Production of Biogas Using Compact Digester & Comparative Evaluation on Performance Parameter of It with Diesel Engine

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ABSTRACT

Solid waste disposal has created a serious problem all over the world. The solution for this problem is to make use of waste for production of biogas. The biogas so produced could be suitably utilized in the surrounding areas for various applications.

The paper focuses with an aim of production of biogas with an efficient compact floating dome design and to do testing on Compression Ignition engine. As the biogas cannot be used directly so my concern is also to invent new method to purify the natural biogas and that is design of scrubber. For effective mixing of biogas and air the air mixture kit is also designed. This study will definitely help in improving the efficiency and emission control of dual fuel diesel engine.

This paper reviews the perspectives of biomass production by an anaerobic digestion of agricultural waste, cow dung, food waste, municipal solid waste, etc. and comparative study on emission of diesel engine running on diesel and on dual fuel mode. Also found out different technical parameter in each case of two different modes.

Keywords

Anaerobic digestion, Biogas, Diesel engine, Dual fuel, Scrubber, Air mixture kit.

1. INTRODUCTION

The biogas technology is not new and has been applied in the processing of manure, sewerage and on landfills from many years. Since India is largest cattle breeding country, there is abundance of raw material for producing biogas. Kitchen waste and municipal sewages can also be used for this purpose [1]. Anaerobic digestion is a low cost method to convert the organic substances into useful energy [2]. Hydrocarbon (HC), Carbon monoxide (CO), Carbon dioxide (CO_2), Oxygen (O_2) and Oxides of Nitrogen (NO_x) has been detected in the diesel engine operating in biogas diesel dual fuel mode. Drop of CO_2 in biogas in dual fueling increases the thermal efficiency and in biogas HCCI mode, the presence of CO_2 controls the high heat release rate, hence the durability of engine components will not be affected. Therefore it is recommended to use biogas as alternate fuel in diesel engines [1].

2. BIOGAS AS FUEL FOR DIESEL ENGINE

Biogas can be used in both light duty and heavy duty vehicles. Without any modification light duty vehicles can normally run, whereas heavy duty vehicles without closed loop control have to be adjusted. Diesel engine requires combination of diesel oil and biogas for its combustion. Biogas cannot be directly used in automobiles as it contains some other gases like CO_2, H_2S and water vapour which is to be upgraded by removing these impurities. Since it has high self-ignition temperature, it cannot be used directly in CI engines. So it is useful in dual fuel engine which is a modified diesel engine in which the primary fuel is induced with air into the engine cylinder [3]. Reduction of CO_2 level to 15% in biogas improves the engine performance and the HC emission reduces. By induction of biogas to the engine the smoke number is found to be reduced. Thus biogas is used effectively in CI engine in dual fuel mode with high cetane pilot fuel injection. [3]

3. METHOD USED FOR MAKING OF BIOGAS PLANT

The conventional biogas systems, using cattle dung, sewerage, etc. use about 40kg feedstock to produce the same quantity of methane, and require about 40 days completing the reaction. Thus, from the point of view of conversion of feedstock into methane, the Appropiate Rural Technology Institute (ARTI) system developed by Dr. Anand Karve is 20 times as efficient as the conventional system, and from the point of view of reaction time, it is 40 times as efficient. Thus, overall, the new system is 800 times as efficient as the conventional biogas system. This technology is very simple and compact as we do not require any concrete work to construct this plant. We make use of synthetic water tanks which are easily available in market and some minute modifications are made to make one tank as digester and other as gas holder [4]. It consists of a digester and a gas holder with various fittings. This process is carried out in two steps.

3.1 Start-up Procedure

Take about 25 to 30 kg of dung and add same quantity of the water. Break all the lumps of the dung and make nicely blended slurry, remove all extraneous matter from it. Add the nutrient (urea and waste flour) in a measured quantity. Add this slurry into the digester and fill the digester with water. Invert the gas holder on the digester open the cock and allow the air to come out from the gas holder. After the gasholder goes half into the digester close the cock. By adding the soap water on the joint checks the leakage. If some leakage found apply the m-seal to the joints. After removing the leakage open the cock and allow the gas holder to settle down into the digester. As the gas generates the gasholder lifts up. We can measure the gas produced by using the scale, which we had marked on gasholder. Check the biogas produced by placing a candle near to the gas cock. If the flame is burn then we can say that the biogas is produced.

