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# Performance and Emission Analysis of Diesel Engine using CNG under Dual Fuel Mode with Exhaust Gas Recirculation

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*Abstract-* An experimental investigation was carried out to find out the performance and emissions of a diesel engine operated with CNG inducted into the engine and compared with that of using exhaust gas recirculation. A single cylinder, 4 stroke, and compression ignition engine was used. Behavior of the engine at 10%, 20%, 30%, 40% and 50% substitution of CNG with respect to Diesel was examined and compared them with behavior with induction of re-circulated exhaust gas. Several experimental cycles were conducted at various loads i.e., at 0.5, 1, 1.5, 2, 2.5, 3KW loads. Emissions such as NOx and UHC was measured by using multi gas exhaust analyzer.

*Keywords: Compressed Natural Gas, Emissions, UHC.*

*GJRE-A Classification : FOR Code: 291801, 091399*

PERFORMANCEANDEMISSIONANALYSISOFDIESELENGINEUSINGCNGUNDERDUALFUELMODEWITHEXHAUSTGASRECIRCULATION

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# Performance and Emission Analysis of Diesel Engine using CNG under Dual Fuel Mode with Exhaust Gas Recirculation

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*Abstract-* **An experimental investigation was carried out to find out the performance and emissions of a diesel engine operated with CNG inducted into the engine and compared with that of using exhaust gas recirculation. A single cylinder, 4 stroke, and compression ignition engine was used. Behavior of the engine at 10%, 20%, 30%, 40% and 50% substitution of CNG with respect to Diesel was examined and compared them with behavior with induction of re-circulated exhaust gas. Several experimental cycles were conducted at various loads i.e., at 0.5, 1, 1.5, 2, 2.5, 3KW loads. Emissions such as NOx and UHC was measured by using multi gas exhaust analyzer.**

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## I. Introduction

Compressed Natural Gas (CNG) has become a better option as a clean burning fuel of an IC engine. In order to comply with the ever-stringent emission norms throughout the world and crunch in petroleum reserves, the modern day automobile industry is compelled to hunt for new and alternative means of fuel sources to keep the wheels spinning globally [1]. Paradoxical objectives of attaining simultaneous reduction in emissions along with high performance has provided with a few alternative. Natural gas produces practically no particulates since it contains few dissolved impurities (e.g. sulphur compounds). Moreover, natural gas can be used in compression ignition engines (dual fuel diesel– natural gas engines) since the auto-ignition temperature of the gaseous fuel is higher compared to the one of conventional liquid diesel fuel [3].

Dual fuel diesel–natural gas engines feature essentially a homogeneous natural gas–air mixture compressed rapidly below its auto-ignition conditions and ignited by the injection of an amount of liquid diesel fuel around top dead center position. Natural gas is fumigated into the intake air and premixed with it during the induction stroke. At constant engine speed, the fumigated gaseous fuel replaces an equal amount of the inducted combustion air (on a volume basis) since the total amount of the inducted mixture has to be kept constant. Furthermore, under fumigated dual fuel operating mode, the desired engine power output (i.e. brake mean effective pressure) is controlled by changing the amounts of the fuels used. Thus, at a given combination of engine speed and load, the change of the liquid fuel ''supplementary ratio" leads to a change of the inhaled combustion air, thus resulting to the alteration of the total relative air–fuel ratio [1-3].In internal combustion engines, exhaust gas recirculation (EGR) is a nitrogen oxide (NOx) emissions reduction technique used in petrol/gasoline and diesel engines. EGR works by re-circulating a portion of an engine's exhaust gas back to the engine cylinders[5]. In a gasoline engine, this inert exhaust displaces the amount of combustible matter in the cylinder. In a diesel engine, the exhaust gas replaces some of the excess oxygen in the pre-combustion mixture, Because NOx forms primarily when a mixture of nitrogen and oxygen is subjected to high temperature, the lower combustion chamber temperatures caused by EGR reduces the amount of NOx the combustion generates. Most modern engines now require exhaust gas recirculation to meet the emission standard [4, 6-9].

