Experimentation on Performance and Emmissions Characteristics of 97.5cc Spark Ignition Engine by Using Hydrogen Inject with Biogas Fuel

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Abstract

There is possibility to run 4-STOKE petrol engine on biogas but the combustion is poor as compared to petrol fuel. One of the reasons of poor combustion is the presence of carbon dioxide in the biogas. Methane and carbon dioxide are the two main constituents of biogas. Biogas also contains traces of nitrogen, hydrogen, oxygen and hydrogen sulphide. Because of a high investment cost and a heavy infrastructure, only fifty percent of the biogas production is upgraded (decrease CO2%) by use of water scrubber. so the natural gas replacement is very low.

This experiment is conducted on modified single cylinder 97.5cc petrol engine, to operate as a biogas-hydrogen fuel spark ignition engine. Hydrogen is added in small amounts by HHO GENRATOR (HYDROXY) KIT to decrease concentration of CO2 in biogas on the energy basis and tested in a spark ignition engine at different range of brake power, with few change in injection of the engine.

The experimental results show that with increase of brake power, specific fuel consumption decrease while brake thermal efficiency is increase for both the fuel engine; but SFC of biogas engine is higher and BTE is lower compare to petrol engine at the same brake power. PUC certificate of emission test show that in petrol the proportion of HC and CO emission is higher and CO2 emission is lower compare to biogas engine at same brake power.

Keywords: *Biodiesel, hydrogen, SI engine, HHO, bio fuel.*

1. Introduction

In the 20th century, world energy usage has increased significantly due to the effect of industrialization, and this increase in usage has resulted in limited petroleum reserves, such as in the 1970s oil crisis [1]. All Most of the energy used in the world is supplied by fossil fuels. Burning of the fossil fuels generates waste materials, mainly emissions to the atmosphere in the form of combustion fuel gases and dust, as well as some ash. These waste materials have hazardous effects on the environment, some of them locally, others with more widespread or even global impact. Not only does the continued use of large amounts of fossil fuels pose a serious threat to the environment, but also the fuels themselves are finite in quantity. There are debates amongst experts about the extractable amount of fossil fuels. General opinion is that at the beginning of the 21st century almost half of the fossil fuels had already been consumed. The known worldwide reserves of petroleum are 1000 billion barrels and these petroleum reserves are predicted to be consumed in about 40 years. Another problem with petroleum is the emission of pollutants, such as CO_2, NOx, CO and hydrocarbons (HC). So, the world had to search for other sources of fuel and now a day the most useful and eco-friendly source are gaseous fuels.

Gaseous fuels have wide flammability limits and can easily form a homogeneous mixture with air for good combustion. Thus they will lead to very low levels of pollutants and can be effectively utilized in both spark ignition (SI) and compression ignition (CI) engines. Moreover, gaseous fuels have high hydrogen to carbon ratios. Thus very low CO_2 emissions are possible when they are used in I.C.Engines. Natural gas and Liquefied Petroleum Gas (LPG) are the readily available petroleum-based fuels, while hydrogen, biogas and producer gas can be obtained from renewable sources. Renewable fuels will not affect the net CO_2 in the environment.

Biogas is an attractive source of energy for rural areas. It can be produced from cow dung and other animal waste and also from plant matter such as leaves and water hyacinth – all of which are renewable and available in the countryside. Also called ''gobar gas'', it is produced by bacteria, which break down organic material under air less conditions. This process is called ''anaerobic digestion''. The composition of biogas, depending on the feed material and the method of digestion, usually lies within the following ranges: 50-70% methane (CH_4), 25-50% CO_2, l-5% H_2, 0.3-3% N_2 and various minor impurities, notably hydrogen sulphide (H_2S). Hydrogen sulphide provides the biogas its bad odder. The presence of carbon dioxide in the biogas reduces the burning velocity which ultimately affects the performance of the engine. Percentage of

methane and carbon dioxide in biogas varies with the maturities of feed stock, temperature, water content, loading rate of raw material and bacterial actions. A biogas can act as a promising (future excellence) alternative fuel by substituting (to put in place of) considerable amount of fossil fuels. Biogas, produced by the anaerobic fermentation of cellulosic biomass materials, is a clean fuel to run internal combustion engines [2].

