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Engine Performance and Emission Characteristics of a Single Cylinder Four Stroke CI Engine in Dual Fuel Mode using Diesel, Karavera (Thevetia Peruviana) Biodiesel and Surahonne (Calophyllum Inophyllum) Biodiesel with CNG

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Abstract: Increasing cost of petroleum, rapid growth of industrialization and the global trend of urbanization along with their increasing pollution by replacing existing fuel. The aim of study is to analyze the performance and emission characteristics existing single cylinder four stroke compression ignition (CI) engine converted into dual fuel mode. In the present studies the effect of Compressed Natural Gas (CNG) gas induction on the performance on dual fuel engine instead of single Diesel fuel. CNG used as fuel and Diesel or Biodiesel used as pilot fuel on dual fuel mode, Karavera (Thevetia Peruviana) and Surahonne (Calophyllum inophyllum) Biodiesel are used. Dual fuel mode is one of the better methods to control emissions from CI engines and instantaneously replacing existing diesel fuel engine. Experiments is carried out under engine laboratory condition, analyze the performance and emission characteristics of single cylinder CI engine on dual fuel mode by using CNG as fuel and Diesel or biodiesels (Karavera and Surahonne) pilot fuels by varying injection timing 23^0, 26^0 and 19^0 bTDC. Brake Thermal efficiency and Brake specific fuel consumption at dual fuel mode of CNG fuel gives better results than pure diesel fuel engine at all engine loads. The reduction in CO and HC emissions on dual fuel mode for all loads and also peak pressure rise. By 70% CNG fuel substitution rate.

Keywords: Compressed Natural Gas, Diesel engine, Biodiesel, Exhaust gas analyzer, Electronic gas conversion kit.

I. INTRODUCTION

Compressed Natural gas (CNG)

Conventional fuels like diesel and petrol are depleting day by day, so we have to search for an alternative fuel like biodiesel, biogas, CNG, LNG, LPG, hydrogen gas, producer gas, ethanol, etc. Among all various gaseous fuels, compressed natural gas (CNG), liquid petroleum gas (LPG) and hydrogen are most useful. Dual-fuel process is initiate methods of conserving diesel and petrol, Natural gas is originate in below the earth crest at high pressures and more commonly is linked with the petroleum [3]. CNG consists of methane about 80 to 95%, and small amounts of other hydrocarbons like ethane, butane, CO_2 and N_2. Natural gas has a good possible as supplementary fuel for IC engines. It may contain some scums in small amounts like hydrogen sulphate (H_2S) and vapor particle (H_2O). It is normally kept in cylinder to the gaseous form at a high pressure of about 200 bar for carrying. The composition of natural gas diverges from well to well and varies from phase to phase [1].

Volume 3 Issue IX, September 2015
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International Journal for Research in Applied Science & Engineering Technology (IJRASET)

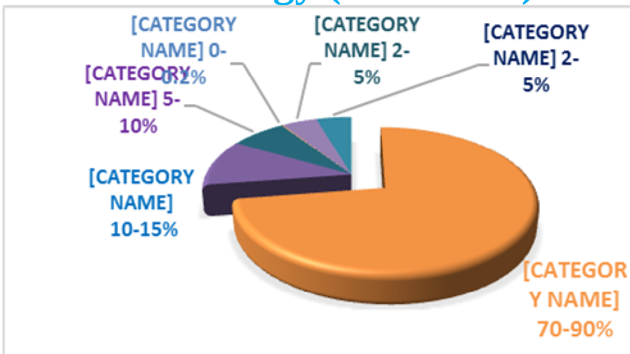


Figure I-1: CNG Composition

Natural gas has been considered as a potential substitute to conventional fuels in Vehicles. Application of CNG in a transport fuel has to be considerably progressive over the last decade. Due to the growth of lightweight high-pressure storage cylinder. CNG is reduced emission and performance problems diesel engines that can be done by using dual fuel mode that is diesel-CNG mode of running engine [2. 3]. CNG is maintained high power output, torque and less engines emissions comparable to the gasoline and diesel. Alternative gaseous fuels are used generally all over the world. Natural gas has moderately high octane number (ON) with low emissions than the liquid fuels. CNG is lighter than air it disperses quickly as compared to other gases fuel. CNG is suitable for engines with higher compression ratios.

