

Experimental Performance Analysis of Six Cylinder Turbocharged Diesel-Cng Dual Fuel Engine

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Abstract

Dual fuel engine is internal combustion engine which works with two fuels simultaneously. Automobile sector is facing challenge of fossil fuel depletion & reducing harmful emissions to meet stringent environmental norms. Alternate fuels like CNG have capabilities of reducing exhaust emissions from automobiles. CNG has other advantages like lower cost as compared to gasoline & diesel, less noise due to high octane no & clean combustion properties. Diesel-CNG Dual fuel engines offer number of potential advantages like fuel flexibility, lower emissions, higher compression ratio and better efficiency. This paper is based on experimental work done on six cylinder turbocharged engine converted to dual fuel engine by using dual fuel kit from M/s Best Prins, Netherlands. Engine was tested on AVL PUMA engine testing system and emissions were measured on AVL emission measuring equipment. 13 mode ESC test was conducted in diesel mode & dual fuel mode. All points were optimized for engine performance & emissions. Optimized engine parameters & emissions were measured. It was observed that, it was possible to achieve engine performance near to BS III emission norms. Engine testing was carried out at ARAI, pune, India.

Keywords: Dual fuel, Emission analysis, Performance CNG, Diesel

1. INTRODUCTION

Advantages of dual fuel technology

1. Existing diesel engines can be easily converted to dual fuel mode without any major changes.
2. It has fuel flexibility. It can be operated on full diesel mode if natural gas is not available.
3. Dual fuel engines have potential benefits like higher power density, better efficiency and lean burn combustion capacity which results in reduced misfire and NO_x emissions.
4. Diesel pilot fuel provides lubrication to valves and rings which results in longer maintenance intervals and reduces maintenance cost.
5. In dual fuel engines exhaust emissions like nitrogen oxides, CO₂ and particulates are significantly reduced.
6. As natural gas has high research octane number (120-130), it is highly resistant to knock. Use of lean air fuel mixtures also reduces knocking tendencies.
7. Major advantage of dual fuel natural gas engine compared to spark ignition engine is its ability to burn very lean air fuel mixtures with high efficiency.
8. Use of extremely lean mixtures and rapid combustion allow dual fuel engines to use higher compression ratios and achieve higher brake mean effective pressure than could be achieved in SI engines without causing knocking (Jessen Scot; 2006).

2. DIESEL-CNG DUAL FUEL ENGINE

2.1 Working of Diesel-CNG dual fuel engine

In diesel-CNG dual fuel engine mixture of natural gas and air is induced in engine cylinder and is compressed during compression stroke. CNG is mixed with air in mixer and then supplied to engine cylinder. Air fuel mixture in cylinder is ignited by injecting small quantity of diesel called as pilot injection in cylinder at the end of compression stroke. Diesel is ignited due to heat of compression and then burns CNG which produces work in engine cylinder. In dual fuel engine natural gas is fumigated in the intake manifold and the mixture of gas and air is compressed in the compressed stroke which is then ignited due to auto ignition of the diesel fuel spray. The quantity of diesel in this case can vary from 100% to 20%. During starting and full load conditions, the engine runs under 100% diesel as a safety measure to avoid knocking, whereas under part load conditions it runs in the dual fuel mode with diesel and CNG. In such dual fuel engine ignition delay of diesel is important because due to admission of mixture of gaseous fuel & intake air results in changes in physical properties of mixture like specific heat ratio & heat transfer parameters. This results in changes in pre ignition reaction activity &

associated energy release & production of active species (R.R.Saraf; 2009).

2.2 Worldwide Status of Dual Fuel Engines.

Dual fuel engines have been tried since 1930's. It was exclusively used for power generation and its availability was only through OEM (Original Equipment Manufacturer). Many hundreds of dual fuel engines were employed in USA for rural electrification purpose. Considering present status of uncertainties in power availability, emissions and current price of diesel, dual fuel engines are gaining new popularity. Gafcor NGV which is division of Gas and Fuel Corporation of Victoria has worked on dual fuel conversion of diesel engines. No of buses and trucks were run by dual fuel technology. NGV has developed pilot ignition Diesel/Natural Gas Lambda 2 system (PING), for heavy duty direct injection diesel engines. It is fully integrated electronic engine management system. It has flexibility so that it can be applied to different diesel engines. This system accurately controls the natural gas/diesel mixture for PING engine operations, to maximize fuel efficiency and minimize emissions. Main applications of dual fuel engines are railway engines, marine vessels, heavy duty trucks, buses and power generation systems (Lambda2; 2006). Detroit diesel corporation and Stewart and Stevenson have developed dual fuel system for two stroke diesel transit bus engine. Pielstick has developed PA 5 DF four cylinder dual fuel engine which produced 224 kW/cylinder. Energy conversions Inc. has converted locomotive diesel engines to dual fuel engines for Burlington Northern Railroad. Cooper Cleanburn™ and the Coltec/Fairbanks Morse were converted to dual fuel operation with prechamber (S.Christopher; 2000).

Literature review shows different experimental aspects of dual fuel engine. Impact of gas air composition on combustion parameters of dual fuel engine was studied (Zdzislaw stelmasiak; 2002).

