Funding programme Biomass energy use

Supported by: Federal Ministry for Economic Affairs and Energy on the basis of a decision by the German Bundestag

FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG TECHNISCHE FAKULTÄT

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EUBCE 2017, Stockholm, June 12-15, 2017

Slagging prevention and plant optimisation by means of numerical simulation

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Motivation & Approach

Slagging and fouling are major problems in solid biomass combustion. Deposition of inorganic matter boiler walls reduces the efficiency, leads to down-times and prolong maintenance periods in biomass fueled power plants. In order to increase the fuel flexibility of commercial biomass combustion chambers, understanding and predicting those ash-related issues is of utmost importance.

At FAU-EVT, we developed a CFD model for the simulation of gas phase combustion and the prediction of slagging in biomass boilers in the megawatt range. We use this simulation framework for the optimisation of existing combustion chambers, aiming for the reduction of depositions for current and alternative biomass fuels.

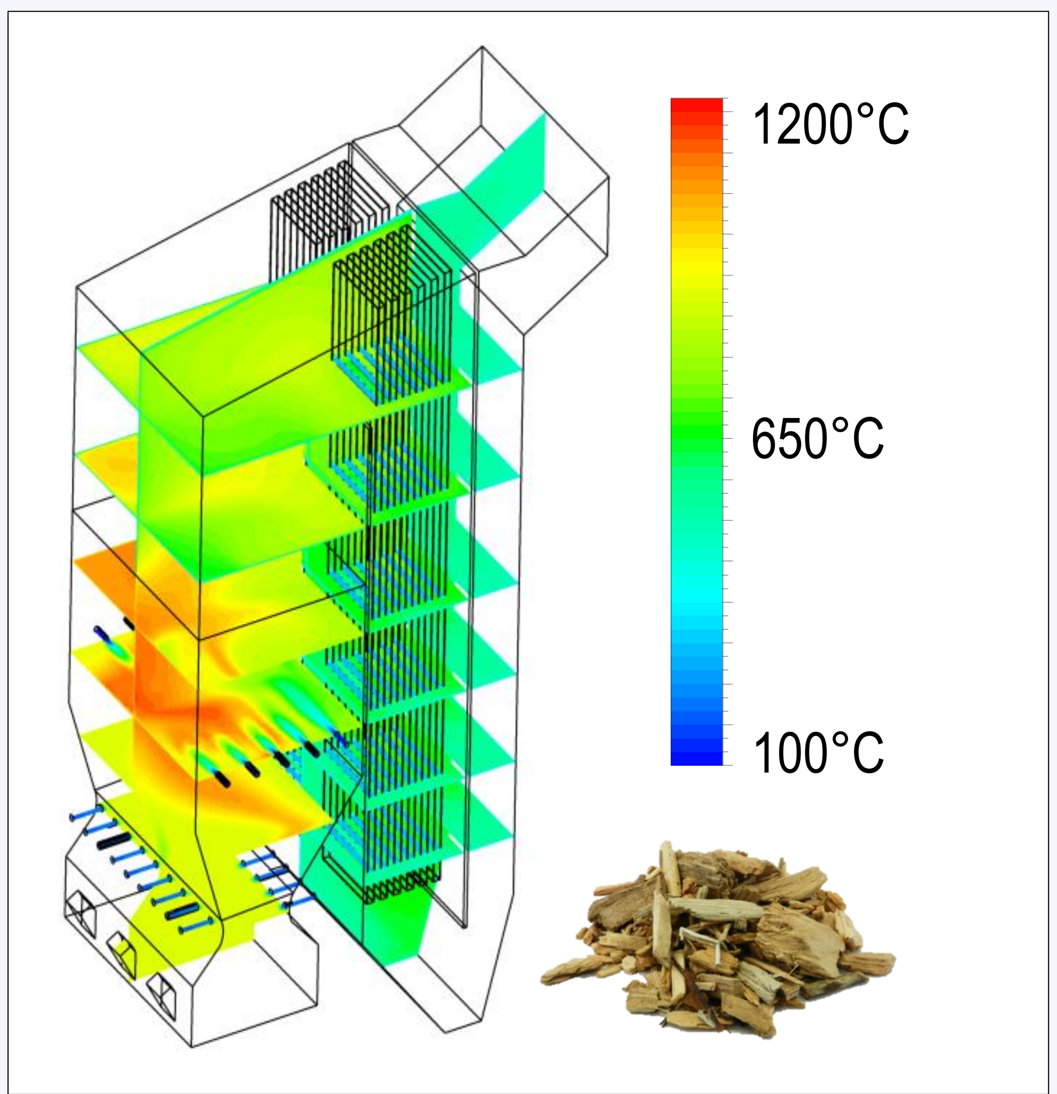

Fig. 1: CFD Simulation of the 50 MW_{th} fluidised bed boiler in Heiligenkreuz (AT)

Simulation of biomass boilers

The model bases on the combustion of millimeter sized fuel fine particles, which are carried away from the fuel bed. Burning in the flue gas duct, particles may exceed ash melting temperature. Hereinafter, on wall contact, the nascent ash may stick, leading to the formation depositions. In order to determine the ash's stickiness, we perform thermodynamic calculations of the molten ash fraction and/or viscosity data. Simulations are carried out in Ansys Fluent™. Inlet boundary conditions are derived from in-house calculation tools. Gas phase combustion is described with a lumped species approach.

