Influence of 3D Infill Pattern on Thermal Transport

Yu Han

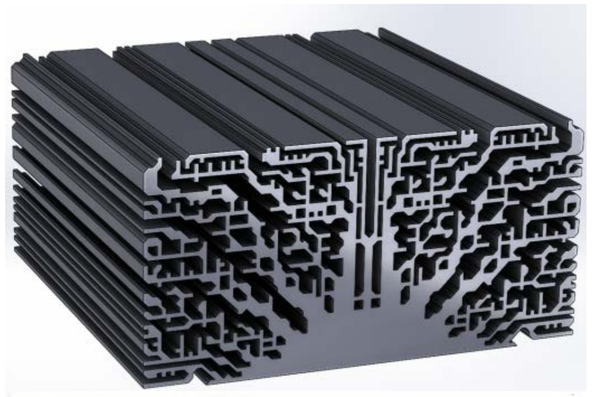
PI: Amy Marconnet

engineering.purdue.edu/MTEC

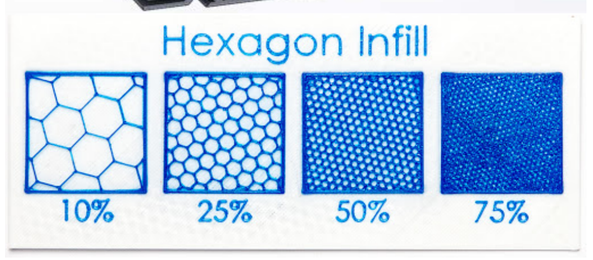
Motivation & Project Goals

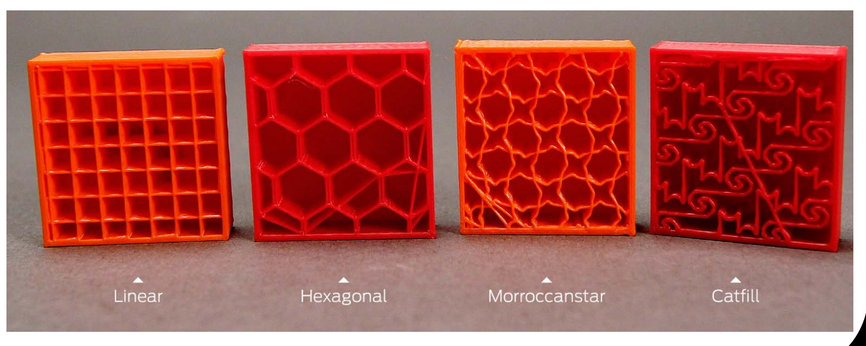
- Most modern 3D printers do not print fully dense structures. Instead, the printed part has an infill pattern that leaves empty space inside the printed parts to save the material and time (see figures to right).
- This causes the properties of the printed part to be anisotropic (not the same in each direction) and to vary with the infill pattern and infill density.
- Generally, the toolpath\infill pattern yields orthotropic material properties (3 planes of asymmetry).
- **This goal of this research is to measure the impact of toolpath and infill pattern on thermal properties of 3D printed parts.**

3d Printed Heat Sink Design (from [1])



Selected Infill Patterns (from [2-3])

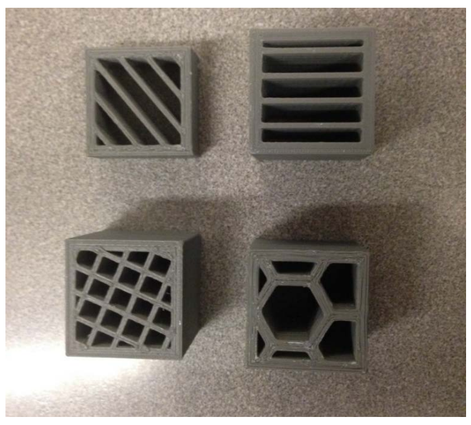




Experimental & Simulation Setup

1. Sample Preparation:

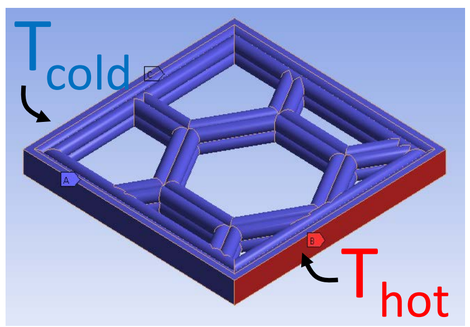
- The sample size is 1cm x 1cm x1cm.
- The four side surfaces are closed.
- The top and bottom surfaces are open for imaging.
- All the samples are printed by ME Makeware printers.
- Infill patterns include: Hexagon, linear Cross, Zig-Zag.
- Acrylic reference layers of known thermal conductivity are attached to each sample in order to perform the cross plane temperature analysis.
- Samples are made with different infill percentages.

