CKK System
– New waste treatment system that achieves waste reduction, energy use and recycling

The CKK System is a new waste incineration system jointly developed by Kawasaki and the Anhui Conch Group, its joint venture partner in China. This innovative system achieves hygienic waste treatment at low cost, and also makes effective use of the energy and ash content of waste as fuel and raw material for cement production. Orders for the CKK System are steadily increasing in China.

Preface

China is faced with serious environmental pollution and waste treatment issues as a result of its rapid economic development. The Chinese government has made it its highest national priority to develop a "system capable of sanitary waste treatment at a low cost." Kawasaki's new waste treatment system does just that.

1 Background

Kawasaki and the Anhui Conch Group, its joint venture partner in China, have jointly developed a new type of waste incineration system that combines a cement manufacturing facility and waste incineration facility. Called the CONCH Kawasaki Kiln System (CKK System), it enables sanitary waste treatment at a low cost. The first CKK System (300 t/d × 1 furnace) was constructed next to the cement manufacturing facility of Anhui Tongling Conch Cement Co., Ltd. in Tongling City, Anhui Province. The plant has been in operation since April 2010.

2 Advantages of the CKK System

The CKK System (Fig. 1) features a fluidized-bed type gasification furnace where waste is gasified. The resulting pyrolysis gas and unburned char are fed into the calciner on the cement manufacturing side along with ash. The system is designed to harness the energy and ash content of waste as fuel and raw material for cement manufacturing. The CKK System offers the following advantages.

① Reduced fuel consumption
By harnessing the energy contained in waste to manufacture cement, the amount of fuel used for cement manufacturing can be reduced.

② High clinker quality
Heavy metals contained in waste are separated from clinker as chlorides during cement calcination. Heavy-metal concentration in clinker remains relatively stable even with mixed-combustion of waste.

③ Minimal harmful substances in combustion gas
The amount of dioxins and other harmful substances in the combustion gas of waste can be minimized as the combustion gas can be kept at a high temperature for a sufficiently long time in the cement manufacturing facility. HCl and SOx in the combustion gas can be separated through reaction with the calcium contained in cement materials.

④ Smaller initial investment
By utilizing the existing cement manufacturing facility, initial investment costs can be significantly reduced compared to when a new waste incineration facility is built.

