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Research Article

Study of Biogas Compact Digester for Bio-diesel dual fuel Engine- A Review

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Abstract

A serious problem of solid waste disposal has created all over the world due to rapid urbanization. One way of solving the problem is to make use of this waste for production of biogas. The biogas so produced could be suitably utilized in the surrounding areas and the digested slurry as organic manure. The paper focuses with an aim of production of biogas with an efficient compact floating dome design and to use this biogas for dual-fuel engine. My concern is also to invent new method to purify the natural biogas and that is design of new model of scrubber. For effective mixing of bio gas and air would design the air mixture kit. This paper shows different methods for the improvement in emission of engine running on bio-gas. This study will definitely use for emission control. Biogas generation from an anaerobic digestion of agricultural waste, food waste, municipal solid waste, cow dung etc. Making biogas from organic waste as alternate fuel in diesel engines and duel fueling is recommended to be the best one for biogas CI operation.

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

1. Introduction

This document is a template. An electronic copy can be dCurrent energy situation and the fact that main resources of energy, such as crude oil, natural gas, coal and nuclear fuel are not renewable throughout the world. This gives importance to other sources of energy, like hydro energy, solar energy, energy of wind and biogas. These sources of energy are all renewable, but biogas is particularly significant because of possibility of use in internal combustion engines, which are commonly used for powering of generators of electrical energy and also for transport vehicles (N.H.S.Ray *et al* 2013). Anaerobic digestion is a low cost method to convert the organic substances into useful energy such as biogas, which is generated from the anaerobic decomposition of a wide range of wet organic materials such as food waste, agriculture waste, municipal solid waste and cow dung (DebabrataBarik *et al* 2013). Production of methane rich biogas provides a versatile future of renewable energy.

2. Mechanism of Anaerobic Digestion

Anaerobic digestion is a biochemical degradation process, in which biodegradable organic matters are decomposed by bacteria forming gaseous byproduct. The byproduct is consisting of methane (CH_4), carbon dioxide (CO_2), and traces of other gases. Anaerobic digestion is a complex process, which can be divided into four stages: hydrolysis, acidogenesis, acetogenesis or dehydrogenation and methanation. In the first stage the hydrolyzing microorganisms converts the polymers and monomers into acetate, hydrogen and some amount of volatile fatty acid (VFA) such as butyrate and propionate. The metabolism of acetogenic bacteria is inhibitedrapidly by the hydrogen accumulation (Debabrata Barik *et al* 2013). Therefore, it is essential to maintain an extremely low partial pressure of hydrogen inside the digester for the survival of acetogenic and hydrogen producing bacteria. The daily biogas production can also be increased by adding hydrogen producing bacteria to the digester slurry (Peter Weiland 2010).

3. Biogas Production

Several mechanical, thermal, chemical and biological pre-treatment methods have been considered to improve the performance of digester by easy accessible of intermolecular matters to anaerobic micro bacteria. The stability of the process and the rate of gas production depend upon the temperature, pH balance, carbon/nitrogen (C/N) ratio, hydraulic retention time (HRT) and organic feed rates (Demirbas. A 2008).CH_4 and CO_2 are the principal gases that are produced during the process of digestion. Small amount of hydrogen sulphide (H_2S) is also produced, which can

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be characterized by the order of the digester gas. For the optimum growth of the microbes during anaerobic digestion, the suitable pH level of 5.5 to 8.5 has to be maintained by feeding the digester at an optimum loading rate (Alfons Buekens, 2005). During anaerobic digestion microorganism utilize carbon 25-30 times faster than nitrogen. High C/N ratio indicates low biogas production. Similarly low C/N ratio indicates accumulation of ammonia that increases the pH level of the digested slurry more than 8.5. Thus, to meet this requirement, microbes need 20-30:1 ratio of C to N (Santosh .Y*et al* 2004). HRT is the average time spent by the input feed stock inside the digester before it comes out. Generally the HRT depends upon the tropical climate condition. Shorter HRT is likely to face risk of less active bacterial action while longer HRT requires larger volume of digester and hence requires high capital investment. For mesophilic digestion where temperature varies from 25-40ºC the HRT is greater than 20 days. Table 3.1 shows different constituents of biogas (Debabrata Barik *et al* 2013).

Table: 3.1 Different constituents of biogas

Constituent	By volume	By mass
CH_4	73%	52.34%
CO_2	19%	37.38%
N_2	6.5%	8.14%
O_2	1.5%	2.15%
H_2S	20ppm	

4. Biogas Properties

The properties of biogas as engine fuel closely depend on the content of individual compounds. Methane, the main combustible component, has the greatest effect on biogas properties. The basic parameter characterizing fuels is the calorific value, which amounts for methane to around 35.8 MJ/m^3 (50 MJ/kg). Therefore, depending on the methane content, the calorific value of uncleaned biogas ranges from 15 to 27 MJ/m^3. Another important parameter for biogas as engine fuel is the methane number, which is the equivalent of the octane number for the liquid fuels. This number similar to the calorific value for biogas depends on the chemical composition of biogas- for methane this number is 100 and for hydrogen it is 0. However, because of the substantial content of non-combustible compounds in biogas such as nitrogen and carbon dioxide, which increase the methane number, this number typically amounts to around 130 for biogas (Slawomir Wierzbicki, 2012).

