Advanced adjustable grate solutions for future fuel flexible biomass combustion Technologies

Acronym: GrateAdvance

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- **Verenum Research (CH)**
- **TU Graz Institute of thermal engineering, (A)**
- **Umea University (S)**
- **Lulea University of Technology (S)**
- **Lucerne University of Applied Sciences (CH)**
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Introduction

Low temperatures in the fuel bed and well-directed air supply in the combustion zone are known as crucial factors in order to avoid/reduce slag formation and minimize the release of PM emissions. Results of recent research projects have also shown a considerable influence of residence time and structure of the fuel bed [e.g. FutureBioTech, AshMelT]. Due to variations in fuel properties – and the ash content in particular – biomass fuels considerably influence the conditions in the combustion zone and particularly in the fuel bed.

The GrateAdvance project dealed with the development of future combustion appliances , in the 100-300 kW range, that can be operated with different types and qualities of biomass fuels, and ensure low emissions and high operational security regarding slag handling at the same time.

Results

As an unfavorable composition of ash forming elements in the fuel leads to slag formation the first step is to improve the understanding of the solid fuel con-version in the fuel bed and to describe slagging mechanisms and the impact of operational parameters on particle- and emission formation. Within the Swedish part of the project, single pellet tests with a lab-reactor (macro-TGA) were conducted considering several conditions, i.e. different process temperatures, as well as oxidizing and reducing atmospheres, using pop-lar, wheat straw, grass and wheat grain. By this research, novel semi time resolved information on the ash transformation reactions of relevance for slagging and fine PM formation were presented. In particular, the influence of combustion (process) temperature during the fuel conversion, on phenomenon like alkali release and ash melting were elucidated, which has great relevance for the development of novel burners that can operate with ash rich challenging biomass fuels. In addition, controlled combustion tests in a small-scale pellet burner were performed, with considerable differences in slagging and fine PM emissions (250-500 mg/Nm3 at 10% O2).

In addition to the release of ash forming elements the Austrian partners investigated issues on tar formation and secondary charring and release of nitrogen species by modelling. A single particle model was amended regarding release of light hydrocarbons as well as tarry compounds and development of a one-step scheme for gas phase tar cracking reaction. Furthermore, a simplified reaction scheme for the release of NOx precursors during pyrolysis (NH3 and HCN) and char oxidation (NO) has been developed. The developed release models for main contaminants during the conversion of solid biomass particles have been implemented in the 3D CFD model for the biomass fixed bed combustion. Assessment of the enhanced models for an improved description of particle movement in the screw burner has been performed and the 3D CFD model has been adapted to be applicable for the screw burner conditions. Finally the overall model has been successfully tested and validated with the experimental data from the Screw Burner prototype (35 kW).

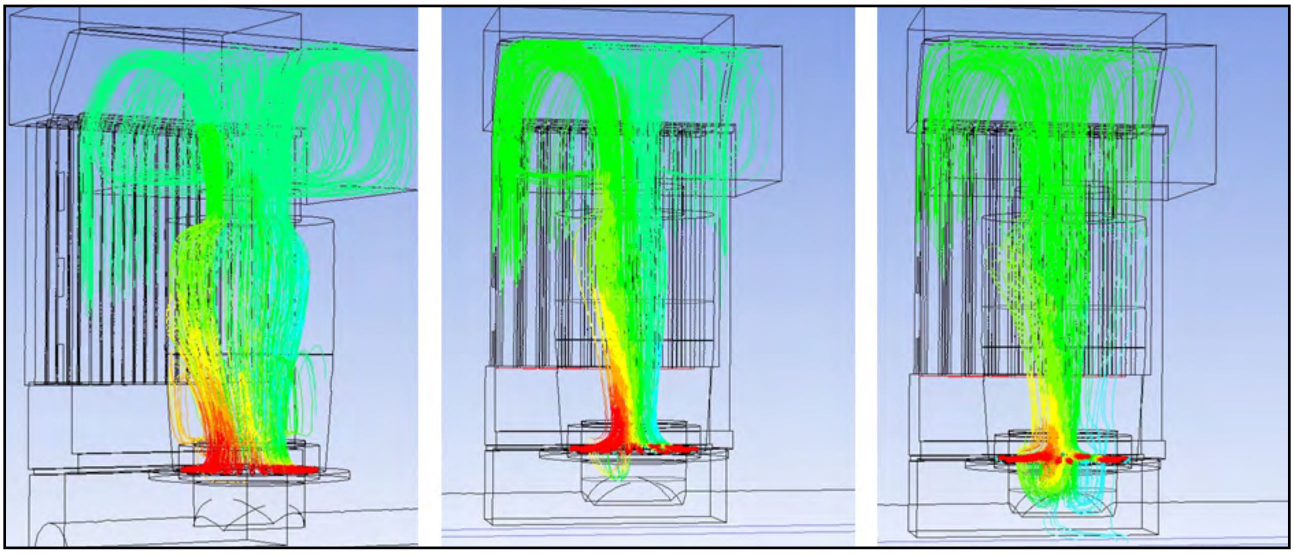

Figure 4.4.1: Flow lines of secondary air of the Screw Burner prototype. Injection with all nozzles (left), 50% of the nozzles (middle) and 25% of the nozzles (right).

The further development of a particular combustion technology – the Screw Burner – was the next step. In Austria and Switzerland simulation tools were applied to study several details with regard to this technology. It was feasible to predict the particle movement by applying the Discrete Element Model and by modelling the gas-solid multi-phase flows (Euler-Granular based on kinetic theory). Aspects in design, e.g. grate geometry, effect of air routing on temperature range and formation of CO and NOx emissions contributed to the construction process of the small-scale proto-type (35 kW) and the scale-up (150 kW). The model approach was introduced and simulation results on variations of grate geometry, combustion chamber and air injection were investigated.