2. Applicability of biogas and hydrogen in ic engines.

2.1 Why Biogas will useful in IC Engines?

We know that the economy of India depends to a large extent on the wheels of transport. However, because of a high investment cost and a heavy infrastructure, only fifty percent of the biogas production is upgraded, and the natural gas replacement is very low. This renewable energy is already used for heat and electricity production, but the best Upgrading solution of this clean energy should be the injection into the natural gasgrid or the production of vehicle fuel. Biogas containing more than 45% carbon dioxide caused harsh (rough or unpleasant to the senses) and irregular running of the engine. Similar results were obtained by others, in which increased exhaust emission of the unburned fuel was found in the region of 45-50% carbon dioxide [3]. The large quantity of CO2 present in biogas lowers its calorific value, flame velocity and flammability range compared with natural gas. The self-ignition temperature of biogas is high and hence it resists knocking which is desirable in SI engines. Thus biogas has a high anti-knock index and hence biogas engine can use high compression ratios, which can lead to improvements in thermal efficiency

Biogas cannot be used to run an IC engine directly on account of its high self ignition temperature. However, it can be utilized in an IC engine with the dual fuelling approach. The dual fuel engine is basically a modified IC engine. In this case, a mixture of air and biogas or other gaseous fuel is sucked into the engine, compressed and then ignited by a spray of fuel with a low self-ignition temperature like diesel, vegetable oil or biodiesel, which is called a pilot fuel [4]. Dual fuel operation always needs a small amount of pilot fuel for ignition.
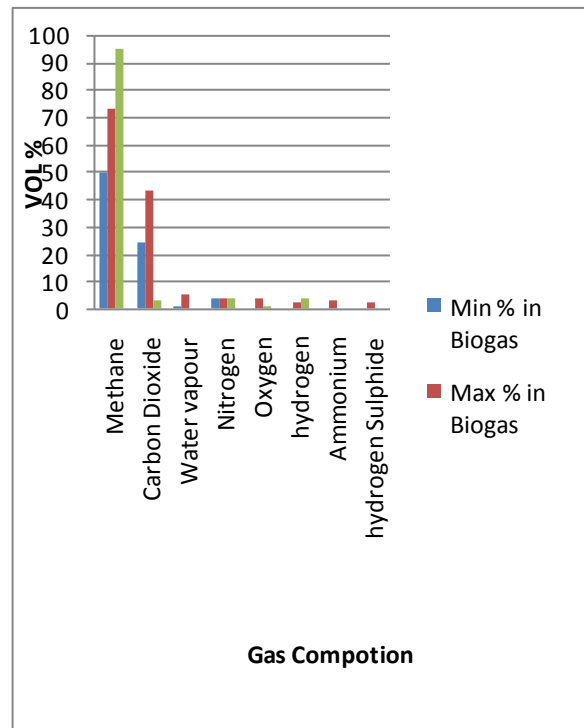

Fig. 1 Comparison of gas impurities of raw biogas with natural gas

2.2 Why and how hydrogen will inject?

Hydrogen is also renewable source, which produce in small amount by use of HH0 Generator, and directly inject into engine with low calorific biogas. Water is contains two Hydrogen atoms (H2) and one Oxygen molecule. In a combined form they are the abundant resource known as water. A HHO Generator is a device that uses electrolysis to convert water into two parts Hydrogen and one part Oxygen. This gas, also known as Brown's Gas, is a very clean burning powerful fuel. Through the simple process of running electric current through the water, the atoms 'split' back into their original elemental forms. This process is known as electrolysis. Electrical current runs through the water and all the Hydrogen atoms run toward the negatively charged electrode, and all the oxygen atoms move toward the positive electrode.
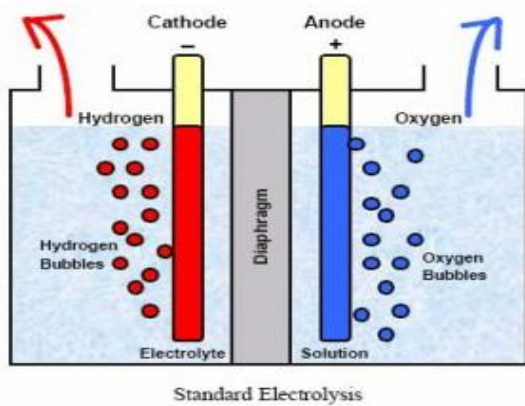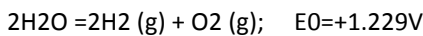
Fig. 2 Electrolysis Process for H2 and O2

