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Single particle modelling for implementation into CFD

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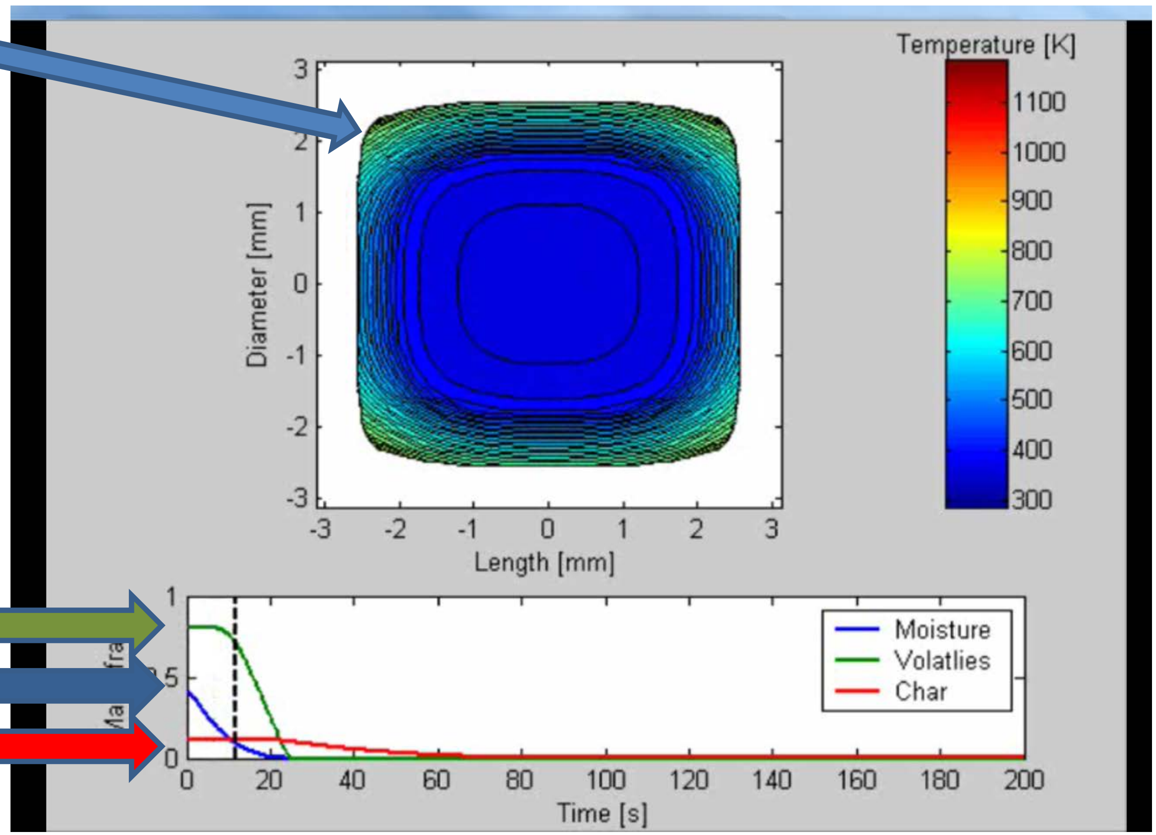
Fuel Conversion in a Great Furnace

