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Combustion study of DDGS char from steam-O_2 blown CFB gasifier and charcoal using TGA and Comsol modeling

Xiangmei Meng, Wiebren de Jong, Adrian HM Verkooijen

Process and Energy Department, 3mE, Delft University of Technology

Email: X.Meng@tudelft.nl

Tel: +31 15 27 86987

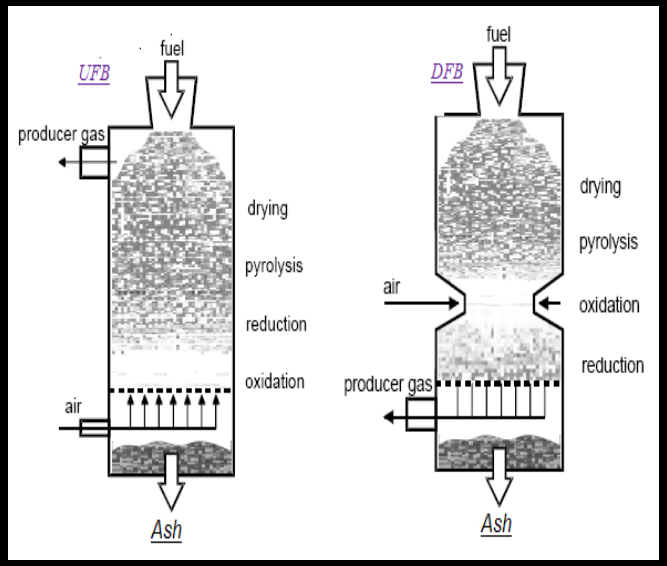
TU Delft Technische Universiteit Delft — Energy Technology

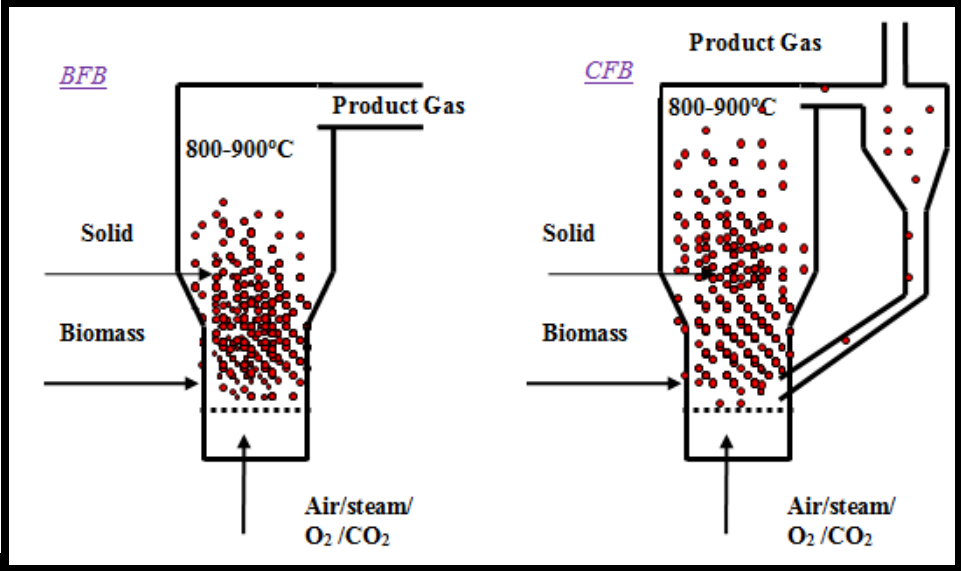
Contents

Research background

- Current issues
  - ↑energy consumption
  - ↑Fossil fuel €€
  - ↑pollution
  - ↑ Renewable energy ➔

- *Biomass conversion technologies*
  - Combustion
  - *Gasification*
  - Pyrolysis
  - Fermentation
  - Anaerobic digestion
  - Extraction



