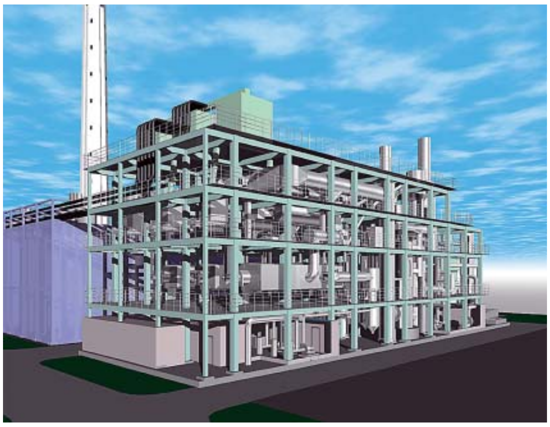

Biomass Solid Fuel Production from Sewage Sludge with Pyrolysis and Co-firing in Coal Power Plant

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MHI has developed a carbonization system to recycle sewage sludge for electric power generation fuel. The technology can satisfy two needs at the same time: first, the need to recycle sludge and suppress the emission of global warming gases in sewage sludge treatment plants; second, the need to substitute fuel with carbon-free fossil fuel in thermal power plants. The main component of the system is an indirectly heated rotary kiln of a type already in practical use in power generation facilities with gasified wood waste. The kiln was considered optimal for the system in light of its ability to produce pyrolysis coke steadily and efficiently from sewage sludge. Bio Fuel Co., Inc. placed an order with MHI for the construction of a sewage sludge carbonization facility, the first facility to use the sewage sludge for power generation fuel by converting it to carbonized fuel. The construction is scheduled to be completed within 2007.

1. Introduction

The use of biomass as a new energy is being promoted to prevent global warming by reducing greenhouse effect gases and to use waste more effectively for the realization of a recycling-oriented society. To use the energy from biomass resources, energy producers must find mechanisms that meet the needs of business entities for achieving stable supply, economic efficiency, and adequate control of fluctuating fuel properties during the processes of biomass collection, energy conversion, and the use of the biomass resources.

MHI has been engaged in energy conversion and the development of utilization technologies and practical applications relative to various types of biomasses based on the environmental equipment technologies and energy conversion technologies the company has accumulated through its work to solve environment and energy challenges. In this connection, MHI has developed a technology of a carbonization system, excellent in stabilizing supply and properties, to recycle sewage sludge as a fuel for power generation. This new system can satisfy the needs for sewage sludge treatment ,for reduced emission of global warming gases, and for carbon-neutral fuel utilization in thermal power plants.

This describes the progress of our efforts to realize the world's first "sewage sludge carbonization business" through the approach described above.

2. Outline and advantage of the sewage sludge carbonization system

2.1 Outline of the system

Fig. 1 is a flow diagram of the carbonization system and **Table 1** shows the major system specifications.

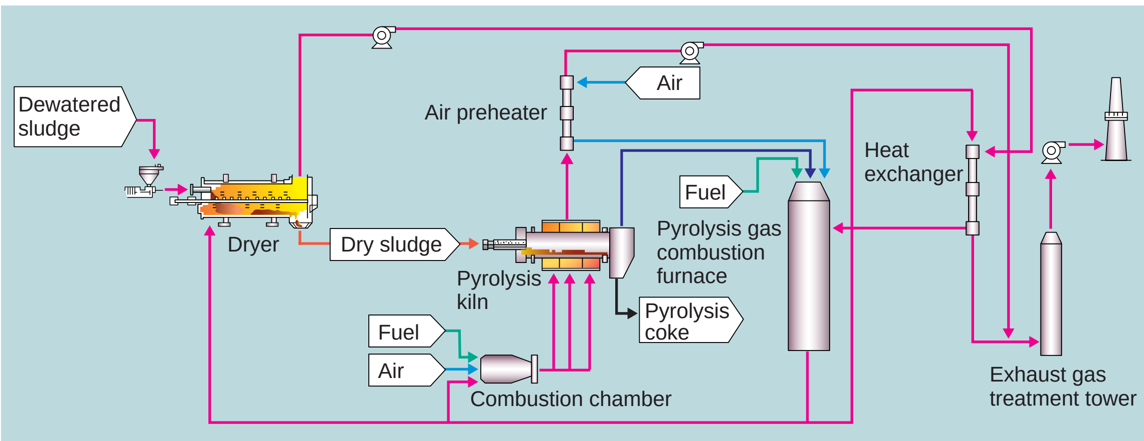

Fig. 1 Flow diagram of sewage sludge carbonization system
Plant system configuration diagram

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Table 1 Major equipment specifications for the sewage sludge carbonization system

Item	Specification
Dryer	Hot air dryer with rotary kiln type agitator
Pyrolysis kiln	Indirectly heated rotary kiln
Pyrolysis gas combustion furnace	Cylindrical furnace insulated by a fire-resistant construction
Exhaust gas treatment	Wet gas scrubbing tower

MHI has concentrated its technologies to realize a system that makes the properties of the sewage sludge carbonized fuel stable and safe, and that can perform the carbonization with a small amount of fossil fuel utilities. The system shown below is now configured.

