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Entrained flow studies on biomass fuel powder conversion and ash formation

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Abstract
Reducing the global dependence on fossil fuels is of paramount importance in tackling the environmental challenges we face, not only tomorrow, but already today. Biomass offers a renewable supply of CO_2-neutral raw material that can be converted into many different forms of fuels and valuable chemicals, making it a prime candidate for the technologies of tomorrow. However, the heterogeneous nature and distinctly different elemental composition of biomass compared to traditional fossil sources present new challenges to be solved. When it comes to thermochemical technologies, key issues concern fuel conversion efficiency, ash formation, ash/fuel interactions and ash/reactor material interactions.

The objective of the present thesis was to provide new knowledge and insights into thermochemical fuel conversion, in particular its application in entrained flow technologies. A laboratory-scale reactor was constructed, evaluated and was used to study several aspects of high-temperature entrained flow biomass fuel conversion. Pulverized fuel particles from different biomass sources were used, and their physical and chemical interactions with the surrounding atmosphere, the concurrent ash element release, ash formation, and phase interactions were also studied in detail. In addition to the entrained flow reactor designed and constructed for this purpose, the main method for data collection was *in situ* optical studies of converting particles, either while entrained in the flow or when impacting upon surfaces. Elemental composition analysis of collected samples and gas analysis were also performed, allowing for a deeper understanding of ash element fractionation and interactions and thus explaining the observed properties of the resulting deposits or slag.

The degree of conversion of fuels with very low ash content, such as stem wood, was well described and modeled by a novel method using optical data, offering a non-intrusive and non-destructive alternative to traditional techniques. Coupling computational fluid dynamics with optical data allowed for improved experimental data interpretation and provided improved accuracy for fuel particle residence time estimations, which is an important parameter when studying fast chemical reactions such as those taking place in reactors for entrained flow conditions. The results from studies on ash formation gave new insights into the feasibility of using dry-mixed K-rich additives for improving slag properties during gasification of Ca-rich and Si-rich fuels. Interpretations of the experimental results were supported by thermodynamic equilibrium calculations, and the conclusions highlight both possibilities and challenges in gasification with high fuel flexibility while at the same time producing a flowing slag. Applications and future implications are discussed, and new topics of interest are presented.

Keywords
Thermochemical biomass conversion, particle image velocimetry, gasification, entrained flow reactor, ash transformation, equilibrium calculations, slag formation

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