System simulation of air-cooling single effect LiBr absorption refrigerating system driven by solar heat source

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Abstract: Air-cooling single-effect absorption refrigeration system has the characteristics of water saving, space saving and maintenance cost compared with water-cooling. In order to study the characteristics of air-cooled system, this paper uses AspenPlus to build an air-cooled single-effect LiBr absorption refrigeration system with a cooling capacity of 23kW and adiabatic evaporation and adiabatic absorption, and the influence of temperature on the system at different condensing temperatures is studied. The results show that with the increase of generating temperature, the load increase of solution heat exchanger gradually slows down and then becomes faster, while the load increase of other equipment gradually slows down. After the system COP value rises to a certain value, it basically remains unchanged.

1. Introduction
With the development of society, building energy consumption is increasing day by day. How to reduce energy consumption and improve the quality of life has become an important issue at present. Solar LiBr absorption refrigeration system has high refrigeration efficiency and is the best absorption technology at present [1,2]. Air-cooling single-effect absorption refrigeration unit has the characteristics of saving water, occupying a small area and being easy to maintain, which shows advantages in residential solar cooling application [3]. However, there are difficulties such as high crystallization risk and low miniaturization. Therefore, it is of great significance to research and optimize the air-cooling single-effect absorption chiller [4,5]. In this paper, AspenPlus software is used to simulate the refrigeration system with 23kW refrigeration capacity using adiabatic evaporator and adiabatic absorber with air-cooling precooler, and the influence of generating temperature change on air-cooling system under different condensing temperatures is simulated and analyzed.

2. Solar air cooled single effect LiBr absorption refrigeration system
The solar air-cooled single-effect LiBr absorption refrigeration system that adopts adiabatic flash evaporator and adiabatic absorber is shown in Fig.1. By introducing the adiabatic flash process, the refrigerant water circulation pump and the heat transfer pipe in the evaporator are eliminated, and the secondary heat exchange between refrigerant water and frozen water can be avoided. By introducing the adiabatic flash process, the refrigerant water circulation pump and the heat transfer pipe in the evaporator are eliminated, and the secondary heat exchange between refrigerant water and frozen water can be avoided. The traditional absorber is replaced by an adiabatic with a finned tube precooler,
the absorbed heat is discharged by the sub-cooler, and the mass transfer process occurs only in the absorber.

![Diagram of Solar air-cooling single-effect LiBr absorption refrigeration system](image)

**Fig.1** Solar air-cooling single-effect LiBr absorption refrigeration system

- a: Evaporator
- b: Absorber
- c: Generator
- d: Air-cooling Condenser
- e: Solution Heat Exchanger
- f: Air-cooling Precoolers
- g: Fan Coil
- 10: Hot Water Return
- 9: Hot Water Supply

**3. System simulation**

Simulation of system flow of absorption unit with AspenPlus software, Fig.2 shows the simulation system of a new air-cooling single-effect LiBr absorption unit with cooling capacity of 5kW, and Table 1 shows the initial parameters of the simulation.

**Fig.2** Solar air-cooling single-effect LiBr absorption refrigeration system

![Diagram of Solar air-cooling single-effect LiBr absorption refrigeration system](image)

| Hot water temperature/°C | Evaporating temperature/°C | Generating temperature/°C | Condensing temperature/°C |
|--------------------------|-----------------------------|---------------------------|---------------------------|
| 90                       | 10                          | 83                        | 33                        |
| Absorption temperature/°C| Dilute solution mass fraction (%) | Dilute solution flow rate/kg/h | Deflated range |
| 35                       | 56.6%                       | 400                       | 4.5%                      |
4. Verification of simulation accuracy

For an ideal air-cooling absorption refrigeration cycle, the mechanical work and other heat losses of the solution pump are ignored. According to the first law of thermodynamics, the heat balance relation of the whole system can be obtained as follows:

\[ Q_g + Q_e = Q_a + Q_c \]  

Type in the:
- \( Q_g \) — Generator load; 
- \( Q_e \) — Evaporator load; 
- \( Q_c \) — Condenser load; 
- \( Q_a \) — Absorber load.

