International Journal of Engineering Science Invention Research & Development; Vol. III, Issue VII, January 2017 www.ijesird.com, e-ISSN: 2349-6185

EXPERIMENTAL STUDY OF COMBUSTION PERFORMANCE AND EMISSION CHARACTERISTICS OF IC DIESEL ENGINE FUELED WITH BIOGAS IN DUAL FUEL MODE FOR RURAL ELECTRIFICATION

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***Abstract*— The electric energy sector is facing problems of fuel scarcity such as coal shortage, average losses of power transmission, distribution rise, insufficient or poor infrastructure and connectivity in distribution lines etc. The renewable energy sources like hydro energy, solar energy, energy of wind and biogas meets domestic energy requirements and has the potential to provide clean environment. All these sources of energy are renewable, but biogas is especially important due to possibility of use in inner combustion engines, and it is the main power source for transport vehicles and also commonly used for powering of generators of electrical energy .Biogas, a renewable fuel, is produced from anaerobic fermentation of organic material. In this paper, an overall valuation of the results have been studied which indicated that the biogas and diesel dual fuel operation could be substituted for diesel fuel in engine possible to work satisfactorily under long term engine operation without any major problems.**

***Keywords:* IC engine, biogas, electrical power, generators, rural electrification.**

I. INTRODUCTION

There is global energy crisis and energy demand is continuously increasing. In order to meet this increasing demand, dependence on fossil fuel have increased in the last few decades and there is increased green house gas emissions with their increased use. In developing countries like India, there is power shortage in rural areas. So there is a need to concentrate on to solve this problem, as an environment aspect as well as conventional fuel shortage. Biogas run dual fuel diesel engines can be a panacea to the problem of acute power shortage particularly in rural areas in India. Biogas is a renewable fuel and is produced from anaerobic digestion of organic material in the absence of oxygen. Its mixture manly consists of 50-70% of methane, 30-40% of carbon dioxide and some other constituents like N_2, H_2, water vapors and traces of H_2S. In this paper, an overall valuation of the results have been studied which reports that the biogas and diesel dual fuel operation can be used to substitute for diesel fuel in IC engine and makes it possible to work adequately under long term engine operation without any major problems. Due to its high self-ignition temperature (650°C), biogas cannot be used to run a compression ignition (CI) engine directly. With minor modifications in the IC engine, biogas in dual fuel mode IC engine may be used for power generation. In dual fuel mode, there are two fuels; one is primary fuel (Biogas), which is gaseous fuel on which the engine runs primarily, and the other fuel is pilot fuel (Diesel), which is used for initiation of ignition.

II. UTILIZATION OF BIOGAS IN IC ENGINE FOR BIOPOWER

Power in India is mainly generated by fossil fuels that are responsible for increased emissions of greenhouse gases. Thus sustainable and potential alternative fuel to electrify rural areas, to meet current and future energy demands, and to mitigate emissions is renewable energy sources. Biogas is particularly important because of its use in internal combustion engines, which is the main source of power for transport vehicles and also commonly used for generators of electrical energy. The properties of biogas have reasonably proven its use for IC engines. ICEs are, in fact, the leading prime-mover technology applied in DG applications under 1000 kW generation capacity [1]. Biogas cannot be used directly in the IC engine. It needs to be purified before entering into the IC engine. After purification process, biogas can be used more efficiently in diesel engine to generate power directly. Purification has many uses, either used for electricity generation and heat, or as vehicle fuels. The presence of large volume of carbon dioxide (CO2) reduces the heating value of the gas, which increases the compression and transportation costs and limits the economic feasibility to uses that occur at the point of production. To use biogas as a fuel, purification is required to remove carbon dioxide (CO_2) and hydrogen sulfide (H_2S) because presence of H_2S corrodes important mechanical components within IC engine sets used or electrical power generation[2].The engine's emissions are also hazardous for the atmosphere and human health. The emissions from biogas contain very fewer amounts of harmful gases than gasoline or diesel, and engines when fueled by purified biogas have no emissions or of very low amount. The problems of refueling with biogas have less environmental and health risks than refueling with gasoline or diesel, because biogas requires a small unit which is located at an consumer's site or industry, minimizing the possible impacts if leaks or spills occur. There are many biogas purification technologies used for large-scale biowaste and sewage digesters, and also well-developed technologies are used for upgrading biogas, compressing, storing and dispensing biomethane.

