Simulation analysis of R134a/DMF absorption refrigeration system based on Aspen Plus

Chunhua Wang 1*, Qiang Wang 1,2, Xiaoyang Hui 3, Rong Zong 1, Baoqi Shan 2

(1. Weifang Institute of Technology, Weifang 262500, China, 2. Shandong Jianzhu University, Jinan 250013, China, 3. Shandong Provincial Key Laboratory of Applied Microbiology, Ecology Institute, Qilu University of Technology (Shandong Academy of Sciences))

wfitsxzx@wfit.edu.cn

Abstract: In order to explore the performance of R134a/DMF absorption refrigeration system, a model of R134a/DMF absorption refrigeration system was conducted based on Aspen Plus software. The cooling capacity of the system is 150kW. The effects of reflux ratio, bottom temperature and refrigerant (R134a) concentration on the system were simulated and analyzed. The results showed that, the reasonable range of reflux ratio and scope of bleed is 0.5~0.7. The system COP is the best when the mass fraction of R134a, the generating temperature and absorption temperature is respectively 56%, 131°C and 28°C.

1. Introduction
In my country's building energy structure, air-conditioning energy consumption accounts for more than 65% of the building energy consumption, and building energy consumption accounts for more than 30% of the total energy consumption [1]. The NH3/H2O and LiBr/H2O absorption refrigeration cycle system driven by low grade heat sources have been widely used. However, NH3/H2O has certain toxicity and the operating pressure is relatively high, LiBr/H2O cannot produce cooling capacity below zero. At present, more research hotspots prefer the working medium pair composed of fluorinated hydrocarbon with low GWP and zero ODP and asolvent-based absorbent [2-3]. R134a/DMF working medium pair is one of them. Based on the R134a/DMF new refrigeration working fluid pair, this paper carries out simulation calculation and analysis on the refrigeration system based on Aspen Plus software, which provides a theoretical basis for the improvement of system performance and optimization design in the future.

2. R134A/DMF absorption refrigeration system
The main equipment of R134a/DMF absorption refrigeration cycle includes: rectification tower, condenser, evaporator, throttle valve, solution heat exchanger, absorber, super cooler, solution pumped. The flow chart is shown in Figure.1. The concentrated solution flowing from the absorber passes through the solution heat exchanger and the high-temperature dilute solution separated from the rectification tower for heat exchange. The concentrated solution after the temperature rises enters the rectification tower. On the one hand, the dilute solution after cooling enters after throttling. The absorber absorbs R134a from the evaporator; on the other hand, the concentrated solution after the temperature rises enters the rectification
tower for rectification. After the rectified refrigerant R134a vapor is condensed by the condenser, it enters the evaporator through the expansion valve to complete the refrigeration effect.

Fig. 1 Schematic diagram of R134a/DMF absorption refrigeration cycle

3. Process construction and simulation

The operation module selection of R134a/DMF absorption refrigeration system simulation unit is shown in Table.1:

| Refrigeration link | Evaporator | Condenser | Rectifier |
|--------------------|------------|-----------|-----------|
| Software unit module | Heater | HeatX | RadFrac |
| Refrigeration link | Throttle valve | Absorber | Solution heat exchanger B2 |
| Software unit | VALVE2 | Heater | HeatX |

According to the parameters in the paper of A.Yokozeki \cite{4}, the simulation calculation is carried out. The parameters of the initial operation of the system are shown in Table.2, and the system flow completed is shown in Figure.4.

| Rectifier pressure/bar | evaporation pressure/bar | solution heat exchanger cold flow outlet temperature/℃ | thin solution mass fraction(%) | thick solution mass fraction(%) | refrigerant flow /Kg/sec |
|------------------------|--------------------------|------------------------------------------------------|-------------------------------|-------------------------------|--------------------------|
| 4.14                   | 52                       | 32.7%                                                | 67.3%                         | 1                             |

Fig.2 Flow chart of R134a/DMF absorption cycle simulation
Table 3 of parameter values at each point of the system:

| Number | Pressure (bar) | Temperature (℃) | Mass flow (kg/s) | Vapour fraction (%) |
|--------|----------------|-----------------|------------------|--------------------|
| 1      | 10.15          | 49.98           | 2.14             | 0                  |
| 2      | 10.15          | 39.94           | 1                | 0                  |
| 3      | 4.14           | 10.06           | 1                | 0.23               |
| 4      | 4.14           | 13              | 1                | 0.99               |
| 5      | 4.14           | 22.60           | 2.14             | 0                  |
| 6      | 10.15          | 23.34           | 2.14             | 0                  |
| 7      | 10.15          | 81.69           | 1.14             | 0                  |
| 8      | 10.15          | 38.34           | 1.14             | 0                  |
| 9      | 10.15          | 38.63           | 1.14             | 0                  |

