Chair of Energy Systems
TUM Department of Mechanical Engineering
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Reaction Behaviour of Fuels of Different Quality in Entrained Flow Gasifiers

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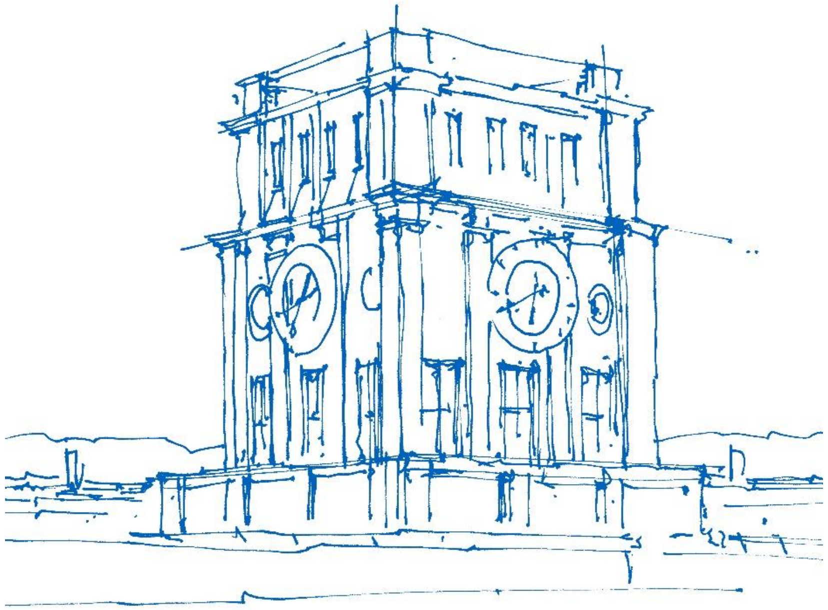

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Agenda

- Motivation and Aim of this Work
- Experimental Procedure
- Experimental Equipment and Experiment Matrix
  - Pressurized High Temperature Entrained Flow Reactor (PiTER)
  - High Pressure Thermogravimetric Analyzer (PTGA)
- Results
- Conclusion and Future Aspect

Motivation

Gasification Technology offering high flexibility

- Feedstock (Coals and renewable fuels)
- Product (Power, Chemicals, Fuels)

Possibility for efficient CCS in IGCC power plants

Entrained flow gasifiers for high conversion rates, gas quality and power density

Detailed knowledge of occurring phenomena during gasification of different fuels important for design and performance of efficient gasifiers

Aim of this Work

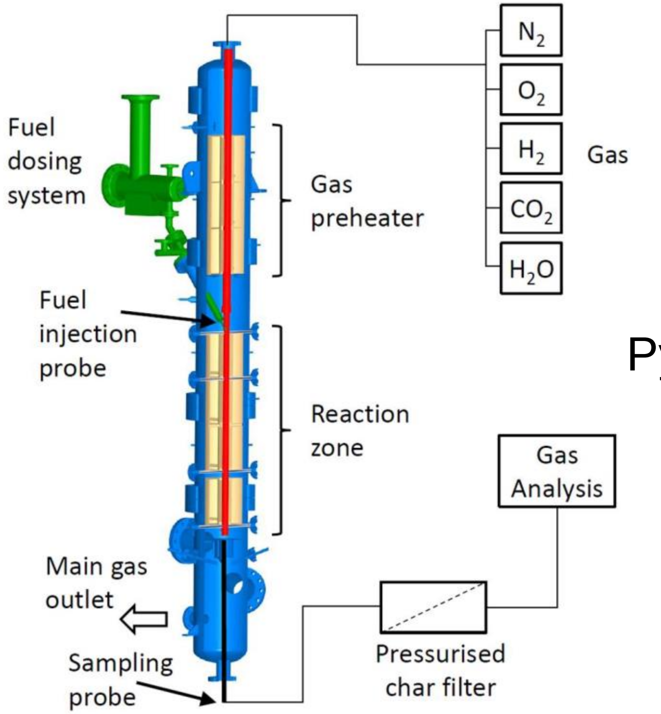
Experimental investigation of entrained flow gasification (pyrolysis and gasification)

