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A Research Paper on Performance Analysis of Four Stroke Diesel Engine by Using Biogas and Diesel

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Abstract — This paper aims the experimental investigation of the IC engine using diesel as a pilot fuel with purified biogas. Biogas, composed principally of methane, has limited use in energy generation due to the presence of carbon dioxide (CO_2). Biogas cannot be burnt because presence of CO_2 causes corrosion in the reaction chamber. There are various existing technologies for the removal of CO_2 from a gas stream. Most of the processes are chemical based and expensive.

In this work, CI engine is operated at different proportions of purified biogas-diesel mixture. Engine performance parameters like engine brake power, brake specific fuel consumption, brake thermal efficiency and volumetric efficiency were measured and compared with parameters obtained from conventional diesel operated engine.

Investigated results show that biogas premixed charge diesel engine NO_x emission is decreased and CO and HC emissions are increased as the flow of biogas is increased.

Keywords- Biogas-Diesel mixture, Exhaust gas temperature,Emission Characteristics, CI engine performance.

I. INTRODUCTION

Now-a-days air pollution is becoming a serious issue due to the emission from petrol and diesel vehicle into environment, which causes environment pollution, which may affect the health of a human being. To avoid this problem, the world is searching for an alternate fuel. The current energy situation throughout the world and the fact that main resources of energies like nuclear resources, natural gas, coal and crude oil and are conventional to give importance to other sources of energy like solar, wind and biogas. Mentioned sources of energy are all sustainable, but biogas is particularly important because of the possibility of use in IC engines, [8].

To operate with gaseous fuels, diesel engines can be conveniently converted to a fumigated dual fuel engine which is the most practical and efficient method. Since biogas has a high octane number, it can be employed in a high compression ratio engine to maximize its conversion efficiency. In dual fuel operation mode, biogas is mixed with air prior to entering the combustion chamber. At the end of compression stroke, a pilot amount of diesel fuel is injected to ignite the mixture, as long as proper spray penetration and evaporation are achieved. One advantage of this method is that the engine can be switched back to conventional diesel operation mode when the gaseous fuel supply is not available. [3]

1.2 Biogas

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Organic waste such as dead plant and animal material, animal dung, and kitchen waste can be converted into a gaseous fuel called biogas.

The general composition of biogas is methane (CH_4), carbon dioxide (CH_4), hydrogen (H_2), nitrogen (N_2), water vapour (H_2O) and traces of hydrogen sulphide (H_2S) Table-1

"Table.1 Composition of biogas"

Components	**Amount (%)**
Methane (CH_4)	66.53%
Carbon Dioxide (CO_2)	20.46%
Hydrogen (H_2)	0.93%
Nitrogen (N_2)	9.66%
Water Vapour (H_2O)	0.3
Hydrogen Sulphide (H_2S)	2649 MG/M3

1.3 Properties of Biogas

The biogas is analyzed for its properties along with diesel available from a local commercial retailer. These are tabulated below,

"Table .2 properties of biogas along with diesel"

Properties	**Diesel**	**Biogas**
Heating value (MJ/kg)	45.91	24.50
Calorific value	10571 kcal/kg	4186kcal/kg
Cetane number	50 minimum	56
Octane number	-	120
Specific gravity @ 15ºC	0.830	0.890gm/CC
Viscosity @ 40ºC (cSt)	3.34	129
Sulfur content (%wt.)	0.037	0.12
Ash (%wt.)	0.001	< 0.001

II. EXPERIMENTAL WORK

2.1 Engine specification:

A vertical, single cylinder, water-cooled, four stroke, and high speed diesel engine has been used for the experiment. The technical specification of engine is as under:

