한국수소 및 신에너지학회 논문집(2010. 10), 제21권 제5호
Trans. of the Korean Hydrogen and New Energy Society(2010. 10), Vol. 21, No. 5, pp. 435~441

A Study on Characteristics of Power Generation System Using Biogas from the Waste of Pig Farm

Thanh-Cong Huynh*†, Xuan-Mai Pham, Dinh-Hung Nguyen**, Minh-Tien Tran****

**Vietnam National University Key-lab for Internal Combustion Engine*
***Department of Automotive Engineering, Faculty of Transportation Engineering, HoChiMinh City University of Technology, 268 Ly Thuong Kiet, District 10, HoChiMinh City, Vietnam*

ABSTRACT

To verify the possibility of a power generation system using biogas from the waste of pig farm for rural electric production, a SI gasoline engine is modified to use biogas fuel and was installed in a 20 KVA power generation system. An electronic speed regulation unit is developed to keep the system speed at 1500 rpm. Experimental investigations have been carried out to examine the performance characteristics of power generation system (such as: system frequency, phase output voltage,...). In addition, the operating parameters and output emissions (NO_x, HC, and CO_2) of biogas-fueled engine are preliminary evaluated and analyzed for the change of system load.

Results indicated that the researched power generation system shows a high stability of output voltage and frequency with help of speed regulator. Biogas fuel (mainly CH_4 and CO_2) has an environmental impact and potential as a green alternative fuel for SI engine and they would not require significant modification of existing engine hardware. Output emissions of biogas-fueled engine are found to be relative low. NO_x emission increases with the increase of output electric power of the power generation system.

KEY WORDS : Power generation system, Biogas, Electronic speed controller, Engine emission, Output voltage and frequency

1. Introduction

The resource limitation of fossil fuels and the problems of air pollution arising from their combustion have led to widespread research on the accessibility of new and renewable energy resources. Solar, wind, thermal and hydro sources, and finally biogas are among these renewable energy resources. As it is well-known, the biogas could be produced from the wastes (manure and water) of pig farms with the help of the anaerobic digesters shown in Figure 1. For these biogas systems, treatment basements are built by concrete and covered by HDPE (high-density poly-ethylene) plastic on the lid. The product of anaerobic digestion is a mixed gas primarily composed of methane and carbon dioxide which commonly is called biogas. Biogas is a gas mixture comprising methane (CH_4) and carbon dioxide (CO_2) that is formed when organic materials, such as livestock's' dung or vegetable

†Corresponding author : htcong@hcmut.edu.vn
[접수일 : 2010.8.16 수정일 : 2010.10.3 게재확정일 : 2010.10.20]

Fig. 1 Biogas HDPE anaerobic digester installed at binh duong province (vietnam).

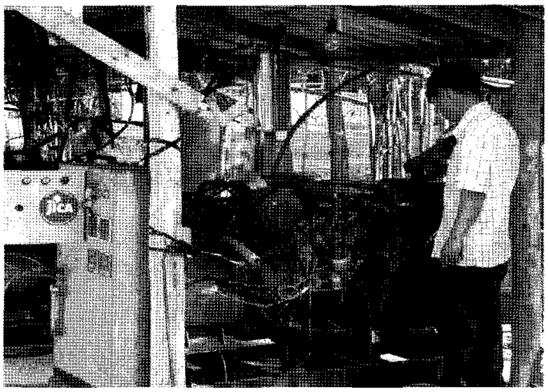

Fig. 2 Power generation system using biogas fuel for this research in the program of JICA - SUPREM project.

matter are broken down by micro biological activity in the absence of air, at slightly elevated temperatures (most effective between 30~60°C). Biogas has the smell of bad or rotten eggs due to the smell of desulfurized biogas is hardly noticeable.

Biogas has a wide variety of applications with many different purposes. In small scale installations the gas is primarily utilized for heating and cooking (e. g. gas cookers/stoves) for and lighting (e. g. biogas lamps), and using as a potential fuel of a burning system for tea processing, fruit storing, hatching chickens, household energy... In larger units CHP's are fueled with biogas. In any case, the driving force for the gas utilization was to economies fossil fuels or wood as in developing countries.