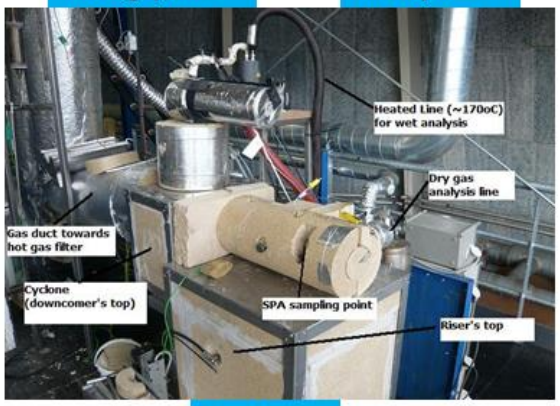


Char =>Product gas yield and quality, as well as system modeling

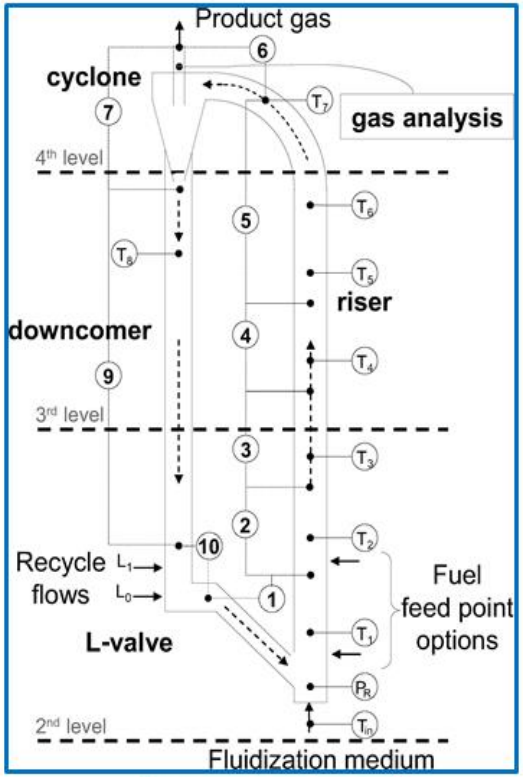
CFB gasification and residual Char

Feeding system

Filter system

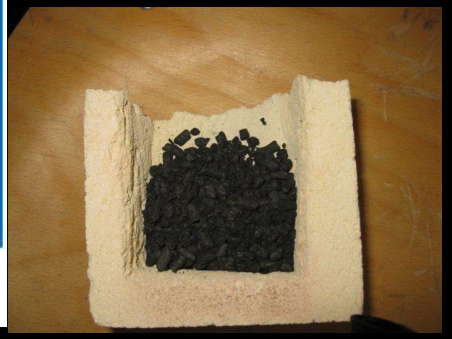


Riser top



CFB gasifier flow chart

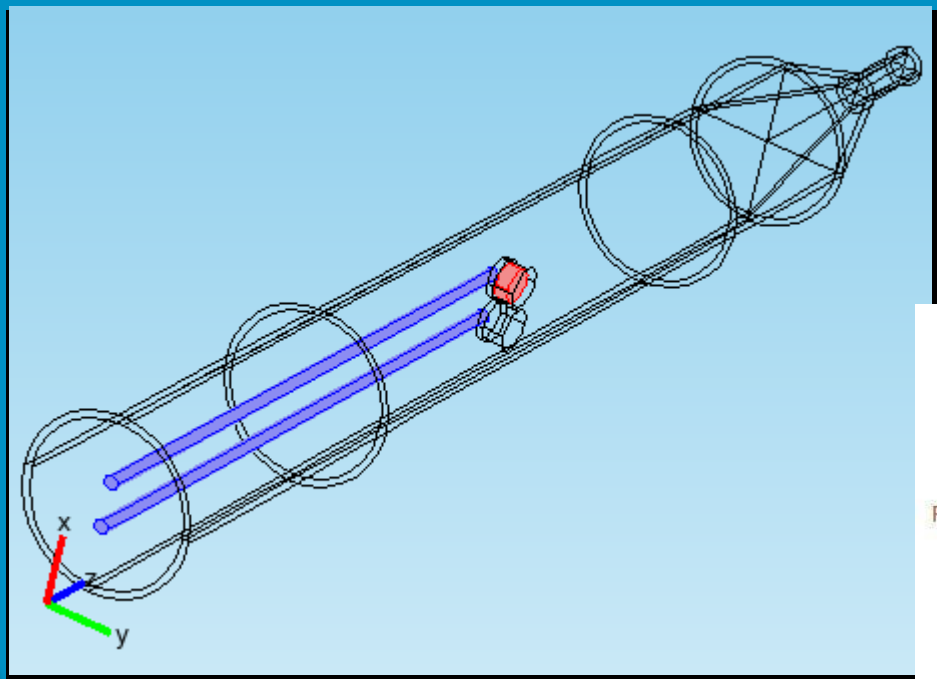
DDGS
(dried distiller's grains with soluble



