DIOXINS CONTROL AND HIGH-EFFICIENCY POWER GENERATION IN A LARGE-SCALE GASIFICATION AND MELTING FACILITY

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Abstract

Shin-Moji Plant in Kitakyushu City is one of the world's largest gasification and melting facilities and has a processing capacity of 720 tons/day-scale (240 tons/day-scale × 3 furnaces). We introduce combustible dust collection and injection technology to the facility, which has proved to be effective in improving the combustion characteristics in the combustion chamber in the experimental plant. In Shin-Moji Plant, we achieve low dioxin concentrations such as 0.0059 ng-TEQ/m^{3}N in the exhaust gas at the stack, 0.18 ng-TEQ/g in the treated fly ash, and a total emission of 7.6 μg-TEQ/t-waste. In addition, with the high-temperature and high-pressure (400°C and 4MPa) steam collected by waste-heat boilers and a water-cooled condenser introduced to the facility, the generation-end efficiency of the waste power generation has improved up to 23.0%. All of the slag and metal collected at the facility are recycled, while only treated fly ash is to be landfilled as final residue.

1. Introduction

The municipal solid waste direct melting system is a shaft-type gasification and melting furnace. Combustible substances are gasified in the upper space of the melting furnace. This pyrolysis gas is burnt in the combustion chamber, improving in combustion characteristics and reducing concentrations of emitted dioxins. Incombustible substances, on the other hand, descend to the lower part of the melting furnace and are melted in a high-temperature coke bed layer, with collected slag and metal utilized efficiently. The system, featuring high adaptability to various types of wastes, has increasingly demonstrated practical applications. Today our development efforts focus on the scale-up of the shaft-type gasification and melting furnace to meet the need for wide-area waste treatment projects expected, for example, in metropolitan areas.

Shin-Moji Plant in Kitakyushu City, which completed its experimental operation in March 2007 (240 tons/day-scale × 3 furnaces), is one of the biggest large-scale gasification and melting facilities in the world. The facility, making the most of the advantages of the direct melting system, aims to reduce the gross emission of dioxins outside of the system and improves the efficiency of waste power generation through the collection of high-temperature and high-pressure steam collected by waste-heat boiler and the introduction of a water-cooled condenser. This paper introduces the achievements of the experimental operation of the facility and reports on the results of the above technology.

2. Approach to Reduce Dioxins and Increase Power Generation Efficiency

2.1 Improvement in combustion characteristics by introducing combustible dust collection and injection technology[1) 2)]

The waste charged from the upper part of the melting furnace is continuously heated in the charging zone to be dried, thermally decomposed, and gasified, thus producing pyrolysis gas. The pyrolysis gas exhausted from the melting furnace consists of nitrogen, carbon dioxide, and steam as well as combustible gases such as carbon monoxide, hydrogen, and methane. The pyrolysis gas also contains combustible dust, which has been burnt together with the pyrolysis gas in the combustion chamber with the conventional system.

