DEVELOPMENT OF HIGH EFFICIENCY COGENERATION SYSTEM USING BIOGAS FOR THE LOWER POLLUTION OF THE ENVIRONMENTAL

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ABSTRACT

The purpose of the study is development and investigation about basic performance of the system operation on a dual fueled cogeneration system(CGS), which is operated with biogas and gas oil. As often seen in dual fueled CGS performance, the electric generating efficiency was obtained about 26[illegible]. Methane contained in the biogas could not burn completely at lower load, and it was discharged into exhaust gas. Considerable amount of the methane burned in the exhaust pipe, and the heat recovery ratio was 42[illegible] on heat balance. As a result, the total heat efficiency, which is a summation of generating efficiency and heat recovery efficiency reached to about 70[illegible]. The supply of biogas into the engine reduces smoke density and NOx concentration in exhaust gas.

At lower load, methane burned slowly and large portion of it was discharged without burning. Therefore the measures are desirable that promotes combustion of methane at lower load.

Key Word : Environment, Biogas, Methane, Dual Fueled operation, Cogeneration system(CGS)

INTRODUCTION

From viewpoints of sustainable energy resources and waste treatment, the biogas production from organic waste is becoming popular especially in dairy farming. For the effective utilization of biogas, a small-scaled cogeneration system (CGS) that is operated with biogas was developed and its basic performance was investigated.

EXPERIMENTAL APPARATUS

The developed CGS is consists of dual fueled compression ignition(C.I.) engine which is operated with biogas and gas oil, synchronous generator, heat recovery system and electric control system (Fig. 1). Biogas is supplied into intake air and pre-mixed. In the combustion chamber, methane in the biogas catches fire from the flame of injected fuel, and then methane and gas oil burn simultaneously. This type of engine can be operative when there is no biogas. Therefore it can supply electricity and heat to a digester in startup process of it. But additional gas oil is necessary on operation. The engine through a timing belt drives a synchronous generator. The heat is collected with coolant from the water jacket of the engine and the exhaust gas heat exchanger. The specification of the engine and generator is shown in Table 1 and the appearance of the apparatus is shown in Fig. 2.

