine using CNG and diesel in a dual fuel mode by [11], performance and emission characteristics are evaluated. From the obtained results they concluded that the engine performance is better on CNG compared to diesel up to loads of about 75.67%. An experiment conducted on CI engine using CNG and diesel in a dual fuel mode by [12], the experiment is carried out at different compression ratio with varying CNG flow rates. From the results obtained they concluded that dual fuel engine is found better than diesel engine at all loads.

2. Fuel Characterization

Compressed natural gas is supplied to the engine through intake manifold. Biodiesel is used as Pongamia oil methyl ester (POME) is used as a pilot fuel. Table 1 and 2 shows properties of POME and CNG respectively.

Table 1. Fuel Properties.

Fuel properties	Diesel	POME
Density (kg/m ³)	830	890
Calorific value (kJ/kg)	43000	40500
Flash point (°C)	56	196
Fire point (°C)	65	206
Kinematic viscosity at 40°C (cst)	3.9	14.7

Table 2. CNG Properties.

Properties	CNG
Density (kg/m ³)	0.65
Normal boiling point (K)	0.77
Burning velocity (cm/s)	45
Molecular mass	16.01
Calorific value (MJ/kg)	45.8
Auto ignition temperature (K)	813
Min. ignition temperature (mJ)	0.29
Flammability limits in air (%)	5-15
Stoichiometric composition vol (%)	9.48
Normalized flame emissivity	1.7
Quenching gap in air (cm)	0.203
% of thermal energy radiated	22-33
Equivalence ratio	0.7-4

3. Experimental Setup and Methodology

The experiment setup and line diagram is as shown in fig. 1 and fig. 2, planned to conduct on 5.2 kW, TV-SR naturally aspirated, compressed ignition single cylinder direct injection water cooled having 50 mm bore and 110 mm stroke. It consists of a test bed, an eddy current dynamometer, a data acquisition system, a computer, an operation panel, exhaust emission analyser, a smoke meter is as shown in fig. 3. A calibrated gas flow meter is used to measure the compressed natural gas consumption rate is as shown in fig. 4.

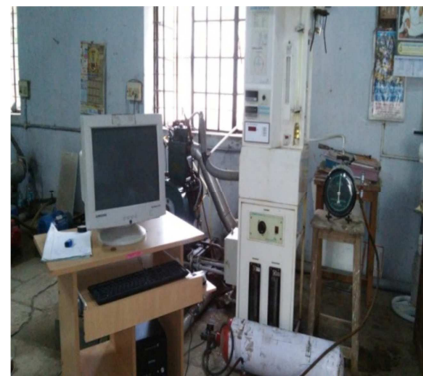


Fig. 1. Photograph of the experimental setup.

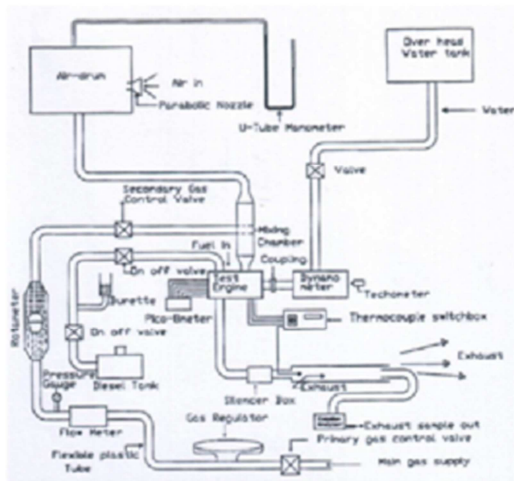


Fig. 2. Line diagram of the experimental setup.



Fig. 3. Gas flow meter.



Fig. 4. Exhaust emission testing machine.

Table 3. Engine Specifications.

Manufacturer	Kirloskar oil engines Ltd, India
Model	Naturally aspirated, TV-SR
Engine	Single cylinder
Bore/stroke	87.5mm/110mm
Compression ratio	16.5:1
Speed	1500 rpm
Rated power	5.2 kW
Working cycle	Four stroke cycle
Injection pressure	200bar/23 deg before TDC
Type of sensor	Piezo electric sensor
Response time	4 micro seconds
Crank angle sensor	1 degree crank angle
Resolution of 1 deg	360 deg

4. Results and Discussion

Performance characteristics

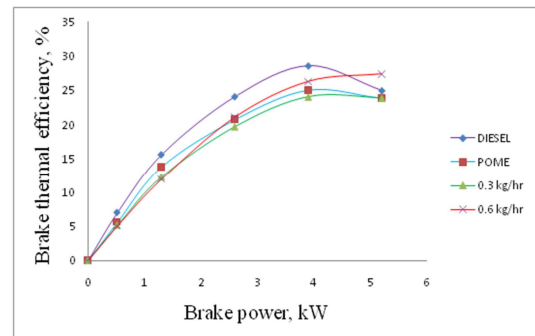


Fig. 5. Brake thermal efficiency Vs Brake power.

