

## BIOGAS AS A FUEL FOR IC ENGINE

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**Abstract**—Biogas derived from organic waste materials is a promising alternative and renewable gaseous fuel for internal combustion (IC) engines and could substitute for conventional fossil fuels. The aims of this study are to review the past researches on biogas fuelled IC engines and from this review, to identify current research needs. A detailed analysis of the previous results of biogas fuelling on the emissions and performance of spark ignition (SI) and dual fuel compression ignition (CI) engines is presented. The literature review reveals that the published research on biogas fuelled IC engines are not rich in number and the scenario of biogas-diesel dual fuel engines is even worse. According to the analysis, biogas fuelling in IC engines causes lower power output compared to natural gas, irrespective of the engine operating conditions. However, the use of biogas allows exhaust nitrogen oxides (NO<sub>x</sub>) emissions to be reduced substantially. Both experimental and computational analyses have been done in the case of SI engines. However, there are needs to investigate the exhaust emissions for the biogas-diesel dual fuel engines both experimentally and computationally. Also the effect of H<sub>2</sub>S on engine emissions and life/durability, which is neglected very often in the literature, needs to be investigated.

**Keywords** –Biogas, IC Engine

### INTRODUCTION

Current energy situation throughout the world and the fact that main resources of energy, such as crude oil, natural gas, coal and nuclear fuel are not renewable give importance to other sources of energy, like hydro energy, solar energy, energy of wind and biogas. Mentioned sources of energy are all renewable, but biogas is particularly significant because of possibility of use in internal combustion engines, which are the main power source for transport vehicles and also commonly used for powering of generators of electrical energy. This possibility of use is justified by biogas' properties, which make it convenient for IC engines. [3]

Biogas typically defines a gas resulting from the anaerobic (i.e. absence of O<sub>2</sub>) decomposition or fermentation of organic material like: Municipal waste or leftovers landfill gas, Sewerage waste, sewage gas, Liquid manure or dung, Energy crops (corn, wheat, grass) etc.

#### 4.1 What is Biogas?

Biogas originates from bacteria in the process of biodegradation of organic material under anaerobic conditions. It consists of a varying proportion of CH<sub>4</sub> (methane) and CO<sub>2</sub> (carbon dioxide) and traces of H<sub>2</sub>S, N, CO, O, etc. The content of CH<sub>4</sub> and CO<sub>2</sub> is a function of the matter digested and the process conditions like temperature, C/N ratio, etc. Methane is the most valuable component under the aspect of using biogas as a fuel; the other components do not contribute to the calorific ("heating") value and are often "washed out" in purification plants in order to obtain a gas with almost 100% CH<sub>4</sub>. For further details of biogas production the use of the respective literature is recommended [3]

#### 4.2 Energy Content of Biogas

The useful part of the energy of biogas is the calorific value of its CH<sub>4</sub> content. The other components have strictly speaking an energy content also but they do not participate in a combustion process. Instead of contributing they rather absorb energy from the combustion of CH<sub>4</sub> as they usually leave a process at a higher temperature (exhaust) than the one they had before the process (mainly ambient temperature).[3]

The following are the thermodynamic parameters of CH<sub>4</sub> at standard conditions<sup>1</sup> (i.e. 273 K, 1013 mbar=0.1013 MPa):

- specific treat  $c_p = 2.165 \text{ kJ/kg K}$ ,
- molar mass  $M = 16.04 \text{ kg/kmol}$ ,
- density  $\rho = 0.72 \text{ kg/m}^3$ ,
- individual gas constant  $R = 0.518 \text{ kJ/kg}\cdot\text{K}$ ,
- lower calorific value

$H_u = 50000 \text{ kJ/kg}$ ,

$H_{u,n} = 36000 \text{ kJ/m}^3$ .

The actual calorific value of the biogas is a function of the CH<sub>4</sub> percentage, the temperature and the absolute pressure, all of which differ from case to case. The calorific value of the biogas is a vital parameter for the performance of an engine, a burner or any other application using biogas as a fuel. The calculation of the calorific value can be done using the standard thermodynamic relations for gases:-Standard gas equation

$p \cdot V = m \cdot \rho \cdot T$  (Equ. 1).

## LITERATURE REVIEW

**E. Porpatham, A. Ramesh, B. Nagalingam (2011) [1]** was examine the Effect of compression ratio on the performance and combustion of a biogas fuelled spark ignition engine. The engine was operated at 1500 rpm at throttle opening of 25% and 100% at various equivalence ratios. The tests were covered a range of equivalence ratios from rich to the lean operating limit and a number of compression ratios. The spark timing was set to MBT (Minimum advance for Best Torque). The performance, emission and combustion characteristics with different compression ratios are compared. The peak power output with a compression ratio of 15:1 is 4.8 kW and it is 10% higher than that with a compression ratio of 9.3:1 is 4.4 kW with an increase in compression ratio from 9.3:1 to 15:1, the peak brake thermal efficiency increases from 23% to 26.8%.