III. EXPERIMENT SETUP

The experimental set up consists of single cylinder, 4-stroke air-cooled diesel engine that was converted into dual fuel diesel engine by connecting a gas mixer at its inlet manifold. A fuel control mechanism was installed to limit the supply of liquid fuel. By varying the flow of quantity of flow of biogas, the power output of the engine was controlled. In this experiment, the performance and emission tests were carried out on the C.I. engine and compared when operated with neat diesel (D) and biogas (at different flow rates) diesel mixtures (D+B). The tests were conducted by varying electrical load at the constant speed. A biogas flow meter was used to calculate the flow of biogas and measures the direct reading of biogas volume in m^3/hr. The brake thermal efficiency, brake specific fuel consumption, brake power, brake energy consumption were calculated.

Fig. 1 Experimental setup for the test

Key: 1. Engine. 2. Dynamo. 3. Resistive load bank. 4. Electric control panel. 5. Air surge tank. 6. Biogas flow meter. 7. Digital tachometer. 8. Exhaust gas temp thermocouple. 9. AVL exhaust gas analyzer. 10. Probe. 11. Fuel measuring burette. 12. U-tube manometer

Table 1 SPECIFICATION OF ENGINE

Parameters	Specifications
Engine	Fc Dod
Stroke Length	110mm
No Of Strokes	4
Cylinder Diameter	102mm
No Of Cylinder	1
Cooling Media	Air Cooled
Rated Capacity	6kw
Fuel	Diesel

IV. PERFORMANCE ANALYSIS (AT DIFFERENT FLOW RATES OF BIOGAS)

The engine performance parameters and exhaust gas emission characteristics of dual fuel engine in which primary fuel is biogas at different flow rates compared with pilot fuel diesel.

A. BRAKE POWER (BP)

Figure of the brake power (BP) as a function of load obtained during engine operation dual fuel engine in which primary fuel is biogas at different flow rates compared with pilot fuel diesel shown in fig 2

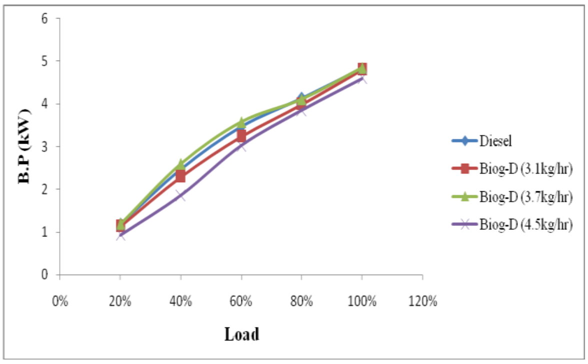

Fig 2 Variations in brake power with change in load

It has been observed that with the increase in load, the brake power of the engine increases which is the function of calorific value and the applied torque. Diesel has more calorific value than the biodiesel and biogas, so diesel has the highest brake power among the different blends of dual fuel. The dual fuel mode with flow rate of 3.7kg/hr having higher brake power than other two flow rates of biogas.

B. GROSS BRAKE SPECIFIC FUEL CONSUMPTION (GROSS BSFC)

Figure of the gross brake specific fuel consumption as a function of load obtained during engine operation dual fuel engine in which primary fuel is biogas at different flow rates compared with pilot fuel diesel shown in fig 3.