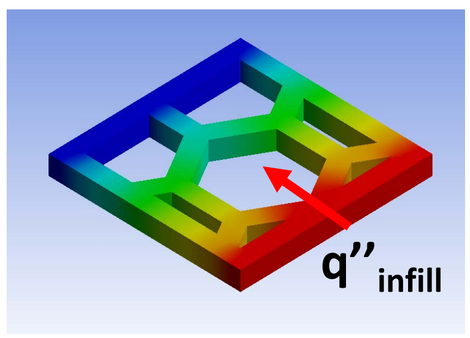


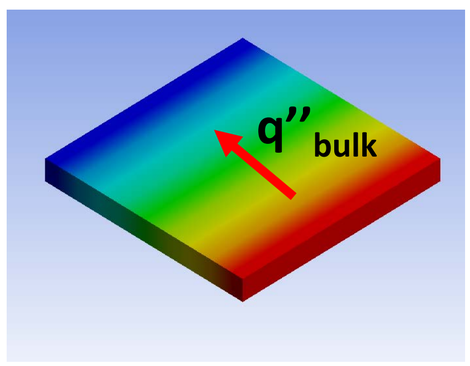
2. Simulation Setup:

- The geometry is modeled in ANSYS and represents the toolpath used by 3D printers.
- A temperature difference is applied across samples.
- Initially, all other surfaces are insulated. Later, convection is applied at internal and external surfaces.
- The heat required to maintain the set temperature difference is measured for the fully solid sample, as well as for the various infill patterns.
- The effective thermal conductivity can be calculated from

$$(1) \quad K_{eff} = \frac{K_{iso} q''_{infill}}{q''_{bulk}}$$

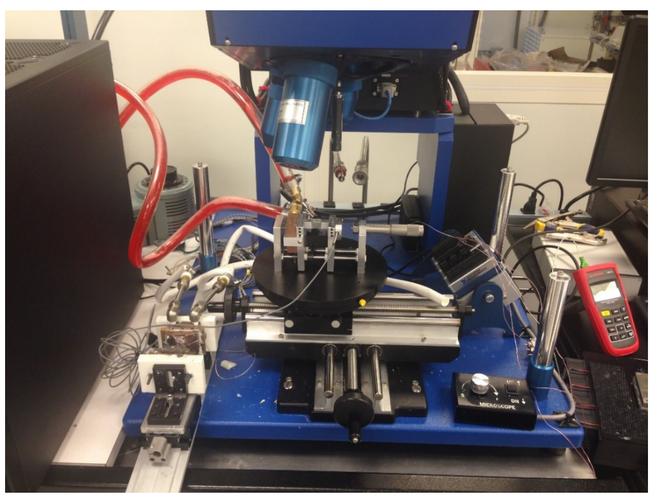


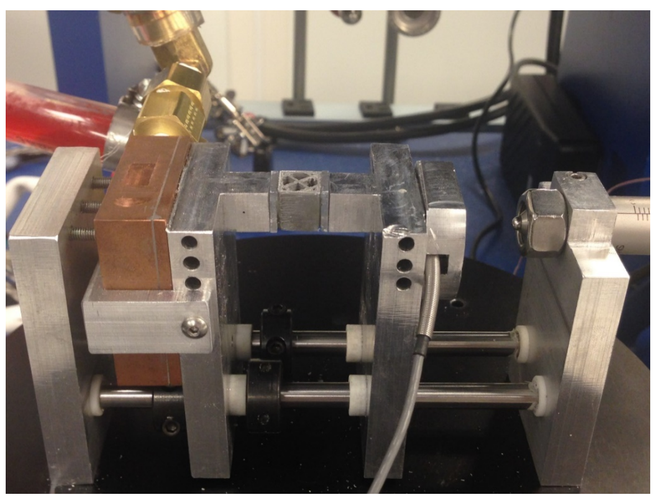




3. Experimental Setup:

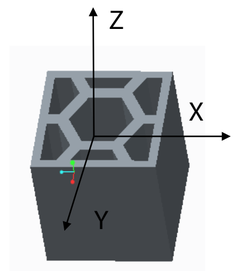
- The reference-sample-reference stack is sandwiched between a chiller and a heat source. These provide the constant temperature boundaries equivalent to the model as the aluminum adapter plates have much higher thermal conductivity than the sample.
- The heat transferred through the sample is measured by integrating the local heat flux through each reference layer, and the effective thermal conductivity is calculated using Eq. 1.
- The experiment is repeated for 5 sets of temperature boundary conditions.

