National Aeronautics and Space Administration

MULTI-FUNCTIONAL OCILLATING HEAT PIPE SYSTEM FOR HIGH-DENSITY HEAT MANAGEMENT

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Program: Topic Area

Project Objective:

The trend toward miniaturization and smaller spacecraft drives higher-density heat dissipations that are a challenge to manage. To solve these issues, an Oscillating Heat Pipe (OHP) is desirable. The OHP is a novel two-phase heat transfer device utilizing self-excited oscillation and circulation of fluid in capillary tubes.

The objective of this task is to develop a multi-functional Oscillating Heat Pipe system that can accommodate high-density heat dissipation. By using additive manufacturing, an OHP can be made to act both as a thermal control system and also as a structure.

FY18/19 Results:

Establishing Fabrication Method

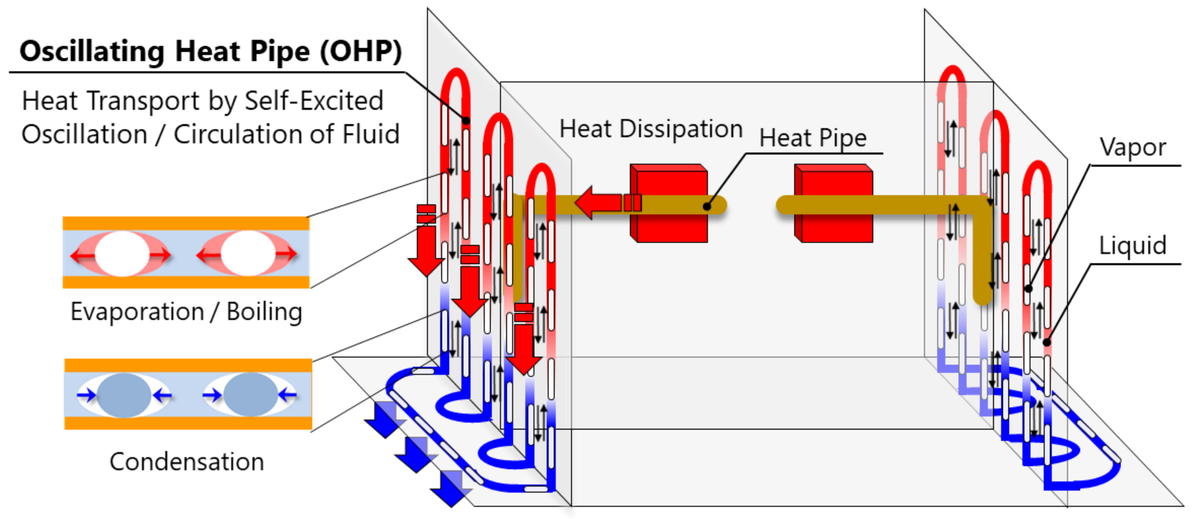
A challenge was to establish the fabrication method of OHPs via metal additive manufacturing. Because 3D printed metal surface is typically rougher than smooth metal pipe wall and that increases pressure loss in the microchannel (< 1mm) used in OHPs. We approached this problem by characterizing 100s of microchannel samples fabricated in different printing parameters in cooperation with the JPL metal additive manufacturing center. As a result, proper fabrication method including powder removal was successfully established.

Design, Test, and Numerical Simulation

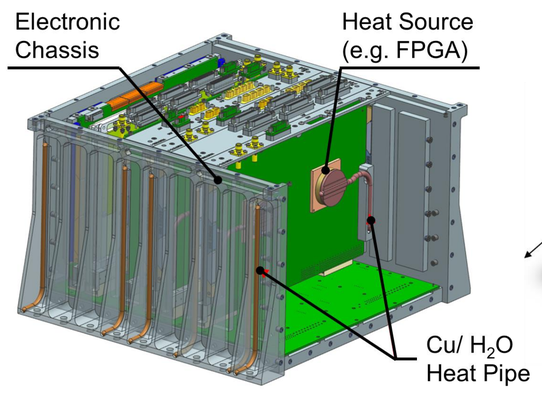
The OHP prototypes were tested at JPL's Two-Phase Lab (125-B85) to evaluate the thermal performance. The OHPs showed they can remove 200 W with 15^{o}C temperature difference resulting in a thermal conductivity of 7500 W/m/K in the horizontal orientation. Furthermore, they can remove 250 W with 8^{o}C temperature difference resulting in a thermal conductivity of 16700 W/m/K in the sideways orientation. A numerical simulation was used to design prototypes and showed good agreement with the experimental data with the difference in evaporator temperature within 7^{o}C. This demonstrates that OHPs have a great potential for high heat-density management system.

Benefits to NASA and JPL (or significance of results):

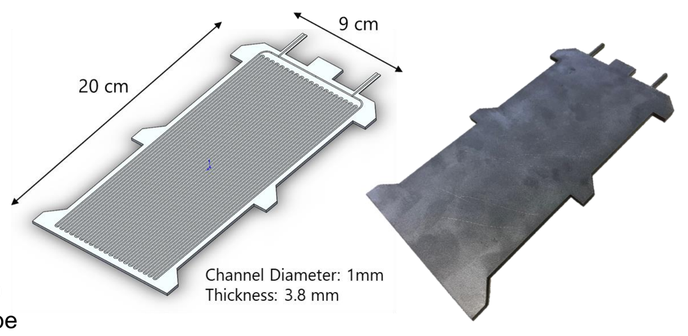
The Multi-functional OHP system can provide a high heat transfer rate and isothermalization across its surfaces. This system can manage higher-density heat dissipation from components such as Field Programmable Gate Array (FPGA), Command Pulse Distribution Unit (CPDU), and High Voltage Power Supply (HVPS). OHPs can also provide large isothermal surfaces to accommodate instruments sensitive to temperature gradients. Furthermore, the system can significantly reduce complexity and mass of the entire unit since the thermal control system is preinstalled in the electrical chassis. The Multi-functional OHP system can be the next-generation standard technology widely used for Earth science missions and deep space and astrophysics mission.



