

MODELING TOOLS AND PROTOTYPE DESIGN OF LOOP HEAT PIPE FOR ELECTRONICS COOLING

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ABSTRACT

In this dissertation, a set of modeling tools for loop heat pipe (LHP) design is developed, and original analytical models for annular two-phase flow are proposed.

LHPs are promising two-phase thermal transport devices for electronics cooling. The developed modeling tools include a system level model, criteria of selecting working fluids, and individual component models for modularized design of LHP condenser and evaporator. Based on these tools, new figures of merit for measuring capillary limit and heat leak effects are defined, the condensation pressure drop is shown to be always dominating the loop pressure drop in air-cooled LHPs, and a published LHP prototype for laptop computer cooling is simulated. The modeling results agree well with the available experimental data and reveal that the air flow is the bottleneck of this prototype.

The analytical models for annular two-phase flow presented in this work is fundamentally different from the previous two-phase flow models in that both the velocity and temperature distributions for the liquid and gas/vapor phases are represented based on the governing equations for laminar flows and based on the universal profiles for turbulent flows. As a result, analytical relations of void fraction, frictional pressure gradient, acceleration pressure gradient, and heat transfer coefficient for all possible flow regimes are derived on a self-contained and self-consistent basis, with the classical single-phase relations as their extreme limits. Detailed comparison with the modeling results shows that the prevailing empirical correlations in engineering practice generally fail to provide reliable and accurate predictions for annular two-phase flows.