ALTERNATIVE TYPES FUELS -MADE FROM AGRICULTURAL BIOMASS (BIOGAS)

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Abstract: *Biogas is a typical "product" of urban discharges, which has a great negative environmental impact. To avoid this negative effect, it can be burnt at very high temperatures, producing smoke emissions composed of CO_2. A useful alternative is to use biogas as fuel to feed co-generation plants, producing electricity.At the moment biogas is used as fuel, introducing it directly in the combustion chamber. Nevertheless the heterogeneity of the gas stresses the engine, reducing its life. The new technology should treat the biogas before putting it into the engine, reducing its heterogeneity and stabilising it in that range of characteristics which are acceptable for the engine. Such a technology has the advantage to preserve the environment from the emission of biogas, guaranteeing, at the same time, a higher safety of discharges. In fact, biogas produced by urban discharges could create big gas pockets with a high pressure, that could cause explosions. Using biogas as fuel for internal combustion engines will make discharges safer than before and at the same time it will be a useful alternative source of power. While biogas has multiple benefits at the individual family level, it also has several qualitative and quantitative benefits at the societal level.*
KEY WORDS: BIOGAS, AGRICULTURE BIOMASS, FUELS.METHANE,

Introduction

Biogas is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. Since biogas is a mixture of methane (also known as marsh gas or natural gas) and carbon dioxide it is a renewable fuel produced from waste treatment. Anaerobic digestion is basically a simple process carried out in a number of steps that can use almost any organic material as a substrate - it occurs in digestive systems, marshes, rubbish dumps, septic tanks and the Arctic Tundra. Humans tend to make the process as complicated as possible by trying to improve on nature in complex machines but a simple approach is still possible, as I hope you see in the links below.
If you are new to biogas/biofuel and anaerobic digestion for waste treatment or fuel production these pages are intended to assist you. If you only need some simple information the first couple of links will be most useful, while the later pages are to help those considering starting a digester project
Methane, which is makes up from 0% to 80% of biogas, forms explosive mixtures in air, the lower explosive limit being 5% methane and the upper limit 15% methane. Biogas mixtures containing more than 50 % methane are combustible, while lower percentages may support, or fuel, combustion. With this in mind no naked flames should be used in the vicinity of a digester and electrical equipment must be of suitable quality, normally "explosion proof". Other sources of sparks are any iron or steel tools or other items, power tools (particularly comutators and brushes), normal electrical switches, mobile phones and static electricity.If conducting a flammability test take a small sample well away from the main digester, or incorporate a flame trap in the supply line, which must be of suitable length (minimum 20 m).
Biogas consists mainly of CH_4 and CO_2, with low levels of H_2S and other gases. Each of these components has its own problems, as well as displacing oxygen.
CH_4 - lighter than air (will collect in roof spaces etc), explosive (see above).
CO_2 - heavier than air (will collect in sumps etc), slightly elevated levels affect respiration rate, higher levels displace oxygen as well.
H_2S - (rotten egg gas) destroys olfactory (smelling) tissues and lungs, becomes odorless as the level increases to dangerous and fatal.
Adequate ventilation, suitable precautions and adequate protective equipment will minimize the dangers associated with biogas, making it a good servant rather than a bad master.

Benefits of biogas

Biogas technology makes optimal utilization of the valuable natural resource of dung; it provides nearly three times more useful energy that dung directly burnt, and also produces nutrient-rich manure.
As a cooking fuel, it is cheap and extremely convenient. Based on the effective heat produced, a 2cu m biogas plant could replace, in a month, fuel equivalent of 26 kg if LPG (nearly two standard cylinders), or 37 liters of kerosene, or 88kg of charcoal, or 210 kg of fuel wood, or 740 kg of animal dung. In terms of cost, biogas is cheaper, on a life cycle basis, than conventional biomass fuels (dung, fuel wood, crop wastes, etc.) as well as LPG, and is only fractionally more expensive than kerosene; the commercial fuels like kerosene and LPG, however, have severe supply constraints in the rural areas.

Potential of biogas

In India, the dissemination of large–scale biogas plants has began in the mid-seventies and the process has become consolidated with the advent of the National Project on Biogas Development (NPBD) in 1981, which has been continuing since. Against the estimated potential of 12 millions biogas plants, 2.9 millions family type and 2700 community, institutional and night soil-based plants have been set up till December 1999. This is estimated to have helped in a saving of 3 million tons of fuel wood per year and manure containing nitrogen equivalent to 0.7 million tons of urea.

