Fine particle emissions and slag formation in fixed-bed biomass combustion - aspects of fuel engineering

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Abstract

There is a consensus worldwide that the share of renewable energy sources should be increased to mitigate climate change. The strive to increase the renewable energy fraction can partly be met by an increased utilization of different biomass feedstocks. Many of the "new" feedstocks puts stress on certain challenges such as air pollution emissions and operation stability of the combustion process. The overall objective was to investigate, evaluate, and explain the effects of fuel design and combustion control - fuel engineering - as primary measures for control of slag formation, deposit formation, and fine particle emissions during biomass combustion in small and medium scale fixed-bed appliances. The work in this thesis can be outlined as having two main focus areas, one more applied regarding fuel engineering measures and one more fundamental regarding the time-resolved release of ash forming elements, with particular focus on potassium. The overall conclusion related to the abatement of particle emissions and slag formation, is that the release of fine particle and deposit forming matter can be controlled simultaneously as the slag formation during fixed-bed biomass combustion. The methodology is in this perspective denoted “fuel engineering” and is based on a combined approach including both fuel design and process control measures. The studies on time-resolved potassium release showed that a Macro-TG reactor with single pellet experiments was a valuable tool for studying ash transformation along the fuel conversion. The combination of dedicated release determinations based on accurate mass balance considerations and ICP analysis, with phase composition characterization by XRD, is important for the understanding of potassium release in general and time-resolved data in particular. For wood, the results presented in this work supports the potassium release mechanism from "char-K" but questions the previously suggested release mechanism from decomposition of K-carbonates. For straw, the present data support the idea that the major part of the potassium release is attributed to volatilization of KCl. To further explore the detailed mechanisms, the novel approach developed and applied in this work should be complemented with other experimental and analytical techniques. The research in this thesis has explored some of the challenges related to the combined phenomena of fuel conversion and ash transformation during thermochemical conversion of biomass, and has contributed with novel methods and approaches that have gained new knowledge to be used for the development of more effective bioenergy systems.

Keywords: Renewable energy, biomass, thermochemical fuel conversion, combustion, fine particle emissions, slag formation, fixed-bed, ash chemistry, fuel engineering, release

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