*International Journal on Emerging Technologies* (Special Issue NCETST-2017) **8**(1): 78-81(2017)
*(Published by Research Trend, Website: www.researchtrend.net)*

**ISSN No. (Print) : 0975-8364**
**ISSN No. (Online) : 2249-3255**

# Investigations on the performance evaluation and emission characteristics of compressed natural gas (CNG) fueled small utility diesel engine

***S.K. Mahla[1], A.P. Papreja[2], V. Singla[1], A. Dhir[3], Someet Singh[4] and G. Goga[4]***
*[1,3]Department of Mechanical Engineering, Adesh Institute of Engineering & Technology, Faridkot, (P.B.), India*
*[2]Director, Amarpali Institute of Technology & Sciences, Haldwani, (U.P.), India*
*[3]School of Energy & Environment, Thapar University, Patiala, (P.B.), India*
*[4]Faculty of Engineering, Lovely Professional University, Phagwara, (P.B.), India*

**ABSTRACT: Efforts have been made to resolve the serious problems of environmental pollution and inevitable declining of energy resources. Towards this, researchers proposed various alternatives, one of which is the utilization of gaseous fuel as a supplement for conventional fossil diesel fuel. The engines, which utilizes both the gaseous fuel, and liquid diesel is referred to dual fuel engine. The main usage of dual fuel system is to minimize the consumption of diesel and reducing the pollutants formation. Natural gas is one such fuel available in many countries around the world at cheaper rates. Moreover, the high self ignition temperature of natural gas is serious advantage to maintain high compression ratio of diesel engine. The combustion of natural gas produces low smoke since natural gas contains less dissolved impurities. An experimental study was undertaken to determine the exhaust emissions and performance characteristics of compressed natural gas fueled DI diesel engine.**

**Keywords:** Dual fuel engine, Natural gas, Smoke, Emissions.

## I. INTRODUCTION

The accelerated depletion of the conventional fossil fuel reserves and growing vehicular exhaust emission has focused the attention on the task of finding alternate clean burning fuels for use in internal combustion engines.

Host of alternate fuels that are available include Ethanol, Methanol, CNG, LPG, Hydrogen, and Biodiesel. It is, therefore, of great importance that all potential fuel alternatives being recognized and examined. Gaseous fuel appears more attractive in view of their environmental friendly nature. CNG has many prospects as a fuel for power production in I.C. engine. It is cheap and available in large quantities in many parts of the world. CNG has a high octane number (RON 131) and is suitable for engines having higher compression ratios, with possible improvement in thermal efficiency and engine power output. Further CNG gives higher resistance to knock which makes it possible to utilize in engine having higher compression ratio. Its self ignition temperature is $730^0$C and it requires intense source of energy to enable combustion i.e. glow plug, spark plug or pilot liquid fuel. It mixes rapidly with air to form homogenous air fuel mixture for efficient combustion inside engine cylinder and substantial reduction in harmful emissions [1].

Pilot-injected dual fuel engines are internal combustion engines are designed or converted to run on a primarily gaseous air-fuel mixture. This homogenous mixture is drawn into the cylinder on the intake stroke and deliberately ignited slightly before top dead centre on the compression stroke by a small amount of diesel fuel injected into the cylinder. Because there is premixing of the primary fuel with air before it enters the cylinder, the combustion process in dual fuel engines is similar to SI engines. However, since dual fuel engines rely on the auto ignition of the pilot diesel fuel, and then they also have some properties of compression ignition engines.

Dual fuel engines can use nearly any type of gaseous fuel such as biogas, producer gas, liquefied petroleum gas, compressed natural gas and hydrogen. The use of these fuels is desirable because they provide a means to increase domestic energy use, have the potential to reduce emissions, and in some cases offer significant fuel cost savings [2]. Of all the options available, CNG is the most widely used in dual fuel engines. This is mainly because, of all the fuel listed above, only CNG offers a fuel cost saving that can justify the increased cost of operation and the initial cost of conversion. Compressed natural gas is a highly knock resistant which makes it suitable for use in a compression ignition engine.

In addition, many years of proven use in internal combustion engines makes CNG the preferred choice for a dual fuel engine [3].