Conversion of a Single Particle

Particle Surface



Char + Volatiles = 1

Volatiles

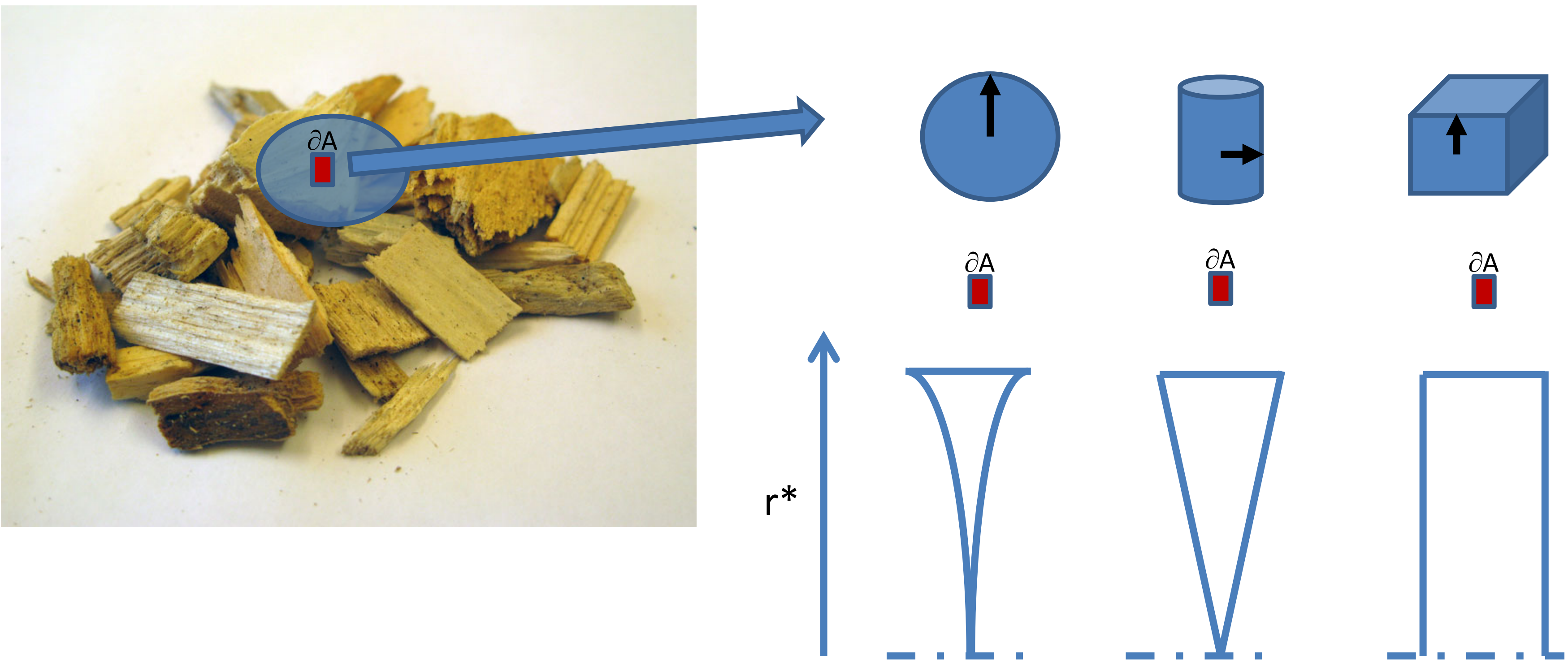
Moisture

Char

Conversion of a Single Particle

Description of Fuel Particles on a Great

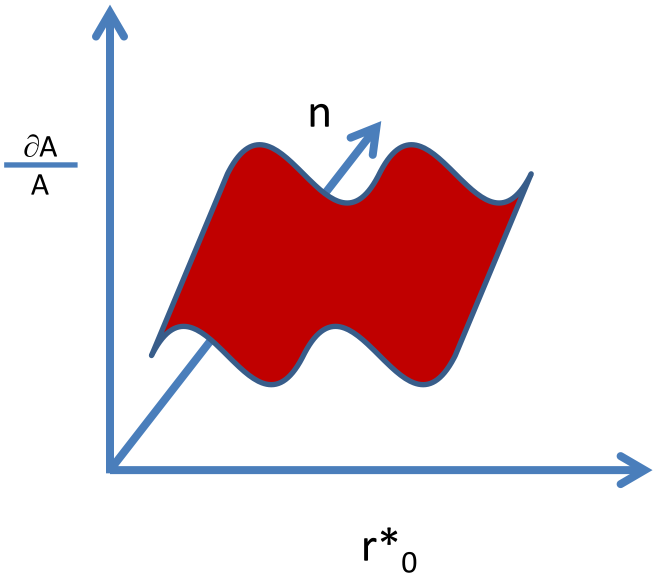
Simplified Models



$A \propto r^{*n}$ n=2 n=1 n=0

$\frac{\partial\ \partial A}{\partial\ r^*} \propto 2r^*$ $\frac{\partial\ \partial A}{\partial\ r^*} \propto 1$ $\frac{\partial\ \partial A}{\partial\ r^*} \propto 0$

