Application of CFB (Circulating Fluidized Bed) to Sewage Sludge Incinerator

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CFB (Circulating Fluidized Bed) is widely used for coal-fired boilers. For combusting sewage sludge in CFB, a suita[illegible] obtain a higher combustion load per unit horizontal cross section, which reduces the construction area required for installing the furnace. Further, combustion air is supplied in two stages:primary air (fluidizing air) and secondary air, and so the power load of the fluidizing blower is reduced. Two-stage combustion is also expected to lower the environmental impact. Bubbling fluidized bed incinerators have a drawbackin that agitation and mixing in [illegible] size is increased. In contrast, even large-size CFB incinerators are expected to maintain excellent combustion because sufficient agitation and mixing are carried out by high-velocity fluidization.

1. Introduction

In CFB combustion, part of the bed material and unburned char carried out from the top of the riser (combustion chamber) are captured by the cyclone and circulated through the system, and are completely combusted. Therefore, it is most suitable for combusting coal that contains much fixed carbon and hence it is widely applied to coal-fired boilers. In contrast, sewage sludge cake has a high water content and in many cases, its solid portion contains volatile matters of nearly 70%. The properties are significantly different from those of coal, and so different fluidization and combustion technologies are required when applying the same CFB technology to sewage sludge cake. The general properties of coal and sewage sludge are compared in **Table 1**.

NKK carried out a series of experiments using a CFB pilot plant that has a riser of inner diameter of 300 mm and height of 12m. It was confirmed that the CFB furnace is satisfactory for incinerating sewage sludge cake. The results are summarized below.

Table 1 Properties of coal and sewage sludge cake

2. Experimental setup and conditions

Fig.1 is a flow diagram of the pilot plant used for the experiments. **Photo 1** is its exterior view. The CFB section is composed of a riser that works as a combustion chamber, a hot cyclone that captures circulating particles, a loop seal that prevents back-flowing of unburned gas from the furnace bottom, etc. The pilot plant also has a flue gas treatment section. The riser has the inner diameter of 300 mm and the height of 12 m and is lined by refractory. It is composed of a wind box, a distributor with primary air feed nozzles, secondary air

Table 3

cake and auxiliary fuel tends to move upward in the riser. Another probable cause of the temperature decrease is that the heat capacity in the lower zone of the riser is lowered because the particle density decreases as the gas velocity increases. Conversely, when the primary air ratio is decreased from 0.6, the minimum combustion required for maintaining the temperature is no longer carried out and hence the dense bed temperature decreases.

The primary air ratio determines the conditions in the early stage of combustion and therefore affects the flue gas properties. **Fig.4** shows the results of measuring the CO concentration at the exit of the cyclone when the plant was operated under the same conditions as in **Fig.3**. The CO concentration decreases with decreasing the primary air ratio. The probable cause is that a suitable thermal decomposition of the sewage sludge cake occurs in the dense bed zone, and combustible constituents generated there undergo complete combustion in the upper zone above the secondary air injection port. All types of sewage sludge cake indicated almost identical trends.

Photo 2 shows the state of the dense bed zone photographed by a CCD camera when sewage sludge cake A was combusted at the primary air ratio of 0.6. The black spherical substances are sewage sludge cakes. The photograph indicates that stable combustion is maintained in the dense bed zone.

From the above, it was concluded that the optimum primary air ratio for the CFB furnace is around 0.6.

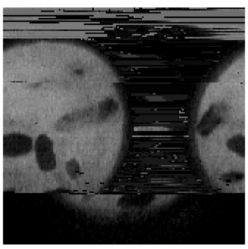

Photo 2　State of dense bed zone

3.3　Combustion characteristics in entire zone of riser

Combustion characteristics in the entire zone of the riser were investigated. **Fig.5** shows the profiles of the oxygen concentration and temperature in the riser when sewage sludge cakes A and D were combusted. It is clear that the oxygen supplied by the primary air is almost completely consumed in the dense bed zone below the secondary air injection port, and a reducing atmosphere is formed. The temperatures in this zone ar

Table 4 Properties of flue gas from cyclone exit

All of CO, NOx, and N_2O emissions from every type of sewage sludge cake were suppressed to low levels at the air ratio of approximately 1.3. The reasons for the reduction of each of these emissions were as follows:

(1) NOx

When sewage sludge cake is combusted in the fluidization mode as described above, nitrogenous compounds are turned into NH_3, HCN, etc. in the dense bed zone that has a reducing atmosphere. They then undergo complete combustion in the upper zone where secondary air is injected. This two-stage combustion helps reduce the NOx concentration.