There are many advantages that dual fuel engines have over their dedicated diesel and spark counterparts. Most dual fuel engines can operate on gaseous fuel with diesel pilot or diesel alone. This makes dual fuel engine particularly attractive in vehicular applications. Another advantage is that an existing diesel engine can be converted to dual fuel with relative ease. Under certain conditions, dual fuel engines are capable of achieving thermal efficiencies equal to that of dedicated diesel engines and greater than that of spark ignited.

First, since dual fuel engine are almost never throttled, pumping losses are reduced to minimum [4]. Second, when pilot fuel is sprayed into the combustion chamber and auto ignition occurs, many flame fronts are created, allowing for more complete and rapid combustion of the CNG-air mixture than with a single spark plug [5]. One efficiency problem is the valve overlap in many diesel engines. In most diesel engines, the intake valve are opened before the exhaust valve have closed, allowing some of the intake air to escape out though the exhaust which promotes good scavenging. In a dual fuel engine the intake stroke draws in a fuel-air mixture and therefore, some fuel escapes out the exhaust before it ever has a chance to burn which compromises thermal efficiency. On the other hand, dual fuel operation may produce knocking, particularly with very high power outputs, even with knock resistant fuel CNG. The main advantage of dual fuel engines is reduced exhaust emissions, namely particulate matter (PM) and oxides of nitrogen ($NO_X$). However, these emissions reductions are only realized during moderate to high operating loads.

## II. EXPERIMENTAL SETUP

The engine typically used for this study was a single cylinder DI commercial diesel engine. It is an air cooled, naturally aspirated constant speed compression ignition engine as per the IS: 10000 [P: 5]:1980 whose major specifications are shown in Table 1. The engine was coupled to a 5 kVA electric generator through which load was applied by increasing the field voltage. The engine was tested at 20, 40, 60, 80 and 100 percent brake load conditions. The engine has capability to run either on pure diesel or dual fuel mode. The engine is modified to run on CNG by introducing it in the intake manifold pipe at a pressure of 1 kg/cm$^2$ and flow rate was determined by a calibrated rotameter. The CNG flow rate was kept fixed for a given speed and loads, and a variable pilot injection is controlled by a governor. The entire test was performed at constant speed of 1500 r.p.m. (rated speed).

The pilot liquid fuel is measured by a calibrated glass tube by measuring the time required for the consumption of 50ml of fuel. During the experiments, engine speed, fuel consumption, air consumption rate and exhaust gas temperature were recorded. Exhaust gases were analyzed on line by an AVL DiGas analyzer, Model 4000 in which UBHC, CO, $O_2$, $CO_2$, and $NO_X$ were measured and AVL make Smoke Meter, Model 437 was used to measure the smoke opacity of exhaust gas. A piezoelectric pressure transducer, Kistler make, model 701A was used for measuring the cylinder gas pressure and magnetic pickup, Electro make, model 3010 AMa was used to measure crank angle.

**Table 1: Engine specifications.**

| Make | Kirloskar |
|---|---|
| Model | DAF 8 |
| Rated Brake Power (BHP/KW) | 8 / 5.9 |
| Rated Speed (rpm) | 1500 |
| Number of Cylinder | One |
| Bore X Stroke (mm) | 95 x 110 |
| Displacement volume (cc) | 779.704 |
| Compression Ratio | 17.5:1 |
| Fuel Injection Timing (Degree) | 26 BTDC |
| Injector opening pressure (bar) | 200 |

**Table 2: Fuel properties of Diesel, CNG.**

| Fuel Properties | Diesel | CNG |
|---|---|---|
| Chemical Formula | $C_{10.8}H_{18.7}$ | |
| Carbon | 84-87 | 75 |
| Hydrogen | 33-16 | 25 |
| Oxygen | 0 | 0 |
| Mole weight (g) | 200 | 16-18 |
| Density (Kg/m$^3$) | 823 -844 | 0.79 |
| Flame Speed (cm/s) | 2.0-8.0 | 34 |
| Flammability limits (%vol.) | 0.6-7.5 | 5.3-15.0 |
| Gross Heat of Combustion (MJ/kg) | 42.5 – 46.5 | 50 |
| Cetane Number | 45 - 50 | 6 |
| Auto Ignition Temperature ($^o$C) | 230-280 | 730 |

## III. RESULTS AND DISCUSSION

*A. Emission Characteristics*

The variation of $NO_x$ emission at the engine exhaust with bmep is given in Fig. 1 at 1500 r.p.m. for various CNG flow rate. The formation of $NO_x$ is due to high oxygen concentration and cylinder temperature. As shown in Fig.1 the $NO_x$ emission is low at light load and high concentration of CNG flow rate.