Evaluating the gasification behaviour of different fuels regarding the influence of operation parameters (temperature, pressure, atmosphere, residence time)

Determination of kinetic and structural parameters necessary for CFD-simulation of entrained flow gasifiers

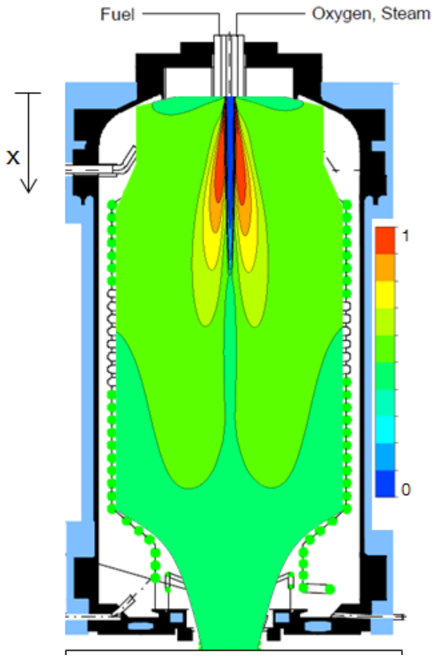
Basis for design optimization of industrial scale gasifiers

Approach of the Research Project HotVeGas



Pyrolysis
Char

Kinetic
Data

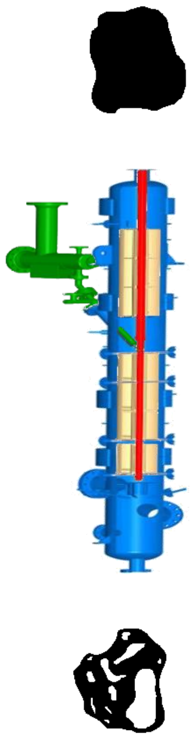


Entrained Flow Pyrolysis and Gasification, Atmospheric and Pressurized Conditions

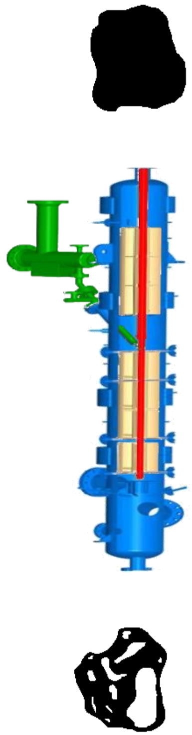
Atmospheric and Pressurized TGA: Kinetic Data for Intrinsic Reactions and Thermal Annealing

Model Validation with Experimental Data
→ Simulation of Industrial Scale Gasifiers

Experimental Procedure



Fuel	Ash Content wt% (dry)	Moisture wt% (ar)	Volatile Content wt% (dry)	Carbon wt% (dry)	Hydrogen wt% (dry)	Nitrogen wt% (dry)	Sulfur wt% (dry)
Lig_1	3.9	9.9	50.0	63.88	4.41	0.72	0.54
Lig_2	5.6	10.8	52.5	60.57	4.19	0.62	0.80
Bit_1	10.3	9.4	34.2	72.57	3.26	0.72	0.82
Bit_2	8.2	4.8	37.4	75.21	4.76	1.52	0.86



