Business from technology

CFD modelling of fluidised bed combustion plants

IEA Workshop: CFD aided design and other design tools for industrial biomass combustion plants

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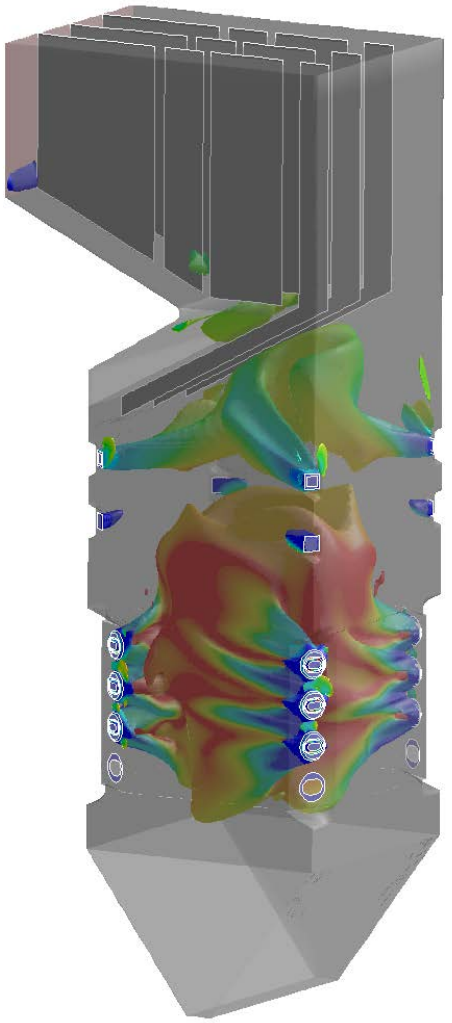
Outline

- CFD Modelling Activities on Combustion at VTT
- CFD Modelling of Fluidised Bed Combustion Plants- An Overview
- Modelling of Combustion in BFB furnaces
  - Modelling Approach
  - Examples of Case Studies
  - Some On-going and Planned Activities at VTT
- Concluding Remarks

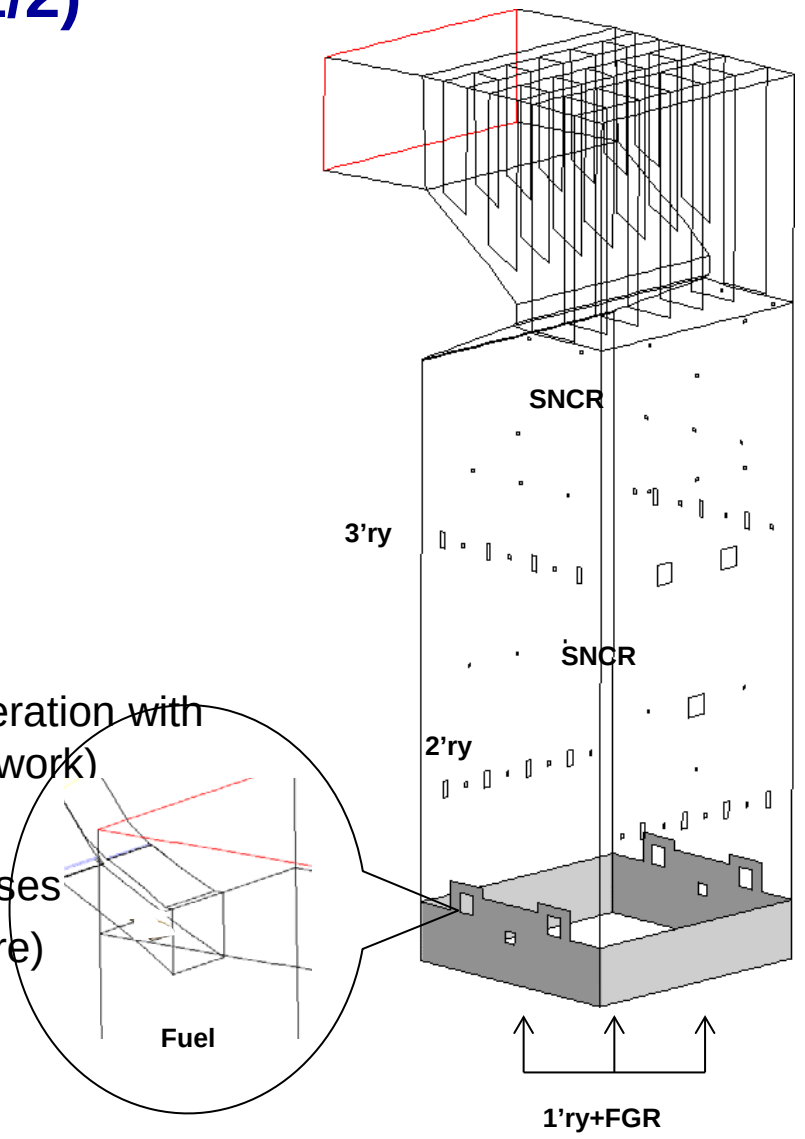
CFD Modelling Activities on Combustion at VTT