3.2 Operating Procedure

At the starting add the starchy material to the plant with water. Slowly switch to the vegetable waste. After the steady production of gas increase the quantity of feed can be reduced maintaining the required water level. Stir the slurry by revolving the gasholder. Every day make the visual observation regarding wellbeing of biogas plant. Keep daily record of rise in gas holder position to measure the quantity of gas generated.

4. PURIFICATION OF BIOGAS

Natural biogas produced in biogas plant has different constituent like carbon dioxide, methane, sulphur, hydroxide, moisture. This improper constitute has adverse effect on performance of diesel in dual fuel mode. It has following adverse effect.

1. Extra quantity of carbon dioxide reduces the calorific value of biogas.
2. Moisture in biogas leads to corrosion of component of diesel engine.
3. Sulphur hydroxide form sulphur oxide at high temp during combustion in engine which react with moisture present in biogas form sulphuric acid which leads to corrosion of engine components. So it become essential to separate unwanted constitute of natural biogas to improve the quality of biogas.

4.1 Construction and Working of Scrubber

Take plastic bucket which is air tight or with proper sealing. With the help of drill form two holes, one is at bottom for inlet of natural biogas and another is for exit of pure gas to the suction of engine. Inside the bucket there is structure, one vertical hollow square pipe of material mild steel. Grooves are formed at three positions in vertical pipe. Small holes are drill on the each circular plate, which act as passage for the biogas to pass. Each plate is covered with tissue paper to avoid the mixing of different chemical kept on each plate. Three circular plates of different diameters are fit into the groove by forming the square hole of dimension same as dimension of vertical square pipe at the center of each plate.

Chemical used:-

1 .Quantity of calcium hydroxide powder = 0.5 Kg on each plate
2. Quantity of ferrous powder = 50 gm.

4.1.1Chemical Reactions taking place

1. When calcium hydroxide reacts with carbon dioxide in the presence of aqueous solution it forms calcium carbonate and water.

$Ca(OH)_2$	+	CO_2	→	CaCO3	+	H_2O
Calcium Hydroxide		Carbon dioxide		Calcium Carbonate		Water

2. When ferrous react with hydrogen sulphide it form ferrous sulphide and hydrogen

Fe	+	H_2S	→	FeS	+	H_2
Ferrous or iron		Hydrogen Sulphide		Ferrous Sulphide		Hydrogen Gas

4.1.2 Performance of scrubber

The performance of the scrubber is checked with the help of gas analyzer and the result is as follows:

Table 1. Gas analysis before feed to the scrubber

Sr.No	CO (%Vol)	HC(ppm)	O_2(%Vol)	NOx(ppm)
1	0.01	1758	0.19	0

Table 2. Gas analysis after the scrubber

Sr.No	CO (%Vol)	HC(ppm)	O_2(%Vol)	NO_x(ppm)
1	0.01	2523	0.18	0

Result table shows that there is considerable change in hydrocarbon (methane) , so as there is increase in concentration of methane so obviously there is decrease in concentration of carbon dioxide.

4.1.3 Significance of scrubber

Biogas generated from different substrate contains different concentration of hydrogen sulphide H_2S. As H_2S is corrosive to the metal especially in contact with water or moisture. When this H_2S enter into the engine on combustion at very high temp above 1000ºC forms the oxide of sulphur. When this oxide comes in contact with moisture, it reacts and form strong sulphuric acid which is highly corrosive to the metal part of engine. This reduces the life of engine and increase the maintenances cost of engine. It became very essential to control the concentration of hydrogen sulphide. CO_2 is not harmful to the engine but it absorb the heat generated during combustion and reduced the C.V of biogas. So because of the above reason scrubber is design.

