3D Printed Jet-Based Cooling Heat Exchanger for Electronic Devices

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Abstract

This project explores the potential of 3D printed jet-based cooling heat exchanger, also called 3D printed jet cooler, to cool electronic devices. Unlike traditional metal-based jet coolers, this 3D printed jet cooler will be fabricated using polymers which considerably reduce the fabrication cost while still offering a wide geometric freedom that would offer new designs and possible configurations. The final goal of this research is to find the best parameter set for such devices by manipulating air flow velocity, nozzle diameter, and distance between nozzle and the heated coil device.

Background

Traditionally, jet impingement cooling has been used for gas turbine engine or metal quenching processes where rapid removal of heat is required. Typically, the jet is turbulent and, at the nozzle exit, is characterized by a uniform velocity profile which then cools off the impingement surface (*figure 1*).

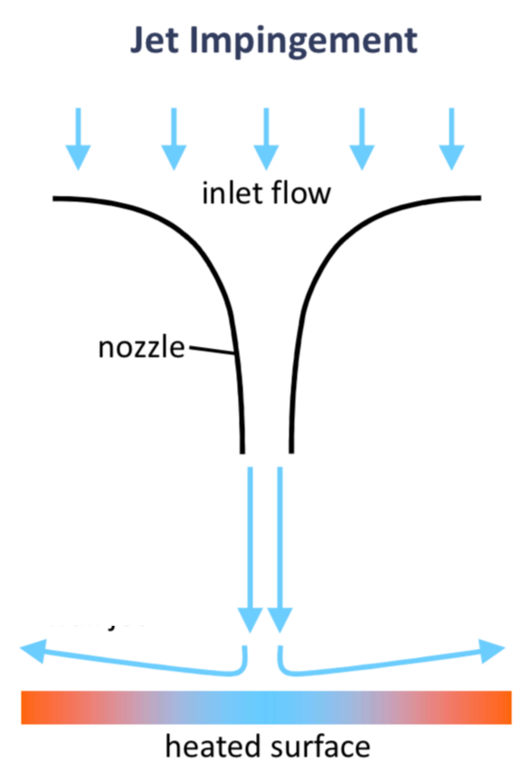

Figure 1: Surface Impingement by a Single Jet Nozzle.

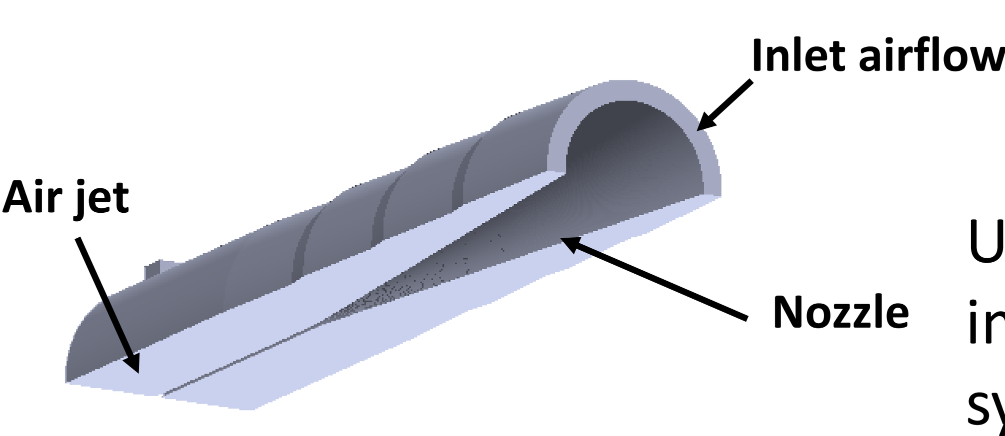

Figure 2: CAD model of 0.4 mm Diameter Jet Nozzle Used for Experiments

Unlike traditional jet impingement cooling systems, 3D printed polymer heat-exchangers with miniature diameters are exceptionally effective to cool off electronic devices as their extreme compact jet nozzle is well adapted to provide high cooling performance within complex electronic system designs requiring small, light-weight, and low cost cooling systems (*figure 2*).