- CFD Applied to Combustion Modelling since 1984
- Major Applications:
  - BFB Boiler Furnaces
  - PF- Combustion
    - Boilers and Burners
    - Coal, Peat, Co-firing, Oil shale
  - Grate Fired Furnaces
  - Recovery Boilers
  - CFB Boiler Furnaces
- Staff: 9 researchers



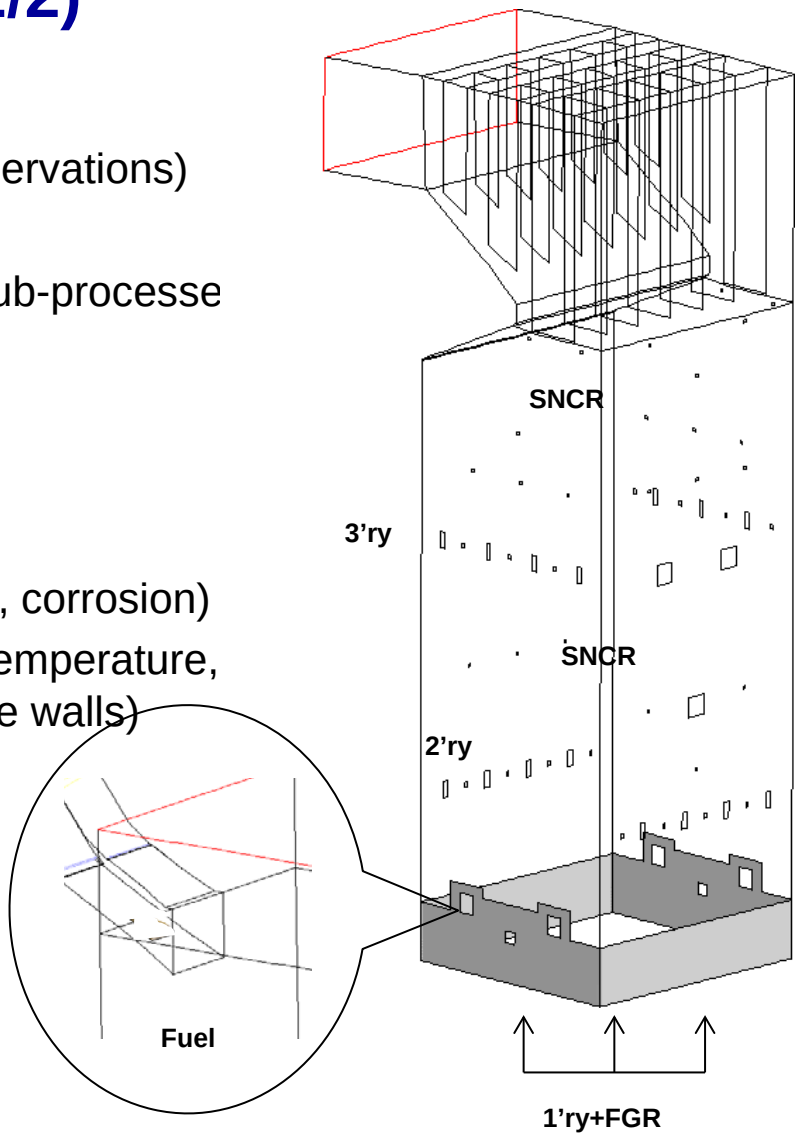
CFD Modelling of Fluidised Bed Combustion Plants- An Overview (1/2)

- Roughly 15 to 20 Boilers Analysed During Last Ten Years
- Boiler Size Range: Fuel Power from 10 to 300 MW
- Fuel and Fuel Mixtures:
  - Fresh wood (chips, bark, forest residue)
  - Peat
  - Sludge
  - REF
- Furnace Models Employed as a Design Tool in Close Co-Operation with Boiler Operators and Designers (mostly confidential contract work)
- Furnace Models Developed Simultaneously with Practical Cases
  - Implementation of new sub-models (mainly from literature)
  - Fine-tuning of existing models
  - Finding best practises (e.g. definition of BC's, combination of sub-models)

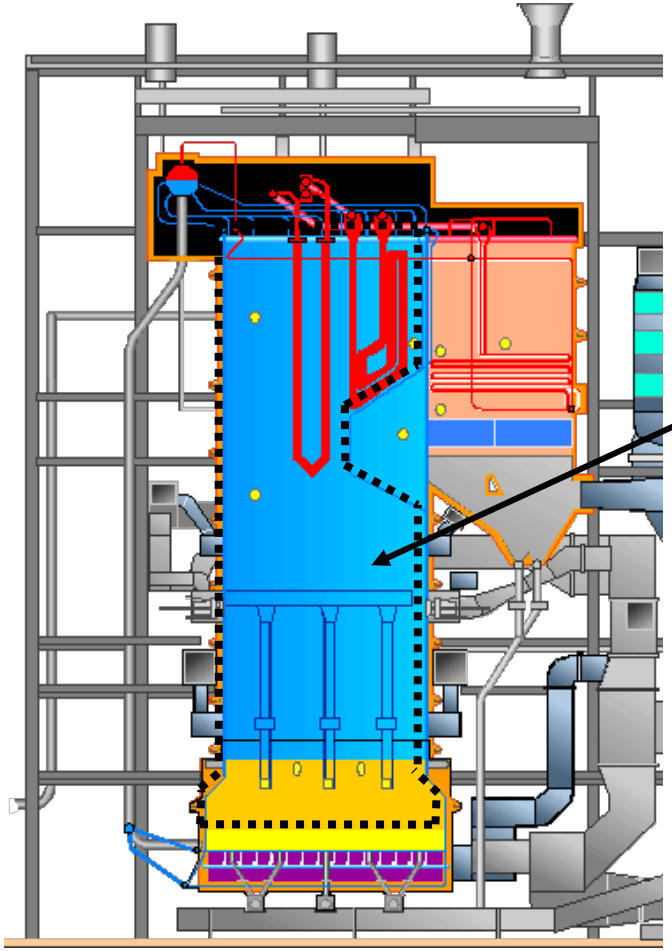


CFD Modelling of Fluidised Bed Combustion Plants- An Overview (2/2)

