Direct Biological Methanation of the Synthesis Gas of an Allothermal Wood Gasifier

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The project addresses the substitute natural gas (SNG) production:
Biological methanation of gasified wood

Main objects: Proof-of-Concept for the coupling of wood gasifier and biological methanation; Usage of gasification residues as nutrient

Methods: Construction of a CSTR for the biological methanation, experimental research, proof of vitality via microscopy
Archaea and reaction equations

- Besides bacteria and eukaryota, archaea are one of the three domains of cellular life
- Some strains of archaea are able to build methane out of different educts like H₂, CO₂, CO, acetates, and others
- Methanogens live in ecological niches, like cow craws, black smokers, marshes

Metabolism of CO₂:

\[ \text{CO}_2 + 4 \text{H}_2 \rightarrow \text{CH}_4 + 2 \text{H}_2\text{O} \]

Stochiometric H₂ to CO₂ ratio of 4:1

Metabolism of CO:

- Direct:
  \[ \text{CO} + 3 \text{H}_2 \rightarrow \text{CH}_4 + \text{H}_2\text{O} \]
- Indirect:
  \[ 4 \text{H}_2 + \text{CO}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O} \]
  \[ 4 \text{CO} + 2\text{H}_2\text{O} \rightarrow \text{CH}_4 + 3\text{CO}_2 \]
Biochemistry of biological methanation

Methanation

Need for Co-factor F420

Fluorescence visible

Continuously stirred tank reactor (CSTR)

Parameters:
- **Volume:** 6.8 l
- **Pressure:** up to 3.6 bar(a)
- **Temperature:** 30 to 80°C
- **Agitator speed:** up to 3000rpm
- **Operation mode:** continuous or batch
- **Educts:** H₂, CO₂, CO
- **Gas volume flow:** 50 to 300 NmL/min
- **Stirrer:** Aeration stirrer Ø 72 mm
- **Steel:** 1.4307, 1.4404, 1.4404
CSTR: Highlights

Basics biological methanation

Facility

Experimental setup

Results

Conclusion

Magnetic coupling

Baffles

Culture broth

Cartridge heaters

Areation stirrer
Structure of experiments

- **Initial point:**
  Culture fed with stoichiometric ratio of H₂:CO₂

- **Approach:**
  Adding of synthetic components to represent parts of the real syngas of the gasification

- **Added components are:**
  - CO
  - Gasification ash
  - Tars (toluene, methylnaphthalene and acenaphtene)

Start of a new experiment → Waiting for a stable culture → Adding of CO → Adding of ash → Adding of tars
Parameters of experiments

- **CO:**
  - Adding 20 vol.-% to the stoichiometric ratio of $H_2:CO_2$
  - Switch to expected composition of gasification syngas without adjustment of stoichiometric ratio ($H_2$ is 40, $CO_2$ is 24, CO is 18 and $N_2$ (same as the amount of $CH_4$, assuming $CH_4$ as inert gas) is 18 vol.-%)

- **Gasification ash:**
  - Produced under defined parameters
  - Given dosage is 0.043 g/d, orientated to an MBR = 10 NL/(L·d), fuel is wood pellets with an ash share of 0.5%-weight, assuming the syngas carrying all of the contained ash

- **Tars:**
  - 150h of experiment per tar component
  - 6.3 g/d for toluene and methylnaphthalene, following the same orientation as for the ash, assuming feed gas to carry 20 g/Nm³ of the tar component
  - 2 g acenaphtene added only once
Results of adding CO

- fluctuation of MBR is in the usual frame, monitored in all measurements with the presented CSTR. This fluctuation cannot be explained, yet. Assumed reasons: Solubles out of the used materials and inhibition of the culture through by-products
- lag periods of MBR are longer under CO-influence
- MBR stays at usual level
- Measurements show: CO is metabolized

CO is not a critical component, but can be turned to CH₄
Results of adding ash

- fluctuation of MBR is in the usual frame
- Ash dosage at a parallel builted trickle bed reactor leaded to stalling of the culture
- Ash dosage in CSTR does not have a visible effect
- Probable reason: Not-ideal living conditions can lead to incomplete building of cellwalls. High shear forces due to stirrer prevent from agglomeration.

Ash dosage has no visible effect in CSTR
Results of adding tars

- Toluene and methylnaphthalene (daily dosage):
  - similar effect
  - High MBR peaks are stopped; stable MBR at low level, but:
    - No stalling of the culture
- Acenaphtene (only one dosage):
  - Break-down of MBR within hours
  - MBR stabilizes at very low level after some time

**tars are the main challenge with biological methanation of gasification syngas**
Conclusion

- **A CSTR has been built**
- **Several components and impurities are added to synthetic feed gas:**
  - **CO:**
    - CO is not a critical component
    - can be metabolized to CH₄
  - **Gasification ash:**
    - Ash dosage has no visible effect in CSTR
    - Problems with ashes in other fermenter types
  - **Tars:**
    - tars are the main challenge with biological methanation of gasification syngas
    - Different effects result from different tars
    - Probably tars have to be cleaned out of the syngas or:
    - Research and adaption of cultures has to be done