Pressurized Entrained Flow Reactor

Devolatilization and Gasification Experiments

Char Sample

Lab Analysis

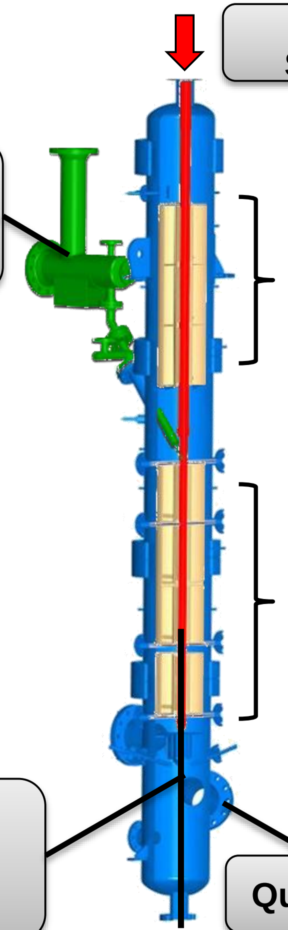
- Proximate and Ultimate Analysis
- Surface Area Measurement

Thermogravimetric Analyzers

- Char gasification kinetics
- Intrinsic kinetic data for different gasification agents

Experimental Equipment - PiTER

Pressurized High Temperature Entrained Flow Reactor



Technical Data	
Gasification Agents	N_2, Ar, O_2, H_2, CO_2, H_2O
max. Temperature	1800°C
max. Pressure	5.0 Mpa
Fuel Mass Flow	Up to 5 kg/h

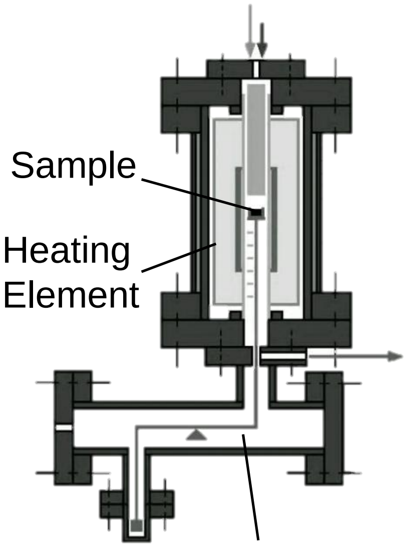
Dimension of the Pressure Vessel:
Height : 7000 mm
Diameter : 700 mm
Dimension of the Reaction Tube :
Length 2200 mm
Inner Diameter : 70 mm

Evaluation: Ash-Tracer-Method

$$X_{Overall} = \frac{m_{0,daf} - m_{daf}}{m_{0,daf}} = \frac{1 - \frac{x_{0,Ash}}{x_{Ash}}}{1 - x_{0,Ash}}$$

Experimental Equipment - PTGA

High Pressure ThermoGravimetric Analyzer



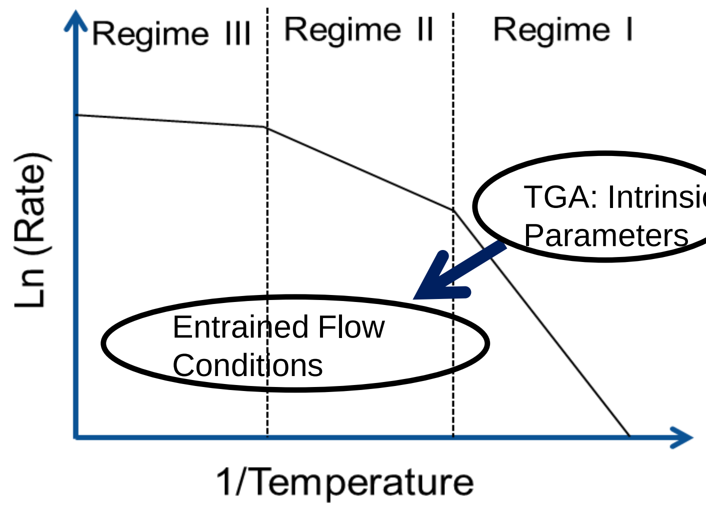
Technical Data	
Gasification Agents	Ar, N_2, O_2, H_2, CO_2, H_2O, CO
Max. Temperature	1000 °C
Max. Pressure	5.0 MPa
Up to 100 % vol. of gasification agent concentration	

$$X(t) = \frac{m_0 - m_t}{m_0}$$

$$r_{obs} = -\frac{1}{m_t}\frac{dm_t}{dt}$$

Kinetics of Gasification and Influences on reaction behaviour

Three different reaction regimes during gasification according to rate-determining step



