Heat and Mass Transfer in Microchannels

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ABSTRACT

A fundamental study of heat transfer characteristics of two-phase slug flow in microchannels has been carried out employing the Volume-of-Fluid (VOF) method. This study was motivated by our earlier attempts to install a rotary-vane expander in a refrigeration system in place of the expansion valve. The problems we encountered especially in combating the internal leakage of the two-phase fluid as it goes through the expander prompted further investigation of the fundamental mechanisms of two-phase flows in microchannels. Despite of the fact that numerical simulations of two-phase flows in microchannels have been attempted by many investigators, most efforts seem to have failed in correctly capturing the flow physics, especially those pertaining to the slug flow regime characteristics. The presence of a thin liquid film in the order of 10 μm around the bubble is a contributing factor to the above difficulty. Typically, liquid films have a significant effect on the flow field and heat transfer characteristics. In the simulations reported in this lecture, the film is successfully captured and a very high local convective heat transfer coefficient is observed in the film region. A strong coupling between the conductive heat transfer in the solid wall and the convective heat transfer in the flow field is observed and characterized. Results showed that unsteady heat transfer through the solid wall in the axial direction is comparable to that in the radial direction. Results also showed that a fully developed condition could be achieved fairly quickly compared to single-phase flows. The fully developed condition is defined based on the Peclet number and a dimensionless length of the liquid slug. Local and time-averaged Nusselt numbers for slug flows are reported for the first time. It was found that significant improvements in the heat transfer coefficient could be achieved by short slugs where the Nusselt number was found to be 610% higher than in single-phase flows. The study revealed new findings related to slug flow heat transfer in microchannels with constant wall heat flux.