This system consists of three processes: carbonization, pyrolysis gas combustion and waste heat recovery, and exhaust gas treatment. In the drying process, dewatered sludge with a water content of about 76% is dried to a sludge with a water content of about 25% directly with a gas heating dryer with agitator. Dewatered sludge charged into a rotating drum is dried efficiently by direct contact with hot exhaust gas of 800 to 850°C during agitation by an agitator installed inside the drum. Once the sludge is dried, the dryer exhaust gas used to dry it drops to a temperature of 200°C and is combusted and deodorized in the subsequent process. A water dry sludge water content of about 25% helps to reduce the consumption of the fossil fuel utilities of the system and reduce the influence of the load fluctuation of the water content during the carbonization process in the later step.

In the carbonization process, pyrolysis coke is obtained by heating the dry sludge to about 500°C and pyrolyzing it with an indirectly heated rotary kiln in a low oxygen atmosphere. The dry sludge is indirectly heated and pyrolyzed with hot gas at a temperature of about 950 to 1,100°C. After being cooled by the cooling conveyer, the pyrolysis coke produced is humidified to prevent spontaneous ignition, and then treated as carbonized fuel. In the pyrolysis gas combustion and waste heat recovery process, the pyrolysis gas and dryer exhaust gas generated in the pyrolysis kiln are blown with air by an independent combustion furnace (pyrolysis gas combustion furnace) and combusted at high temperature (950°C). A part of the combustion exhaust gas is used as the heat source for the indirectly heated rotary kiln. The waste heat is recovered by two heat exchanges: one between the combustion exhaust gas of the pyrolysis gas and the dryer exhaust gas, and one between the combustion air and the combustion exhaust gas after the heating of the pyrolysis kiln.

In the exhaust gas treatment process, the exhaust gas generated during the combustion process is desulfurized (SOx) and desalinized (HCl) in an exhaust gas treatment tower, cooled and dehumidified, and treated for removal of soot and dust by an wet electric precipitator, if required. If necessary, white smoke prevention is carried out at the outlet of the stack.

2.2 Advantages of the system

(1) Stable carbonization by indirect heating

By adopting indirect heating with hot combustion gas from outside of the rotary kiln, the water vaporization and heating temperature rise take place more slowly than they do during direct combustion inside the kiln. As an added advantage, the pyrolysis conditions never fluctuate rapidly, even if the water content of the sludge does. Thus, a stable heating pyrolysis is ensured.

The inside of the muffle for the heating gas around the kiln circumference is divided into multiple divisions in a longitudinal direction, and the respective heating gas amounts can be adjusted. With this kiln configuration, the heating value distribution can be adjusted to suit the water content of the sludge. Thus, pyrolysis coke of constant quality can be obtained by stable pyrolysis gasification.

(2) Hot and clean combustion and the use of pyrolysis gas

An independent pyrolysis gas combustion furnace is installed in this system for the clean combustion of the pyrolysis gas at high temperature and the combustion and deodorization of dryer exhaust gas containing odorous components. By adopting an independent combustion furnace, the pyrolysis gas can be combusted at an appropriate air ratio and combustion temperature, enabling stable and clean combustion. The released N_2O (dinitrogen monoxide), a gas with a greenhouse effect 310 times more potent than that of carbon dioxide, can be reduced to levels far lower than the levels released by the fluidized bed incinerator generally adopted for sewage sludge treatment.

(3) Reduction of the fossil fuel utilities through the recovery and use of waste heat

Multiple heat exchangers provided in this system take the combustion heat of the pyrolysis gas generated from the sewage sludge and effectively use it as the heat source for the drying and carbonization processes. The combustion exhaust gas generated after heating the indirectly heated rotary kiln is used as a heat source for preheating the combustion air. The combustion exhaust gas of the pyrolysis gas is used as a heat source to preheat the dryer exhaust gas before this gas is introduced into the combustion furnace. The heat recovery from these combustion exhaust gases reduces the amount of fossil fuel utilities.