Regime I : Chemical Reaction
Regime II: Pore Diffusion
Regime III: External Mass Transfer

Determination of intrinsic kinetic data for Regime I conditions in TGA

Modeling with Arrhenius- and Power-Law-Approach

$$r_{observed}(X,T,p_i) = S(X) \cdot r_{int}(T) \cdot {p_i}^n = S\,(X) \cdot k_0\, \exp\left(-\frac{E_A}{R \cdot T}\right) \cdot {p_i}^n$$

Experimental Matrix

PiTER:

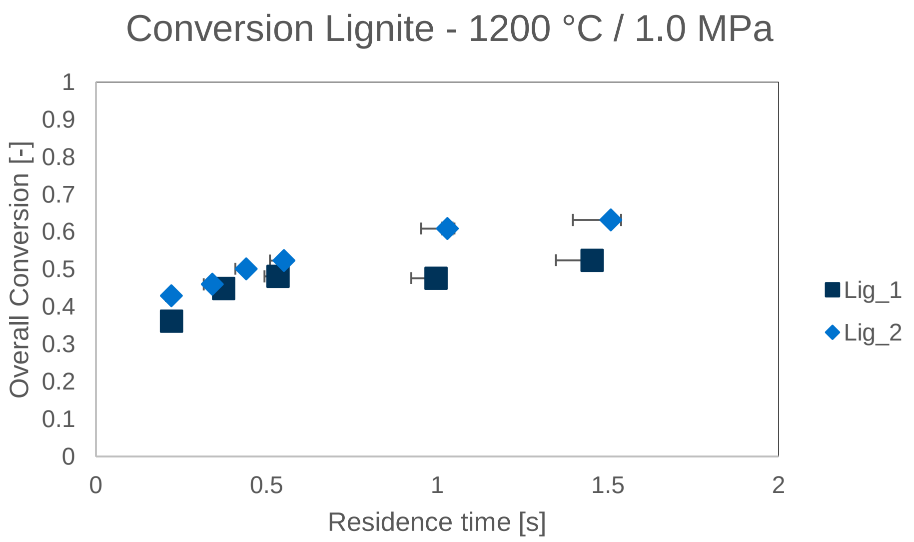
- Pyrolysis experiment: Gas residence time between 0.2–1.5 s in N_2
- Gasification experiments:
  - ➢ Residence time up to 2.5 s
  - ➢ Temperature of 1400 °C, Pressure of 0.5 to 1.0 MPa
  - ➢ Constant O/C-Ratio of 1
  - ➢ CO_2-Gasification: Constant partial pressure of 0.2 MPa

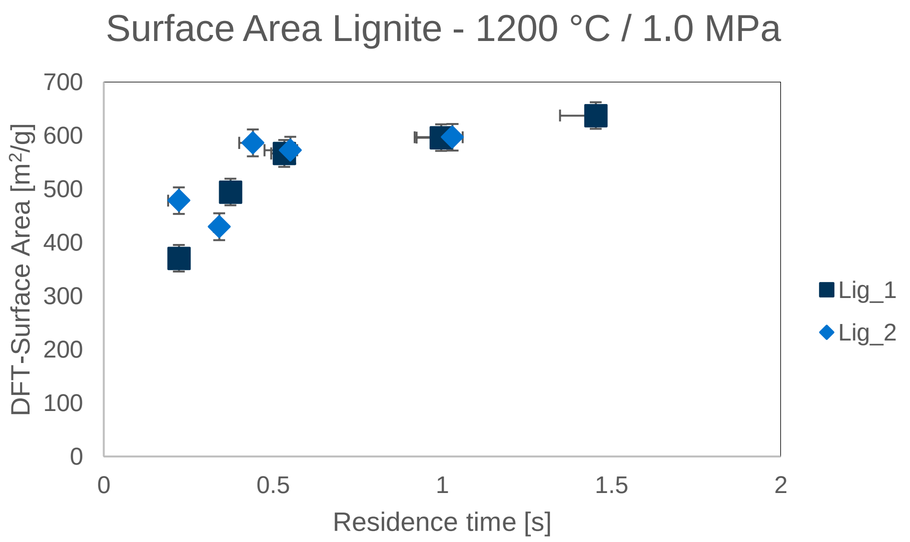
Thermogravimetric Analyzer:

- PTGA: Determination of intrinsic kinetics of fuel chars

Results Pyrolysis

Overall Conversion and Char Surface Area of Lignites in dependence of the residence time





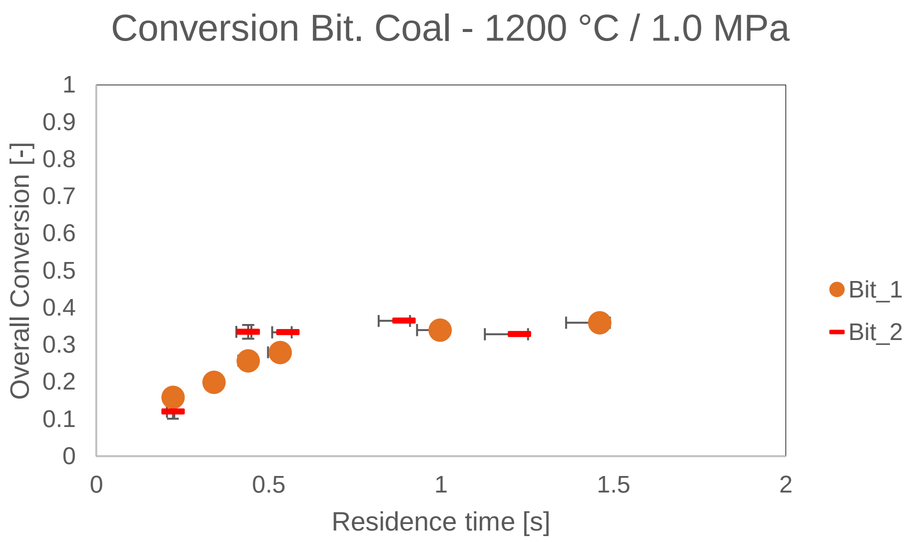
Overall Conversion increases with increasing residence time

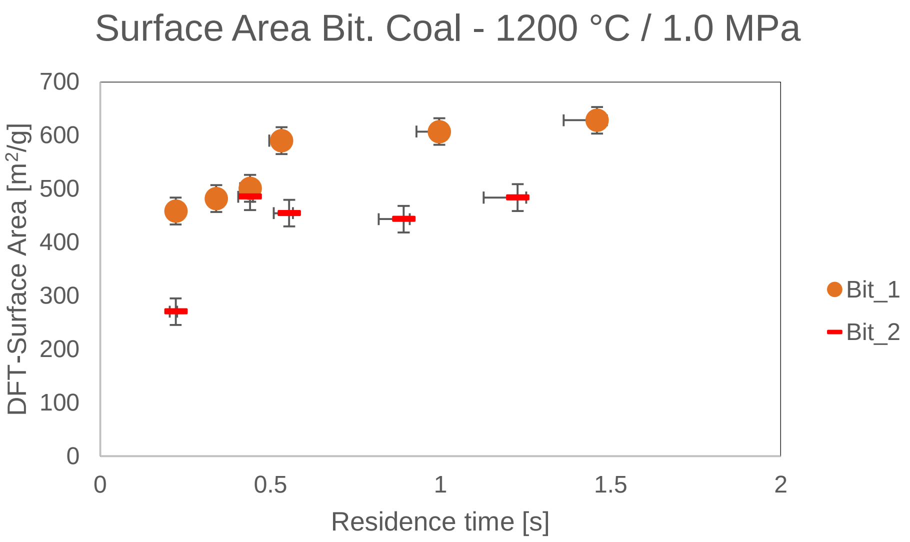
Surface Area increases with progressing devolitalization, constant value after completed devolitalization