However, in terms of total dung that is available in the country, the potential is much more. The bovine population in India is 260 millions. Adult bovine produces an average of 10kg of dung per day. Since grazing is a common practice in India, all the dung produced cannot be collected. If it is assumed that 75% of the dung is collected, nearly 2 millions tones of dung would be available everyday. At 25 kg per one cubic meter, this dung can feed as many as 40 millions biogas plants of 2 cubic meter capacity, which can be considered the ultimate potential for biogas technology.

But even this high potential of biogas is based on animal dung only. However, all organic matter can technically be used to generate methane; if the scientific experiments that are going on in the country under the patronage of MNES to develop alternative feed stocks (such as water hyacinth, kitchen waste, and poultry waste) come to fruition, potential for biogas generation could be virtually unlimited. It can be mentioned in this context that human waste is an excellent source of biogas which would enhance the potential; substantially. With such high potential, which can be routed to hitherto unemphasized applications of shaft power and electricity generation, biogas can make a significant contribution to the development of small industries and agriculture, and thus to the overall advancement of the rural areas.

Materials and methods of biogas production

Two kinds of materials are used to produce biogas in this Base: Dung (pig waste) and distiller's grains.

In a small pig farm, the quantity of dung collection is 4 kg/d per head. There are 90 heads of pigs in the Base, so the quantity of dung each day equals to 360 kg/d. The total solids (TS) are 18%. If the fermentation materials entering the digester are calculated by 8% of TS concentration, the quantity of input mixed materials of digester is 810 kg. In the different fermentation process and digester construction, the outputs of biogas are different. If using a small hydraulic biogas digester, 13 m³/d of biogas can be produced; If the mesophyllic fermentation is practiced, the biogas yield will increase greatly. The distiller's grains are stillage of ethanol production excluding from the workshop with high temperature of 80°C. The distiller's grains can be used not only for the raw materials alone of biogas fermentation but also for a mixed material with dung so that the higher temperature of the distiller's grains is beneficial for increasing the temperature of fermentation slurry. Because the ethanol production from sweet sorghum may be only carried out during the harvest season, the distiller's grains as raw materials of biogas fermentation will not be supplied continuously. Therefore, the pig waste will be the main raw materials of biogas fermentation throughout the year.

Digester

There are three kinds of digesters: hydraulic, half-plastics, and anaerobic filter with sludge bed which were respectively built under the ground of pig houses, beside the pig house, and on the slope to form a biogas supplied system jointly.

A. Hydraulic biogas digester

Two round hydraulic digesters were built under the ground to the eastern side of pigsty, each of them has 10 m^3 volume and 2.6 m diameters. On the basis of 80% of volume to input materials, each digester can be inputted 8000 kg slurry to produce the biogas which will be used directly for the biogas stove and lamp in the pig houses. Combined with other digesters, the biogas produced can be provide to the generator as a power fuel. Because the hydraulic biogas digester was built under the ground of pig houses, and the pig house was covered by the plastic film, the digester can avoid the severe cold during the cold seasons and in winter safely. The biogas residue is a kind of high quality organic manure.

B. Plastic covered digester

The plastic covered digester is a rectangle half-underground pool with 6 m long, 2.6 m wide, and 3 m deep, the pool is covered and sealed by the black red-mud plastics. After the digester is filled with the materials in batch (according to 60% of volume), the digester start-up and produce the biogas which is led out through the duct on the plastic cover and delivered to the biogas tank. In order to increase the outlet pressure of biodigester, a certain load can be added to the plastic cover to adjust the pressure. Because of the bigger area of plastic cover, when the solar radiation is intense, it can have the slurry gain more heat energy, which enables to have an active biogas production process and a high production rate. However this kind of digester does not work during the severe cold seasons. In this case the digester is only as a dung tank. The biogas residues of the digesters after fermentation need to be pumped out.

C. Sludge bed + Anaerobic digester (UASB + AF)

This digester will be built on the slope in front of the pigsty. It consists of biogas engineering system with slurry collector, pretreater of raw materials, slurry measuring meter, biogas tank, biogas hydroextrator, desulphurising and post-treatment equipment.

a. Slurry collector: The solid dung is collected into the slurry collector, the water after washing the cement floor and the waste water of ethanol workshop through the heat exchanger flow into the slurry collector to wait for using.

b. Pretreatment equipment: The slurry after getting rid of big solid, with the aid of the natural slope, flow onto the pretreater through the filter. The concentration of the slurry must be above 7% TS, and PH value should meet the needs of biogas fermentation.

c. Measurer: The fermentation materials were introduced to the digester according digester requirements. At the same time, the temperature of the slurry should reach the requirements for mesophyllic fermentation.