- Furnace Model Development Based on
  - Feedback from customer (plant data, practical observations)
  - Furnace measurements, if available
  - Predictions of more detailed models of separate sub-processe
- Some Issues Considered by Modelling:
  - Reduction of NOx by primary methods and SNCR
  - Combustion efficiency (CO, UBC)
  - Furnace availability (tendency for fouling, slagging, corrosion)
    - By in-direct methods (control of furnace gas temperature, solid fuel and gaseous conditions near furnace walls)
  - Bed behaviour (bed temperature)
  - Heat transfer to water walls
  - Criteria for incineration of wastes (2 sec. /850 ºC)
- FLUENT as Solver
  - UDF's + built-in sub-models of Fluent



Modelling of Combustion in BFB furnaces- A Modelling Approach (1/2)



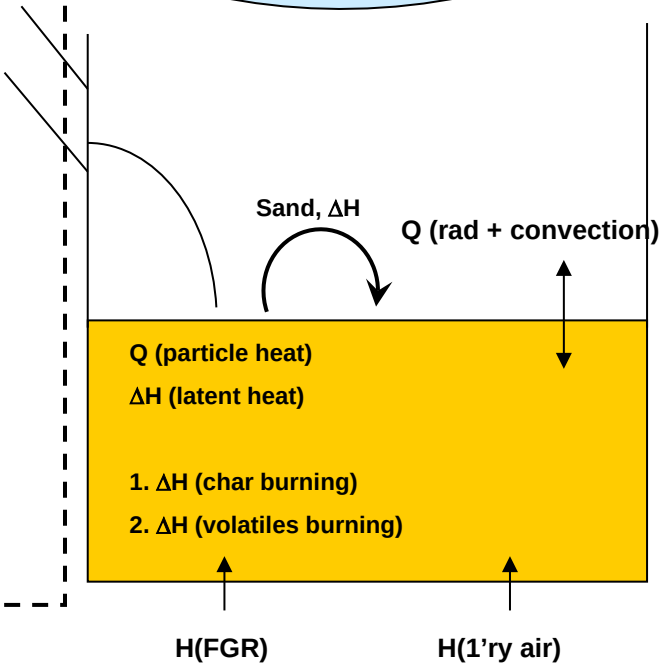
FREEBOARD Model: solve fluid and particle flow, combustion, heat transfer

DOM-radiation (built-in), Eddy dissipation (EDCM or EDC), 2-eqs. turbulence models (built-in), Langrangian particles + UDF's for particle conversion, 2(3) –step global schemes for main chemistry, NOx sub-model for BFB combustion (global chemistry + mixing)