## II. Experimental Procedure

Series of several experimental cycles have been conducted with varying CNG percentages and iterations were done with varying exhaust gas recirculation and the results were compared. The engine used in the present study is a Kirloskar AV-1, single cylinder direct injection, Water cooled diesel engine with the specifications given in Table N0 1. Diesel injected with a nozzle hole of size 0.15mm.the engine is coupled to a dynamometer. Engine exhaust emission is measured. Load was varied from 0.5 kilo watt to 3 kilo watts. The amount of exhaust gas sent to the inlet of the engine is varied. At each cycle, the engine was operated at varying load and the efficiency of the engine has been calculated simultaneously.

The experiment is carried out by keeping the compression ratio constant i.e., 16.09:1. The exhaust gas analyzer used is MN-05 multi gas analyzer shown in Fig.1. (4 gas version) is based on infrared spectroscopy technology with signal inputs from an electrochemical

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cell. Non-dispersive infrared measurement techniques use for CO, CO2, and HC gases. Each individual gas absorbs infrared radiation absorbed can be used to calculate the concentration of sample gas. Analyzer uses an electrochemical cell to measure oxygen concentration. It consists of two electrodes separated by an electrically conducted liquid or cell. The cell is mounted behind a polytetrafluorethene membrane through which oxygen can diffuse. The Device therefore measures oxygen partial pressure. If a polarizing voltage is applied between the electrodes the resultant current is proportional to the oxygen partial pressure. The important properties of diesel fuel and natural gas are given in Table 1.

*Table 1 :* Properties of Diesel Fuel and Natural Gas

| Fuel | Diesel | Natural gas |
|---|---|---|
| Chemical formula | $C_{10.8}H_{18.7}$ | -[a] |
| Density ($kg/m^3$) | 43 | 0.695[b] |
| Low heating value (MJ/kg) | 830 | 49 |
| Flammability limits (% vol.) | 0.6-5.5 | 5-15 |
| Laminar flame speed (cm/s) | 5 | 34 |
| Octane number | N/A | 120 |
| Cetane number | 52 | N/A |
| Autoignition temperature ($^0C$) | 220 | 580 |
| Stoichiometric air-fuel ratio ($AFR^{stoic}$, kg air/kg fuel) | 14.3 | 16.82 |

[a]Natural gas consists of various gas species; from which methane (CH4) is the main constituent. The equivalent chemical composition of natural gas may be expressed as C1.16H4.32[10].

[b] At normal temperature and pressure.


*Figure 1 :* Multi gas analyzer experimental set up

## III. Engine Specifications

*Table 2 :* Engine Specifications

| | |
|---|---|
| Type | 4- Stroke, single cylinder, compression ignition engine, with variable compression ratio. |
| Make | Kirloskar AV-1 |
| Rated power | 3.7 KW |
| Speed | 1500 RPM |
| Bore and stroke | 80mm×110mm |
| Compression ratio | 16.09:1, variable from 13.51 to 19.69 |
| Cylinder capacity | 553cc |
| Dynamometer | Electrical-AC Alternator |
| Orifice diameter | 20 mm |
| Fuel | Diesel |
| Calorimeter | Exhaust gas calorimeter |
| Cooling | Water cooled engine |
| Starting | Hand cranking and auto start also provided |

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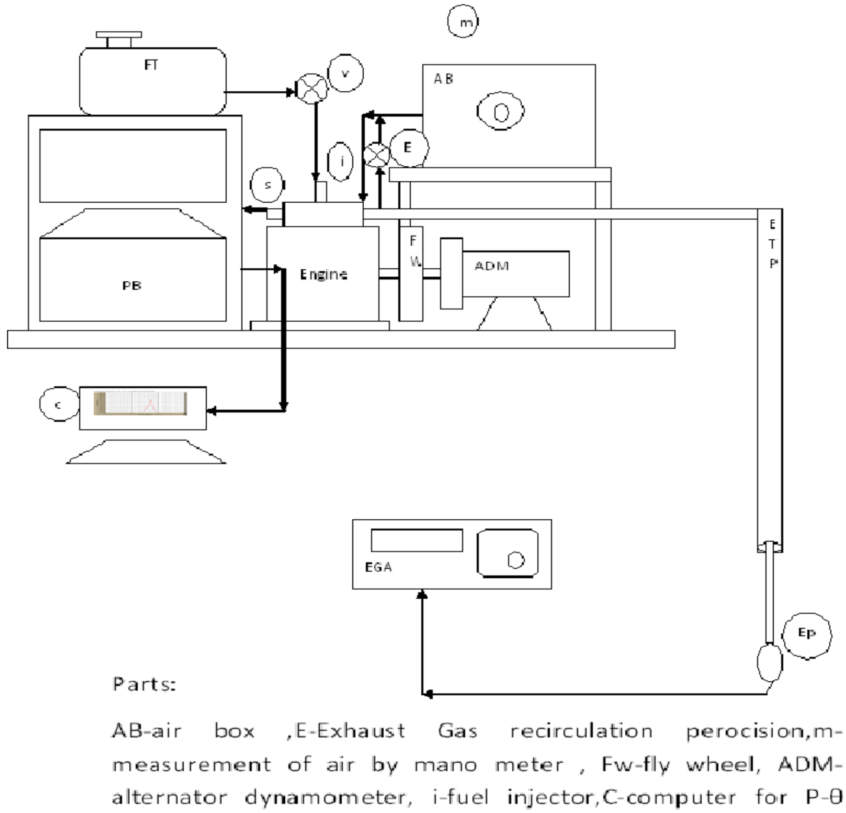