5. Biogas Storage

There are two basic reasons for storing biogas, one is for later onsite usage and the other one is before and after transportation to offsite distribution points, based on this they can be stored at low, medium, and high pressure.

5.1 Low Pressure Storage

Floating drum gas holders on the digesters form low pressure storage option. These storage systems typically operate at pressure up to 0.137 bar and maximum temperature of 50 ºC. These floating gas holders can be made of steel, flexible fabric, fiberglass poly vinyl chloride (PVC). The thickness of these materials varies from 0.5-2.5 millimeter.

5.2 Medium Pressure Storage

Biogas can also be stored at medium pressure between 0.137-13.78 bar. This can be done only by compressing with a two stage compressor having an intercooler. Biogas can be stored in typical propane gas tanks at 17.23 bar pressure. As biogas is of 60% methane and heating rate of 14348 kJ/kWh, the energy needed for compression is about 10% of the energy content of the stored biogas.

5.3 High Pressure Storage

Biogas can be stored as compressed bio methane after purification. At high pressure storage gas scrubbing is important because impurities like H_2S and water vapour are likely to condense and cause corrosion. The cost of compressing biogas to high pressure between 137.89 bar and 344.73 bar is much greater than the cost of compressing gas for medium pressure storage. Because of this high cost biogas is upgraded to bio methane. (Kapdi.S.S 2005)

6. Attempting Design of Arti Biogas Plant

I have selected compact biogas plant which is prepared by ARTI (Appropriate Rural Technology Institute, Pune), because of its small size, material of construction and can be used in cities etc. Dr. Anand Karve (President of ARTI) developed a compact biogas system that uses starchy or sugary feedstock (waste grain flour, spoilt grain, overripe or misshapen fruit, nonedible seeds, fruits and rhizomes, green leaves, kitchen waste, leftover food, etc.). Just 2 kg of such feedstock produces about 500 g of methane, and the reaction is completed with 24 hours.

The conventional biogas systems, using cattle dung, sewerage, etc. use about 40 kg 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 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.

7. Scrubber

Introduction

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 lead to corrosion of engine component. So it become essential to separate unwanted constitute of natural biogas to improve the quality of biogas.

Construction of scrubber

Take plastic bucket of 20 liter capacity, which is air tight or proper sealing. With the help of drill form two hole, one is at bottom for inlet of natural biogas and another is for exit of purify gas to the suction of engine. Inside of the bucket there is structure, one vertical hollow square pipe of material mild steel. Grooves are form at three positions in vertical pipe as shown in fig. Small hole of 3 mm dia. are drill on the each circular plate, which act as passage for biogas to pass. Each plate is covered with tissue paper to avoid the mixing of different chemical kept on each Plate. Three circular shape of different diameter as per the dimension specified. Each circular plate 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, circular plate as shown in fig.7.1. This circular plate are removable, which make convenient to change the chemical .

Working of scrubber

Fix all three circular plate into the groove formed on the square hollow pipe at their specific position according to the diameter of circular plate. Each circular plate is covered with tissue paper, which has small pore in macron which avoid the mixing of different chemical kept on different plate but do not block the path of gas flow.

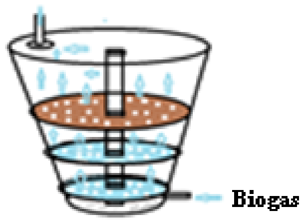

Fig. 7.1 Working of Scrubber

Keep Calcium hydroxide on the two circular plate fixed at bottom which absorb the moisture and carbon dioxide present in natural biogas. Calcium carbonate and Carbonic acid is form as product. On the top plate keep ferrous powder which reduces the concentration of Hydrogen sulphide to the safe level. Ferrous which react with Hydrogen sulphide and form ferrous sulphate. This reaction requires more than 45^{0}C temp. Natural Biogas is passed into the scrubber through the inlet at bottom of scrubber. As the gas pass through first two plate which feed with Calcium hydroxide. Biogas reacts with this chemical which absorbs the moisture and carbon dioxide present in the biogas to get dry and more concentrated methane biogas. This filter biogas is then passed to the next plate which feed with ferrous powder. This ferrous powder reacts with hydrogen sulphate present in the biogas which reduces the concentration of sulphur up to safe level.

