Research Project

HOTVEGAS
Hochtemperaturvergasung und Gasreinigung

Basic research in the field of future high temperature gasification and gas clean up processes for IGGC power plants with CO$_2$ removal and for the production of synthetic fuels

Hartmut Spliethoff, TU München,
Bernd Meyer, TU Freiberg,
Michael Müller, FZ Jülich
Klaus Hack, GTT Technologies
Motivation

- Gasification is an old technology ↔ knowledge base is low
- IGCC-CCS power plant today is a combination of available gasification and gas cleaning technologies

→ Future CCS-PP require higher efficiencies
→ Gasification offers a high potential (integration, membranes)

\[
\begin{align*}
\text{Coal} & \rightarrow \text{Gasifier} \rightarrow \text{Gas cleaning} \rightarrow \text{High T shift} \rightarrow \text{Low T shift} \rightarrow \text{CO}_2 \text{ separation} \rightarrow \text{H}_2 \rightarrow \text{CO}_2 \\
& \text{Membrane reactor} \\
\text{Coal} & \rightarrow \text{Gasifier} \rightarrow \text{Gas cleaning} \rightarrow \text{Membrane shift} \rightarrow \text{H}_2 \rightarrow \text{CO}_2
\end{align*}
\]
- with CCS $\eta < 40\%$
- without CCS $\eta \leq 50\%$
Research demand

- The utilisation of the future potential requires:
  - Integrated concepts with gasification, gas cleaning and gas utilization (concepts with membranes)
  - High temperature gas cleaning and separation
  - Modelling of gasification and gas cooling
  - Materials for high temperatures and reducing conditions

**KEY for future IGCC CCS power plants:**
Knowledge of coal behaviour including mineral matter and trace components at highest temp./pressures and reducing conditions
## HOTVEGAS - Long term research

<table>
<thead>
<tr>
<th>Phase</th>
<th>Duration</th>
<th>Research Areas</th>
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| Phase 1 | 4 years  | • Fundamental investigation of coal gasification including mineral matter and trace components at highest temperatures and pressures under reducing conditions  
          |          | • Fundamentals and requirements of integrated gas cleaning and CO₂ separation  |
| Phase 2 | 4 years  | • Concepts of integrated gasification and gas cleaning  
          |          | • Components gasifier, gas cleaning and separation  
          |          | • Materials                                                                 |
| Phase 3 | 4 years  | • Development of integrated processes with membranes  
          |          | • Component development                                                      |
Research project Hotvegas (Phase 1)

• **Research partner**
  – Institute for Energy Systems (Technische Universität München) – project coordinator
  – Department for Energy Process Engineering and Chemical Engineering (TUB Freiberg)
  – Institute of Energy Research (Forschungszentrum Jülich)
  – GTT – Technologies (Herzogenrath, Aachen)

• **Funding**
  – Research initiative of the German Federal Ministry of Economics and Technology (BMWi), COORETEC
  – **Industrial partners:** EnBW, E.ON, RWE, Siemens, Vattenfall

• **Time frame:** September 2007 – August 2011
Work packages phase 1

1. Experimental analysis of gasification reactions at conditions relevant to industrial gasifiers
2. Experimental analysis of ash and slag behavior
3. Development of a database for the modelling of thermochemical and thermophysical properties of ashes and slags
4. Development of CFD models for simulating flow, reactions and heat transfer of entrained flow processes
5. Ash reaction at high temperatures and during gas cooling and hot gas clean-up
6. Overall process simulations
WP 1: Gasification reactions

PiTER (Pressurized High Temperature Entrained Flow Reactor)

analysis of gasification reactions:
• pyrolysis at high pressure and temperature
• char gasification kinetics
• trace element behavior
• development of optical measurement techniques

Operating parameters:
up to 1800°C, 50 bar
WP 1: Gasification reactions

PiTER installed at TU München

Status
• components are installed
• first functional tests were successful
• commissioning

CCT Poster Presentation
Tremel, Haselsteiner, Gleis, Spliethoff: Experimental Investigation of Coal Gasification at Very High Temperature and Pressure
WP1/ WP 5: Optical measurement techniques at PiTER

FTIR (Fourier Transformation IR-Spectroscopy)
→ gas analysis (e.g. CO, CO₂, H₂O, H₂S, HCl)

