UMEÅ UNIVERSITET

# Application of fuel design to mitigate ash-related problems during combustion of biomass

**Anders Rebbling**

Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av filosofie doktorsexamen framläggs till offentligt försvar i N460, Naturvetarhuset,
onsdagen den 11 december, kl. 09:00.
Avhandlingen kommer att försvaras på engelska.

Fakultetsopponent: Dr Sonja Enestam, Manager for Energy Technology R&D at Valmet Technologies Oy, and visiting researcher at the Johan Gadolin Process Chemistry Center at Åbo Akademi University, Åbo, Finland.

Thermochemical Energy Conversion Laboratory
Department of Applied Physics and Electronics

**Organization**
Umeå University
Applied Physics and Electronics

**Document type**
Doctoral thesis

**Date of publication**
20 November 2019

**Author**
Anders Rebbling

**Title**
Application of fuel design to mitigate ash-related problems during combustion of biomass

## Abstract

The energy supply of today is, through the use of fossil energy carriers, contributing to increased net emissions of greenhouse gases. This has several negative effects on our environment and our climate. In order to reduce the impact of this, and possibly to reverse some of the effects, all renewable energy sources must be used. Biomass is the renewable energy carrier that has the greatest potential to reduce net greenhouse gas emissions, but the transition from fossil fuels to biofuels is challenging.

The combustion of biomass is associated with various technical and environmental problems such as slagging, corrosion, and emissions of particles, soot, or harmful chemical compounds. Most of these problems are linked to ash chemical reactions involving alkali metals. Therefore, to reduce the risk of operational and environmental problems, it is important to understand and control the ash transformation reactions involving alkali metals.

The research presented in this thesis has focused on the development of tools, such as models and indices, for predicting the behaviour of various biofuels during combustion, and on the development of the concept of fuel design and implementation of the same during industrial combustion of biomass. The development of easy-to-use tools for predicting problematic ash behaviour is crucial in order to make it possible to increase the use of biomass as an alternative to fossil fuels. The tools presented here are based on theoretical and empirical knowledge and can be used to predict challenges concerning the fuel ash composition and to propose relevant fuel design measures.
The purpose of fuel design, as used here, is to broaden the fuel feedstock and to increase the usability of biomass in the global energy system. This is achieved through measures to change the ash chemical composition in order to enhance beneficial properties, or reduce problematic properties, via the use of additives or blending of two or more different fuels.

More specifically, a slagging index has been developed using the results of several years of combustion experiments. Fuel designs based on the index was demonstrated during normal operation in local and district heating plants. Furthermore, a model was developed for predicting slagging problems that take into account both the chemical composition of the fuel and the burner technology.

Several studies have also been performed on different fuel designs based on the same foundation as the index and the model. Additives to supply for example calcium and sulphur, as well as the clay kaolin, have been used to reduce both technical and environmental problems.
The conclusion is that fuel design, based on ash chemistry, is a possible path for increased fuel flexibility and a broader feedstock for bioenergy.

**Keywords**
Thermochemical energy conversion, biomass, combustion, ash chemistry, fuel design, ash transformation reactions, renewable energy

**Language**
English

**ISBN**
978-91-7855-143-9

**Number of pages**
48 + 9 papers