*Figure 2 :* Block diagram of experimental set up

A. Parts

AB-air box, mmeasurement of air by manometer,FW-fly wheel, ADM-alternator dynamometer, i-fuel injector, C-computer for P-θ interface, V-valve for fuel control, EGA-exhaust gas analyzer, S-piezoelectric sensor for p-θ interfacing, PB- panel board, EP-exhaust gas probe, FT-fuel tank.

B. Nomenclature

| | |
|---|---|
| $NO_X$ | Oxides of nitrogen |
| $B_{th}$ | Brake thermal efficiency |
| Vol. Eff. | Volumetric Efficiency |
| UHC | Unburnt hydro carbons |
| PPM | Parts per million |
| EGR | Exhaust Gas Recirculation |
| CA | Crank Angle |

*Table 3 :* Engine nomenclature

C. Brake Thermal Efficiency

Chart1 represents the trends of brake the rmal efficiency with the substitution of compressed natural gas (CNG) with corresponds to Brake power



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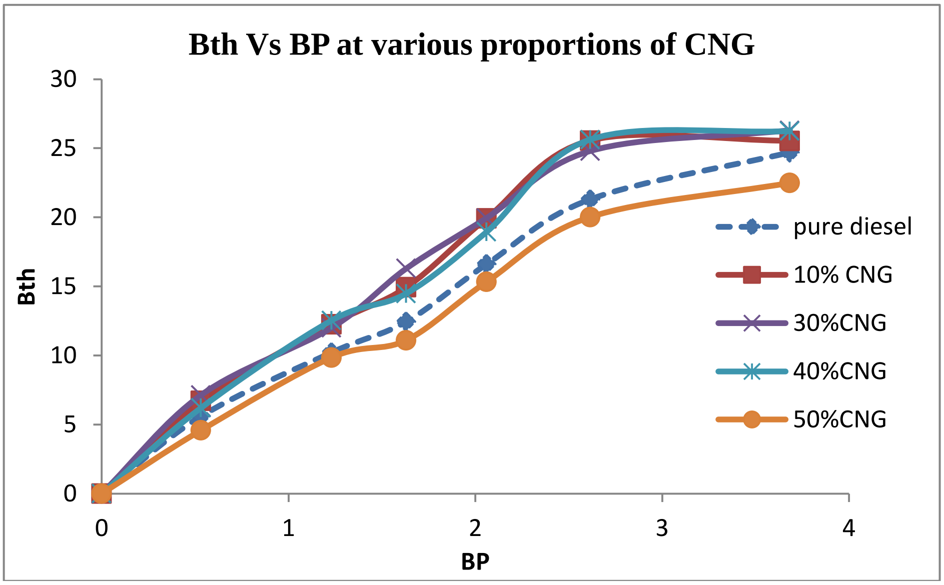


*Chart 1 :* Bth Vs BP at various proportions of CNG

From the chart1 it can be seen that up to 40% CNG substitution would be observed an increase in brake thermal efficiency of 10% compared to that of pure diesel, but 50% substitution of CNG has shown 5% decrease in brake thermal efficiency when compared to that of pure diesel.

