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Deposit analysis of water-wall tubes in a municipal solid waste grate incinerator

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HIGHLIGHTS

- Deposition studies of water-wall tubes in a waste incinerator are novel.
- Comparison of characteristics between deposits and fly ash was investigated.
- Several mechanisms explain the existence of molten materials in deposits.
- Effects of deposits and steam temperature on the corrosion are discussed.
- Deposit corrosion mechanism of water-wall tubes is analyzed.

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ABSTRACT

To understand the deposition mechanism and determine the factors influencing corrosion, a municipal solid waste grate incinerator with the steam parameter of 6.5 MPa, 450 °C was investigated. Deposits from the first pass as well as fly ash were characterized by SEM-EDS, XRF and XRD. Deposits contained more or less molten or semi-molten materials, due to the chemical reaction heat during sulfation, low melting point compounds and molecular cramming. The content of K, Na, Cl or Fe in the deposits was bigger than fly ash, but fly ash contained more Ca, S, Si and Al, due to their different source and deposition mechanism. Chlorides and alkali metal compounds were identified. The molten deposits increased the corrosion because liquid phase had faster chemical reactions and also provided an electrolyte for ionic transport or electrochemical attack. The chlorides and alkali metal compounds accelerated corrosion not only by lowering the melting temperature of the deposits, but also by attacking the metal surface with active oxidation mechanism. Moreover, entirety of deposits had a high strength, therefore, deposits were subject to stress impact and resulted in the metal defect on the heating tubes.

1. Introduction

The increasing production of municipal solid wastes (MSW) and the lack of suitable disposal areas for land filling as well as the demand of environmental protection, require a suitable waste treatment, such as utilization by thermochemical methods [1,2]. Over the past few decades MSW incineration has been widely used with its reliable modern facilities operating on a fully commercial basis [3]. A growing number of cities in China are switching to incineration as the preferred option for MSW treatment [4]. Indeed, the percentage of MSW treated by incineration increased from 2.5% in 2003 (3.7 million tonnes) to 14.7% in 2010 (23.2 million tonnes) [5].

MSW differs from coal, due to its elevated ash content [6] and the high amounts of chlorine and alkali [6,7]. Therefore, MSW is considered as the fuel which is prone to deposit formation and corrosion [6,7]. Deposition and corrosion influence the efficiency of power and heat production negatively, due to decreased steam quality, and are the main reasons for unscheduled shutdowns of incineration plants and for high operational costs [1].

Until now, there have been studies about bottom ash, fly ash and deposits from the superheater in the MSW incinerators [1,6,7]. The corrosion of the superheater in the MSW incinerators also has been investigated [8–10]. However, most research only focuses on the

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deposition and corrosion of the convective heat exchanger, especially superheater. The deposition and corrosion of water-wall tubes in the pass must not be overlooked in actual operation [11], particularly when MSW heating value and the steam parameters increase. Several explosion events of water-wall tubes which took place in a MSW grate incinerator plant have been reported and these events caused casualties and property loss. As a result, a need has been identified for research of ash deposits and corrosion of water-wall tubes in the MSW grate incinerators.

The main objective of this research was to characterize various deposits taken from different locations of the first pass in a MSW grate incinerator. This work included determining the elemental composition and chemical phase as well as the surface morphology of the deposits. The deposit corrosion mechanism of water-wall tubes was discussed. The study is beneficial to alleviating deposition and corrosion in the MSW grate incinerators.

2. Materials and methods

2.1. The waste-to-energy plant

The sampling operation was conducted at a large-scale MSW incineration power plant in Guangdong Province, China. This plant put in commissioning in October, 2005 and passed the completion of acceptance in September, 2006. The incinerator consists of a furnace section, followed by the second and third passes, before the entrance to the convective section. The incinerator is equipped with a single, horizontal traveling grate. The schematic diagram of the MSW grate incinerator is shown in Fig. 1. The main parameters of this plant are shown in Table 1. Several explosion events of water-wall tubes occurred in this incinerator especially after 2009.