User-implemented or built-in sub-models of Fluent, if stated above

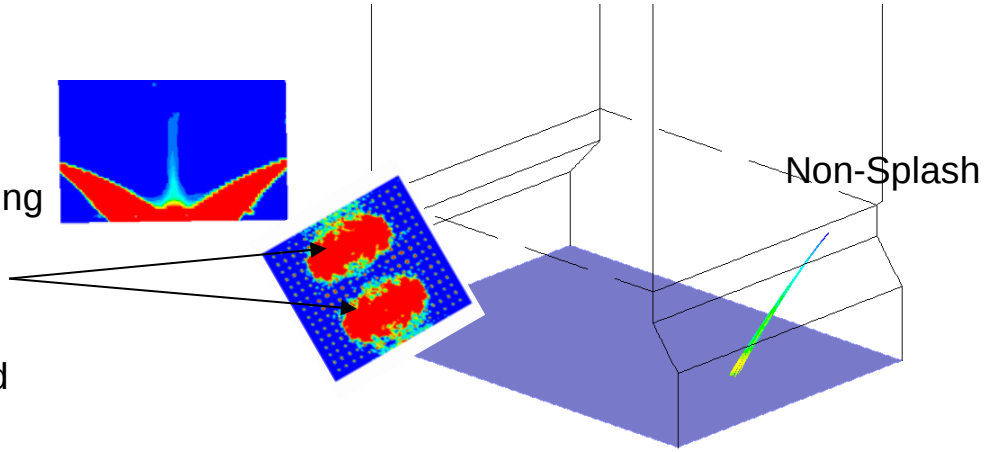
Exchange of mass and heat

BED Model: Solve heat and mass balance

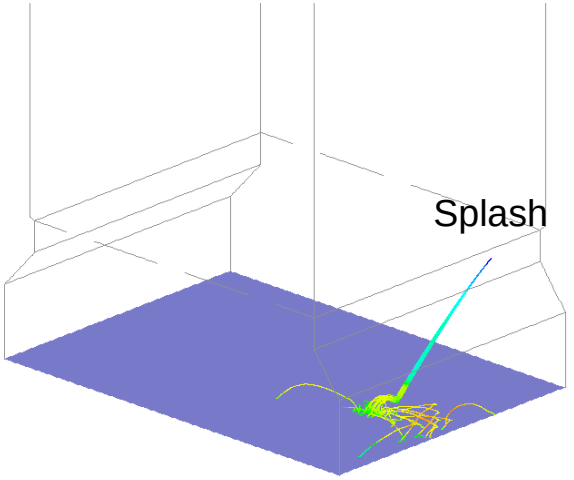


Modelling of Combustion in BFB furnaces- A Modelling Approach (2/2)

- Particle Mixing and Conversion in Bed
  - Non-Splash model
    - ✓ Particles 'trapped' as they reach bed surface
    - ✓ Remaining moisture and volatiles of particles released at or close to location of particle landing
  - Splash Model
    - ✓ Track particles in splash zone and in freeboard

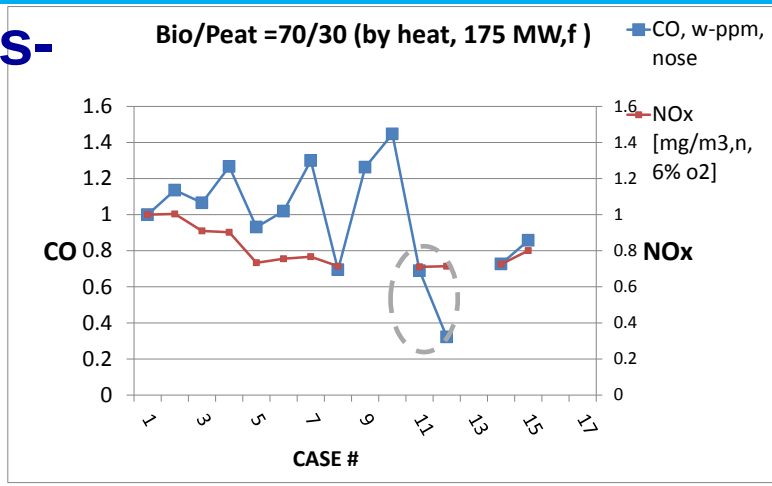


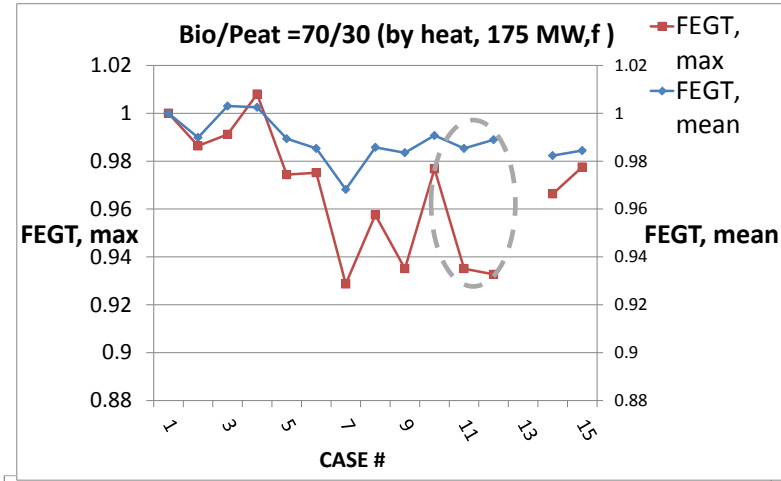
- Bed (Mean) Temperature Fixed or Estimated
  - Fix Bed Temperature, Estimate Heat of Combustion in Bed by Bed Heat Balance
  - Fix Heat of Combustion in Bed, Estimate Bed Temperature by Bed Heat Balance

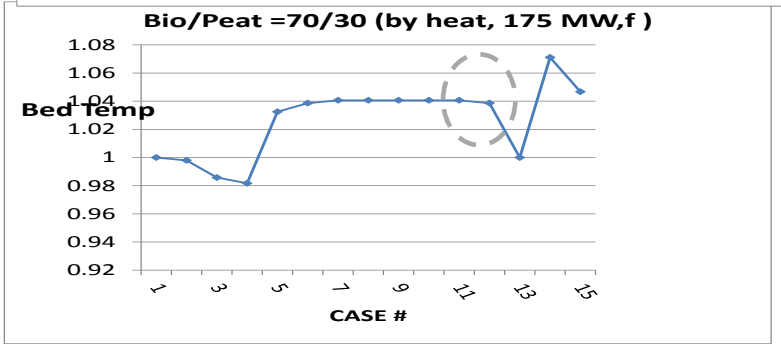


Modelling of Combustion in BFB furnaces- Examples of Case Studies (1/5)

