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Performance Investigation of CNG – Diesel Dual Fuel Engine

[1]Shivaji V. Gavali, [2]Prasad A. Bojage

[1]Mechanical Engineering Department, P.V.G College of Engineering and Technology, Pune 411009, India

[2]Mechanical Engineering Department, Sanjivni College of Engineering Kopargaon 423603, India

[1]*svgawali@yahoo.com*, [2]*prasadbojage@gnail.com*

Abstract: In a dual fuel engine, a gaseous fuel called the primary fuel is induced along with the intake air and compressed like in a conventional diesel engine. The dual fuel engine works on diesel cycle. This fuel-air mixture which is homogenous in nature does not auto ignite due to its very high self-ignition temperature. A small amount of diesel fuel usually called pilot fuel is injected as in a normal diesel engine near the end of compression. This pilot diesel fuel auto ignites first and acts a source of ignition for the combustion of gaseous fuel-air mixture by flame propagation. Controlling the fuel flow inside the cylinder of a dual fuel engine is a major challenge. Small increase or decrease in the fuel quantity will seriously affect the engine performance characteristics. In conventional diesel engines, it is relatively easy to control the fuel flow as their only diesel fuel which is to be controlled. To be very specific, more diesel fuel will be needed as compared to CNG for higher torque and power conditions. Similarly at part load conditions more CNG is required. The work involves performance investigation of Dual fuel engine and to study is various emission characteristics such as NO_x, CO, HC and Smoke.

Keywords: CO, Diesel Engine, Dual Fuel, HC, NO_x, Smoke.

I. INTRODUCTION

The use of alternative gaseous fuel 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 satisfies the previous requirements as a result of its worldwide usage. It has a high octane number and therefore it is suitable for engines with relatively high CR. Moreover it mixes uniformly with air, resulting in efficient combustion and substantial reduction of emissions in the exhaust gas [1-4].

One of the major advantages of dual fuel engine is that it can operate interchangeably on dual fuel mode or 100% diesel mode. Another advantage of dual fuel engine is the case with which it can be easily converted to dual fuel engine without major modifications [5]. Conventional fossil fuel like diesel increase the impact on environment pollution, the present work intends to modify the current diesel to work on dual fuel mode by substituting diesel with CNG at different Loads.

II. DUAL FUEL CONCEPT

Internal Combustion engines are divided into two categories basically compression-ignition (CI) and spark-ignition (SI) engines. Diesel engines work on lean burn technology, these are also called heterogeneous charged engines where air is compressed and diesel is injected at a high pressure. Consequently SI engines are homogenous charged engines and operate on relatively lower compression ratio [6].

In a dual –fuel engine, both combustion coexist at the same time, i.e. a carbureted mixture of air and natural gas is compressed like in case of conventional diesel engine. The compressed air and gaseous fuel mixture does not auto-ignite due to its high self-ignition temperature. Hence a pilot diesel fuel is injected which ignites the charge at the end of compression phase. The main advantage of dual fuel engine is that, it uses gaseous fuel and liquid diesel fuel at the same time. In case of lack of gaseous fuel the engine can work on conventional diesel fuel [7].Table 1 below compares some important properties of diesel and CNG [8].

Table1. Properties of Diesel and CNG

Properties	Diesel	CNG
Boiling Point (K)	433-655	147
Density (Kg/m^3)	785-881	128
Auto ignition Temperature (K)	477-533	900
Flash Point (K)	325	124
Cetane/Octane	46-51	130
Flammability Limits	0.7-5	5.0-15
Net Energy content (MJ/Kg)	43.9	49.5
Combustion Energy (KJ/m^3)	36	24.6
Vaporization Energy (MJ/m^3)	192	215-276

III. Experimental Setup

The experiment is conducted on a constant speed single cylinder four stroke diesel engine. The engine is mounted on the test bed; dynamometer shaft is connected with the engine flywheel. All test were conducted at a constant speed of 1500 rpm at various load condition on baseline diesel mode and dual fuel mode. The dual fuel tests were conducted on 15%, 30% and 45% diesel substitution at varying loads. The diesel flow rate is varied by governor and the gas flow rate is varied manually. The diesel to gas substitution is restricted to 45% in this experiment as higher compression ratio of the engine can cause detonation. Table 2 gives details of the engine used for experimentation.

