Keynote Lecture 9

Flow boiling and condensation heat transfer comparison of refrigerants HFO-1234yf and HFC-134a

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Dr. Chien-Yuh Yang is currently a professor in the Department of Mechanical Engineering at the National Central University, Taiwan. He received his Ph.D. from the Pennsylvania State University in 1994, and stayed at the same university as a post-doctoral research associate following his graduation until the next year. Then he went back to Taiwan and joined the Department of Mechanical Engineering, National Central University in 1995. His current research interests include air-conditioning and refrigeration, heat exchanger design, electronic devices cooling, two-phase heat transfer, heat transfer enhancement and micro-scale heat transfer. His research has strong connection with related industries. He has conducted more than one hundred heat transfer related research projects, most of them were supported by the industrial companies. He participated in the organization of several international conferences and workshops. He has co-authored more than one hundred journal articles and conference papers and has more than 20 heat exchanger-related patents.

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ABSTRACT

HFO-1234yf has similar thermodynamic properties to HFC-134a but much lower GWP value. It is expected as a good candidate to replace the refrigerant HFC-134a in the near future. Even though several papers have been published in the past years regarding to the two-phase heat transfer performance of this new refrigerant, but some of their results are not in consistent with each other and the detail heat transfer mechanism is still not very clear. This study provides an experimental measurement and comparison of flow boiling and condensation heat transfer of refrigerants HFO-1234yf and HFC-134a in a small circular tube and a microchannel heat exchanger. It is aimed to provide more experimental evidences for further understanding of the detail heat transfer mechanism and to find out the major controlling parameters of this new refrigerant on the two-phase heat transfer.

The experimental and analysis results show that both flow boiling and condensation heat transfer performance depend on the fluid properties, flow conditions and flow patterns. For flow boiling in circular tubes, at low mass velocity and low vapor quality conditions, the flow pattern is slug flow. Liquid viscosity, thermal conductivity, latent heat, vapor density and surface tension are all important. The interaction of these properties caused no significant difference between these two refrigerants for both pressure drops and heat transfer coefficients. For higher mass velocities, the flow pattern changed to annular. Liquid viscosity and thermal conductivity are the major controlling properties for pressure drop and heat transfer respectively. Since the viscosity and thermal conductivity of liquid HFC-134a are much higher than those of liquid HFO-1234yf, this caused the pressure drop and heat transfer coefficient of HFC-134a are obviously higher than those of HFO-1234yf. While at the highest mass velocity, the flow pattern is dispersed flow. Vapor viscosity become the major controlling property for pressure drop but liquid thermal conductivity is still the major controlling property for convective boiling heat transfer. Therefore, the boiling heat transfer coefficient of HFC-134a is much higher than that of HFO-1234yf but the pressure drops difference between these two refrigerants is small.

For condensation in circular tube, at low mass velocity, gravity is the major force that dominates the heat transfer mechanism and the flow pattern is slug. Higher liquid viscosity retarded the condensate flow but higher liquid conductivity provided better heat transfer through the liquid film. Both liquid viscosity and conductivity are the important controlling properties. While mass velocity and vapor quality increased, the effect of shear force increased and the flow pattern transferred into annular. Liquid thermal conductivity became the major controlling property at high vapor qualities. But at low vapor qualities, gravity is still important and therefore liquid viscosity is one the major controlling parameter. At the highest mass velocity conditions, gravity effect is negligible even though at very low vapor quality condition. Shear force dominated the condensation heat transfer mechanism and liquid conductivity is the most important controlling property.

For flow boiling and condensation in microchannels, the above stated flow pattern model is still applicable but some other geometric parameters are also important. For flow boiling in microchannels, the small channel confined bubble growth and blocked vapor flow. It caused a liquid deficient condition and partial dry out happened at lower vapor quality than that in larger tubes. For condensation in microchannels, the effect of surface tension drainage force is important. The surface tension drainage force pulled the condensate to the corner of the square microchannels. This caused a very thin liquid film left on the tube wall and liquid conductivity became the major controlling property on the condensation heat transfer.