A single cylinder compression ignition DI engine with bore 90 mm, stroke 90 mm, compression ratio 16.8 and power 6.1 kW was tested. It was observed that composition of inlet gas air mixture influences events of gas combustion. In rich range of gas air mixture, rate of gas combustion determines parameters of combustion like pressure, rate of pressure rise and heat release rate. In lean range of mixture these parameters are mainly influenced by combustion of pilot diesel (D.T Hountalas et al.; 2002).

A single cylinder four stroke cycle, direct injection diesel engine was tested and experimental results were compared with theoretical results obtained from computer simulation program. It was observed that dual fuel operation has positive effect on NOx and soot emissions compared to normal diesel operation. It was observed that peak cylinder pressure is lower and brake specific fuel consumption is more in dual fuel operation as compared to normal diesel operation (D.T.Hountalas et al.; 2005).

A single cylinder, indirect injection, four stroke cycle engine with bore 76.2mm, stroke 111.1 mm, compression ratio 22 and power 9 kW has been tested and parameters along with combustion noise were studied (Y.E Mohamed. Selim; 2004).

A four stroke, four cylinder, water cooled, indirect injection, naturally aspirated diesel engine with bore 84.2 mm, stroke 102.2mm, compression ratio 21 and power 16.3 kW was tested and effects of engine speed on different parameters were studied. It was observed that maximum cylinder pressure in dual fuel mode is slightly less than diesel mode. It was observed that brake power reduces as percentage of CNG substitution increases. Maximum exhaust gas temperature in dual fuel mode was lower than in diesel mode (Nafis Ahmad et al.; 2005).

Above engine was operated in turbocharged condition and different engine parameters were studied. Power developed by engine and thermal efficiency in turbocharged dual fuel mode operation was more as compared to naturally aspirated dual fuel mode (Nafis Ahmad et al.; 2005).

2.3 Engine Specifications

In present experimental work engine of following specifications was tested.

Bore*stroke (mm) - 97*128

Number of cylinders- Six

Rated speed (RPM) - 2400

Rated power (KW) - 100

Fuel - CNG and Diesel

Cooling system- Water cooled

Injection timing – Variable

Compression ratio - 17.5:1

3. EXPERIMENTAL SET UP



Fig.1 Computerized test set up



Fig.2 Dual fuel engine kit

Fig.1 shows AVL computerized test set up used for testing engine. A six cylinder engine was converted to dual fuel engine by using conversion kit. A dual fuel kit with gas injection was installed and adapted on the engine. Gas injection pulse was adjusted to inject natural gas during inlet valve open duration. All other operating conditions were maintained at standard reference conditions.

Fig.2 shows dual fuel kit. The dual fuel (Diesel-CNG) kit consists of a separate ECU for controlling the CNG flow rate according to the diesel flow rate. Since it is electronically controlled throttle it gives the voltage output to diesel ECU proportional to increase or decrease in speed. This voltage is sensed by the ECU. As voltage increases, it indicates that the speed has increased so the CNG kit ECU will start injecting CNG at certain speed other than the Idle speed and at high speed.

The typical dual fuel kit consists of regulator, ECU, wiring harness, filter & connecting pipes & hoses. Speed sensor was mounted on pump shaft which detects TDC position of piston & measures engine speed & accordingly CNG is supplied in required quantity. Pressure regulator reduces pressure from 200 bar to 2bar. considerably & ice formation takes place which may damage the diaphragm of regulator. In order to avoid this hot water at temperature of 80-90⁰ C is supplied to regulator. As this pressure is reduced, temperature also decreases due to the throttling effect. CNG is supplied from CNG cascade at 200 bar. ECU is in the form of 16, 32 or 64 bit microprocessor. It receives analyses & sends signals. Wiring harness interconnects ECU of diesel engine & ECU of dual fuel kit. It reads feed back signals from engine sensors. A sensor panel is provided at top to which all engine sensors are connected. Separate connections for diesel supply, exhaust gas, cooling water, air, CNG are provided. Two blowers were used to simulate actual working condition of engine.

Eddy current dynamometer of low inertia & water cooled type with capacity of 720 kW was used to measure power produced by engine. It produces torque using the principle of eddy currents induced on a rotating metallic disk, immersed in a magnetic field. The dynamometer includes a strain gage load cell to provide torque measurement capabilities. A reluctance sensor is provided for speed sensing. The test bed control system is supplied by IASYS. This consists of the controls system and the console for the controls. The module consists of several temperature and pressure sensors which are of ADAM make. The thermocouples (4018) are used for temperature measurement for temperatures more than 200 K. Resistance Temperature Detectors (4015) RTD are used for temperature measurement less than 200 K..Electronically controlled throttle actuator was used for controlling throttle position. The throttle of the engine is controlled by the throttle motor. The throttle lever cable is connected with the throttle motor. This can be controlled both manually and automatically from the control system. The throttle motor consists of a throttle position sensor which senses the throttle position and gives the feedback. Mass flow meter was used to measure mass flow of fuel. Horiba analyser was used to measure emissions.

Table 1.Details of thirteen mode cycle.

Mode	Engine Speed	% Load	Weight Factor %	Duration
1	Low idle	0	15	4 Minutes
2	A	100	8	2 Minutes
3	B	50	10	2 Minutes
4	B	75	10	2 Minutes
5	A	50	5	2 Minutes
6	A	75	5	2 Minutes
7	A	25	5	2 Minutes
8	B	100	9	2 Minutes
9	B	25	8	2 Minutes
10	C	100	10	2 Minutes
11	C	25	5	2 Minutes
12	C	75	5	2 Minutes
13	C	50	5	2 Minutes

Engine was tested as per 13 mode ESC (European stationary cycle).Table 1 shows details of this cycle. Three speeds A, B, C were calculated. Engine was run at these speeds for four torque positions and all important engine parameters like power, temperatures, and emissions were measured.