In production and living activities in rural areas, the electrical energy is needed to reduce. In previous works, the basic technologies were studied to use biogas as fuel for the stationary engines can generate electricity[1-4]. These help the engine-generator combination replacing the use of available gasoline by dual fuel of biogas/gas or biogas/diesel. The solution helps farmers save the production costs significantly, especially when the gasoline and electricity price keep rising up[3,5]. However, the output power of generation system is changed with the variation of biogas flow rate and pressure that is conducted from the anaerobic digesters. This leads to damage the electric-used equipments in the farm. Thus, studying the characteristics of power generation system using biogas fuel with help of speed regulator is highly demanded.

In this paper, it is present the research results of the characteristics (such as variation of output voltage) of power generation system using biogas fuel, the properties of speed regulator, and the operating parameters and emission outputs of biogas-fueled SI engine with the change of electric system load.

2. Power generation system

A power generation system is developed in this work shown in Figure 2. This system includes a biogas-fueled engine coupled with a commercial alternator. The engine under study is a commercial 2.0 liters Liquefied Petroleum Gas (LPG) engine coupled to a 3-phase 4-pole alternator to produce electricity at 220V@50Hz. The engine is modified by an addition of biogas mixer for air-fuel mixing and a modification of spark ignition system so the

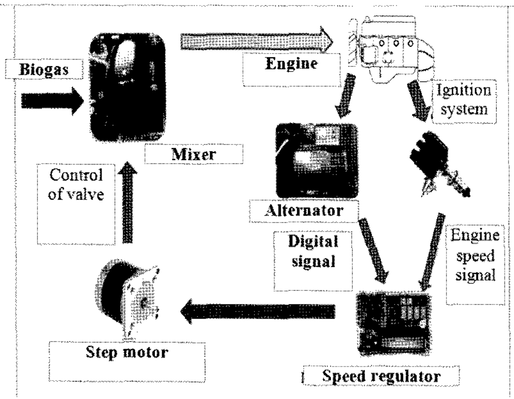

Fig. 3 Schematic of speed regulator for stability of system.

spark timing can be adjusted. An engine speed regulator is properly designed for estimating the stability of power output. When the alternator is synchronized to power grid, the operating speed of engine is about 1500 rpm.

When the biogas flow rate and/or biogas supplying pressure has changed, the engine speed is changed and so the frequency of power generation system. To manage the engine speed, a speed regulator was developed and shown in Figure 3. The speed regulator realize the changing signal of engine speed and will control the step motor changing the engine load or biogas valve installing in the engine intake system.

3. Experimental setup

3.1 Material

As above remain, biogas conducted from the anaerobic digesters has the typical components was listed in the Table I. To use the biogas as fuel, it is necessary to eliminate H_2S and reduce CO_2 to increase heat capacity of the fuel and to remove. Other poisonous components which are harmful to human beings and to materials. However, as the

Table 1 The composition of tested biogas

Matter	Volume (%)
Methane, CH_4	69.6
Carbon dioxide, CO_2	29.4
Hydrogen sulfide, H_2S	0.96
Other	0.04

preliminary steps of this project, the biogas is supplied directly from anaerobic digesters to the intake system of SI engine without filtration system.

3.2 Testing procedure

To determine the characteristics of power generation system, the stability of output voltage and frequency was estimated by using of speed regulator.

To investigate the operating conditions (intake temperature, exhaust temperature, intake air flow, biogas flow) and the engine emissions (CO_2, HC, NO_x) were conducted for the change of system load.

3.3 Testing conditions and equipments

The engine speed is set at 1500 rpm. The cooling temperature is kept between 70 and 90°C. Spark timing is set at 14°bTDC. The intake and exhaust temperature are measured directly by the temperature sensor with thermocouple type and installed in the intake and exhaust system, respectively. The engine emissions are measured by Hesbon HG-520 5 Gas (Korea). The system load (or output electric power) is determined by a simulated system and is developed by the key-lab for internal combustion engine, HoChiMinh City University of Technology. Intake air flow is measured by AVL Sensyflow system and monitored by a display ABB system.

