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Modelling and measurements of the characteristics of ash deposition and distribution in a HRSG of wastewater incineration plant

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ABSTRACT

Ash related problems such as fouling and slagging are crucial for operation of the heat recovery steam generator (HRSG) of the wastewater incinerator. In this paper, numerical studies of the characteristics of ash particle deposition and distribution under different operating conditions in the HRSG of a wastewater incinerator have been performed using numerical deposition model coupled with gas–solid two phase turbulent flow model. Based on ash melting thermo-analysis and critical moment theory, a numerical deposition model was adopted to predict ash particle sticking and rebounding in the thermal boundary layer, as well as shedding of deposited particles from tube surfaces, using the commercial computational fluid dynamic code FLUENT 6.3.26. Field measurements from an industrial-scale HRSG of the wastewater incinerator in Acrylic Fiber Plant, Sinopec Qilu Petrochemical Corporation Group, China, have been used to validate the model. The predicted results under different operating conditions are in good agreement with the measured data. The results show that ash deposition and distribution have significant particle size and temperature dependence. Strong deposition propensity of large particles on the windward side of tube surfaces should be responsible for the formation of serious fouling deposits near the entrance of the furnace. High temperature will accelerate ash particle deposition in the furnace.

1. Introduction

Incineration is the common treatment of highly toxic and poorly biodegradable wastewater produced from chemical production processes, whilst the heat recovery steam generators (HRSGs) are usually employed to recover waste heat from the hot flue gas to create the steam [1]. However, the release and transformation of incombustible inorganic substances during wastewater incineration can form a large number of ash particles which are carried by hot flue gas into the furnace of HRSG. Deposition of ash particles on the tube surfaces over time can pose some severe operation problems, such as fouling, slagging and corrosion, which cause low heat transfer efficiency from the hot flue gas to the working fluid inside the tubes, in serious cases, even lead to capacity-limiting plugging and unscheduled shutdown [2]. Many attempts have therefore been made to reduce ash deposition rates or remove ash deposits from tube surfaces, some modifications in combustion pattern, burner design, furnace configuration, as well as thermal spraying on tube surfaces and use of soot-blowing techniques are expected to be the effective ways to minimize ash related problems and improve heat transfer efficiency [3–6].

Ash particle transport and deposition is a sophisticated combination of physical and chemical processes which include many factors: release and transformation of inorganic materials containing in the wastewater and fuel; chemical reactions in the flame front or in the hot flue gas; particle motion in a complex turbulent flow field; ash sticking, rebounding and shedding mechanisms based on the size distribution, chemical composition and other properties [5]. Some research have been conducted to estimate fouling and slagging propensity based on the chemical compositions, physical properties and microstructures of ash particles and deposits [7–9]. As the rapid development of Computational Fluid Dynamics (CFD), numerical simulation methods combined with laboratory tests and field measurements have been implemented to predict ash deposition and slagging propensity in different kinds of boilers, such as pulverized coal-fired boilers [10–12], biomass-fired boilers [4,13,14] and kraft recovery boilers [15,16]. However, it should be noticed that ash particles formed originated from wastewater incineration are quite different from those from coal-fired boilers or biomass-fired boilers in terms of combustion behaviours and physical properties (e.g. lower melting temperatures, higher content of Na and S, and lower content of K, Ca and Si, etc.) [5]. The relative important mechanisms of ash transport and

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