Natural gas has several advantages

1) Natural gas less harmful than solid and liquid fuel.
2) Natural gas can be easy storage and transportation.
3) Gas burns cleaner without smoke.
4) Natural gas abundant than the other vehicle fuels.
5) Natural gas more in industries the other fuels.
6) Natural gas is lighter than air so it easily dissipates when it leaked, which is used instead of LPG.
7) Natural gas cheaper than gasoline nearly 30% cheaper.

Biodiesel

Karavera (Thevetia Peruviana) seed oil yield is nearly 50-60% and Surahonne (Calophyllum inophyllum) seed oil yield is nearly 55-65% from these oils is transesterified producing a mixture of fatty acids alkyl esters and glycerol. Biodiesel is referred to as the mono-alkyl-esters of long-chain-fatty acids derived from fatty acid sources. Biodiesel minimizes the formation of CO and HC emissions during the combustion process due to the presence of oxygen. Biodiesel has high Cetane Number (CN) compared to the diesel fuel. Engines are operating maximum blend up to 30% of biodiesel with diesel. By using CNG fuel in diesel engines will be reduced energy consumption, will gives significant improvement in Brake Thermal Efficiency and also economical and environment friendly. The effect of Diesel, biodiesels blends along with CNG over the performance and emission characteristics of a CI engine on dual fuel mode was experimentally examined.

II. MATERIAL AND METHODS

Diesel engines (CI) run on a dual fuel mode by attaching Gas mixer at inlet manifold of existing engine. CNG fuel used in dual fuel mode and Diesel and Biodiesel used as a pilot fuel.

A. Fuel properties

The properties of Diesel, CNG, Karavera (Thevetia Peruviana) and Surahonne (Calophyllum inophyllum) as shown in table 2-1.

Volume 3 Issue IX, September 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Table II-1: Properties of fuels

properties	Diesel	CNG	Karavera	Surhonne
Density kg/m^3	830	0.6512	870	890
Kinematic Viscosity (mm^2/s)	3.98	-	4.5	4.925
Flash point ^{0}C	49	-	164	169
Fire point ^{0}C	55	-	174	178
Calorific value kJ/kg	42382.4	50020	40107.8	37874

Experimental test set up

A single cylinder 4 stroke water cooled diesel engine installed at laboratory. We run and converted diesel engine into dual fuel mode by attaching venturi gas mixer to intake manifold. Four pass venturi gas mixer, gases fuel and intake air mixes then flow to the cylinder through intake valve. CNG used as fuel, Diesel and Biodiesel used as a pilot fuel. Test conducted by changing injection timing with 23^0, 26^0 and 19^0 and the engine was operated at 1500 rpm, under naturally aspirated conditions. In the test set up instruments were used which included test engine, CNG conversion kit, dynamometer, air box with orifice meter and manometer, venturi gas mixer, CNG cylinder, pressure sensor, speed encoder, temperature sensor, Electrical loading, load sensor, engine performance analysis software(engine soft), exhaust gas analyzer, etc.

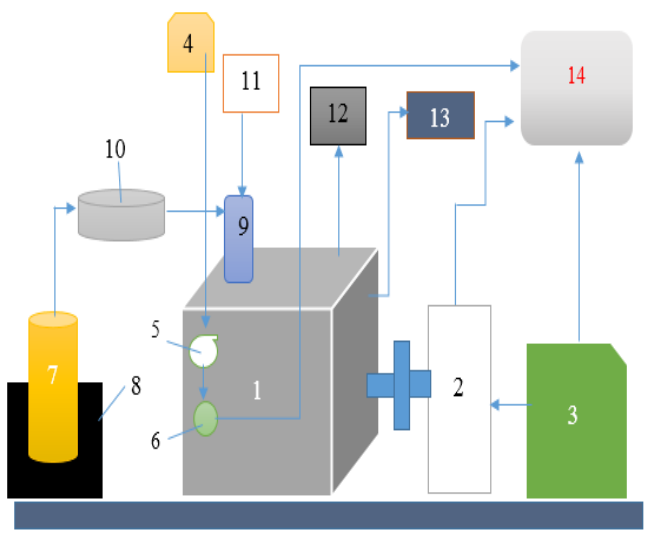


Figure II-1: Schematic layout of four stroke single cylinder Diesel engine on duel fuel mode

1. Diesel Engine.
2. Alternator.
3. Electrical loading.
4. Fuel tank.
5. Fuel injector.
6. Pressure Sensor.
7. CNG Cylinder.
8. Weighing machine.

