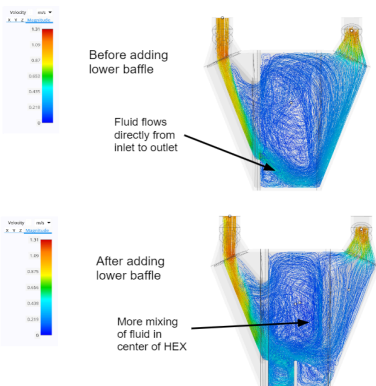
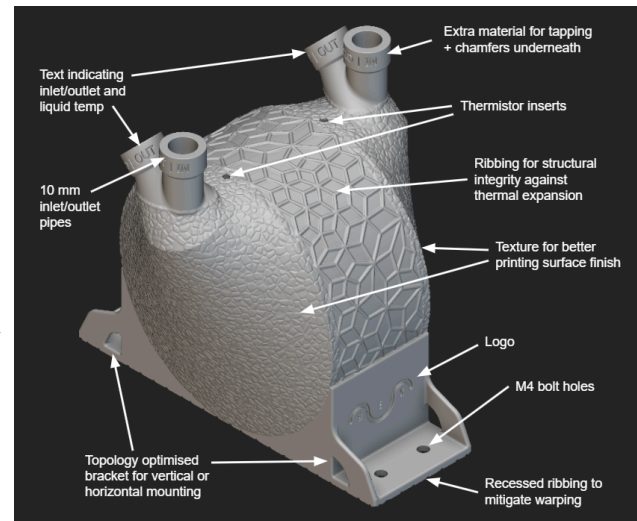


1. Heat Exchanger Design in CAD

I chose to create a cylindrical, liquid/liquid counter-flow heat exchanger (HEX) with a “pipe within a pipe” inlet/outlet design. This shape was chosen to promote more fluid mixing and eliminate dead zones that might otherwise be present in a prismatic shape. Counter-flow was chosen because, although co-current flow can enable greater heat transfer, counter-flow allows the outlet temperature of the cold fluid to exceed the outlet temperature of the hot fluid which may be more useful in a wider variety of applications.

To make my design parametric and fit within a bounding box with a width, length and height of 100 mm, I implemented an iLogic rule that would select the cylinder diameter to be equal to the width *or* the height, whichever was shorter. The inlet/outlet sections were created using lofts, angled 65 degrees from horizontal so they could be printed without external supports, and with a diameter of 10 mm where pipes could be attached. If the length or height of the bounding box is changed, the width would adjust to maintain the same overall volume. Due to the geometry of the inlet/outlet sections, any length larger than 125 mm or smaller than 70 mm will break the model, but the angle and length of these sections can be adjusted separately to enable more dimensional configurations. Other features of my CAD model include: extra material on the inlet/outlet pipes for tapping, chamfers underneath this extra material to aid in printing, fillets on sharp internal edges to reduce stress concentrations, thermistor inserts and a topology optimised bracket (see below for more details), a logo, and debossed text indicating which pipes are the inlets and outlets for the hot and cold fluids.



To validate my HEX design, I wanted to conduct a flow simulation in Ansys but was unable to do so using nTop’s .STL export or by converting the file using the FE meshes. As a compromise, I conducted a flow simulation of the CAD part in Ansys Discovery without the lattices to get an idea of where the fluid would move. This simulation revealed that the fluid at the bottom of the HEX flowed directly from the inlet to the outlet at a higher velocity, meaning it wouldn’t transfer heat very well. Thus, I added a baffle at the bottom to force the fluid to be more turbulent and “mix” throughout the main HEX body, then verified this result with another simulation.

2. Workflow in nTop

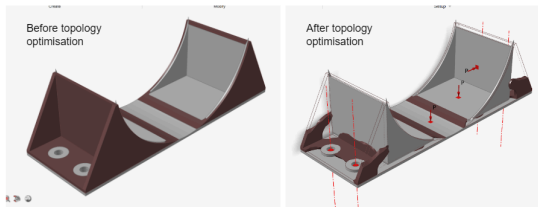
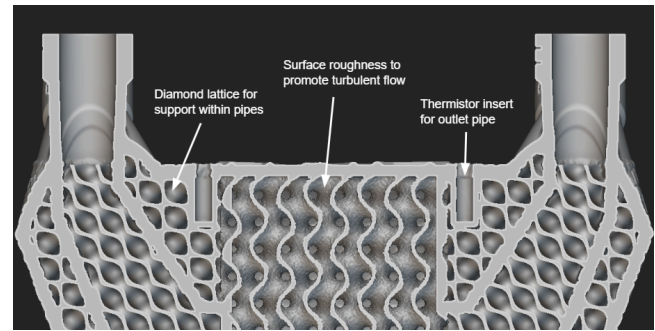
To simplify my nTop workflow, I created the “core” and “cap” parts in Inventor that would be transformed into the lattices in nTop. These lattices include the gyroid heat exchanging component, its cell size set by a scalar variable, and 9 mm diamond lattices to support the inlets, outlets and bracket for printing. The latter cell type and size was chosen as it visually seemed appropriate for printing (and was later verified to be printable in Magics). I also implemented ribbing on the exterior of the heat exchanging portion using a surface triangle lattice with a vertex centroid method. This ribbing would help maintain structural integrity of the HEX walls amidst thermal expansion due to the fluids within the exchanger. Another feature I added in my nTop workflow was surface texture: this included surface roughness on the gyroid lattice to help promote more turbulent flow and increase heat transfer efficiency, and a “leathery” texture on the lower exterior half of the inlet/outlet sections to improve printing surface finish by hiding printed layer lines on the cylindrical surface.

