Development of Biomass/Waste Power Generation System with Carbonizing Gasifier and Gas Engine

Background

To create a sustainable recycle-oriented society, it is important to develop the utilization technology for biomass and solid waste, which are promising energy resources. In general, biomass and solid waste are widely and thinly distributed, so it is not easy to gather up them in large amounts. Therefore it is difficult to improve the generating efficiency of the biomass and solid waste power generation system through adoption of large-scale operations.

Objectives

The aim of our project is to suggest a small-scale and high-efficiency power generation system utilizing biomass and solid waste. The integration of carbonizing gasification technology and the gas engine technology allows such a power generation system. The performances of the carbonizing gasifier and the gas engine are evaluated with the demonstration test facilities as a joint research of CRIEPI and Kansai EP (Kansai Electric Power Co., Inc.), in order to put the developed system to practical use.

Principal Results

1. Features of the system

CRIEPI has developed the carbonizing gasifier using biomass and solid waste as fuel. On the other hand, Kansai EP has developed the small and high-efficiency gas engine generator with natural gas. The small-scale and high-efficiency power generation system with biomass and solid waste (as shown in Fig.1) has been devised by integration of both technologies. The installation of carbonizer, as a pretreatment of gasifier, makes it possible to use a variety of fuels. The utilization of waste heat from the gas engine, as a heat source of the carbonizer, results in high thermal efficiency of the system.

2. Performance of carbonizing gasifier

A gasification test (as shown in Fig.2) of Japanese cedar as a typical woody biomass was carried out. Table 1 shows the industrial analysis and ultimate analysis of Japanese cedar. As the result of the test, the calorific value of produced gas was higher than 1,000kcal/m3N by maintaining air ratio of 0.42 or less. The performance of gasifier achieved cold gas efficiency over 67.5% (calorific value of produced gas 1,170 kcal/m^3_N, carbon conversion over 99%) at 0.39 air ratio.

3. Performance of gas engine

The original gas engine generator (rated power 440kW) runs on natural gas, and has adopted a pilot ignition system which shows high ignition performance. The gas-supplying system of the gas engine was redesigned for the low-calorie gas. In case of the produced gas, of which calorific value is about one-tenth of that of natural gas, the rated power of the gas engine was 320kW, and the generating efficiency of the gas engine reached 34% in LHV basis. Furthermore, the stable operation of the gas engine with a low-calorie produced gas, of which calorific value is 850kcal/m^3_N, was carried out by optimization of fuel-feeding condition. It means that high-moisture biomass is available as the fuel of this system. Fig.3 shows the operation condition of the gas engine.

4. Performance of the system

In the operation of the carbonizing gasification and gas engine power generation system with biomass and waste, the performance targets of gasifier and gas engine were attained (as shown in Table 2). The combined efficiency of the gasifier and gas engine power generation system was over 23% on LHV basis. So, the system was found to be small-scale, but to have an extremely-high performance (as shown in Fig. 4).

Future Developments

Some modifications of the system for higher performance will be made. The heat transfer test of the gas-gas heat exchanger will be planned. The test data will be useful in the design of the exhaust gas heat exchanger. The feasibility study on the practical plant of this system with food-processing waste will be carried out.

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Reference

M. Otaka, M. Ashizawa, K. Kidoguchi and M. Tashiro, 2007, "Development of High-Efficiency Small-Scale Biomass Gasification Process", Proceedings of 3rd International Bioenergy Conference and Exhibition (BIOENEGY 2007), Finland, pp.499-505.

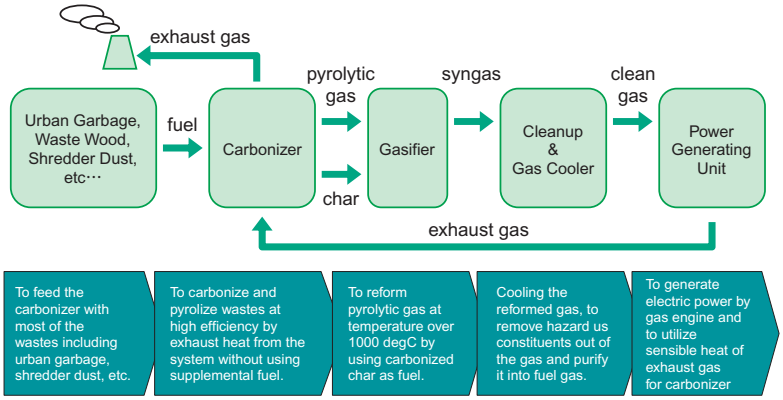

Fig.1 Basic flow of carbonizing gasification gas engine power system

Table 1 Industrial analysis and ultimate analysis of woody biomass (cedar)

industrial analysis	moisture	6.0 - 7.3	wt%
	ash	0.2	wt%,db
	VM	84.5	wt%,db
	FC	15.3	wt%,db
ultimate analysis	C	50.30	wt%,db
	H	6.21	wt%,db
	N	0.06	wt%,db
	O	43.21	wt%,db
	S	0.02	wt%,db
higher heating value		19.84	MJ/kg