Surface Area of Lignites in the same dimension

Results Pyrolysis

Overall Conversion and Char Surface Area of Bituminous Coals in dependence of the residence time





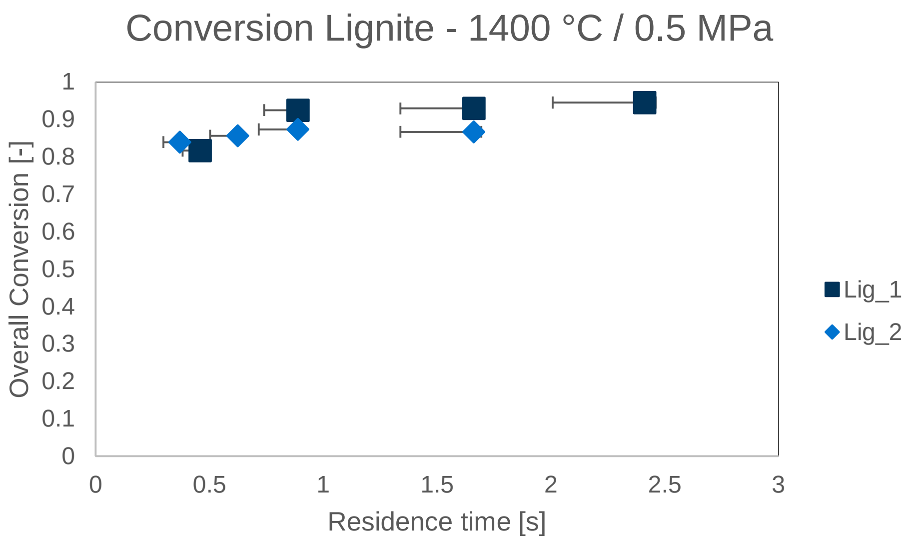
Overall Conversion increases with increasing residence time, constant after 0.5 s

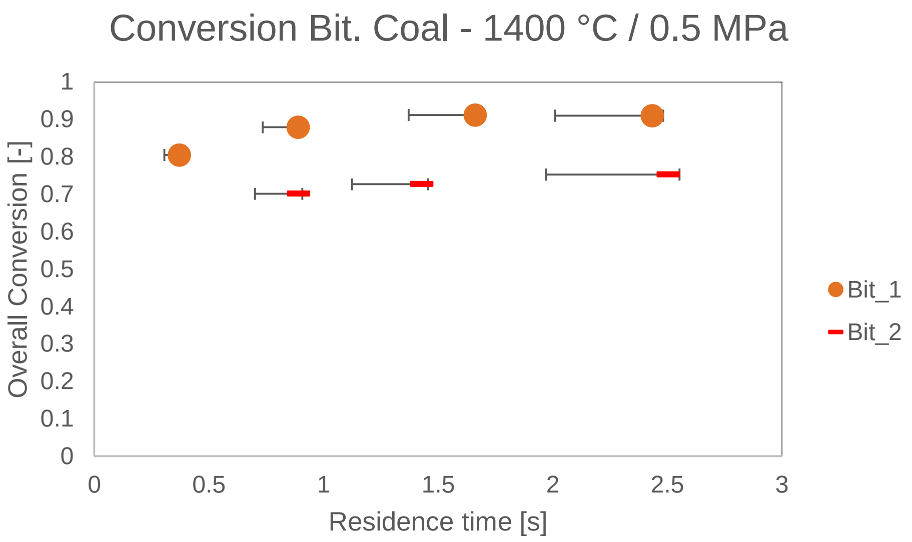
Surface Area increases with progressing devolitalization, constant value after completed devolitalization

