BIOGAS PRODUCTION AND ENGINE CONVERSION FROM DIESEL ENGINE TO BIOGAS ENGINE FOR LIGHTING IN RURAL AREA

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ABSTRACT

The research of alternative fuels implemented in internal combustion engines are becoming the subjects of interest nowadays. This paper describes a production of biogas from cow dung, diesel engine conversion process with piston modification of ZH1115 diesel engine. To produce biogas, the usual practice is to mix water with some organic material, such as cow dung (a free source of the appropriate micro-organisms). The slurry is placed in a leak-proof container (called a digester) and leaves it to ferment. After several days at suitable temperature, sufficient methane will have formed to make a combustible gas. Fix dome type of biogas plant is chosen in this gas production for cost saving and to produce sufficient gas at lower temperature. The biogas engine which are modified from diesel engine emphases the ignition system, gas governing and carburetion systems along with a change in compression ratio, in some cases also a change in the combustion chamber.

Since diesel engine cannot be operated by biogas alone, this paper covers the conversion of diesel to spark ignition engine i.e. conversion of four stroke of ZH1115 diesel engine to biogas engine based on 30 biogas inlet holes which was recommended by the experienced designers. This paper also describes methods of reducing compression ratio, changing ignition system with timing and fueling system, the comparisons of technical parameters and performance between ZH1115 diesel engine and converted biogas engine. It describes the criteria of technological selections, engineering aspects and short term and long term plans for lighting. The goal to develop and implement BIOGAS engine and use biogas as the renewable energy and bio-fertilizer is to control pollution, to protect environment, to develop rural area and also to reach the ambitious emissions goals and to reduce dependence on imported foreign oil.

Key words: Internal combustion engines, Digester, Fix dome type of biogas plant, Biogas engine, Diesel engine

ABSTRAK

Penelitian tentang implementasi energi alternatif untuk digunakan dalam mesin pembakaran internal semakin menarik perhatian. Makalah ini menguraikan produksi *biogas* dari kotoran sapi, proses konversinya dalam mesin *biogas* dan piston hasil modifikasi suatu mesin diesel ZH1115. Untuk menghasilkan *biogas* umumnya dilakukan pencampuran air dengan bahan organik, misalnya kotoran sapi (sumber mikro organisme yang tersedia bebas) dan meletakkan campuran ini dalam tanki *digester* dan membiarkannya berfermentasi pada suhu tertentu. Setelah beberapa hari, gas methan yang mudah terbakar akan terbentuk. Sistem *biogas* dengan kubah-tetap digunakan dalam produksi biogas karena dapat menghemat biaya dan menghasilkan gas pada suhu rendah. Mesin *biogas* yang dimodifikasi dari mesin diesel memerlukan perubahan sistem penyalaan, pengaturan gas dan sistem karburator guna menyesuaikan adanya perubahan rasio kompresi, dalam beberapa kasus juga karena adanya perubahan ukuran ruang bakar.

Karena mesin tidak bisa dioperasikan dengan *biogas* saja, maka makalah ini juga menguraikan perubahan mesin diesel menjadi mesin nyala percik seperti pada konversi mesin 4 tak. Mesin diesel ZH1115 yang diubah menjadi mesin biogas memiliki 30 lubang untuk masuknya *biogas* sesuai yang disarankan para disainer berpengalaman. Makalah ini juga menguraikan metoda menurunkan rasio kompresi, perubahan sistem penyalaan sesuai waktu dan sistem pengisian bahan bakar, perbandingan mesin *biogas* dan mesin diesel ZH1115, yang mencakup kriteria pemilihan teknologi, aspek teknik dan rencana penerangan jangka pendek dan jangka panjang. Sasaran pengembangan mesin *biogas* yang memanfaatkan *biogas* sebagai energi terbarukan dan menghasilkan pupuk kandang adalah untuk mengontrol polusi, lingkungan, pengembangan pedesaan dan untuk meraih target penurunan emisi yang ambisius serta menurunkan ketergantungan pada impor minyak.

Kata kunci: Mesin pembakaran dalam, *Digester*, Sistem *biogas* dengan kubah-tetap, Mesin *biogas*, Mesin diesel

1. INTRODUCTION

In a developing country, energy is an essential factor of production. It grows by a factor greater than of gross domestic product. The main source of energy for the rural people, who constitute the majority of the population of the country, is biogas fuel like fire-wood, agricultural residues and cattle dung.

