Experimental Investigation of Heat Transfer Enhancement in Microchannels using Flow Control

by

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ABSTRACT

Experimental investigations to study the heat transfer enhancement mechanisms in a microchannel were performed. A 220 μm deep, 1.5 mm wide and 15.5 mm long rectangular microchannel with a 1 mm × 1 mm heater was designed and fabricated to measure the average heat transfer coefficient and to visualize the flow. Secondary flow was introduced into the main flow, upstream of the heater, and effects on the heat transfer and flow field was investigated for single-phase and two-phase flows. Depending on the combination of the flows, three different types of flow was studied: single-phase steady jet (single-phase), shear-driven liquid film flow and bubbly flow (two-phase). Flow visualization techniques including high speed imaging and micro particle image velocimetry (μ-PIV) were used to elucidate the governing heat transfer mechanism.

For single-phase jet experiments, steady stream of water was introduced into a water stream through a 350 μm circular orifice upstream of the heater and changes in the average heat transfer coefficient were measured. The main flow was seeded with fluorescent particles to illustrate the effect of the jet.

For shear-driven liquid film experiments, a stream of water was introduced into a nitrogen stream through the orifice upstream of the heater. Average heat transfer coefficients were obtained for different gas and liquid flow rates and results were compared to single phase flow. Significant improvement in heat transfer performance was observed with no appreciable change in the pressure drop. Experimental data combined with a heat transfer analysis was used to infer the mechanisms controlling the heat transfer process. In bubbly flow experiments, a stream of air was injected into a main flow of water to introduce the bubbles. High speed imaging and micro particle image velocimetry (μ-PIV) measurements were used to elucidate the mechanisms governing bubble dynamics and the liquid velocity field. This, in turn, revealed mechanisms controlling the heat transfer process.