Thin Heat Pipes for Low Power Applications

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Objectives/Questions

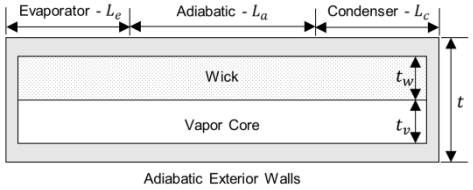
1. What is the performance compared to solid conduction heat spreaders?
2. What is unique about very thin form factor and low power conditions?
3. Do notional design criteria for fluid/wick selection hold true as the device cross-sectional area is reduced?
4. Do conventional reduced-order modeling assumptions hold true at these form factors?
5. How does the transient performance of heat pipes compared to heat spreaders?

Motivation

Need for high-performance heat spreading technologies that can be deployed in ultra-thin form factors where heat dissipation power is relatively low

Prior to tackling practical manufacturing challenges, *assess heat pipe theoretical limits and design objectives*

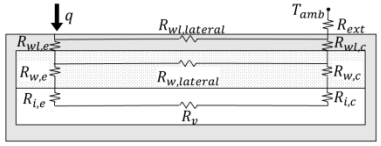
Example Case and Geometry

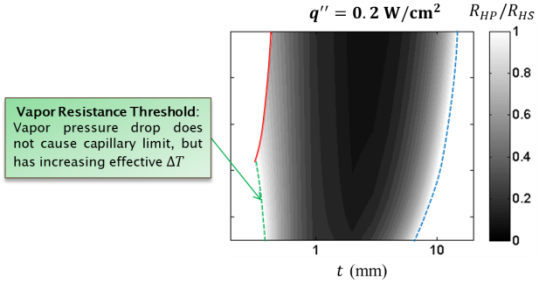


Key Conclusions

1. Defined *performance thresholds* where heat pipe is effective
2. Vapor resistance threshold governs *the smallest device thickness*
3. A novel vapor figure of merit was identified for *working fluid selection*
4. Identified *key transport mechanisms* which are not captured in reduced-order models
5. Showed that *transient performance* during startup and with variable input heat flux must be considered

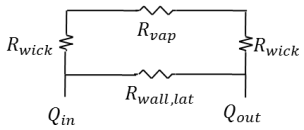
Thermal Resistance Network Model





Limiting Thickness Threshold

Simplified Network



Applicability Criteria

Negligible wall resistance:

$$R_{wl} << (R_w + R_v/2)$$

Negligible lateral wick conduction:

$$R_{w,lateral} >> R_{wl,lateral} R_v / (R_{wl,lateral} + R_v)$$

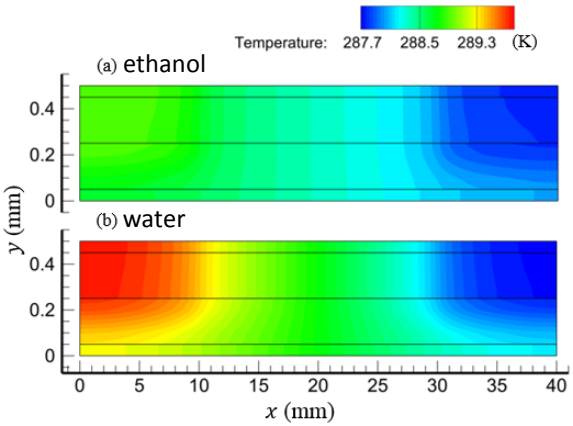
$$\frac{R_{HP}}{R_{HS}} > 1 \Rightarrow t_{limit}$$

Vapor figure of merit

$$M_v = \frac{h_{fg}^2 \rho_v P_v}{R \mu_v T_v^2}$$

A fluid with a higher M_v is less susceptible to the vapor resistance

Numerical Modeling Results



Publications:

Y. Yadavalli, J. A. Weibel and S. V. Garimella, *IEEE Transactions on Components, Manufacturing and Packaging Technology* (*in review*), 2014.

Member Benefits & Outcomes:

- Figure of merit for working fluid selection
- Analytical tool for predicting heat pipe performance
- Identification of conditions that require numerical modeling

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