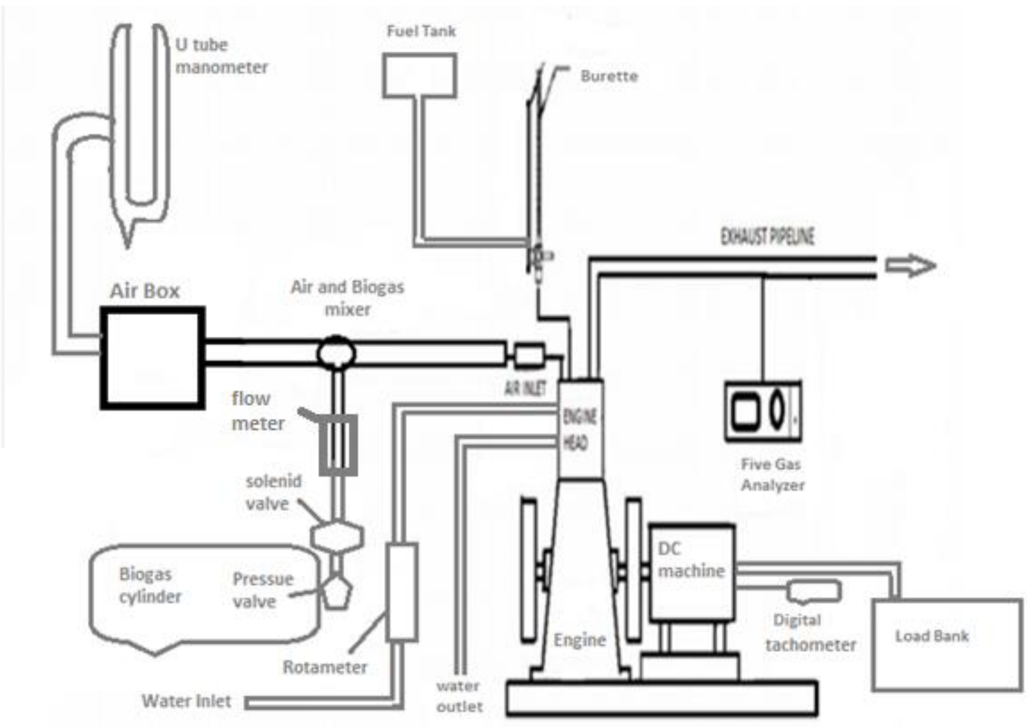
"Table.3 Technical Specification of the Experimental set up"

Engine	Capton
Generator	Direct current type
Bore (mm)	87.5
Stroke (mm)	110
Displacement (cm3)	661
Compression ratio	17.5
RPM	1500
H.P.	6.5

2.2 Experiment set up

2.2.1 Block diagram of experimental setup

Schematic diagram of water cooled dual fuel diesel engine is shown, where Engine is coupled with DC generator. DC generator is connected with load bank. To measure flow of water rotameter is attached with water inlet line. Air is sucked from air box which is connected with U-tube manometer for measuring the air flow. Biogas is supplied from biogas cylinder with the help of solenoid valve which reduce the pressure of gas. Emission parameters are recorded by gas analyser. Set up is shown in figure 1.



"Figure1. Schematic Diagram of Dual Fuel Diesel Engine

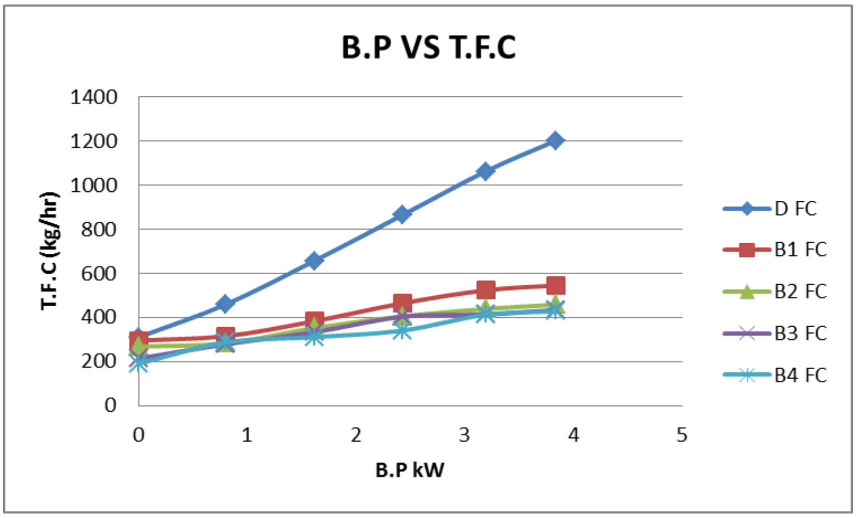
III. RESULTS

Performance and emission parameters for diesel and biogas blend are measured and compared with pure diesel where biogas flow rate is maintained 5 lpm, 9 lpm, 11 lpm and 15 lpm. Engine is operated for no load condition to full load condition in the steps of 20% rise in load. Performance parameters like brake power, fuel consumption, brake specific fuel (diesel) consumption, brake thermal efficiency and volumetric efficiency are evaluated while emission parameters like CO, HC, CO_2, O_2, and NO_X are measured.