1. Properties of the sludge and pyrolysis coke, and evaluation of the reduction in the environmental load
- Survey of sewage sludge properties and pyrolysis coke properties
- Evaluation of the environmental loading reduction effect during fuel utilization by sewage sludge carbonization

2. Carbonization test and carbonized fuel evaluation (Verification of item 1 above)
- Performance verification of carbonization system
  - Operation stability
  - Environmental impact such as exhaust gas, waste water, etc.
- Evaluation of carbonized fuel
  - Combustion properties (ignitionability, exhaust gas, combustion ash)
  - Handling properties (grindability, dust dispersion, etc.)
  - Safety (spontaneous ignition property, dust explosion)
  - Harmfulness (bacteria, elution)

3. Test with an actual coal-firing thermal power generation plant
(Cooperation with an electric power company that uses carbonized fuel)

Fig. 2 Major verification and evaluation items aiming at the use of the carbonization system and carbonized fuel
(Approach aiming at practical application)

Fig. 3 External view of the demonstration facility
An external view of the demonstration facility is shown.

3. Developments aiming at practical application

MHI has completed the verification tests shown in **Fig. 2** to assess the use of the carbonization system for the production of carbonized fuels from the sewage sludge, and to assess the use of carbonized fuels for co-firing in a pulverized coal firing boiler (a facility developed under the joint development projects with Tokyo Electric Power Company, Inc. targeting the use of sewage sludge pyrolysis coke as power generation fuel). The verification data on operability of the carbonization system and the evaluation of the carbonized fuel are shown below.

(1) Verification of operability of carbonization system

We carried out a test to verify the stable operability of the system and the stability of the properties of the fuels produced. The test system is assumed to be an actual system consisting of a dryer and pyrolysis kiln. Various conditions, such as fluctuating amounts of inlet input, are set using an integral system. **Fig.3** shows an external view of the test facility. The system consists of a dryer and sludge carbonization facility now under operation in the Yokohama Dockyard & Machinery Works of MHI. The combustion exhaust gas of pyrolysis gas was used as the heat source for the dryer and pyrolysis kiln for drying and carbonizing, respectively.

According to the operation method of the dryer, the hot exhaust gas of the pyrolysis gas combustion furnace is introduced into the dryer with the fan at the dryer outlet, and the water content of dry sludge is adjusted to about 25% by adjusting the amount of the hot exhaust gas from the pyrolysis gas combustion furnace to a level that brings the dry exhaust gas temperature at the dryer outlet to about 200^{o}C. The carbonization conditions in the pyrolysis kiln are adjusted by adjusting the amount of exhaust gas from the pyrolysis gas combustion furnace to a level that brings the carbonization temperature to about 500^{o}C.