The technologies used for the conversion of organic materials to biogas have been in existence for many years in both the developed and developing countries, the gas being used either for direct combustion in cooking or lighting, or indirectly to fuel combustion engines delivering electrical of motive power. A biogas mainly consists of methane and carbon dioxide liberated from degraded organic wastes fermented by methanogenic bacteria in anaerobic condition. This process can be used to the great benefit of the rural community for a number of reasons. First, it produces a smoke-free fuel. Secondly, it produces an excellent fertilizer. Thirdly, it destroys most of the disease-carrying pathogens and pathogens and parasites. Fourthly, the biogas technology is appropriate to rural conditions as comparatively sophisticated devices and highly qualified expertise are not involved.

The biogas burns with an almost odorless blue flame with a heat of combustion equivalent to 21.5 MJ/m^3.The relative density of biogas compared to air is about 0.8. The auto-ignition temperature is similar to that for pure methane and has been found to vary from 923 K to 1023 K (650-750 deg C). The main interest in the biogas technology is due to the potential of producing energy at low cost and which is readily available source of energy. Therefore the importance of biogas is an efficient, non-polluting fuel energy source is now well recognized.

Many countries became aware of biogas technology by the middle of the twentieth century. International organizations like the food and Agriculture Organization of the United Nation (FAO), the United Nations Industrial Development Organization (UNIDO), etc have done considered work in disseminating and developing biogas technology. Three countries have installed a large number of units. In numerical order these are: China (7.8 million digesters), India (100,000), and South Korea (29,000). The remaining countries, except

Brazil (2900) have less than 1000 and usually the numbers are below 200. Most of the developing countries utilize two basic designs: the fixed dome (Chinese) and the floating cover (India) concept. These designs have not been without problem, these being briefly that the Chinese design leaks and the Indian design are too expensive, but work is going to improve both of them. From the Chinese and Indian experience, it would appear that strong government support for biogas is a prime necessity for a successful biogas dissemination programmer and one of the reasons why such system are not widespread in order parts of the world is due to the low level of importance most governments attach to the potential of biogas.

In Myanmar, biogas activities were initiated in the late 1970 with the Agriculture Corporation and Agriculture Mechanization Department of the Ministry of Agriculture and Forest playing a leading role in the introduction of biogas technology. Due to realizing the multiple benefits of biogas technology and the importance and need for promoting its wide use throughout the country in 1983 the Government created the Biogas Production and Utilization Centre (BPUC) under the Ministry of Agriculture and Forests. The production of biogas has been developed at Myanmar Scientific and Technology Research Department (MSTRD), Yangon Technological University (YTU) and several other departments since 1980.

A number of developing Countries and International Organization have been showing interest in biogas technology from various points, such as the renewable source of energy, bio-fertilizer, pollution control and environmental protection, recycling of wastes, rural development and hygiene and appropriate technology and technical co-operating among developing countries.

2. AIM AND OBJECTIVE

The aim of the present research work is to reveal the performance characteristics of converted biogas engines used in Myanmar.

The other objectives are:

1) To observe optimum running condition from performance curve of biogas engine
2) To make the performance and economic comparisons of biogas engine with original diesel engine
3) To improve the performance of biogas engine
4) To recommend the use of biogas engines instead of diesel engines for electricity generation in rural areas.
5) To reduce (smoke) emission from engine
6) To protect environmental pollution

3. BIOGAS

To produce biogas, the usual practice is to mix together water with some organic material, such as some cow dung (a free source of the appropriate micro-organisms), place the resulting slurry in a leak-proof container (called a digester) and leaves it to ferment. After several days at suitable temperatures, sufficient methane will have formed to make a combustible gas (Anon, 1984).

4. PROPERTIES OF BIOGAS

Biogas is a mixture of gases. The principle ones affecting gas plants are Methane (CH_4) usually 60-70 percent. Carbon dioxide (CO_2) usually 30-40 percent. Nitrogen (N_2) 1 percent. Hydrogen sulphide (H_2S), Hydrogen (H_2), Carbon monoxide (CO) usually less than 1 percent. The percentage of methane is affected by the biological process and the type of dung or vegetable matter used in the gas plant .Hydrogen sulphide (sometimes called "rotten egg gas" because of its unpleasant smell) has both advantages and disadvantages. Its smell warns people if there is a leak. It forms an acid when mixed with water and this is mildly corrosive. Biogas is a wet gas because it picks up water vapour from the slurry. This vapour condenses in the pipes and has to be removed. The amount of air required for complete combustion depends on the percentage of methane in biogas. For 60 percent CH_4 per $1m^3$ biogas, use $8m^3$ airs. Usually burners use a ratio of 1:9 or 1:10.

