Re-design of a heat exchanger, using triply periodic minimal surface structures.

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Norma is a high-precision and high-tech metal manufacturing company. In early 2022, a new metal 3D-printing department was started, using the MetalFABG2 from Additive Industries. The goal of the department is to become a one-stop shop, executing all processes needed, to deliver a 3D-printed and post-processed product. Currently, the department focuses on existing clients of NTS Norma, to gain experience in a familiar market segment. However, in the future, the 3D-printing department wants to expand, to new customers and possibly new markets as well. The goal of this assignment is to design a product, which shows potential clients what the 3D-printing department is capable of and convinces them to choose metal additive manufacturing at NTS Norma. The first step was to choose a market to focus on. With the use of literature research and discussions with staff members at NTS Norma, the choice was made to go for the current markets of NTS Norma. As the 3D-printing department first wants to expand within these industries. These are the semi-conductor, analytical and life sciences and optical markets. Then, the thresholds, which keep potential clients from choosing additive manufacturing, have to be indicated. The most common "fears" are the stiffness and fatigue of the material. The eigenfrequency of the printed product. And the strength and leak tightness of printed thin walls. After setting up design requirements and generating several concepts, the choice was made to focus on the design of a heat exchanger, containing a triply periodic minimal surface structure (TPMS). This concept should show the ability of metal 3D printing, as these structures are not manufacturable with conventional techniques, while also showing off the ability to print leak-free thin walls. The goal is to re-design a conventionally made heat exchanger. Afterwards, both heat exchangers are compared and evaluated. The brazed plate heat exchanger (BPHEX) is a compact and highly efficient heat exchanger, suiting the re-design for additive manufacturing. The WP112M-20 was used as the starting point (Figure 1). A brazed plate heat exchanger that is built up from 20 plates, brazed together with copper. The heat exchanger is re-designed for the same application, with the use of triply periodic minimal surface structures. These equation-driven three-dimensional structures have a constant mean curvature of zero [1]. Due to the possibility of evenly separating two fluids, the smooth structure and thin wall thickness, the structures are useful for fluid-to-fluid heat exchangers [1][2]. The diamond TPMS structure was chosen, having a great heat transfer capability to pressure drop ratio [3]. To optimize this structure for the best heat transfer performance, a balance must be found between the heat transfer surface area and pressure drop [4][5]. The last step before the design phase is the material choice, NTS Norma can print in stainless steel and titanium. Stainless steel offers high thermal conductivity at a lower price and is highly resistant to corrosion from water [6]. The diamond TPMS heat exchanger is therefore printed from 316L stainless steel. In the design phase, a combination of Solidworks and nTopology was used, to model the first concept of the diamond TPMS heat exchanger. A severe increase in surface area is noticed, compared to the BPHEX. This indicates that the diamond structure heat exchanger can be shrunk in size, to match the brazed plate heat exchanger in effective surface area. Then, the design is adjusted to accommodate a more efficient flow at the ins and outlets. In the test phase, a test plan was set up (figure 2). The first test uses small samples to validate the leak tightness and the pressure resistance of the diamond TPMS structure (Figure 3). The results show that cell size does not have a major influence. However, the wall thickness should be at least 0.50 mm, to guarantee water tightness. Due to time and modelling restrictions, tests 2 and 3 are yet to be executed. Test 2 measures the flow rate and test 3 measures the heat transfer

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rate of both the brazed plate heat exchanger and the Diamond TPMS heat exchanger. This results in a good insight into the performance of both heat exchangers. Performance-wise, the 3D-printed heat exchanger looks like the best option (Figure 4). The 3D-printed heat exchanger has a higher surface-to-volume ratio, an efficient flow within the structure and a lower weight. However, the cost price per part is significantly higher than the price of the brazed plate heat exchanger. Three things are shown, to convince clients of choosing metal additive manufacturing at NTS Norma. The BPHEX, the first concept and final design display the design progress. Test 1b is shown, to visualise the water tightness and pressure resistance of the thin-walled structure. Three posters provide background information, to offer a self-explanatory whole. Finally, The Diamond TPMS structure heat exchanger needs further research and tests, to be developed into a working prototype. This means that the entire heat exchanger must be printed. However, the diamond TPMS heat exchanger, only manufacturable with metal additive manufacturing, shows what is possible with metal additive manufacturing at NTS Norma and how the design for additive manufacturing can meet the standards of conventional manufacturing techniques or even strive beyond.

Figure 1 - Picture of the WP112M-20, the brazed plate heat exchanger (BPHEX).

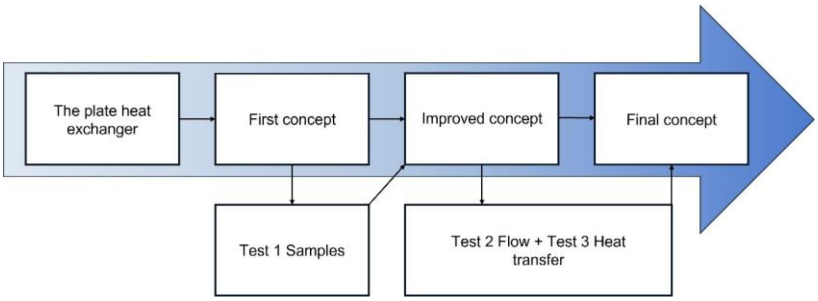

Figure 2 - A visual representation of the design process, including tests 1, 2 and 3.

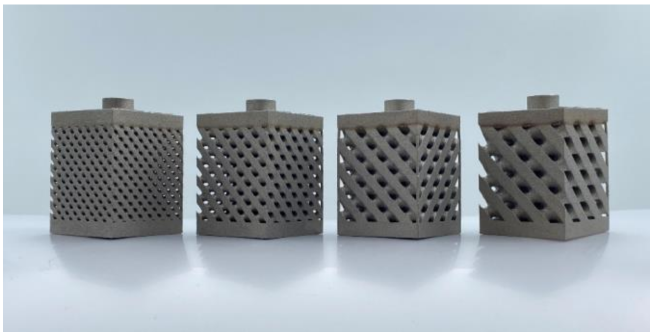

Figure 3 - Four samples, designed for test 1. The cell size changes from 4 mm (left) to 6 mm to 8 mm to 10 mm (right).

Figure 4 - A rendering picture of the final design of the Diamond TPMS heat exchanger

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