Methodology

Step 1: Vary experiment parameters:

- Nozzle diameter;
- Airflow Velocity;
- Gap distance between nozzle and RF coil

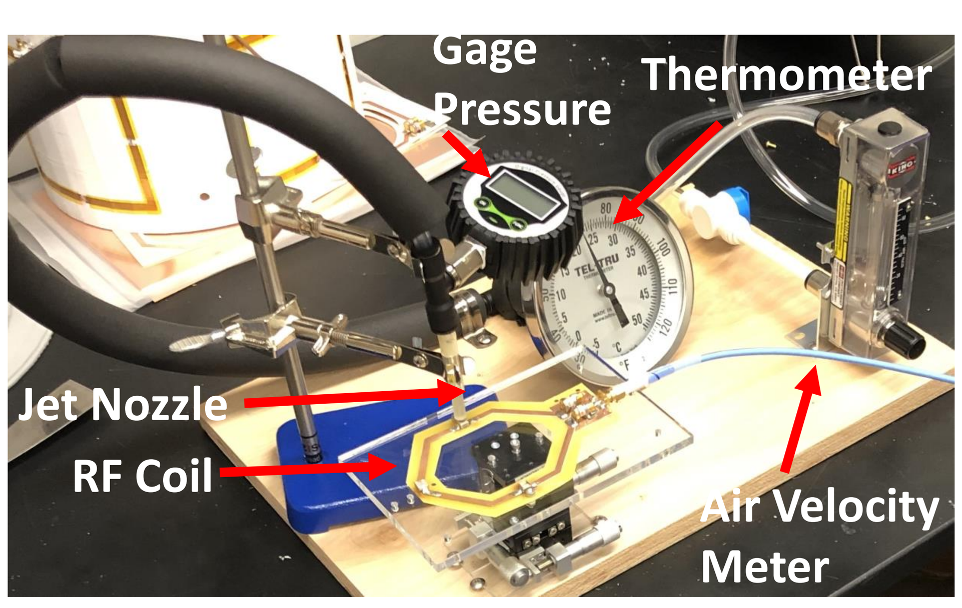

Figure 2: Experiment Setup.

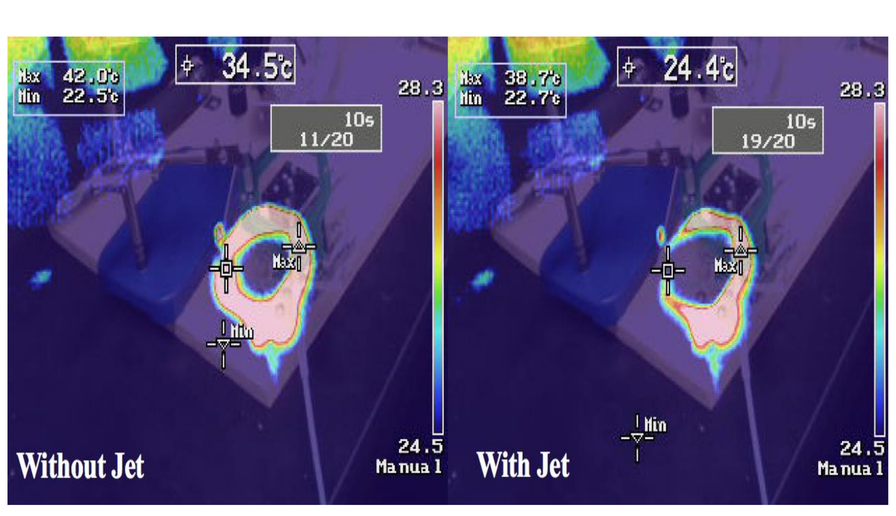

Figure 3: Infrared image of RF Coil Before and After Cooling.