5. TYPES OF BIOGAS PLANT

There are three types of biogas plants:

1) Fixed Dome types
2) Floating Drum
3) Flexible Bag

A long retention time is used, which helps to kill harmful pathogens and parasites. In this type of plant the emphasis is more on fertilizer and removal of pathogens and parasites. A fixed dome plant consists of an underground pit lined with brick of concrete with a dome-shaped cover, also made from brick or concrete. This cover is fixed and held in place by earth (about 1 m^3) piled over the top to resist the pressure of the gas inside. A second pit, the slurry reservoir, is built above and to the side of the digester. The digester and the gasholder are both built below ground levels. As gas is used the slurry flows back into the digester to replace it. The reservoir is made from brick or stone masonry. The gas is taken out from the center of the dome, via a pipe, which is supported by a small masonry turret. Access to the digester pit during building, and also if the pit needs cleaning, is through the slurry reservoir and outlet. Gas pressure increases with the volume of gas stored; therefore the volume of the digester should not exceed 20 m^3. If there is little gas in the holder, the gas pressure is low (Ludwig Sasse,1988)

Floating gas holder digests without water seal design. It is run on a continuous basis. This plant consists of a digester and a moving gasholder. The digester consists of a cylinder wall, most commonly made from bricks. The wall has a partition wall in the middle, dividing it into two semicircular compartments. From the inlet tank (at the left) cement or steel pipe goes down to the bottom of one of the compartments of the digester. As material is filled in, this compartment will be full and digesting material will flow over to the next compartment. This compartment has a pipe, similar to the inlet pipe that leads to the outlet tank, where the effluent is corrected. The digester is covered with a floating steel cylinder with an open bottom. As biogas is formed in the digester, the gas moves into the cylinder through the open bottom, causes the cylinder to float higher in the digester contents (Ludwig Sasse, 1988).

Flexible bag digester usually called "bag digester", although the bag holds both the slurry and gas. This design consists of a plastic or rubber digester bag, in the upper part of which the gas is stored. The inlet and outlet are attached direct to the skin of the balloon. The slurry fills the lower two-thirds of the bag and gas collects above it. As the biogas is used the bag collapses.

Advantages of fixed dome types are described as follows:

1) No steel shaped required (no rusting parts)
2) Low initial cost and long useful life span (about 20 years)
3) Well insulated, slurry temperature uniform
4) Compact design and saves space

My country is developing country. So fixed dome type is also used in our project. The successful plant design in our project is as shown in **Fig.1**.

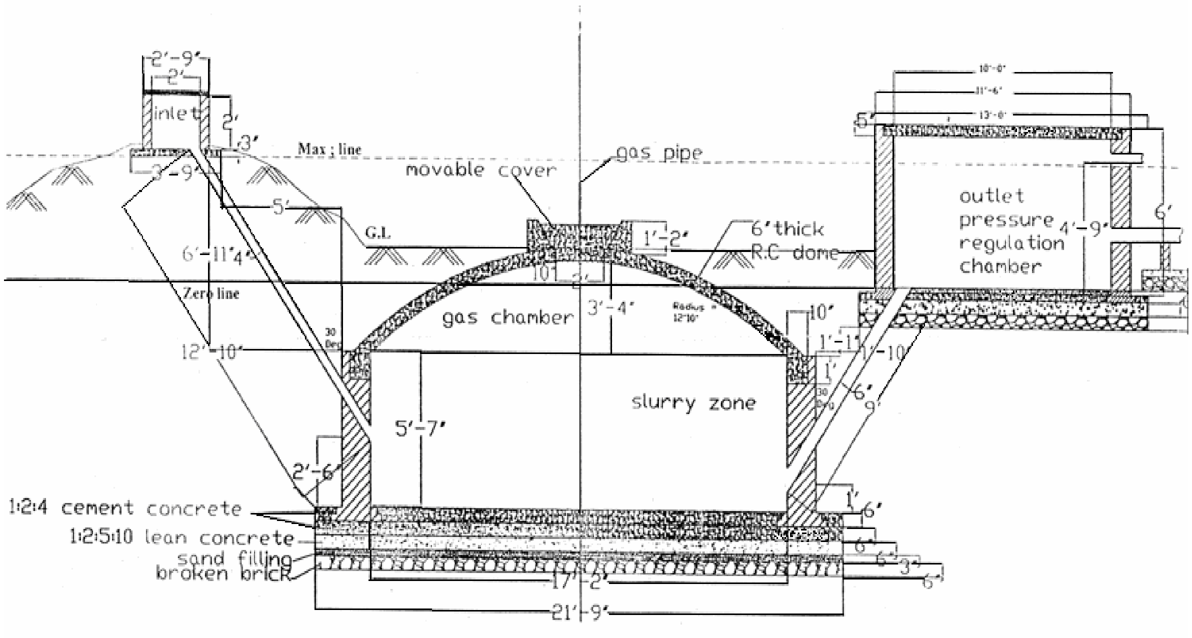

Fig.1. Design for 50 m^3 of biogas plant
Source: Mya Mya Oo (2005)