Three speeds were calculated as mentioned below.

$$A = n_{lo} + 0.25(n_{hi} - n_{lo})$$

$$B = n_{lo} + 0.50(n_{hi} - n_{lo})$$

$$C = n_{lo} + 0.75(n_{hi} - n_{lo})$$

Where n_{hi} is high speed which is speed corresponding to 70% of declared maximum net power. It is highest engine speed at which this power value occurs.

n_{lo} is low speed which is speed corresponding to 50% of the declared maximum net power. It is the lowest engine speed at which this power value occurs.

These A,B,C speeds were calculated as 1560 rpm,1883 rpm and 2208 rpm respectively. The brake mean effective pressure at rated engine load is 14 bar. Four torque (load) conditions were obtained as per 13 mode ESC cycle. Thus effect of dual fuel operation over entire load range of engine was studied. Engine was tested with three speeds & four loads under 100% diesel operation and then in dual fuel mode. Gas supplement ratio (GSR) was calculated by using following formula.

$$GSR = m_{ng} / (m_{ng} + m_d)$$

Where m_{ng} is mass of CNG in Kg/hr & m_d is mass of diesel in Kg/hr

4. EXPERIMENTAL PROCEDURE

1. Engine was mounted on test bed, Dual fuel kit was mounted & adapted and all connections like sensor, connections for exhaust gas, intake air, cooling water, fuel supply, opacimeter, emission measuring device etc.
2. Engine was started & checked for startability, misfiring, noise, vibrations, leakages etc.
3. Engine was run from no load to full load by varying GSR after being loaded just to ensure that the engine is running in closed loop condition throughout and all the electronic components are working properly.
4. Idle setting: The idle RPM was set according to the specified values.
5. Full throttle performance at selected RPM and load was observed and the engine parameters were recorded on computerised system.
6. All emission data was recorded on emission measuring system.
7. Graphs have been plotted to show trends of different engine parameters.

5. OPTIMIZATION

No of Initial tests were conducted & performance & emissions were optimized by using best prins software.ECU of system has look up table in which speed, load values are fed. Quantity of CNG required at each speed & load are also fed in look table. Power, emissions, exhausts gas temperature & fuel economy was considered while estimating quantity of CNG.This is called as engine mapping or ECU calibration. Each point of 13 mode cycle was optimized by considering above important engine parameters and emissions like CO, NMHC, CO₂, NO_x and smoke. GSR value was decided based on this optimization. Best results from this were considered & most efficient percentage substitution was frozen (selected).

6.EMISSION CALCULATIONS

Final emissions are calculated by dividing total of NO_x,CO & NMHC emissions considering weight factor by total of power considering weight factor.For example all emissions in diesel mode and dual fuel mode are calculated as below.

$$\text{(Final NO}_x\text{ Emissions in dual fuel mode) } NO_x = \frac{223.2}{49.2} = 4.53g/kWhr$$

$$\text{(Final NO}_x\text{ Emissions in diesel mode) } NO_x = \frac{225.571}{49.177} = 4.59g/kWhr$$

$$\text{(Final CO emissions in dual fuel mode) } CO = \frac{9.9}{49.241} = 0.20g/kWhr$$

$$\text{(Final CO emissions in diesel mode) } CO = \frac{1.87}{49.177} = 0.04 g/kWhr$$

$$\text{(Final NMHC emissions in dual fuel mode) } NMHC = \frac{344.17}{49.241} = 0.87g/kWhr$$

$$\text{(Final HC emissions in diesel mode) } HC = \frac{1.87}{49.177} = 0.04g/kWhr$$

Table-2. Final Emissions in Diesel mode

NO _x in g/kWhr	CO in g/kWhr	HC in g/kWhr
4.59	0.04	0.04

Table-3. Final Emissions in Dual fuel mode

NO _x in g/kWhr	CO in g/kWhr	HC in g/kWhr
4.53	0.20	0.87

Table.2 and Table.3 show emissions in diesel mode and dual fuel mode.CO and NMHC in dual fuel mode are more than in diesel mode.NO_x and CO emissions in dual fuel mode meet requirements of BSIII emission norms.NMHC emissions are slightly higher than BSIII requirements.These can be reduced by using proper catalytic converter.

7. RESULTS & DISCUSSIONS

Speed A = 1560 rpm. Speed B = 1883 rpm Speed C = 2208 rpm.