Distilled water + Baking soda + Electricity = cheap, clean fuel.

$$2H2O = 2H2 (g) + O2 (g); \quad E0 = +1.229V$$

Any HHO generator simply adds 'free' hydrogen and oxygen in a gaseous state to the combustion process. The mixture of this burns so hot, and so fast, it helps to complete the combustion process of the original gasoline. It burns more of the carbon atoms to create lower emissions (fewer hydrocarbon and carbon monoxide particles). It reduces excess heat (a cooler running engine) and it offers more power from a more complete combustion of the gasoline. HHO Gas has proven to increase mileage while improving horsepower and lowering emissions.

This small device forces each litre of water to expand into 1833 litters of combustible gas. The effects of this technology are lowered emissions and improved efficiency as a result of creating a more complete combustion. With electricity from vehicle's battery HHO is being produced from water (and often catalyst like KOH or NAOH) HHO gas is directed to vehicle's air-intake. In general, because the HHO gas is, mixed with air, a highly (better) explosive gas will be needing between 8% and 35 % less with conventional fuel like gasoline, diesel, LPG, biodiesel etc.

3. Theoretical Considerations, Experiment Setup and Experimental Procedure
3.1 Theoretical Consideration

S. Orhan Akansu (2007) and E. Porpatham (2012) conclude that presence of up to 30% carbon dioxide in biogas improved the engine performance as compared to the same running with natural gas (96% methane).

But Percentage of methane and carbon dioxide in biogas varies with the maturities of feed stock, temperature, water content, loading rate of raw material and bacterial actions.

Theoretical study shows that concentration of CO_2 in biogas is decrease and increase combustible component of fuel by injecting hydrogen with biogas. Also, Hydrogen is cleanest world fuels which add with fossil fuel in engine to increase calorific value, flame velocity, flammability range of fuel.

	mass fraction of carbon dioxide	mass fraction of combustible component		
		CH4	H2	TOTAL
very bad biogas(MAX CO_2)	0.4	0.52	0.015	**0.535**
good biogas	**0.3**	0.62	0.015	**0.635**
biogas injected with hydrogen	**0.307**	0.4	0.242	**0.642**

3.2 Experimental Setup

The experimental apparatus included compressor and biogas storage tank, biogas purification, internal combustion engine and its attachments and H.H.O generation kit, biogas injection kit, fuels-air injection, dynamometer as shown in figure 3.1.
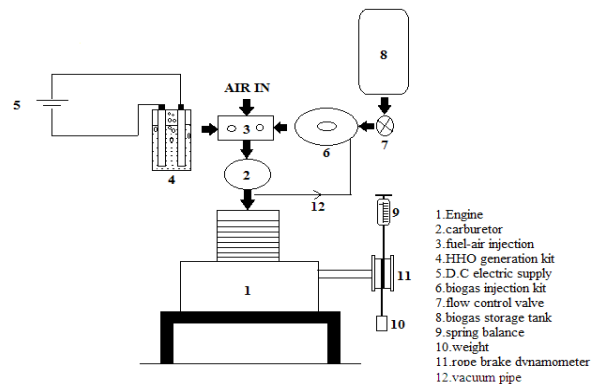

1.Engine
2.carburetor
3.fuel-air injection
4.HHO generation kit
5.D.C electric supply
6.biogas injection kit
7.flow control valve
8.biogas storage tank
9.spring balance
10.weight
11.rope brake dynamometer
12.vacuum pipe

Fig.3.1 Experimental setup

Sufficient biogas was filled up in biogas storage tank by use of compressor and distilled water was filled up in HHO generation kit up to required height with salt.
D.C. power was supplied to HHO kit and HHO gas was supply to fuel-air injector, also connected biogas storage tank and vacuum pipe with biogas injection kit.