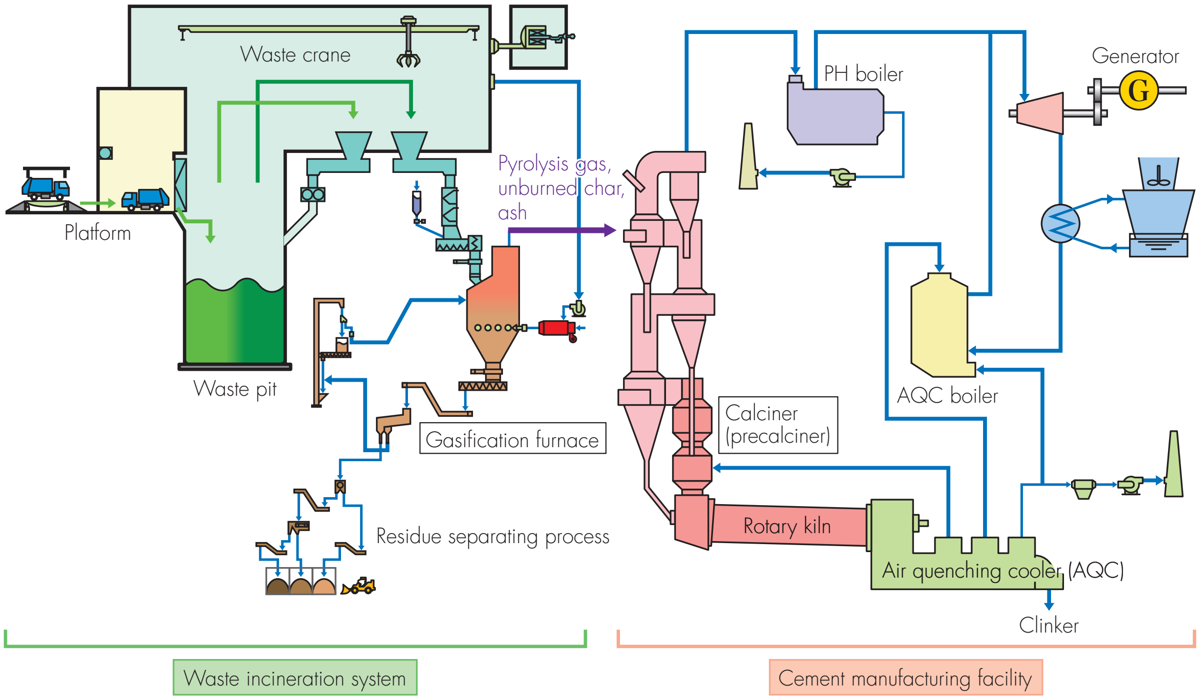


Fig. 1 CKK system flow

3 Development of the CKK System

(1) Basic concept

- Build a waste incineration facility next to a cement manufacturing facility, and continue cement (clinker) manufacturing
- Make full use of the components of the existing cement manufacturing facility in constructing the waste incineration facility
- Minimize impact on cement (clinker) quality by building the waste incineration facility next to the cement manufacturing facility

(2) Selecting the waste incineration technology

In selecting a waste incineration technology, we considered the type of incinerator to use based on Kawasaki's proprietary technology.

As a result, we adopted the fluidized-bed type gasification furnace, which boasts minimal gas volume and low gas temperature at the furnace outlet, a characteristic that makes it possible to reduce the furnace size (Table 1).

(3) Determining the pyrolysis gas injection point

The pyrolysis gas generated in the fluidized-bed type gasification furnace can be injected into the cement

Table 1 Comparison of waste incineration system

Incinerator type	Fluidized-bed type gasification furnace	Fluidized-bed type incinerator	Stoker type incinerator
Incinerator outlet gas volume	Low	High	High
Incinerator outlet gas temperature	Low	High	High
Handling of incinerator ash	Easy	Easy	Difficult (dry ash removal)
Evaluation	◎	○	△

Table 2 Comparison of pyrolysis gas injection positions

Pyrolysis gas injection point	Calciner	Kiln
Gas temperature (max. temperature)	Approx. 900°C	Approx. 1,800°C
Furnace pressure	−0.8 to −0.9 kPa	Approx. −0.2 kPa
Impact of moisture contained in waste on clinker property	No	Yes
Evaluation	◎	△

manufacturing facility either at the calciner (precalciner) or rotary kiln. As shown in Table 2, we chose the calciner due to the large negative pressure inside the furnace, which is an advantage in drawing in pyrolysis gas, and because the moisture content of waste does not impact clinker property in the calciner.

Furthermore, exhaust gas generated in the cement kiln changes the direction of flow from horizontal to vertical at the kiln inlet as it flows into the calciner. We ran a number of simulations to derive the optimal injection point and angle for feeding pyrolysis gas to this gas flow to achieve full combustion inside the calciner.

Specifically, we created an analytical model in which pyrolysis gas is fed from a horizontal direction into an upward flow of gas inside the calciner. We studied several patterns of injection points and angles to examine how they affect the gas temperature, oxygen concentration, and gas flow rate.

The analytical shape model is shown in Fig. 2, and sample simulation results of gas temperature distribution and oxygen concentration distribution are shown in Fig. 3. ① to ④ in Fig. 3 indicate the following areas.