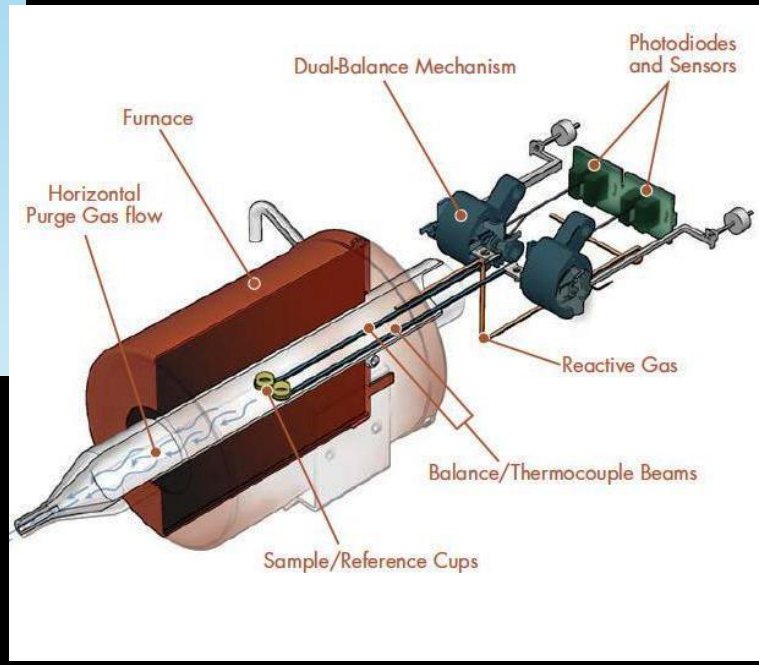
Experiments and Modeling

- *TGA experiments:*
  - CFB-Char, Char coal (from PE lab)
  - *Char combustion*
    - ✓ Isothermal
      - O_2= 7.5-21 vol.% in N_2
      - LTR = 400- 600 ºC
      - HTR = 750- 900 ºC
    - ✓ Non-isothermal
      - O_2= 7.5-21 vol.% in N_2
      - T = 150- 900 ºC

Char combustion Comsol simulation



- TG furnace geometry (beams, plates, wall, samples, diameter)
- Alumina, carbon, air



- Reaction sub-model: DDGS at 500 °C and charcoal at 850 °C
- General heat transfer:

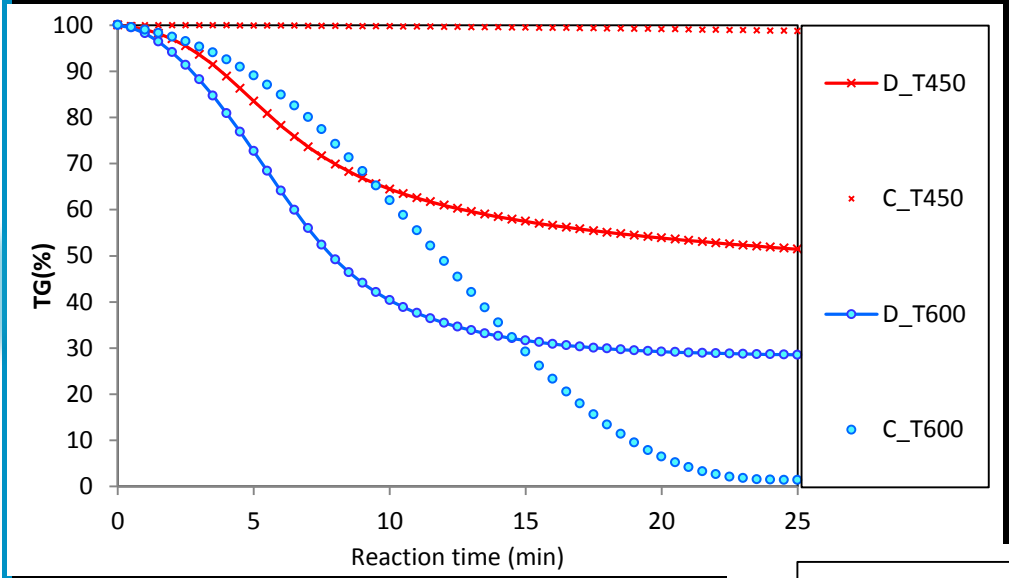
$$\rho_g C_p \frac{\partial T}{\partial t} + \rho_g C_p u \nabla T = \nabla \cdot (\kappa \nabla T) + Q$$

