The development of gasification system for sewage sludge

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Introduction

With respect to the effective collection system, sewage sludge is an ideal biomass source. The amount of sewage sludge in Japan reaches as much as 2.13 million dry-t/year. However, most of the energy of the sewage sludge has not been utilized due to its high moisture content and many ashes.

Therefore, we developed a technology to extract and utilize energy from the sewage sludge. Using the waste heat from the gas engine and the gasifier for drying the sewage sludge enables a highly efficient system. After development of a pilot plant, we built and operated a demonstration plant under a joint project with New Energy and Industrial Technology Development Organization (NEDO) in Japan.

Outline of the demonstration plant

Table 1 Specification of gasification system.

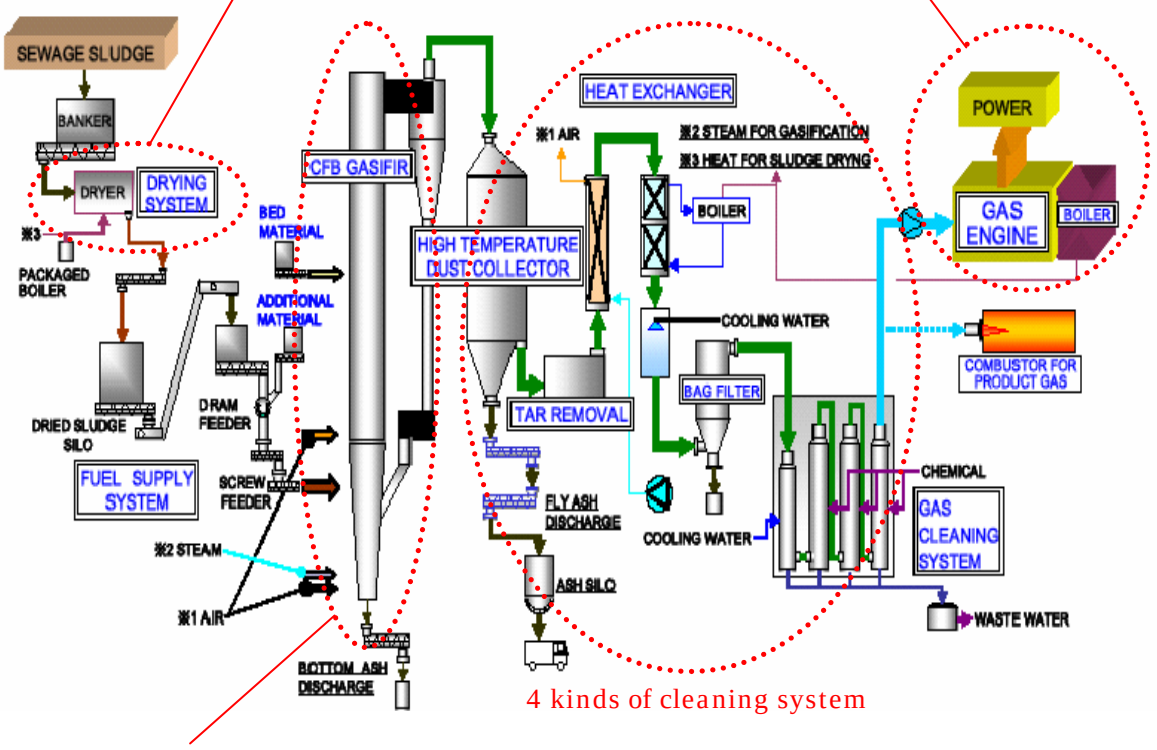
Gasifier	Circulating Fluidized Bed System
Raw Material	Sewage sludge
Air ratio	0.3-0.4
Gasification temperature	850-900 C
Calorific value	18-20 MJ/kg-dry
Capacity	15t/day (80%wet)
Gas yield	350-400Nm^3/day (wet)
Dryer	Heat conduction system for steam
Gas cleaning system	High temperature dust collector＋Tar removal ＋Baghouse filter＋Wet scrubber
Gas engine	GE-Jenbacher-JMS208 200kW (At the gasification gas 100%)

Advantages of this system

- The sludge can be incinerated and used as energy source, simultaneously.
- This system is highly-efficient because it uses the waste heat for sludge drying.
- The disposal of the residual is treated as that of the conventional incineration residual.

