Simulation and analysis of solar subcooled absorption-compression hybrid cooling system

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Outline

- Introduction
- Model
- Results and discussion
- Conclusion
- Prospect
1. Introduction

- Solar absorption chiller is easy to be commercially applicable
- Its cooling capacity usually depends on the aperture area of collector
- The collector installing at the facade of building works inefficiently, so that the collector should be only installed at the roof of building
1. Introduction

- Except for some small buildings, the total area of commercial building is larger than the area of roof.
- The auxiliary energy is essential in the solar absorption cooling system to satisfy the cooling load.
- The usual auxiliary energy is thermal energy and electric energy.
1. Introduction

- The system assisted by thermal energy is not feasible due to the expensive working cost.
- To develop the solar absorption chiller which is economical and can satisfy the cooling load with the insufficient solar irradiance is important and urgent.
- The system assisted by electric energy (solar absorption compression hybrid cooling system) can deal with it better.
1. Introduction

- Five type absorption-compression hybrid cooling systems
  - First: based on the cascade cycle
  - Second: based on the vapor compression cycle with solution circuit (VCCSC)
  - Third: compressor connecting between the absorber and evaporator
  - Fourth: discharge gas of compressor to heat the generator
  - Fifth: some new systems
1. Introduction

First

Second
1. Introduction

[Diagram of a refrigeration cycle, showing the flow of refrigerant, weak solution, rich solution, and their interactions with components like the condenser, evaporator, compressor, and absorber.]

Third

Fourth

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1. Introduction

- Not all the hybrid systems is suitable to be used in solar LiBr/H\(_2\)O absorption-compression system
  - First and second: is unreliable when the solar irradiance is insufficient
  - Third: compressor is very huge
  - Fourth: poor performance of compressor since its suction temperature is very high

- Subcooled absorption compression cycle (Chen GM)
1. Introduction

- The solar subcooled absorption-compression hybrid cooling system (SACHCS) is better and efficient
  - Construction is not complicated
  - Always satisfies the cooling load regardless of solar irradiance
  - Evaporator temperature of absorption subsystem is higher
  - Wider working range of generator temperature
  - Subcooled compression
1. Introduction

SSACHCS

Cycle principle

Cooling capacity from absorption subsystem
1. Introduction

- The variation of working characteristic of absorption subsystem does not have significant effect on the working characteristic of compression subsystem.

- The low grade cooling capacity of absorption subsystem transform into the high grade one without extra work by the throttling valve.
1. Introduction

- The generator temperature is not stable and depends on the system parameter.
- Once the system parameter can not match each other, too higher or too lower generator temperature deteriorates the performance and reliability seriously.
- Objective: analyzes the variation of performance with the system parameter.
2. Model

- Parametric model
- Mass and energy conservation
- quasi-static
- the component is adiabatic except the collector
- Time step is 2 min
- Maximum deviation is 1.8%

Validation

$$\begin{align*}
Q_{HYS} &= 16\text{kW} \\
Q_G &= 3\text{kW} \\
T_2 &= 40^\circ\text{C} \\
T_5 &= 40^\circ\text{C} \\
T_{13} &= 5^\circ\text{C} \\
T_8 &= T_5 + 10^\circ\text{C}
\end{align*}$$
2. Model

- The system parameter is based on a typical commercial building of which cooling load is 240kW, number of floor is 5, area of floor is 384m² and so on.

### System parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of CPC</td>
<td>54</td>
</tr>
<tr>
<td>Aperture area of single CPC (m²)</td>
<td>3</td>
</tr>
<tr>
<td>Volume of single CPC (m³)</td>
<td>2.4 × 10⁻³</td>
</tr>
<tr>
<td>Volume of storage tank (m³)</td>
<td>1.7</td>
</tr>
<tr>
<td>Initial $T_0$ (° C)</td>
<td>35</td>
</tr>
<tr>
<td>Inlet temperature of cooling water (° C)</td>
<td>32</td>
</tr>
<tr>
<td>Outlet temperature of chilled water (° C)</td>
<td>5</td>
</tr>
<tr>
<td>Cooling capacity of absorption subsystem (kW)</td>
<td>17</td>
</tr>
<tr>
<td>Cooling capacity of hybrid system (kW)</td>
<td>240</td>
</tr>
<tr>
<td>Effectiveness of SHX $\varepsilon$</td>
<td>0.7</td>
</tr>
<tr>
<td>Isentropic efficiency of compressor $\eta_i$</td>
<td>0.8</td>
</tr>
<tr>
<td>Mechanical efficiency of compressor $\eta_m$</td>
<td>0.9</td>
</tr>
</tbody>
</table>
2. Model