① High-temperature area generated by the combustion of pyrolysis gas

② High-temperature area generated by the combustion of pulverized coal

③ High oxygen concentration area due to the passage of combustion air

④ Low oxygen concentration area due to the passage of kiln gas

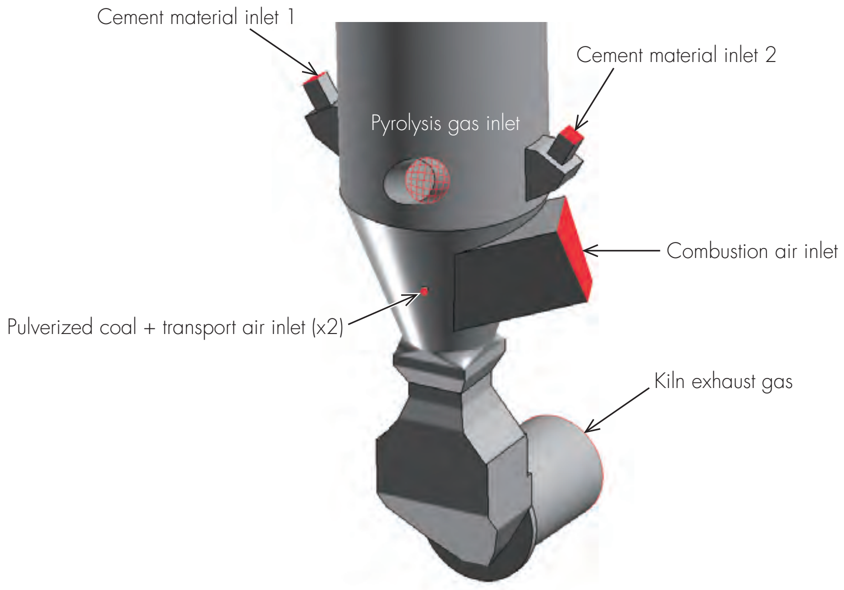
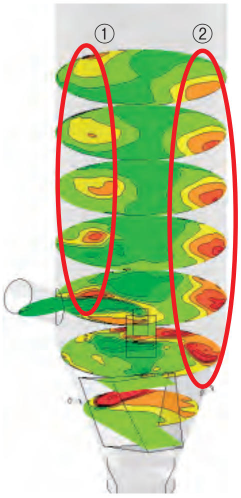
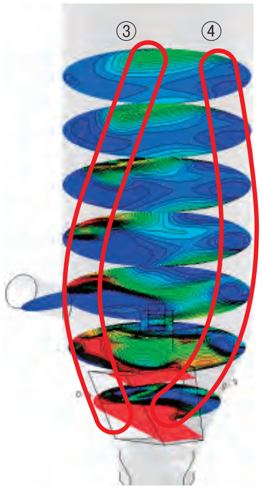


Fig. 2 Geometric model for analysis



(a) Gas temperature distribution



(b) Oxygen concentration distribution

Fig. 3 Simulation results

The following two points transpired as a result of these simulations.

- Inside the calciner, the combustion air causes a rotational flow, and oxygen concentration is distributed. These conditions create a high oxygen concentration area suitable for the combustion of pyrolysis gas.
- Pyrolysis gas is agitated and mixed inside the calciner by the effect of the rotational flow. Therefore, a cross-sectional view of the top section of the calciner shows a roughly even distribution of gas temperature and oxygen concentration.

Based on the above, the injection point and angle of pyrolysis gas were determined so that the gas can be fed to the high oxygen concentration area inside the calciner, and the mixture of the gas can be promoted inside the calciner.

(4) Maintaining stable cement manufacturing operation and high clinker quality

To ensure stable operation of the cement manufacturing facility and high clinker quality, it is important to minimize coating due to concentration of chlorine (and alkali).

Therefore, we studied an effective way to reduce chlorine concentration in the clinker calcining system, based on the chlorine concentration in waste and in the clinker produced by the existing cement manufacturing facility. As a result, we adopted a chlorine bypass system (patent held by Taiheiyo Cement Corporation) as a measure against chlorine concentration in the CKK System, based on cost and effectiveness in reducing the occurrence of coating and chlorine concentration in clinker.