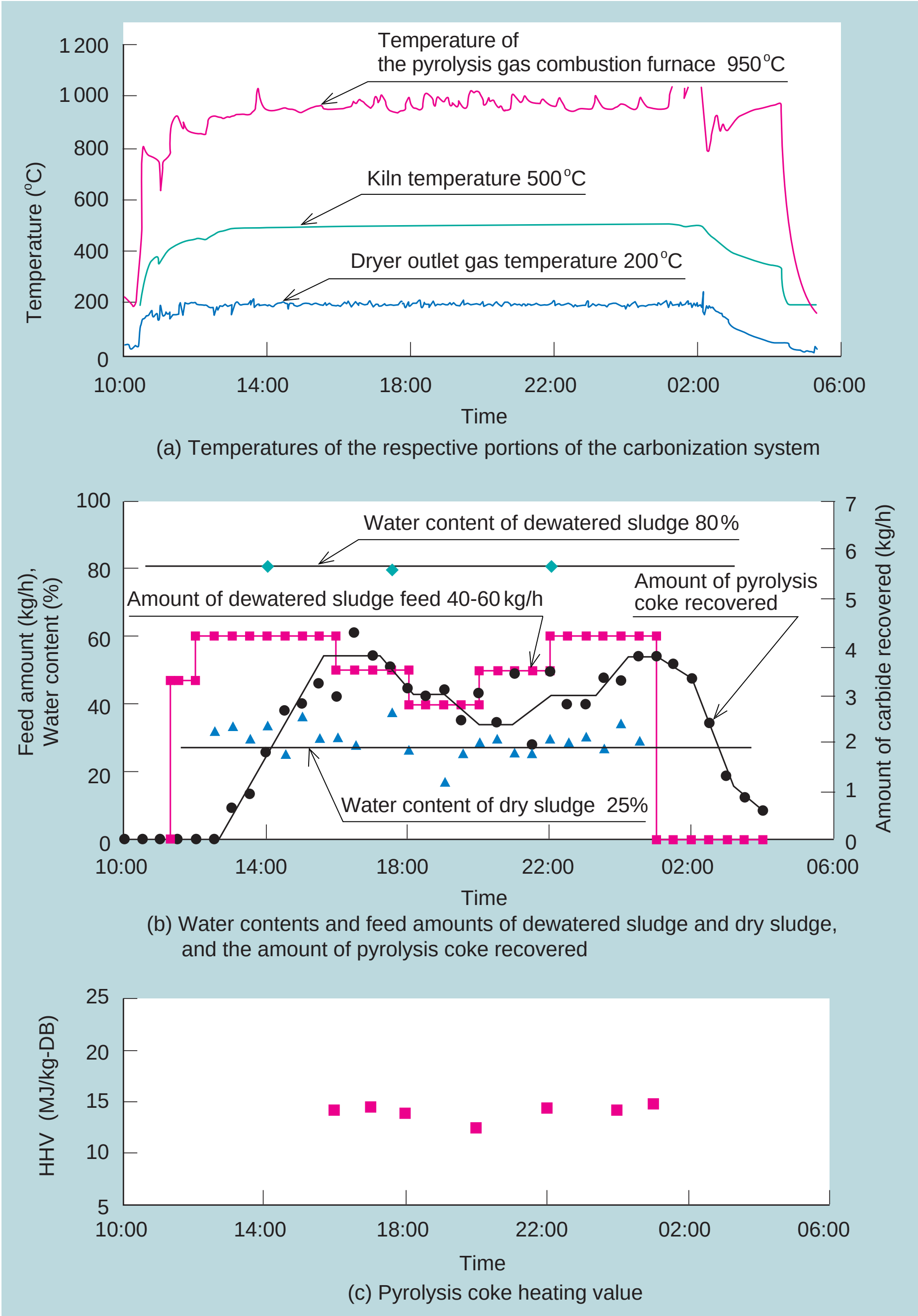


Fig. 4 Operation of the carbonization system
Pyrolysis coke can be stably produced by controlling the dryer outlet temperature and pyrolysis temperature to constant values.

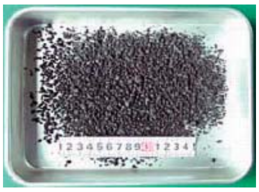
Furthermore, a hot gas producer is installed at the inlet of the pyrolysis kiln to adjust the exhaust gas temperature of the pyrolysis gas combustion furnace to an arbitrary temperature and to provide a heat source for the pyrolysis kiln.

Fig. 4 shows the test results. The respective figures verify the stability of the system when the sludge supply amount is varied. Even if the dewatered sludge supply amount varies from 60 to 40 kg/h, the dry sludge water content is stabilized at about 25 +/–10% during operation. The carbonization temperature is also stably controlled. The heating value of the obtained pyrolysis coke is stable, as shown in Fig. 4(c).

(2) Evaluation of carbonized fuel properties

Table 2 shows the properties of sewage sludge and carbonized fuel, and the appearance of the carbonized fuel. The carbonized fuel has a heating value of about half that of coal. The fuel particles measure several millimeters in diameter and can be handled in the same manner as the coal for the existing pulverized coal firing boiler. The grindability is excellent, hence the fuel can be ground by a coal pulverizer without any problems. A combustion test has confirmed that fuel mixing combustion of several cal % with coal leads to no problems with ignitability or flammability.

Table 2 Properties of sewage sludge and pyrolysis coke

		Dewatered sludge	Pyrolysis coke
Water content	(wt. %-WB)	79.7	–
Ash content	(wt. %-DB)	17.7	55.3
Combustibles content	(wt. %-DB)	82.3	44.7
C	(wt. %-DB)	44.4	38.6
H	(wt. %-DB)	6.5	0.8
N	(wt. %-DB)	4.5	3.0
S	(wt. %-DB)	0.82	0.62
Cl	(wt. %-DB)	0.09	0.05
HHV	(kJ/kg-DB) (kcal/kg-DB)	20 040 (4 790)	13 950 (3 330)
Appearance of carbonized fuel			

The sewage sludge pyrolysis coke has a spontaneous ignitability like that of coal, but this property can be suppressed by adjusting the carbonization temperature in the carbonization system and by humidifying the pyrolysis coke to 10–20 %.

4. Practical application of technology to convert sewage sludge to fuel by carbonization

MHI received an order to construct a sewage sludge carbonization facility from Bio Fuel Co., Inc. (subsidiary company of Tokyo Electric Power Company, Inc.), a company engaged in the sewage sludge carbonization business. The facility is now under construction in the Tobu Sludge Plant of Tokyo Metropolitan Government. The construction is scheduled to be complete within 2007. The project is to annually produce 8,700 tons of carbonized fuel from 99,000 thousand tons of sludge, and to use this fuel as an alternative to coal.

5. Conclusion

This article has described the development of a carbonization system for sewage sludge, studies on the use of fuel produced for power generation, and the progress towards the realization of what will be Japan's first sewage sludge carbonization business.

In the future we intend to practically apply and promulgate the fruits of these efforts in response to the public demand for the promotion of the effective use of carbon neutral biomass resources, and to further develop and improve related new technologies.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