- Typical solar irradiance and outdoor temperature of August in Guangzhou
2. Model

- Three indexes of performance
  - Mean COP
    \[
    \overline{COP}_{HYS} = \frac{1}{n} \sum_{i=1}^{n} COP_{HYS}
    \]
  - Working time fraction of absorption subsystem (WTF)
    \[
    \lambda = \frac{t_{AS}}{t_{HYS}}
    \]
  - Energy saving fraction of hybrid system (ESF) (key)
    \[
    \psi = \lambda \cdot \frac{Q_{AS}}{Q_{HYS}} \times 100\%
    \]
3. Results and discussion

- Working process with different $Q_{AS}$

- $Q_{AS}=17\text{ kW}$

- $Q_{AS}=13\text{ kW}$
3. Results and discussion

- Working process with different $Q_{AS}$
- Too low $Q_{AS}$ leads to crystallization
- Too high $Q_{AS}$ results in the oscillation of COP and generator temperature, shortens the time of absorption subsystem
3. Results and discussion

- Too low or too high $Q_{AS}$ is harmful to the system performance
- The maximum ESF is 5.98% when the $Q_{AS}$ is 21 kW

![Graph showing performance with $Q_{AS}$]
3. Results and discussion

- The decrease of $V_{ST}$ can improve the ESF by the increase of working time of absorption subsystem.
- Too low $V_{ST}$ also makes crystallization.
3. Results and discussion

- By the appropriate change of $V_{ST}$, the maximum ESF goes up to 7.2%
- The corresponding $Q_{AS}$ is 23kW
3. Results and discussion

- The performance goes down significantly as the $A_C$ is less than $126m^2$
- When the $A_C$ exceeds to $126m^2$, the performance only rises slightly with the increase of $A_C$
3. Results and discussion

Performance with effectiveness of SHX

Performance with efficiency of compressor
3. Results and discussion

$\Delta T_1$ denotes the temperature drop of storage tank and generator
$\Delta T_2$ denotes the temperature drop of outlet refrigerant of
compression subsystem and subcooler

$Q_{\text{HYS}} = 240 \text{kW}$
$Q_{\text{AS}} = 17 \text{kW}$
$V_{\text{ST}} = 1.7 \text{m}^3$
$A_c = 162 \text{m}^2$

Performance with $\Delta T_1$

Performance with $\Delta T_2$
4. Conclusion

The efficient working condition of SSACHCS matches the feature of cooling load of office and commercial building

- The $Q_{AS}$ is not required to be too high to increase the system performance
- Not all the space of roof is required to install the collector so that the collector can be mounted more flexibly in the roof
4. Conclusion

- The WTF and mean COP go down with the increase of $Q_{AS}$. The performance drops significantly due to the repeated start and stop as well as the long stop of absorption subsystem as the $Q_{AS}$ is greater than 21kW. But the crystallization happens as the $Q_{AS}$ decreases to 13kW. The optimal $Q_{AS}$ that maximizes the ESF is 21kW. The corresponding maximum ESF is near 6%.
4. Conclusion

- The COP and the crystallization risk of absorption subsystem all go up with the decrease of $V_{ST}$. Especially, the decrease of $V_{ST}$ can improve the performance evidently as the $Q_{AS}$ is higher than 21kW. The maximum ESF is 7.2% when $Q_{AS}$ and $V_{ST}$ are 23kW and 0.71m$^3$, respectively.
4. Conclusion

- The system performance gains significant improvement as the $A_C$ is larger than $126m^2$. But the system performance just rises slowly when the $A_C$ increases from 126 to $162m^2$. 
4. Conclusion

- The performance goes up slightly with the improvement of effectiveness of SHX when the effectiveness of SHX exceeds to 0.6. The variation of efficiency of compressor only changes the mean COP. The performance goes down with the increase of $\Delta T_1$ and $\Delta T_2$. And both effect on the ESF is somewhat higher than that of effectiveness of SHX.
5. Prospect

- Improvement of working process model
- Design principle of system based on the meteorological data in the period of cooling supply (April to October)
- Appropriate control based on the variation of cooling load
- Prototype development and experiment
Thank you for your attention!