Step 2: Record cooling performance:

The cooling effect of jet nozzle on the RF coil was measured using an IR camera.

Results and Discussion

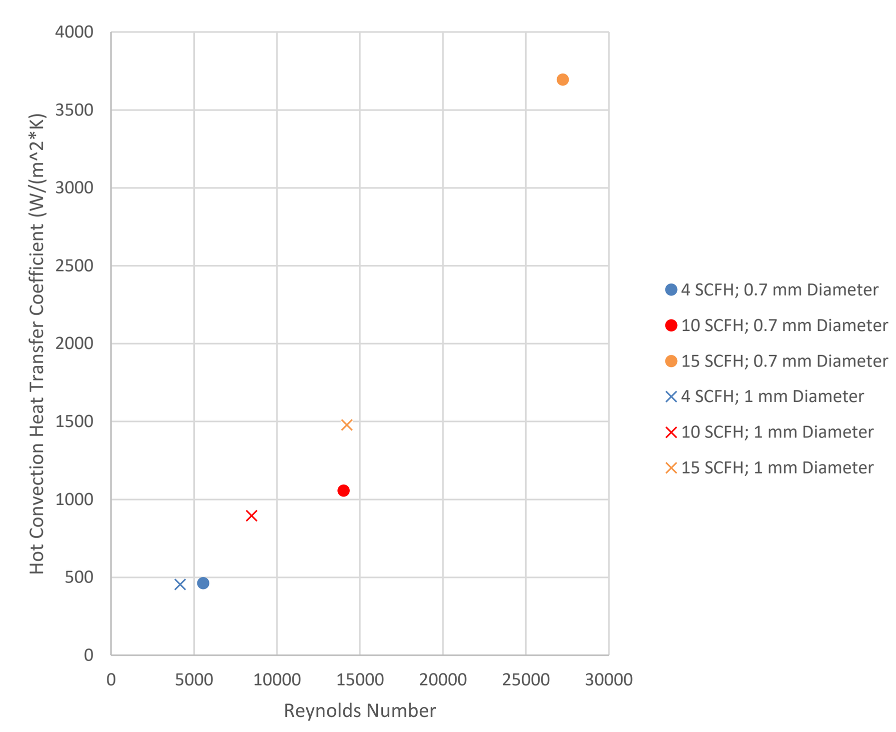

Figure 4: Convective Heat transfer Coefficient VS Reynolds Number.

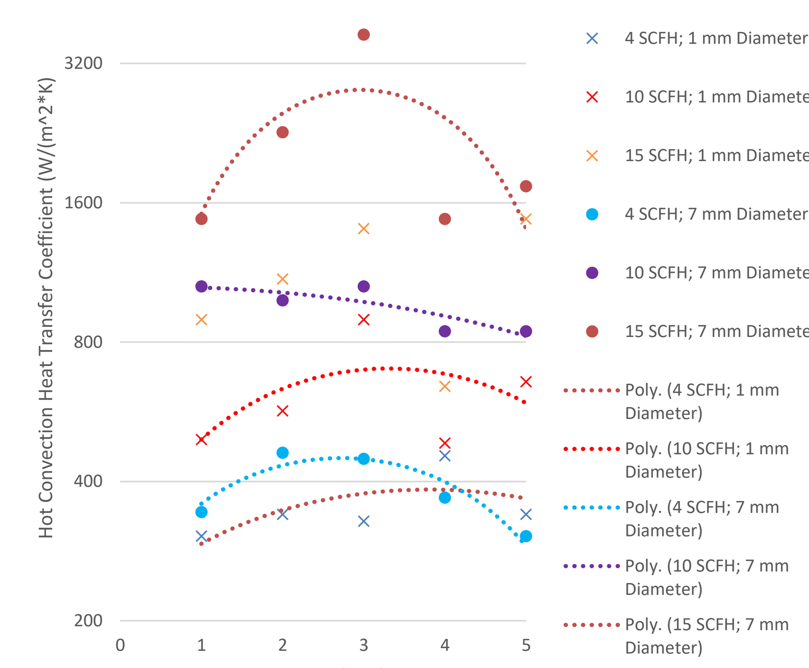

Figure 5: Convective Heat transfer Coefficient VS Gap Distance.

