biosweet
Biomass for Swiss Energy Future
Swiss Competence Center for Energy Research

In cooperation with the CTI
Energy funding programme
Swiss Competence Centers for Energy Research
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation
Commission for Technology and Innovation CTI

Combined 1D-Fuel-Bed- and 3D-CFD-Model as Design Tool for Biomass Combustion

G. Barroso[1], S. Roth[1], T. Nussbaumer[1], R. Schmid[2]

[1]Lucerne University of Applied Sciences and Arts, 6048 Horw, Switzerland; [2]Schmid AG energy solutions, 8360 Eschlikon, Switzerland

Introduction

Motivation

Bioenergy has a significant potential to substitute fossil fuels and to reduce greenhouse gas emissions for heating, high temperature processes and electricity production. The use of biomass according to the cascade principle, first for food and goods and then the use of resulting residues and waste materials for energy generation is uncritical and therefore favoured.

Biogenic fuels with increased moisture and ash content such as forestry wood chips, bark and agricultural residues are difficult to handle due to their tendency to slag formation on the grate and due to condensation and deposition of fly ash in the furnace. In addition, wood combustion is related to the following air pollutant emissions: On the one hand, health relevant organic compounds (OC) as volatiles (VOC) and condensables (COC), and soot particles as carrier of organics are emitted due to incomplete combustion. These pollutants can be reduced by improved burn-out conditions.

On the other hand, nitric oxide emissions (NO_X) are formed from fuel-bound nitrogen at high temperature and sufficient oxygen availability. Hence there is a target conflict between OC and NO_X. To overcome this conflict, staged combustion with a sub-stoichiometric zone prior to the gas-burnout can be introduced by air staging (Figure 1) [1].

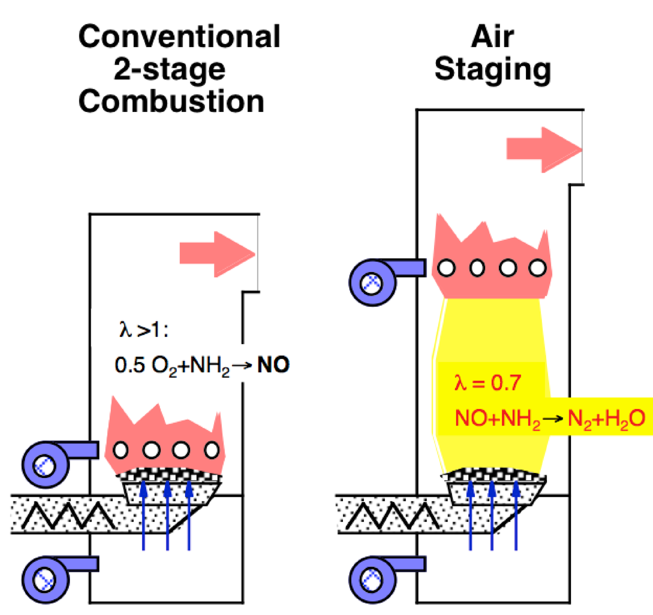

Figure 1
Air staging principle to reduce fuel bound NO_X in a sub-stoichiometric zone [1].

Target

The target of the work is the further development and validation of a generic model which describes the solid fuel conversion on a moving grate and the subsequent gas-phase chemistry, both considering the nitrogen chemistry. The model is applied for the optimisation of the boiler design in particular with respect to reduce both types of pollutants, i.e. OC and NO_X.

Methodology

For the solid phase conversion a one-dimensional transient model based on a two-phase porous medium is used whereas the gas phase is simulated using CFD with reduced chemical mechanisms [2].