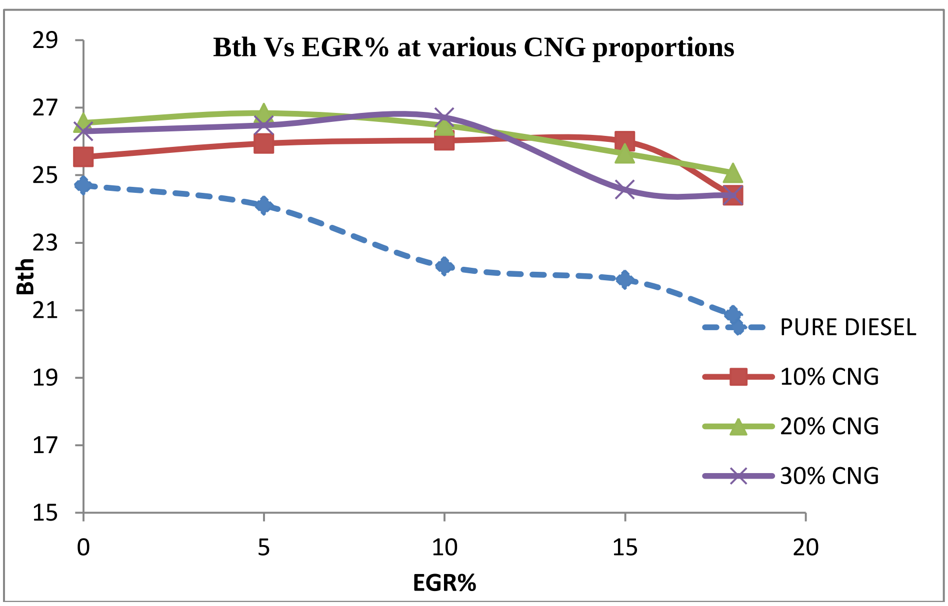


*Chart 2 :* Bth Vs EGR% at various CNG proportions

The chart 2 represents the relation between brake thermal efficiency and percentage of Exhaust gas recirculation. it shows that with an increase in exhaust gas recirculation proportion the brake thermal efficiency has increased till 10% of substitution but decreased with above 10% substitution .



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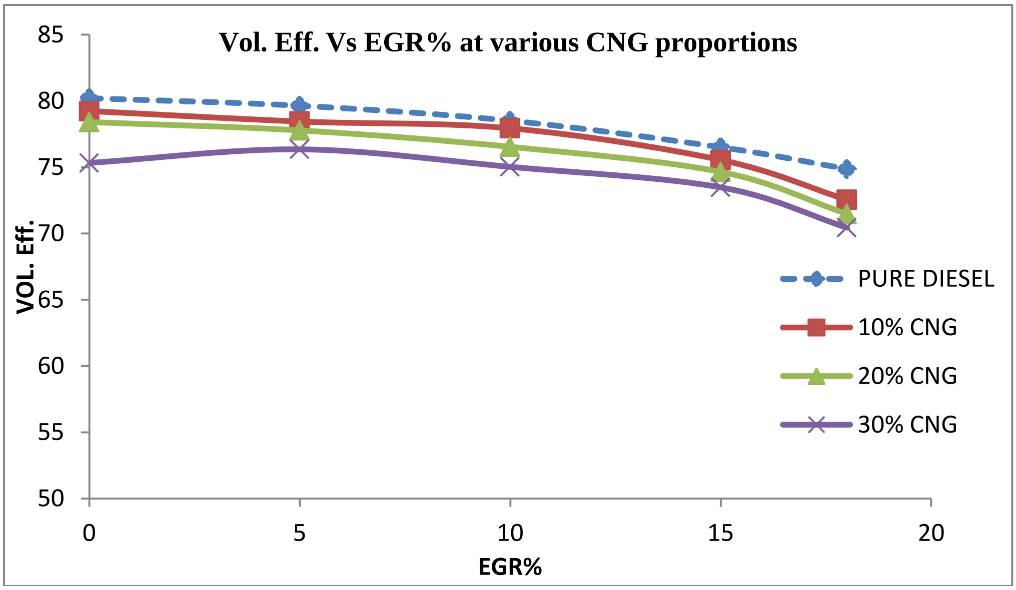


*Chart 3 :* Vol. Eff. Vs EGR% at various CNG proportions

The relation between volumetric efficiency and exhaust gas recirculation is represented in chart 3. It has been observed that the volumetric efficiency decreases with an increased substitution of compressed natural gas (CNG) and with increased exhaust gas recirculation (EGR).