Volume 3 Issue IX, September 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

9. Gas mixer/Mixing chamber.
10. Electronic gas conversion Kit.
11. Air box.
12. Exhaust temperature Measurement meter.
13. Exhaust gas analyzer.
14. Data stored in Computer.

Table II-2: Engine Specification

Company	Kirloskar
Engine type	4 Stroke Single Cylinder
Power	5.2 KW
Bore	87.5 mm
Stroke	110 mm
Cooling	Water Cooled
Speed	1500 rpm
Compression Ratio	17.5:1
Fuel injection	Mechanical Injection with injection timing 23^0 BTDC, 210bar injection pressure.

Figure II-2: Computerized, Electrical loading single cylinder four stroke CI engine converted to Dual fuel mode with CNG used as a fuel

Figure 2-1. Shows a schematic layout of four stroke single cylinder Diesel engine on duel fuel mode and Figure 2-2. Shows actual image of Diesel engine on dual fuel mode. Engine Specification shown in Table 2-2. The experimental study is to be conducted on a four stroke signal cylinder, by varying the compression ratio diesel engine with CNG as fuel and Diesel, Biodiesel as a pilot fuel. The engine performance and emission characteristics are to be evaluated by running the engine at varying the injection timing and varying loads.

III. RESULTS AND DISCUSSIONS

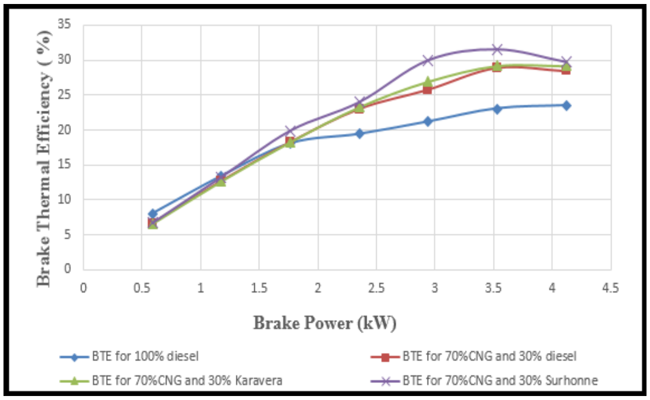
The results obtained by performing experiments under pure diesel mode and dual fuel mode and results are shown in figures.

A. Varying the Injection Timing

Changing the injection timing by varying the number of shims, thickness of single shim is 0.124 mm. Engine Performance and emission characteristics of CI engine studies by varying the injection timings.

1) *Engine Performance: Variation of performance parameters at different values of injection timings 23^0, 26^0 and 19^0 bTDC with a brake power of 0.588 kW, 1.176 kW, 1.765 kW, 2.353 kW, 2.941 kW, 3.5294 kW and 4.118 kW.*

a) Brake Thermal Efficiency: Engine operating condition: Pressure at 210 bar, speed 1500rpm and varying the injection timing 23^0 bTDC, 26^0 bTDC and 19^0 bTDC



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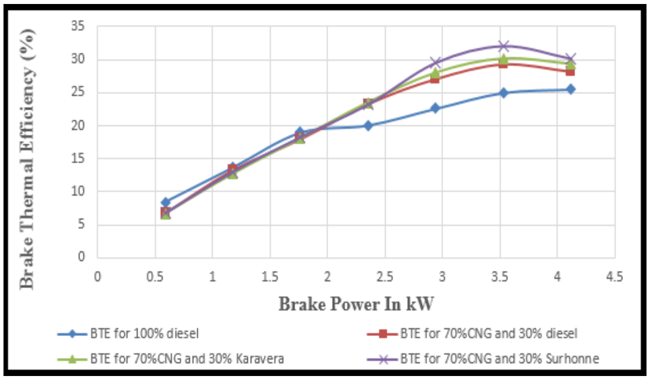

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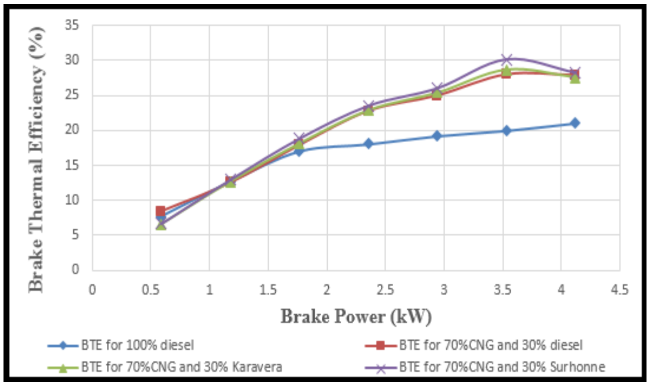

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Figure III-1: Comparison of Variation of BTE with BP at injection timing 23^0, 26^0 and 19^0 bTDC at Fig A, B, C.