5. MIXING KIT

For dual fuel operation a mixing device has to meet the following requirements: Provide a homogeneous mixture of both air and fuel gas, vary the fuel gas flow according to performance required, able to supply sufficient air and fuel for operation at maximum load and speed under consideration of the actual pressures of gas and air and the fact that the excess air ratio shall not be less than about l: 1.5 because sufficient excess air is needed for combustion of the pilot fuel also.

5.1 Construction and Working of Air Gas Mixing Kit

Cut the piece of pipe of appropriate length and diameter. Select pipe cap of same dimension so there will not be leakage of air after fixing of pipe. Before caps are fixed on pipe three hole of different dimension is formed with the help of drilling machine. On one cap two hole of different dimension are formed, among them one hole is for receiving the air from atm. Through filter, another hole is for receiving the biogas. Another hole on another cap is for outlet of air and biogas mixture.

The function of air and gas mixing kit is to prepare proper air and fuel (biogas) ratio another function is to act as reservoir of air and fuel. Filter air is passed to the air and gas mixture kit through the passage pipe and biogas from the scrubber is carry to kit by another small opening. After the air and biogas is rushed into the kit. The enlarge area of air and gas mixture kit provide sufficient space and time for proper mixing (homogenous mixture) of air and biogas. This homogenous mixture will combust properly. Outlet of air and gas mixture kit is couple to the inlet manifold of engine. During suction stroke pressure is drop in cylinder which create pressure drop in inlet manifold and subsequently in the air gas mixture kit. This negative pressure sucks the air forcefully into the air gas mixing kit and also the biogas. As air is sucked in the air gas mixing kit it flows in turbulence. The enlarge section vertex are form at its entrance edge which results into reduction in pressure.

6. LABORATORY TESTING CARRIED OUT

In this experiment about 80% biogas and 20% diesel is used. In this experiment we require some parameter like, mass flow rate of biogas and mass flow rate of air can be find out with the help of 'U' tube manometer. The fig below shows the experimental setup.

Fig: 1 Practical set up

6.1 Test on diesel engine run on diesel as fuel

6.1.1 Observation table for diesel

Sr.No	1	2	3	4
Voltmeter 'Volt'	230	230	230	230
Ammeter 'Amp'	14	16	18	20
Time for 10ml diesel 't'	6.10	4.94	14.5	14.16
Manometer difference (hw)	2.5	2.3	2.1	2
RPM	719	719	719	719

6.1.2 Exhaust Gas Analysis

Sr.No	1	2	3	4
CO (% Vol)	0.06	0.04	0.03	0.03
HC (ppm Vol)	16	12	9	11
CO2 (% Vol)	3.7	3.5	3.7	4.5
O2 (% Vol)	14.66	16.44	13.97	13.24
NO_x (ppm Vol)	924	837	1019	1142

6.1.3 Result table for diesel engine

Parameters	1	2	3	4
Brake Power (kW)	4.6	5.26	5.91	6.57
Fuel Consumption (Kg/hr)	1.86	1.87	1.94	1.98
Specific Fuel Consumption (Kg/kWhr)	0.4	0.36	0.32	0.30
Heat Supplied By Fuel (kJ/Kghr)	78120	80123	82531	103164
Indicated Power(kW)	9.4	12.76	13.41	14.07
Heat Equivalent to BP (kJ/hr)	151120	18936	21290	23652
Heat Equivalent to IP (kJ/hr)	33840	45936	48290	50652
Mechanical Efficiency (Ƞm %)	48.94	41.22	44.1	46.69
Brake Thermal Efficiency (Ƞbt %)	19.35	23.63	25.79	27.97
Indicated Thermal Efficiency (Ƞit %)	43.32	57.33	58.51	59.92
Air Consumption Ma (Kg/hr)	17	16.08	15.7	15.36
Air Fuel Ratio	9.14:1	8.56:1	8.10:1	7.74:1
Friction Power (kW)	4.8	4.8	4.8	4.8