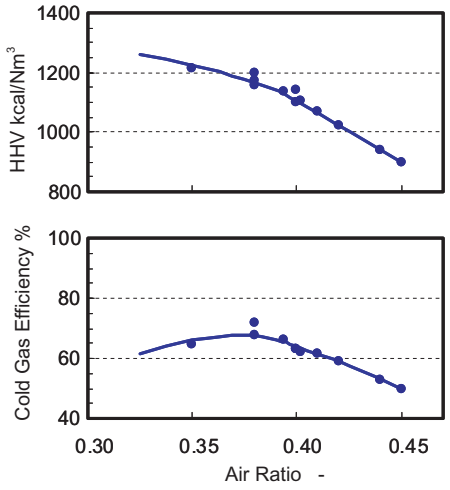

Fig.2 Gasification performance of cedar

A decrease in air ratio increases calorific value of produced gas, but air ratio under 0.39 increases unburnt carbon, and decreases cold gas efficiency.

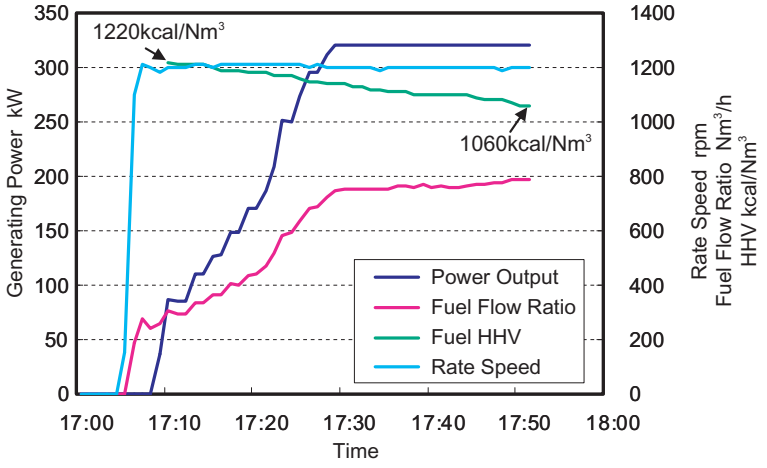

Fig.3 Operation condition of gas engine (decreasing HHV of fuel gas)

The calorific value of produced gas decreases from 1220kcal/m^3_N to 1060kcal/m^3_N, the gas engine generator is to be stably-operated. Therefore, the rated power and rated speed maintain the constant value 320kW and 1200rpm respectively.

Table 2 Performance of present system

	unit	target	actual
higher heating value of produced gas	kcal/m^3_N	1000	1000-1250
cold gas efficiency	%	65	67.5
carbon conversion	%	90	99
flow rate fluctuation	%	15	10
generating efficiency of gas engine	%,LHV	32	34
total efficiency of system	%,LHV	20	23

As a result of the demonstration test, the carbonizing gasifier and gas engine showed good performance exceeding the targets. Total generating efficiency of the system reached 23% on the LHV basis.

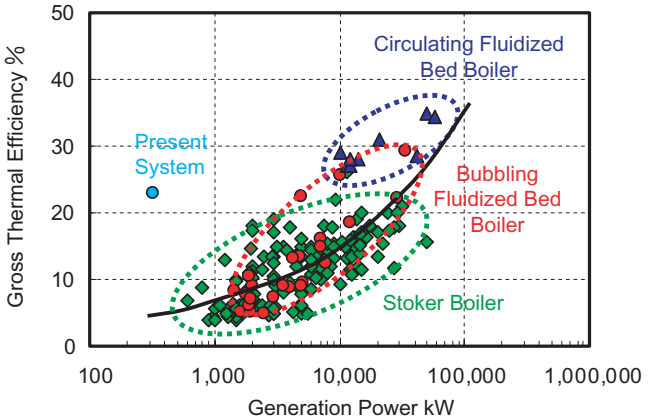

Fig.4 Comparison with other biomass-fired power plants

The new biomass/solid waste power generation system co-developed with Kansai EP is small-scale, but shows higher efficiency than other biomass/solid waste-fired power systems.