Surface Area of Bit_2 significantly lower than Surface Area of Bit_1

Results Gasification

O_2-Gasification Lignites and Bituminous Coals, O/C = 1



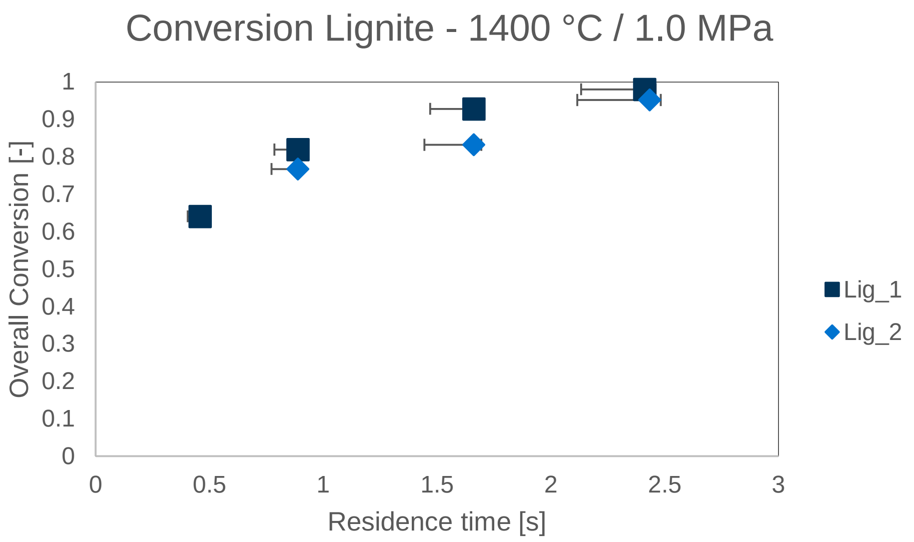


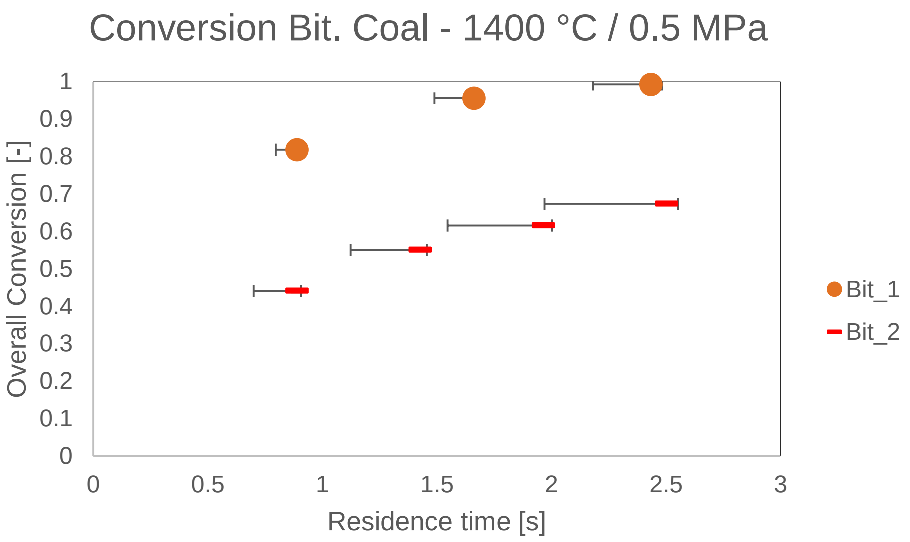
Lignites conversion of over 95 % is reached with oxygen