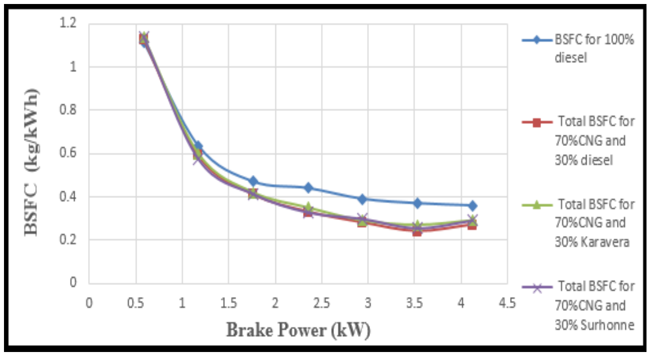
Variation of BTE with brake power at different injection timing of 23^0, 26^0 and 19^0 for the fuel CNG, Surahonne biodiesel, Karavera biodiesel and Diesel for different proportions are shown in the Figure3-1 A, B, C respectively. From the trend of brake thermal efficiency with various injection timing for different fuel blends are observed as BTE increases with increase in BP up to part load condition but at full load condition BTE decreasing with increasing BP as shown in figure 3-1. The maximum brake thermal efficiency obtained 31% for the fuel 70% CNG and 30% Surahonne at an injection pressure of 210 bar at injection timing 26^0.

Volume 3 Issue IX, September 2015
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Engine performance of single cylinder CI engine working on dual fuel mode of Gases, liquid fuel by advancing the injection timings the BTE has increased due to increasing ignition delay period, complete combustion of fuel take place. The lowest brake thermal efficiency obtained for the Diesel fuel because CNG having higher Calorific value than the Diesel.

b) Specific Fuel Consumption: Engine operating condition: Pressure at 210 bar, speed 1500 rpm and varying the injection timings 23^0 bTDC, 26^0 bTDC and 19^0 bTDC



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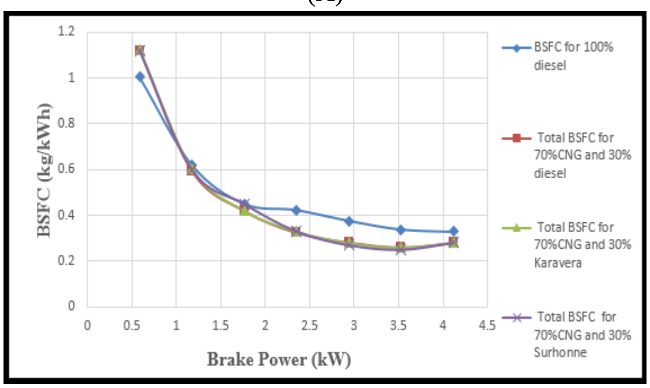

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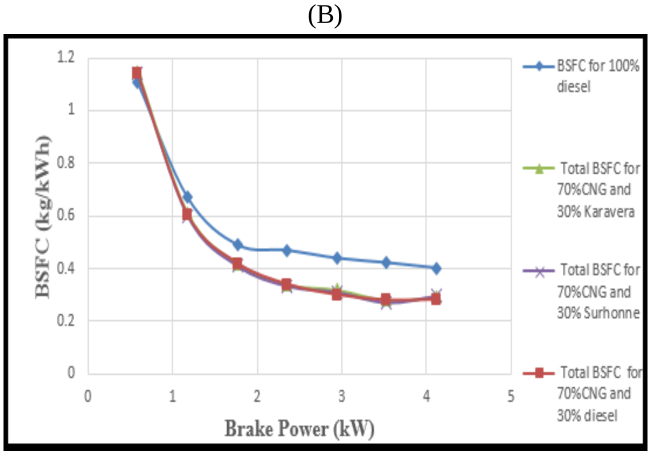

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Figure III-2: Comparison of Variation of BSFC with BP at injection timing 23^0, 26^0 and 19^0 bTDC at Fig A, B, C.