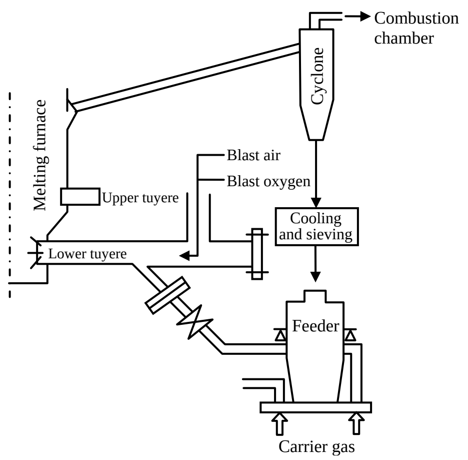

Fig. 1 Combustible Dust Collection and Injection Unit

Figure 1 shows the combustible dust collection and injection system installed in the test facility (20 tons/day-scale). Combustible dust collected by dust collector (cyclone) is injected into the melting furnace via the tuyere. We confirmed through use of this system that the solid combustion load in the combustion chamber is reduced and the combustion characteristics in the combustion chamber is remarkably improved. Figure 2 shows the results of the simultaneous measurement (n=3) of the concentrations of dioxins in the combustion exhaust gas; measured at three positions, at the exit of the combustion chamber, the exit of the gas-cooler, and the exit of the catalytic reactor (stack). The concentration at the exit of the combustion chamber without combustible dust collection (condition before improvement) was 0.27 ng-TEQ/m^3N, which was reduced to 0.05 ng-TEQ/m^3N with dust collection (condition after improvement). As for the concentrations at the exit of the catalytic reactor, 0.07 ng-TEQ/m^3N without combustible dust collection was reduced to 0.02 ng-TEQ/m^3N with dust collection. Thus, it can be concluded that combustible dust collection and injection technology has improved the combustion characteristics in the combustion chamber and suppressed the generation of dioxins in the combustion chamber to ultimately lower the concentrations of dioxins at the exit of the catalytic reactor.

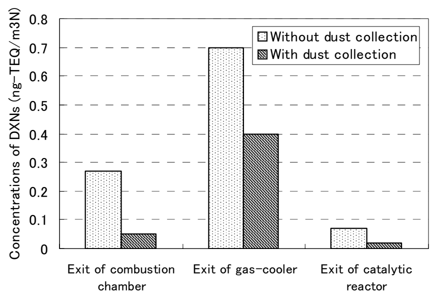

Fig. 2 Effect of combustible dust collection in reducing dioxins in exhaust gas

Figure 3 shows the relationship between the concentration of dioxins in exhaust gas at the exit of the combustion chamber and the concentration of CO in exhaust gas at the stack which is an indicator of the combustion characteristics in the combustion chamber. The CO concentration varies in the range of 10 to 30 ppm without combustible dust collection (condition before improvement), the average being approximately 20 ppm. On the other hand, the CO concentration varies in the range of 0 to 15 ppm with combustible dust collection (condition after improvement), the average being approximately 10 ppm or less. In short, it can be considered that the combustion characteristics improved as a result of introducing combustible dust collection and injection technology to reduce the concentration of dioxins at the exit of the combustion chamber.

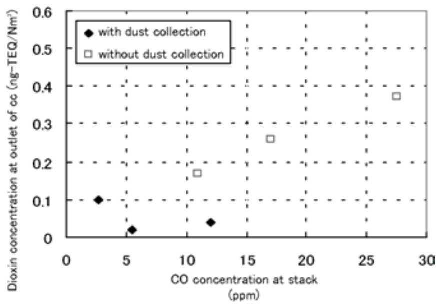

Fig. 3 Dioxin Concentration at Outlet of CC and CO Concentration at Stack

2.2 Improvement of efficiency of waste power generation[3)]

We have tried to realize high-temperature and high-pressure steam in the boiler for the purpose of developing a high-efficiency waste power generation system. To overcome the problem of high-temperature corrosion of the boiler superheater, we have carefully selected suitable materials and optimized the boiler structure. As a result, 400°C- and 4 MPa-class boilers were actually introduced at five plants in Japan. In order to develop more efficient waste power generation, in addition to high-temperature and high pressure steam in boiler, there is a way to introduce a water-cooled condenser which can reduce turbine exhaust pressure (see Fig. 4).

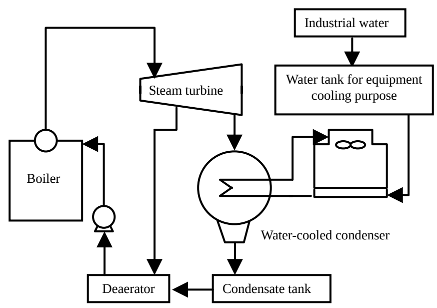

Fig. 4 Water-cooled condenser flow chart

3. Operating Records at a Large-Scale Gasification and Melting Facility

3.1 Outline of Shin-Moji Plant in Kitakyushu City

Shin-Moji Plant in Kitakyushu City (240 tons/day-scale × 3 furnaces) is one of the world's largest gasification and melting facilities, equipped with

Table 1 Outline of facility at Shin-Moji Plant in Kitakyushu City

Capacity	720 tons/day (240tons/day×3furnaces)
Furnace type	Shaft-type gasification and melting furnace
Power generation system	Turbine generator rating: 23,500 kW Steam conditions: 3.92 MPa and 400℃ Condensing method: Water-cooled Turbine exhaust pressure: 0.052 ata
Wastes to be treated	Municipal waste Residue of crushed bulky waste

state-of-the-art technologies. The facility completed its experimental operation in March 2007 and started substantial operation in April 2007 and has been operating smoothly since then.