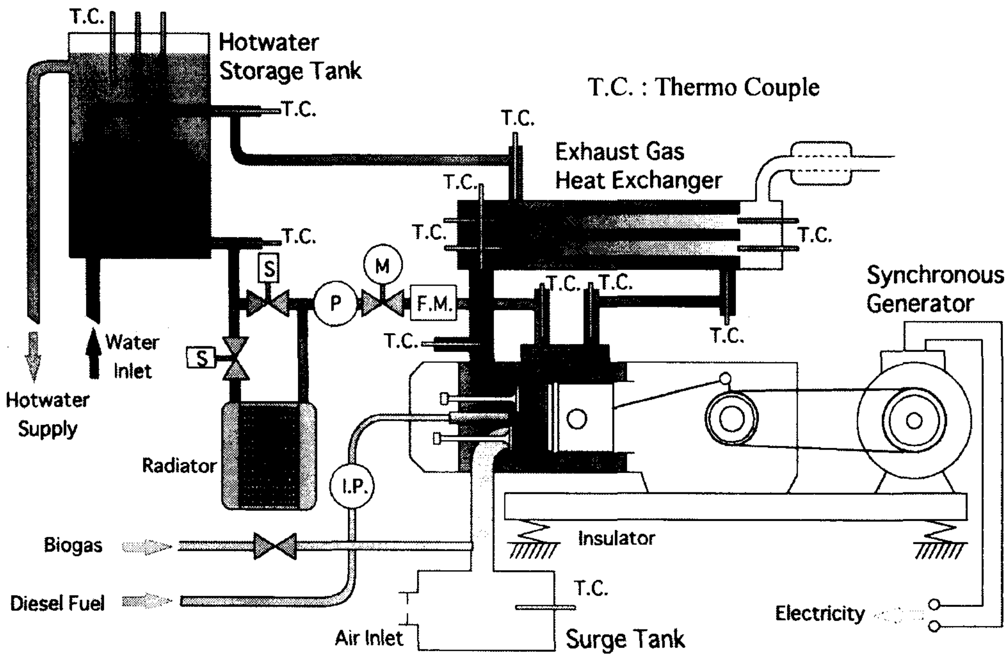

Fig. 1 Schematic diagram of developed biogas cogeneration system

Table 1 Specification of the engine and the generator

Engine type	Water cooled 4 stroke diesel Diesel
Number of cylinder	1
Type of combustion chamber	Direct injection
Displacement	0.309 L
Compression ratio	18.4 : 1
Rated power	4.0 kW / 2,600 rpm
Operating speed	1,800 rpm
Generator type	Synchronus type
Rated electrical power	3.0 kW
Rotation of generator	3,000 rpm
Frequency	50 Hz

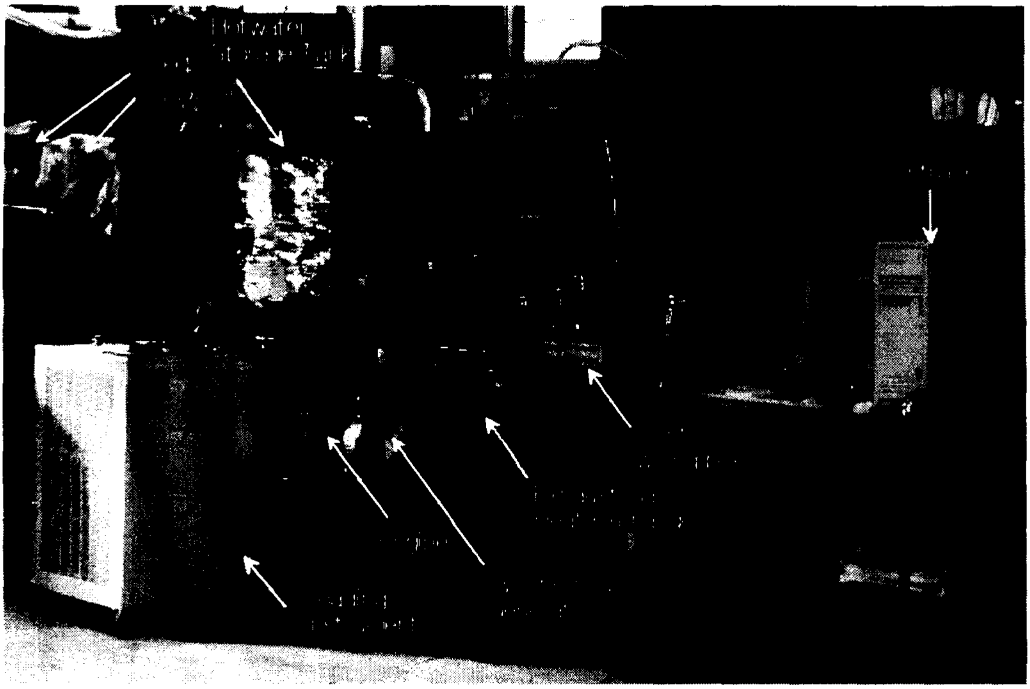

Fig. 2 Appearance of the biogas cogeneration system

RESULTS AND DISCUSSION

Control parameters in the experiment are biogas supply rate, which differ from 0 L/min (gas oil only) to 20 L/min, and electrical load, which differ from 0.6 kW (25% load)