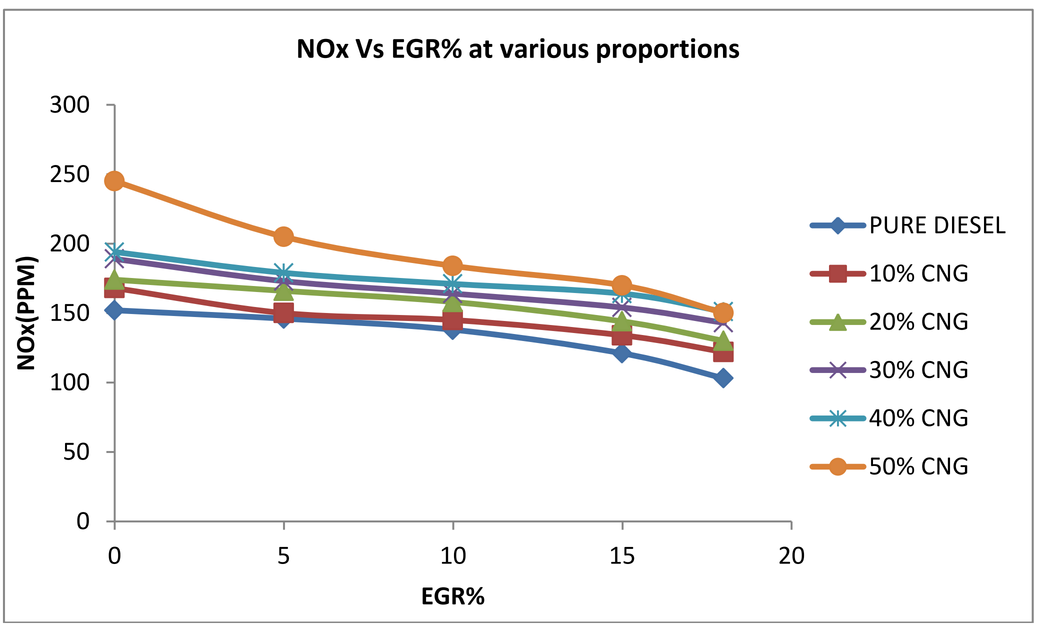


*Chart 4 :* NOx Vs EGR% at various proportions

The chart 4 represented the trends of NOx with the EGR substitution. it is observed that, with an increase in exhaust gas recirculation NOx emission havedecreased by 28% at all proportions of CNG substitution.



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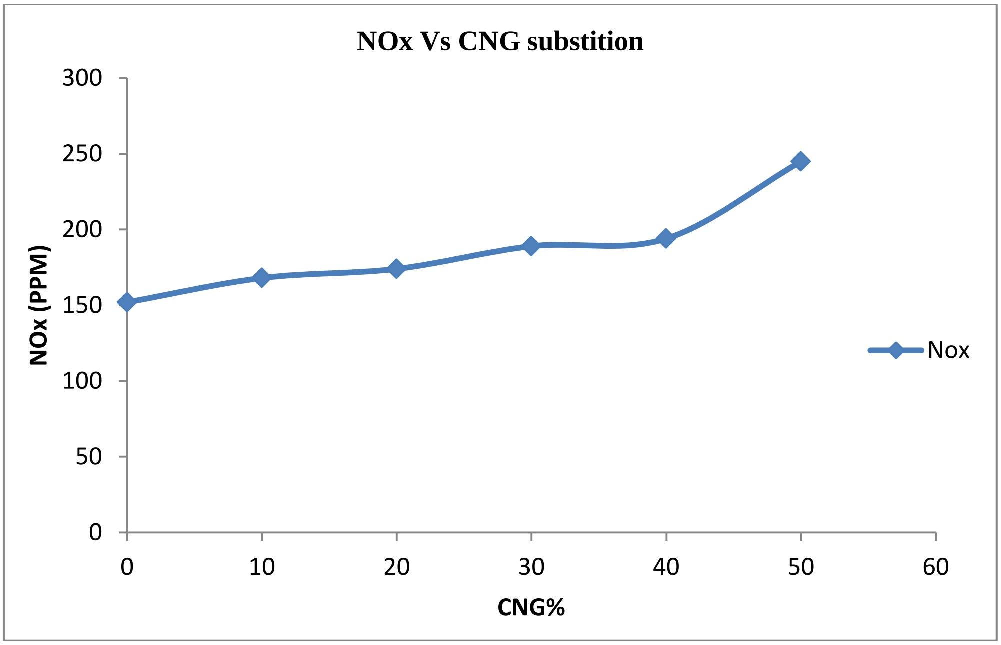


*Chart 5 :* NOx Vs CNG substitution

It is observed from chart 5 that with increase in CNG substitution Nox emission has increased, there 45% increase in NOx emissions when compared to that of pure diesel.

