BEST
Bioenergy and
Sustainable Technologies

Virtual biomass combustion plant

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FFG
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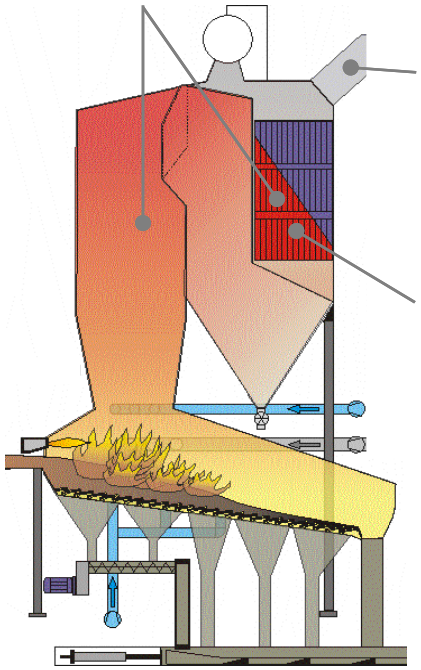
Design aspects of biomass boilers & furnaces

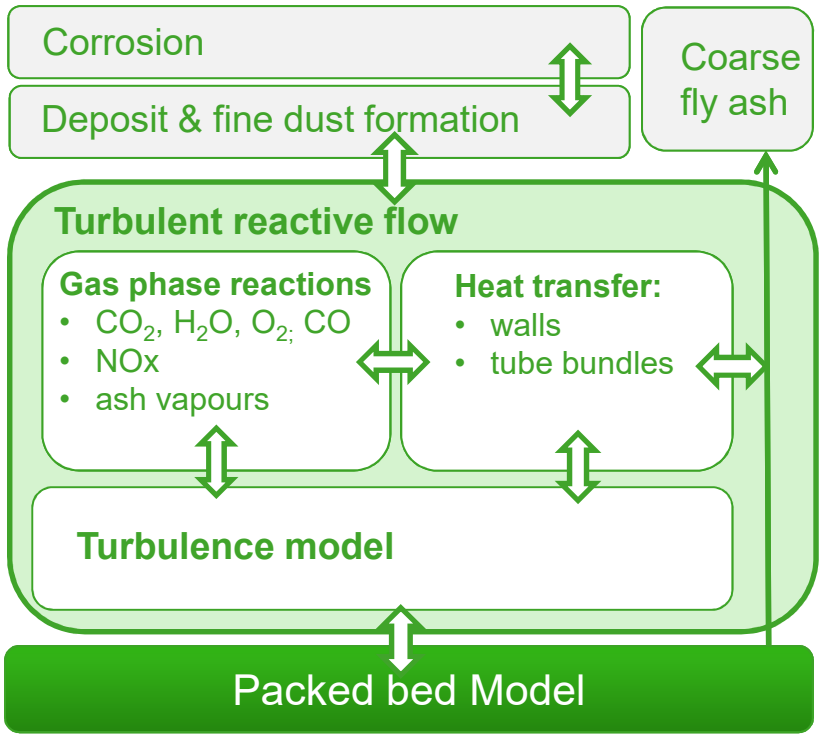
Corrosion rates
Deposit formation



Emissions
- CO
- NOx
- Dust

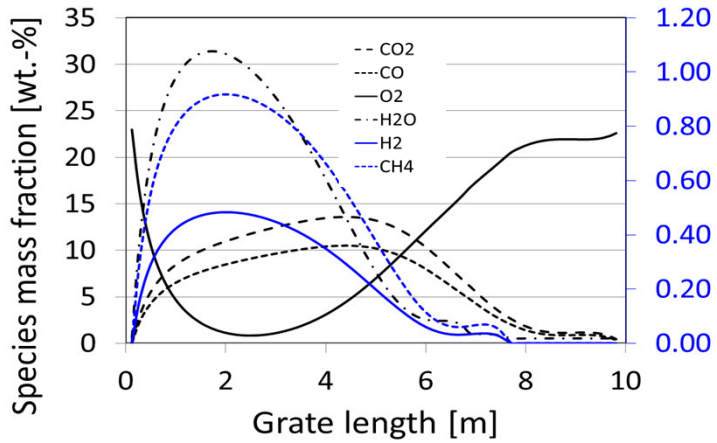
Heat transfer rates

Virtual biomass combustion plant



Packed bed thermal conversion

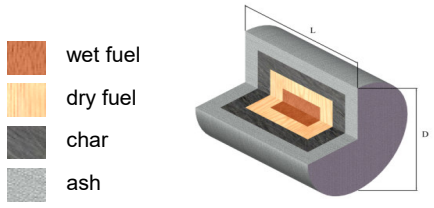
Empirical release model

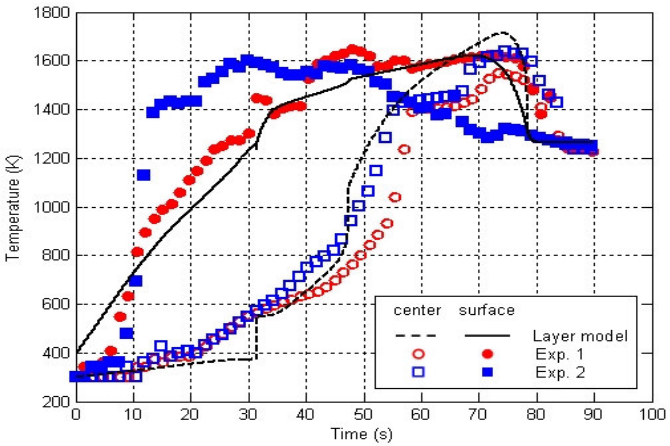


Release curves of major components

- Based on experimental data
- Fulfils mass and energy balance
- Free parameters

Layer model



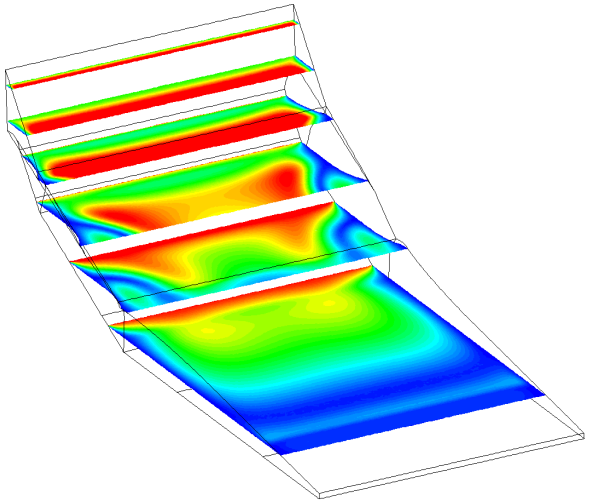


Single particle reactor, oxidising condition, fuel: poplar wood (cylindrical particle)