The sewage sludge is dried by using waste heat from the gasifier and the gas

The gasification gas is mixed with city gas and supplied in the gas engine.



4 kinds of cleaning system

The dried sludge is gasified with preheated air and steam at air ratio of 0.35-0.4 at 850-900 C.

Fig. 1 Flow diagram of gasification system.

Results of the gasification tests

(1)Optimization of operating condition

・The optimum operating condition for the gasification was studied in 2006.

Table 2 Gasification gas compositions.

H_2	9-12 %dry
CO	7-9 %dry
CH_4	3-4 %dry
C_2H_4	1-2 %dry
C_3H_6	0.1-0.2 %dry
CO_2	14-16 %dry
N_2	57-60 %dry
Heat value	3.4-5.0 MJ/Nm^3

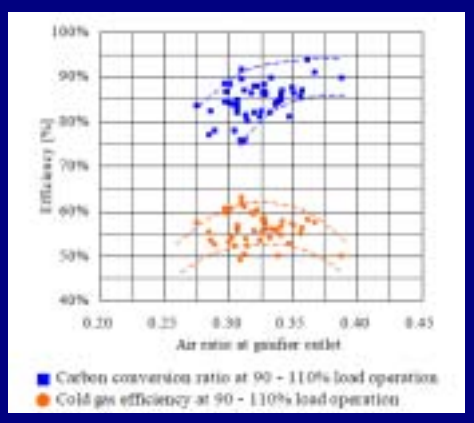


Fig. 2 Correlation between air ratio and gasification efficiency.

Optimum Air ratio： **0.3-0.35**
Cold gas efficiency： **Max 65%**
Carbon conversion ratio： **Max 95%**

(2)Durability test

・Based on the optimum operating condition, the durability test was conducted 90 days in 2007.

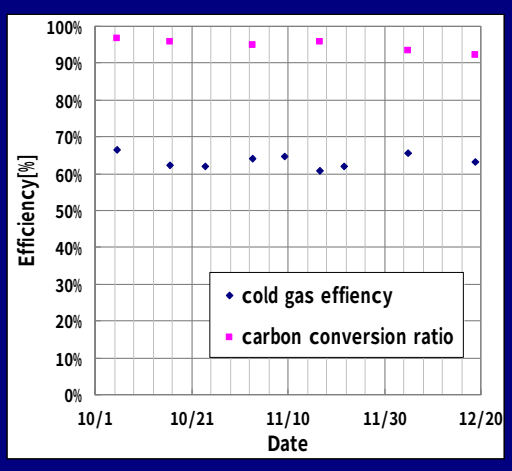


Fig. 3 Change of the cold efficiency and carbon conversion ratio.

Continuously operation time：**2000hours**
Cold gas efficiency： **Ave 62%**
Carbon conversion ration： **Ave 94%**

Results of the engine tests

GE-Jenbacher-JMS208

Reasons of city gas mixing

(A) The amount of the heat from the gasifier and the generator is not sufficient for drying sewage sludge. Adding city gas enables a highly effective system.

(B) The amount, the compositions, and the carolific value of the gasification gas fluctuate, but adding city gas makes them more stable.

(C) Not many engines can run with the gasification gas due to the very low calorific value and the operations of gas engines with it leads to low power output and low power generation efficiency.

(1)Removal characteristic of minor harmful components

Table 3 Removal characteristic of minor harmful components.

	Outlet of gasifier	Inlet of scrubber	Outlet of scrubber	Removal ratio
Tar(g/Nm^3)	3.2	0.13	0.07	97.8%
NH_3(ppm)	36620	408	3.3	99.9%
HCN(ppm)	349	2.1	0.3	99.9%
SOx(ppm)	147	28	1.6	98.9%
H_2S(ppm)	138	388	0.1	99.9%
N_2O(ppm)	<1	-	<1	-

No problem to drive gas engine

(2)Gas engine test

Table 4 Results of gas engine operation.