Description of Fuel Particles on a Great



Model description to be Developed

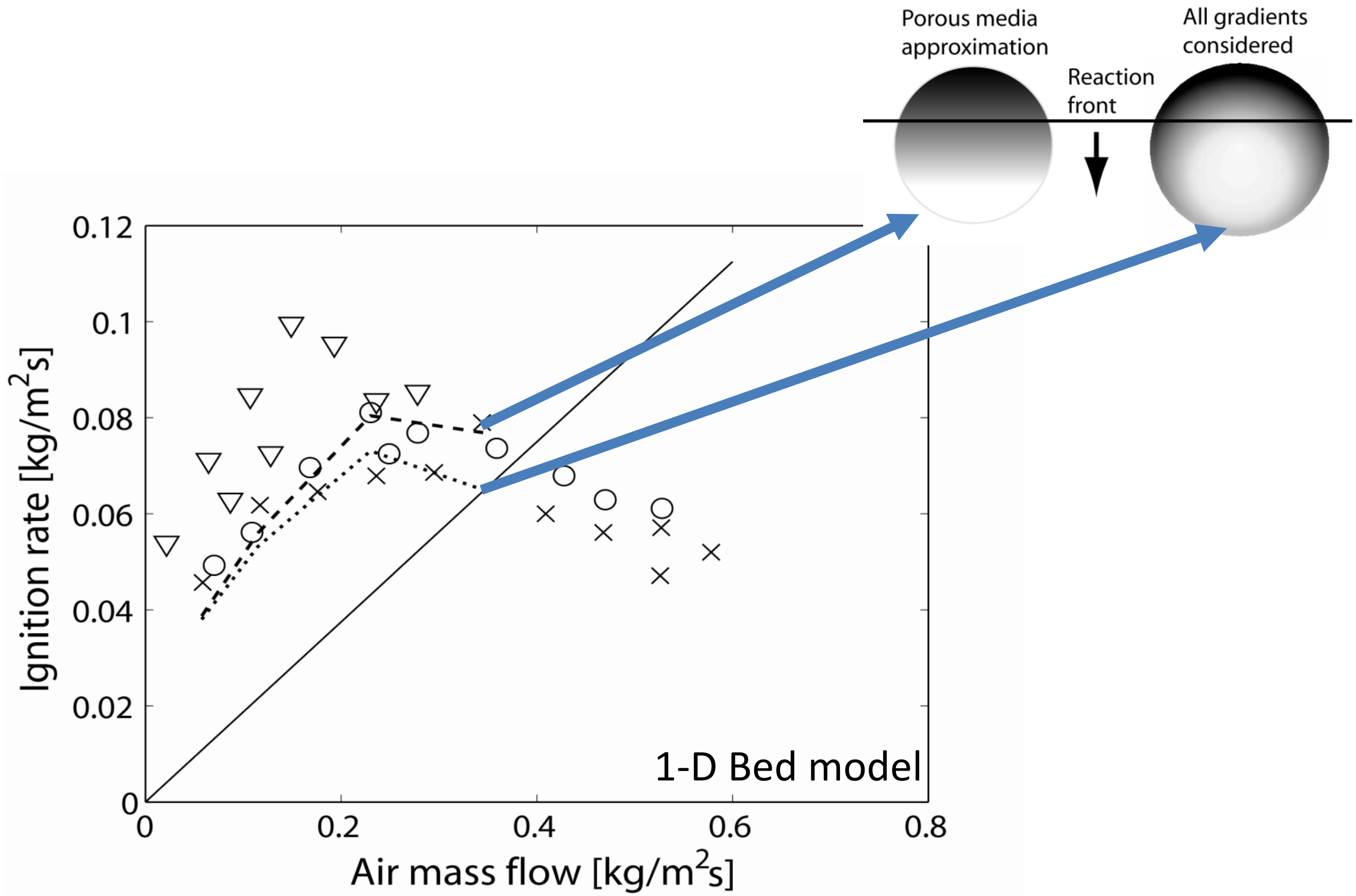
$dT/dt = f(t, r^*, r^*_0, n)$

$dm/dt = f(t, r^*, r^*_0, n)$

Assumption

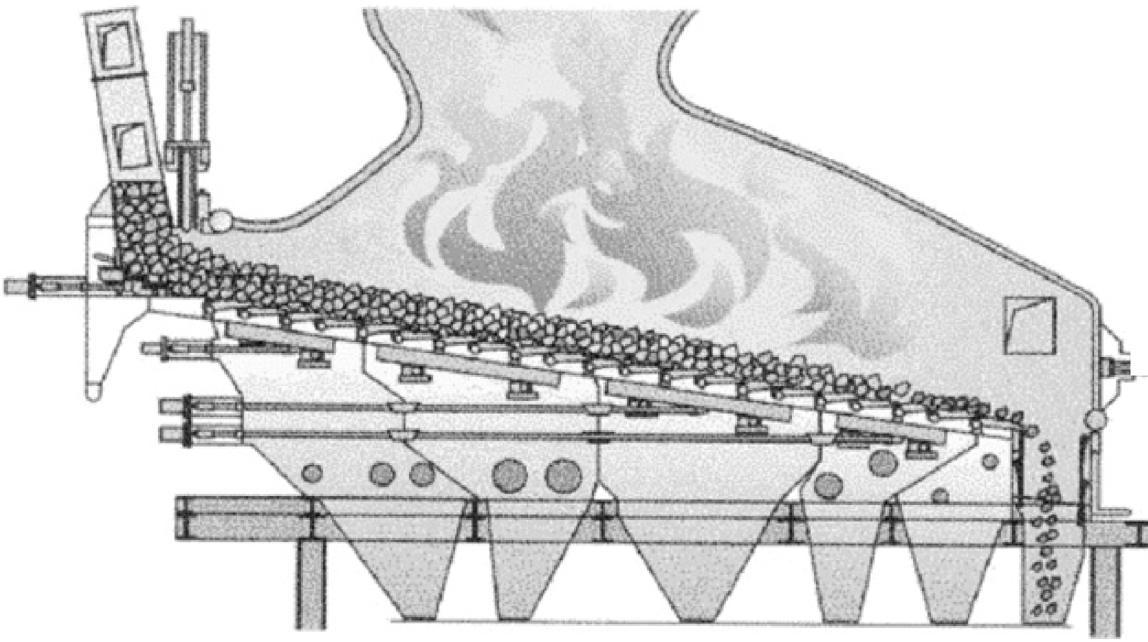
- Heat and mass transfer in perpendicular direction of r* is negligible