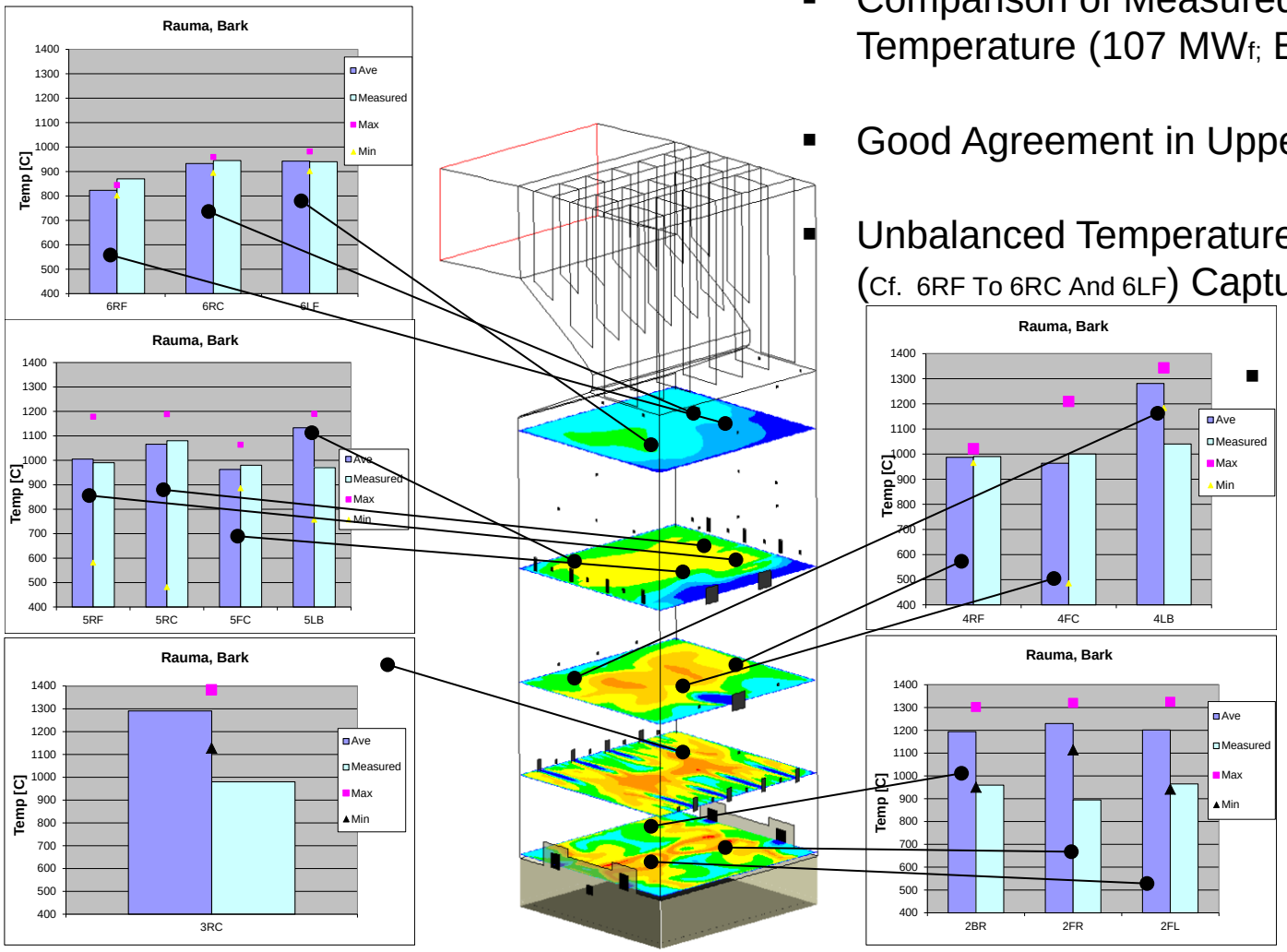
- Reduce Emissions (CO, NOx) of Existing Boiler Design (175 $MW_{f;}$ Bio/Peat = 70% / 30 % of Fuel Power)
  - Arrangement and Positioning of Air Nozzles, Nozzle Damper Positioning and Air Staging are Considered
  - Furnace Exit Gas Temperature [FEGT] at Nose Elevation Monitored to Assess Risks for Upper Furnace Corrosion and Fouling Tendency
  - Bed Heats Monitored to Assess Risk of Bed Sintering
- NEW DESIGN VS. EXISTING DESIGN:
  - Reduction of NOx: ~ 30 %
  - Reduction of CO: ~ 30-70 %
  - Peaks of FEGT (at nose elevation) lowered due to enhanced mixing
  - Rise of Bed Temperature a Concern







Modelling of Combustion in BFB furnaces- Examples of Case Studies (2/5)