Concept of Multi-Functional Oscillating Heat Pipe System



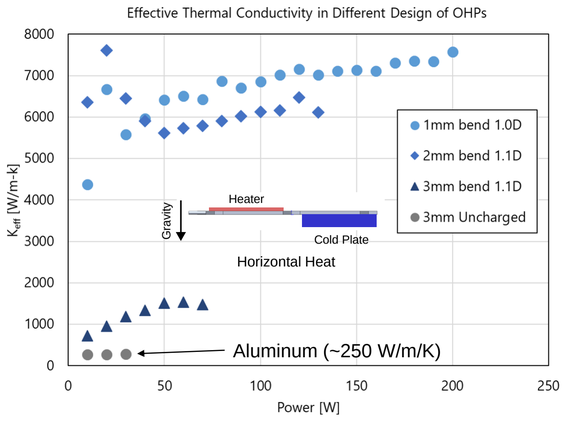
Current Thermal Management System for High-Density Heat Dissipation



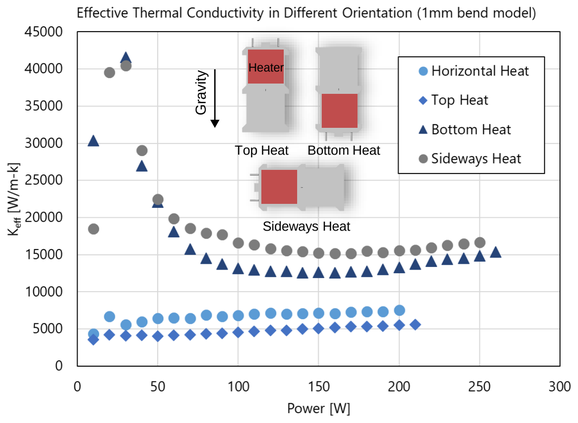
OHP Channel Design

OHP Prototype Fabricated via Metal Additive Manufacturing

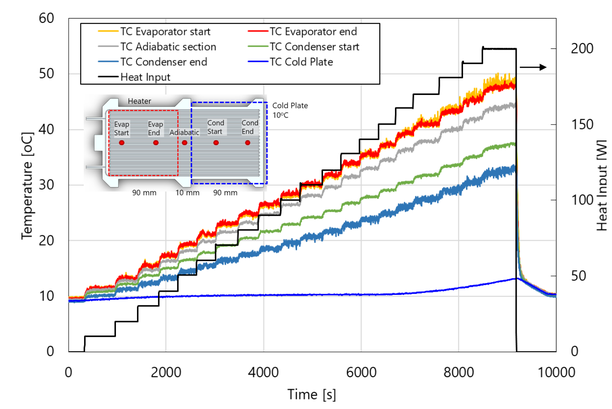
Design and Prototype Fabricated via Metal 3D Printing



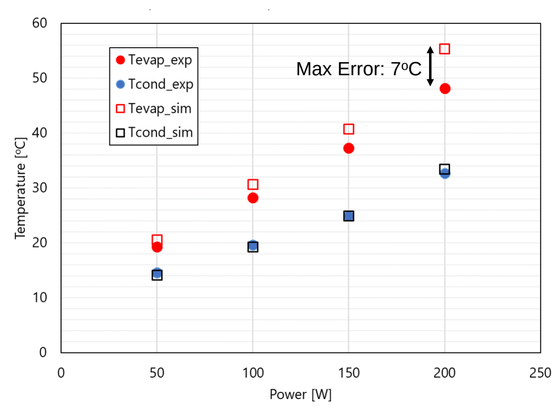
Thermal Performance in Different Designs



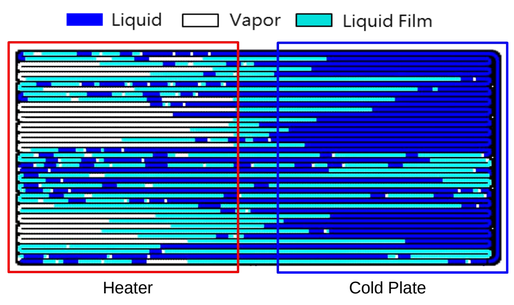
Thermal Performance in Different Orientation



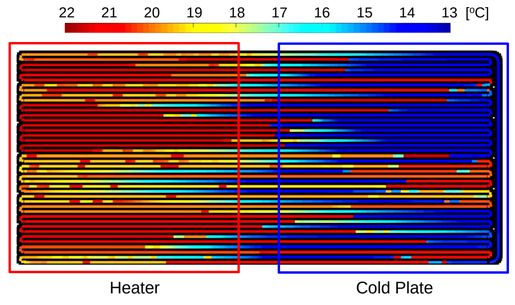
Temperature History
1mm bend model, Horizontal Heat



Comparison between Experiment and Numerical Model



Numerical Simulation (50W)



Temperature Field

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