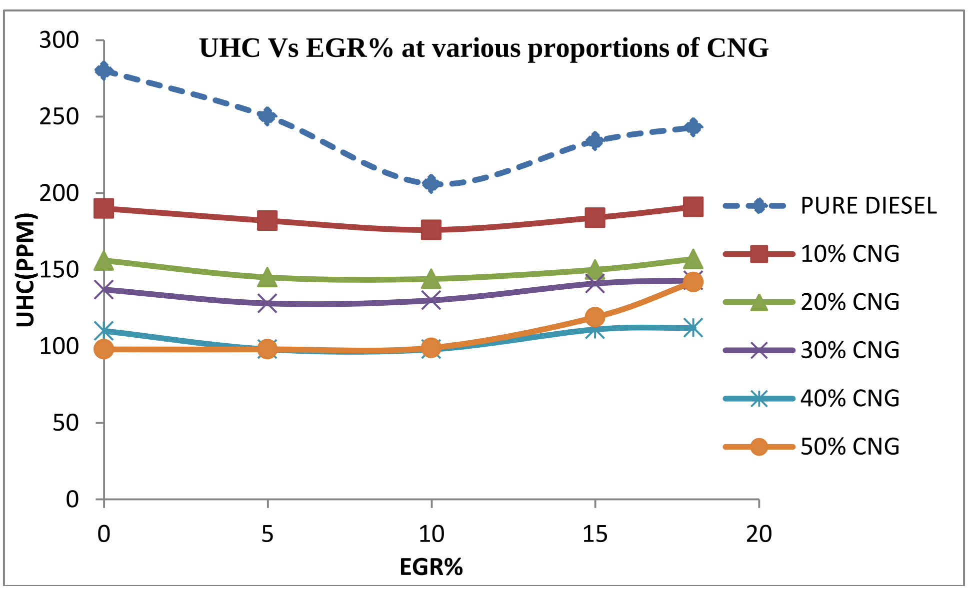


*Chart 6 :* UHC Vs EGR% at various proportions of CNG

Chart 6 represents the relation between un-burnt hydrocarbons and percentage of EGR for various proportions of CNG. The chart shows that with increase in exhaust gas recirculation up to 10% UHC have slightly decreased and again increased for further substitution.



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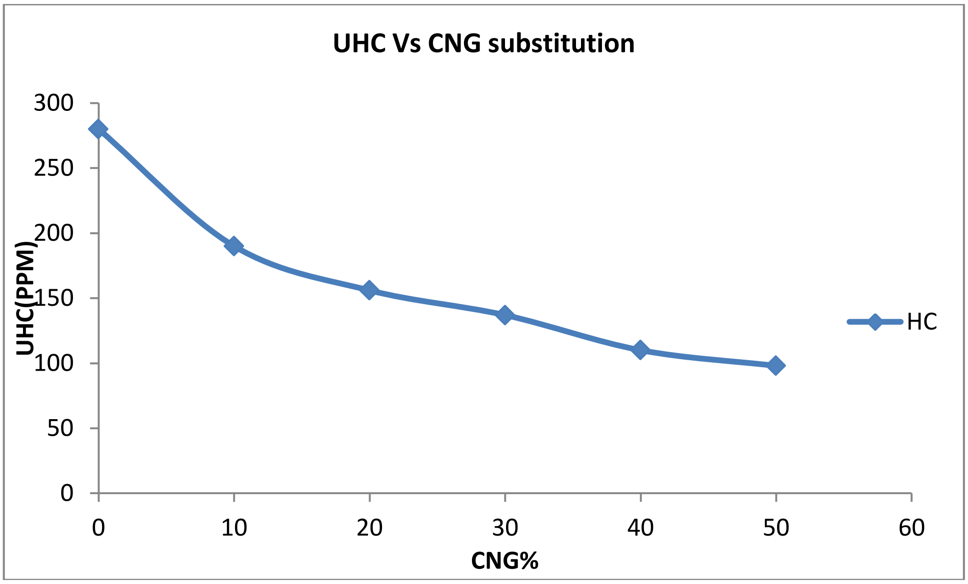


*Chart 7 :* UHC Vs CNG substitution

The chart7 represents the relation between un-burnt hydrocarbons and percentage of CNG substitutions which shows that with increase in CNG substitution un- burnt hydrocarbons have decreased, 50% of CNG substitution shows 61% decrease in UHC emission rate when compared to that of pure diesel.