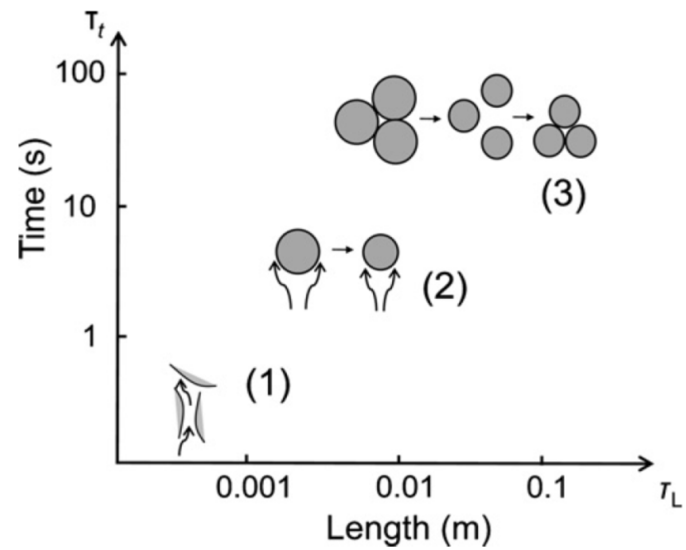
Influence of Resolving the Particles



Johansson, R. ; Thunman, H. ; Leckner, B. (2007). Influence of intraparticle gradients in modeling of fixed bed combustion . *Combustion and Flame*. 149 s. 49-62.

Characteristic Time Scales in a Converting Fuel Bed





1. Gas flow and homogenous combustion
2. Conversion of Fuel Particles
3. Overall bed Movements

Hermansson & Thunman, Comb. Flame 158 (2011)