6.2 Test on diesel engine run on dual fuel mode

6.2.1 Observation table for dual fuel

Sr.No	1	2	3	4
Voltmeter 'Volt'	230	230	230	230
Ammeter 'Amp'	14	16	18	20
Time for 10ml diesel 't'	19.02	21.64	30.20	35.28
Manometer difference (hw)	2.2	2.9	3.8	2.6
Manometer diff. for air (hw meters)	5.5	4.8	6.2	6.7
RPM	730	730	730	730

6.2.2 Exhaust Gas Analysis

Sr.No	1	2	3	4
CO (% Vol)	0.33	0.47	0.532	0.18
HC (ppm Vol hex)	120	113	92	72
CO2 (% Vol)	3.8	3.8	4.5	4.8
O2 (% Vol)	16.24	13.49	16.93	13.95
NO_x (ppm Vol)	1100	617	305	336

6.2.3 Result table for dual fuel engine

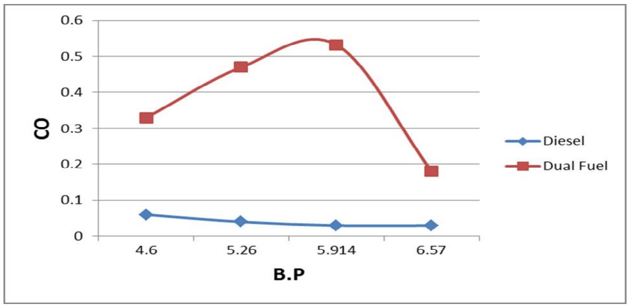
Parameters	1	2	3	4
Brake Power (kW)	4.6	5.26	5.91	6.57
Fuel Consumption (Kg/hr)	3.03	2.72	2.48	2.89
Specific Fuel Consumption (Kg/kWhr)	0.726	0.591	0.539	0.628
Heat Supplied By Fuel (kJ/Kghr)	108612	97987	86019	96749
Indicated Power(kW)	13.72	14.38	15.034	15.69
Heat Equivalent to BP (kJ/hr)	16560	18936	21290	23652
Heat Equivalent to IP (kJ/hr)	49392	51686	55224	56484
Mechanical Efficiency (Ƞm %)	33.52	36.57	39.33	41.87
Brake Thermal Efficiency (Ƞbt %)	15.25	19.32	24.75	24.44
Indicated Thermal Efficiency (Ƞit %)	45.48	52.74	64.2	58.38
Air Consumption Ma (Kg/hr)	13.29	15.26	17.47	14.45
Air Fuel Ratio	4.39:1	5.61:1	7.04:1	5:1
Friction Power (kW)	9.12	9.12	9.12	9.12

7. GRAPH BASED ON EMISSION

On the basis of the emission graphs are prepared of diesel engine run on dual fuel and on diesel.

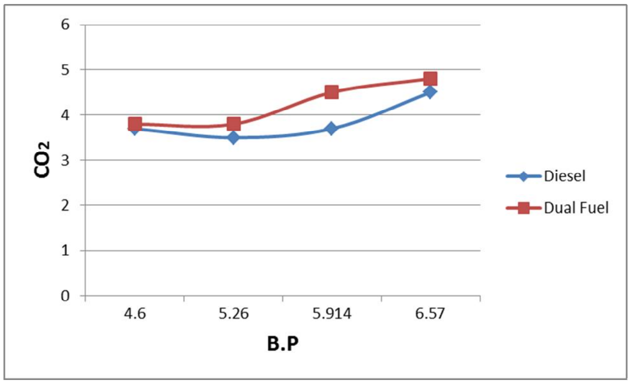
7.1 B.P Vs CO

In comparison between single and dual-fuel combustions, the concentration of CO emissions for the dual-fuel mode fuels was considerably higher than those of the single-fuel mode under all test conditions.