This is because of less intense premixed combustion, the reduction of gas temperature due to increase of the specific heat capacity, the slower combustion and finally the reduction of oxygen content [6]. At high bmep the $NO_x$ is high due to the rapid combustion of the overall air-fuel mixture.

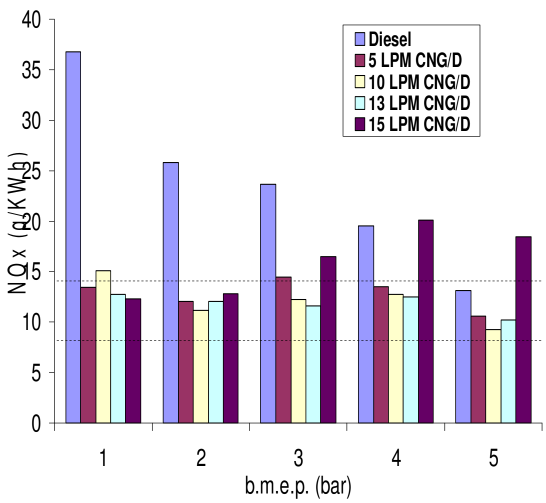


**Fig. 1.** Variation of $NO_x$ emission versus bmep.

The variation of HC emission with bmep for different CNG flow rate is given in Fig. 2. As observed, the HC emission is high at light load because of low pilot quantity and slower burning causes most of the fuel left unburned in the exhaust. As bmep progresses, it increases burnt gas temperature, which promotes more oxidation of unburned hydrocarbons.

It is clear from this figure that dual fuel operation is a potential way of reducing smoke emission. At light load with increase in CNG flow rate the smoke formation decreases because less quantity of diesel injected. At high engine load and less amount of CNG inducted the smoke emission is high but less than normal diesel operation. But at high CNG flow rate the smoke formation decreases mainly because of high flame temperature results in more soot oxidation rate.