d. Digester: The digester is cylinder, folding style, made of reinforced concrete with 25 m diameters, 7 m high and 36 m^3 volume. This is because the Base is located at high ground, the digester is not suitable at a place too high, and should avoid wind and preserve heat energy. The digester is consists of two cylinders, the one outside is anaerobic sludge bed digester and the one inside is anaerobic filter. The digester is located at half underground and a greenhouse is arranged on it to enhance the temperature of digester. The slurry is processed by mesophyllic fermentation (35°C).The slurry in the filter was pumped into digester after getting heat energy from the cooling water of the cogenerator and the waste water of ethanol workshop to ferment. This kind of UASB + AF digester has two advantages, namely promoting the biogas production rate and decreasing the hydraulic retention time to make the digester function steady. The materials inletted a day is 1600 kg, and the hydraulic retention time is 21 days.

e. Biogas storage vessel: The storage vessel adopts the pillow type, with a attached weight plate, increasing the pressure to 350 mm of water column to meet the requests of biogas generator.

f. Hydroextracted and desulphurizing equipment: In order to prevent the generator from the erosion of biogas, the centrifugal hydroextractor and the ferrous oxide should be used to get rid of H_2S in the biogas.

g. Post-treatment equipment: The exhausted materials are separated into solid and liquid. The liquid flows into the fish pool and solid residue is used as manure.

The start-up of USAB process: After the sludge granules are cultivated, it can improve the subsidence ability of sludge, avoid the sludge up float, and make digester work at a high volumetric COD loading to ensure the system to have a steady ability. The granule sludge can stay in the digester for a long time and hence long average cell retention time, so it may accumulate a lot of methanogens to make sludge have higher activity. The biofilm of the granule can protect methanogenens against unfavorable impacts, such as, shock loadings and low pH in the short term, etc. The granule forming of the sludge is the key to UASB digestive process. To keep a long steady ability of the sludge is very important to the normal function.

As the seed sludge is selected, the thicker types of digested sewage sludge can be considered as proper seed materials for UASB digester .If no this condition, the small amount of crushed granule sludge should be added to the seed materials to promote the bacteria growing and divisive. This attached loading is particularly important to stimulate the sludge curdy. Experimental results obtained indicate that 12-15 kg Vss/m^3 suffices are adopted when a thick digester sewage sludge is applied for mesophyllic digester start-up, whereas 6 kg Vss/m^3 is recommended in the case the seed sludge is relatively thin (<40 kg TS/m^3).

The factors which affect cultivating granular sludge are mainly the kinds of substrate, control and operation conditions, nutrients and environmental conditions.

* Slurry concentration and nutritious substance: In the mesophyllic fermentation using pig dung, it is suitable to use 5% TS of slurry in the beginning. And 7% TS should be added after start-up. The method of backflow sludge is recommended when the concentration of inlet water is high.

Trace elements have significant effect on the growth of bacteria in an anaerobic fermentation system. The researches show that the supplementary enzyme F_{420} of the methanogen contains Nickel. The addition of trace elements, such as Ni, Co, Mo, and $ZnSO_4$, into digesters results in positive effects. All theses elements should be considered during the cultivation of granule.

* Operation and control conditions: The experiments show the main control conditions influencing the process of forming sludge granule is the sludge loading. The granule will be cultivated when the pig dung is 5% TS, and after functioning for a period of time, 7% TS should be added.

* Environmental conditions: All the conditions which are suitable to bacteria growing will promote cultivation of sludge granule. The suitable temperature suggested for the cultivation of granule sludge is ranged within 35° C to 38° C.

Biogas as a substitute for diesel fuel

- Introduction

Because of the current energy shortage, there has been much interest in developing new fuels as alternatives to petroleum fuels. Biogas appears to be a feasible fuel for internal combustion engines because it can be derived from agricultural surpluses and residues which provide the raw material for biogas production. By feeding the byproduct of the biogas production process, a farmer may even incorporate the production of his own fuel as an integral part of the food production system. Because a majority of Chinese farmers are equipped with diesel-powered farm machinery and this trend is growing rapidly, it is important to have a clear understanding of the effects of the use of biogas in diesel engines.

- Objectives

The objective of the research was to demonstrate the feasibility of using biogas as a alternative fuel for diesel engines, and to determine any associated problem. More specific objectives were to modify diesel engines of types commonly used on farms so that they would operate as efficient as possible on biogas alone, or a mixture of biogas and diesel fuel, and to study the performance of the modified engines.

