Solid Fuel Conversion under Entrained-Flow Gasification Conditions

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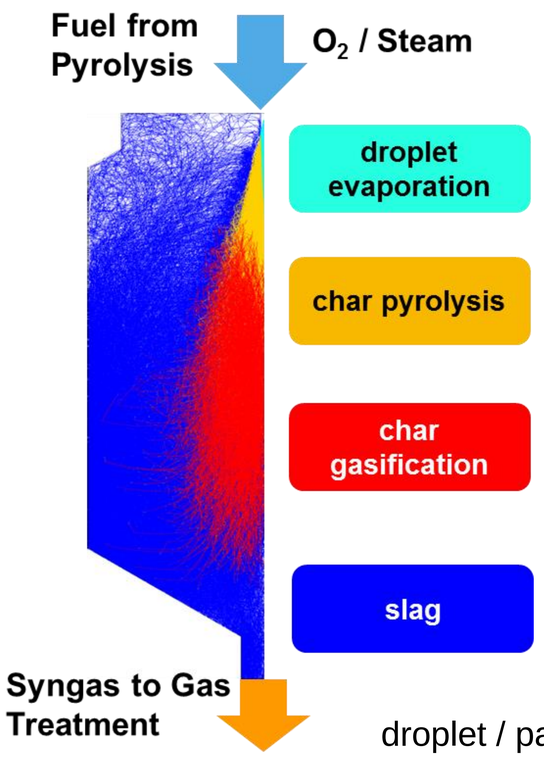
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Motivation

Entrained-Flow Gasification, EFG



droplet / particle trajectory pattern derived from RANS simulation

Multi-Phase reacting system at high temperature and pressure

- Development and validation of mathematical models for sub-processes
- Integration of sub-models into total process model

➔ Design and scale-up of technical gasifier

➔ Optimization of process parameters for wide range of fuel specifications

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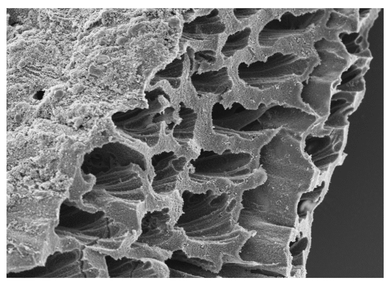


SEM image of biogenic char

Objectives

Kinetic model for the gasification of solid char particles

- Characterization of char properties and reactivity
- Fuel properties: morphology & catalytic ash components
- Process parameters $T, \mathrm{d}T/\mathrm{d}t, \tau, p$

Approach

Pyrolysis

$T = 800 – 1600$ °C

$\mathrm{d}T/\mathrm{d}t \approx 10^4$ K/s

$\tau = 100 – 1000$ ms

→ **Volatiles**

→ **Char**

Experimental Setups

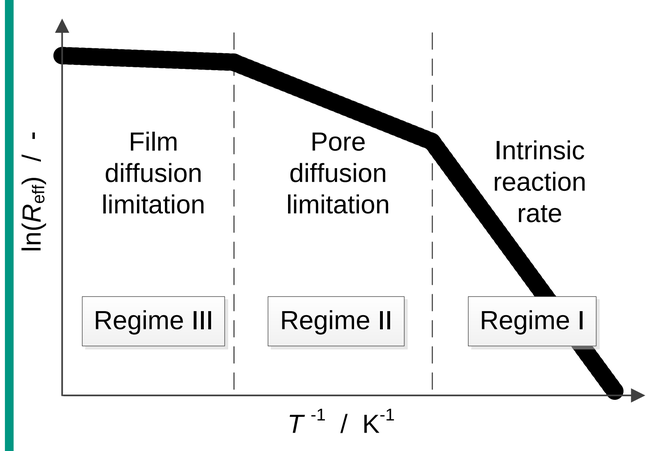
- Drop-Tube Reactor
- Pressurized TGA
- Chemisorption Analyzer
- Pressurized Fixed-Bed