Finally, I incorporated heat transfer calculations in nTop to aid in choosing the HEX gyroid cell size. The workflow will calculate the required surface area to accomplish certain heat transfer performance characteristics based on user-set parameters, including the rate of heat transfer, the inlet and outlet hot and cold fluid temperatures, the thermal conductivity of the solid material and the heat transfer coefficients at the inlet and outlets. The starting values I used for these calculations are explained in comments throughout the workflow.

The calculated required surface area can then be compared with the actual surface area of the gyroid section and indicate whether the gyroid cell size should be adjusted to generate more or less surface area.

3. Additional Features

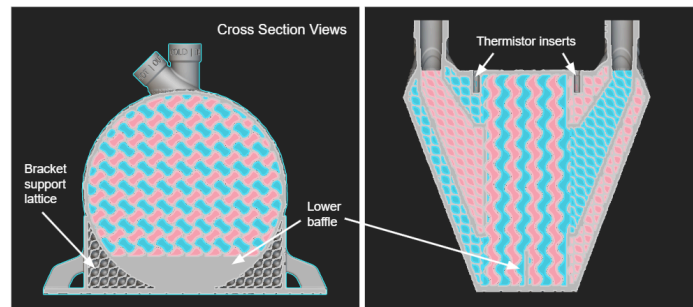
For the topology optimised bracket, I started with a simple shape with two M4 bolt holes on each side that would allow the HEX to be mounted either horizontally or vertically. I then imported the bracket into Inspire where I sectioned off the area around the screw holes and the backs of the bracket (as this would be used to support the HEX during printing) before choosing my design space to be optimised. I set the bolt holes as the fixed mounting points and added a 3000 Pa pressure to the top and inner sides of the bracket where the HEX would go, calculating this based on the density of aluminium and the approximate 100 x 100 x 100 mm cylinder size. Inspire then optimised the design, reducing the weight from 0.081 kg to 0.057 kg, which I used as a reference to redesign the bracket in Inventor. Afterwards, to mitigate warping while printing, I added recessed ribbing to the bottom face of the bracket by using a surface lattice in nTop on the bottom of the part.



The thermistor inserts are located on the outlet pipes to measure the temperature of the hot and cold exiting fluids. Through researching HEX installation guides, I learned that these thermistors are usually attached to pipes with a separate bracket, so this insert eliminates the need for this extra part by allowing the thermistors to be directly inserted into the HEX.

4. Overall Learnings and Stretch

I enjoyed exploring how AM technologies can enable the integration of different elements to improve the overall functionality of a part. Such examples that stretched my engineering knowledge in this project include generating lattices in nTop for practical purposes (such as a HEX gyroid or surface ribbing), for permanent support structures, or to reduce material in a part. I also explored generating custom surface textures to achieve certain characteristics, such as a better printed surface finish or more surface roughness to induce turbulent flow, and adding custom elements such as text and logos. My biggest learning from this project, however, was the power of AM in part consolidation through examples such as the thermistor insert that eliminated the extra bracket part, and the gyroid lattice that replaces numerous fins or tubes in a HEX.



However, I was also faced with the drawbacks of AM when making choices where it was not always the optimal solution. For example, consolidating the entire HEX into one part makes it more difficult to clean and maintain, especially with a gyroid structure, thus limiting the fluid type that can be used. Additionally, I experienced firsthand how some aspects of a design shouldn't necessarily be consolidated into one part: I had planned to add an offset underneath the bracket to avoid mounting the HEX directly against a surface, as recommended by installation guides, but decided that off-the-shelf components would be a more cost-effective solution.

Finally, I stretched my engineering knowledge by learning firsthand how simulation technology can influence AM design. Using Ansys Discovery allowed me to improve upon my HEX geometry to encourage more fluid mixing and greater heat transfer. Additionally, topology optimisation in Inspire helped me refine my bracket design to cut down on material usage while still maintaining structural integrity.

Total material volume: 259,448.838 mm³

Total support material volume (assuming 3 mm offset from bed of printer): 1272.425 mm³