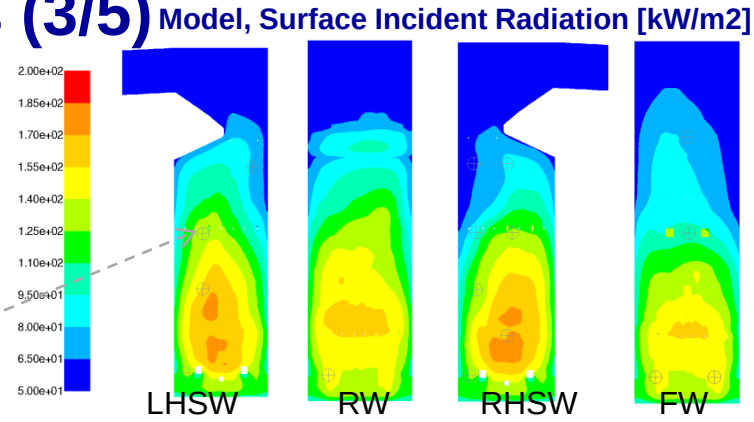


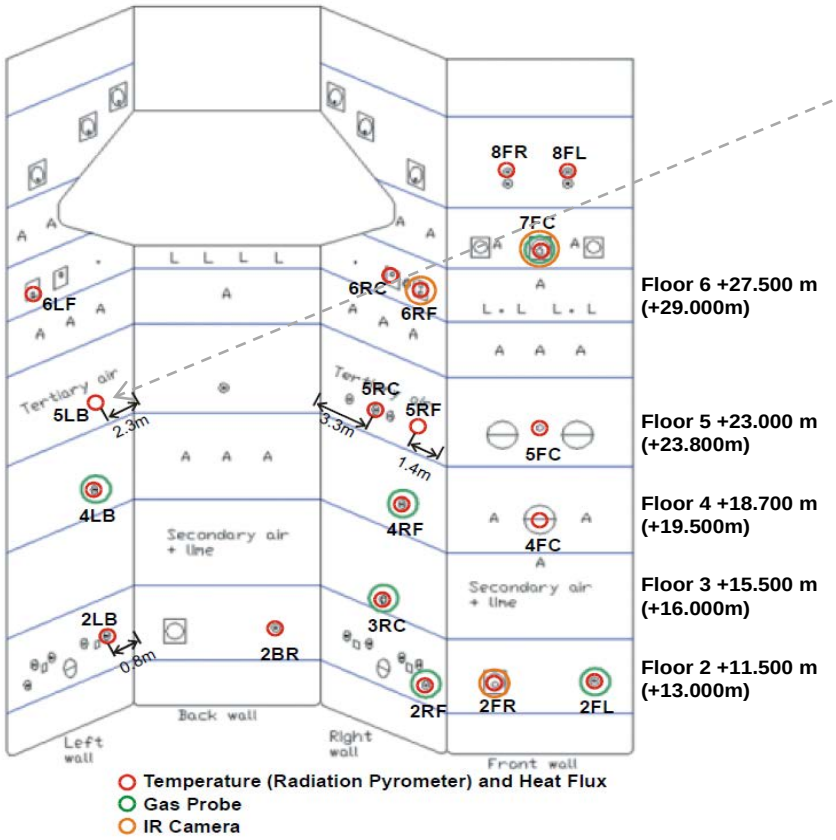
- Comparison of Measured and Predicted In-furnace Gas Temperature (107 $MW_{f;}$ Bark)
- Good Agreement in Upper Furnace
- Unbalanced Temperature in Upper Furnace (Cf. 6RF To 6RC And 6LF) Captured Also by the Model
- Most Discrepancies for Gas Temperatures Exist at Lower Part of Furnace
  - Large Gradients of Temperature in Lower Furnace Predicted by Model
  - Minor Changes at Expected Measuring Locations May Yield Better (or Worse) Agreement

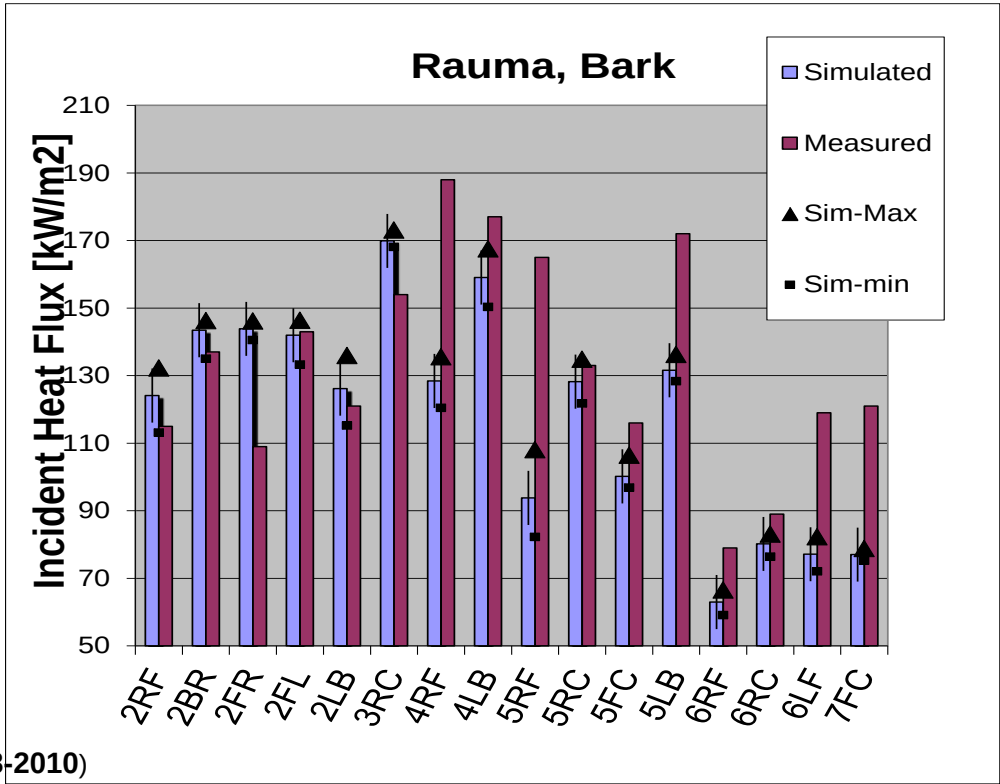
Part of the work has been carried out within the project ChemCom 2.0 (2008-2010)