Table 1 shows the outline of the facility, while Fig. 5 is a flow diagram of the facility. In shaft-type gasification and melting furnace, coke and limestone as well as waste are charged into the furnace through the central port at the top of the melting furnace. The waste is heated in the drying and preheating zone (300 to 400°C) to cause water contents to evaporate and descend in the furnace. Then combustible substances are thermally decomposed and gasified in the thermal decomposition and gasification zone (300 to 1000°C). The generated pyrolysis gas is combusted completely in the combustion chamber. The combustion exhaust gas is subjected to heat recovery by the waste heat boiler, and then quenched by the gas-cooler. Then the exhaust gas, with dust removed by a bag filter, is circulated through the catalytic reactor and finally discharged into the air through the stack. The remaining ash, after thermal decomposition, descend together with coke to the combustion zone (1000 to 1700°C), followed by the melting zone (1700 to 1800°C). The coke is burnt with air and oxygen supplied through the tuyere (air-blowing port) positioned at the bottom of the furnace to form a high-temperature melting zone, where ash is melted completely. The melt with suitable fluidity is discharged from the discharge port at the bottom of the furnace to the water tank and quenched to produce granular slag and iron (metal), which are separated and collected by a magnetic separator for effective recycled use.

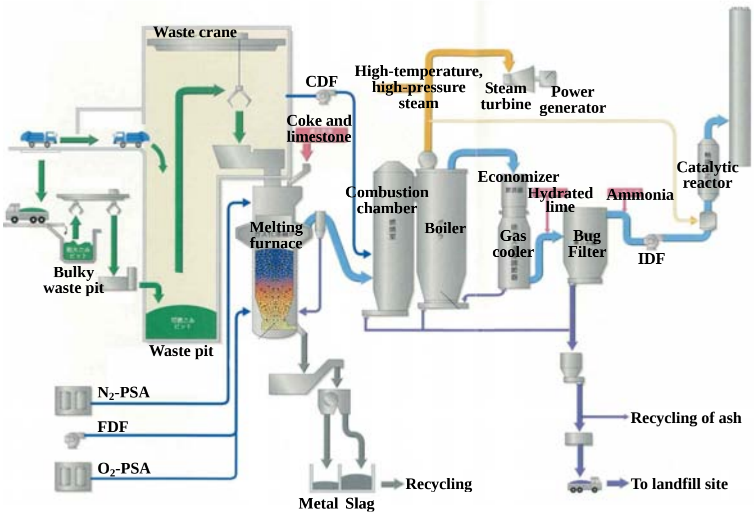

Fig. 5 General flow diagram of Shin-Moji Plant in Kitakyushu City

Table 2 Emissions of dioxins out of the facility

Exhaust gas (n=3)	ng-TEQ/Nm^3	0.0059
Treated ash (n=2)	ng-TEQ/g	0.18
Metal (n=2)	ng-TEQ/g	0.00096
Slag (n=2)	ng-TEQ/g	0.0000015
Effluent wastewater (n=2)	ng-TEQ/L	0.27
Gross emission	μ g-TEQ/t-waste	7.6

3.2 Reduction of dioxins

We have evaluated the effect on reduction in the concentrations of dioxins in the exhaust gas and fly ash of the improved combustion characteristics, with the combustible dust collection and injection technology introduced to the facility. With the technology introduced, the temperature at the exit of the combustion chamber remained stable at approximately 1000°C and the concentration of CO at the stack was controlled to an average of 0.19 ppm without any instantaneous peak value (see Fig. 6). As a result, as shown in Table 2, the concentrations of dioxins were 0.0059 ng-TEQ/m^{3}N in the exhaust gas in the stack, 0.18 ng-TEQ/g in the treated fly ash, with the gross emission level of dioxins outside of the system reduced to 7.6 μg-TEQ/t-waste.