The waste feeding stream has average low heating value around 6.5 MJ/kg (as received basis). The precise temperature profile may vary as a function of plant operation and feedstock composition. According to the average measured values under a stable operation in 2010 and 2011, the temperature in the first pass was around 1000 °C, while it was around 950 °C at the entrance to the second passes. A protective evaporator was fitted in third pass. In the convective section, the flue gas passed through final superheater (SH3), secondary superheater (SH2), primary superheater (SH1) and economizer for energy recovery. Two spray attemperators were fitted between SH1 and SH2 and between SH2 and SH3. Before the entrance to the convective pass the gas temperature was around 510 °C, while the temperature after the economizer was around 240 °C. The gas then entered the treatment system, which contained semi-dry spray reaction tower, activated carbon injection system and bag filter, for the removal of acid gases, dioxins/organic pollutants and heavy metals. The amounts of lime and activated carbon injections were about 7.92 kg/tonne-waste and 0.60 kg/tonne-waste, respectively. The temperature after the reaction tower was around 165 °C. The tube materials of membrane water-wall, evaporator, multi-staged superheaters and economizer were φ60 × 5, 20G; φ40 × 4, 20G; φ42.7 × 8, SA213-T12 and φ42 × 4, 20G, respectively.

Table 1
Main performance parameters for the MSW incineration power plant.

Item	
Site area	101,778 m^3
Daily waste treatment capability	1060 t/d
Annual waste treatment capability	346,660 t/a
Boiler evaporation capacity	48 t/h
Steam parameters	6.5 MPa, 450 °C
Generating unit capacity	22 MW
Efficiency of power supply	22.3%
Annual generation	1.59×10^8 kW h/a
Annual power supply	1.24×10^8 kW h/a
Annual operation hour	8000 h/a
Production line	Two sets of incinerators with waste heat boilers, and a steam turbine electrical generator unit

The components of the raw MSW are listed in Table 2, tested by Guangzhou urban Management Research Center. Vario EL-II chons elemental analyzer (Elementar Analysensysteme Gmbh, Germany) was used for the ultimate analysis based on ASTM D5373-2008 criterion. The chlorine content was tested based on IC(EN 14582-2007 addenda A) criterion in China National Analytical Center, Guangzhou. The ultimate analysis of MSW fuels (on dry basis) is shown in Table 3. The components and ultimate analysis given in Tables 2 and 3 were the average measured values in the winter in 2011. Sampling and analysis methods for MSW fuels were based on CJ/T 313-2009 criterion. The MSW samples were collected every 15 days and the number of sampling place in this plant was 6 and 200 kg waste was collected each time. The method of coning and quartering was used to sample.

2.2. Collection of ash deposit samples

Three deposit samples were collected from three different locations, as numbered in Fig. 1: (1) deposits from the front water-wall tubes (FW deposit); (2) deposits from the forward part of ceiling tubes (FC deposit); (3) deposits from the slag screen tubes around junction of first pass and second pass (SS deposit). The ash

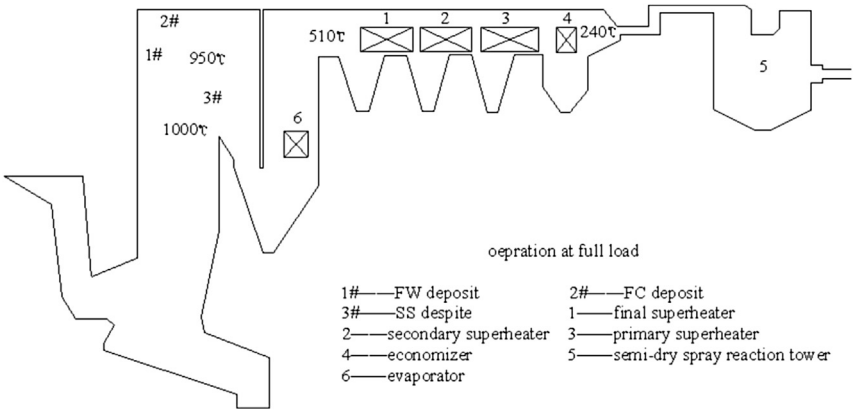

Fig. 1. Schematic figure of sampling location of deposits.