Condensation in Ultra-Compact Heat Exchangers

by

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ABSTRACT

Thermal management is a major challenge for the further compactness of electronics cooling systems. Vaporization is a very effective way to take heat away from electronic components and in order to return the fluid back to liquid after it being vaporized in an electronics system, the evaporated cooling fluid has to be condensed. Hence, ultra-compact heat exchangers with the purpose of condensing the cooling fluid from the vapor phase back to the liquid phase are important. Ultra-compactness ensures such a condenser fits into the compact electronics systems, as well as provides high heat transfer performance.

Research on micro and mini channels have been carried out for single channels as well as multiple channels. However, the channel hydraulic diameters were mostly larger than 150 μm. Studies on a micro/mini heat exchanger are few. Moreover, condensation studies were mainly carried out on refrigerants. This study experimentally examines the condensation heat transfer in two ultra-compact cross-flow heat exchangers with channel hydraulic diameters of 133 μm but with different channel numbers and channel lengths, using steam as the working fluid.

For condensation experiments, the overall thermal resistances, which composed of condensation resistance, single-phase cooling resistance, and wall resistance, were measured. The Wilson Plot method was used to correlate the single-phase cooling thermal resistance and the wall resistance so that the condensation resistance (or condensation heat transfer coefficient) can be obtained. The correlated single-phase Nusselt numbers were in good agreement with the predictions of the Sieder-Tate correlation with 13 to 20 % difference for the small test section, and 22 to 28 % for the large one.

A parametric study was conducted with the following parameters: mass flux, saturation pressure, and the size of the heat exchanger. For the small heat exchanger, mass fluxes of 120, 150, 200, 250, and 300 kg/m^{2}s were tested under two saturation pressures of 112 and 170 kPa measured at the outlet of the test section. For the large heat exchanger, mass fluxes of 70, 150, and 200 kg/m^{2}s were tested under the same two saturation pressures of 112 and 170 kPa at the outlet of the test section. Average qualities varied from 0.24 to 0.87 for different mass fluxes. Mass flux and average quality had strong effects on the condensation heat transfer coefficients. The

saturation pressure and the heat exchanger size did not have significant effects on the condensation heat transfer coefficients in the ranges in this study.

Three conventional and three mini and microchannel correlations were used to compare with the experimental data. All six correlations overpredicted the experimental data. The five correlations that were developed for the annular regime flow condition significantly overpredicted the data, with the lowest overall *MAE* value of 107%. The Soliman correlation, which was developed for the mist flow regime, best predicted the data with the lowest overall *MAE* value of 47% for the small test section.