Experimental Investigation of Alkali Release during Pyrolysis and Gasification of Coal

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Outline

• Motivation
• Aim of HotVeGas project
• Experimental
• Results
• Conclusion and Future Aspects
Motivation

• Release of mineral matter during gasification of solid fuels

• Alkali problems:
  – Slagging and fouling at the raw gas cooling
  – Hot corrosion in the gas turbine
  – Degradation of anode material in SOFCs

• Knowledge of alkali behavior necessary for the design of a hot gas cleaning
Aim of HotVeGas project

→ Design of an alkali hot gas cleaning system

Alkali release

Wire mesh reactor

Entrained flow reactor

Alkali sorption

Fixed-bed reactor

HP-TGA
Experimental procedure

**Fuel sample**
Lab analysis:
- Proximate and ultimate analysis
- Alkali content

**Wire-mesh reactor**
- Pyrolysis experiments
- Determination of alkali content in char

**Thermochemical Data**
Equilibrium calculations
- Conversion
- Alkali content

**Entrained flow reactor**
- Gasification experiments
- Determination of alkali concentration in gas phase

Comparison arrows point between the fuel sample, wire-mesh reactor, thermochemical data, and entrained flow reactor.
Experimental equipment

Wire Mesh Reactor (WMR)

Technical Data:

- Temperature: up to 1800 °C (WMR-HT)
- Pressure: 1 - 50 bar (WMR-HT)
- Heating rate: > 1000 K/s
- Atmosphere: N₂, Ar

Evaluation:

- Collection of solid char samples
- Determination of conversion by mass loss
- Determination of alkali content by AAS
Experimental equipment

Entrained Flow Reactor

**Technical Data:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>N₂, Ar, O₂, H₂, CO₂, H₂O</td>
</tr>
<tr>
<td>max. Temperature</td>
<td>1600 °C</td>
</tr>
<tr>
<td>Pressure</td>
<td>atmospheric</td>
</tr>
<tr>
<td>Massflow</td>
<td>Up to 500 g/h</td>
</tr>
</tbody>
</table>

**Reactor dimensions:**

- Length: 1500 mm
- Inner diameter: 40 mm

**Evaluation:**

- Collection of gaseous and solid samples during gasification
- Determination of conversion by ash-tracer method
- Determination of alkali concentration in gas phase by AAS
Experimental equipment

Entrained Flow Reactor – Hot gas sampling system

1. Sampling modus
2. Closed loop (Stand-by)
Experimental Matrix

**Wire-mesh reactor**
- Residence time: 0 s – 10 s
- Temperature: 400°C – 1600°C
- Pressure: 1 bar – 25 bar
- Atmosphere: N₂ (Pyrolysis)

**Entrained flow reactor**
- Residence time: 0.7 s – 1.7 s
- Temperature: 1200°C – 1600°C
- Pressure: atmospheric
- Atmosphere: H₂O (Gasification)

**Fuels**

<table>
<thead>
<tr>
<th>Proximate</th>
<th>Lignite</th>
<th>bit. Coal</th>
<th>Ultimate</th>
<th>Lignite</th>
<th>bit. Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O</td>
<td>11.57 %</td>
<td>4.17 %</td>
<td>C</td>
<td>60.23 %</td>
<td>70.82 %</td>
</tr>
<tr>
<td>Volatiles</td>
<td>44.96%</td>
<td>34.18 %</td>
<td>H</td>
<td>4.01 %</td>
<td>4.43 %</td>
</tr>
<tr>
<td>Ash</td>
<td>3.75 %</td>
<td>7.78 %</td>
<td>N</td>
<td>0.63 %</td>
<td>0.99 %</td>
</tr>
<tr>
<td>Fixed C</td>
<td>39.71 %</td>
<td>53.87 %</td>
<td>S</td>
<td>0.61 %</td>
<td>0.83 %</td>
</tr>
</tbody>
</table>

**Alkali content**

- Sodium
- Potassium

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Results – WMR

Influence of residence time (T = 1000°C, p = 1 bar, Pyrolysis)

- Overall conversion increases with higher residence times → devolatilisation finished after aprox. 2 s
- Decreasing alkali content with higher residence times
- Sodium content of bit. coal shows no influence
- Sodium release of lignite finished after aprox. 5 s
Results – WMR

Influence of temperature (p = 1 bar, t = 10 s, Pyrolysis)

- Overall conversion increases with higher temperature → no more volatile release above 1200°C
- Decreasing alkali content with higher temperature
- No alkali release below 800°C
- No sodium release of lignite below 1200°C
Results – WMR

Influence of pressure (T = 1000°C, t = 10 s, Pyrolysis)

- Overall conversion decreases with higher pressure
- Alkali content of lignite shows no influence on pressure
- Slightly increasing alkali content of bit. coal with higher pressure
Results – Entrained flow reactor

H₂O-Gasification of lignite (H₂O/C = 1) – Conversion and alkali release

- Overall conversion increases with higher residence times and higher temperatures
- Alkali release increases with higher residence times
- Alkali release increases with higher temperatures
Results – Entrained flow reactor

H₂O-Gasification of bit. coal (H₂O/C = 1) – Conversion and alkali release

- Overall conversion increases with higher residence times and higher temperatures
- Alkali release increases with higher residence times
- Alkali release increases with higher temperatures
- Sodium release lower and potassium release higher than lignite
Conclusion and future aspects

Conclusion

- Pyrolysis and gasification experiments of a bituminous coal and a lignite in a wire-mesh reactor and in an entrained flow reactor
- Determination of sodium and potassium release
  → Relevant data for the design and construction of a hot gas cleaning unit in IGCC/IGFC power plants

Future aspects

- Modelling of alkali release kinetics
- Combined investigations of alkali release and alkali sorption with getter materials
Thank you for your attention!

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