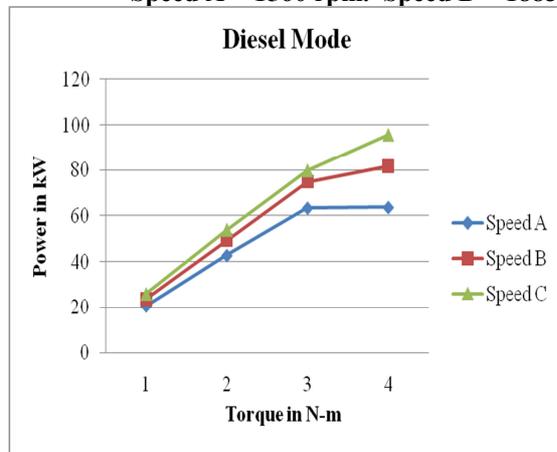


Fig.3.Power vs Torque in diesel mode

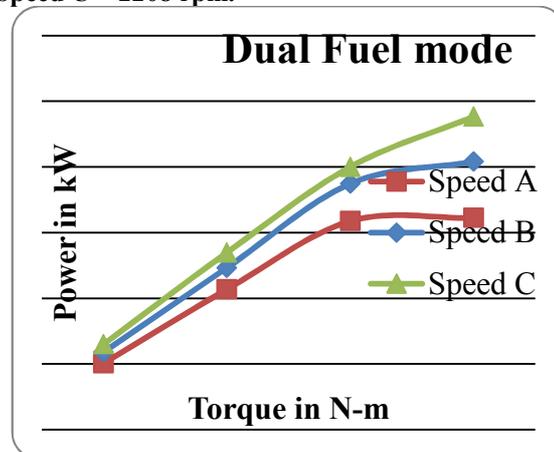


Fig.4 Power vs Torque in dual fuel mode

Fig.3 & Fig.4 show graphs of power vs torque in diesel mode & dual fuel mode at speeds A, B & C.Maximum power in diesel mode & dual fuel mode was almost same. There is no drop in power in dual fuel mode as compared to diesel mode. Power increases with increase in torque & maximum power occurs at maximum speed.

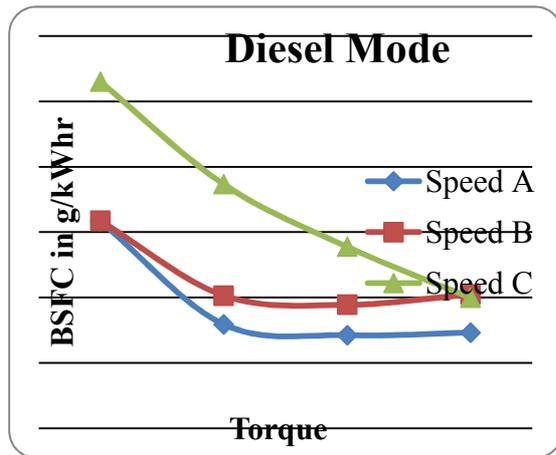


Fig.5. BSFC vs Torque in diesel mode

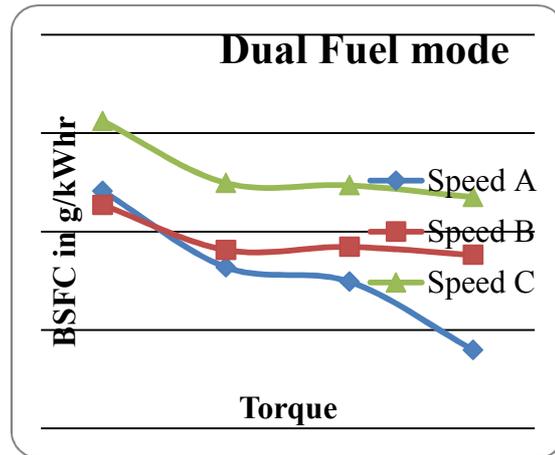


Fig.6. BSFC vs Torque in dual fuel mode

Fig.5 & Fig.6 show graphs of brake specific fuel consumption vs torque (load) in diesel & dual fuel mode. BSFC increases with increase in load in both modes. Minimum value of BSFC was 189.9 in dual fuel mode & 228.5 in diesel mode. Fuel economy is almost same in both modes. It is slightly better in dual fuel mode. BSFC was more at higher speed & lower at lower speed.

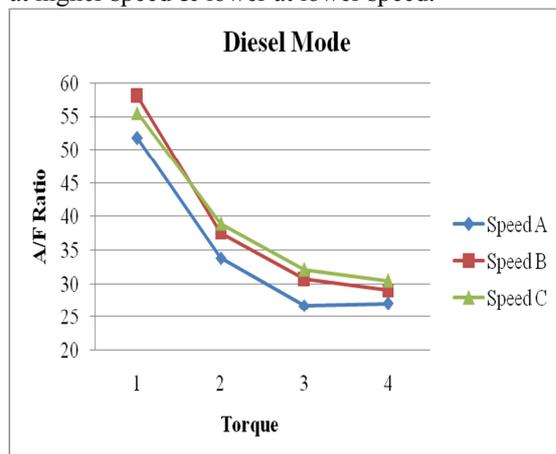


Fig.7. Air fuel ratio vs Torque in diesel mode

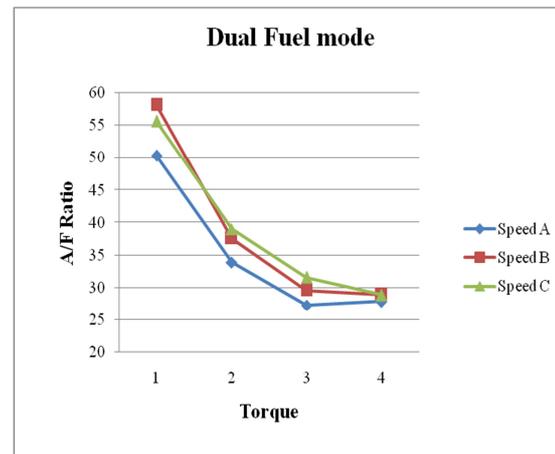


Fig.8. Air fuel ratio vs Torque in dual fuel mode

Fig.7 & Fig.8 show graphs of air fuel ratio vs torque (load) in diesel & dual fuel mode. Air fuel ratio decreases with increase in load in both cases. Air fuel ratio values were almost same in both modes. Maximum value of air fuel ratio was 140 at idle speed & minimum value was 27.3.