3.1 Performance parameters:

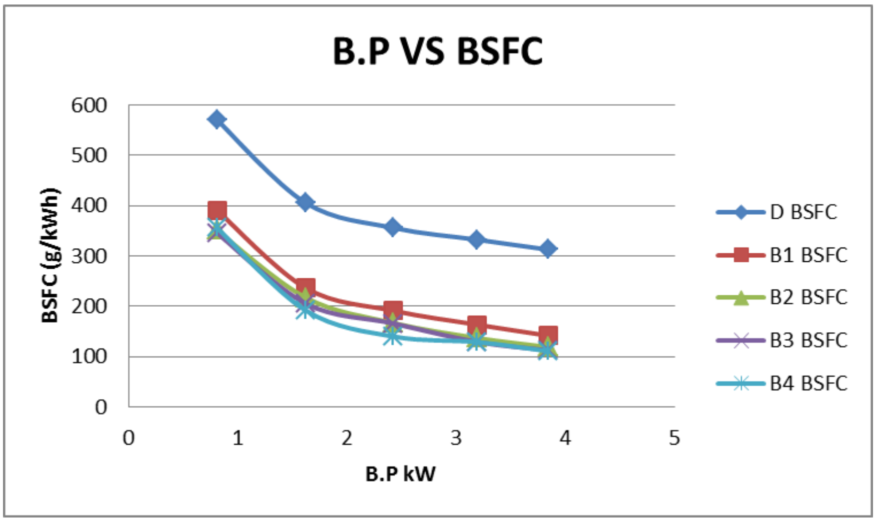
3.1.1 Variation in total fuel consumption

As shown in figure-2, the total fuel consumption increases with increase in brake power but when biogas is supplied into the engine diesel fuel consumption decreases with increases in diesel-biogas ratio. For full load with maximum biogas flow rate of 15lpm diesel consumption is decreases 1201.91 gm/hr to 427.38 gm/hr.



"Figure2. Variation in total fuel consumption"

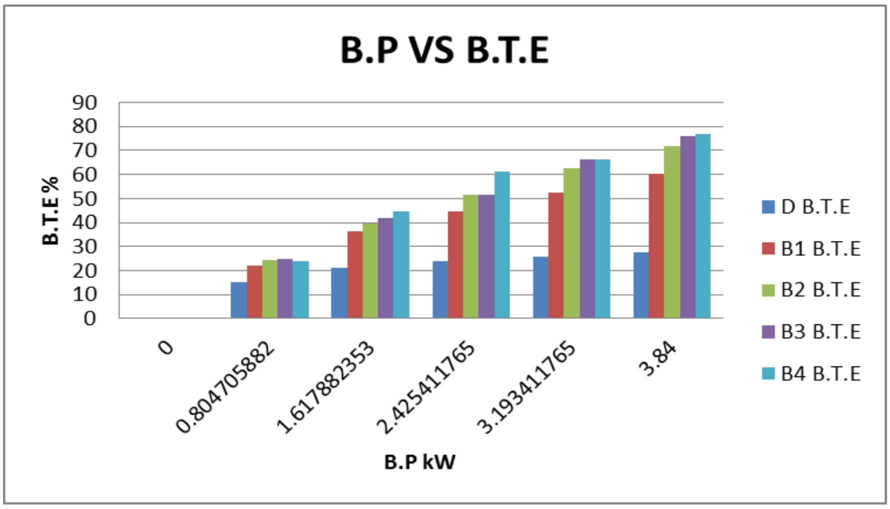
3.1.2 Variation in brake specific fuel consumption



"Figure3. Variation in brake fuel consumption"

From the above figure-3, it is observed that BSFC is maximum at low brake power and it decreases with increase in brake power for all blends of diesel and biogas fuel. For pure diesel BSFC at full load is 312.997 g/kWh which is decreases to 111.294 g/kWh for maximum 15lpm flow rate of biogas.

