

Ash Behavior in Fluidized-Bed Combustion and Gasification of Biomass and Waste Fuels

Experimental and Modeling Approach

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Abstract

Over the past few decades, a growing interest in the thermal conversion of alternative fuels such as biomass and waste-derived fuels has been observed among the energy-producing companies. Apart from meeting the increasing demand for sustainable heat and power production, other advantages such as reducing global warming and ameliorating landfilling issues have been identified. Among the available thermal conversion technologies, combustion in grate-fired furnaces is by far the most common mode of fuel conversion. In recent years, Fluidized-Bed (FB) technologies have grown to become one of the most suitable technologies for combustion and gasification of biomass and waste-derived fuels.

In spite of the benefits, however, some difficulties are attributed to the thermal conversion of the alternative fuels. Ash-related issues could be a potential problem, as low-grade fuels may include considerable concentrations of ash-forming elements such as K, Na, S, Ca, Mg, P, Si and Cl. These elements undergo many undesirable chemical and physical transformations during the thermal conversion, and often cause operational problems such as deposition-related issues, slag formation in furnaces, corrosion of the heat transfer surfaces, and bed agglomeration of the fluidized-beds. Ash-related problems in the utility boilers are a major concern that may result in decreased efficiency, unscheduled outages, equipment failures, increased cleaning and high maintenance costs.

This thesis investigated the ash behavior and ash-related problems in two different FB conversion systems: a Bubbling Fluidized-Bed (BFB) boiler combusting solid waste, and a Dual Fluidized-Bed (DFB) gasifier using biomass as feedstock. Full-scale measurements, chemical analysis of fuel and ash, as well as thermodynamic equilibrium modeling have been carried out for the BFB boiler (*Papers I-IV*), to investigate the impact of reduced-bed temperature (RBT) and also co-combustion of animal waste (AW) on the ash transformation behavior and the extent of ash-related issues in the boiler. For the DFB gasifier (*Paper V*), a thermodynamic equilibrium model was developed to assess the risk of bed agglomeration when forest residues are used as feedstock.

The experimental results showed that the RBT and AW co-combustion could decrease or even resolve the ash-related issues in the BFB boiler, resulting in a lower deposit-growth rate in the superheater region, eliminating agglomerates, and a less corrosive deposit (in RBT case). Thermodynamic equilibrium modeling of the BFB boiler gave a better understanding of the ash transformation behavior, and also proved to be a reliable tool for predicting the risk of bed agglomeration and fouling. The modeling of the DFB gasifier indicated a low risk of bed agglomeration using the forest residues as feedstock and olivine as bed material, which was in good agreement following the observations in a full-scale DFB gasifier.

Keywords: Fluidized-bed, combustion, gasification, waste-derived fuels, biomass, ash-related problems, deposit, fouling, slagging, bed agglomeration, thermodynamic equilibrium modeling