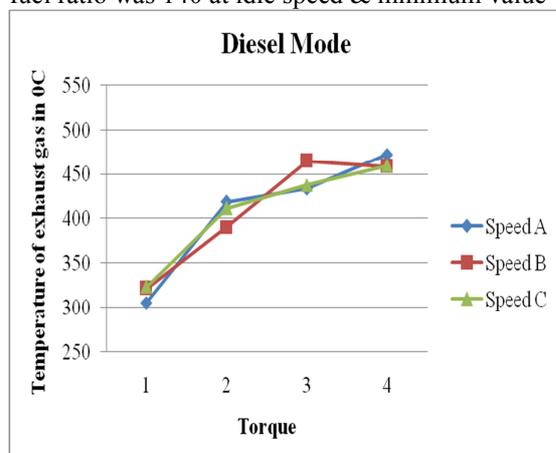


Fig.9 Temp. of exhaust gas vs Torque

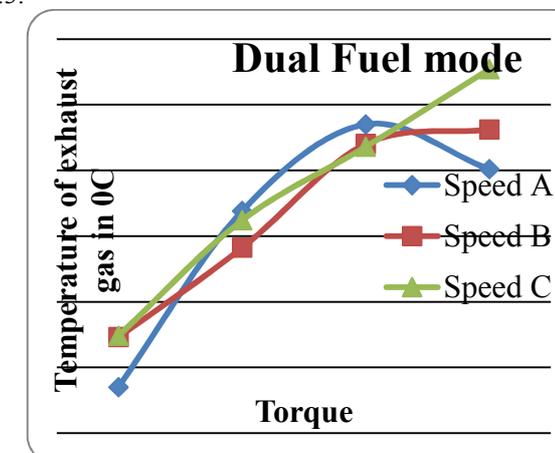


Fig.10 Temp. of exhaust gas vs Torque

Fig.9 & Fig.10 show graphs of temperature of exhaust gas vs torque (load) in diesel mode & dual fuel mode.

Exhaust gas temperature increases with torque in both modes. Maximum value of exhaust gas temperature was 473⁰C in diesel mode. It was 527⁰C in dual fuel mode. Temperature is more in dual fuel mode due to higher calorific value of CNG. Minimum value of exhaust gas temperature was 230⁰C in diesel mode & 229⁰C in dual fuel mode.

Emissions were measured in diesel & dual fuel mode. Following graphs show comparative emissions in diesel mode & dual fuel mode.

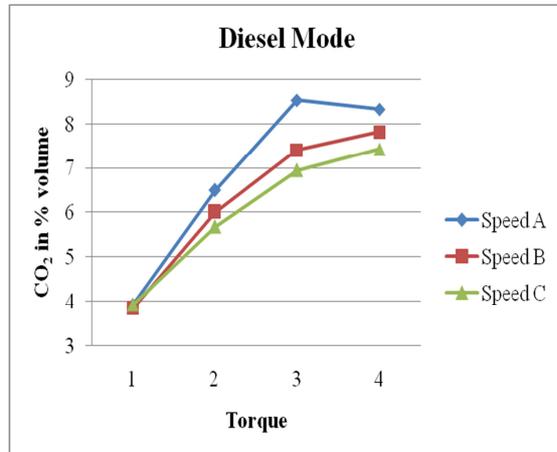


Fig.11 CO₂ vs Torque in diesel mode

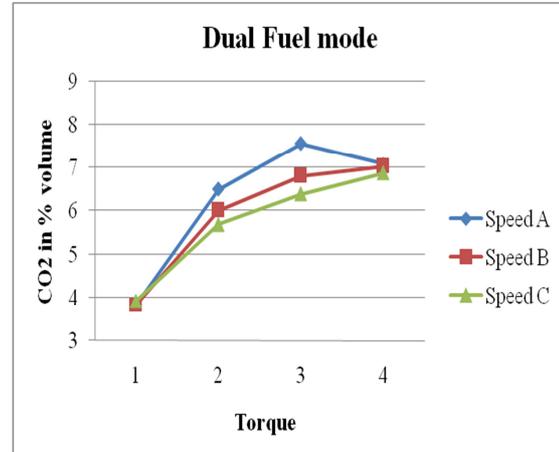


Fig.12 CO₂ vs Torque in dual fuel mode

Fig.11 & Fig.12 show graphs of CO₂ vs torque in diesel mode & dual fuel mode. Carbon di oxide in dual fuel mode is reduced as compared to diesel mode. Maximum value of CO₂ in diesel mode was 8.54 %. It was 7.56 % in dual fuel mode. CO₂ formation is more at lower speed & decreases at higher speeds.