Packed bed thermal conversion

- Particle movement
  - Laminar Flow Model
  - Euler Granular Model
  - Discrete Element Method (DEM)

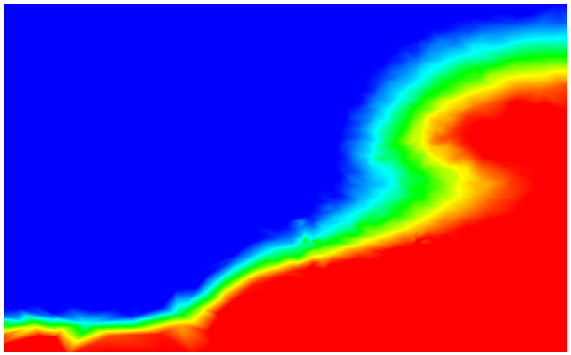
- Further extensions of the packed bed model:
  - NOx precursor species NO, NH_3 and HCN in the layer model, soot and PAH formation and destruction
  - Release behaviour of ash forming elements (K, Na, S, Cl, Pb, Zn) and coarse fly ash particles
  - Transient release model to describe of a complete wood log batch in a natural draft stove



Velocity field of a laminar flow model

Turbulent reactive flow

- Turbulent flows contain a spectrum of eddies
- Turbulence-reaction Models
  - Eddy Dissipation Model (EDM)
  - Eddy Dissipation Concept (EDC)
- Detailed chemical kinetics
  - Kilpinen 92
  - Kilpinen 97-skeletal for NOx prediction