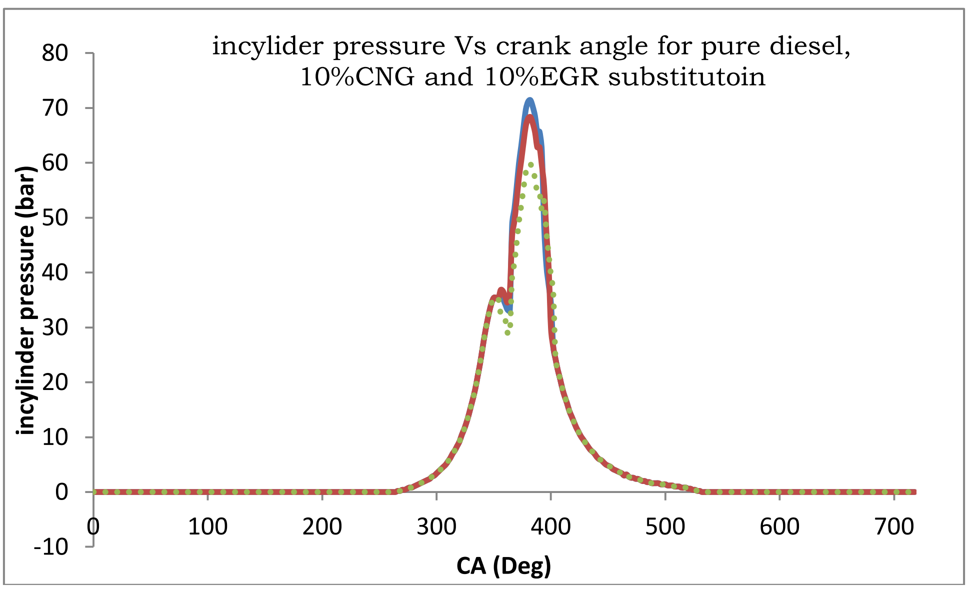


*Chart 8 :* in-cylinder pressure Vs crank angle for pure diesel, 10%CNG and 10%EGR substitution

Chart 8 shows the pressure inside cylinder at varying crank angles of the cycle for pure diesel, 10% CNG substitution and 10% exhaust gas recirculation at 10% CNG substitution.

## IV. Conclusion

From the above obtained results the following conclusions were drawn:

a) Substitution of CNG up to 40% has shown increase on brake thermal efficiency of 20% compared to that of pure diesel, but 50% substitution of CNG has shown 11% decrease in cylinder pressure (bar) CA (Deg) in cylider pressure Vs crank angle for pure diesel, 10%CNG and 10%EGR substitutoin in brake thermal efficiency when compared

b) to that of diesel. The normal injection timing has shown higher volumetric efficiency. Any how the trend of varying volumetric efficiency has stood very general.

c) Substitution of 10% EGR to 10% CNG substitution has shown 15% increase in brake thermal efficiency



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when compared to that of 10% CNG substitution of CNG.

d) With increase in exhaust gas recirculation proportion brake thermal efficiency has increased till 10% of substitution but decreased above 10%.

e) Volumetric efficiency decreases with increased substitution of CNG and with increased exhaust gas recirculation.

f) Increase in exhaust gas recirculation NOx emissions have decreased by 28% at all proportions of CNG substitution.

g) With increase in CNG substitution NOx emission has increased, there 45% increase in NOx emissions when compared to that of pure diesel.

h) With increase in exhaust gas recirculation up to 10% UHC have slightly decreased and again increased for further substitution.

i) With increase in CNG substitution un-burnt hydrocarbons have decreased, 50% of CNG substitution shows 61% decrease in UHC emission rate when compared to that of pure diesel.

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