Abstract related to topic 2 Biomass conversion for bioenergy -
2.4 Gasification for power, CHP and polygeneration

Detailed CFD simulations of the fuel bed of an updraft gasifier and comparison to experimental results

Martina Blank[1], tel: +43 316 48130015; email: blank@bios-bioenergy.at
Claudia Benesch[1], tel: +43 316 48130061; fax: +43 316 481300 4; email: benesch@bios-bioenergy.at
Günter Knauss[1], tel: +43 316 48130017; email: knauss@bios-bioenergy.at
Ingwald Obernberger[1*], tel: +43 316 48130012; email: obernberger@bios-bioenergy.at
[1] BIOS BIOENERGIESYSTEME GmbH, Hedwig-Katschinka-Straße 4, A-8020 Graz, Austria

Introductive summary: This work has been performed in the framework of the R&D project HiEff-BioPower (funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 727330). The objective of this project is to develop a novel CHP technology that combines biomass fixed-bed updraft gasification with a solid oxide fuel cell, via the utilisation of a novel high temperature gas-cleaning unit. The aim of this technology is to achieve a high fuel-flexibility, electrical efficiencies above 40% (related to the fuel power input), a high overall efficiency and extremely low emission (equal-zero) for a medium-scale application (1 – 10 MW of total power output).

Purpose of the work: One central element of this new technology is the fuel-flexible updraft fixed-bed gasifier, and an important issue within this project is the fundamental understanding of the conversion processes and their location in the fuel bed. This is of relevance in order to understand the influence of operation conditions on the gas quality achievable as well as on the temperature profiles occurring over the fuel bed. Based on the results the influence of different operation conditions on the gas quality and process stability can be evaluated – for instance the influence of steam addition versus flue gas recirculation. To study these aspects and relevant influencing parameters, CFD simulations of the fuel bed of a pilot-scale gasifier (nominal fuel power 450 kW) were performed in a 2D setup with a first-principle modelling approach for softwood chips (M30) as biomass fuel.

Approach: In our approach, the conversion of the fuel is described with a particle-layer model, which allows for realistic modelling of thermally thick fuel particles. In addition, the model contains a detailed pyrolysis mechanism, which is an adaptation of the mechanistic scheme developed by Ranzi et al. (2008), modified to include secondary char formation reactions. The gas phase reactions are also described with a detailed mechanism (POLIMI_BIO), which is complementary to the pyrolysis modelling and was specifically developed for thermochemical biomass conversion. The operating conditions for the simulation were chosen according to a test run performed at the gasifier, where water cooling of the grate as well as flue gas recirculation below the grate were employed to control the temperatures in the fuel bed. During the test run, data was collected regarding the composition of the producer gas and the gas temperatures at fuel bed exit, as well as the temperature-profiles over the height of the fuel bed.

Scientific innovation and relevance: Employing the approach described above, a detailed analysis of the processes in the gasifier bed are possible. The gasifier bed can be divided into several zones, where certain release mechanism are dominant e.g. drying, pre-, main- and post-pyrolysis as well as char gasification and char burnout. The simulations allow a clear location of these zones and provide the basis to understand the complex interactions of fuel and gas produced in a counter-current fixed bed. From the results, the gasifier geometry as well as the operating conditions can be adapted to the needs of a specific fuel (e.g. regarding ash melting behaviour or gas quality achievable).

Results and conclusions: A comparison of the simulation results with the experimental findings shows good agreement for the composition of the producer gas, and the temperature profile along the fuel bed. Additionally, in accordance with the test run results, the simulation confirms a complete burnout of the fuel. The simulations also clearly outline where temperature peaks are expected and thus form a good basis for the selection of appropriate bed cooling measures and geometric adaptations in order to avoid strain formation along the bed. Moreover, the influence of operation conditions on the tar load of the gas can be evaluated.

*Corresponding author