6. FEED STOCK

Any organic material can be converted into biogas. The rate at which biogas is produced, and how much varies with the type of feed stock. For example, woody materials such as straw are very difficult to digest, while cow dung digests readily. Some material may be difficult to collect. For example, dung from animals such as sheep which are not usually kept in stalls. For other materials, pre treatment may be needed, for example, before it is fed into the digester. Human waste digests well but there may be cultural objections to handling the feed stock or using the gas produced from it for cooking. My country is agricultural country. So we chose cow dung as feed stock in our Biogas production.

7. OPERATING THE DIGESTER

Digester can be operated on a semi-continuous (once a day) or batch- fed systems. Gas production is continuous. Batch operation is the usual method for small (about 5m^3) digesters used for individual households. To maintain a constant level of production needs careful organization; a second digester is needed to produce sufficient gas to compensate for the first digester's declining output.

Digester looks simple to operate and this can be misleading. They need daily attention and, with some design, the materials inside the digester (the slurry) need to be mixed. Also the micro-organisms are sensitive to environmental conditions, especially temperature, and so care needs to be taken with a number of parameters which discussed briefly below.

Anaerobic micro-organisms work at a range of ambient temperatures between 20˚C and 60˚C. In many developing countries ambient temperatures allow most digesters to operate at around 30˚~35˚C, which is considered to be optimum. There can be problems during winter months when temperatures drop significantly. Research is currently under way to develop digesters which can produce sufficient gas at lower temperatures. Anaerobic micro-organisms prefer a solution that is neither acid nor alkaline. No special chemicals need to be added under normal circumstances to provide these conditions inside the digester since the micro-organisms are able to regulate the acidity level themselves. However, if the temperature drops too much or too suddenly the slurry can become many acid and gas production will cease.

Our biogas projects are constructed in the middle region of our country. This region is hotter than other region. Therefore we can get required temperature sufficiently for operating. To avoid facing the problems during winter months, all digesters in our project are constructed under ground because ground temperature is uniform. It is important to remember that the solid waste must be mixed with water before it is put into the digester. To get biogas, the feeding ratio for water and cow dung is 1: 1. In starting time, it is needed to feed 2000 kg of water and 2000 kg of cow dung. After seven days, the gas will emit. And then there is needed to add 504 kg of water and 504 kg of cow dung in each day. This amount is sufficient to get biogas for lighting in the whole village.

8. ANAEROBIC FERMENTATION

Biogas technology is concerned to micro-organisms. These are different types of micro-organisms. They are called bacteria, fungi, virus etc. This type of bacteria which causes disease both in animals and human beings is called pathogen. When organic matter undergoes fermentation through anaerobic digestion, gas is generated. This gas is known as biogas. Biogas is generated through fermentation or bio-digestion of various wastes by a variety of anaerobic and facultative-organisms Facultative bacteria are capable of growing both in presence and absence of air or oxygen.

Aerobic and anaerobic fermentation can be used to decompose organic matter. Anaerobic fermentation produces CO_2, CH_4, H_2, and traces of other gases. In a biogas plant the main aim is to generate methane and hence anaerobic digestion is used. The complex organic molecule is broken down to sugar, alcohols, pesticides and amino acids by acid producing bacteria. Biogas fermentation processes are as shown in **Fig.2** and **3** (Mya Mya Oo, 2005).

The anaerobic digestion consists of three phases. They are (1) enzymatic hydrolysis, (2) acid fermentation and (3) methane formation.
The process of biogas formation from simple organic matter is as shown in figure.

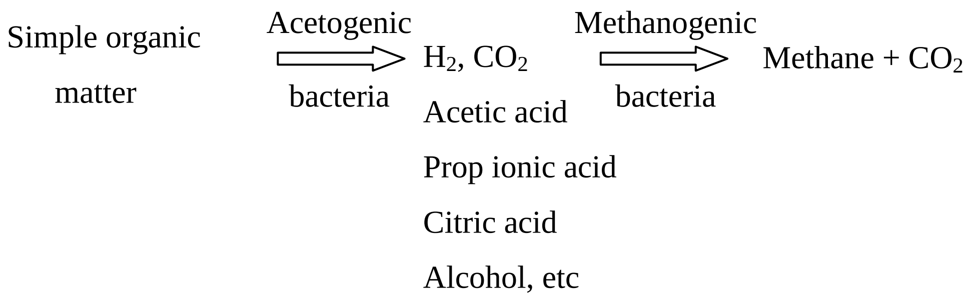

Fig. 2. Biogas fermentation process from simple organic matter
Source: Mya Mya Oo (2005)

In acid fermentation stage, the micro-organisms of facultative and anaerobic group collectively called farmers, hydrolyses and ferment, are broken to simple compounds into acids and volatile solids in methane formation stage, organic acids as formed above are then converted into methane CH_4 and CO_2 by the bacteria which are strictly anaerobes. These bacteria are called methanogenic bacteria.