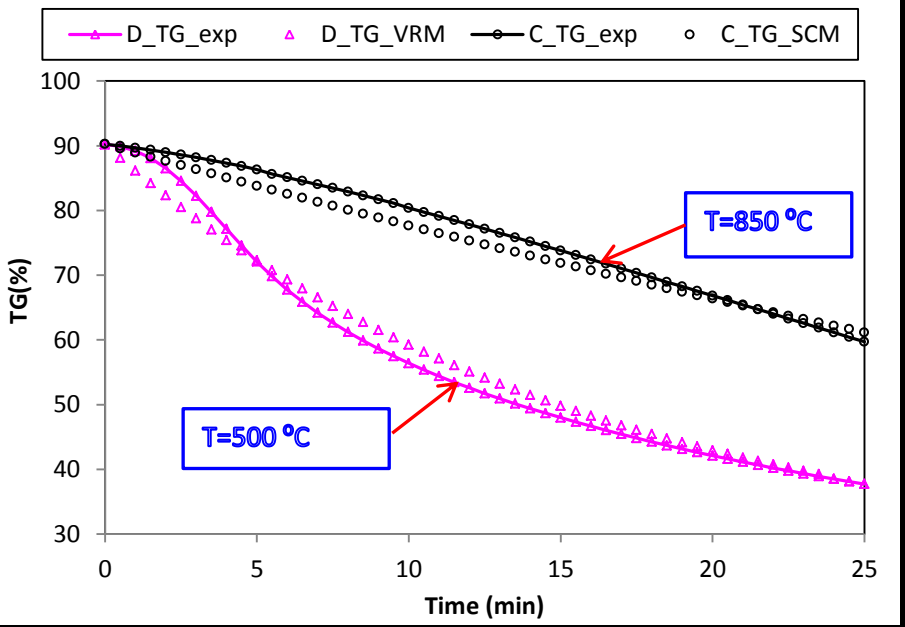
- Laminar gas flow using the Navier–Stokes (NS) equations

$$\rho_g \frac{\partial u}{\partial t} + \rho_g u \cdot \nabla u = \nabla \cdot \left[-pI + \mu_g \left(\nabla u + (\nabla u)^T \right) - \frac{2}{3} \mu_g (\nabla \cdot u) I \right] + F \quad \text{(a)}$$

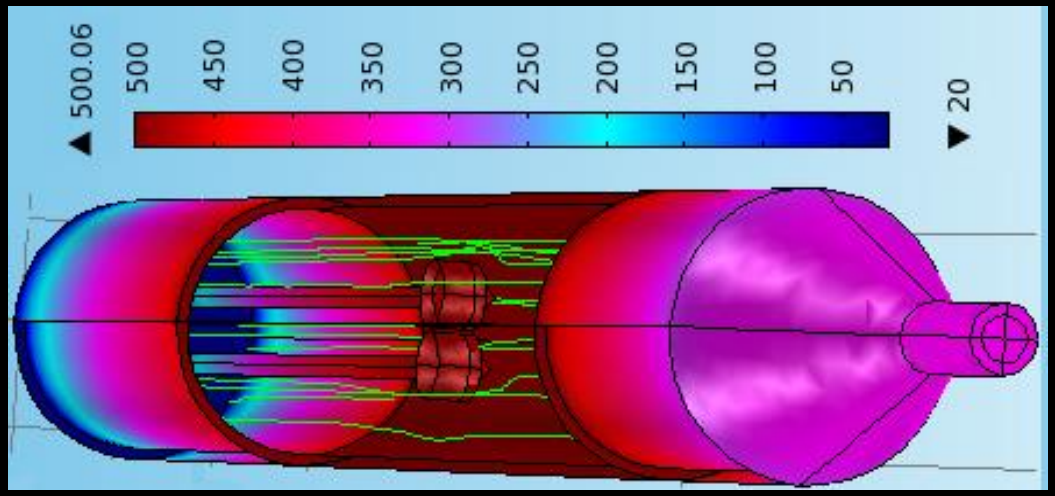
$$\frac{\partial \rho_g}{\partial t} + \nabla \cdot (\rho_g u) = 0 \quad \text{(b)}$$

