Implementation of a Topologically Optimized Heat Sink for Non-Uniform Heat Fluxes in an Electric-Vehicle Fast-Charger

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Motivation

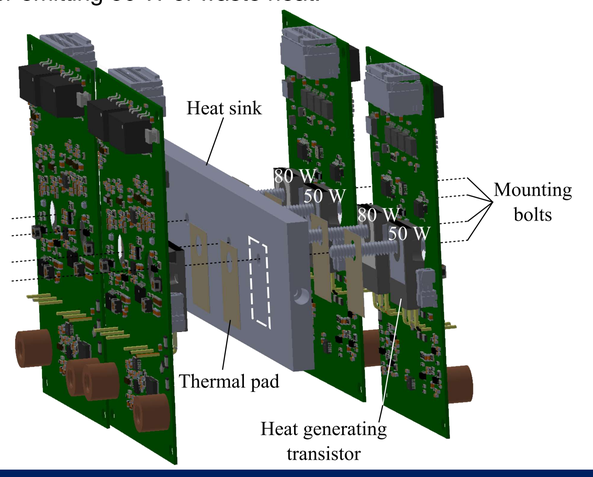
- High-power electric vehicle (EV) chargers use a variety of power semiconductor devices resulting in non-uniform heat loads and temperatures.

Objective:

- Maintain uniform device junction temperatures below the maximum temperature rating given non-uniform heat loads.

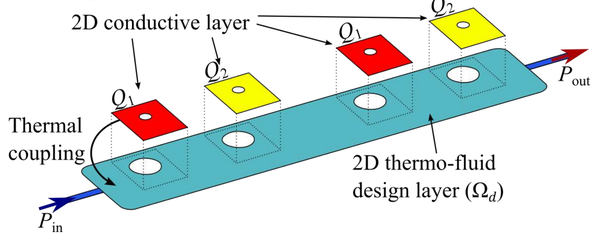
Fast-Charger Layout

- Applied to the power stage of a custom 100-kW EV fast charger.
- Each PCB has two TO247-packaged devices, with one emitting 80 W and the other emitting 50 W of waste heat.

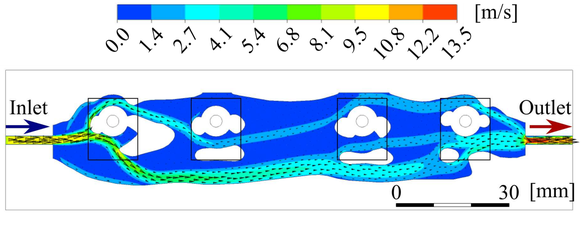


Topology Optimization

- Computational space of the topology optimization problem. (Q_1 = 160 W, Q_2 = 100 W)

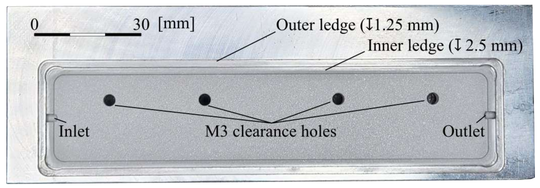


- Velocity contours of the optimized design at 1 L/min.



Fabrication

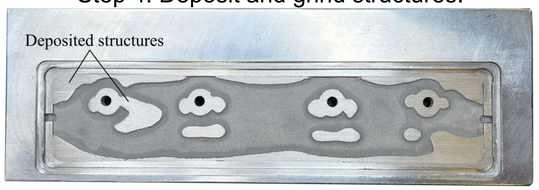
Step 1: Machine pocket and grit blast surface.



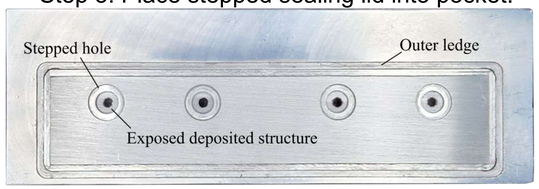
Step 2: 3D print mask.

Step 3: Wire-arc spray.

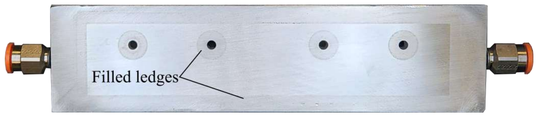
Step 4: Deposit and grind structures.