Preconditions for Implementation of a Particle Model into CFD

- Conservation of heat and mass must be fulfilled at all times

- Robust and efficient particle sub model with an acceptable level of accuracy

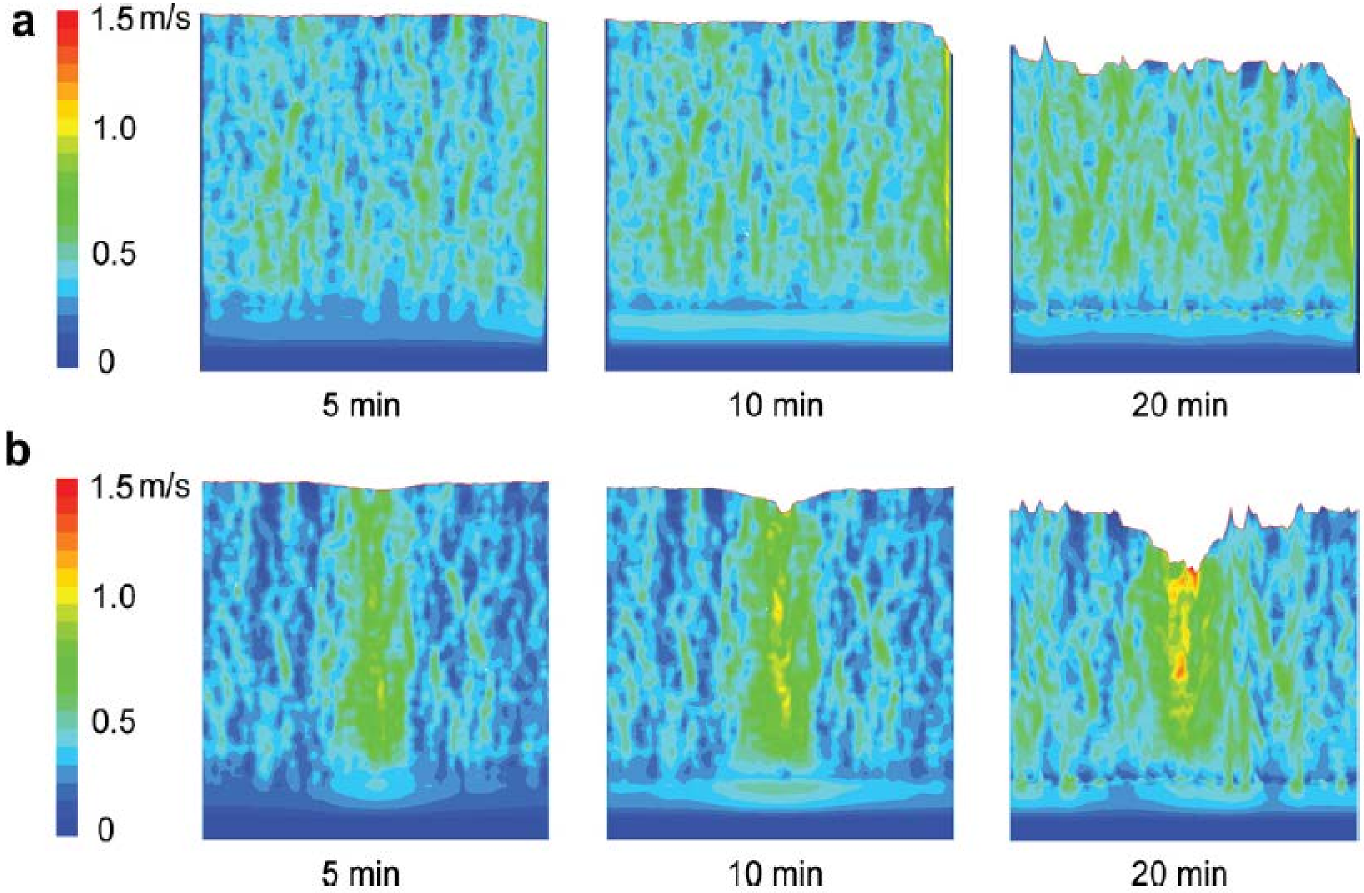
Accuracy higher than uncertainty generated by assumed:

- distribution of the surface elements
- shape for heat and mass transfer into the particles