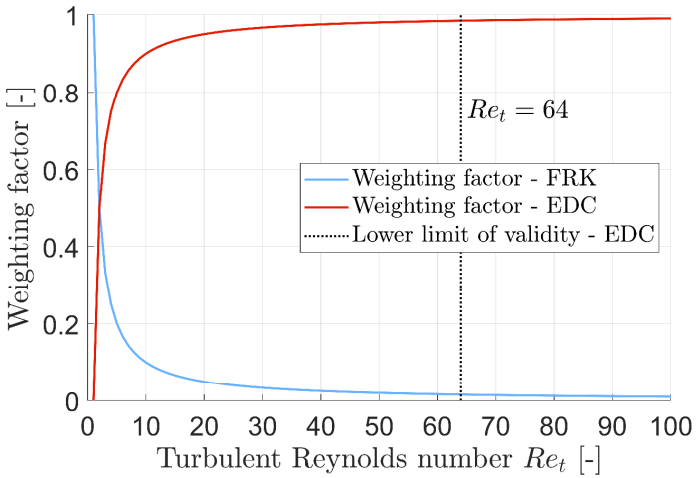


Turbulent structures in a reactive flow

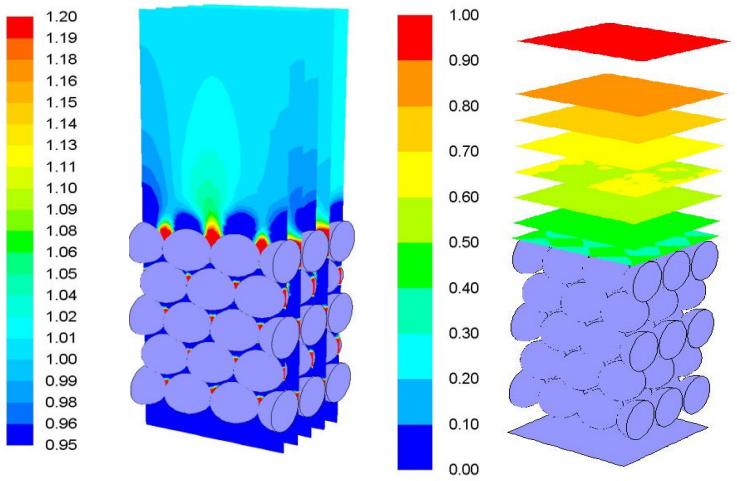
Turbulent reactive flow - extensions

Hybrid model (based on EDC)

$$(R_i)_{Hybrid} = \left(\frac{1}{Re_t}\right)(R_i)_{FRK} + \left(\frac{Re_t - 1}{Re_t}\right)(R_i)_{EDC} \quad for\ Re_t > 1$$



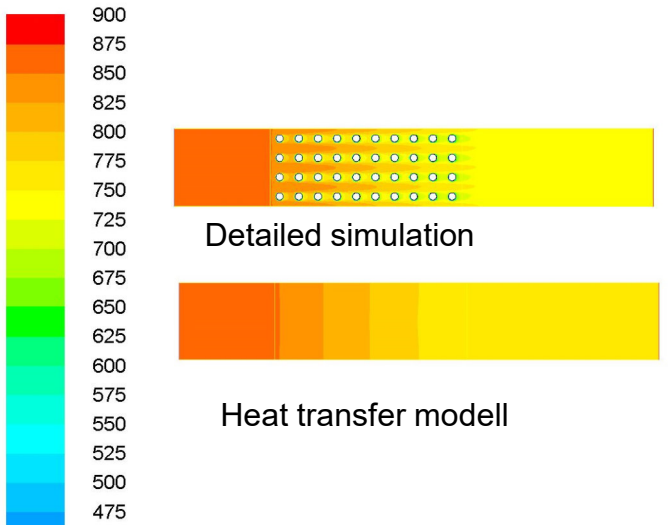
Streak formation model:



Fluctuations of concentration [-] (left) and mixing function [-] (right)

Convective Heat Exchanger Model

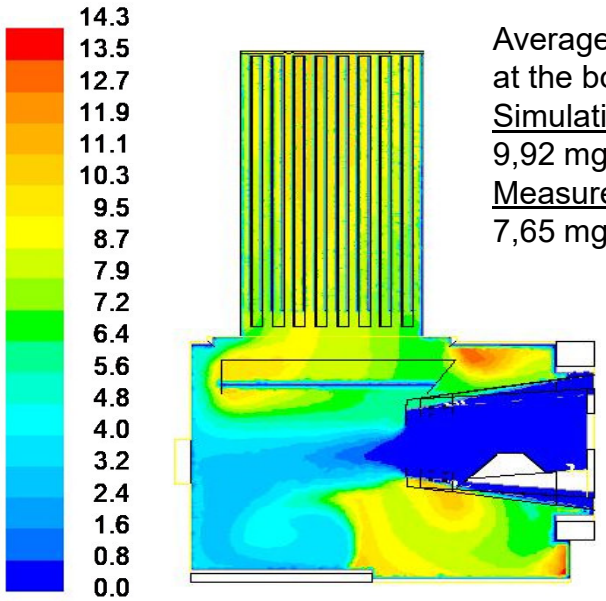
- Sub-models based on literature data
  - Staggered
  - In-line arrangement
- Influence of the flow direction on
  - Flow resistance
  - Convective heat transfer and radiation



Comparison of the flue gas temperature [°C] of a detailed simulation and the result of the heat exchanger model

Fine dust formation

- Ash forming vapors are released from the fuel bed
- Cooling of the flue gas causes:
  - Decrease of the vapor pressure of the components
  - If vapor pressure < saturation pressure
    → Fine particles formation