Modelling of Combustion in BFB furnaces- Examples of Case Studies (3/5)

- Predictions of Incident Radiation and Measured Values are Compared (107 MW_f; Bark)
- Most Intense Measured Heat Fluxes Exist at Floors 3 And 4, and This is also Realised by the Model







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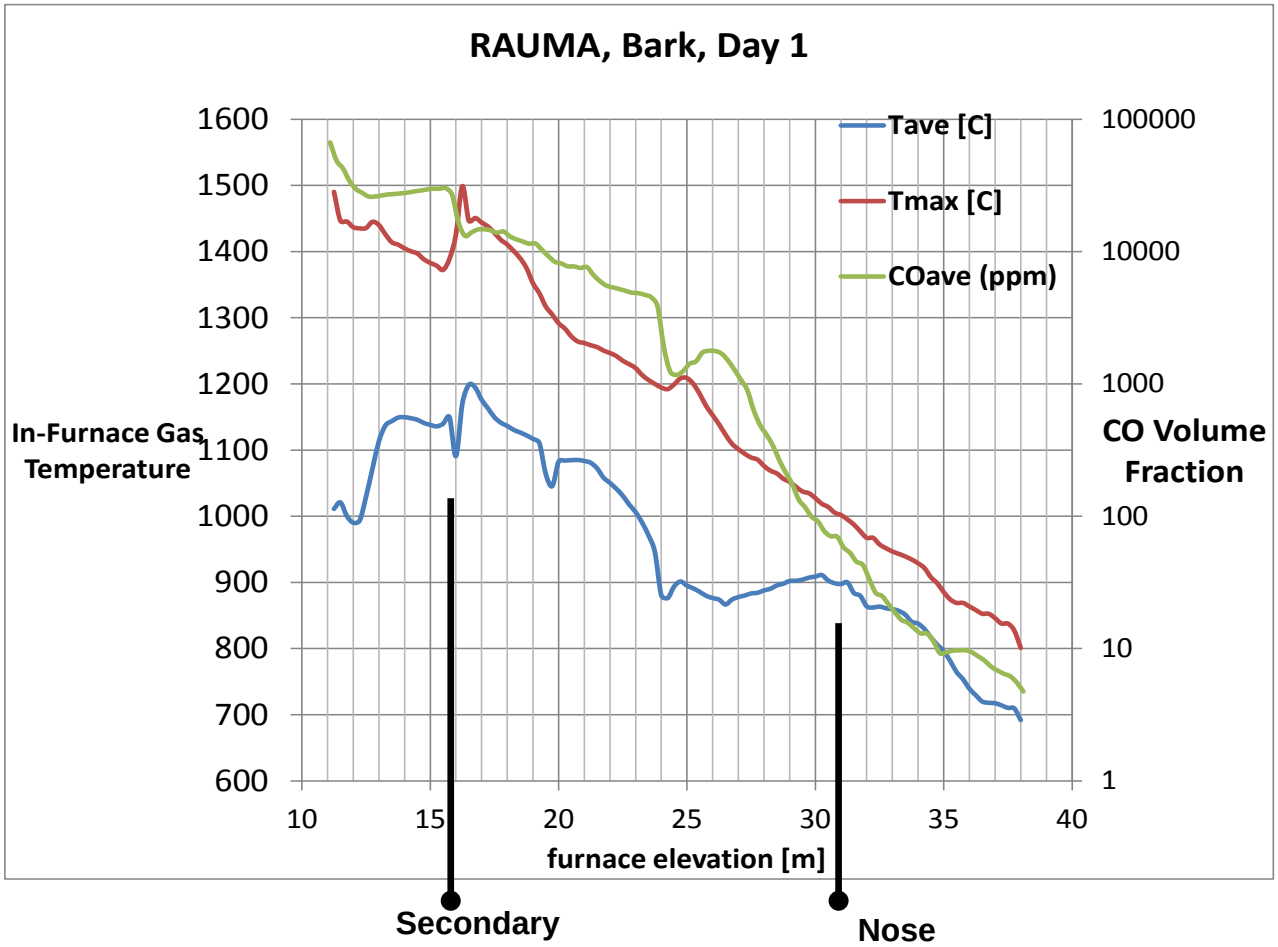
Modelling of Combustion in BFB furnaces- Examples of Case Studies (4/5)

- Furnace Profiles (107 $MW_{f;}$ Bark)
- High Temperature Regions at Secondary Air Level, where Most Intense Combustion Takes Place
- Peaks of In-Furnace Gas Temperatures ~ 1400-1500 C
- Low Emission of CO Predicted by the Model
  - Measured 25-30 v-ppm