Overall Conversion of Bit_1 over 90 %, Bit_2 only 75 %

Results Gasification

CO_2-Gasification (p_{CO_2} = 0.2 MPa) Lignites and Bituminous Coals



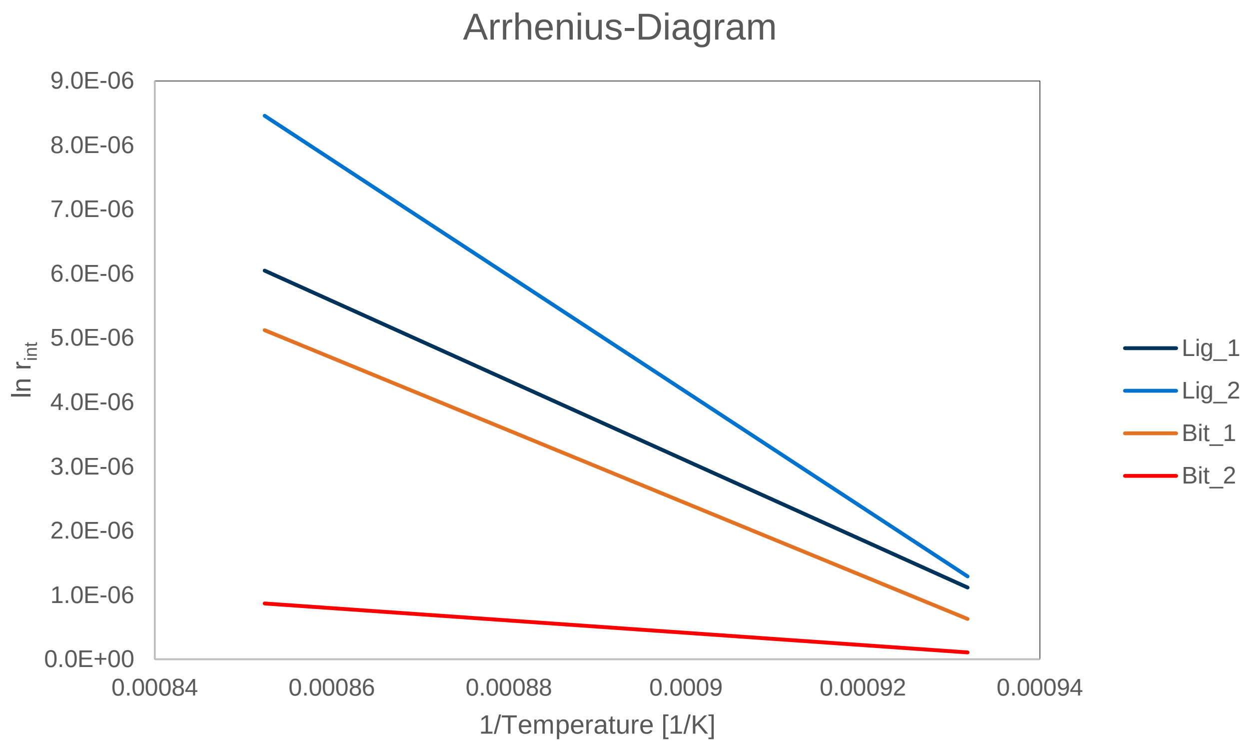


Almost complete conversion for Lignites and Bit_1

Conversion of Bit_2 significantly lower

Kinetics of Gasification

Intrinsic Reactivity of Coal Chars with CO_2



Reactivity of Bit_1 similar to reactivity of lignites

Reacitivity of Bit_2 much lower than reactivity of Bit_1

Conclusion and Future Aspects

Conclusion

- Data for experiments at high temperature and pressure are presented
- Higher reactivity of lignites → Higher conversion of lignites at equal conditions
- Bituminous Coals show high deviation of reaction behavior
  → Necessity of investigating different fuels
- Lower Surface Area and lower reactivity responsible for lower conversion of some bituminous coals (further parameters e.g. annealing under investigation)
- **Obtained data can be used for design of large scale applications according to the fuel rank**

Future Aspects

- Use data for model validation
- Test further coals regarding the influences on reaction behaviour of bituminous coals
- Create fuel databank with kinetic data and further parameters relevant for gasification

Thank you for your Attention!

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