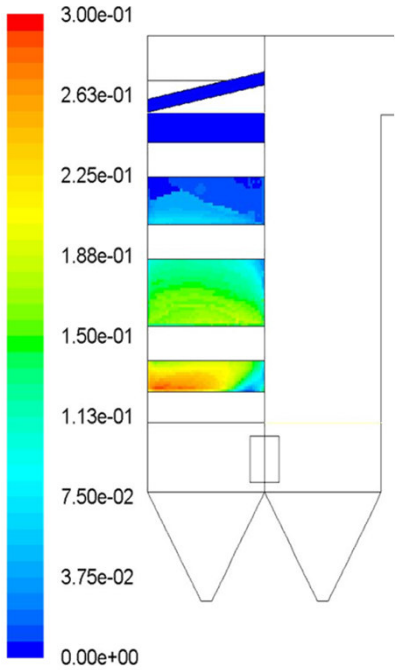


Average concentration at the boiler outlet:
Simulation:
9,92 mg/Nm³
Measurement:
7,65 mg/Nm³

Total fine particle concentration (mg/Nm³ dry flue gas, 13% O_2 in a 70 kW pellet boiler

Ash deposit formation

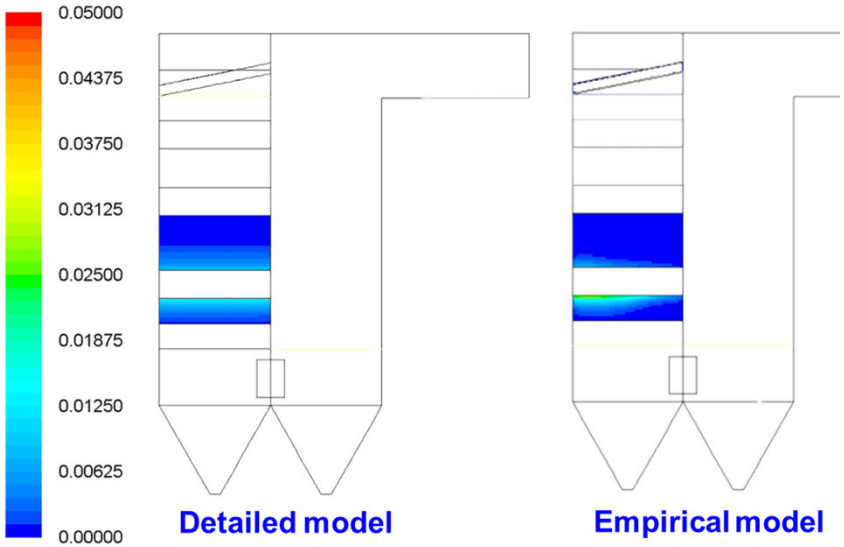
- Deposition mechanisms
  - Fine particles
  - Ash vapors condensation
  - Coarse fly ash particles
- Coupling with a heat exchanger model
- Link to the corrosion model



Deposition rate of chlorine (kg/m²s) in the symmetry plane of the simulated plant.

High temperature corrosion model

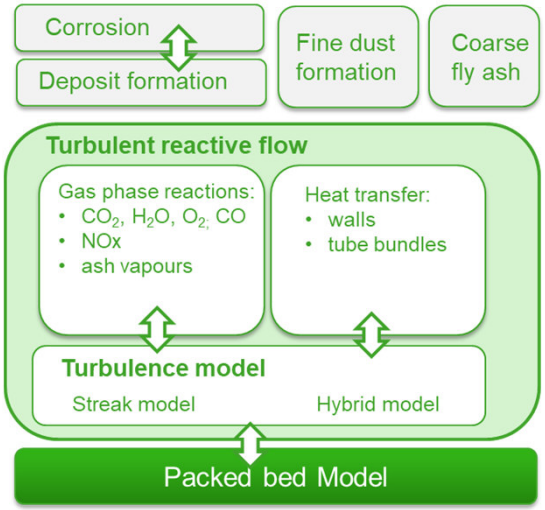
- Detailed model
  - Based on local deposit formation
  - Prediction of the dominating local corrosion mechanism
  - Predicts local corrosion potential
- Empirical model
  - Predicts local corrosion potential as a function of the gas and wall temperature



Comparison of the mass loss calculated after 1000h (mm) with the detailed model (left) and with the empirical model (right).

Outlook

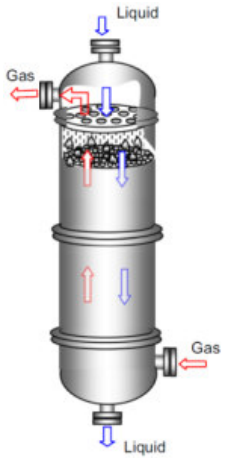
Virtual biomass combustion plant



Fixed bed

Virtual biomass conversion plant

Fluidized bed



Bioconversion