DYNAMIC MODELING AND ADVANCED CONTROL OF VAPOR COMPRESSION CYCLES FOR ELECTRONICS COOLING

By

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A Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: MECHANICAL ENGINEERING

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September 2011
(For Graduation December 2011)

ABSTRACT

The ever increasing power density of high-end electronics has made vapor compression cycles (VCC) a viable and attractive alternative for electronics cooling, especially in high-heat-flux applications, such as military ships and computer servers. Among the advantages of VCC for electronics cooling are the high heat transfer coefficients achievable during boiling and low temperatures of the cooling fluid. However, due to different boundary conditions at the evaporator from traditional VCC, VCC for electronics cooling require new modeling techniques and control algorithms to guarantee its safe operation in real applications. The two major differences with traditional VCCs are large transients during operation, and that for imposed heat flux in the evaporator the critical heat flux (CHF) condition becomes a major concern. This dissertation presents modeling and control strategies of VCC developed specifically for electronics cooling. To improve the fundamental understanding of VCC with imposed heat flux boundary condition an experimental testbed is developed with electric heaters immersed in the fluid flow. This testbed is used to demonstrate the effects of evaporator pressure, mass flow rate and inlet quality on the CHF condition at the evaporator for the VCC. Additionally, a first-principle lumped-parameter model is developed including new empirical correlations to model static components. The model is used for steady-state optimization and controller design with special considerations to the conditions at the exit of the evaporator which are critical for CHF prediction and control. Experimental validation shows a significant improvement of the optimized system compared to a nominal operating condition by avoiding CHF for small disturbances in heat load. For larger disturbances where steady-state optimization is not enough to prevent the CHF condition a gain scheduling control is developed and is validated experimentally for large pulses and steps in heat load. Finally, an extremum seeking control is developed to optimize energy consumption when CHF is not a concern and an improvement of 14% in compressor power is achieved compared to nominal operating conditions.