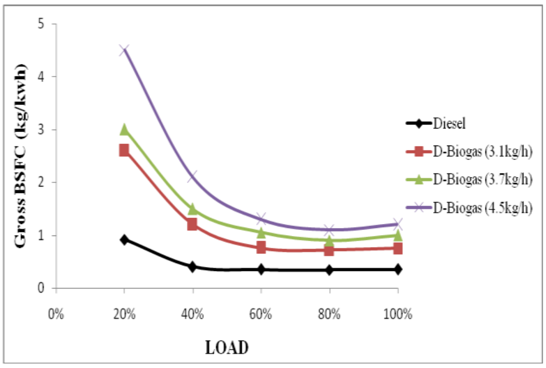

Fig 3 Variations in Gross brake specific fuel consumption with change in loads

For the single fuel mode and dual fuel mode the BSEC decreases with increase in load. Figure 3 shows that the diesel has lower BSEC than the dual fuel mode at the higher loads the dual fuel mode having a similar BSEC to the single mode. Because the calorific value of biogas is less than pure diesel. Among the different flow rates the 4.5kg/hr. flow rate having a BSEC is almost similar to diesel at higher loads.

C. BRAKE THERMAL EFFICIENCY

Figure of the brake thermal efficiency as a function of load obtained during engine operation dual fuel engine in which primary fuel is biogas at different flow rates compared with pilot fuel diesel is shown in fig 4.

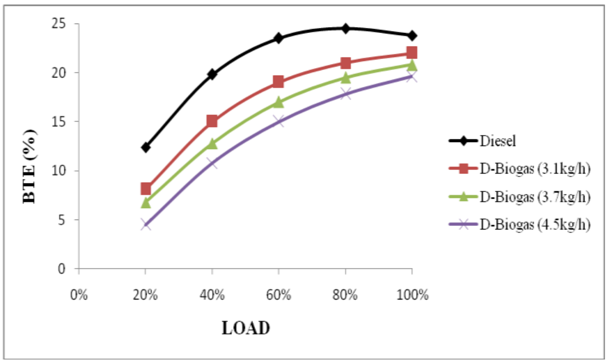

Fig 4 Variations in Brake thermal efficiency with change in load

Brake thermal efficiency changes with change in load. It increases in all the cases with increase in load. This can be attributed to reduction in heat loss and increase in power with increase in load. Biogas has lower calorific value than diesel. So brake thermal efficiency of dual fuel mode is lesser than diesel. For lower flow rate of biogas brake thermal efficiency is more than higher flow rate.

V. EMISSION ANALYSIS

A. CO EMISSIONS

The variation of carbon monoxide with respect to load for different flow rates compared with pilot fuel diesel shown in fig 5.

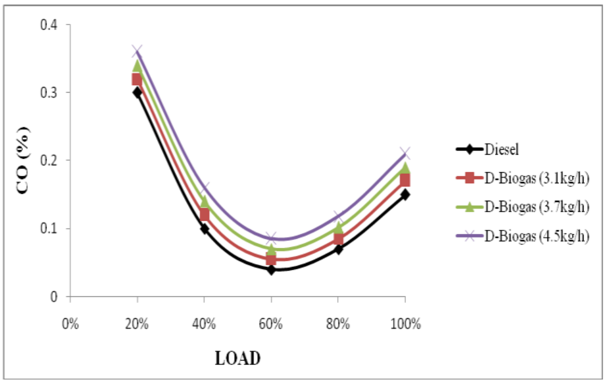

Fig 5 Variations in CO with change in load

The formation of carbon monoxide (CO) in diesel engines takes place during the intermediate combustion stages. Diesel engine operates well on the lean side of the stoichiometric ratio. This is due to incomplete combustion caused by dilution of charge by the CO_2 present in biogas and deficiency of oxygen. Under all tests performed the brake specific CO emission in the dual fuel operation is significantly higher than that of diesel. Until the biogas fuel air mixture reach a minimum limiting value for auto ignition, the flame formed in the ignition region of the pilot fuel is normally suppressed and does not proceed [3,4,5].The another reason for the higher CO emission may be poor mixture formation of gaseous and liquid fuel [6].