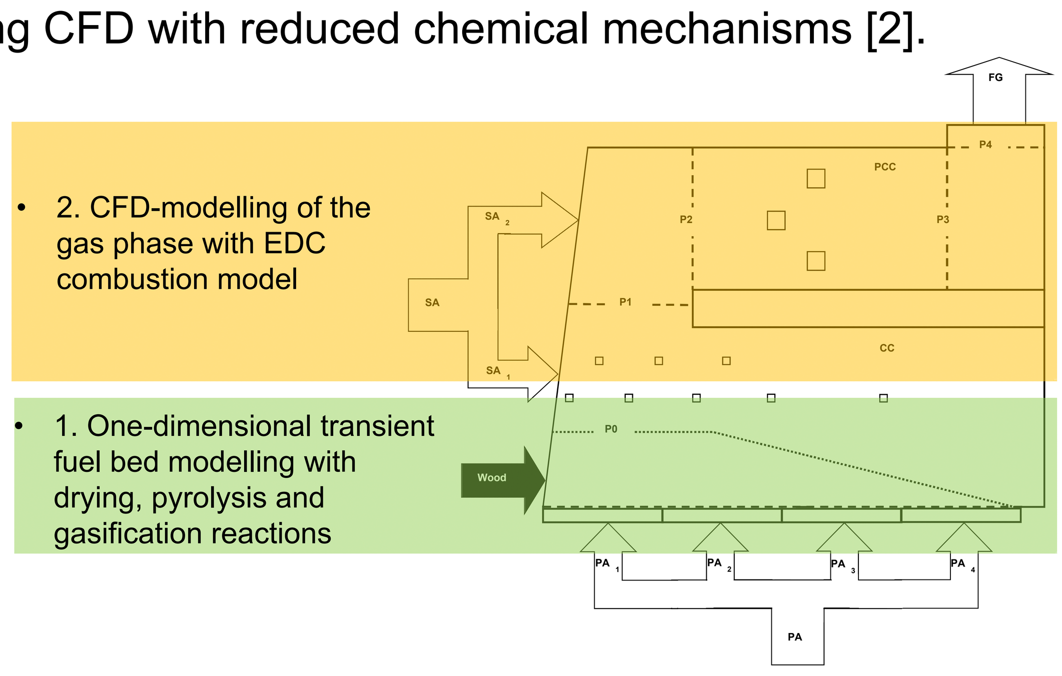

Figure 2
Methodology of Combined 1D- 3D -Model [2].

Results

Fuel Bed Model Validation with Pyrolysis Gas Measurements

To validate the simulation results, a gas sampling equipment with an oil cooled steel probe was built to measure gas profiles above the fuel bed in a moving grate boiler. The gas analysis covers the concentration of VOC, H_2O, CH_4, CO, CO_2, H_2 and O_2 as main indicators of the combustion. Figure 3 shows a comparison of calculated and measured data for the bed height and the water vapour release. The results show reasonable agreement of the simulation with the measurements.

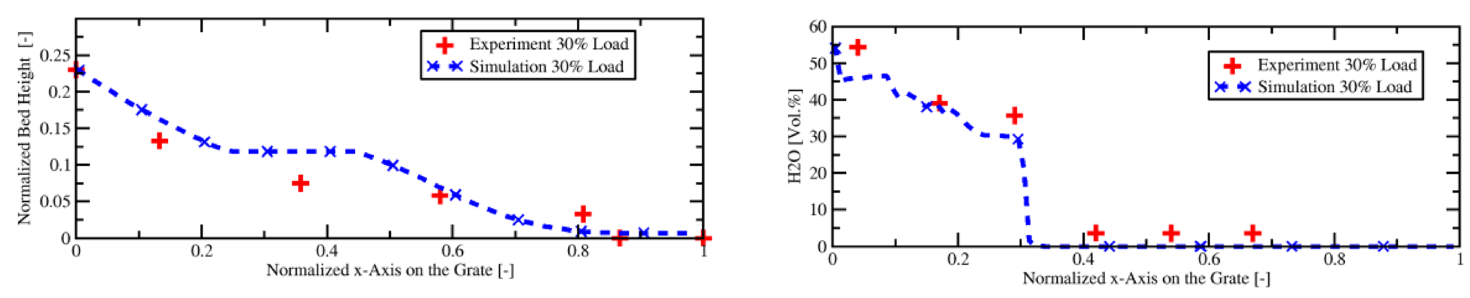

Figure 3 Comparison of the simulated bed height (leftt) and the water vapour above the fuel bed (right) with measured data at part load.

