

# Biogas Diesel Dual Fuel Engine

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## ABSTRACT

Gaseous fuels are considered to be good for IC (Internal combustion) engine, because of their good mixing characteristics with air. The high self-ignition temperature enables them to operate with lean mixture and higher compression ratios, resulting in an improvement in thermal efficiency and reduction in emission. Biogas is a good renewable gaseous fuel, and is produced by the anaerobic waste, sewage sludge, animal waste, food waste, agriculture waste, municipal waste, etc. Methane is the main constituent of biogas, and the proportion varies from feed stock to feed stock.

Diesel engines have inherently a capacity of burning low quality fuels with dual fuel mode. A low cetane number fuel can be combusted in CI engine by igniting it with diesel.

In this work a single cylinder, 4-stroke, water cooled, constant speed CI engine is converted to operate on dual-fuel mode. The primary fuel used is biogas whose mixed with air is ignited by injection of small quantity of diesel. Various air-biogas mixing devices are designed and tested for various loads and performance of engine is obtained. Quantity of pilot diesel injection is fixed for all loads with special arrangement. Variation in the load is compensated by changing flow of biogas alone. Performance parameters like thermal efficiency, volumetric efficiency, fuel consumption, brake specific fuel consumption and percentage diesel replacements are calculated. Opacity of exhaust smoke is measured by smoke meter.

It has been observed that emission (opacity) is considerably reduced for all loads. Percentage replacement of diesel also increased with load. Considerable reduction in the operating cost is observed.

However, a drop in thermal efficiency and volumetric efficiency is observed for all loading conditions. This may be due to low calorific value of unpurified biogas and replacement of some volume of air by biogas, respectively.

**Keywords-** C I engine, Biogas, diesel, Dual-Fuel operation, Emissions.

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## I. INTRODUCTION

Biogas is a flammable mixture of different gases that is produced by decomposition of biodegradable organic matters by microorganisms in absence of air (or oxygen). Biogas is produced by anaerobic digestion of biological wastes such as cattle dung, vegetable wastes, sheep and poultry droppings, municipal solid waste, industrial wastewater, landfill, etc. Production of biogas involves a complex physiochemical and biological processes involving

different factors and stages of change. Main products of the anaerobic digestion are biogas and slurry. Biogas is constituted of different component gases the majority of them being methane (CH<sub>4</sub>) and Carbon dioxide (CO<sub>2</sub>) with traces of Sulphur Dioxide (H<sub>2</sub>S) and Hydrogen (H<sub>2</sub>) gas.[1] In this study, biogas was used in a single cylinder, direct injection, compression ignition engine, which has been modified to operate under dual-fuel condition to generate electricity. Gaseous fuels are considered to be good for IC (Internal combustion) engine, because of their good mixing

characteristics with air. The high self-ignition temperature enables them to operate with lean mixture and higher compression ratios, resulting in an improvement in thermal efficiency and reduction in emission. [2]

A dual engine is a diesel engine operating on gaseous fuel generally at low heating value. The modification is simple and involves introducing the gaseous fuel with the air at admission, maintaining a small amount of diesel fuel for ignition as pilot fuel. [3] Since biogas has a high octane number, but in CI engine diesel have high cetane number to burn the fuel when it compress. That wise to burn the biogas small quantity of diesel are supply continuously. [4]

Short-term performance between conventional diesel and dual-fuel operations was studied. Biogas/diesel dual-fuel engine was observed to operate successfully with biogas substitution rate at above 90% by mass. Only drawback is carbon disposal inside engine cylinder because of H<sub>2</sub>S present in biogas. N Tippayawong and Promwungkwa,(2007).[2]

Electricity generation from biogas in small pig farms with H<sub>2</sub>S removal prior to biogas utilization was studied by Suneerat Pipatmanomai, (2008).[3] The 2% potassium iodide (KI) impregnated activated carbon selected as H<sub>2</sub>S adsorbent was introduced to a biogas-to-electricity generation system. Analysis of various metal trace present inside the engine and change in there metallic property is investigated by N.Tippayawong (2010),[4] After completion of the endurance test, the engine was dismantled for physical inspiration and wear assessment of various parts.