B. CO_2 EMISSIONS

The variation of carbon dioxide with respect to load for different flow rates compared with pilot fuel diesel shown in fig 6.

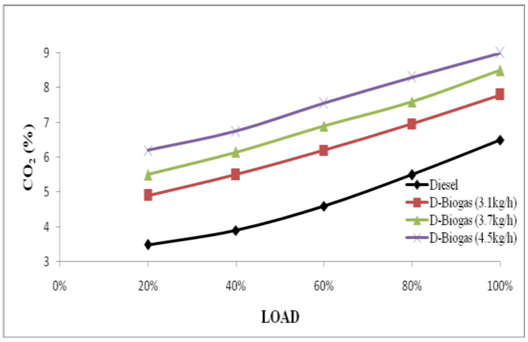

Fig 6 Variations in CO_2 with change in load

Figure 6 show that the CO_2 emissions in case of diesel are less than dual fuel mode on all loads. When flow rate of biogas increases the CO_2 emissions are also increases. This is due to the presence of carbon dioxide content in the biogas. The CO2 emission is an indication of complete combustion of fuel in the combustion chamber with the presence of excess oxygen [7]. The brake specific CO2 emission for all the test fuels shows a decreasing trend from no load to full load. Because, at no load the fuel consumption of the engine is found to be lower, than that of full load and the supply of air in the combustion chamber is sufficient enough to perform complete combustion, which is quite impossible at full load. The dual fuel operation shows a lower CO_2 emission compared to diesel. This is due to the deficiency of oxygen, lower combustion chamber temperature, and less time for combustion, which leads to incomplete combustion, causing less CO_2 emission [8].

C. LAMBDA

The variation of lambda with respect to load at different flow rates compared with pilot fuel diesel shown in fig 7.

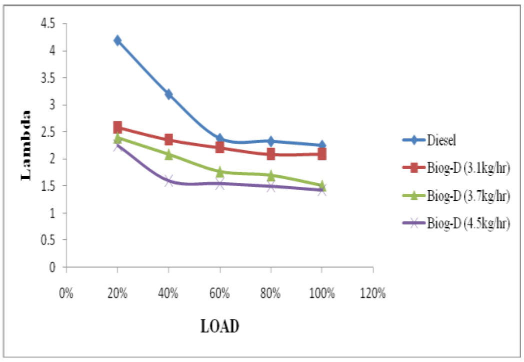

Fig 7 Variations in lambda with change in load

Lambda represents the ratio of the amount of oxygen actually present in a combustion chamber compared to the amount that should have been present in order to obtain "perfect" combustion. Thus, when a mixture contains exactly the amount of oxygen required to burn the amount of fuel present, the ratio will be one to one. The figure 7 shows that the value of lambda for diesel is more than dual mode on different load conditions. When flow rate in dual fuel mode increases the value of lambda decreases with increase in load.

VI. CONCLUSIONS

From this experiment, it has been concluded that biogas is a renewable fuel, which can be used in dual-fuel mode in the diesel engine without any changes to an IC engine for power generation at remote areas. When compared at equal power output situation, the dual fuel engine (Diesel-Biogas) performance is better than neat diesel. In this set up, Diesel engine performance experimentally investigated and the following conclusions may be drawn:

1) The use of biogas in dual fuel mode in diesel engines has not only reduced the consumption of diesel but also protect environment and human health.

2) The CO_2 emission in the dual fuel mode has been reduced when compared to neat diesel.

3) Biogas has lower calorific value than diesel. So brake thermal efficiency of dual fuel mode is lesser than diesel. For lower flow rate of biogas brake thermal efficiency is more than higher flow rate.

4) The dual fuel mode with flow rate of 3.7kg/hr having higher brake power than other two flow rates of biogas.

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