3.1.3 Variation in brake thermal efficiency for diesel

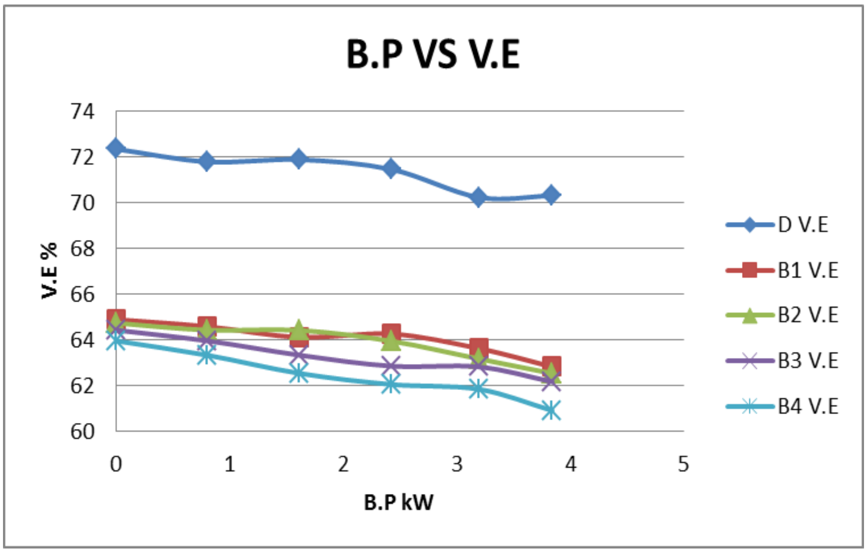


"Figure4. Variation in brake thermal efficiency"

Figure-4 shows the variation of brake thermal efficiency (BTE) with different proportion of diesel and biogas fuel combinations. The results were obtained in the form of increment in the BTE with increases in brake power from 0kW to 3.84kW due to reduction in diesel fuel consumption as per increase in biogas flow. If biogas use as a conventional fuel, then the break thermal efficiency will be lower when compared to diesel because due to carbon content present in the biogas.

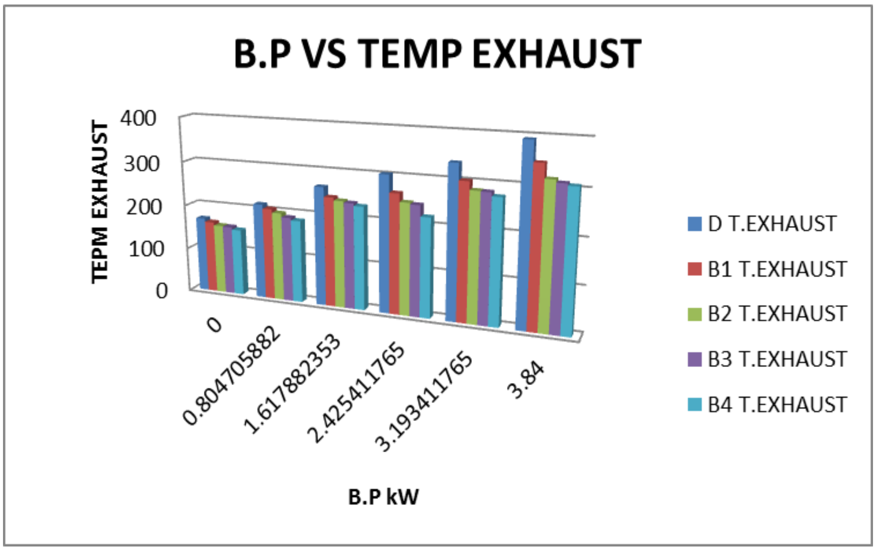
3.1.4 Variation in volumetric efficiency for diesel

As figure-5 shows that engine has very high volumetric efficiency for diesel which is lightly decreases with brake power (about 72.35% at low brake power and 70.31% at high brake power). But with slight reduction is seen in using dual fuel operation (about 63.96% at low brake power and 60.91% at higher load) due to increase of ratio of diesel and biogas, but in general the volumetric efficiency decreases with increases in brake power.