3.3 Experimental Procedure
With starting engine and increasing the speed of engine which is measured by tachometer and note down spring

balance scale at different speed. Mass of biogas and HHO (lit/sec) were measured and calculated brake power, brake thermal efficiency and specific fuel consumption at different speed.

3.4 Mathematical Modelling
3.4.1 Brake Power (kw)
$$Bp = \pi . D_{eff} . N . (W-S)/60000 . 0.3$$

Here,

Deff = (Dp + Dr), Effective diameter of pulley (m)

Dp = diameter of pulley

Dr = diameter of rope

W = Total mass supported at rope (kg)

S = spring balance (kg)

N = pulley speed, RPM

Assuming dynamometer efficiency 30% brake power of the engine.

3.4.2 Mass of the petrol fuel (kg/hr)
$$mf_p = \zeta_p . 10^{-5} . 3600/t_p$$

here,

ζ_p = density of petrol (kg/m3)

tp = time taken for consume 10 ml of petrol (sec)

3.4.3 Mass of gases fuel (kg/hr)
$$mf_g = m_b + m_h$$

Here, mb = mass of biogas (kg/hr)

Mb = ζ_b . 10-3.3600/ tb

here, ζ_b = density of biogas (0.85 kg/m3)

tb = time consume for filling 1 lit (sec)

mh = mass of hydrogen (kg/hr)

mh = ζ_h . 10-3.3600/ th

here, ζ_h = density of hydrogen (0.089 kg/m3)

th = time consume for filling 1 lit (sec)

3.4.4 specific fuel consumption(kg / kw.hr)
$$SFC = mf / Bp$$

Here, mf = mass of fuel (kg/hr)

3.4.6 Efficiency
It is desirable that the power produced by the engine should be fully (100%) utilized. But it is not possible as power losses are inevitable. It is due to losses of two kids viz Mechanical losses due to friction and Thermal losses

Hence power produced inside the cylinder is not fully transferred to the crankshaft. The relationship between power produced and the power utilized can be expressed in terms of efficiency.

3.4.7 Brake thermal efficiency
As the power output may be indicated power or brake power, therefore thermal efficiency may be expressed as indicated thermal efficiency or as brake thermal efficiency.

BTE = Bp.3600.100/ mf.CV

Where, CV = calorific value for fuel (kj/kg)

mf = fuel consumption Kg/hr

4. Results and Discussion
4.1 Performance Test

Sr. No.	Speed (RPM)	Effective diameter of pulley, D_eff	Total mass support	Spring balance, S (kg)	Density of petrol, ζ_p (kg/m³)	Time for consume 10 ml	Mass of fuel, mf_p (kg/hr)	calorific value for fuel, CV
1	620	0.065	9.9	1.3	772	102	0.272	42000
2	865	0.065	9.9	2	772	83	0.336	42000
3	1115	0.065	9.9	3	772	76	0.365	42000
4	1956	0.065	9.9	4.5	772	65	0.427	42000

Table 4.1 Observation Table for petrol fuel engine

Sr no	BP	Specific Fuel consumed.	Brake thermal efficiency.
	(kw)	(kg/kw.hr)	(%)
1	0.589	0.462	18.55
2	0.76	0.442	19.39
3	0.856	0.427	20.1
4	1.17	0.365	23.46