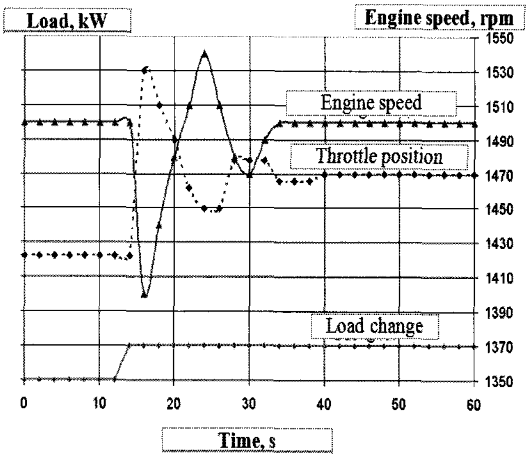

Fig. 4 The variation of engine speed and throttle position with respect to load change from the power generation system.

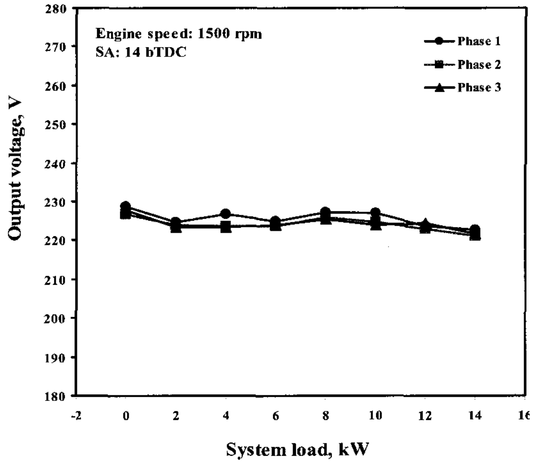

Fig. 5 Effects of system load on output voltage for each phase.

4. Results and discussion

4.1 Stability of power generation system using biogas fuel

The speed regulator: the response capacity of the speed regulator was checked in the different operating conditions of system load. Figure 4 shows the variation of system load consumption from the power generation system. When the system load is increased suddenly, the brake power is increased and so the engine speed is reduced lower than a normal level 1500 rpm. To keep the engine speed remaining at about 1500 rpm (respect to ~50Hz or 220V output voltage), the speed regulator will control the step motor to open the throttle position (biogas valve) more.

To check the change of frequency for three phases of power generation system, Figure 5 presents the output voltage with change of system load. The figure shows that output voltage of three phases changes between 220 and 230 voltage. This means that the change of system load has a small effect on the voltage. Here, system load is defined as the consumption of output power that is determined by simulated equipment.

Figure 6 shows the change of throttle position with system load at engine speed of 1500 rpm. It is found that when the system load increases, the throttle position (or biogas valve) increases linearly. The reason for the results is due to the increase of biogas flow rate with larger throttle position to generate more output power and remain the speed at 1500 rpm.

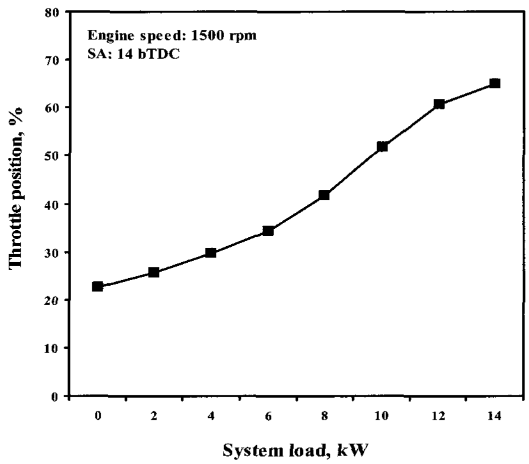

Fig. 6 Effects of system load on throttle position.

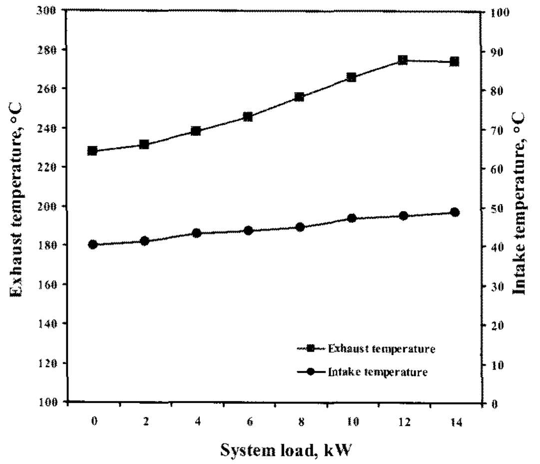

Fig. 7 Effects of system load on intake/exhaust temperature.