"Figure5. Variation in volumetric efficiency for diesel"

3.1.5 Variation in exhaust gas temperatures



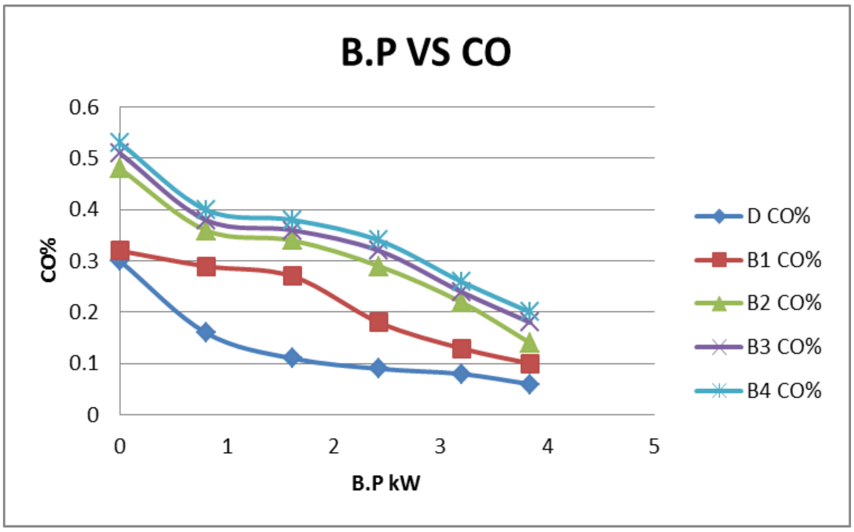
"Figure6. Variation in exhaust gas temperature"

Figure-6 shows the variation of exhaust gas temperature (EGT) with brake power for diesel and different proportion of diesel and biogas exhaust gas temperature. EGT increases with increases in brake power but it decreases with increases in ratio of diesel-biogas for given brake power. For no load exhaust gas temperature of pure diesel is 169°C and at full load it was increased to 393 °C. When for blend of biogas and diesel with 15lpm flow rate of biogas at no load temperature is 150 °C and for full load it was increased to 308 °C.

3.2 Emission parameters:

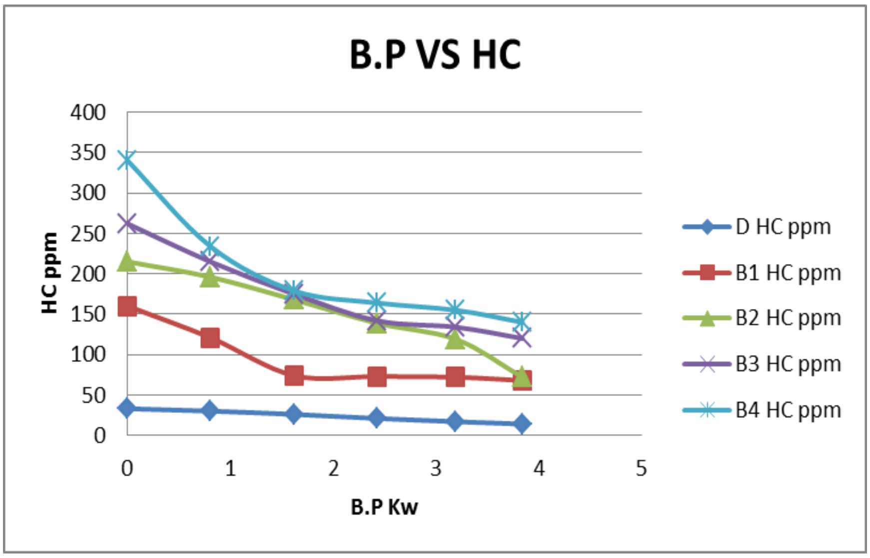
3.2.1 Variation in CO% by volume

Figure-7 shows the variation of carbon monoxide (CO) emission in percentage volume with brake power for diesel and different proportion of diesel and biogas. The CO emission decreases with the increase in break power and CO emission increases with increases in biogas flow rate because biogas contains 20.46% (by volume) of CO_2. The CO emission is high with biogas due to high carbon content that adversely affects the combustion efficiency. The combustion is incomplete therefore CO is converted into CO_2 due to low gas temperature.