Influence of the moisture content on the fuel bed

Figure 4 shows an analysis of the influence of the moisture content of the wood chips on the fuel bed at 30% load. The moisture content was varied from 25% to 50%. The results show that an increased moisture content extends the fuel bed and leads to a delay in the pyrolysis and gasification reactions.

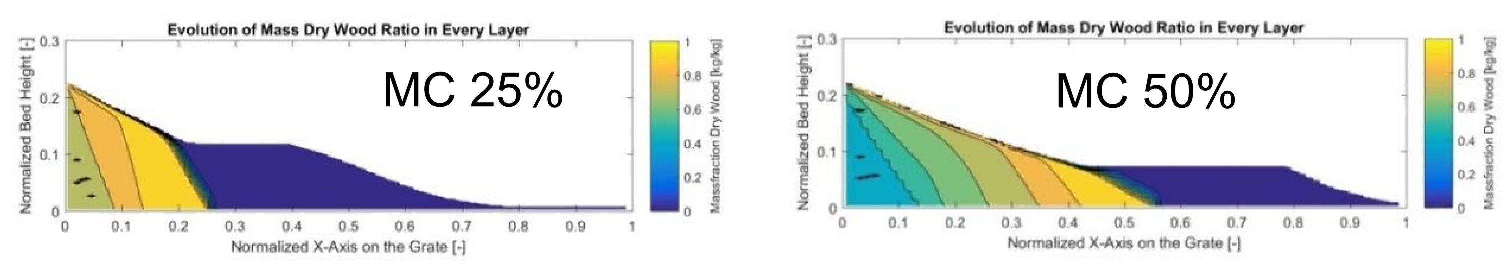

Figure 4 Mass fraction of dry wood for the case of wood chips with moisture content 25% (left) and 50% (right).

Results CFD Simulations

Table 1 compares the simulated pollutant emissions with data measured in a 150 kW prototype moving grate boiler. The simulation shows, that the largest share of the NO_X emissions is released from the bed and that the NO_X production out of the bed mainly occurs in the first half of the bed (Figure 5).

	Experiment	Simulation
NO_x in pyrolysis gas	-	89
CO in flue gas	195	185
NO_x in flue gas	135	128
Air excess ratio λ in flue gas [-]	1.80	1.88

Table 1: Comparison of simulated and measured emissions at part load. CO and NO_X in [mg/m$_n^3$]@13% O_2.

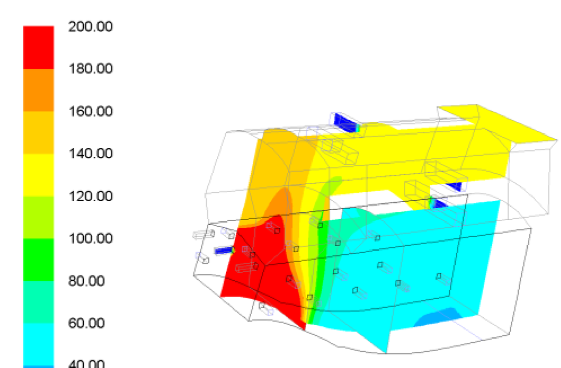

Figure 5 NO_x concentration in [mg/m$_n^3$ @ 13% O_2] in various planes — part load.

Conclusions

The presented combined 1D-3D-simulation method using reduced chemistry can be used to analyse and improve existing furnaces and "virtually" develop new combustion processes. Nevertheless, investigation and model development is continued to further improve the model predictability for a broad number of operating conditions.

Literature:
[1] Nussbaumer, T., *Energy & Fuels*, Vol. 17, No 6, 2003, 1510–1521
[2] Barroso, G., et al. *Proceedings 25th EUBCE 17*, 358–362

Lucerne University of Applied Sciences and Arts
HOCHSCHULE LUZERN

SCHMID energy solutions