Table 2.Technical Specification

Bore X Stroke(mm)	87.5 X 110
Cubic Capacity(Ltr)	0.661
Compression Ratio	17.5 : 1
Rated Output kW(hp)	5.2 (7)
Rated Speed rpm	1500
Torque at Full Load (Crankshaft Drive) kN-m(kg-m)	0.033 (3.342)
Type of Fuel Injection	Direct Injection

IV. Result and Discussion

The readings Brake thermal Efficiency (BTE), Carbon Monoxide (CO), Hydro Carbon (HC), Nitrogen Oxides(NO_x) and Brake Specific Fuel Consumption (B.S.F.C) were obtained by running the engine on diesel mode. The engine load was varied from idle to rated load 5kW in the steps of 1 up to 5 kW. The engine performance parameters were recorded by using the Software engine Soft and other instruments. The emissions were recorded by using Gas Analyzer and the opacity was recorded by Smoke meter. Similarly, the engine was tested on Dual fuel mode by switching ON the gas supply with substitutions rate of 15%, 30% and 45% respectively.

A. CO Emissions

The rate of CO formation is a function of the relative air/fuel ratio, of the unburned gaseous fuel availability and also of the cylinder charge temperature, both of which control the rate of fuel decomposition and oxidation.

It can be observed in the Figure 2 that, on diesel mode the CO emissions are very high. But as the gas replacement rate increases from15% to 45% the CO emissions reduced considerably. At constant speed of 1500 rpm and varying load conditions, the CO emissions higher on base diesel mode. Due to high value of Carbon to Hydrogen ratio for diesel as compared to CNG, the CO emissions are higher in case of diesel mode Fig 1 Are Shows.

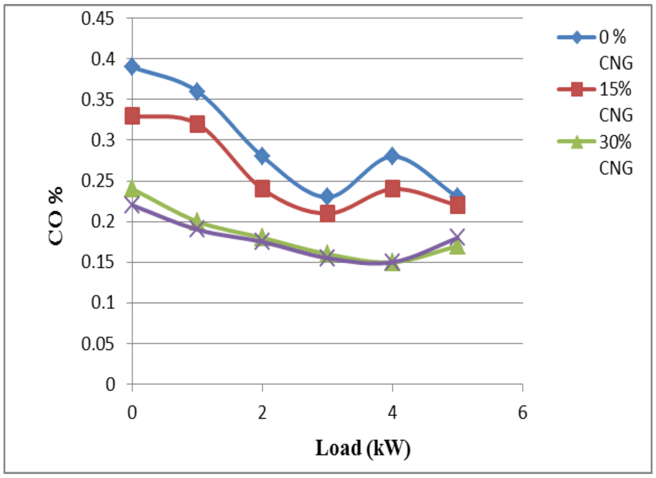

Fig: 1 CO emissions are higher in case of diesel mode

B. Nitrogen Oxide (NO) Emissions

The formation of NO_x is a complex process. When the cylinder temperature reaches above 1500^{0}C the inert nitrogen gas reacts with excess oxygen to form oxides of nitrogen (NO_x). In dual fuel engine, at higher gas replacement rates the NO_x increases. The Figure 3 shows the NO_x at constant speeds and varying loads. At dedicated diesel mode it is observed that NO_x increases with increase in the engine load condition Fig 2 Are shows.

The NO_x decreases as the CNG substitution increases from 15% to 45% in an interval of 15%. This is due higher temperature on diesel mode increases the formation of NO_x.