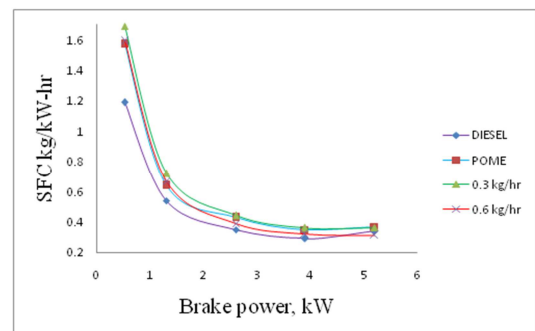


Fig. 6. Specific fuel consumption Vs Brake power.

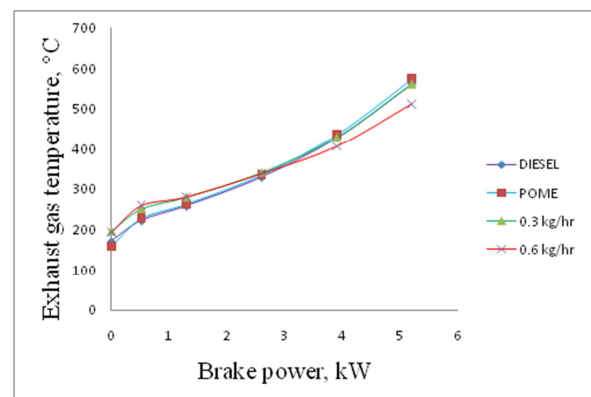


Fig. 7. Exhaust gas temperature Vs Brake power.

Emission characteristics

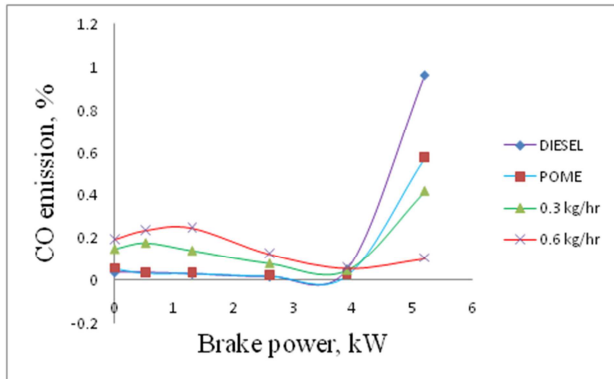


Fig. 8. CO emission Vs Brake power.

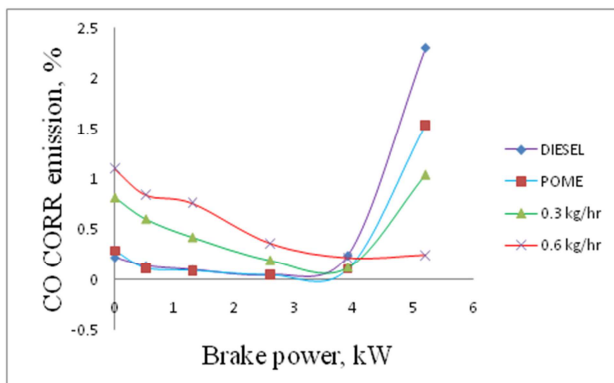


Fig. 9. CO CORR emission Vs Brake power.

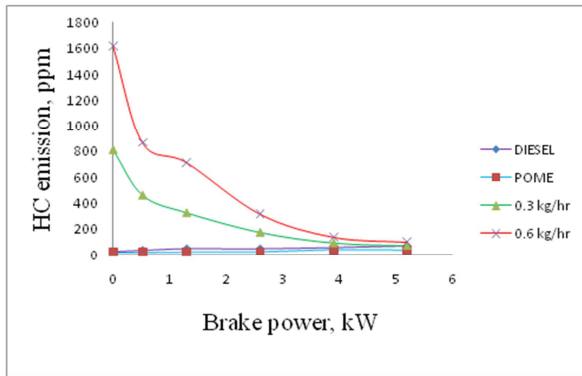


Fig. 10. HC emission Vs Brake power.