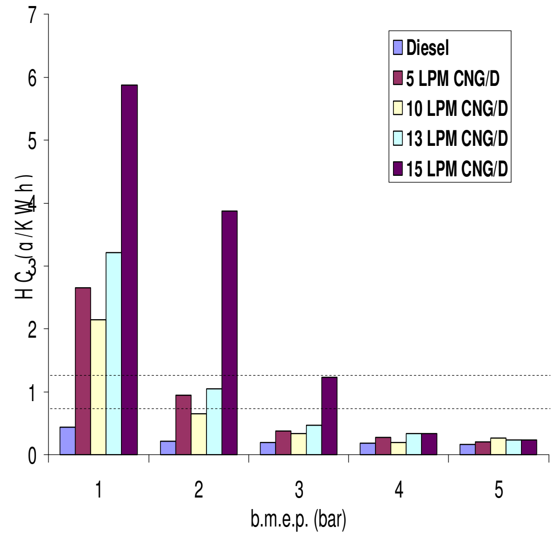


**Fig. 2.** Variation of unburned hydrocarbon versus bmep.

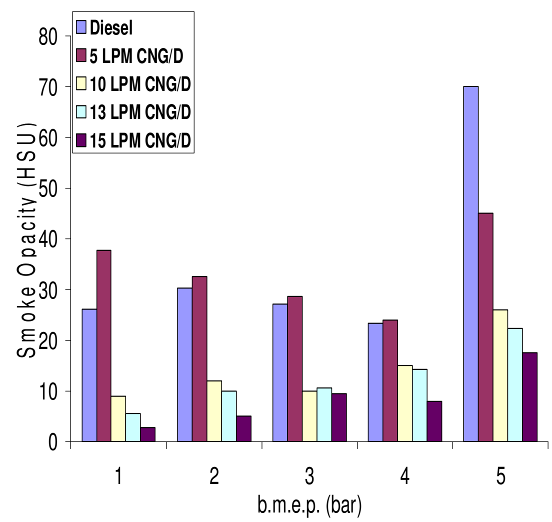


**Fig. 3.** Variation of Smoke opacity versus bmep.

*B. Performance Charcteristics*

Fig. 4 represents the variation of b.t.e. versus bmep for different CNG flow rate. At light loads the dual fuel operation yields poor performance and higher emissions at higher induction of CNG. This is mainly because of weak ignition source and flame will not propagate fast enough to burn the surrounding air fuel mixture. As the result most of the fuel left unburnt and decreases brake thermal efficiency. As load increases the pilot quantity increases causing more air-fuel burn properly and has thermal efficiency comparable and decreases the emissions.

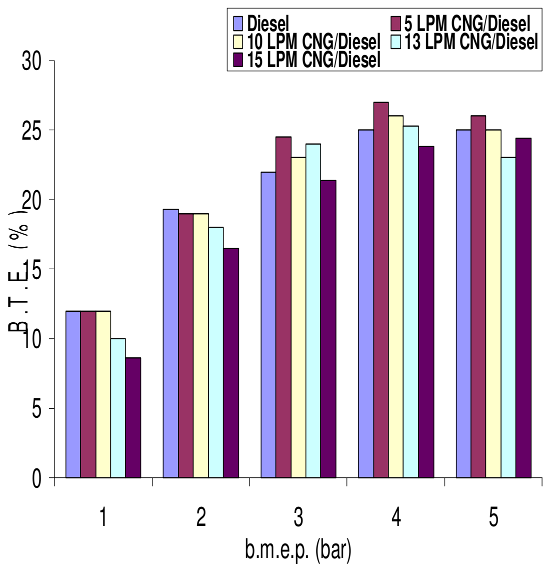


**Fig. 4.** Variation of brake thermal efficiency versus bmep.

## IV. CONCLUSIONS

An experimental study was conducted to determine the performance and emission characteristics on a single cylinder direct injection diesel engine fueled with CNG with an aim to reduce the harmful emissions and improving the performance.

1. The use of CNG up to 5 LPM is useful in improving the brake thermal efficiency. However, with increasing CNG flow rate the thermal efficiency decreases.

2. Higher substitutions of CNG are effective in reducing the emissions of smoke and unburned hydrocarbons without deteriorating the performance parameters.

3. At full load the $NO_x$ emission increases with increase in NG flow rate. This is mainly due to rapid combustion and heat release rate.

## REFERENCES

[1]. Abd Alla GH, Soliman HA, Badr OA, Abd Rabbo MF., (2002), Effect of injection timing on the performance of a dual fuel engine, *Energy Conversion and Management,* Vol. **43**, pp. 269-277.

[2]. Badr OA., Karim. G.A, Liu B., (1999), An examination of the flame spread limits in a dual fuel engine, *Applied Thermal Engineering,* Vol. **19**, pp. 1071-1080.

[3]. Kuaska J, Okamato T, Diasho Y, Kihara R., Saito T., (2000), Combustion and exhaust gas emission characteristics of a diesel engine dual fueled with natural gas, *JSAE Review* Vol. **21**, pp. 489-496.

[4]. Narayana Reddy J, Ramesh A. (2004), Experimental studies on a straight vegetable oil-biogas dual fuel engine, *SAE Paper* 2004-28-031.

[5]. Papagiannakis RG, Hountalas DT., (2003), Experimental investigations concerning the effect of natural gas percentage on performance and emission of a DI dual fuel diesel engine, *Applied Thermal Engineering* Vol. **23**, pp. 353-365.

[6]. Senthil Kumar M, Ramesh A, Nagalingam B., (2003), Use of hydrogen to enhance the performance of a vegetable oil fuelled compression ignition engine; *International Journal of Hydrogen Energy,* Vol. **28**, pp. 1143-1154.