- Performance of biogas alone in L195 diesel engine

a Equipment

A L195 diesel engine which was coupled to a water-brake dynamometer was converted to biogas alone. Engine specifications are given in Table 6.1. Biogas from digester of brewer's grain liquid was chosen as a fuel. The composition of the biogas was 63 percent methane, 31 percent carbon dioxide and traces of CO, H_2 and H_2S. The lower heating value of the biogas was 3000 kcal/m^3 And the average pressure for biogas inside the storage tank was 600 mm of water column.

Table 1. Specifications of LI 95 engine

Number of cylinders	1
Displacement (cm^3)	815
Compression ratio	20
Combustion chamber	Indirect injection
Governed speed (RPM)	2000
12 hr. power (hp)	12
Specific fuel consumption (g/hp □ hr)	195

A gas carburetor, especially designed for biogas, was used to mix the gas and the air. It contains a control valve and a T-tube with a venture throat. Fig.6.4 shows its schematic diagram. the amount of biogas was controlled by the throttle valve of the carburetor to improve the properties of biogas and air mixture. In this way, the biogas was first mixed with air from air filter inside venture throat of the gas carburetor. And then, the mixture of biogas and air was introduced to the combustion chamber of the engine.

b. Modifying combustion chamber

Because the LI 95 engine has a indirect injection combustion chamber, an intensive eddy of air will be produced during operation of the engine. This makes it difficult to start the engine, and to maintain a stable inflammation. Therefore, the area of combustion chamber section was increased in order to eliminate the above problems. After modification of the combustion chamber, the compression ratio also had a slight decrease.

c. Installing a spark ignition system

The original fuel injection system was eliminated. A spark plug was installed in the position of the original diesel injector orifice. The spark plug should be considerably chosen so that its electrodes could be located at a proper position of the combustion chamber.

d. Appending a biogas control apparatus

A conical valve was used in order to control the amount of biogas admitted to the gas carburetor. In addition, a linkage which connects the conical throttle of the gas carburetor and governor of the engine was mounted on the engine. Moreover, a main valve was used for controlling the flow of biogas. A gas flow meter was used for measuring the flow rate of biogas. And a U-shape manometer was used for measuring the pressure of biogas, and a pressure regulator for maintaining pressure of biogas was installed on the engine.

C. Testing procedure

Variables measured were: torque, speed, flow rate of biogas, and exhaust temperature. The torque output and engine speed were measured using a water-brake dynamometer (Model SCJ-l).The temperature of the exhaust gases was determined by thermocouple connected to a potentiometer. The flow rate of biogas was measured by the gas flow meter (Model LZB-25).The compression ratio was changed through increasing or reducing the numbers of cylinder head gaskets. The tests were carried out at different compression ratio conditions, such as 13.4: 1, 16.5: 1 and 17.4: 1. A proper spark timing was determined under each compression ratio after comparison. A piezoelectric pressure transducer was installed in the cylinder head to measure the pressure in the combustion chamber when the compression ratios were 13.4: 1 and 16.5: 1. From the pressure curves, it can be seen that no denotation and misfire occurred. When load performance of the engine, using biogas alone, was tested, the amount of biogas supply was controlled manually.

D. Results

a. Load Performance of the engine

The load performances of the engine at three compression ratios were tested. The results are shown in Fig.6.6. Specifically, when the engine using biogas alone operated at 2000 RPM with 39.2° rank angle of spark timing and compression ratio being 17.4: 1, its load performance data are shown in next table.

Table 2. The load performance of L195 engine using biogas

Force (kg)	Power (HP)	Biogas consumption (m^3/hr)	Specific biogas consumption (m^3/hp/ hr)
2	2.45	5.43	2.22
4	4.89	5.85	1.20
6	7.34	6.06	0.83
8	9.79	6.27	0.64
9	11.02	6.89	0.63
10	12.24	7.52	0.62

From the Table it can be seen that the maximum power of the engine operating on biogas alone was about the 90 percent that of the engine's original power. The temperature of the exhaust gases were ranged within 550 °C to 610"C, which was slightly higher than the usual temperature level. The heat consumption rate was 3000 kcal/hp/ hr.

C. Stability of engine performance at low speed

The engine using biogas alone showed a stable operation at a low speed. No vibration occurred. And the engine running with biogas alone performed well at low speed (around 400-500 RPM).

D. Start performance

The engine using biogas alone could be started well as other gasoline engines do. No other fuels were needed to start the engine.