2D CFD simulations

Even Porosity in Fuel Bed

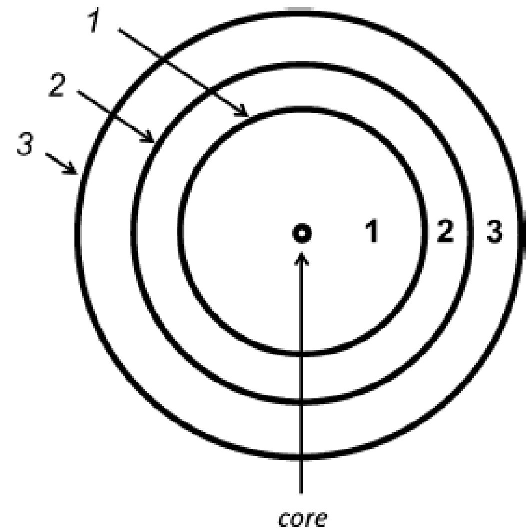
Low Porosity in center of Fuel Bed

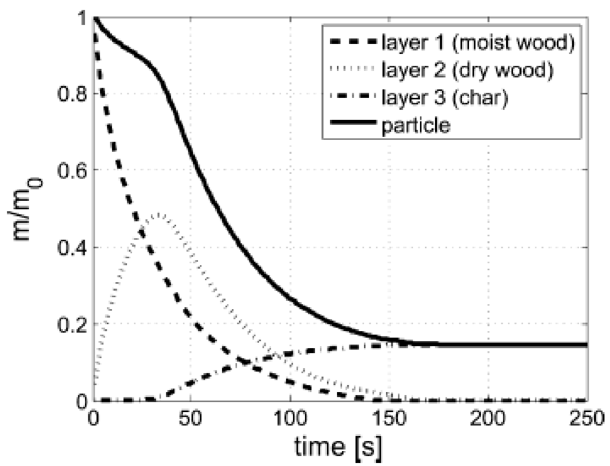


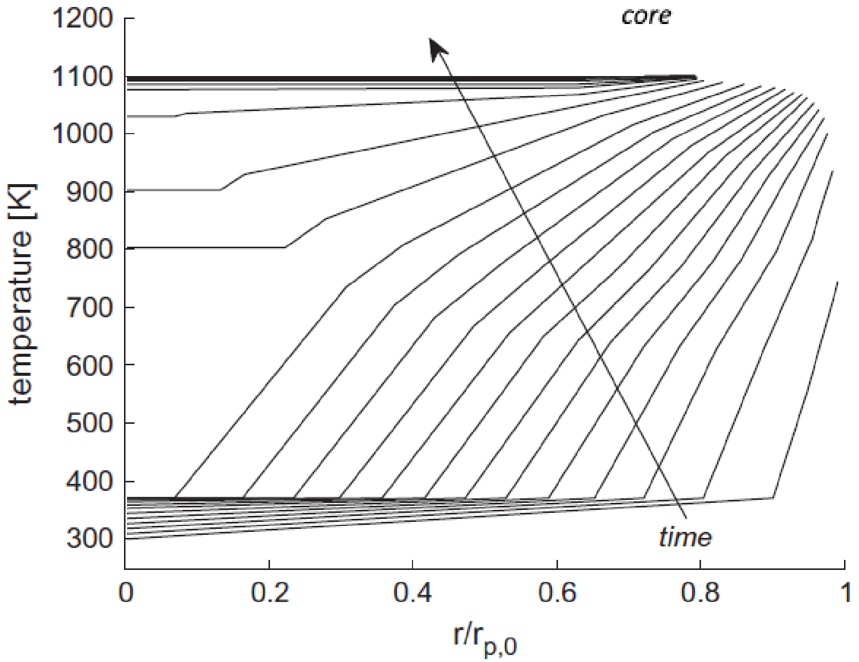
Hermansson & Thunman, Comb. Flame 158 (2011)

Subgrid modeling of fixed-bed conversion with CFD

- Sharp-interface subgrid-scale modelling
- Robust and efficient integration with the bed
- Can predict simultaneous processes (drying, devolatilization, combustion)



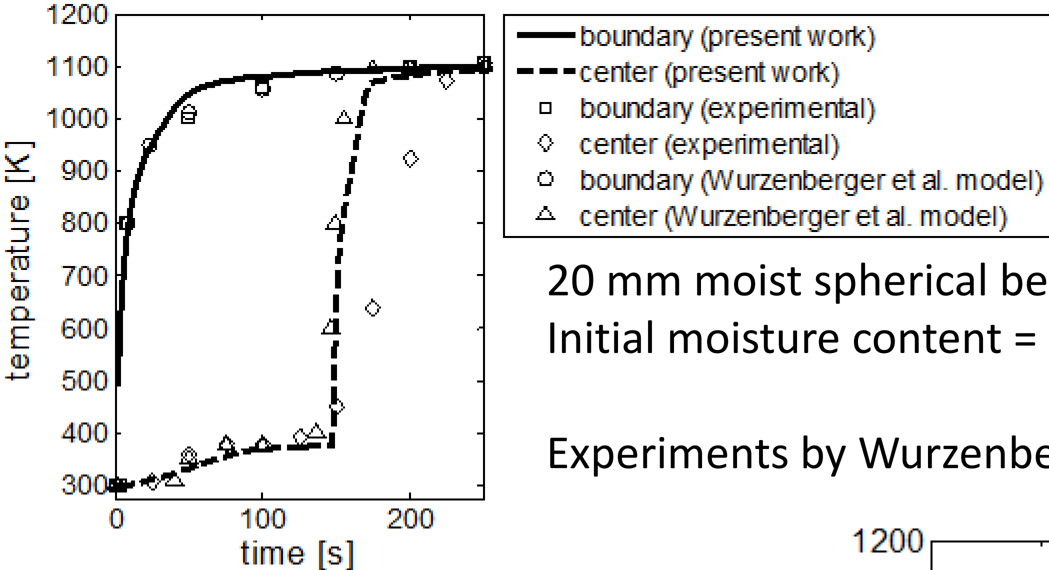




The evolution of the radial temperature profile inside a 20 mm moist wood particle during drying and devolatilization in an inert atmosphere at 1098 K.

Ström & Thunman, Proc. ICAE2012 (2012)
Ström & Thunman, Comb. Flame 160 (2013)
Ström & Thunman, Appl. Energy, In press (2013)