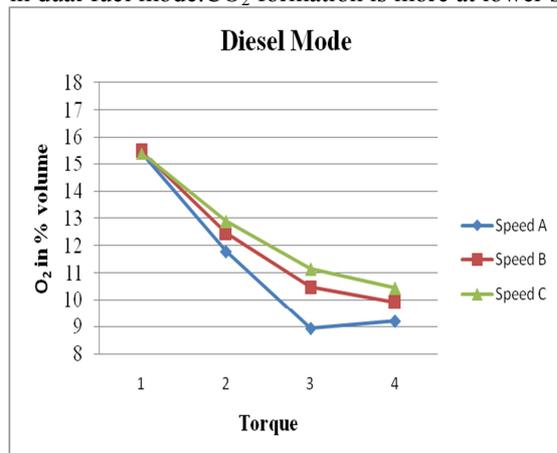


Fig.13 O₂ vs Torque in diesel mode

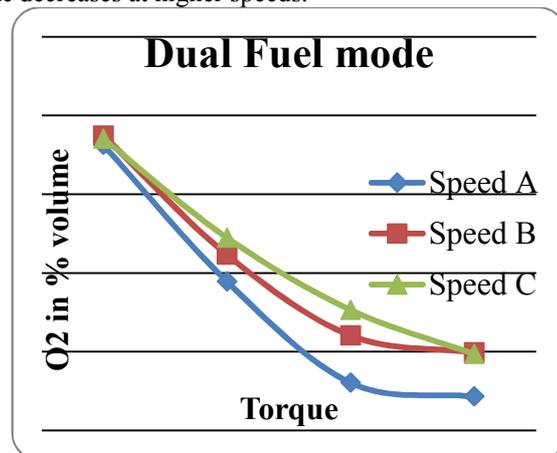


Fig.14 O₂ vs Torque in dual fuel mode

Fig.13 & Fig.14 show oxygen percentage in exhaust in diesel mode & dual fuel mode. Oxygen percentage was almost same in both modes. At higher speed oxygen content in exhaust was more. At lower speed oxygen content in exhaust was reduced. Maximum value of oxygen in both diesel & dual fuel mode was 19.14%. Minimum value of oxygen in diesel mode was 8.93% & in dual fuel mode was 8.86%.

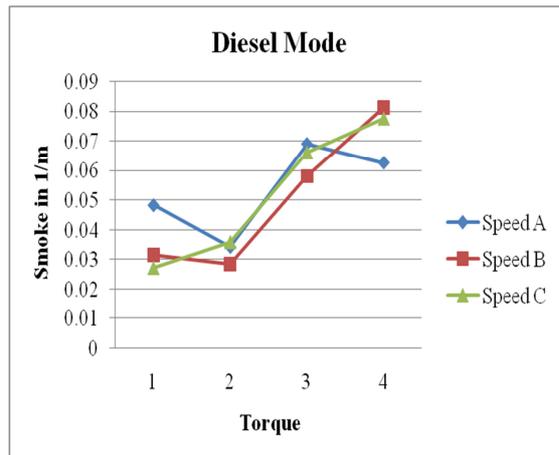


Fig.15 Smoke vs Torque in diesel mode

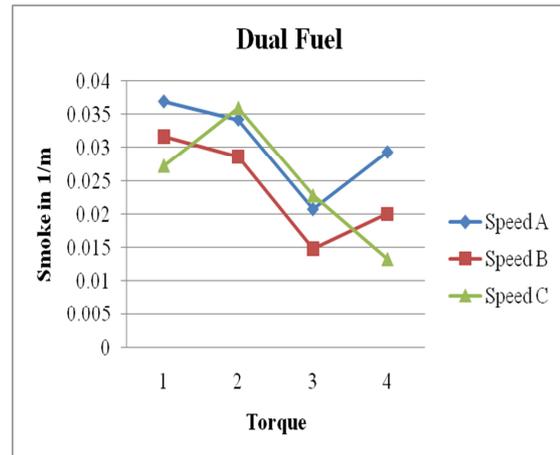


Fig.16 Smoke vs Torque in dual fuel mode

Fig.15 & Fig.16 show graphs of smoke vs torque in diesel mode & dual fuel mode. Smoke is reduced in dual fuel mode as compared to that of in diesel mode. Maximum value of smoke in diesel mode was 0.0815 & in dual fuel mode was 0.037. Smoke was measured by opacimeter. In diesel mode smoke formation takes place due to unburnt fuel. In dual fuel mode as diesel is replaced by CNG smoke is reduced.