As expected, we can clearly see the relationship between the Reynolds number and the convective heat transfer coefficient. The higher the Reynolds number, the better the the convective heat transfer coefficient.

These trendlines show a common pattern between the various combinations of parameters and the gap distance between the nozzle and the coil. We can observe that for all the different combinations, the optimal distance is 3mm.

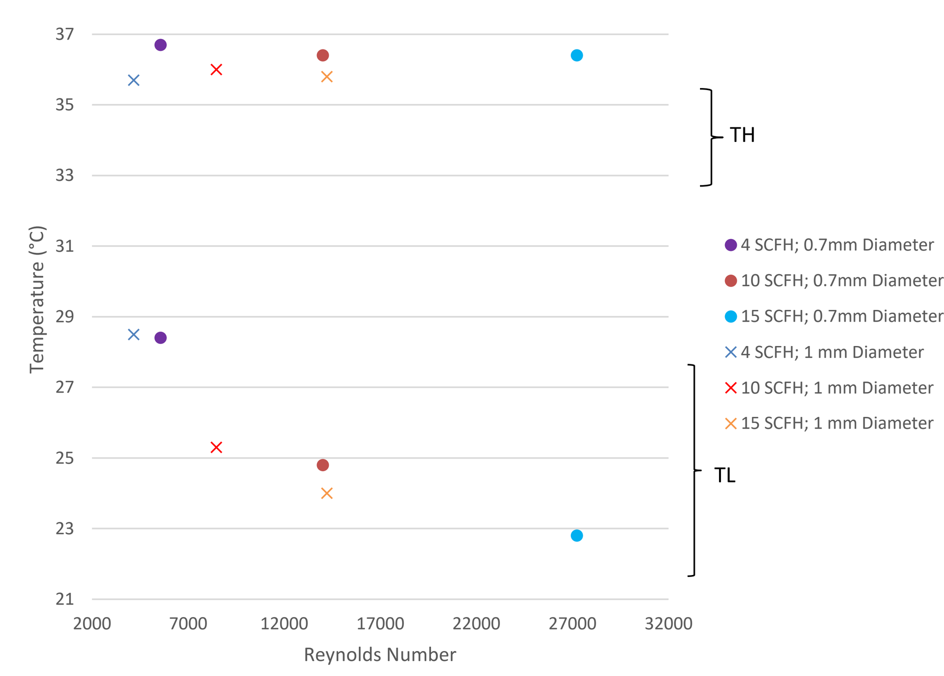

Figure 6: Max/Min Temperature VS Reynolds Number.