Specific Fuel Consumption was calculated by fuel consumption divided by the rated power output of the engine. Variation of BSFC with BP for different injection timing 23^0, 26^0 and 19^0 shown in Figure 3-2 A, B and C respectively. Brake Specific Fuel Consumption for diesel, biodiesel with CNG fuel is calculated at different injection timing and loads. The engine fuel consumption depends on speeds, load and different injection timing. It can be seen that BSFC is decreased with increasing brake power due to

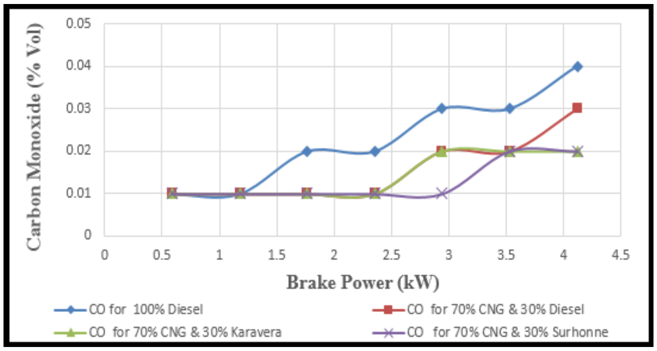
Volume 3 Issue IX, September 2015
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

high percentage of conversion of heat energy into useful work. The maximum BSFC obtained is 1.12 kg/kWh for 70% CNG with 30% Surahonne at injection timing 19^0. At 23^0 70% CNG and 30% Diesel is better and at 26^0 and 19^0 70% CNG with 30% Surahonne is better. The decrease in BSFC will be explained by the engine load both are inversely proportional, the rate of increasing brake power is much more than that of the increased fuel consumption due to rise in the combustion temperature with load. The translation of heat energy to mechanical work increases with rise in combustion temperature and that leads decrease of BSFC with respect to load. And it is also observed that the BSFC has decreased by increasing with retarding injection timing. The lowest BSFC is for at injection timing 19^0.

2) Emission characteristics

a) Carbon Monoxide (CO) emission: Engine operating condition: Pressure at 210 bar, speed 1500 rpm and varying the injection timing 23^0 bTDC, 26^0 bTDC and 19^0 bTDC



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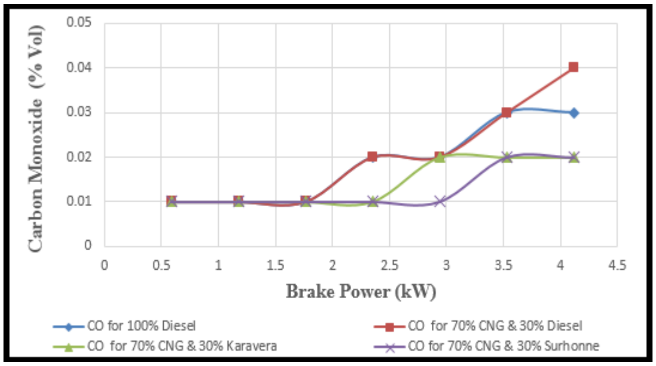

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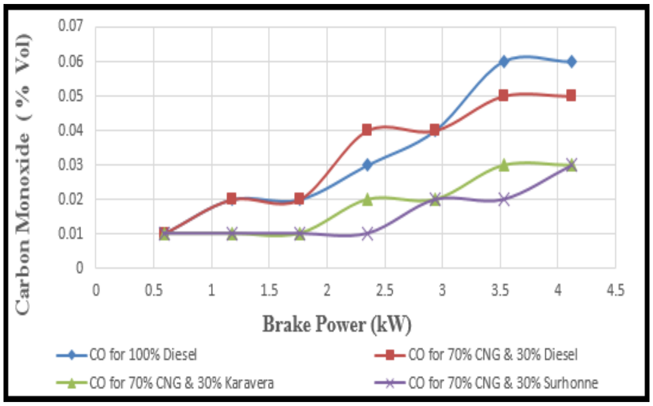