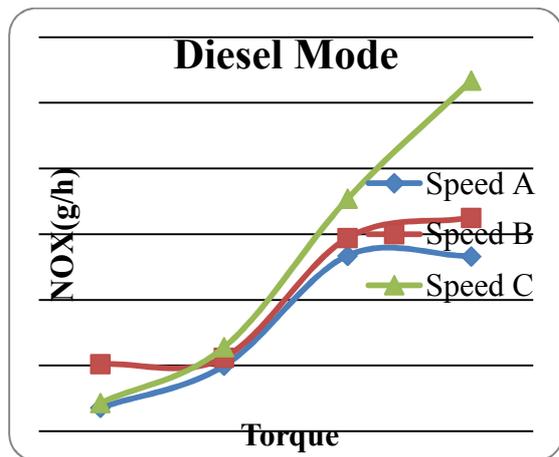


Fig.17 NOx vs Torque in diesel mode

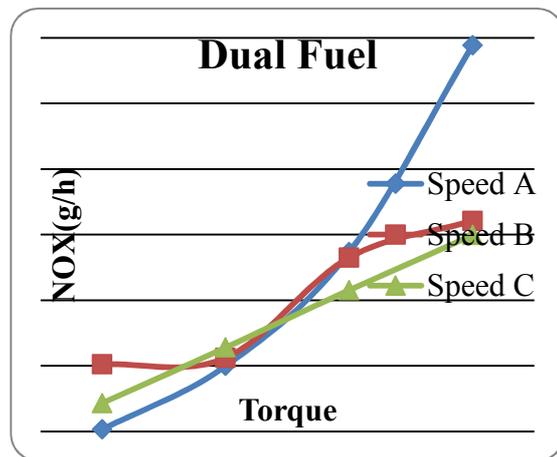


Fig.18 NOx vs Torque in dual fuel mode

Fig.17 & Fig.18 show graphs of NOx vs torque in diesel & dual fuel mode. NOx values for five modes were less in dual fuel mode as compared to diesel mode. These values were equal in diesel mode & dual fuel mode for six modes. For two modes NOx values were more in dual fuel mode as compared to diesel mode.

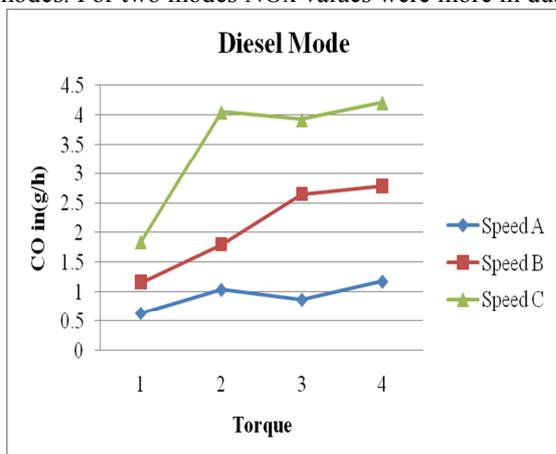


Fig.19 CO vs Torque in diesel mode

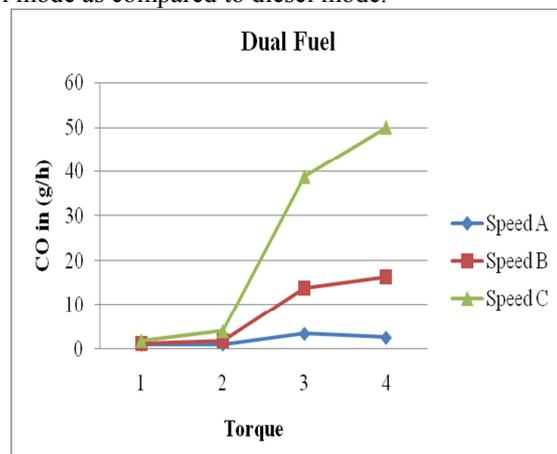


Fig.20 CO vs Torque in dual fuel mode

Fig.19 & Fig.20 show graphs of carbon monoxide vs torque in diesel & dual fuel mode. Values of CO in six modes were equal in diesel & dual fuel mode. For seven modes CO was more in dual fuel mode as compared to diesel mode. CO was maximum at higher speed in both modes.

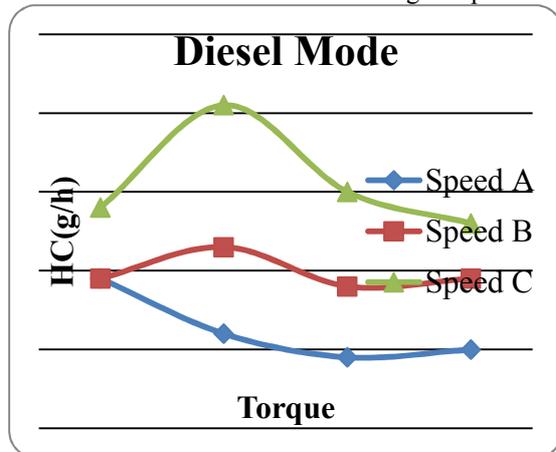


Fig.21 HC vs Torque in diesel mode

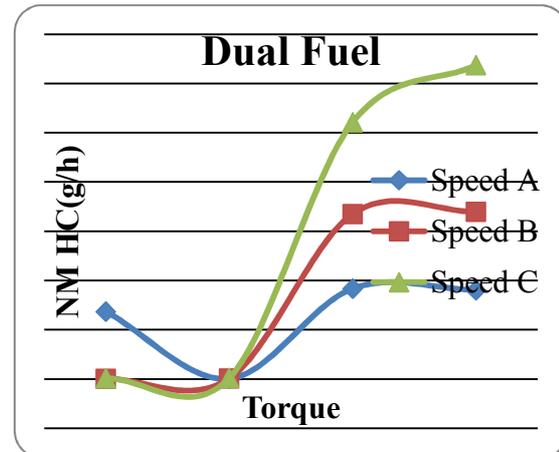


Fig.22 HC vs Torque in dual fuel mode

Fig.21 & Fig.22 show graphs of HC vs torque vs. in diesel & dual fuel mode. NMHC values were more in dual fuel mode as compared to diesel mode. At higher speed NMHC values were more in dual fuel mode & HC values were also more in diesel mode.