Raman-Spectroscopy
→ gas analysis (e.g. H₂, N₂)

Two-color-pyrometry
→ particle size, particle temperature

ELIF (Excimer Laser Induced Fragmentation Fluorescence)
→ gas concentration of alkali components
WP1/ WP 5: ELIF (Excimer Laser Induced Fragmentation Fluorescence)

Objective:

- Quantitative measurement of gaseous alkaline compounds (NaCl, NaOH, KCl, KOH)
- Online and in situ

Functional principle:

- Simultaneous fragmentation and excitation by excimer laser (VUV)
- Detection of fluorescence signal at optical wavelengths
WP 5 Ash reactions (cooling)

Pressurized Cooling Line (PCL)

Project aims:

- Deposition and condensation behavior of ash and trace elements along a pre-defined temperature profile
- Correlation with lab-scale investigations of trace element release from ash and slag
- Comparisons with sorption studies on laboratory facilities like a pressurised thermal balance

Current status PCL:

- Completion of hardware
- Commissioning
WP1: Pressurized Wire Mesh Reactor

Pressurized Wire Mesh Reactor:
• Experimental analysis of coal pyrolysis
• Simulation of heating rates relevant to industrial gasifiers
• Development of optical measurement techniques

Current status
• testing of different net materials
• measurements with ELIF
WP 1/ 5: Pressurized simultaneous thermal analyzer (P-STA)

Current status:

• Current operating parameters:
  1750 °C
  0.5 Mpa overpressure

• Currently experiments on potential high temperature getter materials (aluminosilicates)

• Development of higher pressures at maximum operating temperatures

CCT Presentation on Tuesday
Hauk, Gleis, Spliethoff:
Investigation of potential alkali getters for gasification using a new high temperature pressurized simultaneous thermal analyzer (STA)
WP 2: Experimental Analysis of Slag and Ash Behavior/ Database of slag/ ash properties at high t and reducing conditions

- Devices for determination of thermochemical and thermophysical properties of slags:
  - Knudsen Effusion Mass Spectrometry (KEMS)
  - Differential Thermal Analysis (DTA)
  - Differential Scanning Calorimetry (DSC)
  - Rotational Viscosimetry
  - Surface Tension Measurements with the High-Pressure Hot Stage Microscope

furnace (1550 °C @ 20 bar)
WP 4: Numerical simulation of EF coal gasification

**Aim**

1. Development of a gasification model suitable for high pressure and temperature conditions to predict fluid flow, reactions and heat transfer
2. Preliminary assessment of the facility
3. Commercial gasifiers

**Current status**

- Construction of the geometry of the gasifier (PiTER)
- Implementation of Yang’s pyrolysis model
- Implementation of Watanabe- Otaka Model
- Simulation of gasification process with Fluent and ANSYS CFX at operating conditions
WP 4: Particle deposition

Aim:
ii) to develop a model for particle deposition, deposit growth and
iii) dynamic behaviour of molten slag layer.

Approach:
• CFD calculation of fluid flow
• Lagrangian Particle tracking
• Viscoelastic model for deposition
WP 6: IGCC base case simulation

- 90% CO₂ capture
- low pressure ASU, 98% O₂
- hardcoal and lignite
- dual stage sour shift
- H-class gas turbine
- 3 pressure HRSG
- major systems verified

η potential: 37% (hardcoal), 39.5% (lignite)
CGE*: 82.9% (hardcoal), 80.2% (lignite)
gas yield (CO+H₂) Nm³/kg coal (daf): 2200 (hardcoal) bzw. 1644 (lignite)

* cold gas efficiency
WP 6 Hot Gas Clean up Concept

O₂ → Gasifier → cooling → sulphur removal → traces removal → membrane shift → CO₂
steam → coal → ceramics, slag → sorbents → sulphur removal → heat for regeneration

Temperature range: 500 – 600°C

T = f(stability, conversion)

T = f(stability, conversion)

1400 °C-1500 °C

partial quench or turbine

alkalines/ metals?

slag removal

heat for regeneration

temp. range: 500 – 800°C

fuel gas

combined cycle

N₂/H₂O

flue gas

power

CO₂

drying

CO₂

compres.
Thank You
for your attention