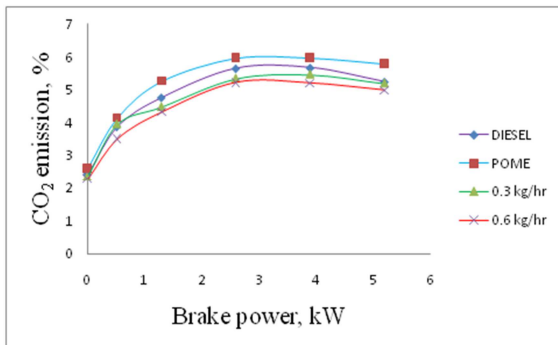
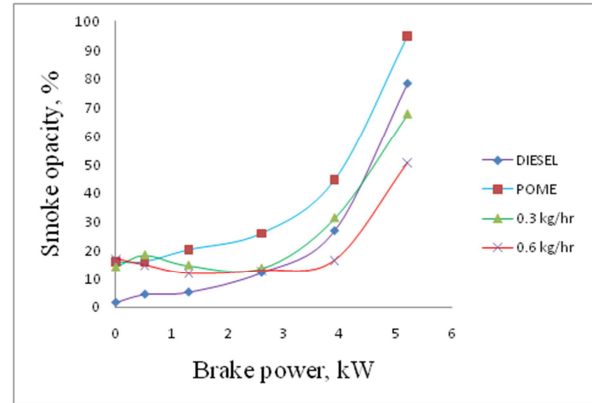
Fig. 11. CO₂ emission Vs Brake power.

Fig. 12. Smoke opacity emission Vs Brake power.

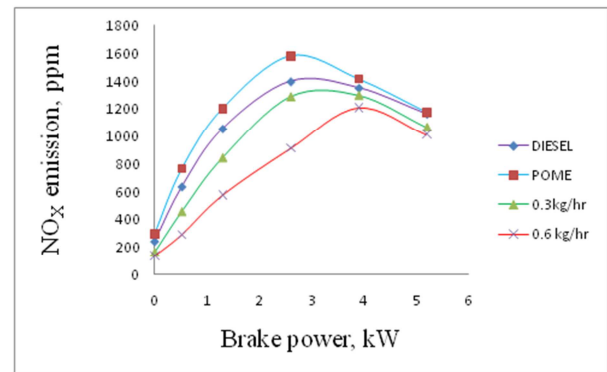
Fig. 13. NO_x emission Vs Brake power.

Fig. 5 shows the brake thermal efficiency variation with brake power for diesel, pongamia biodiesel and CNG flow rates of 0.3 kg/hr and 0.6 kg/hr with pongamia biodiesel. Here pongamia biodiesel is used as a pilot fuel to ignite CNG. The brake thermal efficiency of pongamia biodiesel is lower because of higher viscosity, atomisation is difficult for biodiesel also having a lower calorific value due to these two reasons brake thermal efficiency is lower for biodiesel compared to diesel. In a dual fuel mode at low load brake thermal efficiency is low due to improper combustion and at high load proper mixing of CNG and pongamia biodiesel takes place which leads to better combustion and also due to higher calorific value of CNG which burns completely results in higher brake thermal efficiency. CNG with biodiesel in a dual fuel mode gives similar performance compared to pure diesel. Fig. 6 shows the specific fuel consumption variation with brake power for diesel, pongamia biodiesel and CNG flow rates of 0.3 kg/hr and 0.6 kg/hr with pongamia biodiesel. From the fig. 6 we see that specific fuel consumption is continuously decreasing with increase in brake power because at low loads mixing of the CNG gas and biodiesel fuel is not proper and hence as the load is increased fuel and gas mixing is also increased and at full load specific fuel consumption is totally decreased for all tested fuels. Fig. 7 shows the variation of (EGT) exhaust gas temperature with brake power for diesel, pongamia biodiesel and CNG flow rates of 0.3 kg/hr and 0.6 kg/hr with pongamia biodiesel. From the fig. 7 we see that exhaust gas