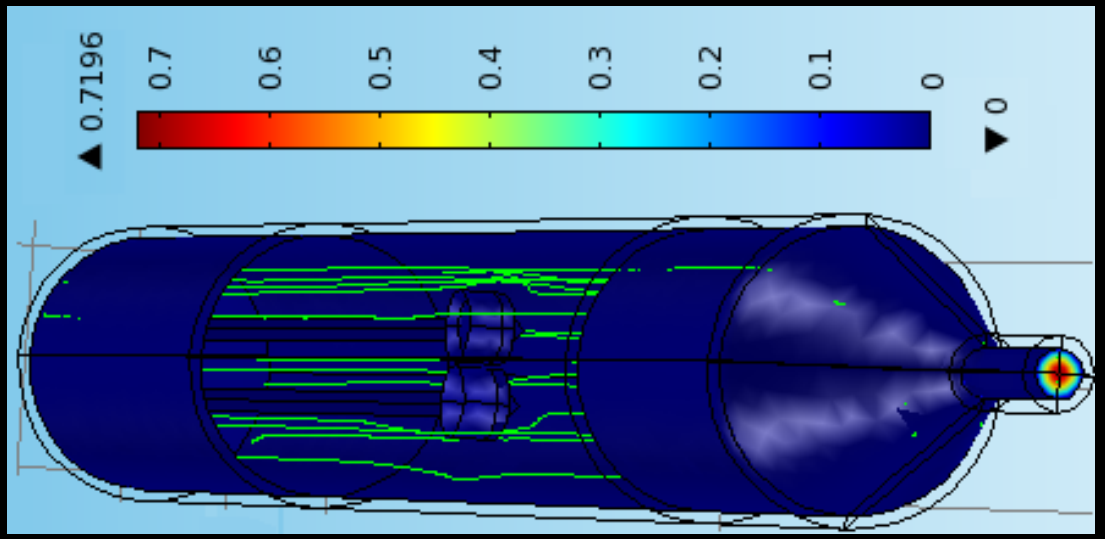
Char combustion TG results





Char combustion Comsol results





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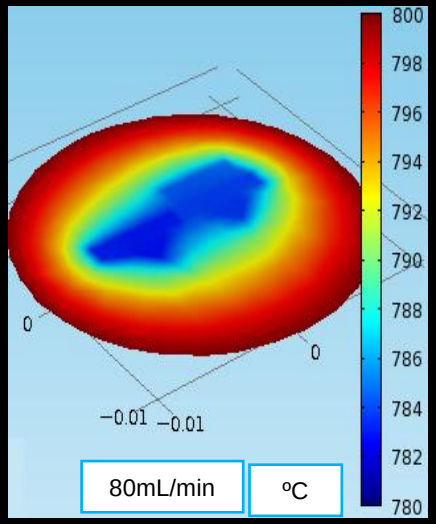