The load simulation results of each equipment in the simulation system are shown in Table 2:

| Block                  | Duty (KW) |
|------------------------|-----------|
| Generator              | 7.406     |
| Evaporator             | 5.298     |
| Condenser              | 5.599     |
| Absorber               | 7.106     |
| Solution heat exchanger| 6.189     |

According to the heat balance formula 2, it can be concluded that:

\[
\frac{(7.420 + 5.301) - (5.601 + 7.112)}{7.420 + 5.301} \times 100\% = 0.063\% 
\]

If the calculation result is less than 1%, the simulation result of the system meets the requirements of thermal balance, indicating that the simulation model of AspenPlus is reasonable and the parameter selection is accurate.

5. Influence of Generating temperature on System Performance at Different Condensing Temperatures

In the solar absorption refrigeration system, the temperature of solar hot water directly affects the temperature of generation, thus affecting the performance of the system. The Evaporating temperature \( T_e = 10^\circ C \) was kept unchanged, and the Condensing temperature was set at 35\(^\circ\)C, 40\(^\circ\)C and 45\(^\circ\)C for simulation. The simulation results of different equipment loads changing with the temperature are shown in Figure 3-7.
Fig. 5 Effect of generating temperature on generator load

Fig. 6 Effect of generating temperature on solution heat exchanger load

As can be seen from Fig. 3-6, the load of evaporator, absorber, generator and solution heat exchanger all increases with the increase of temperature. This is because with the continuous rise of the generating temperature, the deflated range will expand, and more refrigerant steam will be separated at the top of the generator. With the increase of temperature, the load increase range of the solution heat exchanger gradually becomes faster, while the load increase trend of the other equipment gradually slows down.

With the increase of condensing temperature, the load of generator, evaporator and absorber decrease with the increase of condensing temperature, while the load of solution heat exchanger changes in the opposite trend. The reason for the analysis is that the condensation pressure increases with the increase of the condensing temperature, in the case of ignoring pipeline and equipment pressure drop, the generating pressure and the condensing pressure remain the same, and the deflated range becomes smaller, and reduced refrigerant gasification in the generator, and the volume of the concentrated solution increases, which leads to the load of the solution heat exchanger increases with the increase of condensing temperature.

Fig. 7 Effect of generating temperature on COP

As can be seen from Fig. 7, COP value rises with the rise of temperature, but the rise gradually slows down. This is because with the increase of temperature, the mass flow of refrigerant becomes larger, and the COP of the system becomes larger accordingly. According to the COP curve of the condensing temperature of 45℃, when the generating temperature is greater than 95℃, the COP remains stable. When the generating temperature rises from 95℃ to 120℃, the COP value of the system only rises from 0.79 to 0.80, with an increase of only 1.3%; when the temperature rises from
85℃ to 95℃, the COP value of the system correspondingly changed from 0.65 to 0.79, with an increase of 21.5%. The COP value decreases with the increase of condensing temperature.

The effect of generating temperature on the range of deflated range is shown in Fig.8. As can be seen from Fig. 8, the deflated range of the system decreases with the increase of condensing temperature and increases with the increase of generating temperature. This is because as the generating temperature increases, the refrigerant vapor production increases, and the concentration of the concentrated solution increases. But the generating temperature can't go up indefinitely. In order to ensure the operation of single effect LiBr refrigeration unit economy, the deflated range of single-effect LiBr refrigeration system is between 0.03 and 0.06. When the condensing temperature is set at 35℃, the lowest generating temperature is 78℃ and the highest cannot exceed 86℃; when the condensing temperature is 40℃, the lowest generating temperature is 83℃ and the highest cannot exceed 90℃; when the condensing temperature is 45℃, the lowest generating temperature is 89℃ and the highest cannot exceed 98℃.

6. Conclusion

By analyzing the simulation results and analysis, the following conclusions are drawn:

In solar air-cooling single-effect LiBr absorption refrigeration system, with the increase of generating temperature, the load increase of solution heat exchanger first gradually slows down and then gradually increases, however, the increase of generator load, evaporator load and solution heat exchanger load gradually slows down, and the COP value of the system will increase with the increase of generating temperature. When the generating temperature reaches a certain value, the COP value is basically unchanged; with the increase of condensing temperature, the generator load, evaporator load and absorber load all show a downward trend with the increase of condensing temperature, while the load of solution heat exchanger shows an opposite change trend with the increase of condensing temperature. COP value decreases with the increase of condensing temperature.

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