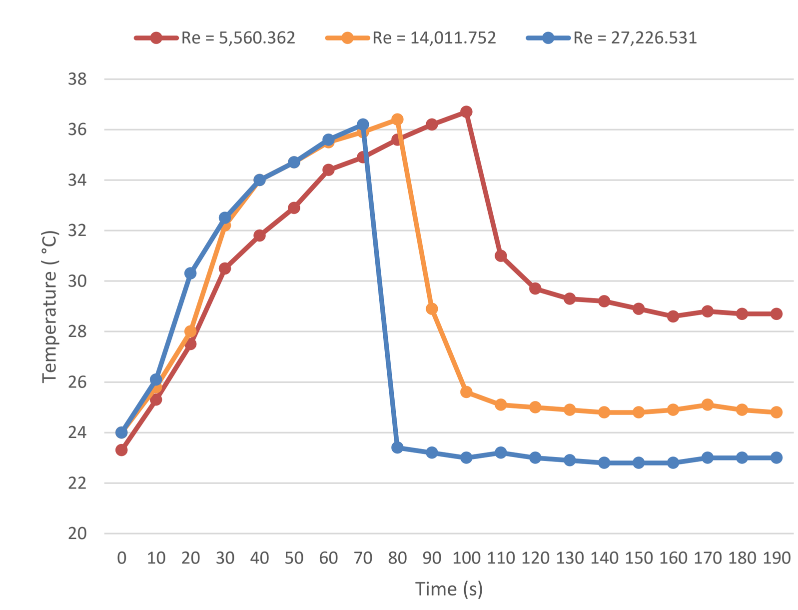

Figure 7: 0.7mm Diameter with Gap Distance of 3mm, Temperature VS Time

Once again, this plot shows the correlation between the Reynolds number and the cooling performance. The higher the Reynolds number, the higher the temperature drop.

Cooling Rates:

- Reynolds Number = 5,560.362 → **0.25 °C/s**
- Reynolds Number = 14,011.752 → **0.54 °C/s**
- Reynolds Number =27,226.531, → **1.29 °C/s**

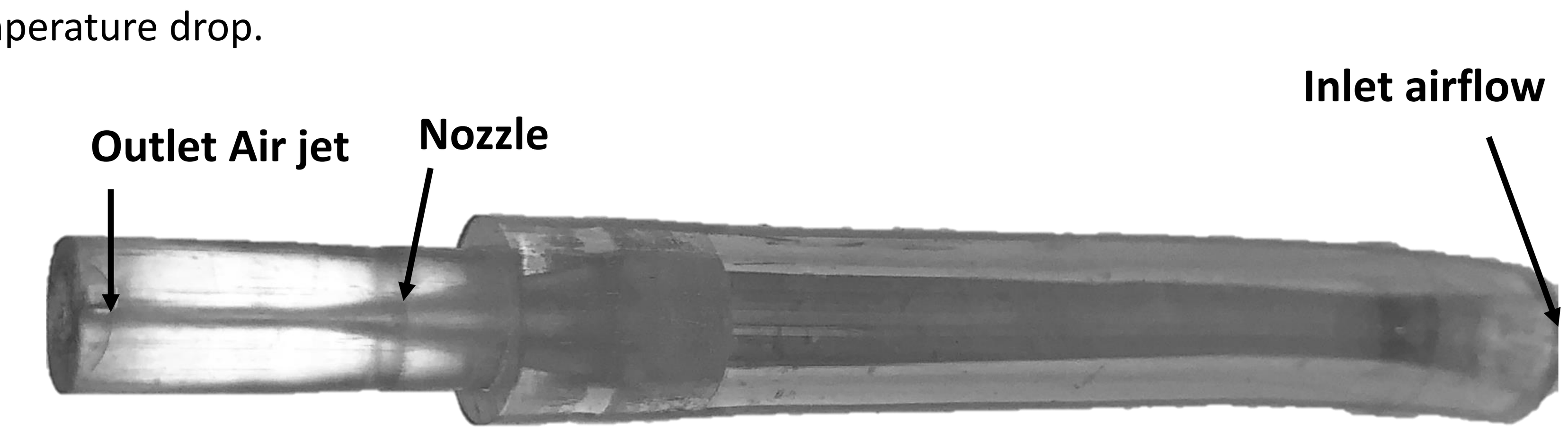

Figure 2: 3D Printed Experimental Jet Nozzle 0.7mm Diameter

Conclusions

- Successfully cooled down heated RF coil using polymer additively manufactured 3D printed jet coolers.
- Among all the different configurations tested during the experiments, the most optimal one turned out to be the nozzle 0.7 mm diameter at a gap distance of 3 mm from the coil.
- Polymer additively manufactured 3D printed jet coolers could effectively be used to enhance thermal efficiency of electronic devices such as MRI.

Future Works

Next semester, our research will be focusing on exploring further the potential of 3D printed polymer heat-exchangers, this time involving multiple jet nozzles which should result in enhancing thermal and hydrodynamic performance.

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