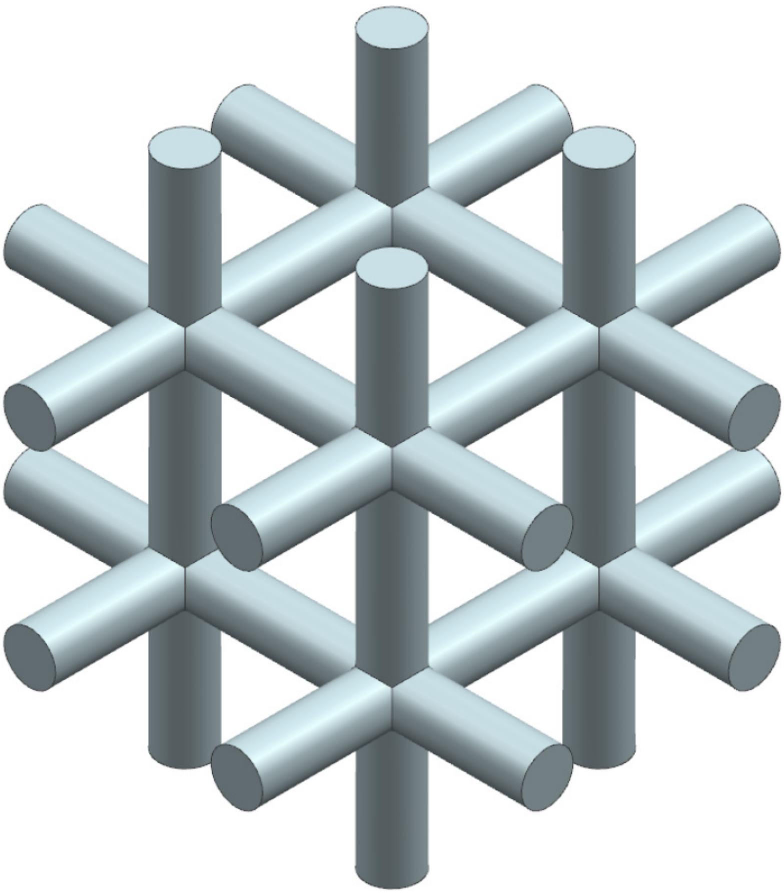
Hessisches Kompetenzzentrum für Hochleistungsrechnen

Enhanced Compact Heat Exchangers



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2013 - 2015

Project Areas
Heat Energy Technology, Thermal Machines, Fluid Mechanics

Clusters
Lichtenberg Cluster Darmstadt

Institute
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Introduction

Heat exchangers are used wherever energy is to be transformed from a high temperature fluid stream to another at lower temperature. Cooling of computer chips, cooling of air plane turbine blades, heating of bleed air and air conditioning are some common examples for heat exchanger applications. Researchers are investigating heat exchangers intensively and aim to build more efficient heat exchangers. Aims of optimization are minimizing the size of the heat exchanger or minimizing the pumping power (cost), which is required to drive the cool fluid through the heat exchanger, or maximizing the amount of heat transferred (benefit) by the heat exchanger.

Methods

The area across which heat transfer occurs is called wetted area and is a possible key factor for optimizing heat exchangers. Pin fins, wire meshes, metal foams and other open-cell structures all serve to increase the wetted area.[1-5] However, the design of these open-cell structures can be influenced only to a certain degree. Furthermore, these structures are not specifically designed to optimize heat exchangers. They are used, because they are readily available. In contrast, Direct Metal Laser Sintering [6] allows the design and production of arbitrary open-cell structures. Direct Metal Laser Sintering is able to produce competitive open-cell heat exchangers.[7] This possibility raises the question, how an optimal open-cell structure looks like. Detailed knowledge about the impact of design parameters, such as pore size or strut diameter, is required to answer this question. In addition, investigations are required on where the heat is actually transferred to within the open-cell heat exchange. In other words: How much of the wetted area contributes to the heat transfer? This project aims to answer this question. Therefore, a numerical investigation of two open-cell heat exchangers is performed in 3D using the openFOAM chtMultiRegionFOAM solver.

Results

Two different open-cell heat exchangers were designed. Figure 1 and Figure 2 show the unit cells that were patterned in space to construct the two open-cell heat exchangers. The wetted area of the cubic design (Figure 1) is twice as large as the wetted area of the tetradecahedral design (Figure 2). However, the maximal solid cross-sectional area of the cubic design is 2.3 times larger than the one of the tetradecahedral design. Numerical as well as experimental results[7] show that the pumping power that is required by the cubic design is 2.5 times higher than the required pumping power (cost) of the tetradecahedral design, while the amount of heat transferred (benefit) is equal for both designs.