In enzymatic hydrolysis stage, the fats, starches and proteins contained in cellulosic biomass are broken down into simple compounds. In methane formation stage, organic acids as formed above are then converted into methane CH_4 and CO_2 by the bacteria which are strictly anaerobes. These bacteria are called methanogenic bacteria (Mya Mya Oo, 2005).
The process of biogas formation from complex organic matter is as shown in figure.

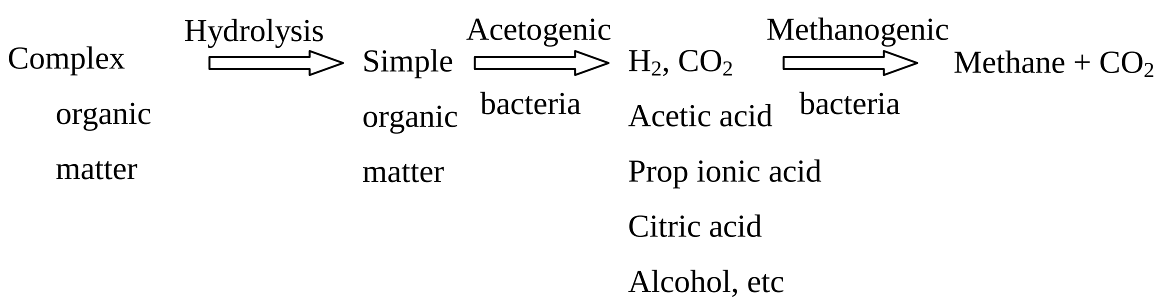

Fig. 3. Biogas fermentation process from complex organic matter
Source: Mya Mya Oo (2005)

Advantages of anaerobic fermentation are 1. Calorific value of gas, 2. New sludge production, 3. Stable sludge, 4. Low running cost, 5. Low odour, 6. Stability, 7. Pathogen reduction, 8. Value of sludge, and 9. Low nutrient requirement

Anaerobic digestion not only breaks down organic materials into biogas, it also releases plant nutrients, such as nitrogen, potassium and phosphorus and converts them into a form that can be easily absorbed by plants. Thus biogas plants are beneficial to many people. Effluent slurry can be added to dry plant material, such as straw or leaves. The dry material absorbs the plant nutrients and water, and conserves them. The slurry contains facultative bacteria that compost the plant material, increasing its fertilizer value.

9. SERVICING AND SAFETY

When using biogas power plant commercially, servicing and safety are important tasks to be carried out regularly. Therefore, procedures of servicing and safety are discussed as follow. Servicing can be divided into two parts: check of gas pressure and measurement of gas production. When checking the gas pressure, the two possible root causes of pressure dropping are:

1) due to pressure in the gas holder
2) due to friction in the pipe

Pressure losses in the gas pipe have to be considered when a gas plant is being installed. Gas pressure in the gas holder can be increased by putting weight on top of the gas holder. Weight should be placed symmetrically on the gas holder and not all on one side. It should never be necessary to decrease the pressure more than by removing any weights from the top of the gas holder. If too high a gas pressure is used, the gas will escape from condensate outlets, which use water to provide a gas seal and mantles for lamps will break frequently. The gas pressure can be measured by means of a manometer. It is attached to a gas tap using a rubber tube. It is not always necessary or usual to have a manometer permanently attached to the gas plant. If a manometer is not available, the gas pressure can be checked in the following way. A rubber tube is attached to a gas tap and put straight down into a container of water to a depth of at least (8 in). The gas tap is turned fully on and the pipe is lifted out of the water until bubbles just start to come out of the rubber pipe. The water level on the rubber pipe can be marked. The gas should then be turned off. In measurement of gas production, gas is usually measured by a flow meter. Special scientific wet type meters can be used but these are extremely expensive. Gas production can easily be measured when a gas holder floating in the slurry is used. The height from the slurry surface to the top corner of the gas holder is measured. The highest point was at the time when fresh slurry was fed into the plant and the gas holder was revolved to mix the slurry. There will always be a peak of gas production during the first three months of operation of a new gas plant while the large amount of dung put on initially produces gas and until the bacteria in the plant are stabilized. Therefore it is better to carry out gas production tests after this time.