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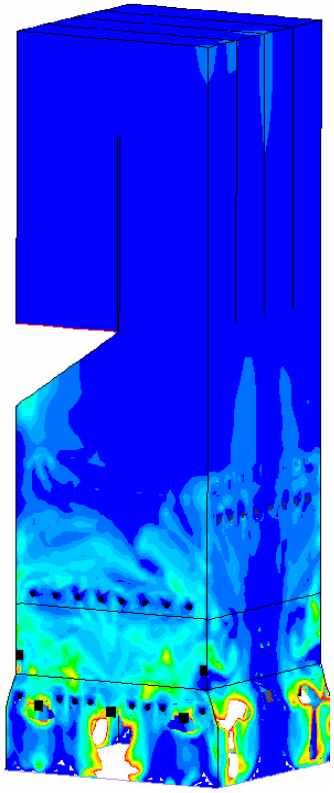
Modelling of Combustion in BFB furnaces- Examples of Case Studies (5/5)

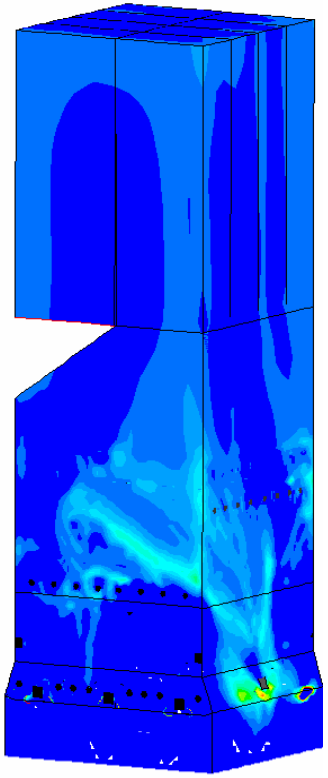
REDUCE FURNACE SLAGGING
Particle concentration near walls

(178 MWf; Bio/Peat = 45% / 55 % of Fuel Power)

Old



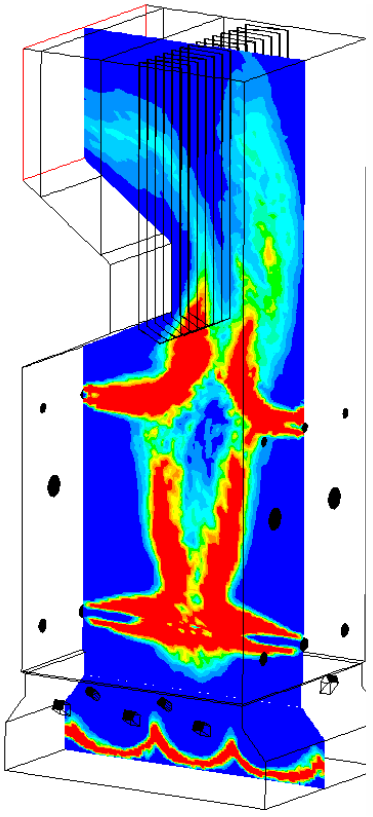
New



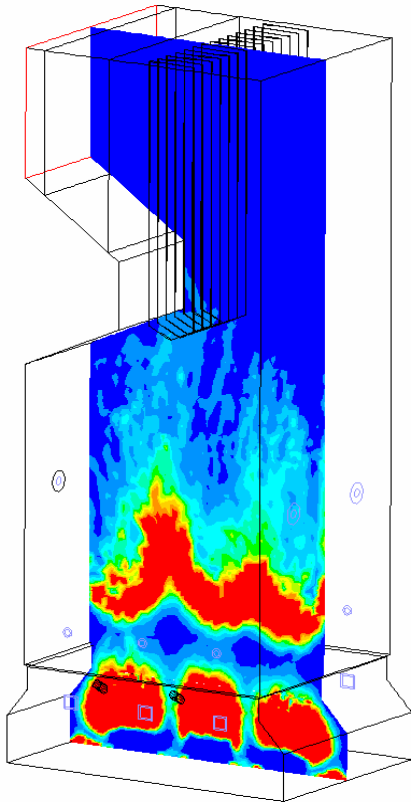
REDUCE SUPERHEATER /REHEATER SLAGGING
Combustion rate of char in freeboard)

(294 MWf; Bio/Peat = 30% / 70 % of Fuel Power)

Old



New



Modelling of Combustion in BFB furnaces- Some On-going and Planned Activities at VTT

- Incorporation of Ash Chemistry into CFD
  - Ash Melting Behaviour, Slagging, Heat Transfer
- Fuel Particles
  - Fragmentation, Mixing in Bed
- Improved Understanding of Bed Processes
  - Utilize multiphase CFD Simulations of Bed
- Integration of CFD Furnace Model with Process Modelling
  - Linking of Furnace and Water/Steam Cycles
- Transient Simulation
  - e.g. Load Changes

Concluding Remarks

- Furnace Models Employed to Analyse Real Processes
  - Design of New Furnace Concepts
  - Retrofitting
- Simultaneous Development of Furnace Models
  - Based on Experiences of Modelling of Real processes
- Combustion Modelling Motivated Largely by Reduction of Emissions (IED) and Furnace Availability Issues
- European Patent Application ”Method for reducing nitrogen oxide emissions and corrosion in a bubbling fluidized bed boiler and a bubbling fluidized bed boiler”, (Application No. EP12397524, Applicant Fortum OYJ)

VTT creates business from technology