Discussion

Thus, the overall heat exchanger costbenefit ratio of the tetradecahedral design is about five times better as the cost-benefit ratio of the heat exchanger cubic design. A closer look on the amount of wetted area that contributes to the heat transfer unveils that only a fraction of the wetted area is contributing to the heat transfer in both cases. Areas with small temperature difference between hot and cold stream, such as recirculation areas, do not contribute to the heat transfer. At the moment, further numerical simulations are executed in order to investigate the two heat exchangers at different operating conditions.

Figures

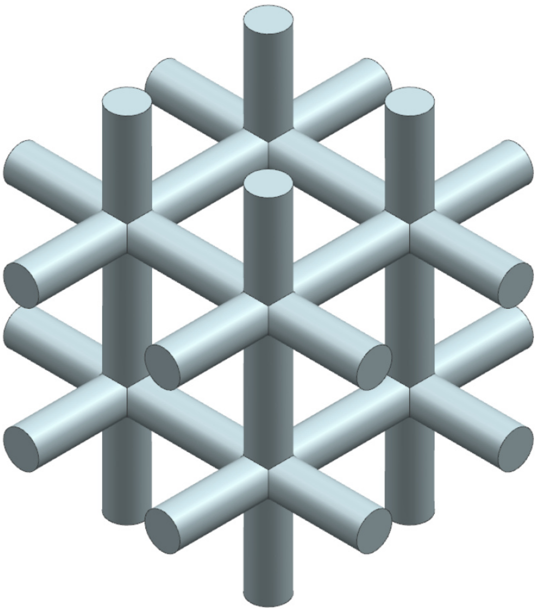

Figure 1: Cubic design.

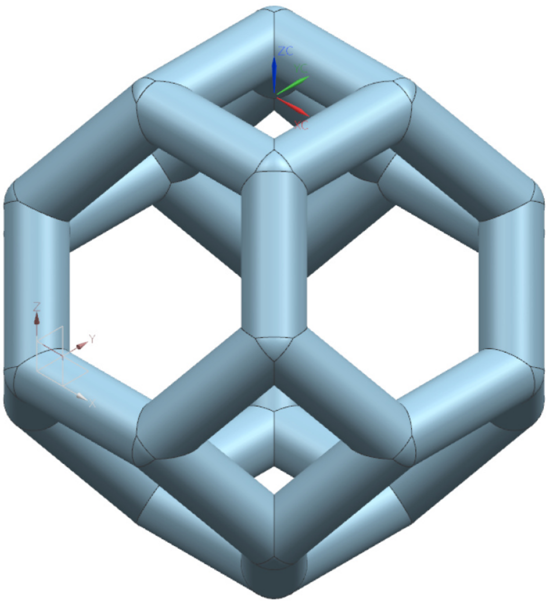

Figure 2: Tetradecahedral design.

Reference

[1] L. Tianjian (2002), Ultralight Porous Metals: from Fundamentals to Applications, Acta Mechanica Sinica, vol. 18(5): 457– 479. http://dx.doi.org/10.1007/BF02486571

[2] J. P. Bonnet, F. Topin, and L. Tardist (2008), Flow Laws in Metal Foams: Compressibility and Pore Size Effects, Transport in Porous Media, vol. 73(2): 233–254. https://doi.org/10.1007/s11242-007-9169-5

[3] A. Bhattacharya and R.L. Mahajan (2006), Metal Foam and Finned Metal Foam Heat Sinks for Electronics Cooling in BuoyancyInduced Convection, ASME Journal of Electronic Packaging, vol. 32(128): 259–266. https://doi.org/10.1115/1.2229225

[4] J. Banhart (2001), Manufacture, Characterization and Application of Cellular Metals and Metal Foams, Progress in Material Science, vol. 46: 559–632. https://doi.org/10.1016/S0079-6425(00)00002-5

[5] T. J. Lu, L. Valdevit, and A.G. Evans (2005), Active Cooling by Metallic Sandwich Structures with Periodic Cores, Progress in Materials Science, vol. 50: 789–815. https://doi.org/10.1016/j.pmatsci.2005.03.001

[6] M.W. Khaing, J.Y.H Fuh, and L. Lu (2001), Direct Metal Laser Sintering for rapid tooling: processing and characterization of EOS parts, Journal of Materials Processing Technology, vol. 113: 269–272. https://doi.org/10.1016/S0924-0136(01)00584-2

[7] R. Rezaey, F. Loosmann, S. Chandra, and C. Tropea (2013), Experimental investigation of heat transfer and fluid flow in laser sintered heat exchangers, ExHFT-8 Book of Abstracts, vol. 8: 67.

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