Biogas, when used as instructed, is safer than other gases used in houses. It can only explode when there is 6 to 25 per cent biogas mixed with air. If all the air is removed from the gas holder and pipes before use, the gas plant cannot explode. The first gas is allowed to escape from a digester. Once the gas holder has filled with gas again, the pipes must be cleared of air. After repairing pipes or even checking for leaks, care must be taken to remove any air from the pipes before the gas is used again. There should be no smoking, no candles, no fires, no matches, no lamps or other open flame until the smell of gas has gone. The main gas valve should be closed. Leaks can be detected by putting soapy water over suspected leaks. If bubbles appear, then it is certain that there is a leak.

10. BIOGAS CONSUMED AS A FUEL

The fuel consumption of equipment using biogas is often specified in m^3/h or m^3/kWh, i.e. standard cubic meters per hour or per kilowatt hour respectively. The standard cubic meter (m^3) means a volume of 1 cubic meter of gas under standard conditions, i.e. at a temperature of 0 °C (273 K) and a pressure of 1013 mbar. The consumption of biogas in actual volume will differ from these data according to the actual conditions of the biogas as fed to the equipment (motor, burner, etc.) in terms of temperature, pressure, and composition, i.e. CH_4 content. The determination of the actual volumetric consumption of an engine operating on biogas fuel is of utmost importance for the dimensioning of biogas plant, engine, mixing device and other equipment. A difference of 50% between actual volumetric consumption and specified consumption of a biogas engine can easily occur and could result in poor performance of the engine if not considered.

Biogases from different materials contain different percentages of hydrogen sulphide H_2S, i.e. 0.10 to 0.50 percentages in volume content (1000 ~ 5000 ppm). As H_2S is corrosive to metals especially in connection with water or humidity, its content should be as low as possible when used as a fuel in engines. Some engine manufacturers specify a maximum allowable value of 0.15 percentages in volume content; others allow more or give no data. Ferrous materials in the form of natural soils or certain iron ores are often employed to remove H_2S. The ferrous material is placed in a closed, gas-tight container (of steel, brickwork or concrete). The gas to be purified flows through the ferrous absorbing agent from the bottom and leaves the container at the top, freed from H_2S. The absorbing material must contain iron in the form of oxides, hydrated oxides or hydroxides. This process terminates, of course, after some time. The greater part of the iron remains as a sulphide.

Depending on the type of biogas plant and piping, some indispensable solids can be drawn with the gas to the mixer. A simple filter in the form of a larger container filled with washed rubble or a tissue filter with no measurable pressure loss is recommendable in any system.

11. ENGINE FOR BIOGAS

Biogas is excellent engine fuel. Its combustion and emission characteristics are superiors to other competing fuel. Engines operating on biogas carried fuel that is gaseous at atmospheric pressure. Nature of gas engines is similar to that of petrol engine. On the other hand, the petrol engine can use biogas effectively with relatively simple modifications, including the addition of a suitable gaseous fuel control system. But the compression ratio of the engine will be too low to produce optimum operating characteristics and fuel economy. Diesel engine can be converted to full biogas operation by lowering the compression ratio and instillation of the spark ignition system. The compression ratio of the typical diesel engine, when converted directly to spark ignition operation, is too high to operate on biogas without knock. There are many reasons for not using on original spark ignition instead of converting a diesel engine. The speed of the spark ignition engine is too high and also there is a large derating of the spark ignition engine when operating on gas resulting in lower power output when compared with modified diesel engine. Diesel engines are easy to variability because of variety use in current mechanized farming and industries. Moreover high power output can be obtained from a single cylinder diesel engine compared with petrol engine. Modifications can be made locally easily.

12. CONVERSION OF DIESEL ENGINE

There are two methods of converting diesel engine to utilize biogas as the main lighting fuel in diesel engine. The first method is to utilize biogas fully in diesel engine known as the biogas dedicated conversion. The second method is the duel fuel conversion using biogas and diesel fuel to ignite the flame in the combustion chamber.

The modifications of diesel engine to use with biogas will involve the following.

(1) Mechanical Modification
(2) Installation Ignition System

The compression ratio can be reduced by three different methods, which are

(1) Modifying the piston groove of bowl
(2) Modifying the length of the connection rod
(3) Inserting of plate onto the piston head

The first method is usually constructed by milling the piston head to create a recessed bowl shape. It is usually suitable for large piston because small piston with recessed bowl can cause thermal stress to build up in the piston head and piston skirt. The second method is to reduce the length of the connection rod. However, this method is very costly and complicated to be constructed. Improper design will cause vibration and thermal stress to build in the piston. The last method is lower construction cost and to be built compared to the other two methods and the design is simple and does not require any complicated calculation. However, the first method is chosen for the design of the piston in the combustion chamber to reduce the compression ratio.

