Two Phase Flow Pattern Map for Propane in a Horizontal Smooth Tube

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Background

Due to environmental problems of traditional chlorinated refrigerants, it has become an urgent task to search for suitable substitutes in the refrigeration industry. Propane is considered as an environment-friendly and potential refrigerant to replace R22 and R502. The heat transfer characteristics of propane, such as two-phase pressure drops and heat transfer coefficients, play important parts in evaluating and optimizing performance of refrigeration cycles. The prediction of local flow pattern is essential to calculate two-phase pressure drops and heat transfer coefficients in refrigerant systems.

Objectives

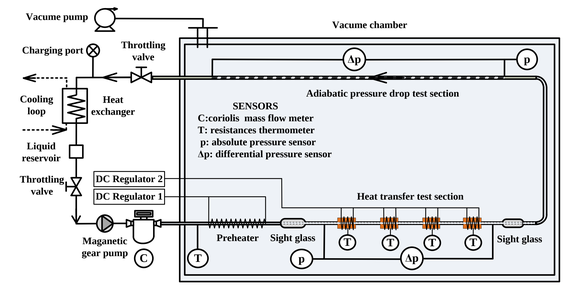
- Presenting data related to the observed flow patterns of propane (evaporation) in a smooth horizontal tube.
- Comparing several flow pattern maps with the experimental data.
- Proposing a modified transition equation from intermittent to annular flow.

Conclusions

- The flow pattern map of Steiner (1993) contained more experimental data than that of Kattan-Thome-Favrat (1998).
- The flow pattern maps of Steiner and Kattan-Thome-Favrat exhibited poor accuracy for the intermittent/annular transition.
- The tendency to the intermittent/annular transition predicted by Barbieri et al. (2008) is the same to the experiments, but the transition vapor quality predicted is higher than the experimental data.
- The intermittent/annular transition in this work was predicted well by the modified transition equation based on Barbieri et al.

Experimental Apparatus

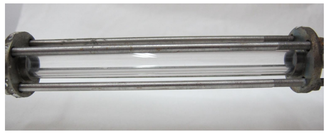
Schematic View



This test facility is modified on the previous work (Zou et al., 2010).

Photograph of the Sight Glass

Two sight glasses with 6 mm inner diameters and 100 mm lengths are located at the inlet and outlet of the heat transfer test section for flow pattern visualization.



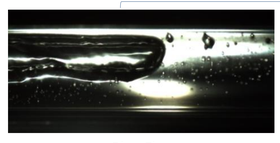
Photograph of the High Speed Camera

The flow patterns were recorded by a Motion Studio high speed camera system with highest shooting frequency of more than 10000 FPS and the minimum exposure time of 1 μs combining with a laser constant cold light source.

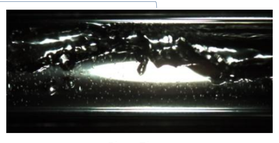
Results

Photographs of Observed Flow Patterns

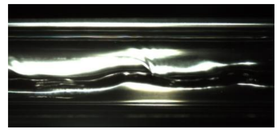
Intermittent Flow (I)



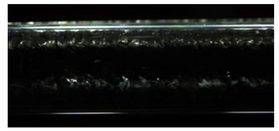
Plug Flow



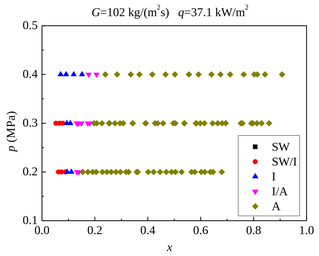
Slug Flow



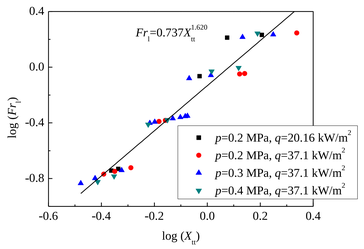
Stratified-wavy Flow (SW)



Annular Flow (A)

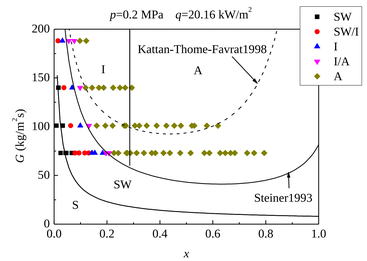


The transition vapor quality from I to A increases with the rise of saturation pressure, but the effect is not obvious.

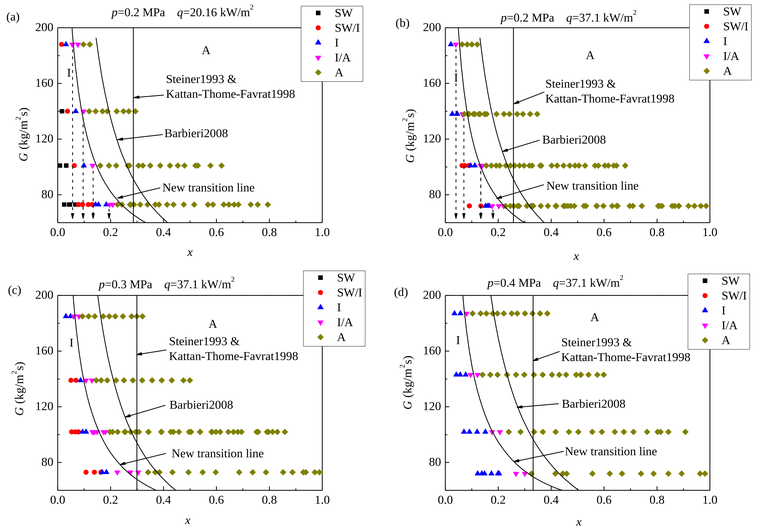


Barbieri et al. (2008) indicated that the I/A transition depended on the parameters such as mass velocity, vapor quality and inner diameter which included by two non-dimensional groups: the liquid Froude number Fr_l and the Martinelli parameter X_{tt}.

The expression which is $Fr_l=0.737X_{tt}^{1.620}$ has been obtained by curve fitting the plot of the experimental data points to the I/A transition in terms of the logarithmic Fr_l and the logarithmic X_{tt}.



The flow pattern map of Steiner (1993) contains more experimental data than that of Kattan-Thome-Favrat (1998).
The transition mass velocities from SW to A predicted by Kattan-Thome-Favrat map is higher than that from the experiments.
The transition vapor qualities predicted by both flow pattern maps from the SW to I are also higher than the experimental data.
The I/A transition vapor qualities from the two flow pattern maps are a constant, while the value is changed at different mass velocities in this study.



The transition vapor quality from I to A decreases with the rise of mass velocity and the rise of heat flux. Moreover, the influence of heat flux is more obvious for high mass velocity.
The tendency to the I/A transition predicted by Barbieri et al. (2008) is the same to the experiments, but the transition vapor quality predicted is higher than the experimental data.
The new transition lines are satisfactory for all of the experimental conditions in the present study.

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