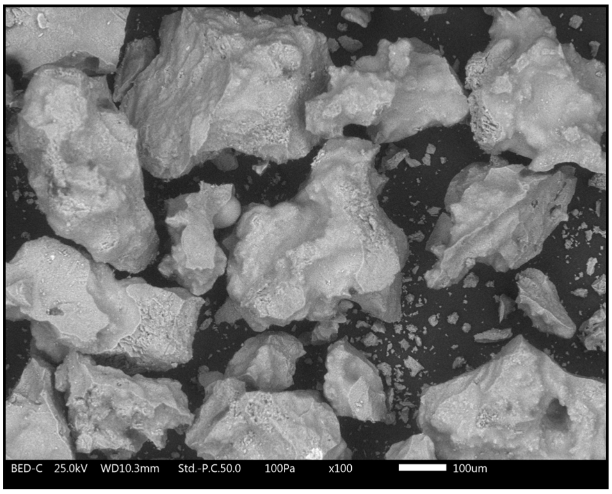

Figure 4.4.2: SEM micrograph of carbonate meltformed from Poplar.

Practical combustion tests were conducted in each of the national projects. A wide range of test fuels (e.g. miscanthus, willow, bamboo, grain mill residues, corn husks, olive stone groats, maize) was utilized. Even with biomass types of high ash content and there-fore low fuel quality, good condition conditions were achieved and the emission limit value of CO was not exceeded. Only for fuels with an increased nitrogen con-tent (> 1 wt.%), the limit value of NOx emissions was exceeded. In addition the most of the test fuels resulted in PM emissions above the limit value of 35 mg/MJ. Consequently, secondary measures to reduce PM emissions e.g. by an electrostatic precipitator (ESP) are therefore necessary. The implementation of an ESP was foreseen in WP5 and hence as part of the Swiss project part, the dimensioning for an ESP integration in the boiler was performed.

The results of combustion tests conducted with the 35 kW prototype served for validation of simulation and modelling results. This prototype was equipped with a basic control system. The heat output is temperature-controlled. The temperature in the combustion chamber regulates the fuel feed rate. The combustion process is Lambda-controlled. The secondary air supply is regulated by the excess oxygen. After optimization the basic control system (WP4) was implemented with the larger Screw Burner Prototype (150 kW, Swiss project).

The Swiss partners developed a methodology to derive the scale-up concept for the commercial size Screw Burner (150 kW) based on the design an results of the small Screw Burner prototype (35 kW). After deriving relevant dimensionless parameters and defining constant parameters (e.g. height to diameter ratio of the combustion chamber, Reynolds number, thermal surface load) various concepts were calculated and evaluated. The influence of different scale-up approaches on several parameters were compared and discussed. The scale-up methodology was validated by CFD simulations to investigate the predicted pollutant emissions and the pressure loss for the scaled 150 kW furnace.

The final techno-economic analysis and sustainability assessment considers the productivity of relevant biomass fuels/feedstocks and includes an estimation of the production cost per unit of bioenergy. The Global Bioenergy Partnership indicators and their possible development through the screw burner technology were mainly assessed as positive. The impact on soil quality and emissions of non-GHG air pollutants, including air toxics might be negative.

Acknowledgment

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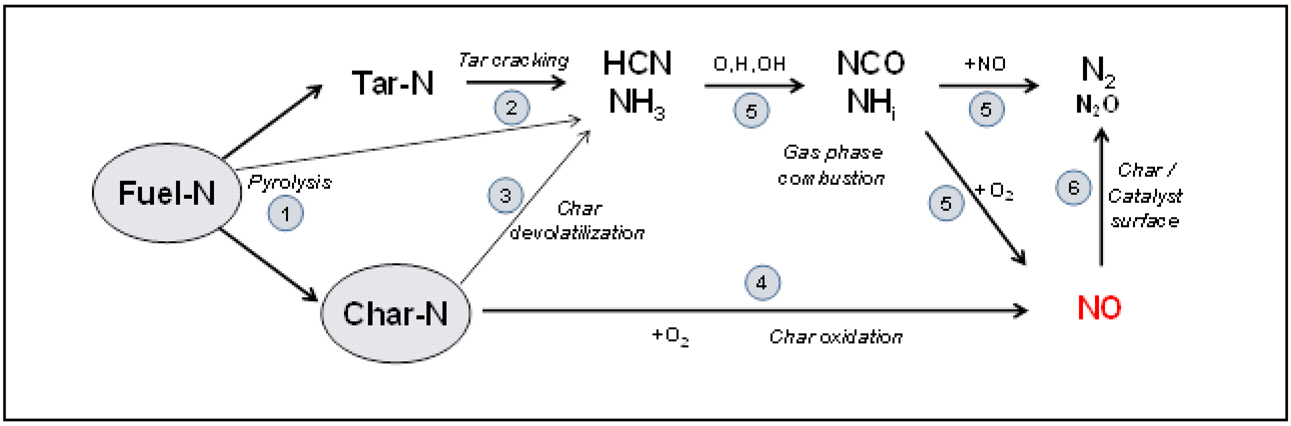

Figure 4.4.3: Model to describe the release of the NOx precursors, NH3 and HCN, for different fuels in typical fixed-bed combustion conditions (reactions 1 and 2). This, combined the previously available knowledge of NOx formation from HCN and NH3, enables a complete description of NOx formation and reduction from nitrogen in the fuel.

The ERA-NET Bioenergy is a network of national ministries and agencies. It contributes to further development of the European research area in bioenergy and strengthening of national research programmes through enhancing international cooperation and coordination.

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