**Shyam S. Kapdi, Virendra K. Vijay, Shivanahalli K. Rajesh and Rajendra Prasad (2006) [2]** was work on the topic of Upgrading biogas for utilization as a vehicle fuel. In this research paper, a model bottling plant has been conceptualized for a 120 m<sup>3</sup>/day capacity biogas plant as a village enterprise. The model bottling plant will give savings of 15768 liters of petrol worth cost about 0.66 million Rs. per annum. It should be replicated at mass scale to reduce import of petroleum products, save environment and generate employment in the villages. The spirit behind the whole concept is to develop self sustained rural enterprises and decentralized fuel station based on compressed upgraded biogas to make rural areas economically developed and competitive in all respects.

**Venkata Ramesh Mamilla, V.Gopinath, C.V.Subba Rao, Dr.G.Lakshmi Narayana Rao (2011) [3]** has work on the performance and emission characteristics of 4 stroke petrol engine fuelled with biogas / L.P.G. blends. From this experiment it was clear that at 50% blending of biogas the engine performance is found to be very appreciable. At this 50% blending trial particularly at full load the specific fuel consumption and brake thermal efficiency are high when compare to the petrol, LPG and the mechanical efficiency is high for the 50% blending with compared to the Petrol, L.P.G, and 40% Blending. And, also the emission values of CO, HC and NO<sub>x</sub> are minimum for the biogas when compared to the petrol, L.P.G.

**Debabrata Barik, S. Murugan (2012) [4]** was work on the area of Production and Application of Biogas as a Gaseous Fuel for Internal Combustion Engines. They conclude that Biogas is a renewable fuel, derived from the anaerobic digestion of organic wastes or biomass crops, and as such it can contribute to reducing carbon emissions from transport and tackling climate change. As a renewable fuel biogas helps to reduce dependence on conventional fossil fuels.

**K.A. Subramanian, Vinaya C. Mathad , V.K. Vijay , P.M.V. Subbarao(2013)[5]** was work on the topic of Comparative evaluation of emission and fuel economy of an automotive spark ignition vehicle fuelled with methane enriched biogas and CNG using chassis dynamometer. The emissions such as CO, HC and NO<sub>x</sub> are marginally higher with the enriched biogas than base CNG. But, the experimental results indicate that the vehicle's emission with the enriched biogas fuel meets to the BS IV Emission Norms. There is no significant change in fuel economy of the vehicle fuelled with the enriched biogas (24.11 km/kg) as compared to base CNG (24.38 km/kg). The experimental data indicates transient emission characteristics (CO, HC and NO<sub>x</sub>) of the vehicle with respect to time for both fuels are very higher with urban cycle (low speed) than extra urban cycle. (High speed) As the methane enriched biogas gives similar performance like fossil CNG, the enriched biogas could be used as an auto fuel for spark ignition vehicles.

## 2. The process of obtaining biogas and its properties

One of the second-generation fuels is biogas, which can be obtained from different raw materials using different technologies and also, in many cases, appears spontaneously as a result of on-going chemical processes, e.g. landfill gas. Because biogas can be obtained using different production technologies, its composition is not constant. The basic and most desired biogas component is methane, which is the simplest CH<sub>4</sub> hydrocarbon. The percentage of methane in biogas depends on the technology for obtaining biogas and ranges from 35% to around 75%. Another combustible compound, which can contain biogas, is hydrogen, although its percentage share is much smaller and typically amounts to 1-5%. The other biogas components are non-combustible compounds and constitute the ballast. The basic non-combustible biogas components are carbon dioxide and nitrogen. Besides the above mentioned compounds, biogas contains trace quantities of other chemical compounds whose percentage share is low. Tab. 1 presents the approximate biogas compositions, including the method of its obtaining, yet it should be noted that the biogas compositions given in some literature diverge significantly from that provided in Tab. 1.[3]

*Tab. 1. Composition of biogas, depending on its origin [2]*

Component	Agricultural biogas	Treatment Biogas	landfill Biogas
methane	45-75 %	57-62%	37-67%
Carbon dioxide	25-55 %	33-38	24-40%
oxygen	0.01-2.0-2.10%	0-0,5%	1-5 %
nitrogen	0.01-5 %	3.4-8.1%	10-25%
Hydrogen sulphide	10-30000 ppm	24-8 000 ppm	15-427ppm

As mentioned above, biogas forms in a biological process, from different sorts of substrates, the most important sources used for its production include:

- waste from agricultural production, including animal excrement,
- biomass grown for energy purposes (e.g. grasses, maize, sugar beet),
- municipal and organic waste (e.g. sewage treatment plants and rubbish dumps),
- waste from the agricultural and food industries (plant and animal waste).