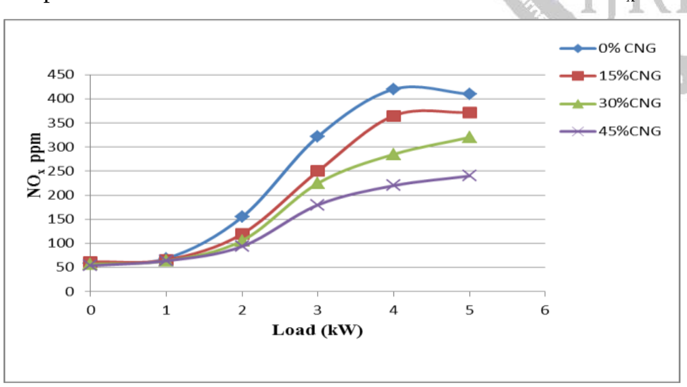

Fig: 2 NO_x increases with increase in the engine load condition

C. THC Emissions

The Total Hydrocarbons (THC) is formed due improper combustion of the fuel in the cylinder. It can be seen from Figure 4, that the THC emissions on diesel mode are much higher that of dual fuel mode. The main problem to have more THC emissions on diesel mode is the unburned hydrocarbons. The carbon to hydrogen ratio for diesel is very high compared to that of CNG.

On diesel mode, with increase in load the THC increases initially and stabilizes further. In case of dual fuel mode the THC emissions decreases with increases in the CNG substitution rate from 15% to 45 %. In dual fuel mode even at higher loads the THC emissions are much less as compared to diesel mode fig: 3 are shows.

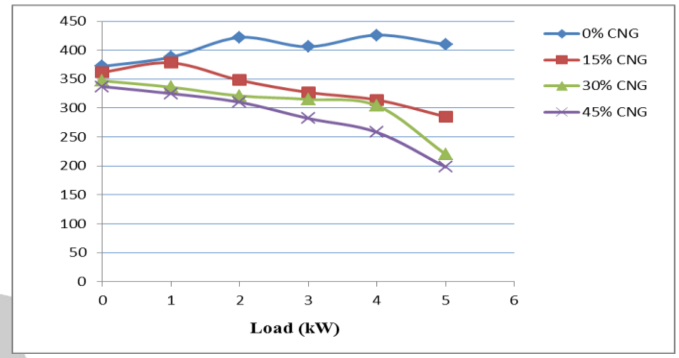

Fig: 3 THC emissions

D. Smoke Opacity

In diesel engines, localized burning of heterogeneous mixture of diesel and air causes improper combustion which results in unburned fuel and hence smoke is produced. In dual fuel engine the air-gas mixture is homogenous in nature. The homogenous mixture burns smoothly with the pilot diesel fuel injected, this results complete combustion of the charge and reduces smoke. In figure 5 it can be observed that the smoke opacity in diesel mode is much high as compared to dual fuel mode. Further, the smoke opacity reduces with increase in the CNG substitution fig:5 are shows.

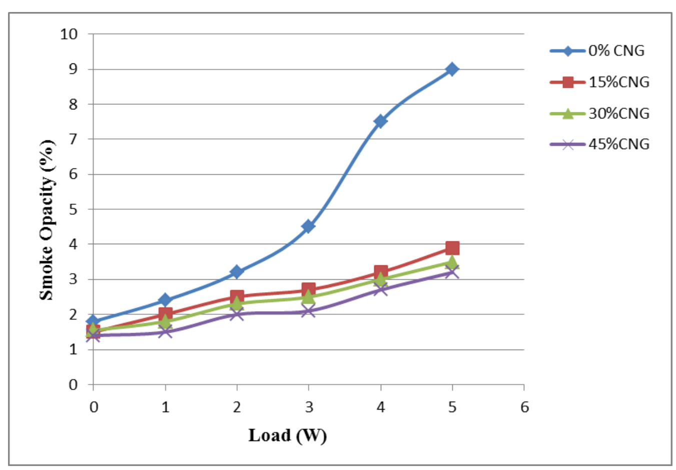

Fig: 5 smoke opacity reduces with increase in the CNG substitution

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E. Brake Specific Fuel Consumption

Specific fuel consumption is a very important criterion from the point of view of economy. Figure 6 shows the effect of dual fuel operation brake specific fuel consumption. It is very clearly evident that dual fuel operation deteriorates engine efficiency and hence specific fuel consumption decreases. It increases more at lower loads due to poor gas utilization and at higher loads it increases moderately. However, the gas utilization further deteriorates due to insufficient time for proper combustion of natural gas, and hence specific fuel consumption increases marginally.

