Heat transfer mechanisms of next generation lower GWP refrigerants during evaporation and condensation processes

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１．Researh Objective

To counter global warming, the interest in next generation lower GWP(Global Warming Potential) new refrigerants increases with their thermodynamics and heat transfer characteristics. But since these refirigerant are mixture of some refrigerants and some of them are non-azeotropic, the heat transfer mechanism has not been clarified yet.

This research aims to grasp the heat transfer mechanisms of next generation lower GWP refrigerants (R454C, R466A, etc.) during evaporation and condensation processes in the smoothed circular tube. The heat transfer coefficient of a refrigerant is usually expressed based on the void fraction. Therefore, accurate void fraction measurement and database expansion are essential parameters for obtaining an accurate heat transfer coefficient.

２．Major Research Results

2.1　The calibration method of void fraction sensor using capacitance method

A calibration method for capacitance sensor based on flow pattern was proposed and verified by comparing it with the void fraction result using the QCV method simultaneously measured under the same conditions. By using the actual QCV void fraction measurement result rather than comparison with correlation, the behavior of the capacitance sensor in the actual measurement can be closely examined. In this calibration method, the flow pattern is applied after comparison with the visualization result based on the Katan flow pattern map.

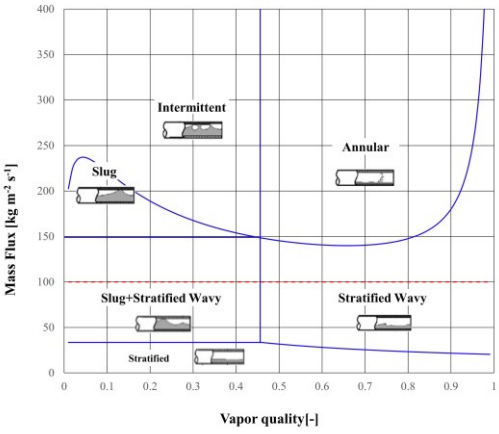

Fig. 1 Considered flow pattern map

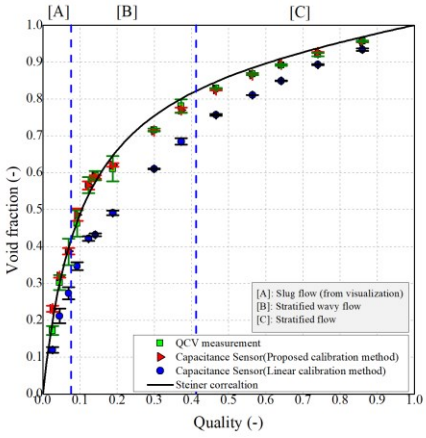

Fig.2　Validation result

As a result, the capacitance measurement method to which the calibration method was applied was in good agreement with the QCV void fraction method, with a relative error of 4.68% and R2=0.978 in the entire area. This shows the possibility of replacing the QCV measurement method through the capacitance measurement method to which the calibration method considering the flow pattern, is applied.

2.2 The visualization of flow charateristics for R32 refrigerant

It is essential to consider the flow pattern in the void fraction measurement. Various flow patterns; Slug flow, stratified flow, stratified-wavy flow, intermittent flow, and annular flow, and transitions between each flow pattern can be considered, which is reflected in the calibration strategy. A high-speed camera (IDT, NR4-ANM1) was applied to the visualization section mounted at the rear end of the test section to examine the two-phase flow pattern under all inlet vapor quality conditions. Using a high-speed camera system equipped with a 1016X1016 pixel size, a sensor of 1 million pixels, and a Nikkor 50mm F2.8 macro lens, the flow for 2s was photographed with an exposure time 5000FPS and 139us.

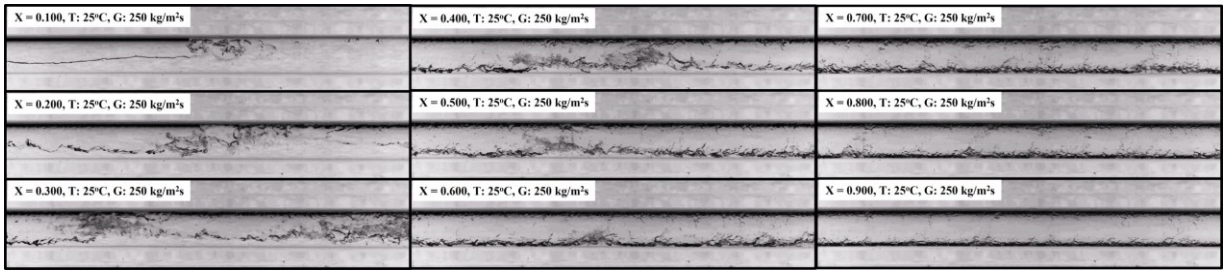

Fig.3 Visualized flow pattern of R32

The gradual transition of the flow pattern can be confirmed by using the capacitance sensor, which can be confirmed by the histogram of the capacitance measured by the temporal distribution. A gradual shift in the flow pattern is reflected in the calibration of the void fraction measurement.

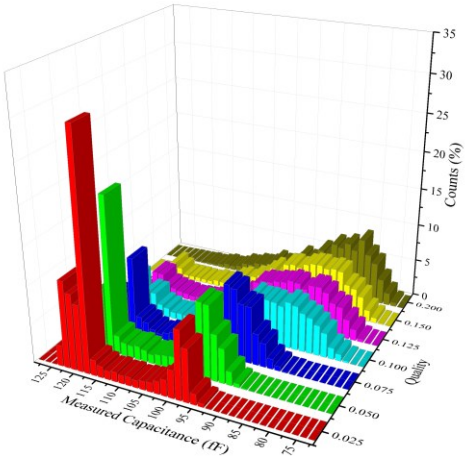

Fig.4 Histogram transition of temporal distribution of capacitance

３．Collaborators

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４．Research Achivement

4.1　学術論文

M. Kim, K. Kanta, J. Jeong, M. Oinuma, T. Satao, K. Saito, Optimizing Calibration for a Capacitance-Based Void Fraction Sensor with Asymmetric Electrodes under Horizontal Flow in a Smoothed Circular Macro-Tube, *sensors*, **22**, 3511　(2022).

５．Issues and Prospect of Research Activities

The capacitance type void fraction sensor developed for measuring refrigerant characteristics can be applied to various diameters and shapes. From this, it is expected that real-time measurement of the behavior of the two-phase thermal fluid of the heat exchanger will be possible. However, sufficient verification for various operating conditions is essential.