Permeability Analysis of Additively Manufactured Wicks for Developing Heat Pipes

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Research questions: What are the characteristics that make an optimum wick for heat pipes and how can they be evaluated?
How do design and process influence the performance of 3D printed metallic wicks?

Background

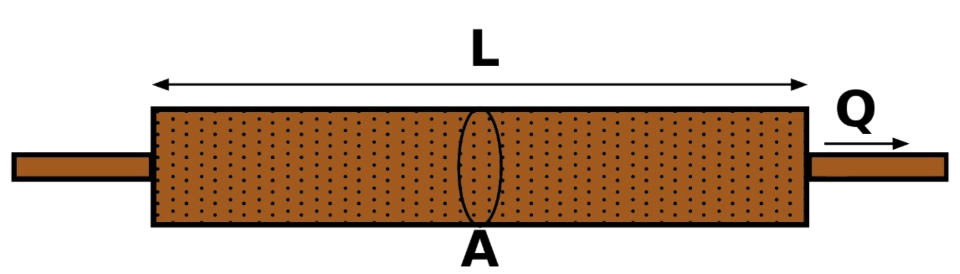
Heat pipes and vapor chambers are methods of passive cooling that rely on phase change of a fluid in a closed loop. They utilize vaporization and wicking of fluids to assist in transfer of heat from one side to the other. Heat pipes are commonly used in high power density electronics applications due to their high thermal conductivity. Heat pipes utilizing copper and de-ionized water are the most common construction method used for electronics applications due to the temperature range in these applications.

Abstract

The development of additively manufactured sintered wicks and heat pipes will allow for the design and creation of integrated heat sinks and pipes in designs not possible through standard manufacturing processes currently relied upon. It is also possible to explore designs of more efficient thermal dissipation designs, such as those seen in nature. This work involves the development of a test rig that will enable the analysis of such wicks prior to implementing high-performing designs in heat pipes. Current progress has included the design, development and prototyping of a permeability rig.

Measuring Permeability

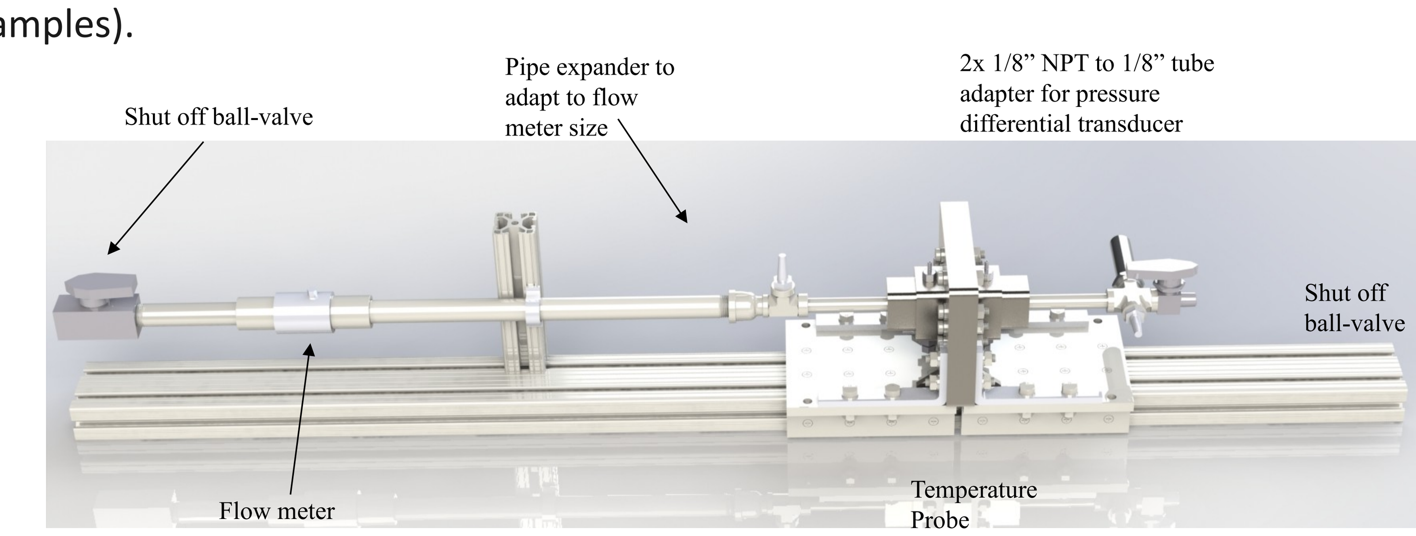
To measure the permeability of a porous substance, the use of Darcy's Law is required. Darcy's Law defines that the flow rate (Q: m^3/s) is equal to the ratio of the permeability (k: m^2) and cross-sectional area (A: m^2) by the dynamic viscosity (μ: Pa*s) and sample length (L: m) multiplied by the drop in pressure across the sample (Δp: Pa).