Juan-Pablo Gómez-Montoya,(2012).[5] Studied the performance by introducing H<sub>2</sub> in Biogas in dual-fuel engine. The hydrogen concentration was varied from 5 to 20% H<sub>2</sub>. Increases in peak pressure chamber up to 10.7 bar, and diesel substitution levels up to 80% under conditions of steady combustion without knocking. Thermal efficiency increases up to 16% and carbon monoxide emissions decreases up to 13% at full load.

Diesel was used as an injected fuel and biogas was inducted through the intake manifold, at four different flow rate 0.3 kg/h, 0.6 kg/h, 0.9 kg/h, and 1.2 kg/h along with air. The combustion performance and emission characteristic of the engine in the dual fuel operation was experimentally analyzed and compared with diesel operation. It was found that 0.9 kg/h give better performance and low emission, than that of other flow rate. Debabrata Barik\*, S. Murugan (2014), [6]

From this literature we conclude that this is possible to use biogas in CI engine in dual fuel mode for power generation. There is possibility to improve performance of engine in duel fuel mode. In future this will be success fully for power generation with better alternating fuel and less emission.

## II. EXPERIMENTAL SETUP

### A. a. Fuel

Biogas is produced from anaerobic biodegradation of organic material in the absence of oxygen and the presence of anaerobic micro-organism. Plant has been installed at canteen which has capacity of 0.5 m<sup>3</sup> biogas generates per day. Biogas is stored in LPG cylinder at 10 bar pressure.

The property of biogas depends on feed which insert inside the container.

The comparison between Diesel and Biogas is given in table I.

TABLE I  
BASIC CHARACTERISTICS OF FUEL

Properties	Heating value, kJ/kg	Density kg/m <sup>3</sup>	Cetane number
Diesel	43942	855	50
Biogas	17739	1.1	-

Experiments are carried out on single cylinder CI engine fuel use as diesel at constant speed of 1500 RPM of stroke length 110mm, Bore (D) 800mm, for variable load test.



Fig. 1 Experimental setup

Testing is carried out at various loads, starting from no load conditions to full load conditions. Initially with no load on engine, it is started by hand cranking. The governor of engine is set at no load with constant speed of engine that is 1500 rpm. Biogas is mixed with air at the inlet manifold of engine cylinder. Mass flow rate of biogas is measured by gas flow meter which is mounted in between cylinder and air-biogas mixture. Time required for consumption of 10cc of diesel is recorded.

Record all data and repeat the same for 0.5kW, 1 kW, 1.5 kW, 2 kW, 2.5 kW and 3 kW respectively.

Calculation:

1. Brake power:

$$B.P = \frac{\text{Electric load}}{\text{Generator transmission Efficiency}}$$

2. Fuel consumption (diesel):

$$F.C = \frac{\text{Volume flowrate of fuel} * \text{Density}}{\text{time}} * \rho$$

3. Brake Specific Fuel Consumption:

For normal diesel operation

$$B.S.F.C = \frac{\dot{m}_{\text{diesel}}}{B.P}$$

For dual-fuel operation

$$B.S.F.C = \frac{\dot{m}_{\text{diesel}} + \dot{m}_{\text{biogas}}}{B.P}$$

4. Volumetric Efficiency:

$$\eta_{\text{vol}} = \frac{\text{Actual volume flowrate of air at NTP}}{\text{Piston displacement rate}}$$

5. Brake Thermal Efficiency:

For normal diesel operation

$$\eta_{brake\ thermal} = \frac{W}{\dot{m}_{diesel} * CV_{diesel}}$$

For dual-fuel operation

$$\eta_{brake\ thermal} = \frac{W}{\dot{m}_{diesel} CV_{diesel} + \dot{m}_{biogas} CV_{biogas}}$$

6. Percentage of diesel replacement by biogas r:

$$r = \frac{(\dot{m})_{diesel} - (\dot{m})_{dual}}{(\dot{m})_{diesel}} * 100$$

where  $(\dot{m})_{diesel}$ , is diesel consumption rate in normal diesel operation  $(\dot{m})_{dual}$  is diesel consumption rate in dual-fuel operation and  $(\dot{m})_{biogas}$ , is biogas consumption rate in kg/hr, W is the engine power output in kW and H is the fuel heating value in kJ/kg.[7]

III. RESULTS & DISCUSSION

a Parameters including Brake power, Brake specific fuel consumption, Volumetric efficiency, Brake thermal efficiency and Percentage of diesel replacement by biogas are plotted against load.

