UMEÅ UNIVERSITET

Co-Firing Complex Biomass in a CFB Boiler

– Ash Transformation, Corrosion Control and Materials Selection

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Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av filosofie doktorsexamen framläggs till offentligt försvar i Sal N460, Naturvetarhuset
fredagen den 16 mars, kl. 13:00.
Avhandlingen kommer att försvaras på svenska.

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Title
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Abstract
The effects of greenhouse gas net emissions on global warming, stricter legislation on waste handling, and the pursuit of ever cheaper heat- and power production are all important factors driving the introduction of complex waste- and biomass fractions in incineration plants. However - without fundamental knowledge regarding ash transformation, fuel blending strategies, emission and flue gas control, and, materials and corrosion – the utilization of economically and environmentally favorable fuels might instead cause economic loss and environmentally adverse effects.
The present work is a contribution to the transition from a CO_2 net generating energy conversion system, to a more environmentally friendly and cost-efficient system. This is done using scientific methods to generate knowledge concerning mechanisms of ash transformation, corrosion control, and materials selection, in a co-fired industrial scale circulating fluidized bed (CFB) boiler, using a novel and potentially environmentally friendly biomass-based fuel mix, rich in Na, K, Cl, N, S, P, Ca and Si. Fuel fractions, ashes, flue gas, deposits, and construction material samples have been collected and analyzed using various techniques, including scanning electron microscope (SEM), energy dispersive spectroscopy (EDS), X-ray Diffraction (XRD). The results have been evaluated and interpreted using chemical equilibrium calculations.
The results of this work include:
1) An analysis of; the failure and preventive maintenance statistics of the industrial scale CFB boiler at hand; the elemental composition of boiler ashes and deposits, the flue gas composition and elemental composition of a multitude of fuel fractions; correlations between boiler design, operational parameters, elemental composition of deposits and boiler availability; a boiler elemental mass balance revealing details regarding deposit buildup mechanisms; properties of the fly ash relevant to flue gas filter design; and findings regarding the nitrogen chemistry of the novel and nitrogen-rich fuel mix used.
2) Speciation and description of the overall ash transformation and fireside alloy interaction, enabling the implementation of on-line corrosion control which significantly inhibits superheater and dew-point corrosion in the boiler; an equation describing the sulfation potential of the fuel mix, as a result of the direct and indirect interactions between all major ash-forming elements.
3) A literature review relevant for the co-fired CFB vortex finder corrosion and alloy selection at 880 °C; An alloy selection study including long term exposures of several commercially available alloys identifying materials that are more than twice as cost-efficient as the often used alloy 253MA; a suggestion of novel methods for both systematic comparison of heavily degraded alloys, and for alloy service-life estimations; a detailed analysis of heavily degraded alloys 310S, 800H/HT and 600, identifying the driving corrosion mechanisms of the VF alloy degradation, including aspects of how the alloy internal mass transport and fireside surface interaction develops over time.
The knowledge gained during this project has been critical to the improvement work of the Perstorp 50 MWth CFB boiler. The improvement work has resulted in a boiler availability increase of 7 %, reducing the overall energy conversion costs with around 1.7 MEUR/year.

Keywords
co-combustion, ash transformation, process control, equilibrium calculations, boiler availability, failures, alloy selection, alloy degradation, vortex finder (VF), service life estimation, sulfation, chloridation, high temperature corrosion, biomass, waste derived fuels, RDF, Biomal, slaughterhouse waste, peat, waste wood, industrial waste water treatment sludge, HAD, RSMT, Alloy 253MA, Alloy 310S, Alloy 800H/HT, Alloy DS, Alloy 600.

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