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The behavior of flue gas from RDF combustion in a fluidized bed

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Abstract

A combustion process of refuse derived fuel (RDF) in a fluidized bed has been recognized as a promising utilization technology for solid wastes management in Japan. To understand the combustion behavior of RDF was very important for the establishment of the RDF combustion technology. In this research, to explain a combustion behavior of RDF, several different types of RDF, which contained different chemical compounds, were incinerated in the fluidized bed combustor or fluidized bed boiler, and combustion tests were carried out under the steady state conditions. The experimental data of the CO, NO_x, HCl and dioxin concentrations in the flue gas were measured by the continuous measurement system. It was found that CO concentration in the flue gas greatly increased with increasing the RDF feed rate and decreased with increasing the air ratio. The CO concentration was also significantly effected by the secondary air injection ratio and air distribution ratio. The NO_x concentration and conversion of fuel-N to NO_x of RDF contained metal compounds were far higher than that of the other RDFs. The conversion of fuel-N to NO_x increased with increasing the calcium component ratio in RDF, because the calcium oxide promoted catalytically production of NO. On the other hand, the HCl concentration decreased with increasing the calcium component ratio. It was also found that the generating pattern of dioxins strongly depended upon the compositions of a RDF.

Keywords: Refuse derived fuel; Fluidized bed; NO_x

1. Introduction

Of late years, increasing municipal wastes and industry wastes on contemporary mass consumption became a big environment issue in Japan. 50 million ton of municipal wastes and 400 million ton of industry wastes were discharged, of which respectively 10 million ton and 50 million ton dumped to a landfill after a wastes incineration reduction treatment in 1999 [1], and the final amount of wastes has been increasing every year. However, a construction of new dump yard is not expected any more from the strict Japanese environmental regulations. Therefore, the management of dump yards is extremely hard recent years due to a landfill shortage. An emission of toxic substances, such as dioxins, from conventional wastes incineration facilities was also closed up as another big social issue to be solved as quickly as possible [2]. As one of the most effective solutions for those issues, a high efficiency power generation process of the wastes material has been focused. The power generation process could make possible just not as the reduction of wastes volume, but as the utilization of wastes energy (about 2000 kcal/kg municipal wastes).

In this Japanese circumstance, several power generation technologies by the wastes have been developed and some of them were already commercialized. The power generation system by using the high temperature and high pressure steam was applied in the wastes treatment field as the well-known technology, which were based on coal

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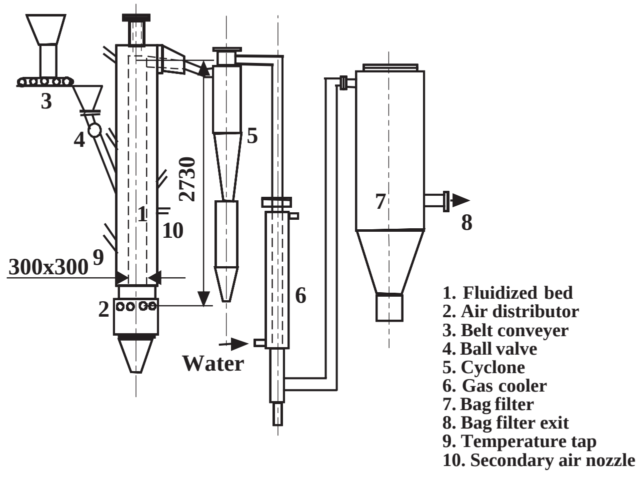

Fig. 1. Experimental apparatus of the FBC.

combustion experiences. The super wastes-power generation for the high efficiency power generation system and the power generation combined gas turbine and steam turbine was also in operation [3]. However, there were problems to apply these technologies for all the wastes treatment. In general, for the effective power generation by a steam turbine, at least 150 t/day wastes combustion facility was necessary. The collection and transportation of wastes would lead economical problem especially in local area. Instability of the wastes property on the locations and seasons also brought technical problems for the commercialization of wastes power generation in local area.

Under these circumstances, the power generation process using refuse derived fuel (RDF) has been attracted attention. RDF was a pellet solidified wastes material. Since RDF was dried and palletized after a separation process, the heating value of RDF increased around 4000 to 6000 kcal/kg RDF and also the quality of RDF stabilized all year long comparably [4]. Furthermore, the transportation and storage of RDF is easy due to the dried pellet shape. Therefore, RDF has big advantages for the wastes power generation in Japan and a large scale power generation system by wide area collection must be allowed.

The studies of RDF combustion were started mid-1990s [5–7]. These works clarified the pyrolysis characteristics and emission mechanism of the flue gas, such as CO, NO_x, SO_x and HCl, against temperature or RDF compositions. Usually, calcium compound, calcium hydroxide or calcium oxide, was added to a RDF to prevent the waste decay, the calcium composition behavior in a combustor was also revealed successively. It has been also figured out that these calcium compositions reacted with chlorine and the HCl concentration in the flue gas could be controlled to the low level [8,9]. However, these experimental results were limited on the analysis of a single RDF pellet or in a small lab-scale fluidized bed incinerator. There were a few report studied a RDF incineration and evaluated the flue gas compositions in a large-scale incinerator or combustor.

In this study, experiments of RDF combustion were conducted in a bench-scale fluidized bed combustor (FBC) and commercial-size fluidized bed boiler (FBB). The experimental results regarding the flue gas behavior and combustion characteristics on several types of RDF in those large-scale facilities were summarized in this paper. The FBC was 0.3×0.3 m of rectangular shape and 4 m in length, and RDF can be feed 15 kg/h continuously. The concentration of CO, NO_x and HCl was measured against the air ratio on different types of RDF. Chlorine material balance was also calculated from the chlorine concentration of the ashes and flue gas chlorine compositions. On the other hand, the commercial-size FBB established by Toyota Motor Corporation was used for RDF combustion measurements. It was multi-fuel combustion boiler of RDF and coal. The RDF feeding rate was around 2700–4300 kg/h. The dioxins concentration in the flue gas and ashes was analyzed, and the behavior of dioxins in the unit and generation mechanism of dioxins was clarified consecutively.

2. Experimental

2.1. Bench-scale fluidized bed combustor (FBC)

Fig. 1 shows the schematic diagram of the FBC experiment set up. FBC consisted of a bubbling type fluidized bed combustor, cyclone, flue gas cooler, bag filter, suction pump and RDF feeder system. The combustor was 0.3×0.3 m rectangular shape and 2.73 m in height from primary air distribution tubes. Silica sand (average particle diameter, 196 μm) was used as a fluidized agent and it was filled up to a height of about 0.35 m from air distribution tubes. Four air distribution tubes, which have 18 holes with 3 mm diameter each, were used for an air supply at bottom of the FBC. Secondary air supply tube was installed on the FBC side wall at a height of 0.7 m from the primary air distribution tubes. RDF was continuously fed by the conveyer belt from the top of FBC. The concentration of CO and NO_x was measured at the outlet port of cyclone, and the concentration of HCl was measured at the both inlet port of the bag filter and outlet port of the bag filter continuously. The emission standard of CO, HCl and NO_x in Japan was shown in Table 1. To keep the bed temperature at 1073 K, RDF feeding rate was changed between 4 and 12 kg/h. The primary air and secondary air injection rate was also controlled between 26 and 74 Nm^3/h. The operation condition of the FBC was summarized in Table 2.

Table 1
The emission standard from RDF combustor in Japan

Component	Emission standard
CO	100 ppm
NO_x	60–400 ppm
HCl	80 mg/Nm^3
Dioxins	0.1–5 ng TEQ/m^3