Table 5.2 Result Table for petrol fuel engine

Sr. No.	Speed (RPM)	Effective diameter of pulley(D_eff)	Total mass supported at rope (kg) (W)	Spring balance (kg) (S)	mass of biogas, m_b (kg/hr)	mass of HHO, m_h (kg/hr)	Mass of fuel mf_g (kg/hr)	calorific value for fuel (KJ/kg) (CV)
1	590	0.065	9.9	1	0.455	0.095	0.55	30000
2	810	0.065	9.9	1.9	0.566	0.095	0.661	30000
3	1095	0.065	9.9	2.5	0.641	0.095	0.736	30000
4	1780	0.065	9.9	4	0.842	0.095	0.937	30000

Table 5.3 Observation Table for HHO & Biogas fuels engine

Sr no	BP	Specific Fuel consumed.	Brake thermal efficiency.
	(kw)	(kg/kw.hr)	(%)
1	0.584	0.941	12.74
2	0.721	0.916	13.08
3	0.901	0.816	14.69
4	1.168	0.802	14.95

Table 5.4 Result Table for HHO & Biogas fuels engine

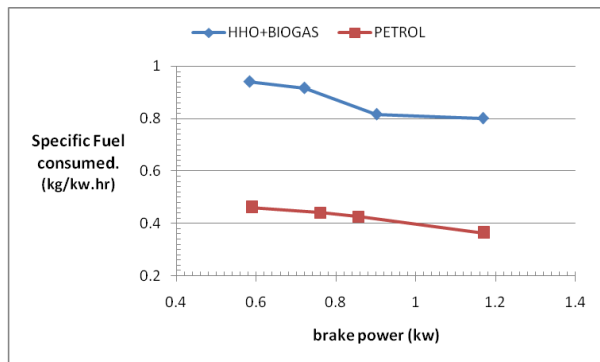## 4.1.1 Effect of Bp on Specific Fuel consumption:

Figure 5.1 Variation in SFC(kg/kw.hr)with BP (kw)

Figure 5.1 shows that at the same brake power the SFC for petrol is less than biogas and HHO due to high calorific value fuel. the specific fuel consumption is higher at low brake power for both fuel, the SFC is continually decrease with increase of brake power for petrol engine but for HHO and BIOGAS engine SFC nearly constant above brake power 0.9.

4.1.2 Effect of BP on Brake Thermal Efficiency

Fig 5.2 shows that brake thermal efficiency of petrol engine is higher compare to HHO and biogas engine at same brake power. Brake thermal efficiency of both fuel engines is increase with increase of brake power, but above brake power 0.9 the brake thermal efficiency not much affected with increase of brake power.
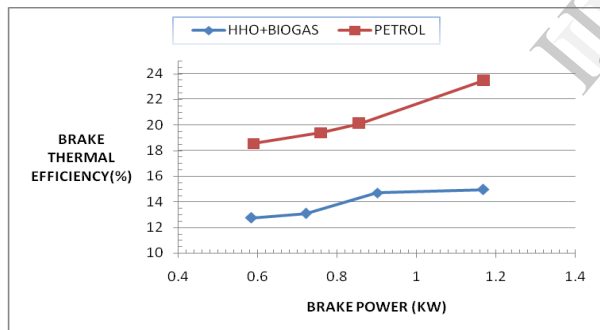

Fig.5.2 Variation in brake thermal efficiency (%) with BP (kw)

4.2 Emission Test

Sr No.	Speed (RPM)	CO %	CO_2 %	O_2 %	HC Ppm
1	674	1.31	2.16	20.89	190
2	949	1.45	2.45	20.89	305
3	1078	1.51	3.05	20.89	396
4	1839	1.79	3.57	20.89	438

Table 5.5 Emission Test Results for petrol fuel engine

Sr No.	Speed N (RPM)	CO %	CO_2 %	O_2 %	HC ppm
1	628	1.16	5.29	20.89	17
2	935	1.23	5.74	20.89	21
3	1010	1.29	6.09	20.89	32
4	1690	1.38	6.75	20.98	38