Step 5: Place stepped sealing lid into pocket.

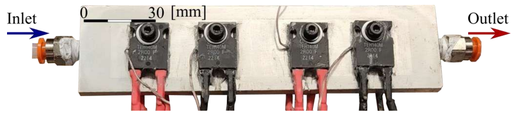


Step 6: Spray, machine, and polish.

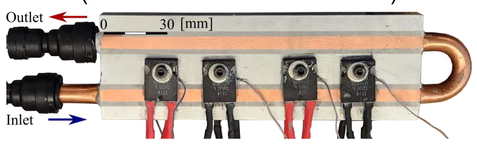


Experimental Results

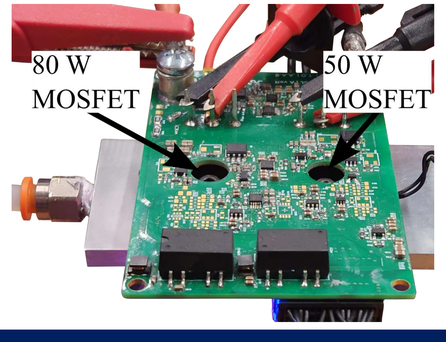
Optimized heat sink.
(150 mm x 37 mm x 5.8 mm)



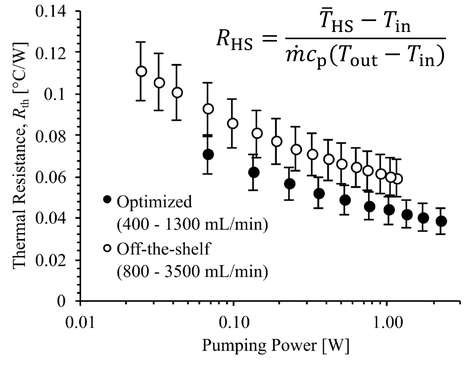
Off-the-shelf heat sink.
(228 mm x 50 mm x 15.2 mm)



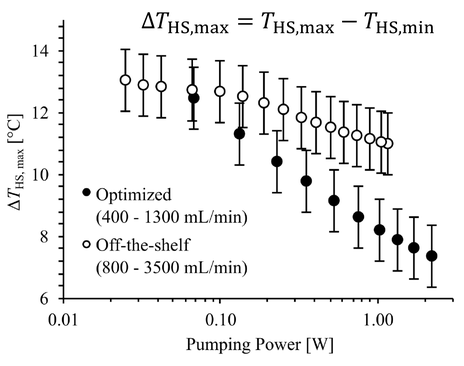
Fast-charger PCB mounted to heat sink.



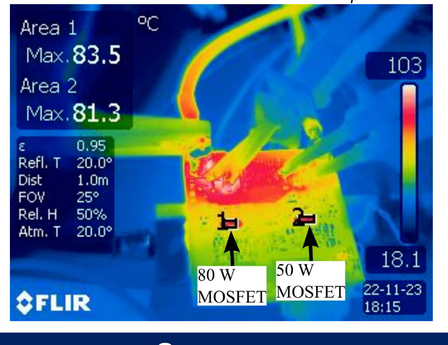
Average thermal resistance under all 8 devices dissipating a total of 520 W.



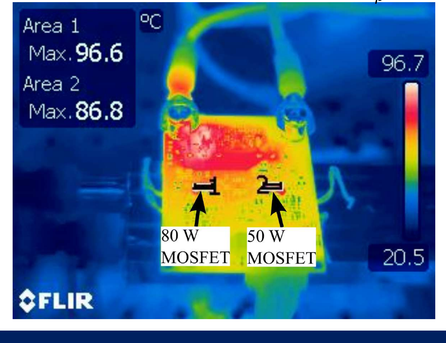
Maximum temperature difference on the surface of the heat sink.



Optimized heat sink at 1 L/min (N_p = 1 W).



Off-the-shelf heat sink at 3.3 L/min (N_p = 1 W).



Summary

- Wire-arc spray was used to additively manufacture a topologically optimized heat sink.
- Thermal resistance reduced by 27%.
- Heat sink surface temperature difference reduced by 25% and maximum temperature reduced by 18%.
- **Combining thermal spray and topology optimization is a promising approach for high-performance heat sinks.**

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