Experiment on condensation charateristics of R1234ze(E) in plate heat exchanger

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ABSTRACT

This study provides a comprehensive examination of research papers pertaining to heat transfer and pressure drop in BPHX. or the development and performance evaluation of a new heat exchanger, it is necessary to compare and verify its performance against existing heat exchangers. In evaluating heat exchanger performance, heat transfer and pressure drop are important. Consequently, this study emphasizes the need to investigate heat exchanger performance based on variations in saturation temperature and mass flux of refrigerant.

KEY WORDS

Condensation, BPHX, Heat transfer coefficient, pressure drop

1. INTRODUCTION

To improve the performance of residential and commercial heat pump systems, the development of a high-efficiency BPHX is necessary. In heat exchangers, as the heat transfer rate increases, the pressure drop also increases. Therefore, it is important to design a heat transfer plate shape that optimizes both heat transfer rate and pressure drop. This study provides an overview of the parameters used in evaluating heat transfer rate and pressure drop, with a particular focus on assessing how well the experimental values align with existing correlations under variations in refrigerant saturation temperature and flow rate.

2. LITERATURE REVIEW

Eldeeb et al. [1] conducted a review paper to examine correlations for heat transfer and pressure drop during evaporation and condensation in plate heat exchangers.

Yan et al. [2] conducted experiments on R134a in a chevron plate heat exchanger, examining the effects of changes in refrigerant mass flux and average heat flux. Based on these experiments, they developed correlations for the convective heat transfer coefficient and the friction factor.

$$Nu = \frac{h_r D_h}{k_1} = 4.118 Re_{eq}^{0.4} Pr_1^{1/3} \qquad (2)$$

$$f\, Re^{0.4} Bo^{-0.5} \left(\frac{p_m}{p_c}\right)^{-0.8} = 94.75 Re_{eq}^{-0.0467} \qquad (3)$$

Kuo et al. [3] conducted experiments on R410A in a chevron plate heat exchanger, examining the effects of changes in mass flux and average heat flux. They represented the heat transfer coefficient and friction factor in terms of the Froude number, which is the ratio of inertial force to gravitational force, and the Boiling number, which is the ratio of heat flux to the product of mass flux and latent heat of vaporization.

$$h = 0.2092\left(\frac{k_l}{D_h}\right) Re_l^{0.78} Pr_l^{\frac{1}{3}} \left(\frac{\mu_{ave}}{\mu_{wall}}\right)^{0.14}$$
$$(0.25 Co^{-0.45} Fr_l^{0.25} + 75 Bo^{0.75}) \qquad (4)$$

$$f = 21500 Re_{eq}^{-1.14} Bo^{-0.085} \qquad (5)$$

Longo et al. [4], [5] conducted experiments on 11 refrigerants, including R1234ze, by varying mass flux, average heat flux, and corrugation. They developed correlations based on Reynolds number.

$$h = 0.943\varphi\left[\frac{(k_l^3 \rho_l^3 g\gamma)}{\mu_l L (T_{sat} - T_w)}\right]^{1/4}, \ Re_{eq} < 1600 \qquad (6)$$

$$h = h_{sat} + F\left(h_l + \frac{c_p \cdot q''}{\gamma}\right), \ Re_{eq} \geq 1600 \qquad (7)$$

3. EXPERIMENTAL SETUP

The experimental apparatus used in this study is composed of a refrigerant circulation loop and a water circulation loop to analyze the pressure drop and heat transfer characteristics of condensation and evaporation in BPHX. The schematic diagram of this experimental apparatus is shown in Fig. 1, and the specifications are provided in Table 1.

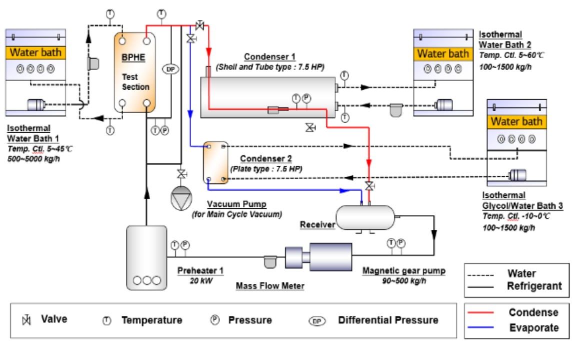

Fig. 1. Schematic diagram of the experimental system

Apparatus [unit]	Specifications
Refrigerant side	
Pump flow rate [kg/h]	90 - 500
Evaporator side heater [kW]	20
Condenser	24.3
Receiver volume [L]	9.1
Water bath 1 (Water side)	
Temp range [℃]	5 - 55
Flow rate [kg/h]	0 - 5000

Water bath 2 (Water side or Refrigerant side pressure control)	
Temp range [℃]	0 - 60
Flow rate [kg/h]	100 - 1500

Table 1. Apparatus specification

4. EXPERIMENTAL PROCEDURE

The experiment will be conducted with reference to the AHRI Standard [6]. It is summarized in Table 2.

Rating Condtion	Sat. Condense Temp.of Entering Ref.	Minimum Temp.of Entering Ref. Vapor	Temp. Enter Water	Temp. Leave Water
1	40.6℃	51.7℃	23.9℃	35.0℃
2	40.6℃	51.7℃	29.4℃	35.0℃
3	29.4℃	40.6℃	10.0℃	21.1℃
4	37.8℃	48.9℃	21.1℃	29.4℃

Table 2. AHRI Standard Rating Conditions

4.1 Energy balance evaluation

A refrigerant-to-water experiment will be conducted through the AHRI 450 condensation test. The heat transfer rate of the refrigerant and water will be calculated during their heat transfer process. The heat transfer rate on the water side is given by the following equation.

$$\dot{Q}_w = \dot{m}_w C_{p,w}(T_{w,out} - T_{w,in}) \qquad (8)$$

Since the refrigerant is in a two-phase state, the heat supplied by the heater must be added. The equation is as follows.

$$\dot{Q}_{ref} = \dot{m}_r(i_{sup} - i_{sub}) + \dot{Q}_{heater} \qquad (9)$$

The energy balance can be expressed as follows.

$$\text{Energy balance }(\%) = \frac{2(\dot{Q}_r - \dot{Q}_w)}{\dot{Q}_r + \dot{Q}_w} \times 100 \qquad (10)$$

4.2 Experimental range

Variables were set within the allowable experimental range, and performance evaluation for each variable will be conducted. The refrigerant saturation temperatures were set at 40°C, 50°C, and 60°C, and the mass flux range was set from 15 to 35 kg/m²s. During the experiment, the inlet and outlet conditions of the heat exchanger will be maintained in a superheated state and a subcooled state, respectively.

5. CONCLUSION

This study provides an overview of various correlations for refrigerants published to date in plate heat exchanger. Improving heat transfer and pressure drop is essential, so an experimental setup was constructed to enable accurate calculations. Using the results from future experiments, correlation evaluations will be conducted. The study also plans to investigate flow maldistribution that influence heat transfer.

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