(5) Handling odors and waste pit drainage

We have studied measures to handle the odors and waste pit drainage generated as a result of waste treatment.

(i) Odors

- An airtight waste pit will be adopted. Flowing air will be drawn from the pit to create a negative pressure environment inside, thereby preventing odor leakage. The odors in the fluidized air will be burned and decomposed in the calciner.
- As a measure against the suspension of the gasification furnace, a deodorizing equipment will be installed. Otherwise, air will be drawn from the waste pit and then blown over the high-temperature clinker in the air quenching cooler to decompose and eliminate the odors.

(ii) Waste pit drainage

- Waste pit drainage will be sprayed into the gasification furnace freeboard to be vaporized.

(6) Minimizing environmental impact through mixed combustion of waste

Primary environmental impacts of the mixed combustion of waste in a cement manufacturing facility include the following.

① Increased concentration of CO and dioxins in exhaust gas

② Increased concentration of heavy metals in clinker

These two points have been theoretically examined, which led to the conclusion that neither is a significant issue.

- While the pyrolysis gas and unburned char generated in the gasification furnace are burned in the calciner of the cement manufacturing facility, the gas temperature inside the calciner is maintained at roughly around 900 °C for the removal of carbon dioxide (endothermic reaction) from cement raw material.

- In addition, gas is kept inside the calciner for at least four seconds, minimizing increase in the concentration of CO and dioxins.
- Most heavy metals contained in waste are separated from clinker as chlorides during the calcining process. As a result, heavy-metal concentration in clinker remains relatively stable.

4 Tongling CKK plant operation results

The following is an overview of the operation results of the CKK plant in Tongling City.

(i) Waste status

The analysis results of waste in Tongling City are summarized in Table 3. The lower heating value was approximately 5,900 kJ/kg, which was equivalent to the standard waste at the time of planning. While sulfur concentration is considerably higher than that of the standard waste, this is presumably because briquettes made of coal are used in large amounts as fuel in Chinese households.

(ii) Waste treatment capacity

Transition in waste treatment capacity as of March 2011, about one year after the start of operation, is shown in Fig. 4. The capacity had stayed at around 300 t/d, indicating stable operation.

Table 3 Analysis results of waste in Tongling city

Item		Summer waste	Winter waste	Standard waste
Lower heating value (kJ/kg)		5,760	5,920	5,900
Three components (%)	Moisture	56.34	57.11	60.18
	Combustibles	30.93	34.18	34.30
	Ash	12.73	8.71	5.51
Elemental composition of combustibles (%)	Carbon	60.88	57.85	52.94
	Hydrogen	8.52	8.08	7.82
	Oxygen	25.49	30.72	37.62
	Sulfur	2.97	1.68	0.08
	Chlorine	1.08	0.84	0.70
	Nitrogen	1.06	0.84	0.85

