THERMAL-HYDRAULIC EFFECTS OF A MICRO-ORIFICE ENTRENCHED IN A MICROCHANNEL

by

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ABSTRACT

In the present work three dimensional numerical simulations were performed on two microchannels, which contained a flow-restricting orifice. Either microchannel had the same internal dimensions with an orifice aspect ratio of 2.89:1, an expansion ratio of 10:1, step size of 90μm, a rectangular aspect ratio of 1.3, and an effective expansion ratio of 6.087. $Model_1$ was a thin walled model, which neglected any conduction through a substrate material prior to heat transfer into the channel. $Model_2$ was theoretically embedded in a silicon substrate and simulated flow through a multi-channel system of microchannels. $Model_1$ was investigated under uniform wall heat flux boundary condition on three sides while the top was considered to be adiabatic. $Model_2$ was investigated under uniform wall heat flux boundary condition, which was only on the bottom of the silicon substrate. Heating in both channels did not occur until the end of the micro-orifice. Both Channels where simulated using Water and R-123 as the working fluids. Tests were done using several different Reynolds numbers in the laminar regime from Reynolds number 10 to 1100. The models were built and meshed using Gambit software and simulations were performed using Fluent software.

The presence of a micro-orifice changes the flow by significantly increasing the hydrodynamic and thermal entry lengths. The flow effects on low Reynolds number flows past a symmetric micro-orifice in a microchannel were also investigated. The laminar flow through the micro-orifice underwent a symmetry-breaking bifurcation at a critical Reynolds number. The critical Reynolds number evaluated from the simulations was compared to other values reported in the literature. Based on the temperature and heat flux distributions obtained, both the local and average Nusselt numbers are presented graphically along with center plane visualizations of the flow after the micro-orifice. The results of this numerical analysis are then compared with experimental results and show very good agreement.

Keywords: Microchannel, thermally developing; Electronics cooling; liquid cooling; Heat Sink, bifurcation, channel flow, critical Reynolds number, effective expansion ratio, sudden expansion, micro-orifice.