Table 5.6 Emission Results Test for biogas & HHO fuel engine

4.2.1 Effect of BP on CO

Hydrogen improves the combustion rate and raises the power output. The brake power increase with increase of mass of fuel injection
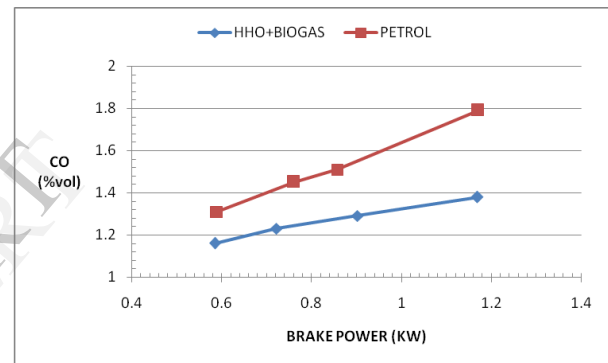

Fig.5.5 Variation in carbon monoxide (%vol) with BP (kw)

so the CO level increases due to incomplete combustion. The CO level falls with an increase in the amount of hydrogen injected with biogas. So CO level for petrol engine is higher compare to biogas engine at same brake power.
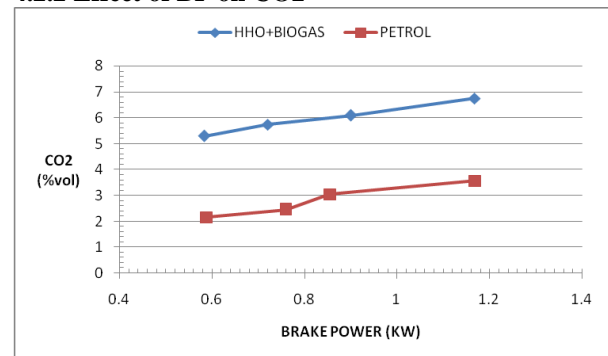
4.2.2 Effect of BP on CO2

Fig.5.6 Variation in carbon dioxide (%vol) with BP (kw)

Biogas containing more than 45% carbon dioxide so CO_2 emission in biogas fuel engine is higher than petrol engine at same load which shown in fig. But the injection of hydrogen in biogas decrease concentration of the CO_2 level in biogas and also avoid misfire.

4.2.3 Effect of BP on HC

The variation of HC emission with brake power is shown in Fig. Hydrogen addition to biogas decreases the HC emission level significantly. At an brake power of 1.15 kw, HC emission
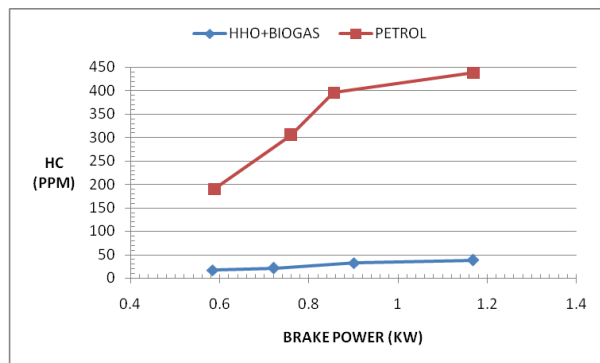

Fig.5.8 Variation in hydrocarbon (ppm) with BP (kw)

level with hydrogen added biogas is 40 ppm as against 450 ppm with petrol operation.

5. Conclusions

Based on this experimental work on the use of hydrogen to enhance the combustion characteristics of biogas the following conclusions are drawn:

- SFC decrease with increase in brake power for both fuels, SFC of biogas and HHO fuel engine is higher than petrol engine due to low calorific value of fuel.
- BTE is increase with increase in brake power for both the cases but the BTE of biogas is somewhat lower compared to petrol engine because the SFC of petrol is lower.
- Emission gases like HC, CO_2 and CO is increase with increase in brake power for both fuel engines. HC and CO emission is higher while CO_2 emission is lower in petrol engine compare to biogas engine at same brake power.
- There is an increase of CO level with brake power due to incomplete combustion of petrol

and decrease of hydrogen concentration in biogas.

- CO_2 level is higher in biogas engine because of higher concentration of carbon percents in raw biogas.
- Hydrocarbon emissions result when fuel molecules in the engine do not burn or burn only partially.

6. References

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