$$Q = \frac{kA}{\mu L} \Delta p$$

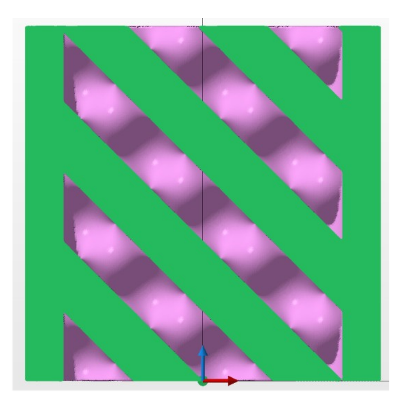
Rig Design and Sensor Positioning

The test rig consists of a single flow sensor, a single differential pressure meter, and four temperature sensors. The data from the flow sensor and pressure transducers is directly used to calculate permeability, while the temperature sensors compensate for temperature irregularity affecting the fluid viscosity. From initial testing we found that the flow rate stayed steady at about 5 L/min while the pressure differential could vary from 0.4psi (for the more open samples) to upwards of 1.5psi (for the more closed off samples).

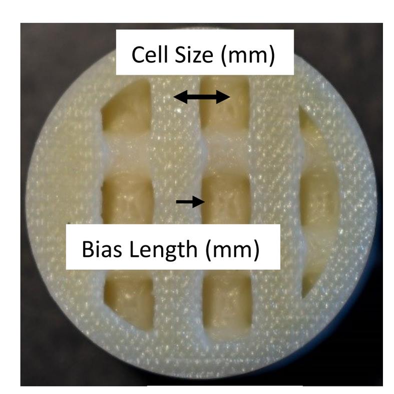


Test Samples

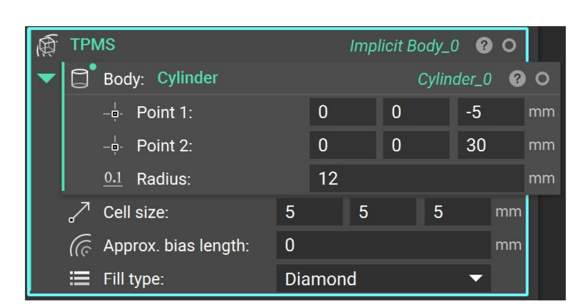
The current test samples used for verification of data from the porosity rig were designed using nTopology. Currently two sets of samples have been printed for testing. The first group of samples have consistent densities but have varying cell sizes. The second group of samples have a consistent cell size but have a varying cell density.