Properties

- Chemical Composition
- Surface
- Pore Structure
- Reaction Kinetics

Experimental methods for gasification kinetics validated, atmospheric

Reaction Regimes



Boudouard Reaction

$$C + CO_2 \rightarrow 2\,CO$$

Reaction Kinetic Modeling

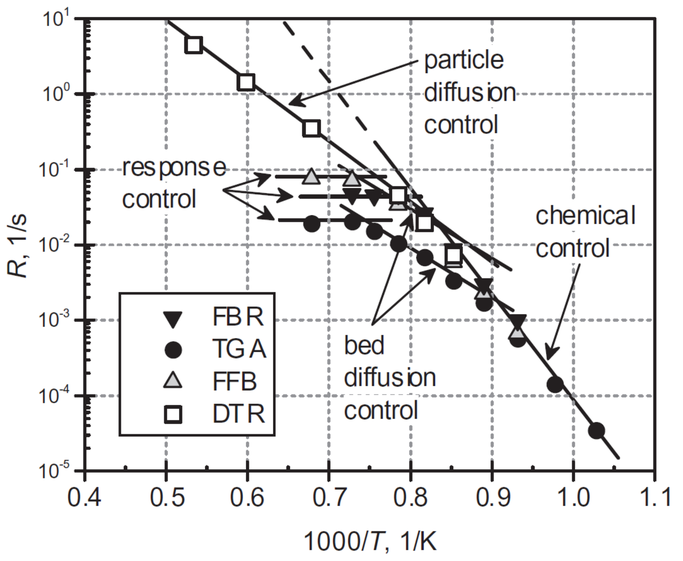
$$R_{\mathrm{intr}} = -\frac{1}{m_C}\frac{dm_C}{dt} = k\,p_{CO_2}^{n}$$

$$R_{\mathrm{eff}} = \eta_{\mathrm{Pore}}\,R_{\mathrm{intr}}$$

$$\eta_{\mathrm{Pore}} = \frac{1}{\phi}\left(\frac{1}{\tanh(3\phi)} - \frac{1}{3\phi}\right)$$

$$\phi = \frac{d_p}{6}\sqrt{\frac{(n+1)kp_{CO_2}^{n-1}}{2\,D_{\mathrm{eff}}}\frac{p\rho_C}{RTM_C}}$$

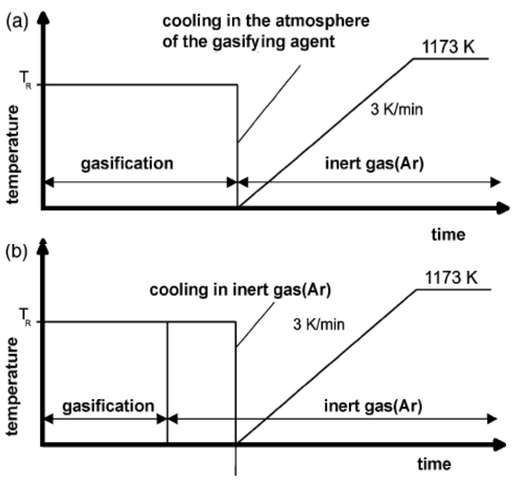
Reaction rate determined in 4 different experimental setups



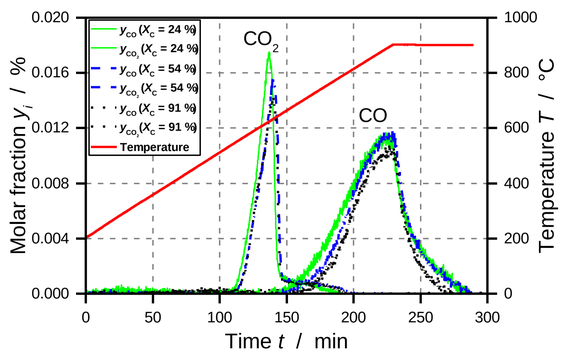
- Consistent results in chemically controlled regime for all setups
- True particle kinetics relevant for EFG conditions in drop-tube reactor (pore diffusion regime)

Stoesser et al., Appl Energy 211, (2018)

Reactivity depends on morphology and active sites



Klose & Wölki, Fuel 84, (2005)



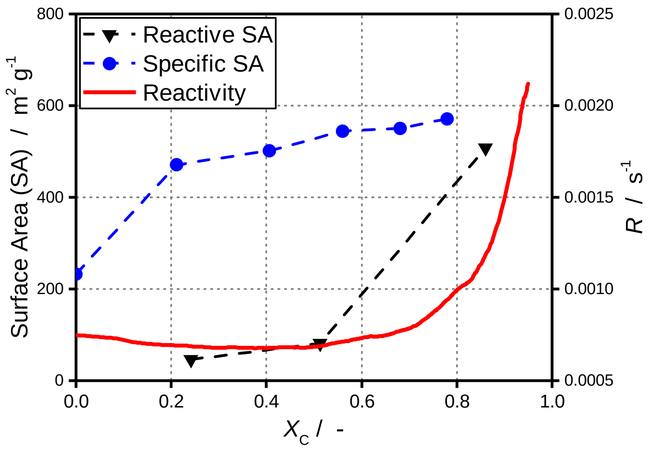
Desorbing species during TPD

Experimental procedure for the determination of Reactive Surface Area

Specific and Reactive Surface Area

- Specific SA remains almost constant for high X_C
- Reactive SA strongly increases for high X_C due to catalysis
- Reactivity corresponds well with evolution of reactive SA

Fuel: WC1600 (beech wood char)



Evolution of reactive / specific surface area and reactivity during gasification

Outlook

- Model for char conversion accounting for the influence of catalytic ash components and morphology
- Transfer of char conversion model to high pressure conditions

Cooperation

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