Heat and Mass Transfer



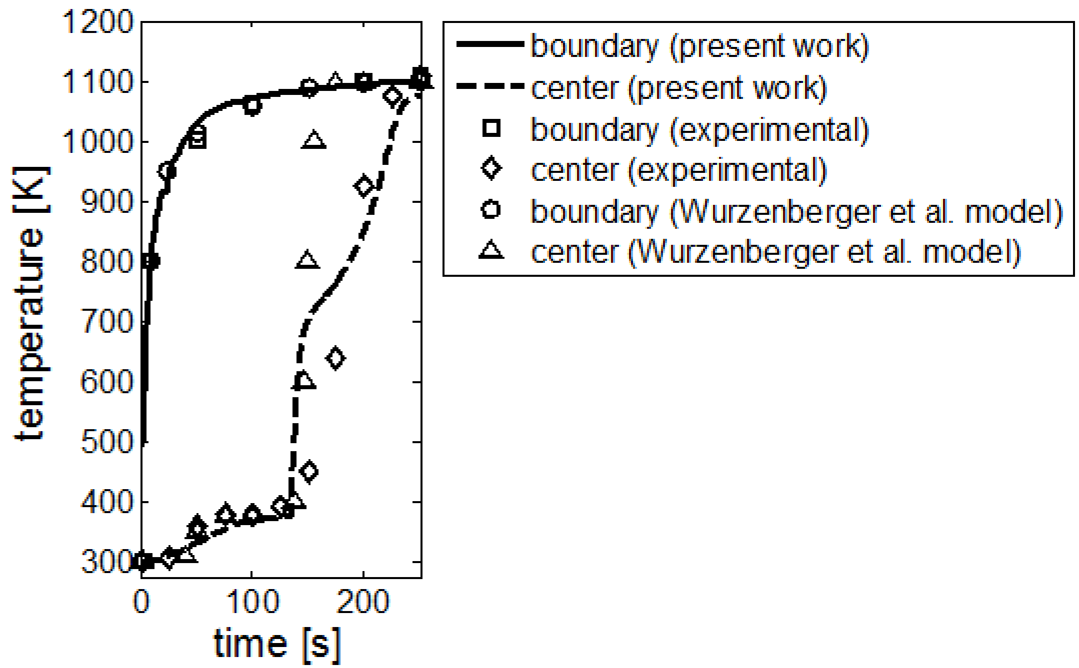
20 mm moist spherical beech wood particle at 1098 K

Initial moisture content = 20 wt%

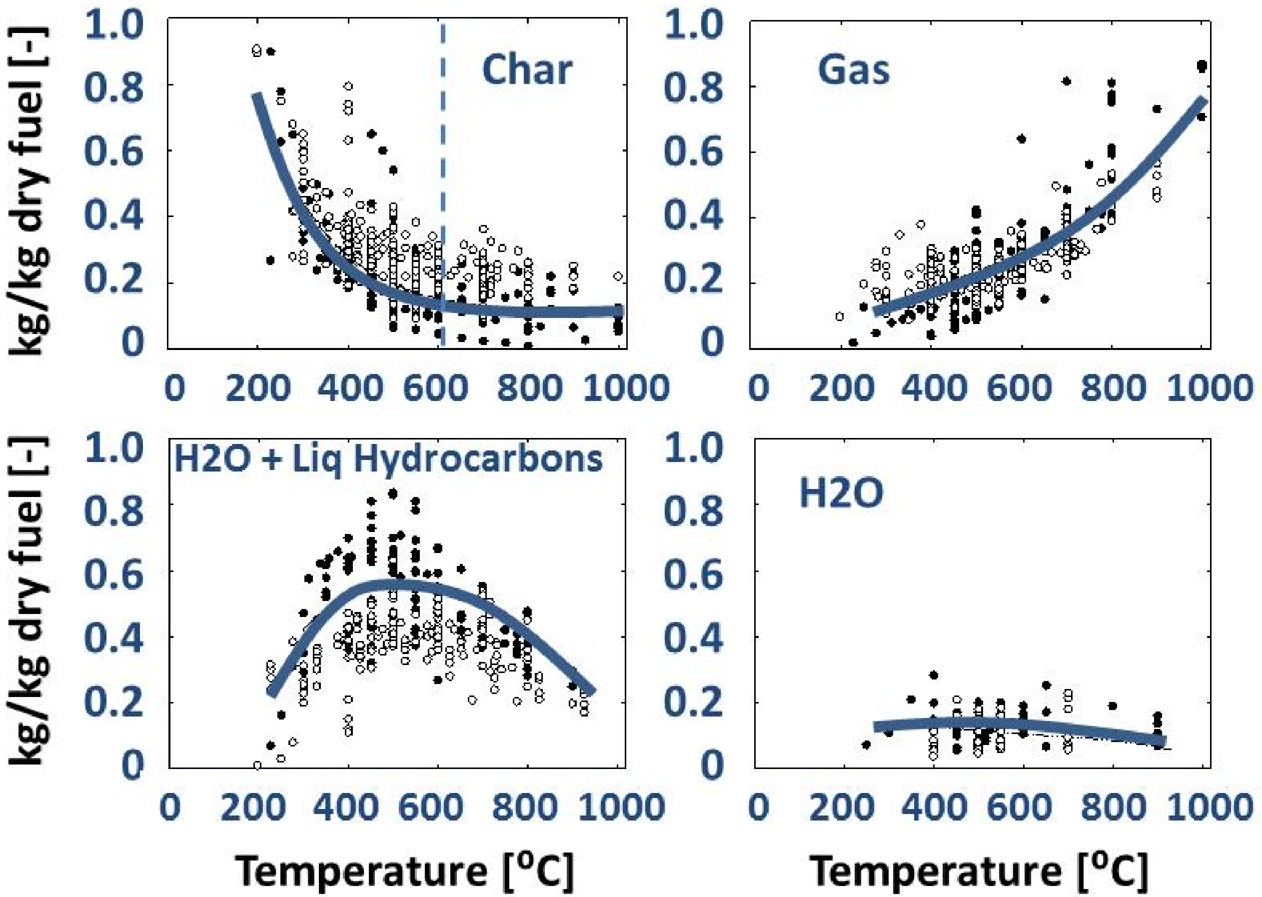
Experiments by Wurzenberger et al., AIChE J. 48 (2002)