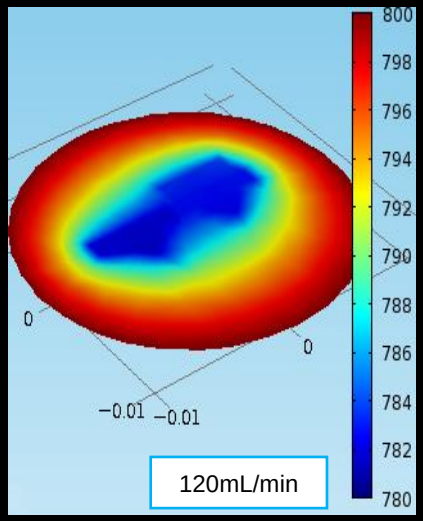
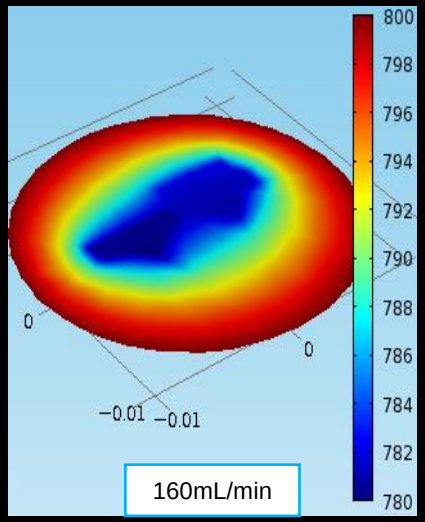
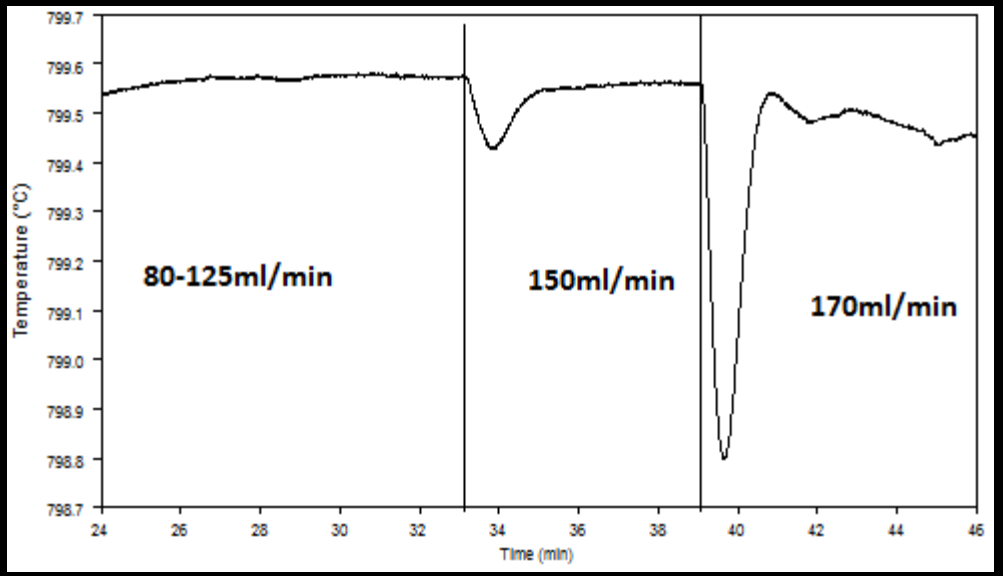
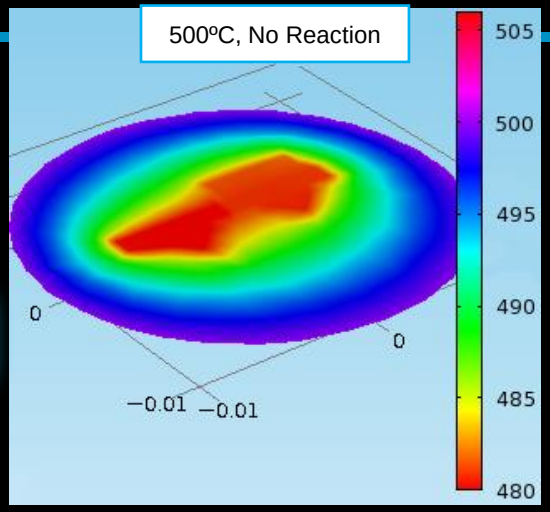