temperature is increasing with increase in brake power for all fuels. As the load is increased the temperature inside the combustion chamber is also increased which leads to better mixing of air and fuel and complete combustion takes place. At full load the exhaust gas temperature for pongamia biodiesel is more due to high inbuilt oxygen content due to which it takes more time for complete combustion. Fig. 8 shows CO emission variation with brake power for diesel, pongamia biodiesel and CNG flow rates of 0.3 kg/hr and 0.6 kg/hr with pongamia biodiesel and fig. 9 shows CO CORR emission variation with brake power for diesel, pongamia biodiesel and CNG flow rates of 0.3 kg/hr and 0.6 kg/hr with pongamia biodiesel. From these two figures we observe that CO emissions and CO CORR emissions are continuously decreasing with brake power upto 75% of the load. CO and CORR emissions are mainly dependent on air-fuel ratio. At full load we observe that CO and CO CORR emissions are more for pongamia biodiesel due to high inbuilt oxygen content and lean mixture. Further CNG addition to biodiesel at different flow rates of 0.3 kg/hr and 0.6 kg/hr, at higher loads CO and CO CORR emissions are still decreased because of rich mixture leads to complete combustion of CNG and pongamia biodiesel. Fig. 9 shows HC emission variation with brake power for diesel, pongamia biodiesel and CNG flow rates of 0.3 kg/hr and 0.6 kg/hr with pongamia biodiesel. In a dual fuel mode we observe that HC emissions are higher at low load because small amount of pongamia biodiesel cannot propagate fast to ignite CNG gas which leads to low temperature inside the combustion chamber. As the load is increased proper mixing of CNG and biodiesel takes place also temperature inside the combustion chamber is increased hence better combustion takes place which leads to lower hydrocarbon emissions at full load. Fig. 11 shows CO₂ emission variation with brake power for diesel, pongamia biodiesel and CNG flow rates of 0.3 kg/hr and 0.6 kg/hr with pongamia biodiesel, fig. 12 shows smoke emission variation with brake power for diesel, pongamia biodiesel and CNG flow rates of 0.3 kg/hr and 0.6 kg/hr with pongamia biodiesel, fig. 13 shows NO_x emission variation with brake power for diesel, pongamia biodiesel and CNG flow rates of 0.3 kg/hr and 0.6 kg/hr with pongamia biodiesel. From these three figures we observe that emissions for pongamia biodiesel is higher because pongamia biodiesel is mainly associated with smoke and molecular structure of the injected pongamia biodiesel is heavier compared to all fuels. The formation of NO_x emissions is mainly dependent on the oxygen content and higher temperature inside the combustion chamber hence NO_x emissions is more for pongamia biodiesel. In the dual fuel mode as the percentage of CNG is increased the temperature inside the engine cylinder is increased hence complete combustion takes place due to which smoke, CO₂ and NO_x emissions are lower at full load.

5. Conclusion

The engine tests were conducted for neat pongamia biodiesel, 0.3 kg/hr CNG-biodiesel, 0.6 kg/hr CNG-biodiesel

and results are compared with neat diesel. Performance and emission characteristics of these fuels are evaluated and presented. Based on the present work the conclusions are drawn as follows.

- In a dual fuel mode CNG flow rate of 0.3 kg/hr and 0.6 kg/hr with biodiesel is lower at low loads and at higher loads brake thermal efficiency increases with increase percentage of CNG. The maximum brake thermal efficiency for 0.6 kg/hr CNG-biodiesel is 28.5% against 24.32% neat biodiesel at full load.
- Specific fuel consumption continuously decreases with increase in brake power for all tested fuels. In a dual fuel mode CNG flow rate of 0.3 kg/hr and 0.6 kg/hr with biodiesel, SFC is higher at low loads and at higher loads decreases with increase in percentage of CNG. The minimum specific fuel consumption for 0.6 kg/hr CNG-biodiesel is 0.32 kg/kW-hr against 0.36 kg/kW-hr neat biodiesel at full load.
- In the dual fuel mode as the percentage of CNG is increased reduces the smoke. The maximum smoke emissions emitted for 0.3 kg/hr and 0.6 kg/hr flow rate of CNG-pongamia biodiesel is respectively 65.48% and 49.78%.
- In the dual fuel mode CO emission reduces with increase in percentage of CNG.
- In the dual fuel mode unburnt hydro carbon is higher at low loads and decreases with increase in percentage of CNG.
- NO_x emissions for pongamia biodiesel are higher and decreases considerably in a dual fuel mode.
- Comparing to all the tested fuels 0.6 kg/hr CNG-Pongamia biodiesel dual fuel has lower emissions with a very little sacrifice in brake thermal efficiency.

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