(2) N_2O

When the furnace has the temperature profile as described above, N_2O is decomposed in the sufficiently wide high-temperature field in the upper zone of the riser. Therefore, it becomes possible to simultaneously reduce both NOx and N_2O, which are generally considered to have a tradeoff relation with regard to their emission behaviors[3),4)].

(3) CO

The gas in the upper zone of the riser is fully agitated and mixed, and undergoes complete combustion in the high-temperature field that spans the wide area in this zone. Therefore, the CO emissions are suppressed.

(4) Dioxins

These also undergo complete combustion in the high-temperature field that spans the wide area in the upper zone of the riser. Therefore, the dioxins emissions are suppressed to extremely low levels.

3.5 In-furnace desulfurization

Sewage sludge cake contains a higher sulfur content than municipal solid wastes and plastic wastes, and tends to emit a high concentration of SOx when incinerated. Therefore the flue gas is usually passed through a desulfurization scrubber that uses caustic soda (NaOH) solution before being released from a stack.

Since CFB furnace provides a high contact efficiency between the bed material and gas, desulfurization absorbents such as limestone (major constituent: $CaCO_3$) charged directly into the furnace are expected to perform desulfurization effectively. This method has been already used for coal-fired boilers. This method does not need flue gas desulfurization and associated wastewater treatment and helps reduce space and running costs. However, CaO generated by decomposition of limestone works as a catalyst for forming NOx from NH_3, and might have adverse effects on the NOx concentration, depending on the combustion conditions.

Experiments of in-furnace desulfurization were carried out under various conditions. Limestone was charged into the riser at the Ca/S molar ratio of 3.0 to 4.5 while sewage sludge cakes A, B, and C were combusted at the air ratio of approximately 1.3. A desirable temperature for a desulfurizing reaction by using limestone is thought to range from 800 to 850°C. In the riser, this temperature zone corresponds to the zone above the secondary air injection port, as shown in **Fig.5**. In order to fluidize the limestone in this zone and promote the reaction, pulverized limestone was used. **Table 5** shows the results.

Table 5 Results of de-SOx experiment

For each type of sewage sludge cake, it was found that more than roughly 95% of SO_2 is removed out of the estimated SO_2 concentration (*) that would have been emitted if all the sulfur in the sewage sludge cake had been converted to SO_2 (conversion ratio=100%). Further, the NOx concentration that posed a concern was almost at the same level as when in-furnace desulfurization was not performed.

Thus, it was proved that in-furnace desulfurization in

4. Conclusions

Four types of sewage sludge cake, each having different properties, were subjected to combustion experiments using the pilot-scale CFB incinerator. As a result, the following conclusions were obtained regarding the applicability of the CFB furnace to sewage sludge incineration.

(1) The CFB furnace can be used to incinerate a wide variety of sewage sludge cakes by forming a fluidization mode optimized for damp material in the riser.

(2) It is possible to simultaneously reduce both NOx and N_2O by utilizing two-stage combustion and the high-temperature field in the upper zone of the riser. It is also possible to reduce the CO concentration, giving complete combustion.

(3) It is possible to reduce the SOx concentration by in-furnace desulfurization.

(4) No leaching of hazardous substances from fly ash or bed material was detected.

It was proven that the CFB technology developed for coal-fired boilers is satisfactory for sewage sludge incineration.

Therefore, CFB combustion can be applied to coal that has a high fixed carbon content and sewage sludge cake that has a high water content. The CFB technology may thus be applicable to combusting a variety of fuels and wastes as a means of effectively utilizing energy that will become increasingly diversified. For sewage sludge treatment in particular, the technology has the potential to achieve mixed combustion with screenings, grit, or other types of wastes, including energy recovery.

Based on the results obtained in these experiments, we are continuing to develop the CFB technology.

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