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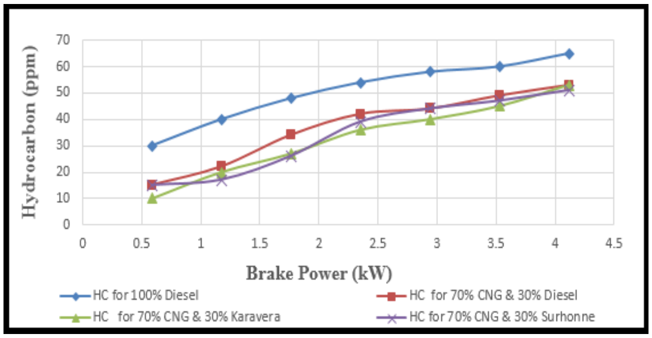
Figure III-3: Comparison of Variation of CO emission with BP at injection timing 23^0, 26^0 and 19^0 bTDC at Fig A, B, C.

Volume 3 Issue IX, September 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

The variation of carbon monoxide with brake power at different injection timing for different fuels as shown in Figure 3-3. As we observed that CO emission increases with load and emission reduces due CNG mixes with fuels, in that biodiesel gives less CO emission than the Diesel fuel. CI engines are operating with lean mixtures the CO emission should be less. So its emission results to the incomplete combustion. Therefore, emission of CO is greatly dependent on the air to the fuel ratio. Rich combustion consistently produces CO. CO emission is harmful so it should be controlled. CO is an extreme product in the combustion of a hydrocarbon fuel. Emission of CO is measuredly dependent on the ratio relative to the stoichiometric proportions. Rich combustion of fuel produces CO. The lowest CO emission occurred at an injection timing 26^0 and maximum CO obtained for retarding injection timing at 19^0. This is due to fact that, when fuel injection timing advance, the ignition delay period during the combustion will increase due this complete combustion of fuel takes place. During retarding injection timing leads to inefficient combustion of fuel in the combustion chamber, it causes the CO emissions.

c) Hydrocarbon (HC) emission

Engine operating condition: Pressure at 210 bar, speed 1500 rpm and varying the injection timing 23^0 bTDC, 26^0 bTDC and 19^0 bTDC



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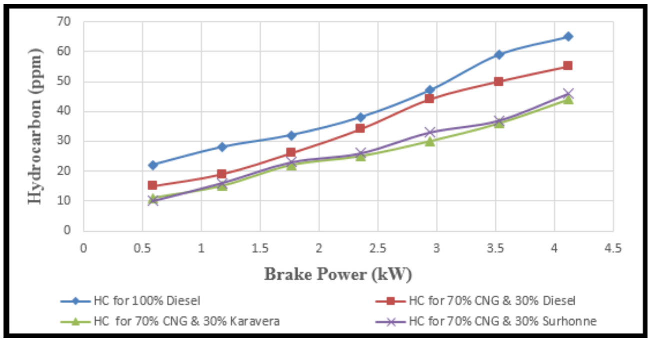

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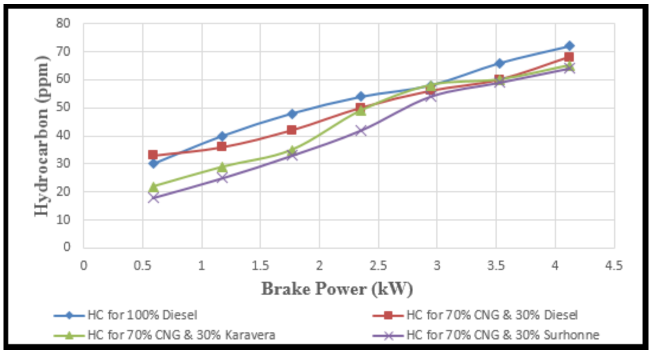

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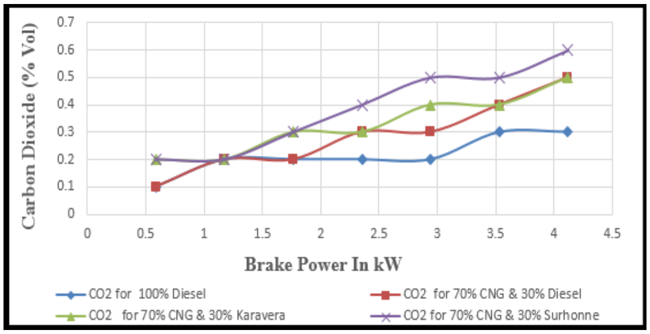
Figure III-4: Comparison of Variation of HC emission with BP at injection timing 23^0, 26^0 and 19^0 bTDC at Fig A, B, C.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

