Influence of refrigerant circuitry arrangement of three-row finned tube evaporator on heat transfer performance under uniform wind speed distribution

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Abstract. The EVAP-COND software was used to simulate 8 different refrigerant circuitry of the three-row tube heat exchanger under different superheat and outlet saturation temperature conditions. The influence of different refrigerant circuitry on the heat transfer performance of the evaporator was explored. And the influence of superheat and outlet saturation temperature on the evaporator and its changing law were analyzed and discussed. The results show that: Cross arrangement facilitated heat transfer. The dual-flow solution was better than the single-flow solution. And countercurrent arrangement was conducive to heat exchange. The best solution was g, and the worst solution was a. Under the conditions of this study, the heat transfer of curve g was 44.78% and 36.20% higher than curve a, respectively.

1. Introduction

The finned tube heat exchanger was a traditional and widely used heat exchange equipment. Its solid structure and diverse raw materials were widely used in high-temperature and high-pressure working conditions and large-scale installations. In order to improve the efficiency of the evaporator, improve the heat transfer effect, and reduce the manufacturing cost, many scholars have carried out a lot of research on the heat exchanger, and the layout of the evaporator flow path has a particularly significant influence on the heat transfer performance. Among them, the layout of the evaporator flow path has a particularly significant impact on the heat transfer performance.

Domanski PA et al. [1] developed EVAP-COND software and conducted simulation studies on the evaporator performance of different refrigerants. Huang Dong et al. [2] studied the effect of different numbers of branches on the flow and heat transfer performance of the heat exchanger when the air inlet state and flow rate, the geometrical structure of the heat exchanger, and the piping arrangement were unchanged. Liang Li et al. [3] used EVAP-COND software to simulated the three-row finned tube evaporator. Selected 3 kinds of refrigerants and 4 different flow path arrangements, respectively calculated the total heat transfer of the evaporator under different refrigerant outlet superheats, analyzed and compared the simulation results, and studied the effect of outlet superheat on the finned tube evaporator The effect of thermal performance. Wang et al. [4] found through experiments that the reverse cross flow has a better overall performance. Based on this, this article aims to improve the
efficiency of the heat exchanger and studies the influence of the flow path layout on the heat exchanger.

2. Operating conditions and Refrigerant Circuitry

2.1. Operating conditions
The structural parameters of the heat exchanger were shown in Table 1\textsuperscript{[5]}. Take the evaporator refrigerant outlet state as the setting condition, as shown in Table 2. And the air inlet status adopts the data specified in "Room Air Conditioner".

| Tab.1 Parameters of evaporator |
|--------------------------------|
| Tube length /mm | Tube size /mm | Pipe spacing /mm | Row spacing /mm | Number of tubes | Fin thickness /mm | Fin pitch /mm | Air flow /m²/min |
|-----------------|---------------|------------------|-----------------|----------------|-----------------|--------------|----------------|
| 400             | 9.52×0.35     | 25.4             | 22              | 3×24           | 0.11            | 1.5          | 25             |

| Tab.2 Simulation conditions |
|-----------------------------|
| Inlet dryness | Refrigerant | Air inlet |
| Inlet saturation temperature/°C | Dry bulb temperature/°C | Relative humidity/% |
| 0.2 | 5 | 27 | 50 |

2.2. Refrigerant Circuitry
Regarding the refrigeration capacity as the evaporator optimization target, 8 different refrigerant circuitry were adopted for the three rows of tubes. The design principle of the refrigerant circuitry followed the conclusion of Han et al\textsuperscript{[6]}. The refrigerant circuitry layout was shown in Figure 1. Schemes a and b were single flow path arrangements, considered the influence of gravity and cross arrangement on heat transfer. Scheme c-h were dual flow path arrangement, which mainly considers the influence of downstream flow, reverse flow, and arrangement mode.

![Fig.1 Refrigerant Circuitry](image-url)
3. Simulation results and analysis

3.1. The influence of superheat on Evaporator capacity
In this simulation, the dryness of the refrigerant was 0.2, and the outlet saturation temperature was 5°C. Figure 2 showed the heat exchange law of the three-row tube evaporator with 8 refrigerant circuitry arranged at different degrees of superheat. It can be seen that under the same refrigerant circuitry, as the degree of superheat increased, the amount of heat exchange decreased. It showed that a smaller degree of superheat is helpful for heat exchange. The heat exchange of a single flow path had a small difference under the same degree of superheat. The dual flow path scheme is more helpful for heat exchange than the single flow path scheme. And the curve c and h dropped most obviously.

![Fig.2 The influence of superheat on Evaporator capacity](image)

The heat exchange rate of curve b was greater than that of curve a, which was 2.20% higher than that of curve a. It shown that the cross arrangement was helpful for heat exchange. The curves cd and gh prove that the reverse arrangement was more helpful for the evaporator. In curves a and b, for every 1°C increase in superheat, the heat transfer decreases by 0.01 kW. The superheat had little effect on curves a and b. In the curves d-e, every time the degree of superheat increased by 1°C, the amount of heat exchange decreases by about 0.04 kW. And the curve g had the highest heat exchange rate, which is about 1.95% higher than curve d, and it is about 44.78% higher than curve a.

3.2. The influence of outlet saturation temperature on Evaporator capacity
In this study, the dryness of the refrigerant was 0.2 and the superheat was 5°C. Figure 3 showed the change law of heat transfer at different outlet saturation temperature. Comparing Figure 2 and Figure 3, the outlet saturation temperature of the refrigerant had a more significant impact on the evaporator capacity than the superheat. And the smaller outlet saturation temperature was conducive to heat exchange. It can be clearly seen that the evaporator capacity of the curve a and b were smaller than other curves. All curves were close to straight lines. In the curve a and b, each increase of 1°C in outlet saturation temperature reduces the heat exchange amount by about 0.16kW. The curves c and h had a obvious fluctuation at 7°C. In the curve c-h, for every 1°C increase in outlet saturation temperature,
the amount of heat exchange reduction fluctuates around 0.3kW. The heat exchange rate of curve g was the largest, which is about 0.19% higher than curve d and about 36.20% higher than curve a.

Fig.3 The influence of outlet saturation temperature on Evaporator capacity

4. Conclusion
To sum up, under the certain conditions of the evaporator structure size, the air inlet state and the flow rate, by changed the superheat and outlet saturation temperature of the refrigerant to simulate the change law of the evaporator heat exchange under different refrigerant circuitry. The results show that:

(1) Within the scope of this study, the Evaporator capacity decreased with the increase of superheat and outlet saturation temperature. And the influence of outlet saturation temperature on the capacity of the evaporator of refrigerant was more significant than that of superheat.

(2) The cross-arrangement and counter-current arrangement facilitate the heat exchange. Dual stream solution was better than single stream solution.

(3) The best solution was g, and the worst solution was a. Keep other conditions certain. When the superheat changes, the heat transfer of curve g was about 44.78% higher than curve a; when the outlet saturation temperature changes, the heat transfer of curve g is about 36.20% higher than curve a.

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