The load simulation results of each device are shown in Table.3:

| Module                  | Evaporator | Condenser | Rectifier | Absorber | Solution heat exchanger | Solution pump |
|-------------------------|------------|-----------|-----------|----------|--------------------------|---------------|
| Load (Kw)               | 151.35     | 248.63    | 308.39    | 214.22   | 87.66                    | 3.17          |

According to the formula \((462.13-465.25) / 462.13 = 0.68\% < 1\%\), the system generally meets the requirements of heat balance, and it is judged that the selected parameters and operation results are normal.

4. Effect of reflux ratio of distillation column on the system

It can be seen from Figure 5 and Figure 6 that as the reflux ratio increases, the rectification effect is better, but the tower reactor load becomes larger and the system COP becomes smaller and smaller. When the reflux ratio is between 0.1 and 0.5, the rectification effect varies greatly with the reflux ratio. When the reflux ratio is greater than 0.5, the rectification effect does not change significantly. When the reflux ratio increases from 0.1 to 0.5, the tower reactor load increases from 245.3263Kw to 308.3938Kw, an increase of 25.7%, and the COP decreases from 0.61 to 0.49; when the reflux ratio increases from 0.5 to 1, the tower reactor load increases from 308.3938Kw to 390.9143Kw increased, an increase of 26.75%, and the COP decreased from 0.49 to 0.387. Considering the rectification effect and the performance of the system, it is more appropriate to choose the reflux ratio between 0.5 and 0.7.
5. Analysis of effect of refrigerant (R134a) concentration on the system

The rectification tower bottom load and the change of the system COP with the concentration of the refrigerant (R134a) at the outlet of the absorber are shown in Figure 7. It can be seen from the figure that as the mass concentration of R134a increases, the bottom load first decreases and then increases. It increases first and then decreases. The optimal performance is reached when the mass concentration is 56%. At this time, the COP value is 0.494407 and the tower reactor load is 305.4164 kW. When the mass concentration is less than 56%, the tower reactor load increases and the COP decreases quickly; when the mass concentration is greater than 56%, the tower reactor load and COP change slightly.

6. Effect of bottom temperature of distillation column on the system

Keep the initial setting condensing temperature, evaporation temperature and other parameters unchanged. When the bottom temperature of the rectification tower changes, the change of the system COP is shown in Figure 9, and the change of the gas release range is shown in Figure 10. It can be seen that when the gas concentration of
release range is guaranteed to be greater than 0, the corresponding tower bottom temperature of the system is only 57.79°C. From this it can be shown that this type of working fluid pair can be driven by a low-temperature heat source, and the applicable range of the heat source is wider. The COP of the system increases rapidly with the increase of the bottom temperature, and increases slowly when the temperature is greater than 69°C.

Fig.6 The influence of the bottom temperature of the distillation tower on the COP

Fig.7 The influence of the bottom temperature of the rectification tower on the cycle rate and gas release range

7. Conclusions
The R134a/DMF absorption refrigeration system was built and simulated using Aspen Plus software. The energy balance of the calculation result system was judged to show the feasibility of software simulation, and the following conclusions were drawn:

1. For the R134a/DMF absorption refrigeration system, the influence of the reflux ratio and the concentration of the refrigerant (R134a) on the system is analyzed, and the reasonable reflux ratio range is 0.5~0.7; when the mass fraction of R134a is 56%, when the occurrence temperature is 131°C and the absorption temperature is 28°C, the COP is the best.

2. If the refrigerant R134a is completely absorbed, the temperature of the required cooling source is lower. Increasing the gas fraction of the solution at the outlet of the absorber can reduce the requirement for the temperature of the cooling source.

3. The 134a/DMF absorption refrigeration system can be driven by a low-temperature heat source, and the COP can reach 0.44 at a temperature of 69°C.

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Plan* Author brief introduction: Chunhua Wang (1968.3-), female, professor, master of engineering, Main research areas: technology and utilization of new energy and renewable energy, air source heat pump technology, design and application of absorption refrigeration unit.

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