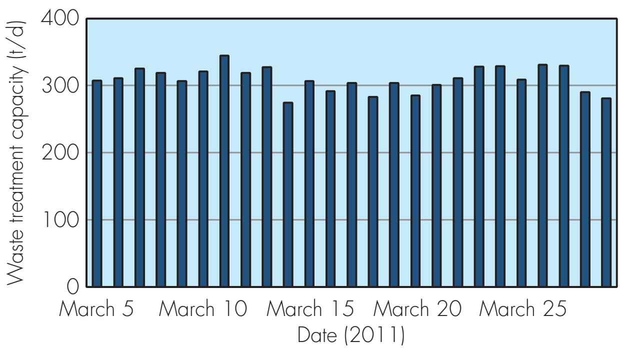
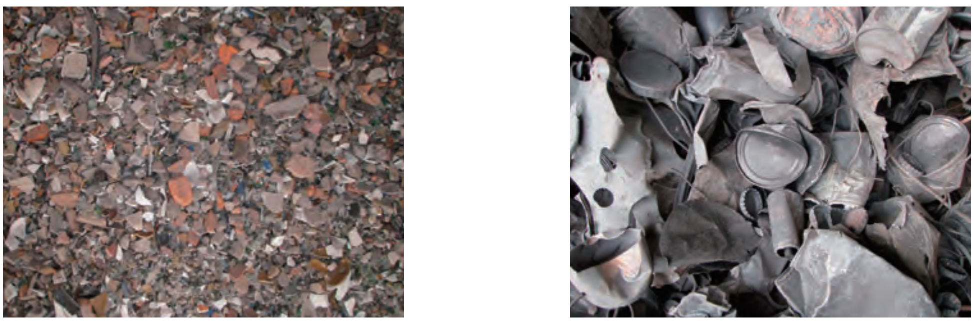


Fig. 4 Amount of waste treated

Table 4 Analysis results of dioxins

Measurement results (stack inlet)		Regulation values
1st	2nd	
0.008	0.033	0.1

Unit: ng-TEQ/m^{3}N: at 11% O_2



(a) Non-combustibles

(b) Material recycled with magnetic separator

Fig. 5 Non-combustibles discharged from gasification furnace

(iii) Concentration of dioxins in exhaust gas

Measurement results of dioxins at the stack inlet of the cement manufacturing facility shown in Table 4 demonstrate that regulatory values are fully met. Incidentally, this plant does not incorporate spraying of activated carbon to reduce dioxins in exhaust gas.

(iv) Non-combustibles discharged from gasification furnace

Non-combustibles discharged from the bottom of the gasification furnace as shown in Fig. 5(a) have been confirmed to be usable as cement material. Iron as shown in Fig. 5(b) has been confirmed to be recyclable in an unoxidized state.

(v) Clinker quality

Ever since it started operation, the plant has never experienced any suspension of the cement manufacturing facility due to low clinker quality. This shows that mixed combustion of waste has no negative impact on the quality of clinker.

(vi) Mixed combustion of dewatered sludge

In China, the increasing number of sewage treatment facilities has made detoxification of sewage sludge (dewatered sludge), which is generated in huge quantities, an issue of great importance. To test whether it is possible to treat dewatered sludge with the CKK System, we had conducted mixed combustion of dewatered sludge starting at the plant in November 2011. As a result, we found that there is no problem if the amount of dewatered sludge is kept within the range of 10-20%.

Concluding remarks

Orders for the CKK System have been steadily increasing in China, where a total of 8 plants are in operation, and 10 plants are under construction as of the end of September 2015.

Furthermore, growing population and rising standard of living in the emerging economies of Southeast Asia as well as India and Brazil have led to increased demand for the hygienic treatment of municipal waste in these countries and regions. The low cost of the CKK System will make it an ideal solution to meet their needs.

The CKK System is also effective in reducing greenhouse gas emissions, a pressing issue across the globe. We will continue to further refine the system to contribute to a healthier planet.

Professional Engineer (Environmental Engineering)
Tadashi Katahata
Environmental Plant Department,
Environmental Plant Engineering Division,
Plant & Infrastructure Company

Hiroaki Osawa
Industrial Plant Department,
Industrial Plant Engineering Division,
Plant & Infrastructure Company

Sadafumi Katoh
Operation and Maintenance Technology Department,
Environmental Plant Engineering Division,
Plant & Infrastructure Company

Mitsuru Kikkawa
Environmental Plant Department,
Environmental Plant Engineering Division,
Plant & Infrastructure Company

Professional Engineer (Environmental Engineering)
Atsushi Hashimoto
Environmental Plant Department,
Environmental Plant Engineering Division,
Plant & Infrastructure Company

Jun Toshihiro
Anhui Conch Kawasaki Engineering Co., Ltd