HEAT EXCHANGER DESIGN WITH HIGH-PERFORMANCE GEOMETRY

Kalinina M.F., Mykolaichuk V.V.
Igor Sikorsky Kyiv Polytechnic Institute, m12.vovk@gmail.com

Introductions. A typical implementation of heat exchange equipment is plate, shell and tube heat exchangers, heat exchangers of the "Pipe in a pipe" type. These designs were designed back in the last century and due to the limitations of technological manufacturing processes for some time were without alternatives. However, the design of heat exchangers with high-performance geometry is a new direction in the development of heat exchangers. These heat exchangers have an unusual shape, which allows to improve their performance and efficiency [1].

Standard heat exchangers have their limitations regarding their productivity and efficiency [2]. For example, they can have a limited effective heat exchange surface, high hydraulic resistance and uneven distribution of heat between heat carriers.

Optimizing standard heat exchangers using high-performance geometries can improve their performance and efficiency, which will reduce process energy costs and increase the efficiency of heat exchange processes [3].

There are several ways to optimize heat exchangers with highly efficient geometry [4]:

1. Use of computer modeling: Modern programs for modeling heat exchange can help in determining the optimal geometry of the heat exchanger. They can provide a detailed analysis of heat transfer efficiency with different geometric parameters of the heat exchanger.

2. Application of new materials: The use of new materials, such as composite materials or materials with high thermal conductivity, can improve heat transfer efficiency and reduce hydraulic resistance.

3. Use of special geometry: High-performance heat exchanger geometries can be designed to improve heat transfer. For example, micro-ribs, micro-channels or perforated plates can provide improved heat transfer efficiency and reduced hydraulic resistance.

4. Selection of optimal parameters: Optimal parameters of the heat exchanger can be determined to increase the efficiency of the heat exchange, such as the size and shape of the heat exchange surface, the size of the tubes or channels, and the number and size of the holes.

5. Use of alternative technologies: New technologies such as direct contact technologies can provide improved heat transfer efficiency.

These optimization paths can be used individually or in combination to achieve the most efficient heat exchanger design [5].

The shape of the surface of heat exchangers with high performance geometry can be very diverse, depending on the specific design of the heat exchanger and its purpose. However, in general, the surface of such a heat exchanger has a complex geometry that includes various elements and structures that provide a larger heat exchange area and improved efficiency [6].

Gyroid channels of complex geometry are a geometric form of channels used in heat exchangers with high-performance geometry to increase heat exchange performance. Gyroid is a mathematical shape that arises when interpreting a mathematical function in three-dimensional space. The geometry of the gyroid has a complex structure with different sizes of pores connected by thin partitions [7]. This structure resembles a network of interwoven hollow tubes (Fig. 1).

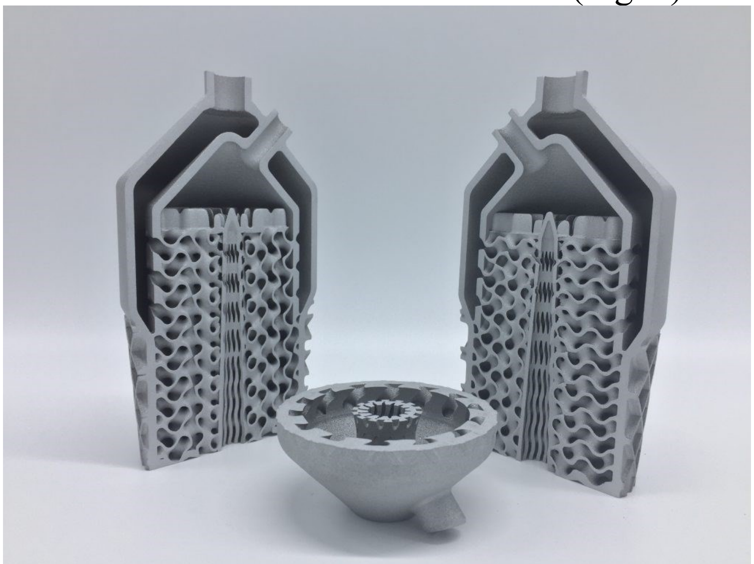

Fig. 1. Heat exchanger with gyroid canal [2]

Channels of complex geometry of heat exchangers with high-performance geometry provide a larger contact surface between heat carriers and contribute to more efficient heat exchange. In addition, such channels make it possible to reduce hydraulic resistance, which reduces energy consumption for pumping coolants through the heat exchanger.