The variation of hydrocarbon with brake power for different fuels composition and for different injection timing 23^0, 26^0 and 19^0 portrayed in Figure 3-4 A, B and C. respectively. Hydrocarbon emission is lower for biodiesel operation at varying injection timings at injection pressure 210 bar. Lower HC emission at injection timing 26^0 for Karavera biodiesel with CNG fuel due to complete combustion of fuel at high pressure and temperature. The maximum HC emission occurred at retarding the injection timings. The attentiveness of hydrocarbon of diesel fuel is higher than biodiesel fuel, because of non-homogeneity of fatty acid mixture some local spot in the combustion chamber should be mixture that lean mixer combustion suitably. Some fuel reach spot too rich with insufficient O_2 to burnt fuel. In fuel rich spot, some amount of fuel do not react due to insufficient of O_2 and the combustion will be incomplete. Due to this higher the HC emission in the case of retarding the injection timing compared to advancing injection timing. Surhonne and Karavera Biodiesel as a pilot fuel instead of Diesel 30% HC emission reduction at injection timing 23^0, 50% reduction at injection timing 26^0 and 14% reduction at injection timing 19^0.

d) Carbon dioxide (CO_2) emission

Engine operating condition: Pressure at 210 bar, speed 1500 rpm and varying the injection timing 23^0 bTDC, 26^0 bTDC and 19^0 bTDC



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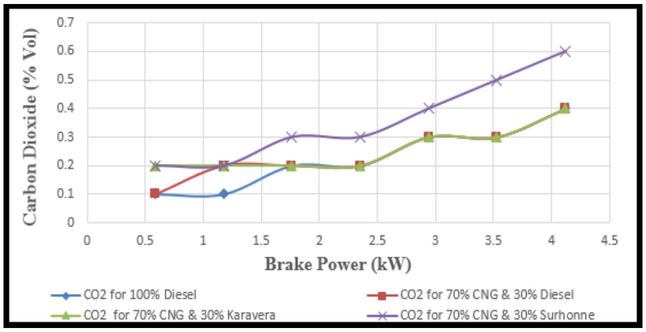

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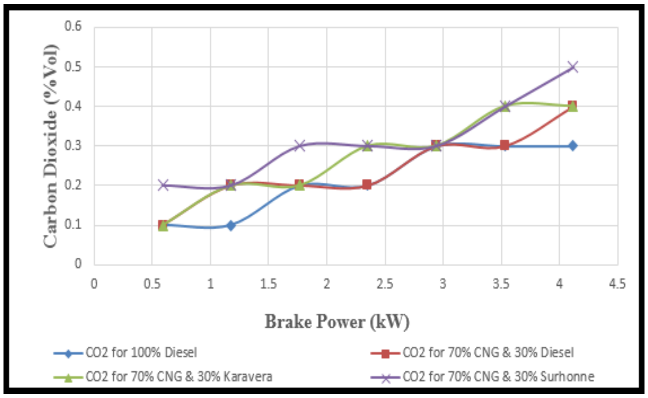

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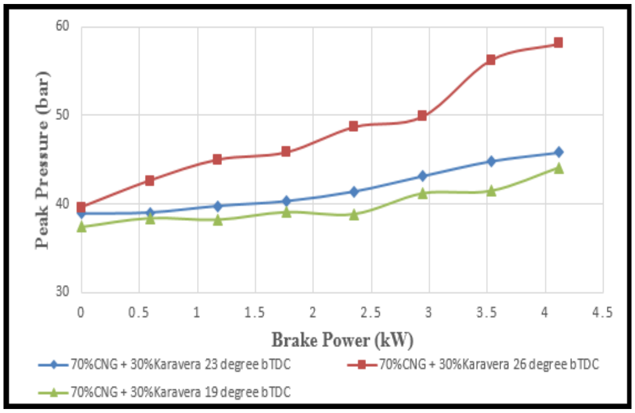
Volume 3 Issue IX, September 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Figure III-5: Comparison of Variation of CO_2 emission with BP at injection timing 23^0, 26^0 and 19^0 bTDC at Fig A, B, C.