The Lagrangian *Discrete Phase Model* is used for the calculation of ~10^6 particle trajectories of burning fine particles. Particle properties during transformation and the sticking model are implemented with *User Defined Functions*.

Slagging prediction

In a first step, we performed CFD simulations for slagging prediction of standard operation points in a 50MW_{th} fluidised bed (Heiligenkreuz, AT) and a 60MW_{th} grate boiler (Ulm, DE) (cf. fig 1 and 2).

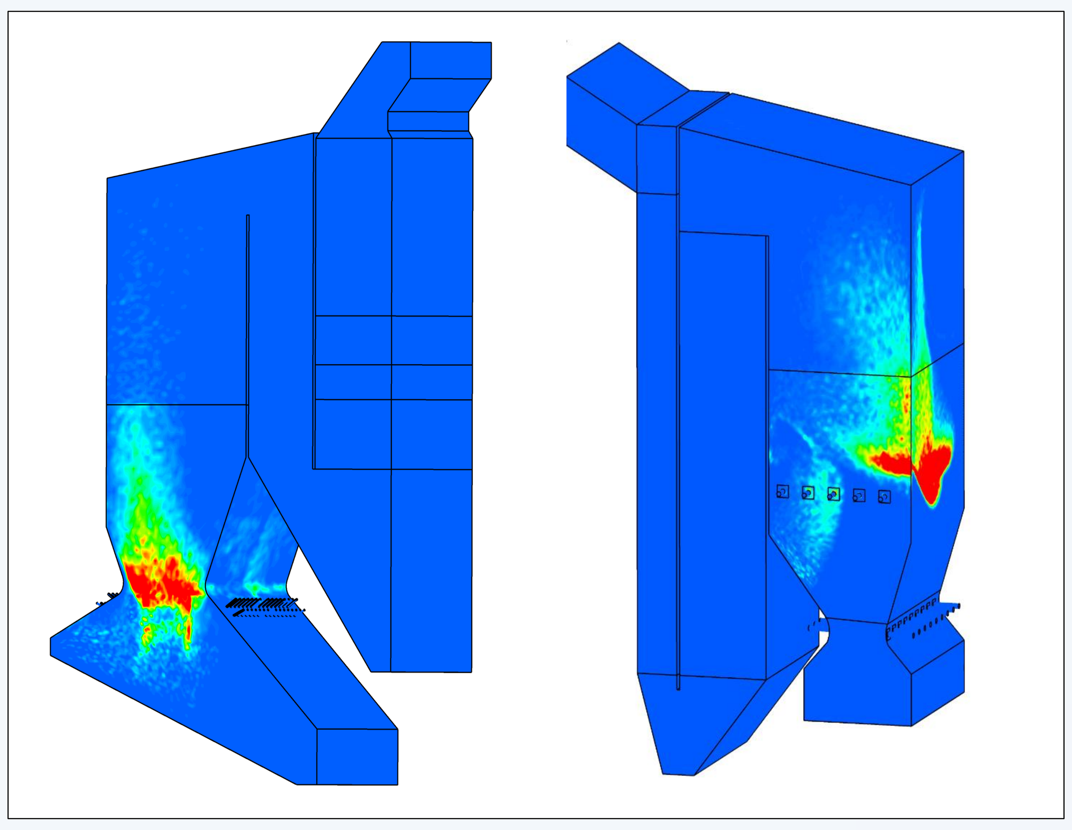

Fig. 2: Predicted slagging in the 60 MW grate (left) and the 50 MW fluidised bed boiler (right)

In both boilers, the highest amount of depositions occurs in the flame-near areas at the concrete walls, especially in the zone of secondary air injection.

Plant optimisation

Consequently, we discuss three possible measures for the optimisation of the slagging behavior in the combustion chamber:

- usage of different feedstock
- changing the height of the refractory lining
- different air-staging

Influence of different feedstock

Fig. 3 shows the influence of the utilization of alternative feedstock with different ash melting temperature. The values of predicted slagging in different boiler regions can be compared to benchmark cases. The simulation shows, that in the typical range of melting temperatures for woody biomass, there is a high sensitivity regarding the fuel quality.