Cross Section



Top View

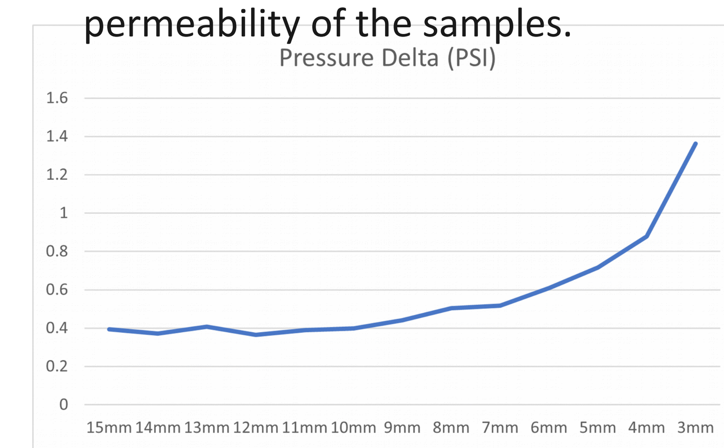


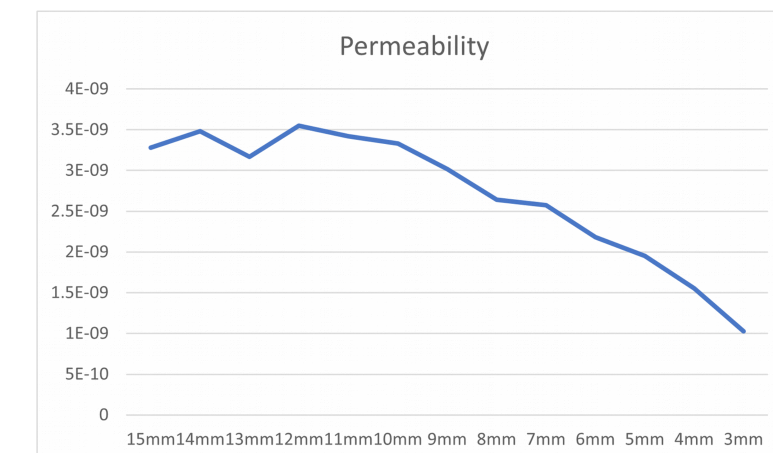
NTopology TPMS Parameters

Parameter 1: Cell Size
Parameter 2: Approx. Bias Length (Cell Density)

Permeability Sample Data Group 1

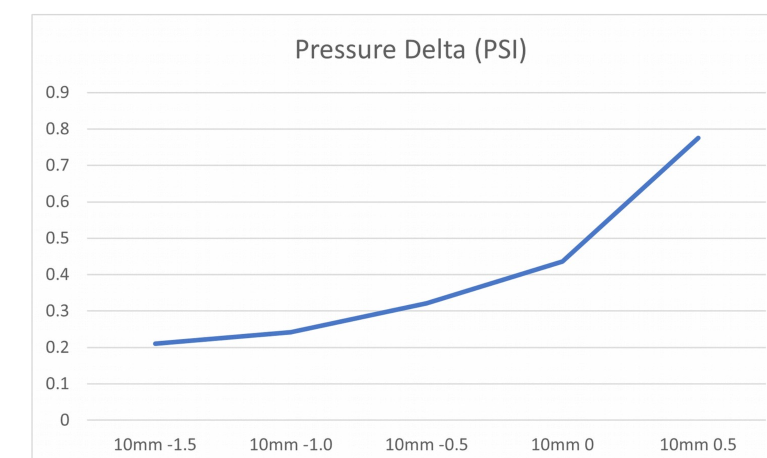
The first group of samples tested have different cell sizes but have a consistent cell density ratio. During our measurements we found that the flow rate stays constant, but the smaller cell sizes led to a larger pressure differential between the open ends of the samples. With an increase in pressure differential, we observed a decrease in the permeability of the samples.

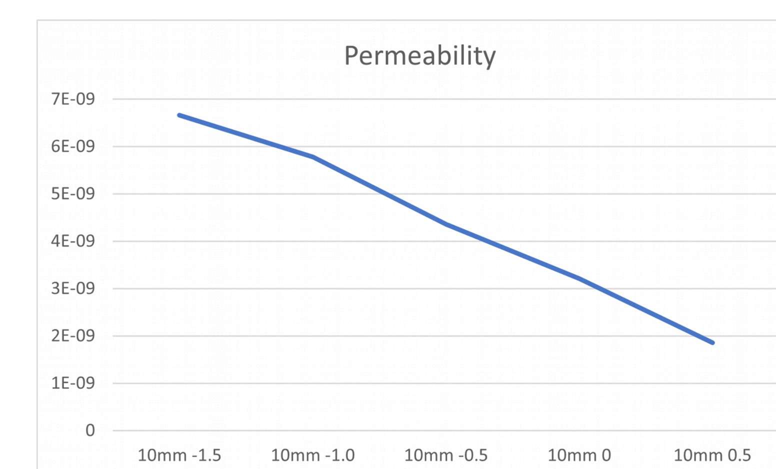




Permeability Sample Data Group 2

The second group of samples tested have a constant 10mm cell size but have varying density ratios. During our measurements we found that the flow rate also stays constant, but the smaller open cell densities led to a larger pressure differential between the open ends of the samples. With an increase in pressure differential, we observed a decrease in the permeability of the samples just like with the data seen above.





Acknowledgments

Rhett Sweeney – Assistance in CNC fabrication of components for porosity testing rig
Kyle Monaghan (NASA) – Assistance in design of rig for testing of 3D-Printed sintered wick samples
Cameron Noe – Assistance in 3D-Printing technologies and general guidance
Dr. Alex Rattner – Assistance in sensor selection and general guidance

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