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A CFD-method for the analysis and optimization of the fixed bed conversion in biomass grate furnaces

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modelling and simulation

Introduction and objectives

In the power range of 100 kW to 40 MW, moving grate systems are the most common biomass combustion technologies with advantages of high fuel flexibility and low investment costs. The main goal of this work was to investigate the influence of different parameters on the thermal conversion inside the fuel bed by means of CFD simulation. A sensitivity analysis is carried out with following three parameters:

- False air (FA)
- Fuel residence time on the grate
- Distribution of primary air (PA) and recirculated flue gas (RECI) below the grate

Methodology

The grate furnace investigated in this work has a nominal fuel input of 330 kW_{th}. The furnace is equipped with RECI and conventional air staging. Part of the total RECI enters the furnace from below the grate, where it is mixed with PA. A scheme of the furnace is shown in Figure 1.

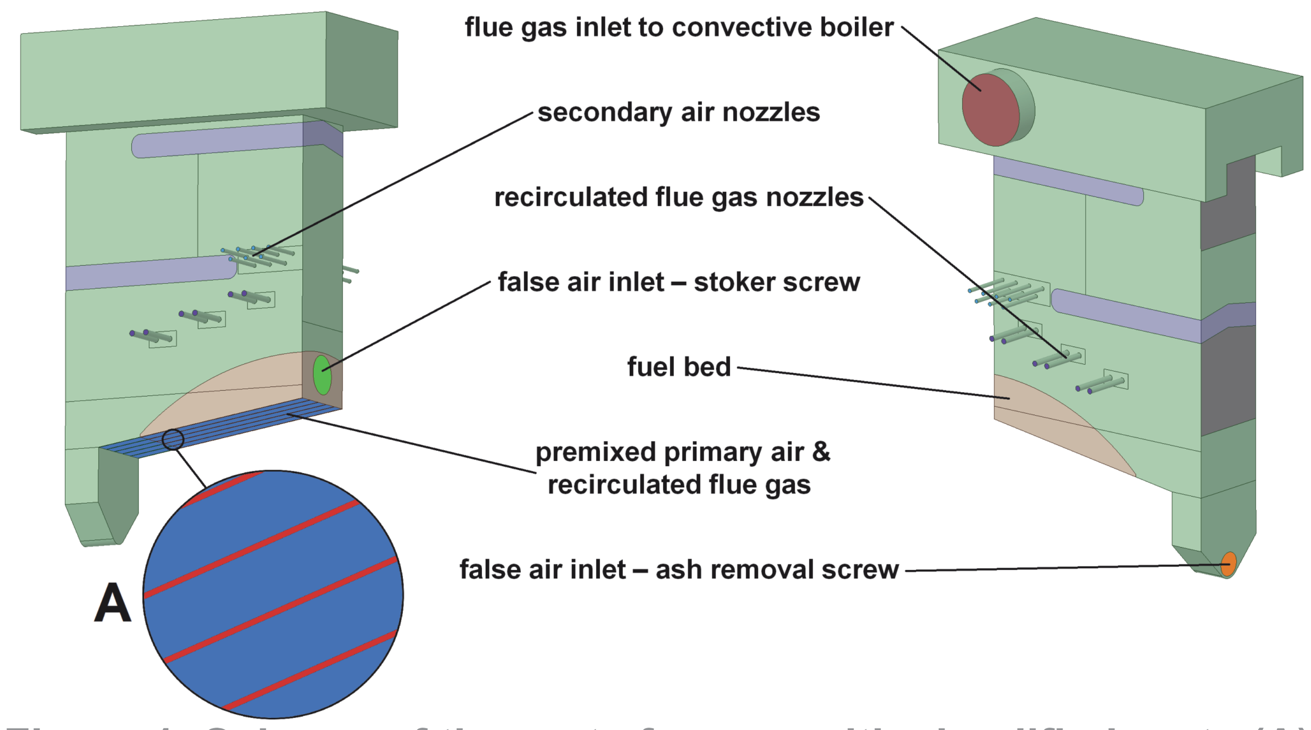

Figure 1: Scheme of the grate furnace with simplified grate (A)

Within the sensitivity analysis, two scenarios for each parameter are assumed. The scenarios are defined and summarized in Table 1.