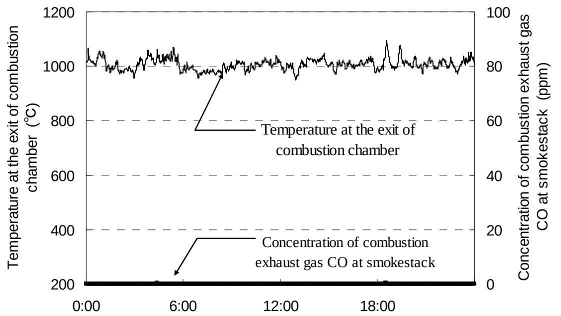

Fig. 6 Temperature at the exit of combustion chamber and concentration of combustion exhaust gas CO at stack

3.3 Achieved high efficiency of waste power generation

Waste power generation in Shin-Moji Plant has introduced a steam temperature of 400°C, a steam pressure of 4 Mpa. In addition, the facility is introduced water-cooled condenser to achieve a turbine exhaust pressure of -96 kPa (0.052 ata), thus a power generation -end efficiency of 23.0% with three furnaces operated (see Table 3). Power generation stands at 21,177 kW (approximately 90%-load operation) and can afford power selling of a surplus amount of 14,460 kW (approx. 70% of power generation) after consuming a required amount within the plant.

The generation-end efficiency was calculated by the equation shown below.

$$\text{Generation - end efficiency (\%)} = \frac{\text{Average power generation}}{\text{Waste calorific value + coke calorific value + kerosene calorific value}} \times 100$$

3.4 Material balance

Table 4 shows amount of the actual municipal waste throughput, slag, metal and treated fly ash during the acceptance performance test period. The total waste throughput during the test period was 1,509 tons, with an average of 251.6 tons/day-scale. The percentages of amounts of slag and metal generated from the total waste throughput are 8.6% for slag and 1.4% for metal (a total of 10%). The slag will be used for secondary products of concrete and asphalt mixture, while the metal will be utilized for reducing agents at non-ferrous refining, as counterweights for heavy construction machinery, scrap in steel works, etc. As a result, the only material to be disposed of at the landfill site from the facility is the treated fly ash and the ultimate volume reduction stands at 0.85%. The facilities are at present operated commercially and further efforts are being made to reduce the amount of fly ash through optimization of the operating conditions.

Table 3 Electric power balance of Shin-Moji Plant in Kitakyushu City

		Average*	Primary unit (kWh/t-waste)
Municipal waste throughput	t/d	252	
Lower calorific value	kJ/kg	9092	
Power consumption (Consumption at plant)	kW	6717 (6378)	214 (203)
Power generation	kW	21177	673
Electric power sale	kW	14460	460
Generation-end efficiency	%	23.0	

*During acceptance performance test period February 21 to February 22, 2007

Table 4 Material balance during acceptance performance test period

	Weight (t)	(%) [vol%]
Municipal waste	1509	100 [100]
Slag	129	8.6 [-]
Metal	20	1.4 [-]
Treated ash	64	4.2 [0.85]

4. Conclusions

This paper finds the following facts on the basis of the results of the test conducted at the test facility and recorded achievements of the experimental operation at the actual facility.

(1) The combustion characteristics of the combustion chamber has been improved by the introduction of the combustible dust collection and injection technology. As a result, generation of dioxins was reduced and the total emission volume of the actual gasification and melting facility of the largest scale has been reduced to 7.6 μg-TEQ/t-waste.

(2) Using the water-cooled condenser in addition to recovery of high-temperature and high-pressure steam by the waste heat boiler, we have realized the generation-end efficiency of 23.0% at the waste power generation.

(3) The only material to be disposed of at the landfill site from the direct melting system is the treated fly ash and the ultimate volume reduction stands at 0.85%.

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