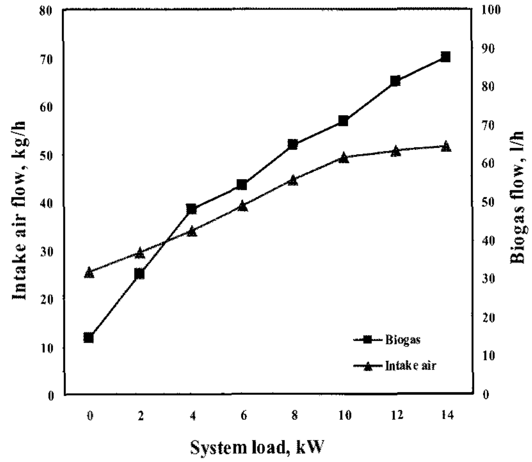

Fig. 8 Effects of system load on intake air/biogas flow.

4.2 Effects of system load on engine operating conditions and engine emissions

The experiments were conducted to estimate the effects of system load on engine working conditions such as: intake temperature, exhaust temperature, intake air flow and so on Figure 7 shows the change of system load with intake temperature and exhaust temperature. It is found that the change of system load has a large effect on exhaust temperature and small effect on intake temperature.

As shown in Figure 7, when the system load increases from 0 to 14 kW, the exhaust temperature is increased about 50°C. This may be caused by the higher biogas flow rate and so higher combustion temperature inside thecombustion chamber with increase of system load. The exhaust temperature is higher.

To understand the relation of biogas flow rate and the system load, Figure 8 shows the change of biogas flow as a function of system load at engine speed of 1500 rpm. It indicates that when the system load increases, both intake air flow and biogas flow increase. The biogas flow at system load of 14 kW is around 2.8 times higher than that of 2 kW. The reason of this is caused by the increase of volumetric efficiency with higher system load and so it is needed to intake more biogas. The speed regulator will control the throttle position to open more to keep the engine speed being constant at 1500 rpm or 50 Hz frequency.

Figure 9 presents the variation of engine emissions (NO_x and HC) as a function of system load. Increasing the system load increases significantly NO_x emission, but small increase in HC emission. In this case, the excess air ratio (biogas-air) was kept at a value of 1.1. So, when the system load changes, CO were used to combine with oxygen forming CO_2 emission. A small amount of CO emissions were found during the experiments. As shown in the figure, when the system load from 2 to 14 kW, the NO_x increases about 21 times while the HC emission increase around 10% higher. This is due to increase of combustion temperature at higher system load conditions that generates NO_x (NO, NO_2) formation.

In addition, the typical compositions of biogas

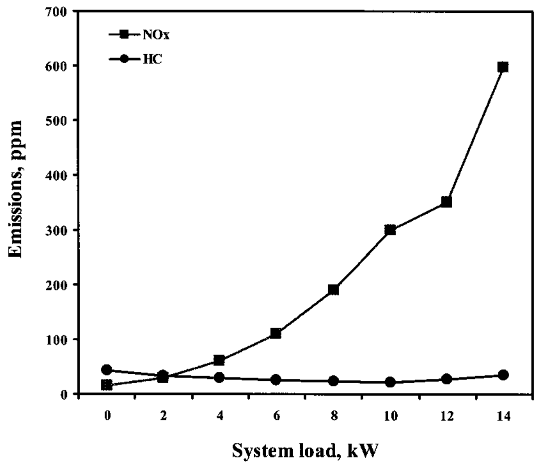

Fig. 9 Effects of system load on engine emissions.