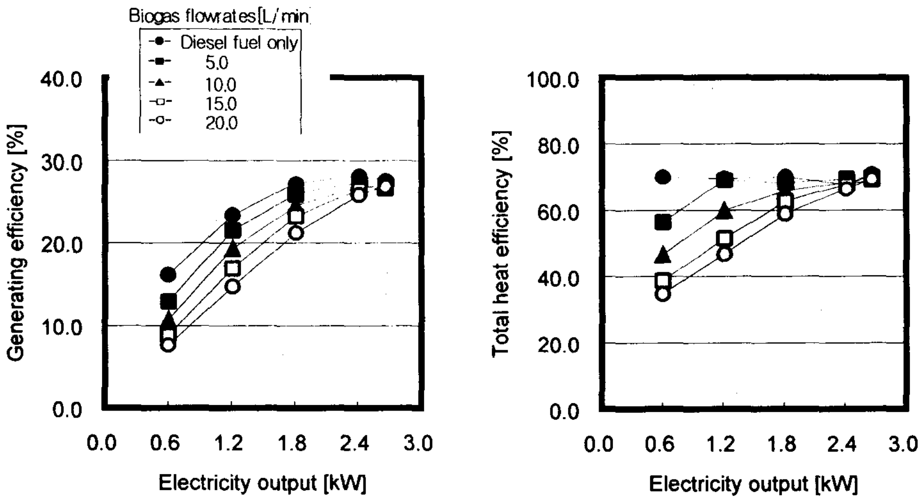

Fig. 3 Generating and total efficiency

to 2.66 kW (110% load). In additional experiment, methane concentration of biogas differs from 40 to 80 %at 2.4kW (100%)load and 20 L/min biogas supply.

The generating and total efficiency is shown in Fig. 3. The total efficiency is summation of generating and heat recovery efficiencies. As a general property of the biogas engine, the generating efficiency become lower as the load become lower. The cause of this property is mainly the discharge of methane which was not burned in the combustion chamber. When the CGS is operated with gas oil only, as the generating efficiency becomes lower, the heat recovery efficiency becomes higher, and the total efficiency is kept at about 70%. But in the dual fuel operation at the lower engine load, the unburned portion of methane becomes greater. Unburned methane does not release heat energy and CGS cannot collect its energy. As a result, the generating and total efficiency become lower at lower load.

The gas oil alternation ratio with biogas is shown in Fig. 4. At the most appropriate condition of 2.4kW load and 20L/min biogas supply, about 70% of the output energy is supplied from biogas.

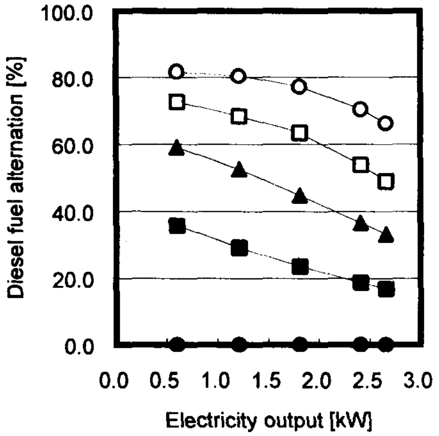

Fig. 4 Gas oil alternation ratio

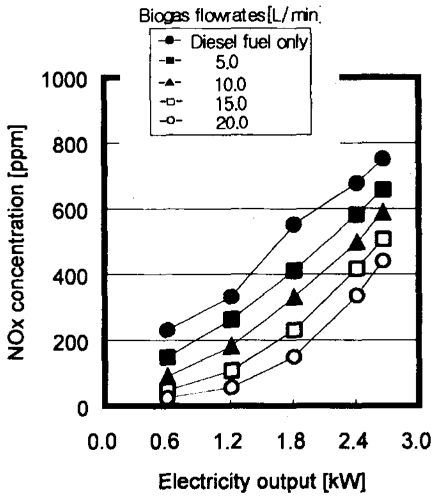

Fig. 5 NOx concentration of exhaust gas

A major merit of biogas utilization on internal combustion engine is to make cleaner its exhaust gas emission. The effect on the reduction of the nitrogen oxide (NOx) by biogas is clearly shown in Fig. 5. NOx is the major pollutant in diesel exhaust gas and is major hazard to use C.I.engine. At rated load, NOx concentration is decreased by one second, at 50% load it is decrease by one fifth as a result of 20 L/min biogas supply. Natural gas generally resembles biogas in combustion property, because it consists of about 90% methane, which is main constituent of biogas. Exceptionally, the NOx emission is increased when natural gas is used as engine fuel. This property is in contrast to that of biogas. The difference between biogas and natural gas is the existence of carbon

