Using the Open Source SorpSim for Simulation of Sorption Water Heating Applications

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Content

• Background
• Introduction to SorpSim
• Example in Hot Water Applications
• Conclusion
Background

• Sorption systems
  – Heat driven systems using affinity of liquid solution (absorption) or solid material (adsorption) to refrigerants to generate heat pumping effect.
  – Advantage in heating applications:
    • Heat driven, low electricity consumption;
    • Wide source temperature range: waste heat, solar heat, steam, natural gas burner;
    • Higher efficiency than electric resistance;
    • Zero GWP working fluid;
    • No moving parts except pumps: low noise/vibration.
Background

• Absorption water heating systems
  – Various configurations for heat sources at different temperatures.
  – Simulation of complex cycles remains a challenging task.

http://www.industrialheatpumps.nl/en/how_it_works/absorption_heat_pump/
SorpSim: Origin

- The Sorption system Simulation program (SorpSim) was developed based on the well-recognized ABsorption SIMulation code (ABSIMW Version 5.0).
- SorpSim combines the built-in component models, fluid properties, and solver subroutines of the legendary code with a versatile graphical interface with enhanced features and functions.
- SorpSim provides a reliable and user-friendly simulation platform that is open-source and compatible across several computer platforms.
SorpSim: Structure

Graphical User Interface (GUI)

System Cycle Config. and Edit
Parametric Analysis
Result Display

Case Data Object
System Performance Simulation Controller

Cycle Config.
Calc. Criteria

Calc. Results
Calc. Details

XML Database File

Simulation Engine

Calculation Controller

Eqn. Matrix
Var. Vector
Calc. Results

Solver Package
Input/Guess Values
Eqn. Residuals

Component Models
Fluid Type
Opt. Condition
Property Parameters

Fluid Property Library
SorpSim: Key Features

- Cycle configuration/edit
SorpSim: Key Features

• Cycle configuration/edit
• Result display
SorpSim: Key Features

- Cycle configuration/edit
- Result display
- Parametric table/plot
SorpSim: Available Components

- Components models
  - Built-in governing equations
  - 12 standard components for absorption systems
  - 7 types of liquid desiccant system components

<table>
<thead>
<tr>
<th>Index</th>
<th>Component</th>
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<td>Pump</td>
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<tr>
<td>13-19</td>
<td>Liquid Desiccant Components</td>
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</tbody>
</table>
SorpSim: Available Working Fluids

- Fluid property library
  - Built-in property correlations for VLE, enthalpy, density, etc.
  - 11 commonly used fluids for absorption systems

<table>
<thead>
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<th>Index</th>
<th>Fluid</th>
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<td>H₂O/NH₃</td>
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<td>H₂O</td>
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<td>LiBr/H₂O/NH₃</td>
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<td>LiBr/ZnBr₂/CH₃OH</td>
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<td>Moist Air</td>
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<td>Flue Gas</td>
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SorpSim: Future Expansion

- SorpSim can be used in many application beyond water heating
- Modular structure of program enable convenient expansion of libraries
  - Liquid Desiccant
  - Adsorption
  - More working pair properties
- Open-source guarantees free access and facilitates continuous improvement and development by the sorption research community
  - www.github.com/oabdelaziz/sorpsim
Examples in Hot Water Applications

• Target systems: various absorption cycles using LiBr/H₂O as working fluid

• Operating Conditions
  – DOE energy conservation standard rating condition for consumer water heaters:
    • Hot water supply: 125°F/51.6°C (tank outlet)
    • Hot water return: 58°F/14.4°C
    • Ambient: 67.5°F/19.6°C & 50% rh

• Parametric Analysis
  – $T_{\text{amb}}$, $T_{\text{src}}$, $T_{\text{hw}}$
  – COP, Capacity
Configurations: SEHP

Single-Effect LiBr/H₂O Absorption
Heat Pump Water Heater

Heat input @ 90°C
HW supply @ 51.6°C
HW return @ 14.4°C
Ambient air @ 19.6°C

<table>
<thead>
<tr>
<th>Component</th>
<th>UA value [kW/°C]</th>
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<tr>
<td>Absorber</td>
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<td>Internal HEX</td>
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<tr>
<td>Air HEX</td>
<td>5</td>
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</tbody>
</table>
Configurations: SEHP

Single-Effect LiBr/H₂O Absorption Heat Pump Water Heater

- Baseline results:
  - Capacity: 90.2 kW
  - COP: 1.71
  - Solution: 62.2%/64.4%
Configurations: SEHP

- Parametric Analysis: Source Temperature
Configurations: SEHP

- Parametric Analysis: Source Temperature
Configurations: SEHP

- Parametric Analysis: Hot Water Supply Temperature
Configurations: SEHP

- Parametric Analysis: Ambient Temperature
Configurations: DEHP

Double-Effect LiBr/H₂O Absorption Heat Pump Water Heater

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<tr>
<td>Air HEX</td>
<td>5</td>
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</tbody>
</table>

Heat input @ 150°C

Ambient air @ 19.6°C

HW return @ 14.4°C

HW supply @ 51.6°C
Configurations: DEHP

Double-Effect LiBr/H$_2$O Absorption Heat Pump Water Heater

- Baseline results:
  - Capacity: 77.7 kW
  - COP: 2.2
  - Solution: 62.9%/65.2%/66%
Configurations: DEHP

- Parametric Analysis: Source Temperature

![COP vs Tsrc](image1)

![Capacity vs Tsrc](image2)
Configurations: DEHP

- Parametric Analysis: Source Temperature

![Concentration vs Source Temperature Graph](image)

- Strong Solution (high desorber)
- Strong Solution (low desorber)
- Weak Solution
Configurations: DEHP

- Parametric Analysis: Hot Water Supply Temperature
Configurations: DEHP

- Parametric Analysis: Ambient Temperature
Configurations: TEHP

Triple-Effect LiBr/H₂O Absorption Heat Pump Water Heater

- Baseline results:
  - Capacity: 84.8 kW
  - COP: 2.6
  - Solution: 65.6%/68.1%/68.3%/70.3%

Heat input @ 260°C
- #14 CONDENSER HT=23.5kW
- #13 DESORBER HT=32.7kW

Heat return @ 14.4°C
- #12 HEAT EXCHANGER HT=29kW
- #6 CONDENSER HT=18kW
- #5 CONDENSER HT=18.2kW

HW supply @ 51.6°C
- #7 HEAT EXCHANGER HT=18.6kW
- #2 HEAT EXCHANGER HT=66.6kW

Ambient air @ 19.6°C
- #1 EVAPORATOR HT=52.2kW
- #21 HEAT EXCHANGER HT=52.2kW

Baseline results:
- Capacity: 84.8 kW
- COP: 2.6
- Solution: 65.6%/68.1%/68.3%/70.3%
Conclusion

- Sorption technologies hold unique advantages in water heating applications.
- The open-source SorpSim program provides a reliable and convenient platform to facilitate research and development of absorption systems for HW applications.
- SorpSim has been continuously updated, and it will include more ready-to-use template cases, new working pairs, and simulation capability for adsorption systems.
- Examples of absorption water heating cycles in SorpSim demonstrated its capability to conveniently simulate and analyze complex sorption system under various operating conditions.
Acknowledgement

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Questions?
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