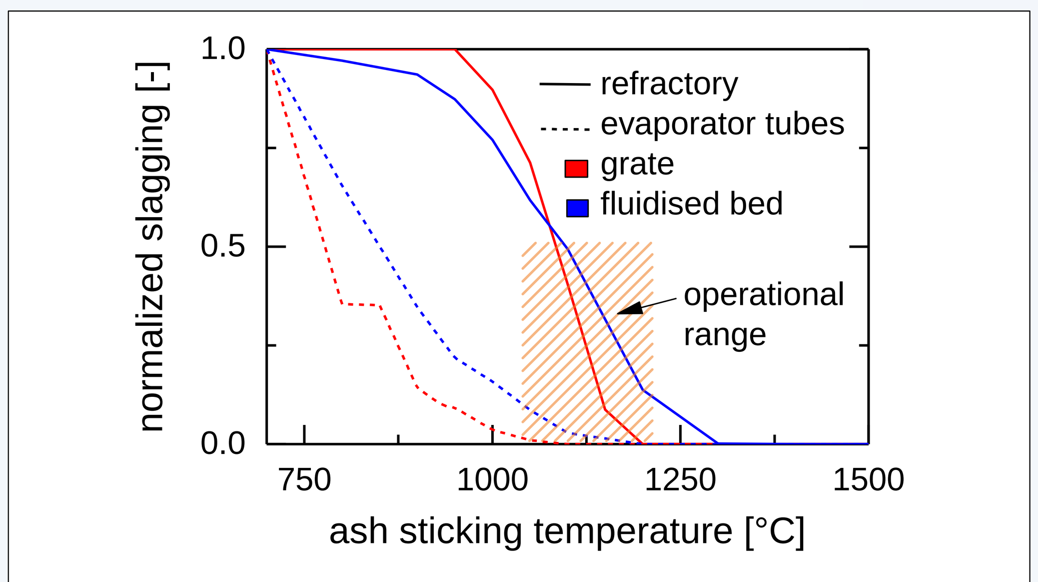

Fig. 3: Predicted slagging with respect to sticking temp.

Influence of refractory lining

Figure 4 shows, that a change in the height of the refractory lining also affects the slagging tendency, especially the area of altered parts. However, also in the zone of secondary air injection, there is an increase in predicted depositions in the case with extended refractory.

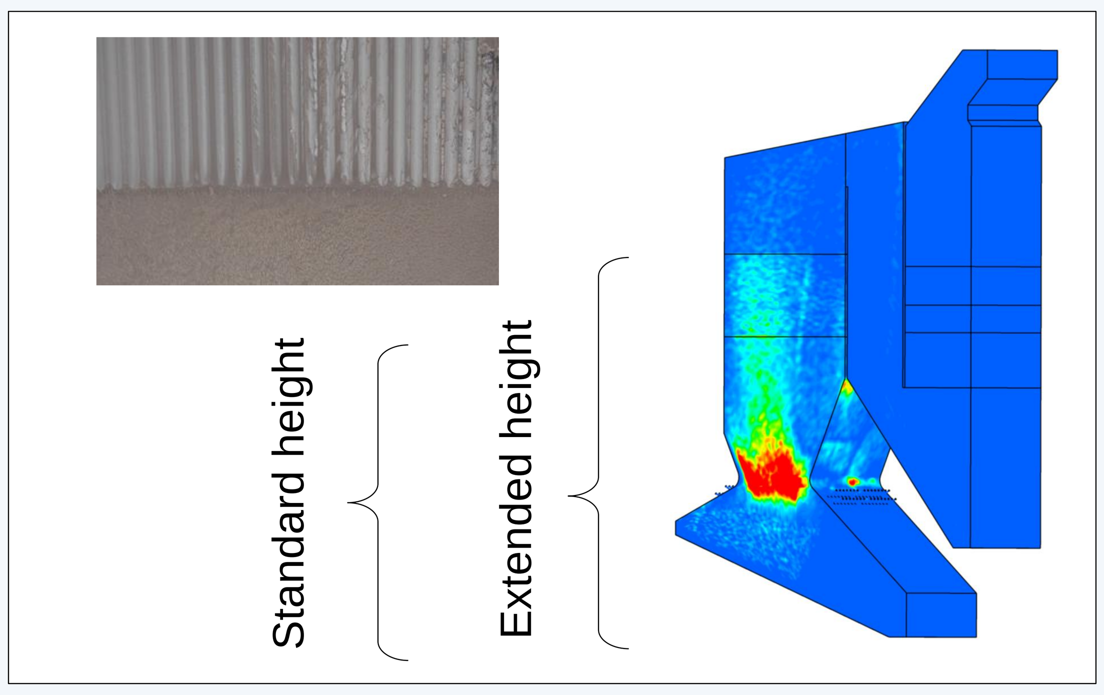

Fig. 4: Modified refractory lining in the 60 MW grate

Alternative air-staging

Huge potential for optimization lies in the airflow setup. Figure 5 shows simulation results in the 50MW_{th} boiler for different setups of secondary air injection at different boiler levels. The standard operation point (1) shows adverse slagging behavior in comparison to case (2) with 50% airflow in the area of constriction over the fluidized bed.