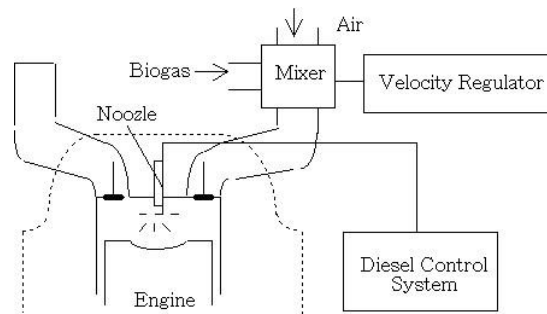
The process of natural gas formation is multi-stage. First, complex chemical compounds such as fats, proteins and carbohydrates decompose hydrolytically.

### Biogas Applications

1. for cooking and heating.
2. as an illuminant for domestic and street lighting.
3. for running tube well and water pump.
4. With minor modifications, conventional internal combustion engines, diesel and petrol engine both run on biogas.

**The principle and engineering application of biogas-diesel dual-fuel engine**

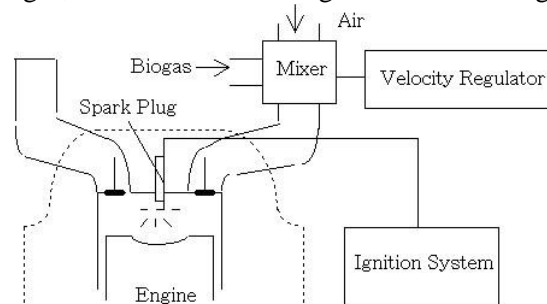
Biogas-diesel dual-fuel engine is on the basis of diesel engine, and refitted the intake hybrid system and dual-fuel accommodation system; its working principle is to mix biogas and air in mixer to form combustible mixed gas. After the combustible mixed gas inhaled in the cylinder, and piston compressing and approaching to the topdead point, there is a little diesel spouted to the chamber; and then after the diesel burning, the mixed gas is immediately ignited to work. Under the normal situation, the quantity of leading diesel in dual-fuel engine is in 8% ~20%.



**Figure 1 Schematic Diagram of Biogas-Diesel Engine [2]**

The character of dual-fuel engine is that if the gas is insufficient or even there is no gas, we can increase the quantity of the diesel, or even we can use diesel only to ensure engine to work normally. Therefore, the engine can be used neatly, and with the situation where produces little gas. The biggest advantage in this method is that it can utilize a small quantity of leading diesel to ignite biogas after compression-ignition. Because even if there is only about 5% of diesel, its burning energy will be much higher than the spark ignition energy, and then it is possible to make that the ignition-lag period and even all the burning period be shorter; sequentially, the severe post combustion, and high exhaust temperature, and severe heat charge in biogas engine will be solved.[2]

**The research and develop of all-biogas engine** Adopting biogas-diesel dual-fuel engine is indeed an efficiency way to solve the problem the combustion velocity is too slow. However, in place where rich in biogas, all-biogas engine should be used more and more from the economic point of view, and meantime, dual-fuel engine also has some ineluctable problems: it must have both the two equipments of feeding diesel and feeding gas. Therefore, on the basis of dual-fuel engine, we also developed spark-ignition biogas engine generators. This kind of engine can work continuously and stably in place of a great plenty of biogas, so it is fit for working at medium or large biogas projects.



**Figure 2 Schematic Diagram of S.I. Biogas Engine [2]**

That biogas engine is refitted from 6160 diesel engine. Its structure is shown in fig.2. Its essential working principle is: biogas and air mix together to form combustible mixed gas; after gas entering into cylinder, when piston presses up to the top dead center, the gas is ignited by spark to burn to work. All-biogas engine always have some problems: the combustion velocity is slow; post

combustion is severe; the exhaust temperature is high; and the heat charge is heavy and so on. In order to increase the combustion velocity of the mixed gas, we can improve the compression ratio and intensify the airflow disturbance of the mixed gas, and increase the ignition energy and so on.[2]

## CONCLUSION

The discussion on biogas lead to this that there is a possibility of supplying these engines with biogas. A complex installation supplying gas fuel is not required to supply these engines. However, if high gas fuel doses are used, a substantial engine power decrease is to be expected. Consequently, it seems appropriate to use relatively low biogas doses (ca. 40-60%, depending on the load) which will obtain relatively high engine power and reduce the operating costs for vehicles and machines.

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