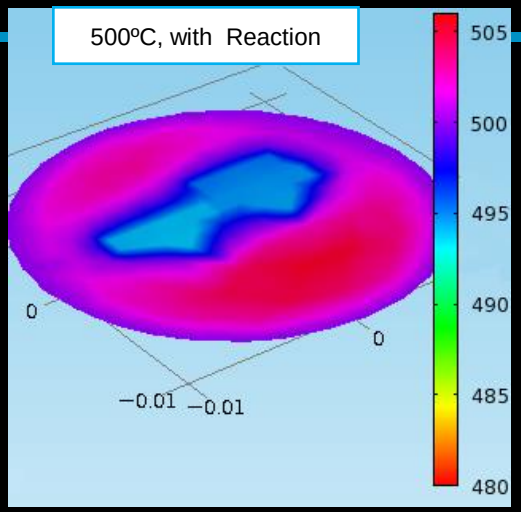


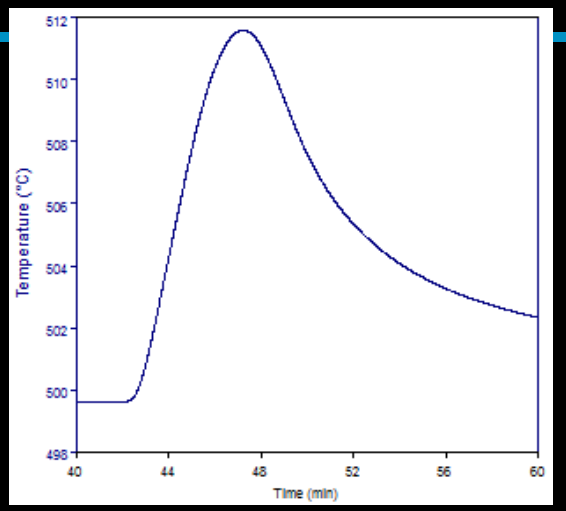


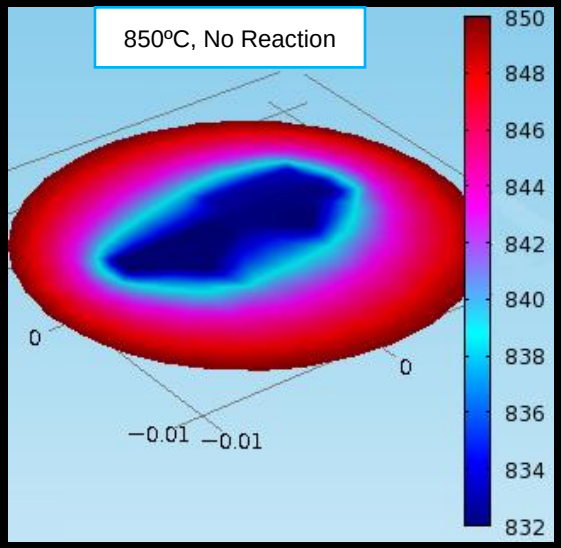


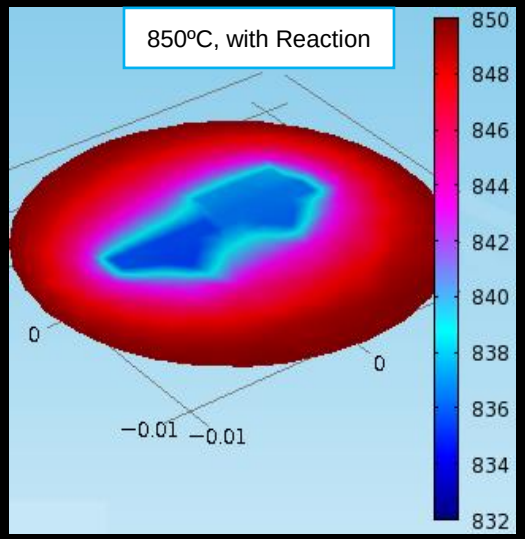
Char combustion Comsol results

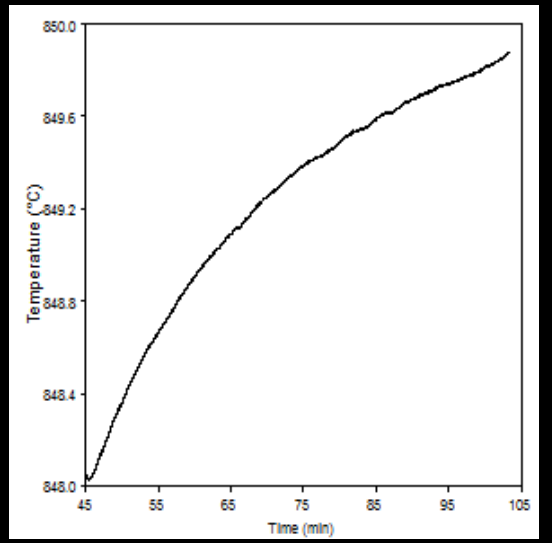












- Meng et al. 2012. Combustion study of partially gasified willow and DDGS chars using TG analysis and Comsol modeling, Biomass and Bioenergy, **39**, 356-369.
- Meng et al. 2011. Biomass gasification in a 100 kW_{th} steam-oxygen blown circulating fluidized bed gasifier: Effects of operational conditions on product gas distribution and tar formation. Biomass and Bioenergy, **35**(7), 2910-2924.

Conclusions and recommendations

BG & LR

E & M

R & D

C & R

➢ TGA experiments

- ✓ Reactive char reaction kinetics is difficult to be determined by TGA
- ✓ Pyrolysis conditions largely affect char reactivity
- ✓ Improve char reaction kinetics by applying more complicated models

➢ Comsol model

- ✓ Geometry improvement
- ✓ Char kinetics in details

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BG & LR

E & M

R & D

C & R

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