Component development for a liquid sorption thermal energy storage system

- Practical application in liquid sorption heat storage with aqueous sodium hydroxide

Webinar, Nov 27, 2019 14:00 - 15:30 GMT

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Subtask 4T: Motivation

• There are many different demonstrator and lab scale systems under design, construction and testing.
• These vary highly in reported process, power, capacity and application.
• In addition to heat transport, components for thermo chemical storage systems have to provide an optimised heat and mass transport.
• The actual heat/mass exchanger design is crucial for the achievable storage capacity and power output.
• The possibilities in designing such a reactor are multiple, and so are the testing methods.

A common basis is required
Subtask 4T: Component Design for Thermo Chemical Materials

- four performance criteria:
  - gross temperature lift (temperature effectiveness)
  - volumetric energy density
  - volumetric power
  - round trip efficiency

- four evaluation scales:
  - material (mg)
  - bulk (g)
  - component (kg)
  - system (Mg)

- varying system process types
- many different testing profiles
Subtask 4T: Component Design for Thermo Chemical Materials

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- **varying system process types**
- **many different testing profiles**

Realistic temperatures
Realistic operating temperatures for building application

Guideline from EN 14511-2

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Pros and Cons
Basic sorption heat storage processes

Closed and transported process

**Advantages**
- increased vapour pressure and density
- no external fouling
- steady state process
- continuous charging and discharging
- capable of single pass and counter flow
- maximum GTL
- discharge to minimum input temperature

**Disadvantages**
- operates at sub atmospheric pressure
- requires condenser and evaporator
- sensitive to non-condensing gases
- requires sorbate storage
- Increase in complexity, storage vessels and means of transport

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- **Theoretical evaluation**
  - varying system process types
  - many different testing profiles

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Aqueous sodium hydroxide


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Gross temperature lift and temperature effectiveness

Vapour pressure 8.1 mbar (4 °C)

Absorption

Desorption

Gross Temperature Lift [K]

Mass fraction NaOH in aqueous solution [-]

Loss in GTL


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Evaporator temperature 1 °C (6.5 mbar)

Mass fraction NaOH in aqueous solution [-]

0.30
0.32
0.34
0.36
0.38
0.40
0.42
0.44
0.46
0.48
0.50
0.52
0.54

Gross Temperature Lift [K]

10
15
20
25
30
35
40
45
50

Condenser temperature 38 °C (67 mbar)

Evaporator temperature 1 °C (6.5 mbar)

Absorption

Maximun discharging GTL

Minimum discharging concentration

Discharging loss due to vapour pressure decrease

Loss in GTL due to vapour pressure decrease

Desorption

Minimum charging GTL

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Theoretical evaluation

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Volumetric energy density

![Graph showing volumetric energy density with energy of solution, energy of condensation, and total energy as functions of final concentration.]

- Energy of solution
- Energy of condensation
- Total energy

Final concentration [wt%]

Energy density [kWh/m³]

- 162
- 190
- 200
- 250
- 300
- 350
- 400
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  - **volumetric power**
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Mass and heat transport
Bulk scale power investigation

Vapour connection

Evaporator / Condenser

Absorber / Desorber
Bulk scale power

Not reached maximum mass uptake

Low power

30 min.
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Absorption machine comparison

1. Absorption cooling machine
   - Desorption: Source In, Sink Out
   - Absorption: Sink In, Source Out

2. Absorption heat transformer
   - Desorption: Source In, Sink Out
   - Absorption: Sink In, Source Out

3. Absorption heat storage
   - Desorption: Source In, Sink Out
   - Absorption: Sink In, Source Out

4. Absorption heat storage
   - Desorption / Absorption: Source / Sink In, Sink / Source Out
   - Storage: Sorbent charged, Sorbent discharged, Sorbate
Heat and mass changer design for sorption heat storage

Material: stainless steel grad 1.4571

Absorbent solution $m_{\text{Absol}} / m_{\text{Dsol}}$ [g/min]

Heat transport fluid $m_{\text{Ahf}} / m_{\text{Dhf}}$ [g/min]

Lab scale HMX

Performance evaluation


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Conclusion

- Choice of process affects performance.
- To compare sorption systems, uniform testing temperatures are essential.
- Sorption storage requires operation close to the vapour pressure, temperature and concentration equilibrium.