Table 1: Different scenarios and their key parameters

Scenario 1	Baseline simulation	Scenario 2
Ideal case with no FA	10% of total air is FA. 60% entering from the stoker screw and 40% via the ash removal screw	100% of the FA comes from the stoker screw
Scenario 3		**Scenario 4**
Residence time 20% decreased	90 min residence time of the fuel particles on the grate	Residence time 20% increased
Scenario 5		**Scenario 6**
Uniform distribution of the PA and RECI mixture below the grate	80% of PA and RECI mixture enters through gaps and 20% over the remaining grate	100% of the PA and RECI mixture enters through gaps

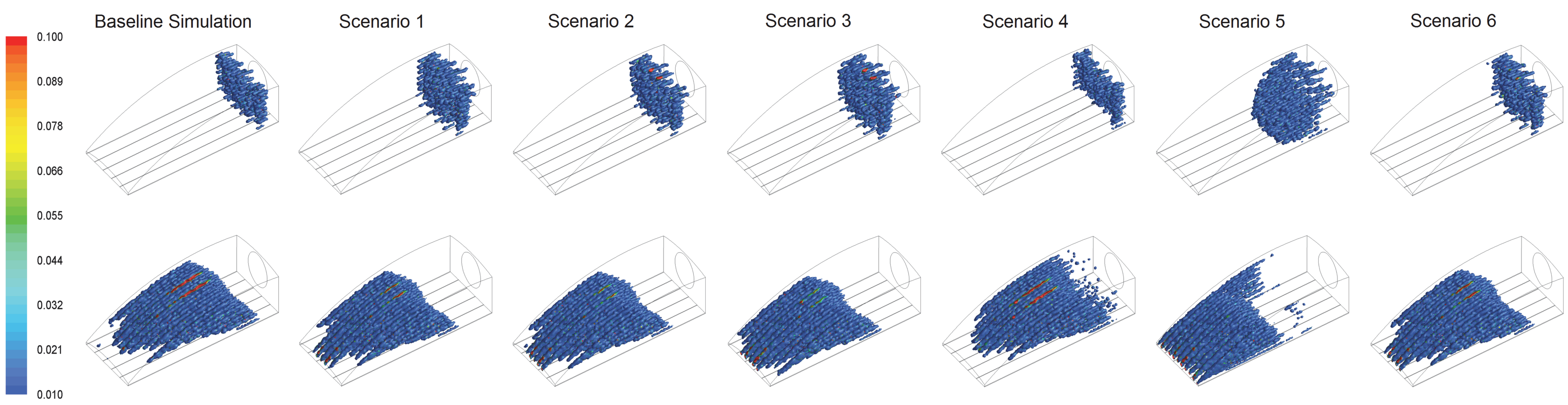

Figure 2: Release rates [mg/s] of H_2O (upper row) and CO (lower row) of the baseline simulation and different scenarios

Results and discussion

The predicted positions of the drying zone (water release) and the char oxidation zone (CO release) are shown in Figure 2. Higher amount of FA from the stoker screw lowers the temperature at the beginning of the fuel bed (Scenario 2). As a result the position of drying and char oxidation on the grate is shifted towards the grate end. A similar effect is observed when no FA is assumed (Scenario 1), as no FA leads to more PA to keep the total amount of combustion air constant. It is due to the fact that increased PA reduces the temperature in the fuel bed. The decreased residence time of fuel shifts the fuel conversion zones to the grate end (Scenario 3). Conversely, higher residence time makes the conversion zones compacter and shifts them towards beginning of the grate (Scenario 4). The uniformed distribution of PA and RECI mixture below the grate leads to a decreased momentum of the gas flow. Since the heat transfer rate is proportional to the gas velocity, a lower gas momentum leads to less convective heat transfer between fuel particles and gas mixture. As a result drying and char oxidation take place later on the grate (Scenario 5). The 20% increase of the PA and RECI mixture entering through the grate gaps hardly changes the gas momentum, hence, it has almost no impact on the thermal conversion processes (Scenario 6).

Conclusion

- FA decreases the fuel bed temperature and delays the combustion on the grate. The use of modern fuel feeding systems can reduce the amount of FA.
- Fuel residence time on the grate changes the position of the conversion zones and consequently influences the combustion in primary combustion zone.
- Higher momentum of the gas mixture below the grate has a positive effect on the conversion behavior. This might result in an undesired increase of coarse fly ash particles.

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