"Figure7. Variation in CO%"

3.2.1 Variation in HC ppm by volume

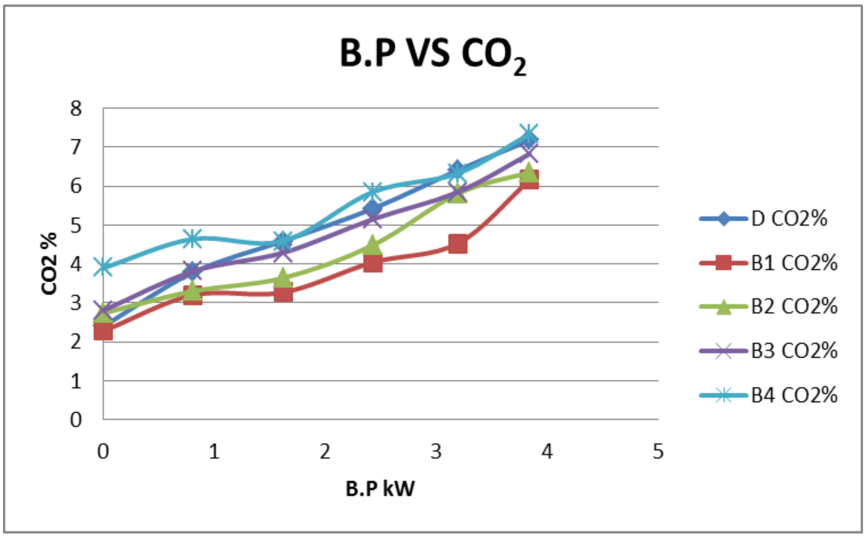


"Figure8. Variation in HC ppm"

From figure-8 it is observed that emission of hydro carbon (HC) in ppm decreases with increase in brake power for diesel and all blends of diesel and biogas fuels. The comparison of HC emissions for diesel and blend of biogas and diesels are shown in Fig. It can be seen that the HC emissions increases with increase in percentage of biogas, it's due to incomplete combustion of HC.

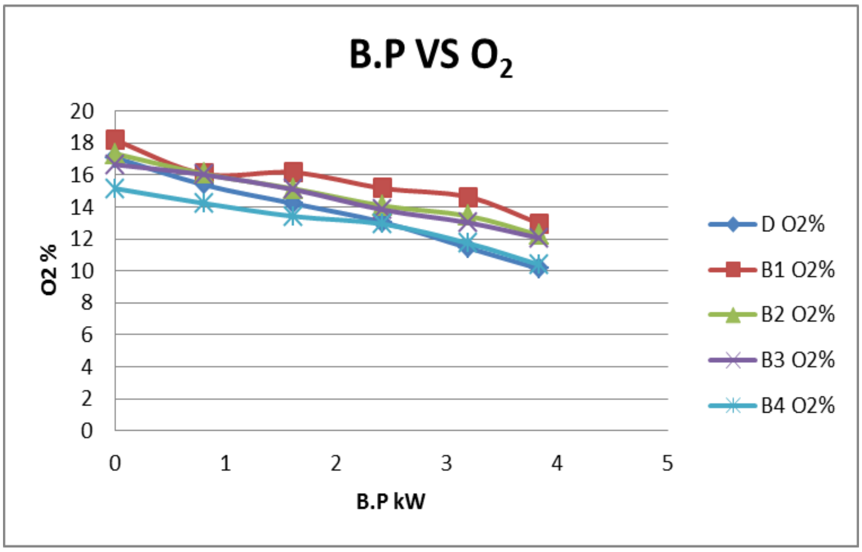
3.2.2 Variation in CO_2% by volume

As shown in figure-9 the variation of carbon dioxide (CO_2) emission in percentage by volume with brake power for diesel and different blends of diesel and biogas. Emission of CO_2 for pure diesel and different proportion of diesel and biogas increases with increases in brake power. As compared to pure diesel emission of CO_2 are mostly similar but as per increases in biogas flow rate CO_2 increases, this is due to the increase of carbon content in the biogas. The increase in CO_2 was due to oxidation of the CO. The late burning of the mixture of diesel and biogas has caused more fuel to remain partially unburned. This increases the formation of carbon monoxide and decreases the proportion of the carbon dioxide level.