On fuel cost basis, dual fuel operation may be cheaper than diesel operation, but up to certain extend Fig: 6 are shows.

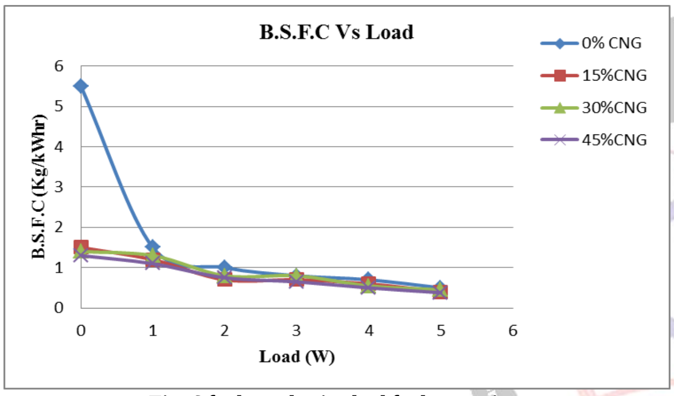

Fig: 6 fuel cost basis, dual fuel operation

F. Brake Thermal Efficiency

Overall, the specific fuel consumption under dual fuel operation decreases. However, up to certain extend, this can be offset by the fact that natural gas costs less than diesel fig: 7 are shows.

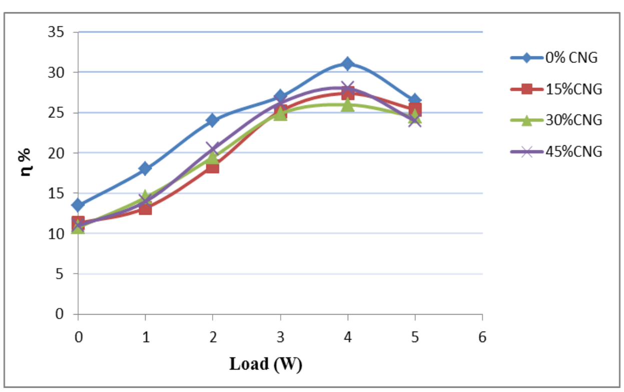

Fig: 7 offset by the fact that natural gas costs less than diesel

V. CONCLUSION

The above experimental investigations on dual fuel engine shows that some parameters like compression ratio, GSR, laminar flame speed and knocking are the crucial in investigation of dual fuel engine. The dual fuel combustion process play a vital role in the emission and thermal load induced on the engine. On dual fuel mode the power and torque obtained is same as that compared to diesel mode. This shows that dual fuel engines can deliver the same performance characteristics as that of a conventional diesel engine.

At higher CNG replacement rates, it can be seen that the thermal load on the engine increases. Also the unburned methane emissions increase at higher GSR. Initially at low loads and higher loads the engine works on diesel mode. This helps to maintain the thermal load and reducing the chances of knocking. The control parameters such as (above 65^0C coolant temperature and exhaust temperatures below 650^0C) are feed into the micro-controller and successfully implemented. Dual fuel control and combustion strategy is an optimum solution to reduce NO_x and PM from diesel engine. Reduction of emissions CO and THC in the range of 93% and 90 % by using catalytic convertor. With increase in engine speed, due to greater turbulence in the combustion chamber and warmer engine, higher gas replacement ratio can be achieved without much change in cylinder pressure. Dual fuel technology suites best for existing diesel engines with retro fitment.

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