heat-neutral

endothermic (fitted)



Decomposition of Biomass



Characterization and prediction of biomass pyrolysis products Review Article

Progress in Energy and Combustion Science, Volume 37, Issue 5, September 2011, Pages 611-630

Daniel Neves, Henrik Thunman, Arlindo Matos, Luís Tarelho, Alberto Gómez-Barea

3D Bed Modelling with Particle Model

Slowly heated biomass bed 15x15x15 cm

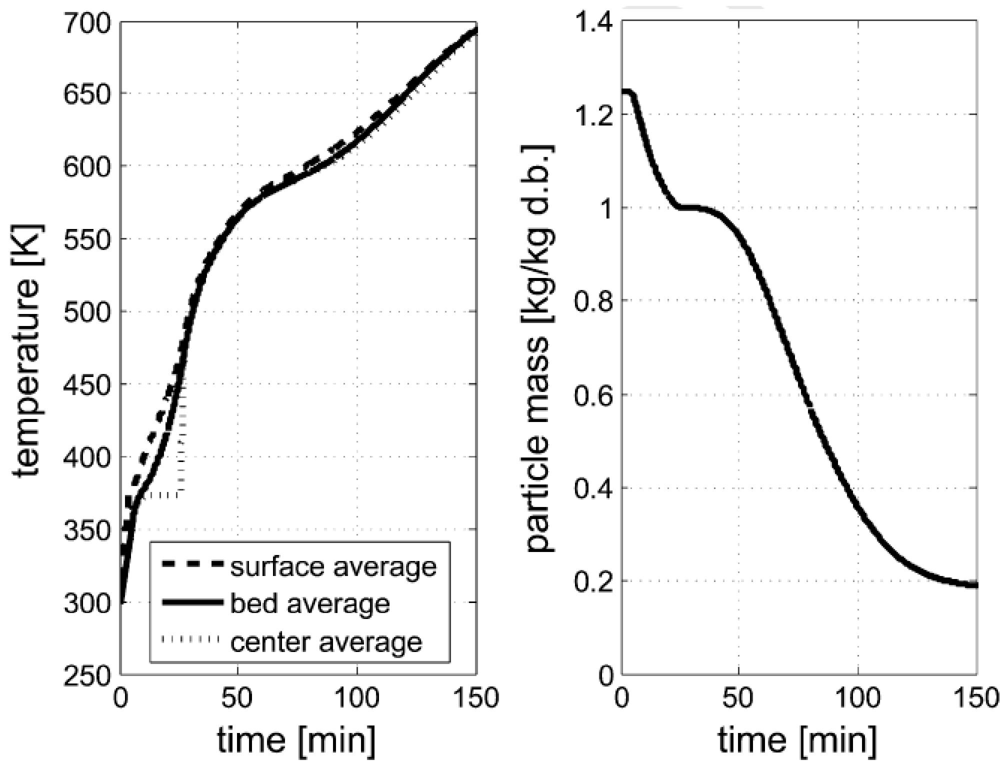


Fig. 18. Sample results from a 3D CFD simulation of the pyrolysis of a fixed bed of spherical moist beech wood particles at 773 K.

Ström & Thunman, Comb. Flame 160 (2013)

Conclusions

- A fuel particle model for 2D and 3D description of biomass combustion on a grate that resolve the internal of the fuel during conversion has been developed and demonstrated

- The heat of devolatilization as function of conversion temperature is important for a correct prediction of the volatile release

- Future work should be focused on an efficient model description of the surface interface between the fuel particles and the gas phase inside the fuel bed