3D printed novel wick structures for enhanced capillary flow

Zachary Walker, Marcus Ang, Felipe Lima, and Gisuk Hwang
Department of Mechanical Engineering, Wichita State University

WICHITA STATE UNIVERSITY

Motivation and Objectives

- **Motivation:** One of the main challenges in traditional evaporative cooling systems is a premature coolant dryout under high heat flux heat demand due to the limited capillary flow through wick structures. A desired wick structure requires good capillary pumping capability and larger permeability, i.e., enhanced wickability.
- **Objectives:** this study aims to create a new microstructure to 3D print as a wick for high heat flux evaporative cooling systems.

Previous Research on Related Wicks

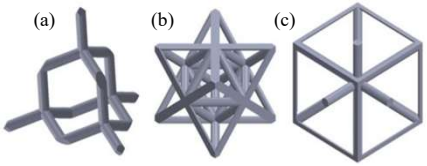

Figure 1. Schematic diagram of the lattice structure design. (a) Diamond, (b) octet, and (c) isotruss. [1]

- The capillary pressure increases by decreasing porosity, and the permeability increases by increasing porosity, which requires a balance due to their competing nature.
- However, the previous study showed that wicks with a lower porosity (Octet) performs better than wicks with a higher porosity (Diamond) [1].

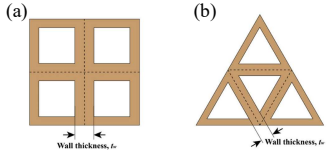

Figure 2. Schematic diagram of channel wicks. (a) Square and (b) triangular channels. [2]

- When microchannels were tested, they performed better than even some 3D printed micro wick structures. The triangular tube performed the best among these structures [2].

Proposed TriLattice Wick

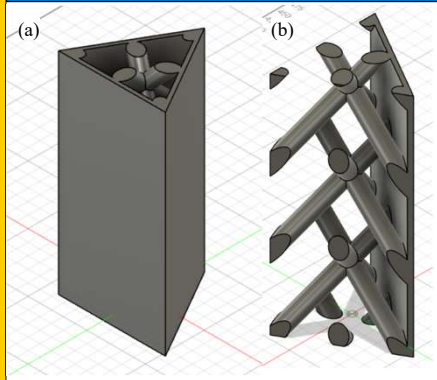

Figure 3. Schematic diagram of the proposed TriLattice structure design. (a) Entire wick structure, and (b) internal wick structure.

- To enhance the wickability, a "TriLattice" wick structure is designed by an internal isotruss in triangular channel.
- The TriLattice names after the lattice-like isotruss within the triangular microchannel.
- It is postulated that the triangular channel offers good wickability, which is further enhanced by the interconnected pore-network through the internal isotruss.

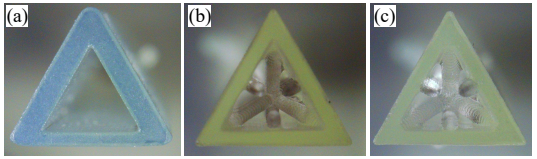

Figure 4. Image of 3D printed wicks (a) hollow wick (no isotruss), TriLattice with trust diameter of (b) 600 μm, and (c) 900 μm.

3D Printing of TriLattice Wick

Figure 5. Formlab's Form 3+ Printer

- All prints were done using Formlab's Form 3+ Printer with standard clear resin.
- The resolution is 25 micrometers and adaptive layer thickness between 25 to 100 micrometers is enabled.
- After printing, Form Wash filled with isopropyl alcohol is used for washing for one hour, followed by an hour of curing in Form Cure at 45°C.
- To remove uncured resin in the pores, wicks are flushed with compressed air during the washing stage.

Rate of Rise Test

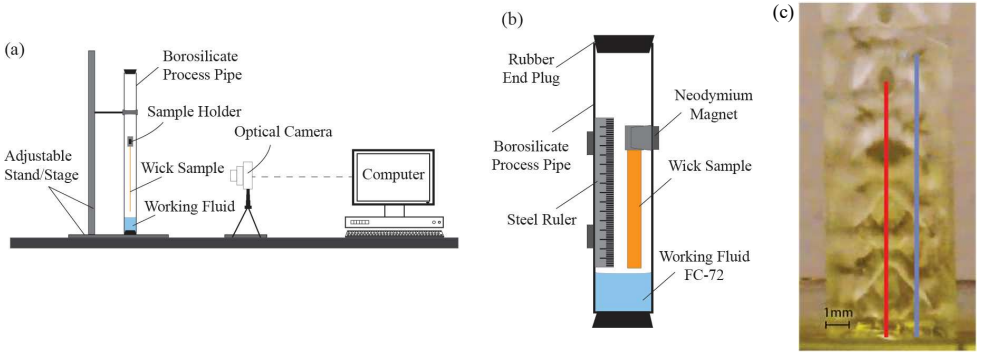

Figure 6. Schematics of (a) rate-of-rise setup and (b) camera view of the wick, glass tube, ruler, and working fluid, and snapshot of the liquid height in TriLattice wick.

Results and Discussion

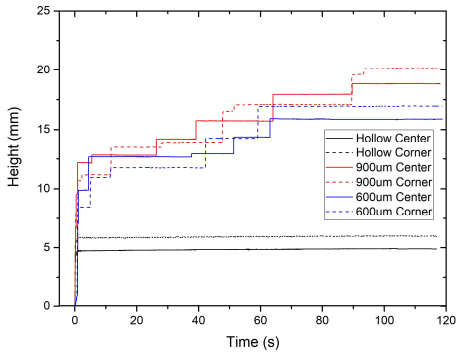

Figure 7. Measured rate-of-rise, i.e., measured liquid height vs time, of hollow triangle channel, TriLattice with truss diameter of 600 and 900 μm.

- The TriLattice with truss diameter of 600 μm quickly increased the liquid height <~ 1 s and continuously step-wise increases until ~ 3 times higher equilibrium height compared to the hollow.

Conclusion

- A new wick structure, the so called, TriLattice, was designed and 3D printed to enhance wickability.
- The TriLattice wick structure enhances the capillary pressure by approximately 4 times compared to that of the hollow wick structures.
- capillary pressure was further increased by increasing the truss diameter.

References

[1] Kuan-Yu Luo, Pratik Prakash Gupta, Kuan-Lin Chen, and Shung Wen Kang, "Study of 3D printed capillary structure", not originated from journal, Melbourne, Australia, February 5-8, 2023
[2] Binjian Ma, "Analysis of Capillary Flow in a Parallel Microchannel-Based Wick Structure with Circular and Noncircular Geometries", "Langmuir", no location given, November 5, 2020

Acknowledgement

This work is financially supported by the summer undergraduate research program, College of Engineering, Wichita State University.