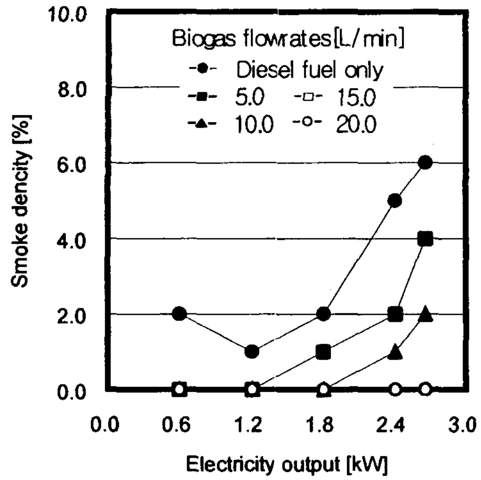

Fig. 6 Smoke density of exhaust gas

dioxide. The generation of NOx is primarily promoted with temperature, therefore the reduction of it by biogas would be the decline of combustion temperature. The oxygen is partly displaced by CO 2 in mixture air. The temperature of combustion gas is almost proportional to the density of heat release, which is proportional to a concentration of O 2 because the amount of O 2 per volume limits the combustion.

The smoke density is also decreased with biogas supply (Fig. 6). When biogas is supplied the amount of injected gas oil is decreased. So the generation of smoke is reduced because it is made from fuel droplets.

The cylinder pressure, heat release rate are shown in Fig. 7. At 2.4 kW load, the ignition delay get longer but the period of combustion and the average heat release rate do not so differ. So there are no significant decreases of efficiency although engine noise becomes quieter as a result of decline of the maximum pressure. But at 0.6 kW load, as a result of biogas supply, the ignition delay and combustion period become greatly longer and the heat release rate get lower. So the released heat cannot be converted to mechanical work effectively but to high temperature of combustion gas. Therefore the measures are desirable that promotes combustion of methane at lower load.

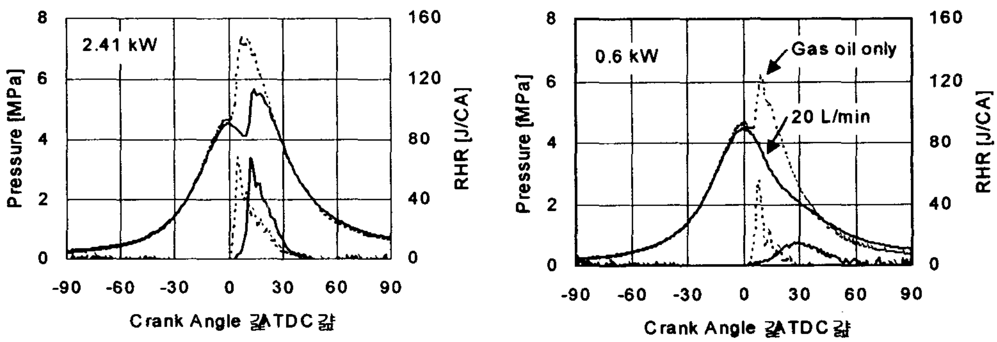

Fig. 7 Cylinder pressure and heat release rate

CONCLUSIONS

1. A small-scaled biogas cogeneration system, which is driven with dual fuel diesel engine, is developed.
2. The generating efficiency is about 26~28 %at higher load, but it is decreased at lower load.
3. Biogas reduces the pollutant in the exhaust gas of dual fuel diesel engine.
4. At lower load, methane in biogas does not burned and released heat cannot be converted to power of the engine.
   So the developments of measures, which promote the combustion of methane, are important.
5. As often seen in dual fueled CGS performance, the heat recovery ratio was 42% on heat balance. As a result, the total heat efficiency, which is a summation of generating efficiency and heat recovery efficiency reached to about 70%.

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