A Study on the Measurement and Analysis of void fraction characteristics on Smooth Tube Considering Evaporation and Condensation Heat Transfer

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１．Researh Objective

Consideration of refrigerant charge amount is one of the options that can be optimized for carbon neutral. While HFO-based, low GWP refrigerants can reduce GHG emissions, consideration of refrigerant charge amount is attractive because it can improve the coefficient of performance (COP) of a RACHP system while reducing the absolute amount of refrigerant used. The COP of a RACHP system is significantly affected by the refrigerant charge amount. An under- or over-charged system can result in reduced efficiency and reduced cooling capacity. However, conventional methods for determining the optimal refrigerant charge amount are limited to repeated experimental trials. A cycle simulation of a RACHP system can provide a prediction of the optimal refrigerant charge amount during the design process. However, in most cases, the predicted refrigerant charge amount differs from the actual system. The heat exchanger undergoes evaporation and condensation, and the void fraction of the Two-phase refrigerant inside the heat exchanger also depends on the evaporation and condensation conditions. In this study, the void fraction of horizontal smooth tubes under evaporation and condensation conditions is measured and compared.

２．Major Research Results

2.1　Flow pattern variations under evaporation and condensation conditions

As shown in Figure 1, evaporation and condensation conditions in horizontal tubes result in different flow patterns.

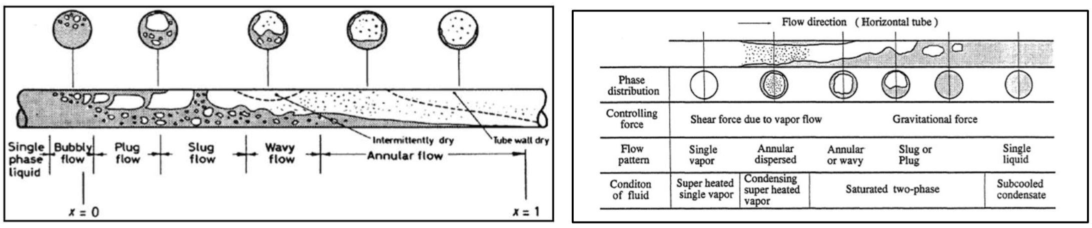

Fig.1　Flow patterns in evaporation and condensation

In two-phase flow, the gas phase is concentrated in the upper part of the tube due to its large volume and low density, and the liquid phase is concentrated in the lower part of the tube due to its small volume and high density. Under evaporative conditions, the entire wall of the tube is evenly heated and continuous evaporation occurs. As a result, the distribution of gas and liquid phases in the tube is asymmetrical and based on stratified flow. In contrast, under condensation conditions, the entire wall of the tube is being cooled evenly and there is continuous condensation on the tube wall. As a result, the distribution of gas and liquid phases in the tube is relatively symmetrical and based on annular flow. Due to the different flow patterns in the evaporation and condensation conditions, the velocity distribution of the gas and liquid phases in each condition is different. The velocity of the liquid phase in the evaporation condition is higher than that in the condensation condition, and the different flow velocity distribution affects the void fraction. As a result, the void fraction of the condensation condition is lower than that of the evaporation condition at the same vapor dryness.

2.2 Measurement results of void fraction

The results of void fraction measurement under evaporation and condensation conditions for R32 refrigerant with a bore diameter of 7.1 mm are shown in Figure 2. The length of the cooling section was about 2 m, and the cooling amount of 5 to 10 kW/m^2 for the condensation condition was maintained under all experimental conditions. The measurement of void fraction was performed using the quick closing-valve (QCV) technique. The description of the QCV technique is described in detail in the author's research achievement.