The use of gyroid canals in heat exchangers with high-performance geometry is the latest engineering solution that can increase the performance of heat exchange and reduce energy costs for its provision.

Materials and methods. The methods and materials used in heat exchangers with high-performance geometry can be varied, depending on the specific design of the heat exchanger and its purpose. However, in general, they are based on a geometric and physical description that helps to provide a larger heat transfer area and improve efficiency.

The geometric description in heat exchangers with high-performance geometry includes the description of the shape of the surface of the heat exchanger and the location of its elements, such as fins, partitions, etc. The description of the shape of the surface of the heat exchanger can be complex and include various geometric elements that provide a larger heat exchange area. The location of the elements on the surface of the heat exchanger and their geometry also help to improve the efficiency of heat exchange.

The physical description in heat exchangers with high-performance geometry includes the description of thermal processes occurring in the heat exchanger and the use of materials with certain properties. For example, using materials with high thermal conductivity that allow heat to be transferred quickly and efficiently can improve heat transfer efficiency. Materials that have a certain porosity or texture can also be used, which provides a larger area for heat exchange.

Regarding the methods, various design and optimization methods are used in heat exchangers with high performance geometry, such as numerical simulation, optimization by simulated annealing method, genetic algorithm method, etc.

Results and discussion. During the production of lysine at the stage of concentration of KRL, the medium is heated to a certain temperature using a shell and tube heat exchanger. Thus, replacing a shell-and-tube vertical heat exchanger with a heat exchanger with a high-performance geometry can have several advantages.

First of all, the new heat exchanger with high-performance geometry can provide more efficient heat exchange, thanks to its complex geometry, which provides an increase in the heat exchange area. This can lead to lower energy costs and lower temperature losses.

With these advantages in mind, replacing a shell-and-tube vertical heat exchanger with a heat exchanger with a high-performance geometry can be a profitable step for the enterprise.

Conclusions. There are different types of heat transfer intensification, such as the use of surface stresses, the installation of internal obstacles, the use of high-performance heat exchanger geometries, etc. Each of these methods has its advantages and disadvantages.

The use of high-performance geometry of heat exchangers, such as gyroid channels, makes it possible to increase the efficiency of heat exchange and reduce energy costs. In addition, high-performance heat exchangers can provide more efficient use of heat exchange in various industries, such as industrial, automotive and energy industries.

On the basis of the conducted analytical research, it is advisable to replace the heat exchanger of the stage of heating the lysine culture liquid from a shell-and-tube heat exchanger to a high-performance heat exchanger with gyroid channels. This will reduce energy costs for heating the liquid and ensure more efficient heat exchange.

References:

1. Tozhbe S., Kokaef D., Kokaef I. (2019). Overview of heat exchanger design and optimization methods: Comprehensive analysis. Energy conversion and management.

2. NTopology. (2021). Heat exchanger design with highly efficient geometry. https://ntopology.com/blog/heat-exchanger-design-high-performance/

3. Ma, H., Balaji, K. (2019). Investigation of heat transfer and fluid flow in corrugated channels using numerical simulation. International Journal of Heat and Mass Transfer.

4. Xu, H., Guo, L., and Wu, H. (2016). Thermal analysis and design optimization of radiators with a hybrid shape. Applied heat engineering.

5. Zhang, P., Wu, Z., Li, S., Li, J., and He, Y. (2021). Design of a radiator with gyroid channels using multi-criteria optimization. International Journal of Heat and Mass Transfer.

6. Savchenko, M. Yu., Kostromina, M. A. (2018). Research of heat exchangers with corrugated surfaces. Technical thermophysics and energy.

7. Skrypchenko, I. I., Bibyk, O. V., Panchenko, O. M. (2018). Study of the influence of channel geometry on the intensification of heat exchange. Scientific Bulletin of the Ivano-Frankivsk National Technical University of Oil and Gas.