Theoretical compression ratio for CI and SI engines are in the range of 16~24 and 5~10 respectively. Although producer gas engine is type of spark ignition engine, its octane number permits higher compression than petrol. Compression ratio and required octane number for spark ignition engines are shown in **Table 1**. Octane numbers of gases are in the range of 85~125. However biogas comprises of various combustible gases. Therefore its octane number is over well120. From an octane number theoretical compression ratio can be estimated by the following formula:
Octane number = 10 × maximum practical compression ratio without pre-ignition

For octane number of 120, compression ratio for producer gas engine is 12:1. Although this ratio keeps knocking effect, engine heat load is very high even for short running time. Spark plug life is very short. Experimental results from our biogas project shows optimum running condition is obtained at compression ratio 8:1.
The mixer used in this present work is of the burner type. The air entered the mixer through the main inlet and biogas entered through small encircling holes located at the throat of the mixer. In this modeling, the number of 30 holes is used to analyze the mixing of the air fuel mixture.

(a)Piston of diesel engine (b) Piston of converted biogas engine

Fig. 4. Piston of diesel and converted biogas engine

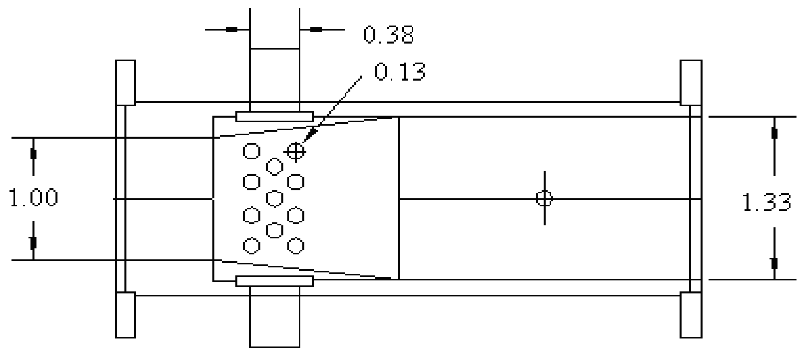

Fig. 5. Schematic diagram of mixer

Dimension for Mixer:
Outlet adaptor diameter = 25.4 mm (1 in) (smaller than intake air diameter)
Length, L = 38.1mm (1.5 in)
Intake air diameter, D = 38.1mm (1.5 in)
Throat diameter, D_t = 25.4 mm (1 in)
No. of Biogas inlet hole = 30
Biogas inlet hole diameter, d_{hole} = 3.175 mm (0.125 in)
Inlet angle = 13˚

Table 1. Compression ratios and estimated required octane number

Compression ratio	Required octane number	Thermal efficiency %
5 : 1	72	23
6 : 1	81	25
7 : 1	87	28
8 : 1	92	30
9 : 1	96	32
10 : 1	100	33
11 : 1	104	34
12 : 1	108	35

13. THE MAIN DIFFERENCES BETWEEN DIESEL ENGINE AND BIOGAS ENGINE

A diesel engine has compression- ignition system. It has no spark plug as in biogas engines. A diesel engine draws into its cylinder air alone intake stroke. On the other hand a biogas engine draw the fuel and air mixture premixed in air gas mixture before entering the cylinder. But, direct injection of biogas as means for improving combustion, emission and performance and manifold injection are used.

Diesel engines use higher compression ratio than biogas engines. It is not limited by knocking in diesel engines. In biogas engines, the compression ratio is limited by detonation. Diesel engines need stronger heavier construction due to high compression ratio. Biogas engines need stronger and relatively lighter construction but the engine cooling system has been increased because a medium working temperature has been increased.

Diesel engines use fuel pumps and precise fuel injection nozzles to inject the diesel fuel into the cylinder in the form of a fine spray. So, it has higher initial cost of engine due to precision of diesel injection equipments. Biogas engines have relatively lower initial cost. Diesel engines have lower maximum operating speed about 3500 rpm limited by higher inertial forces and centrifugal forces due to heavy moving parts.

14. TEST STAND RESULT

The technical parameters for the converted biogas engine are in **Table 2**. If we consider biogas as a fuel with a gas composition of 75%CH_4 and 25%CO_2, the energy density factor is 0.64 molecules reduce by a factor 0.91 and temperature effect is about 3% taking into account the change in compression and other gas properties.