A. Single fuel operation (Diesel)

TABLE II  
RESULT TABLE FOR FUEL USE AS DIESEL

Parameter	0	0.5	1	1.5	2	2.5	3
Brake Power (kW)	0	0.625	1.25	1.875	2.57	3.125	3.75
Fuel Consumption (kg/hr)	0.32	0.357	0.384	0.452	0.549	0.57	0.64
B.S.F.C. (kg/kW.hr)	0	0.571	0.307	0.241	0.219	0.182	0.170
Volumetric Efficiency(%)	82.1	80.58	82.15	81.42	80.65	80.26	79.87
Brake Thermal Efficiency(%)	0	14.3	26.6	33.9	38.35	44.8	47.9
Emission (opacity%)	1	7.3	19.7	40.2	60.4	78.3	90.8

From above table we observe that, as the load increase the brake power, mass flow rate of diesel, brake thermal efficiency and emission (opacity) goes to increase but brake specific fuel consumption is decreasing.

B. Biogas-Diesel dual fuel operation:

Fuel use as biogas diesel dual-fuel and there is air-biogas mixture device which have throat diameter of 28mm.

Similar reading has taken for all type of venture and performance showing in graph.



Fig. 2 Biogas-Air mixing device



Fig. 3 Modified 28 mm throat diameter with multiple holes

It is basically ventury with holes for injecting Biogas. Experimentation was carried out for variation od different diameter.viz 28 mm, 25 mm and 22 mm. One more venturi with 28 mm diameter with multiple holes for better mixing was also tested.

TABLE III  
RESULT TABLE FOR FUEL USE AS DIESEL

Parameter	0	0.5	1	1.5	2	2.5	3
Brake Power (kW)	0	0.625	1.25	1.875	2.57	3.125	3.75
F.C of diesel (kg/hr)	0.35	0.35	0.35	0.35	0.35	0.35	0.35
F.C of Biogas (kg/hr)	0	1.55	1.73	2.14	2.5	2.7	3.1
B.S.F.C. (kg/kW.hr)	0	3.05	1.66	1.33	1.14	0.97	0.92
Volumetric Efficiency(%)	79.4	80.4	84.6	80.8	78.2	76.74	76.34
Brake Thermal Efficiency(%)	0	4.45	9.71	12.57	14.94	17.69	19.09
Emission (opacity%)	3.7	4.8	7.4	21.2	34.8	54.4	75

From table, we observed that as load increase mass flow rate of diesel is constant but mass flow rate of biogas increase, bake thermal efficiency reduce as compare to diesel, and emission (opacity) reduces as compare to diesel.