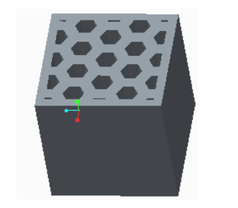


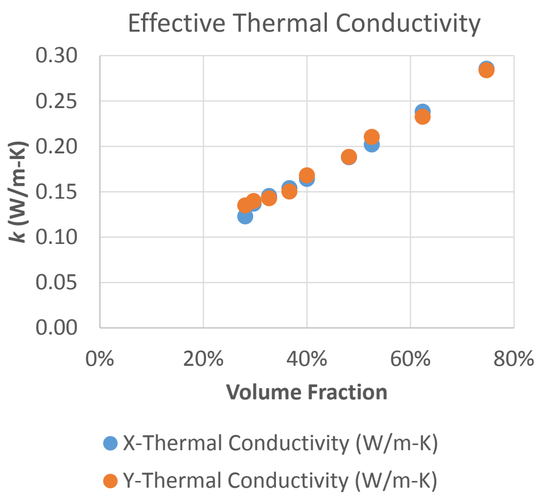


Simulation Results

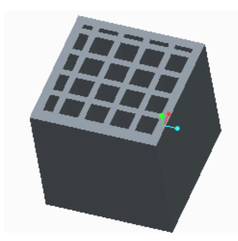
Hexagon Infill

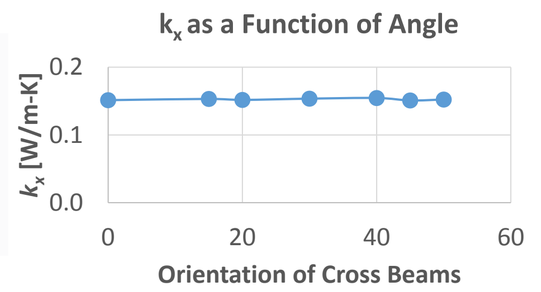


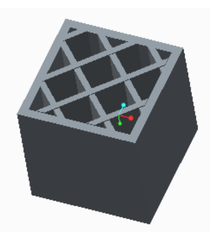


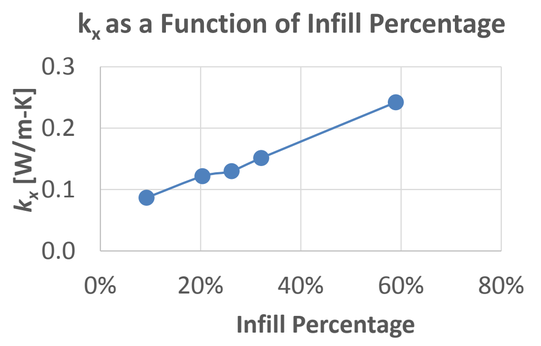


Linear Cross Infill

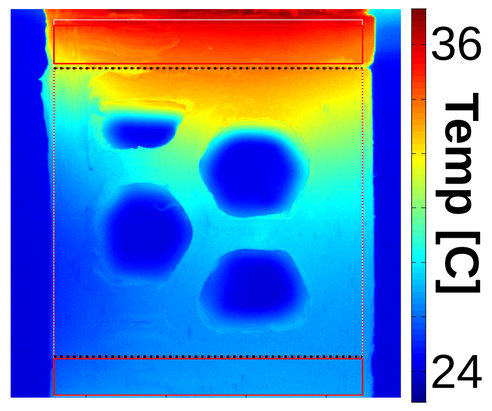




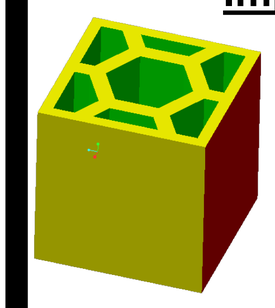




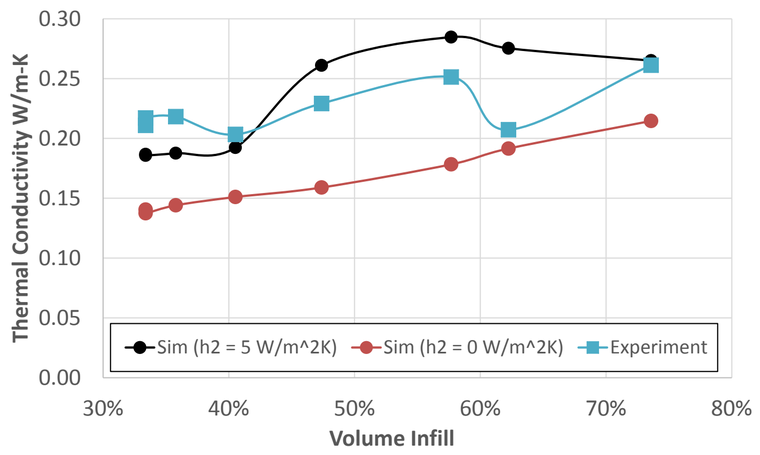
Experimental Results



Impact of Convection



External Convection:
Yellow Surfaces: 10 W/m^2-K
Internal Convection:
Green Surface: 0 or 5 W/m^2-K



We hypothesized that the discrepancy between experiments and modeling was due to convection in the system. Simulations show that including convection increases the apparent thermal conductivity. There are still some variations between experimental and modeling results.

References

1. https://blogs.mentor.com/robinbornoff/blog/2015/03/24/organically-grown-3d-printable-heatsinks-part-1-a-simple-iterative-procedure/
2. https://www.matterhackers.com/articles/slice-settings-explained-part-2
3. http://neyasystems.com/tailoring-mechanical-designs-for-3d-printing/3.