8. Air and Gas Mixing Kit

Introduction

Mixing Devices for Dual Fuel 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. Enable automatic control of operation in partial load by means of a governor or electronically controlled mechanisms if required. During the suction stroke of engine there is pressure drop in inlet manifold and subsequently in air gas mixture cylinder. Which force the flow of air and gas mixture into the mixing kit. Cylinders enlarge section give provision for extra space for proper mixing of air and gas in large amount so it is reserve of mixture of air and gas. The mixture of air and gas vary according to the load on the engine which can be made possible by providing flow control valve at inlet of the gas to the air gas mixture kit.

Working of air gas mixing kit

The function of air and gas mixing kit is to prepare proper air and fuel (biogas) ratio another function is to act as reserve of air and fuel. Air from atmosphere comes through air filter so any contamination like dust particle get filter which prevent engine. This filter air is pass to the air and gas mixture kite through the passage pipe and biogas from the scrubber is carry to kite by another small opening .This design have ratio of dia. of opening is 8:1. The air entrance passage is eight time large then passage for biogas. The passage of biogas has set a value which controls the mass flow rate of biogas. After the air and biogas is rushed into the kite the enlarge area of air and gas mixture kit

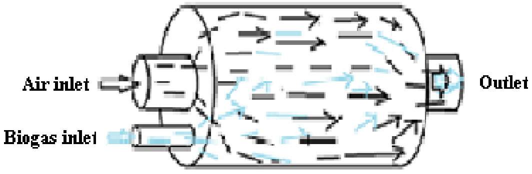

Fig. 8.1 Air Gas Mixing Kit

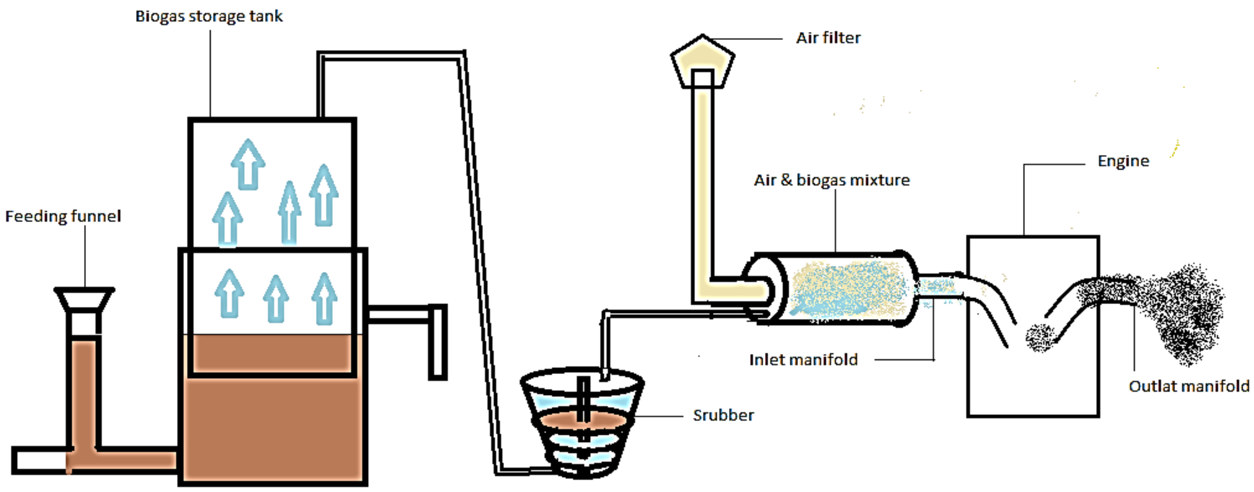

Fig.9.1 Practical Set up

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 kite is couple to the inlet manifold of engine. During suction stroke pr.is drop in cylinder which create pressure drop in inlet manifold and subsequently in the air gas mixture kite This negative pressure sucks the air forcefully into the air gas mixing kite and also the biogas. As air is suck in the air gas mixing it flow in turbulence as it enter into the enlarge section vertex are form at its entrance edge which results into reduction in pressure.

9. Practical Set Up

Block diagram is shown in following fig.9.1 Floating dome biogas plant is used for biogas production. After a week from feeding cow dung and wheat powder biogas start producing. This biogas is then pass through scrubber for purification as explain in previous topic. This pure biogas is then mixed with air in proper mixture in the air gas mixing kit. And then this mixture is passed to the intake manifold of diesel engine.

Conclusion

From this analysis it is clear that making biogas from organic waste as alternate fuel in diesel engines and duel fueling is recommended to be the best one for biogas CI operation. Biogas could be better substitution for fossil while considering the environment impact as it is clear from different literature review that on increasing the load NOx emission is decreasing significantly as compare to the diesel and also with biodiesel. With the development of new technologies for mixing, process monitoring and process control further improvement of biogas plant can be done. The study conclude that using scrubber for purification of biogas and mixing kit for proper mixing of biogas and air would increase the efficiency of the diesel engine.

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