Mixing ratio of gasification gas	%cal	0	14.5	23.1	33.5	38.9
City gas input	m^3_N/h	45.7	39	34.9	30.4	28.1
Gasification gas input	m^3_N/h	0	81.6	129.9	188.0	221.6
Efficiency	%	38.7	38.7	38.8	38.7	38.4

Although the calorific value of the fuel decreased with the increase of the ratio of gasification gas, the power generation efficiency was almost constant.

The reason can be the burning velocity increase by the presence of H_2 and the increase of specific heat ratio with increasing CO_2 concentration.

Evaluation of environmental impacts

(1) Comparison of primary energy consumption

Table 5 Calculation condition of primary energy consumption.

Capacity for sewage sludge		150 ton/day
Power generation output of the gas engine		6800 kW
Primary energy conversion coefficient	Electric power	9.76 MJ/kWh
	City gas	45.00 MJ/ m^3_N

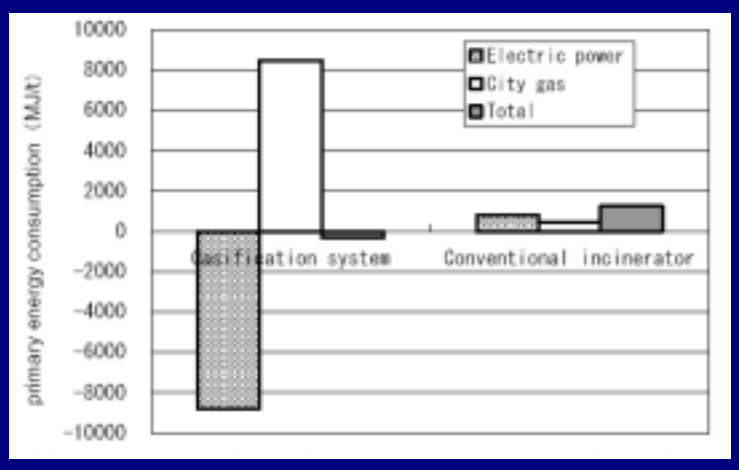


Fig. 4 Comparison of primary energy consumption.

(2) Comparison of green house gas emission

Table 6 Calculation condition of green house gas emission.

Capacity for sewage sludge		150 ton/day
Power generation output of the gas engine		6800 kW
CO_2 emission	Electric power	0.555 kg- CO_2/kWh
	City gas	2.290 kg- CO_2/kWh
N_2O emission of conventional incinerator		0.645 kg-N_2O/t

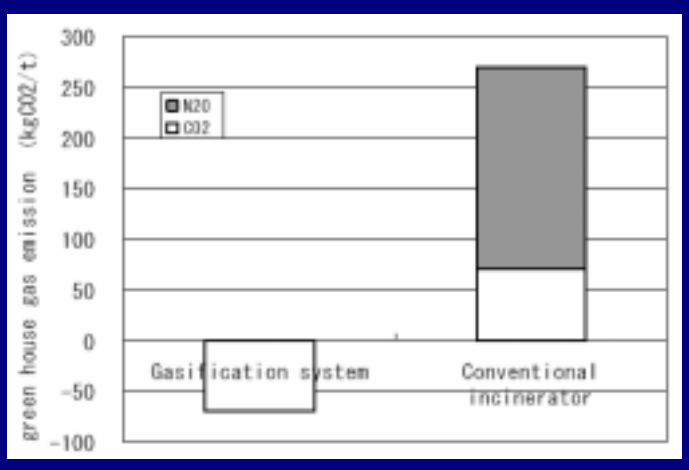


Fig. 5 Comparison of green house gas emission.

Conclusions

1. Stable and highly efficient gasification operation for over 90 days was achieved using sewage sludge.
2. Minor speceis such as tar, NH_3, HCN, SOx, and H_2S in the gasification gas can be removed by the cleaning system.
3. A gas engine CHP system can stably be operated over a full range of mixing ratio (0% - 100%) of gasification gas and city gas.
4. City gas addition to the gasification gas was proved effective to have higher power outputs and higher power generation efficiency, which leads to a key technology in efficient energy utilization of biomass.
5. Our gasification system can offer advantages with respect to primary energy consumption and environmental impacts compared with the conventional incineration systems.