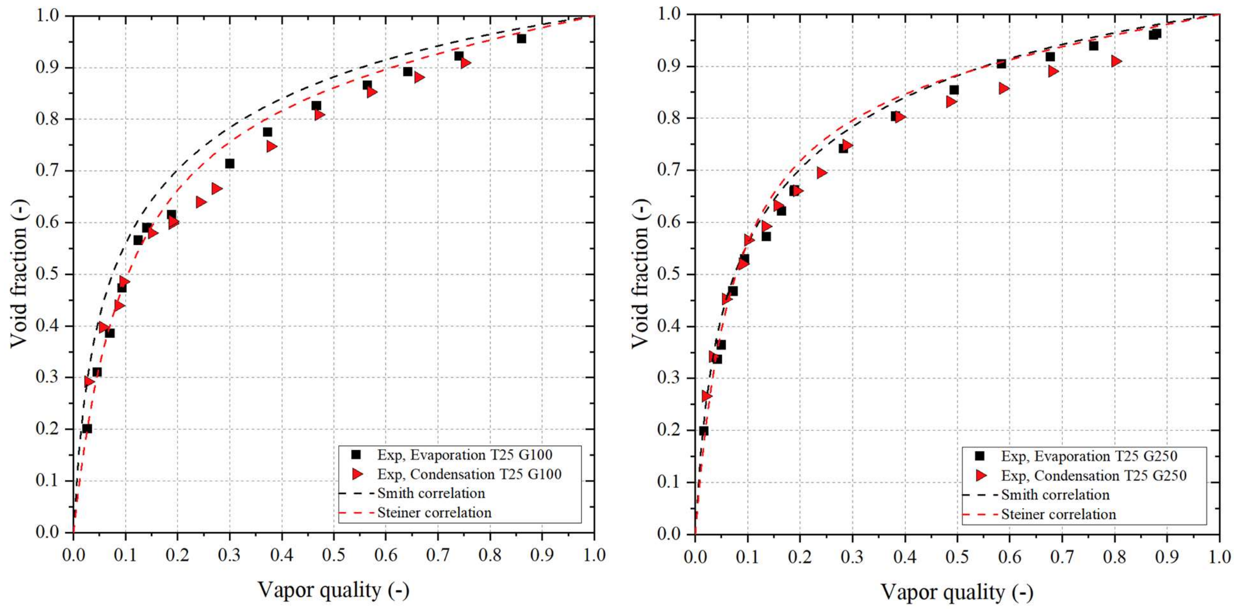

Fig.2 Void fraction measurement result

Figure 2 shows the void fraction measurement results for two mass flux conditions (100, 250 kg/m^{2}s) at the same temperature (T=25℃). For all conditions, a slight decrease in void fraction is observed upon condensation, but the change is within about 3%. At lower mass fluxes, a decrease in the entire vapor dryness range is observed. This is a result of the greater difference in flow patterns between evaporating and condensing conditions. The flow pattern for evaporative conditions at low flow rates has a clearly stratified flow. On the other hand, as the mass flux increases, the flow pattern in the evaporation condition increases the area in contact with the tube and shows the characteristics of annular flow. On the other hand, as described above, the condensation condition is based on the nature of annular flow even at low mass flux, which causes the difference in flow pattern between the evaporation and condensation conditions at low mass flux to be intense, and the void fraction difference becomes clear.

３．Collaborators

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４．Research Achivement

4.1　学術論文

M. Kim, Y.Uemura, T.Sato, K.Saito, 2023, Experimental investigation of the void fractions of refrigerants R32 and R1234yf in a 1 mm diameter horizontal channel using a capacitance-based method, *Applied thermal engineering*, Vol.238, pp. 122113,

M. Kim, T.Sato, K.Saito, 2023, Measurement of the relative permittivity of the liquid phase of R454C with vapor quality change under two-phase condition, *International communication of heat and mass transfer*, Vol. 146, pp. 106908,

M. Kim, J.Jeong, T.Sato, K.Saito, 2023, Experimental investigation of void fraction of R32 refrigerant in horizontal flow configuration using capacitance-based and quick-closing valve-based methods,*Applied thermal engineering*, Vol. 229, pp. 120497,

５．Issues and Prospect of Research Activities

In this study, the void fraction under evaporation and condensation conditions was observed for smooth tubes. The use of smooth tubes to investigate void fraction is appropriate for basic research. However, it is essential to investigate the void fraction in actual devices to improve the applicability of the research. In a practical heat exchanger, microfin tubes with grooves in the inner wall of the tube are applied to promote heat exchange. It is predicted that the behavior of two-phase flow is different in microfin tubes, and detailed studies are required.