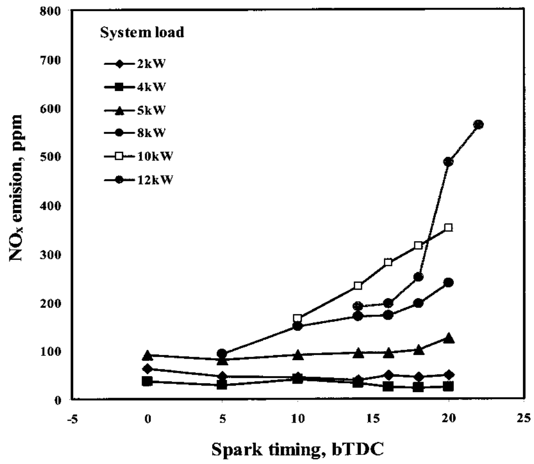

Fig. 10 Effects of spark timing on NOx emissions.

are CH_4 and CO_2. Therefore, the combustion of biogas did not generate too high HC emissions and its' emissions seems to close the combustion of CNG (Compressed Natural Gas, mainly CH_4).

To evaluate the effects of spark timings on NO_x emissions, the change of spark timing in a wide change is checked and Figure 10 indicates the variation of NO_x as a function of spark timings. Here, the spark timing is adjusted for a wide range from TDC (top dead center) to 20 degree crank angle before TDC. The system load is increased from 2 to 12 kW. For each value of spark timing, NO_x emission is measured for each value of system load. The obtained results show that there is a small change in NO_x emissions at the low load conditions.

At higher system load, NO_x emission increases with increase of spark timings and /or system load conditions. For the system load of 12 kW, the increase of NO_x is significant with the advance of spark timing. When the spark timing is adjusted from 14 to 22 bTDC, the NO_x emission increases about 3 times. The results of this tendency are caused by higher combustion temperature and faster combustion flame velocity of biogas-air mixtures at higher load condition and advanced spark timings.

5. Conclusions

Following are the conclusions based on the experimental results obtained while operating the power generation system using biogas fuel generated from the waste of pig farm. The preliminary findings are as follows:

1) Biogas fuel can be directly used in the SI engines without any large engine modifications, but it should be refined and upgraded to eliminate the harmful to human health and engine components.
2) Power generation system using biogas fuel shows the high stability of voltage output when the system load changes due to the developed electric speed regulator.
3) Properties and compositions of biogas fuel have small influenced the engine emission characteristics.
4) The output emissions exhausted from the SI engine was found to be low relatively when operating in biogas fuel. Increases of system

load will increase NO_x emissions.

Good stability for output voltage, reliability in engine operation, and low emission are the key factors for good power generation system using biogas generated from the waste of pig farm. These factors are highly influenced by power consumption/system load and the composition of biogas. For biogas as a fuel, these factors are mainly decided by the effectiveness of filtration system. To apply biogas as a fuel for further researches, the composition of clean biogas through filtration system should be studied to provide a useful substitute for gasoline and/or diesel thereby promoting our economy.

Acknowledgment

The authors of the paper would like to thank to the program of project JICA-SUPREM-HCMUT at HoChiMinh City University of Technology for the research fund. Also, the full support of Mr. Nguyen Huu Nhiem (Tan Uyen, BinhDuong Province) and the anaerobic digesters generated from his pig farm for biogas supplying system to power generation system is appreciated truly.

References

1) N. Mustafi et al., "Biogas Fuel for Internal Combustion Engines", Department of Mechanical Engineering, The University of Auckland.
2) M. T. Tran, X. M. Pham, D. H. Nguyen, T. C. Huynh, "Power Generation System using Biogas as fuel", IFOST 2010, University of Ulsan, Oct. 12-16, 2010.
3) K.C. Dharma, "Biogas Purification and Compression System", Training program in Kathmadu University, January 3, 2010.
4) V. G. Bui et al., "Optimization of Supplying System for Dual Fuel Biogas-Diesel Stationary Engine", Journal for Science and Technology, DaNang University, Vol. 5, 2008.
5) V. G. Bui, V. N. Tran, B. T. Le, "The 6th Seminar on Environment Science and Technology Issues Related to Climate Change Mitigation", Japan-Vietnam Core University Program, Osaka, Japan, 26-28 November 2008, pp. 243-250.