Firstly cylinder head is drilled by twist drill to the nearly valve seats for the spark plug adapter. Then whole timing side cover is at the center of camshaft. Distributor attached to timing side cover hole and ignition coil locate the suitable place. Remove the air cleaner from intake manifold. Construct a mixing valve and assemble the mixing valve on the air cleaner location. Air cleaner locate on the mixing valve.

This engine use to drive a 15 kVA generator. At about 1500 rpm the engine produce the maximum power. The engine tested 350 numbers of 20 watt lamp, 10 pairs of 21 inches TV and video continuously about 6 hours a day. The engine of fuel consumption is 9m^3/h. The engine combines 15 kVA generator and test run. The engine pulley diameter is 6 in. The generator pulley change 6 in to 5 in diameter. It can get 240000 kyats with 600 kyats for each fluorescent per month for 400 parts. It costs 300000 ~ 400000 kyats for constructing biogas plant. So, the capital can be regained within one and half year. By the way, over 100 villages in our country have been supplied for lighting.

Table 2. Specification of the converted biogas engine

Horsepower	17HP / 1500rpm	
Peak Torque	60N-m / 1000rpm	
Displacement	1.246 L	
No of Cylinders	Inline 1	
Aspiration System	Natural aspiration	
Ignition System	Spark ignition	
Fuel	Biogas	
Bore & Stroke	115 mm × 120 mm	
Displacement volume	1.246 L	
Compression Ratio	9 : 1	
Operation Cycles	4 stroke cycles	
Type of Combustion Chamber	Semi-spherical type (open-chamber)	
Valve Configuration	Pushrod Actuated Overhead Valves	
Fuel System	Firing Order	
	Mixer	Ventury Type
Electricity System	Ignition	Plug System
	Starter	24V-5.0 kW
	Generator	15 kVA
Cooling System	Water Cooled	

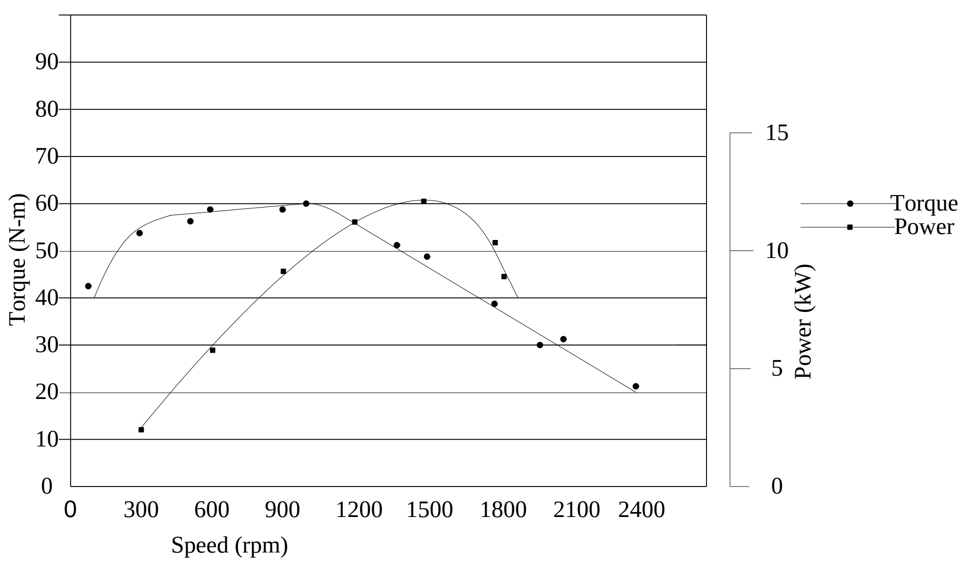

Fig. 6. Performance curve of converted biogas engine

From the results it is clear that the simple analysis using empirical relations seems to predict the power out put of a diesel engine modified to operate on gas quite satisfactorily. The optimum power output at running condition is 11.5 kW (1500 rpm) because of using loading.

16. DISCUSSION AND CONCLUSION

Emission of carbon monoxide, carbon dioxide and unburned hydrocarbons form a biogas fuelled engine is lower than diesel engine. Decrease of compression ratio affect on decrease of CO and CO_2 products. Less HC was produced by biogas fuelled engine than that of diesel engine. Theoretically, HC emissions from biogas fuelled engines should be lower due to the gaseous from which gives an excellent mixing. Decrease in compression ratio affected on decreased of the HC product.

Although the project successfully carried out the research and simulation work to achieve the objective of this project, there are still a lot of improvement and adjustment to be made on the design of the converted biogas engine.

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