8. CONCLUSIONS

1. Maximum power in diesel mode & dual fuel mode was almost same. There is no drop in power in dual fuel mode as compared to diesel mode.
2. Minimum value of Brake Specific Fuel Consumption was 189.9 in dual fuel mode & 228.5 in diesel mode. Fuel economy is almost same in both modes. It is slightly better in dual fuel mode. BSFC was more at higher speed & lower at lower speed.
3. Exhaust gas temperature increases with torque in both modes. Maximum value of exhaust gas temperature was 473°C in diesel mode. It was 527°C in dual fuel mode. Temperature is more in dual fuel mode due to higher calorific value of CNG. Minimum value of exhaust gas temperature was 230°C in diesel mode & 229°C in dual fuel mode.
4. Carbon dioxide was less in dual fuel mode as compared to diesel mode. It was 8.54 % in diesel mode & 7.56 % in dual fuel mode. At lower speed CO₂ formation was more & it reduces at higher speed.
5. Oxygen percentage in exhaust was almost same in diesel & dual fuel mode. At higher speed oxygen formation was more & it was reduced at lower speed.
6. In 100 % diesel operation smoke formation takes place due to unburnt fuel. In dual fuel operation as diesel is replaced by CNG, combustion is complete & smooth hence there is less formation of smoke in dual fuel mode.
7. NO_x values for five modes were less in dual fuel mode as compared to diesel mode. These values were equal in diesel mode & dual fuel mode for six modes. For two modes NO_x values were more in dual fuel mode as compared to diesel mode. Maximum value of NO_x in diesel mode was 416.9 g/hr. This value was 444.3 in dual fuel mode.
8. Values of CO in six modes were equal in diesel & dual fuel mode. For seven modes CO was more in dual fuel mode as compared to diesel mode. CO was maximum at higher speed in both modes.
9. Non methane Hydrocarbons values were more in dual fuel mode as compared to diesel mode. Main reason for this is methane content of CNG. Unburned methane gas in combustion chamber is responsible for producing more HC emissions in exhaust. At higher speed NMHC values were more in dual fuel mode & HC values were also more in diesel mode.
10. Final NO_x emissions calculated as per 13 mode ESC test is less in dual fuel mode as compared to diesel mode. Final CO and NMHC emissions are more in dual fuel mode as compared to diesel mode. NO_x and CO emissions meet requirements of BSIII emission standard. NMHC emissions in dual fuel mode are slightly higher than that of BSIII requirement. However these emissions can be reduced by modifying substrate of catalytic converter and proper selection of catalytic converter.

9. NOMENCLATURE

ARAI	Automotive Research Association of India
ECU	Electronic Control Unit
CNG	Compressed Natural Gas
CO	Carbon Monoxide
HC	Hydro Carbon
NO _x	Oxides of nitrogen
NMHC	Nonmethane hydrocarbon
CO ₂	Carbon di oxide
PPM	Parts per million
GSR	Gas substitution Ratio
λ	Excess Air Ratio
RON	Research octane number
OEAR	Overall excess air ratio
O ₂	Oxygen

10. REFERENCES

- Jensen Scott, "Converting diesel engines to dual fuel, the pros and cons of common gas engine types" Energy conversions Inc. 1/12/06. pp 1-3.
- R.R Saraf., S.S, Thipse. P.K Saxena.. "Lambda Characterization of Diesel-CNG Dual Fuel Engine" International conference of Computer & Environmental Engineering, 28-30 Dec, 2009, Dubai, UAE. pp170-174
- R.R Saraf., Dr.S.S.Thipse, Dr.P.K.Saxena "Diesel-CNG Dual Fuel Technology-A viable Alternate Energy Source", International Conference on New Horizons of mechanical engineering, Rajiv Gandhi Technological University, Bhopal, 18-20 March, [2008]. conference proceedings pp 168-178.
- LAMBDA 2, PING, 2006, Pilot Ignition Diesel/Natural Gas System, NGV Australia, 2 Victor Road, Bentleigh, Victoria, 3204, Australia. [2006], pp 1-2.
- S.Christopher.2000 weaver and Sean H. Turner, "dual fuel natural gas/diesel engines: Technology performance and emissions." SAE 940548, pp 77-92.
- Zdzislaw stelmasiak, 2002, "The Impact of gas-air composition on combustion parameters of dual fuel engines fed CNG". SAE 2002-01-2235,
- D.T Hountalas. and R.G. Papagiannakis, 2002 "Theoretical and experimental investigation of a direct injection dual fuel diesel-natural gas engine," 01-0868.
- D.T.Hountalas R.G. Papagiannakis, P.N.Kotsiopoulos 2005, "Experimental & Theoretical Analysis of the Combustion and Pollutants Formation Mechanisms in dual fuel engines," 1726.
- Y.E Mohamed. Selim, 2004, "Combustion noise measurement and control from small diesel and dual fuel engines". SAE 2004-32-0072/20044359.
- Nafis Ahmad, M.K. Gajendra Babu and A. Ramesh, 2005, "Experimental investigations of different parameters affecting the performance of a CNG-Diesel dual fuel engine." SAE 2005-01-3767,
- Nafis Ahmad, MK. Gajendra Babu, A.Ramesh, 2005, "Experimental Investigations of Different Parameters Affecting the Performance of a CNG-Diesel Dual Fuel Engine", SAE 2005-01-3767.

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