C. Similar reading has taken for different ventures shown graphically

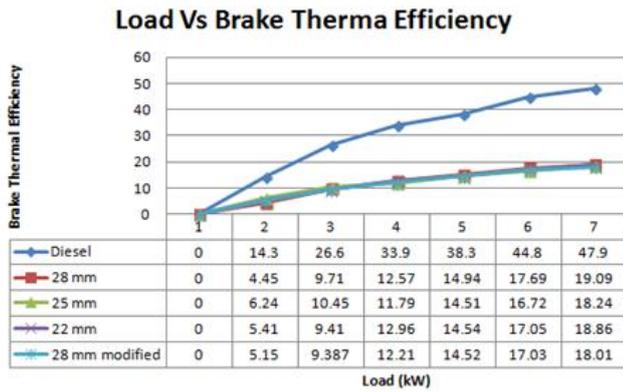


Fig. 4 Load Vs Brake Thermal Efficiency for different Ventures

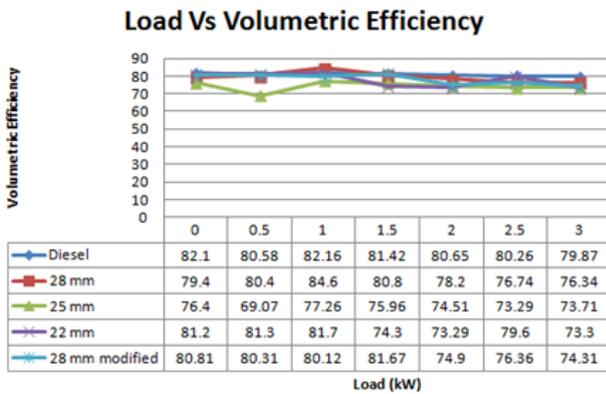


Fig. 5 Load Vs Volumetric Efficiency for different Ventures

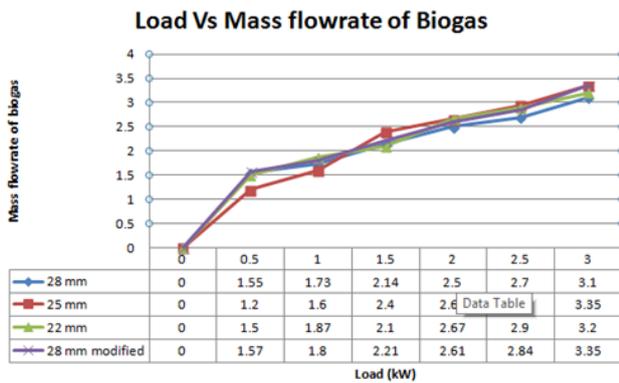


Fig. 6 Load Vs Mass flow rate of Biogas

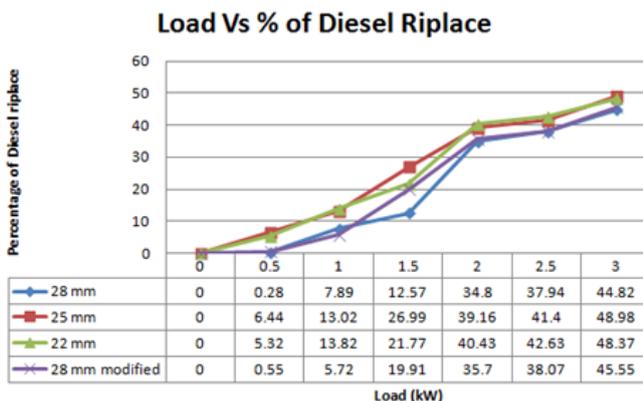


Fig. 7 Load Vs Percentage of Diesel Replace

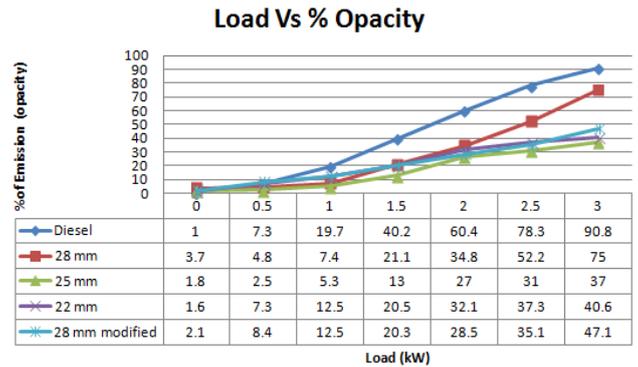


Fig. 8 Load Vs Emission (% opacity)

- From first graph we observe that the thermal efficiency of diesel is double as compare to dual-fuel mode. The reason behind that un-purified biogas has less calorific value, due to water vapor presence and in-proper mixture of air-biogas. 28mm throat diameter of venture gives more thermal efficiency.
- Volumetric efficiency is less in dual-fuel mode because replaces some volume of air by biogas.
- All type of venture has same mass flow rate of biogas for all loads.
- At maximum load 50 percent diesel is replaced by biogas. 25mm of throat diameter of venture gives better percentage of diesel replacement

IV. CONCLUSION

In the present work, an experimental investigation has been carried out to evaluate the effect of biogas diesel dual-fuel operation on single cylinder, constant speed, diesel engine. It has been observed that emission (opacity) is considerably reduced for all loads. Percentage replacement of diesel also increased with load. Considerable reduction in the operating cost is observed.

However, a drop in thermal efficiency and volumetric efficiency is observed for all loading conditions. This may be due to low calorific value of unpurified biogas, presence of water vapor in biogas and replacement of some volume of air by biogas.

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