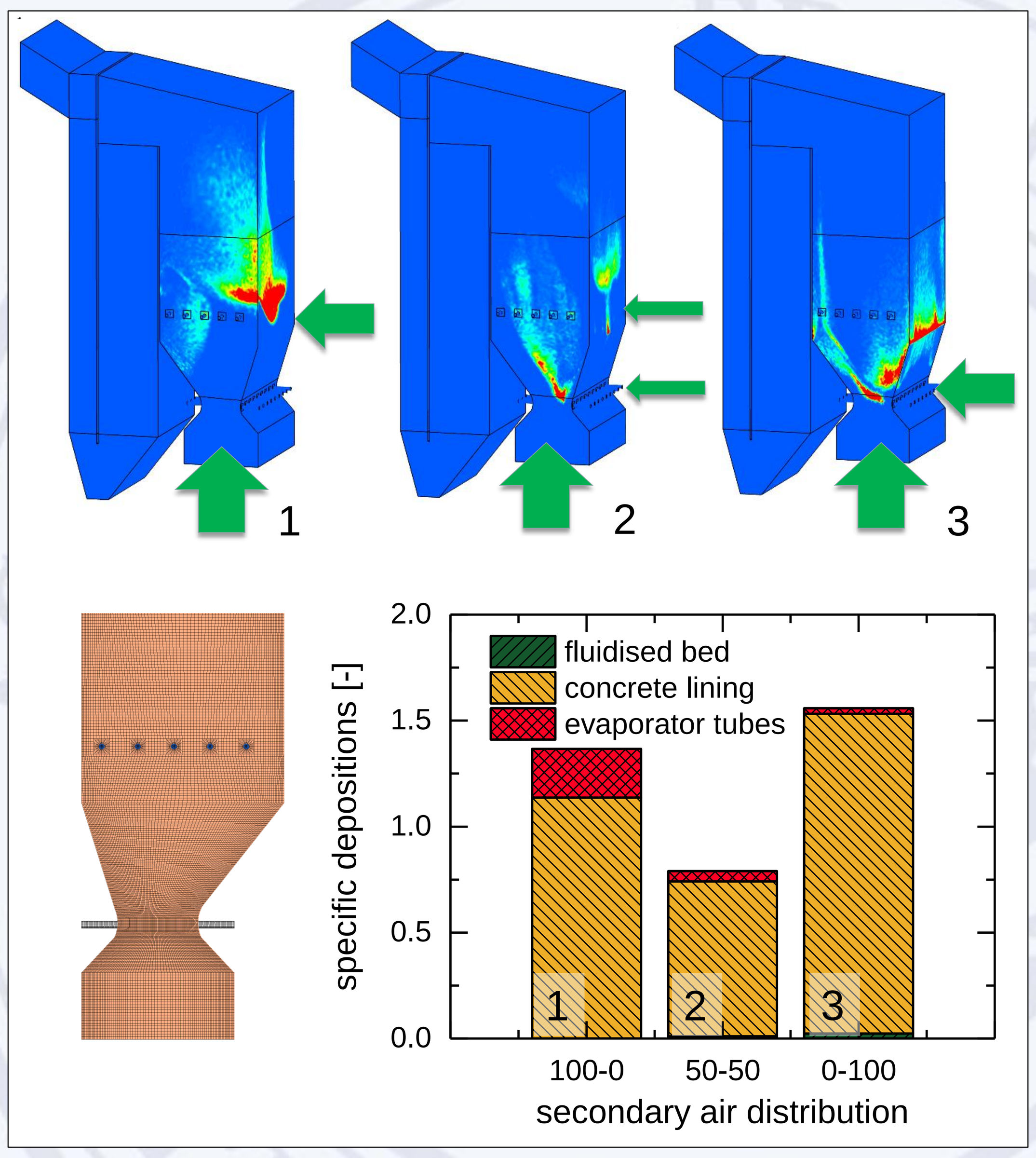

Fig. 5: Simulation results for altered secondary airflow

Conclusion

Comparisons of our standard case simulations with the real depositions in the Ulm and Heiligenkreuz plant boilers matched excellently the real slagging observed during maintenance works. Furthermore, FAU-EVT's slagging prediction model proves to be an useful tool for the evaluation of potential improvements in biomass boilers.

Acknowledgement
This work has been supported by the Bundesministerium für Wirtschaft und Energie under the grant „Energetische Biomassenutzung" (03KB069).

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