Carbon dioxide occurs naturally in the atmosphere. Ideally, combustion of a HC fuel produce CO_2 and water. Variation of CO_2 with BP at different injection timing 23^0, 26^0 and 19^0 for the fuels are shown in Figure 3-5 A, B and C. respectively. CO_2 emission varies from 0.10% to 0.70% for diesel at different injection timing with injection pressure 210 bar. If fuels are completely combusted than gives more CO_2 emission means fuel got sufficient amount of oxygen to react with hydrocarbons and the maximum CO_2 emission occurs at advancing injection timings at 26^0.

3) Peak Pressure Curves for changing the injection timing:

Peak Pressure are shown for diesel, diesel with CNG, Karavera biodiesel with CNG and Surahonne biodiesel with CNG at various injection timings as shows bellow figures



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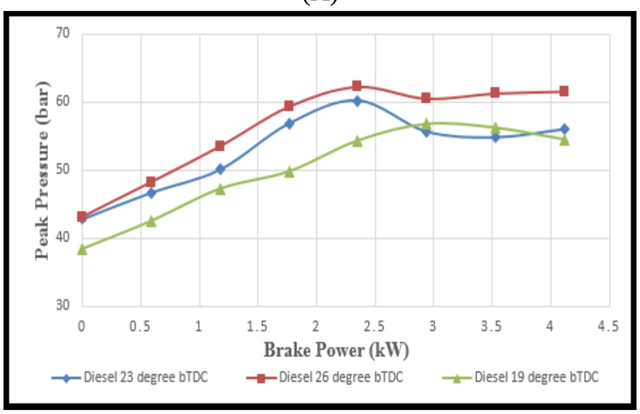

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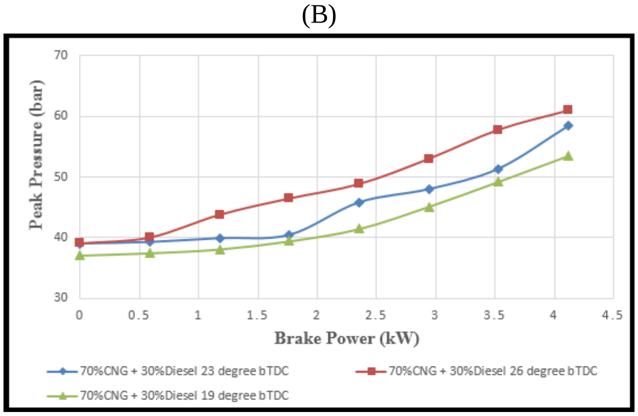

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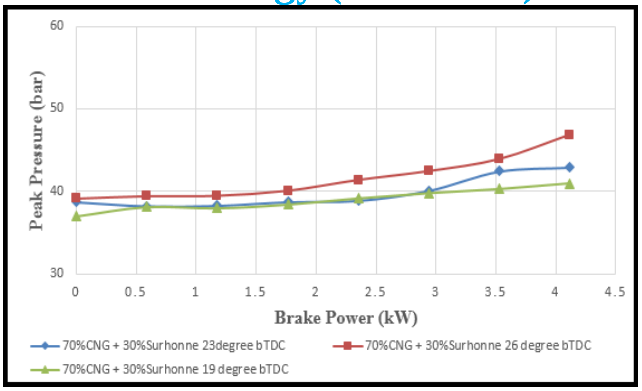

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Figure III-6: Variation of Peak Pressure with BP for varying injection timing at Figure A, B, C and D

Variation of Peak Pressure with brake power shown in Figure 3-6. It is clearly seen that peak pressure rise by advancing the injection timing and peak pressure reduction due to retarding the peak pressure. Maximum Peak pressure rise for Diesel with CNG fuel. At no load peak pressure rise less than the full load due to delay period, pressure and temperature. High viscous fuel like biodiesel less peak pressure rise due to slow burning. Peak pressure rise is range between 40-60 bar, as load increases peak pressure rises.

IV. CONCLUSION

From the results obtained, the fallowing conclusion are made.

A. Achieved 70% replacement of Diesel fuel over CNG at Dual fuel mode.
B. Dual fuel operation is very effective method to reduce unburned hydrocarbons.
C. Advancing the injection timing increase the Brake Thermal Efficiency.
D. Advancing the injection timing reduction of CO and HC emission.
E. The maximum BTE obtained 31% at injection timing 26^0 with fuel 70% CNG and 30% Surahonne biodiesel.
F. Best result is obtained for engine performance and emission at injection timing 26^0 with fuel 70% CNG and 30% Surahonne biodiesel, CO and HC emission reduction takes place up to 50%.

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