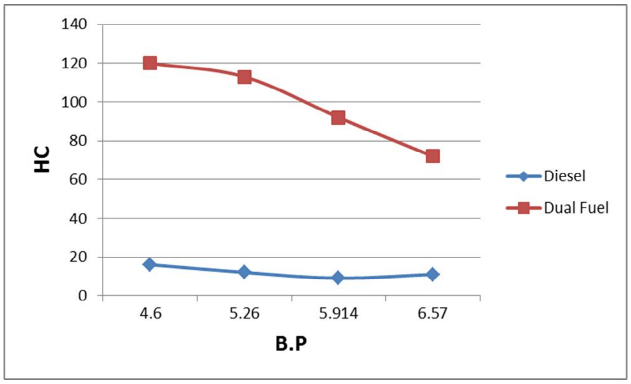
7.2 B.P Vs CO_2

Emission of CO2 in both the case shows same nature of curve, on increasing the load, CO2 concentration also increases. This trend of increasing in CO2 on increasing the load shows that high concentration of CO2 induces during the emission.



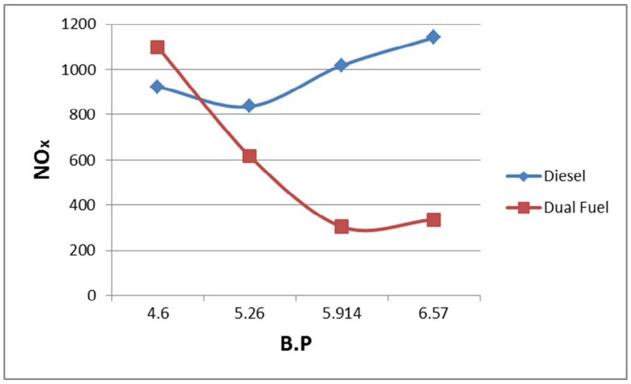
7.3 B.P Vs HC

Comparing the single and dual-fuel combustions, the HC emissions for the dual-fuel mode with both pilot fuels were found to be higher than those of the single-fuel mode under all test conditions. With the induction of biogas into the engine, the CO_2 content in the mixture increases at the expense of fresh air which in turn reduces the air–fuel ratio and combustion temperature. At higher engine loads the HC emissions were found to be reducing for dual fuel mode whereas the same was found to be slightly increasing for single fuel mode with both the pilot fuels. The reason towards this can be stated as the higher octane rating of biogas results in faster rate of combustion in the combustion chamber.



7.4 B.P Vs NO_x

In case of dual-fuel operations, the concentrations of NOx emissions were significantly lower at all engine loads, on average about 60% below the levels measured in single mode combustion. This is because of low combustion rate of the gaseous fuel in the presence of CO2 in biogas. The CO2 of biogas dilutes the oxygen concentration of the intake fluid. It has been reported that the induction of biogas increases the specific heat capacity of the working fluid which causes the slowing of the flame propagation and the lowering of the combustion temperature during the combustion process compared to the single-fuel mode.



8. CONCLUSION

It was concluded that while increasing carbon dioxide present in biogas does not affect the formation of CO emissions, there was a minor increase in the emission of unburned HC when biogas is used and the emission is increased with increasing amount of carbon dioxide present. On the contrary, as shown in curve NOx emissions were reduced tremendously when biogas is used. The experiment conducted also showed that at low engine load, both NOx and soot emissions decreased with the use of biogas compared to normal diesel operation. The reduction in charge temperature contributes to the prolonged ignition delay for biogas-diesel dual fuel operation, which in turn is beneficial in reducing the NOx emissions. A thorough investigation was done to understand the characteristics of methane-air mixture turbulent premixed flames diluted with carbon dioxide. The study concluded that with the presence of carbon dioxide, the local turbulent burning velocity was reduced and the combustion oscillation of the premixed gaseous fuel-air mixture was restrained, hence resulting in less gaseous fuel being burnt.

So this investigation show that biogas could be better substitution for fossil while considering the environment impact as it is found that on increasing the load NOx emission is decreasing significantly as compare to the diesel and also with biodiesel.

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