Discussion:

The compression ratio has a great effect on thermal efficiency and combustion performance of the engine. High compression ratio means a high thermal efficiency. However, too big in a increase of the compression ratio may cause detonation of the engine. It was unknown what the maximum compression ratio was. However, according to experiments, when the compression ratio reached 17.4: 1, no severe combustion and detonations were observed. From the Fig.6.6, it can be seen that the specific biogas consumption was not very high within a very wide load range when the combustion ratio was 17.4. And the power was also not lower than that of engine's original power. This suggests that biogas has a higher anti-detonation value. Therefore, to increase compression ration is an effective way for improving the performance of the engine operating on biogas alone.

- Dual-fueling a 2100 diesel engine with biogas

A. Equipment and procedure

The engine used in this study was a case model 2100 2-cylinder, direct injection diesel engine which was connected to a 12 kw generator. The engine was rated to 22 hp at 1500 RPM. The compression ratio was 16: 1, because the engine could not reach its maximum loads under the regulated electric load, a baseline study was run in which all of the fuel energy was supplied by diesel oil before it was converted to diesel/biogas blended fuel. The load performance of the engine using diesel oil alone is shown in Table 6.3. Latter, the original diesel supply system was maintained in order to supply diesel oil as a pilot fuel. A gas carburetor was used to mix the gas and air. The converted engine was loaded in a similar manner while diesel/biogas blended fuel was used. Thus, the performance of the engine using blended fuel could be compared to that of engine operating on diesel only.

Table 3. Load performance of 2100 diesel engine running on diesel oil alone at 1510 RPM

Power (hp)	Fuel consumption (kg/hr) G_T	Specific fuel consumption (g/hp/ hr)
0	1.01	-
5.66	1.82	321
12.24	2.79	228
16.46	3.43	206
18.36	-	-
19.72	3.93	199

During experiments, both the compression ratio (16: 1) and the original injection timing were maintained. The flow rate of biogas was also measured by the gas flow meter (Model LZB-25). An automatic fuel weighing system (Model TCY-69) was used to measure diesel consumption. In order to avoid instability of working load, several lamps were used as loads of the dynamo. Each time when the load was added, the amount of biogas and diesel oil were adjusted manually and automatically, respectively. The percentage of biogas should be increased as much as possible as long as normal combustion was achieved, and the speed and voltage were stable.

Results and discussions

The 2100 diesel engine using biogas/diesel blended fuel could perform very well at its original power levels. Table 6.4 shows the performance data of the engine with duel fuel at 1510 RPM. From the Table it can be seen that percentage of the pilot diesel fuel was ranged within 10.4% to 17.7% when the load of the engine varied from zero to one hundred. And the percentage of pilot diesel fuel was 15% at medium and full loads. In addition, the relative saving rate of diesel fuel was slightly higher than that which is wanted. Because the high relative saving rate of diesel fuel means the small amount of pilot fuel, leading to instability of combustion. Hence, it is suggested that the pilot diesel fuel should not be less than 15%-20%, and the relative saving rate of diesel fuel should be controlled within 75%-80%. From the tests, it is known that the biogas consumption was 0.6 m^3 (at standard atmospheric conditions) when 1 kw / hr electricity was generated.

After experiments, the engine unit was put into real production. It operated more than 132 hours, generating more than 1000 kw / hr electricity. The data from production practice were about the same as that from the tests.

Power	Fuel consumption		Specific fuel consumption			Pilot	R	Heat consumption	
	Diesel	Biogas	Diesel	Biogas		fuel	diesel		
(hp) (kcal/hp hr)	(kg/hr)	(m^3/hr) G'_T	(g/hp / hr)	m^3/hp /hr)	(%)	□	(%)	Diesel	Biogas
0	0.41	4.18	-	-		10.4	59.4	-	-
5.66	0.70	4.08	124.0	0.721		17.7	61.5	1265	3605
12.24	0.49	6.58	40.0	0.538		12.4	82.5	408	2690
16.46	0.48	7.63	29.2	0.464		12.1	86.0	299	2320
18.36	0.49	8.15	26.7	0.444		12.4	-	272	2220
19.72	0.53	8.15	26.9	0.413		13.4	86.5	274	2065

Note: G_T -See Table

□ $=(G_T-G'_T)/G_T$ x 100%, at the same performance conditions
R-Relative saving rate of diesel fuel
The volume of biogas was measured at standard atmospheric conditions

Conclusions

The modifications of a conventional diesel engine to operate on the dual-fuel system using carbureted biogas and injected diesel fuel as proposed in this paper is practicable. When there is no biogas available, the engine can be switched over to diesel oil alone easily.
The engines running on biogas alone or diesel/biogas dual-fuel can perform well at a very wide load range.

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