"Figure9. Variation in CO_2%"

3.2.3 Variation in O_2% by volume

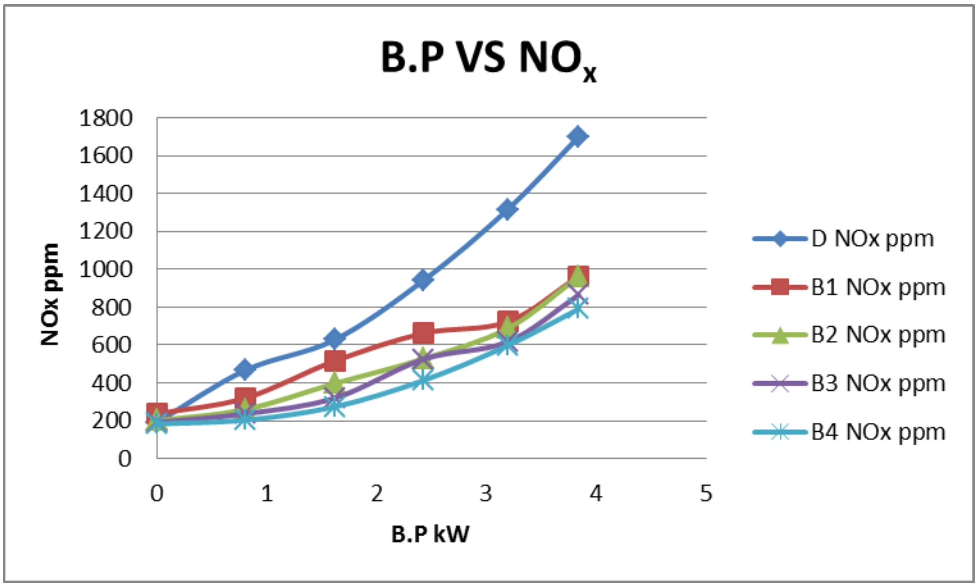


"Figure10. Variation in O_2%"

This figure-10 shows the variation of oxygen (O_2) emission in percentage by volume with brake power for diesel and different blends of diesel and biogas. The oxygen content in the exhaust gas decreases gradually with increase in brake power, because of the complete combustion. And oxygen is also decreases with decrease in biogas flow rate. However in the biogas the oxygen content remains increases, this is because of the residual content in the biogas.

3.2.4 Variation in NO ppm by volume

As shown in figure-11 the variation of oxygen (NO_x) emission in percentage by volume with brake power for diesel and different blends of diesel and biogas. NO_x increases with increases in brake power but it highly decreases with increases of biogas flow rate. The oxides of nitrogen in the exhaust emission contain nitrogen oxide (NO_x) and nitrogen dioxide (NO_2). The formation of NOx is highly dependent on in-cylinder temperature and oxygen concentration in the cylinder. The NOx is very low in biogas when compared to the diesel fuels. The NOx emissions are lower for biogas due to less heat value than that of diesel. For biogas NOx is reduced due to the low cylinder gas temperature and also due to the lower rate of combustion of gaseous fuel in the presence of CO_2 in biogas dilutes the oxygen concentration of intake fluid.



"Figure11. Variation in NO_x ppm"

IV. CONCLUSION

- The biogas is a renewable fuel that can be used as supplementary fuel with diesel with little modification in inlet manifold of diesel engine.
- Biogas content with the diesel in the diesel engine reduces exhaust gas temperature. As the amount of biogas is increased exhaust gas temperature is reduced.
- As the flow rate of biogas is increased, consumption of diesel is decreased for the same brake power.
- As the flow rate of biogas is increased emission of NO_x is reduced but emission of CO, CO_2 and HC are increased.

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