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NUMERICAL SIMULATION OF THE EFFECT OF BAFFLE ON HEAT TRANSFER PERFORMANCE OF SHELL-AND-TUBE HEAT EXCHANGER

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ЧИСЛЕННОЕ МОДЕЛИРОВАНИЕ ВЛИЯНИЯ ПЕРЕГОРОДКИ НА ТЕПЛООБМЕННЫЕ ХАРАКТЕРИСТИКИ КОЖУХОТРУБНОГО ТЕПЛООБМЕННИКА

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Abstract. Baffle heat exchanger is widely used in various production activities because of its simple design and strong adaptability, so the structural optimization of baffle heat exchanger is of great significance to engineering practice. COMSOL software was used to simulate the shell-and-tube heat exchanger with baffles. By comparing and analyzing the simulation results, we find that the temperature field and pressure field of baffle plate are distributed evenly; The existence of baffles leads to the transverse flow of air, which increases the heat exchange area. Another advantage of using baffles is that vibration due to fluid flow can be reduced.

Аннотация. Теплообменник с перегородками широко используется в различных производственных процессах из-за его простой конструкции и высокой адаптируемости, поэтому оптимизация конструкции теплообменника с перегородками имеет большое значение для инженерной практики. Программа COMSOL использовалась для моделирования кожухотрубного теплообменника с перегородками. Сравнивая и анализируя результаты моделирования, мы обнаруживаем, что поле температуры и поле давления перегородки распределены равномерно; наличие перегородок приводит к поперечному потоку воздуха, что увеличивает площадь теплообмена. Еще одно преимущество использования перегородок заключается в том, что можно уменьшить вибрацию из-за потока жидкости.

Keywords: shell and tube heat exchanger, baffle plate, COMSOL, numerical simulation.

Ключевые слова: кожухотрубный теплообменник, перегородка, COMSOL, численное моделирование.

Research Background and Theoretical Research

Heat exchanger is an important equipment widely used in chemical, petroleum, power, food and other industries. Its function is to transfer some heat of hot fluid to cold fluid [1]. At present, there are many heat exchangers, such as tube-shell heat exchanger, interwall heat exchanger, casing heat exchanger and so on. Among many kinds of heat exchangers, shell and tube heat exchangers are widely used in various industries because of their advantages [2] simple manufacture, perfect R & D process and can be used in various working conditions. The conventional tube-shell heat exchanger uses a single bow baffle as its supporting structure for enhanced heat transfer. However, the tube-shell heat exchanger has some disadvantages such as large shell side pressure loss, low heat transfer efficiency, easy scaling and easy flow dead zone during heat exchange [3–5]. Because the heat transfer performance and operation reliability of the heat exchanger affect the product quality and the enterprise benefit, it is necessary to optimize the structure of the tube-shell heat exchanger to improve the heat transfer performance and operation reliability of the tube-shell heat exchanger. One of the most effective methods is to open holes on the bow baffle.

Yu Jiuyang designed a variety of opening schemes, combined with the advantages of large tube hole baffle and bow baffle, the flow resistance and heat exchanger were tested. According to the experimental results, Expand the opening of the baffle plate, helps to enhance heat transfer efficiency and reduce shell flow resistance, Heat transfer and flow performance of shell side have been significantly improved [6]. Xie Guoxiong designs 5 kinds of opening schemes on the single bow baffle and carries on the experiment inquiry, A proper number of holes in the proper part of the bow baffle plate is found to be beneficial to improve the heat transfer efficiency of the heat exchanger and reduce the flow resistance [7] of the shell side. J. Taborek in the process of studying the tube - shell heat exchanger, it is found that the relationship between the diameter of the shell of the tube-shell heat exchanger and the distance between the baffle plate, the better heat transfer effect of 0.2~1 time shell diameter is [8]. With the development of numerical heat transfer (NTH) and computational fluid dynamics (CFD) research, Numerical simulations and calculations of heat transfer have also developed rapidly, and widely used in practical engineering, among them, it is very important to explore the numerical simulation of shell side of tube-shell heat exchanger. S. V. Pakanter and D. B. Spalding in the process of numerical simulation of shell side of tube-shell heat exchanger, put forward the idea of distributed resistance, Hydraulic tube-shell heat exchanger is used for numerical simulation [9]. W. T. Sha based on our predecessors, Introducing the concept of surface permeability, and successfully use the model to complete the two-dimensional numerical simulation [10] of the shell side. Chao Zhang et al. target the power plant condenser, by means of mass conservation equation, momentum conservation equation and fractional air mass conservation equation, the error of simulation results and test data is small, Data are consistent [11].

Methodology and shell-and-tube heat exchanger geometry

The flow and heat transfer process of tube-shell heat exchanger follow the law of mass conservation, energy conservation and momentum conservation. Because the shell flow of tube-shell heat exchanger usually belongs to turbulent state, the standard model is selected according to the basic heat transfer equation and fluid flow law. A standard κ-ε model [12] is as follows:

$$p\frac{\partial k}{\partial t}+pu_i\frac{\partial k}{\partial x_i}=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\delta_k}\right)\frac{\partial k}{\partial x_j}\right]+G_k+G_b-p\varepsilon-Y_M+S_k \quad (1)$$

$$p\frac{\partial k}{\partial t}+pu_i\frac{\partial \varepsilon}{\partial x_i}=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\delta_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right]+C_{1\varepsilon}\frac{\varepsilon}{k}\left(G_k+G_{3\varepsilon}G_b\right)-C_{2\varepsilon}p\frac{\varepsilon^2}{k}+S_\varepsilon \quad (2)$$

In the formula, the turbulent dissipation rate is ε; G_k is the turbulent kinetic energy generation term caused by the average velocity gradient; Y_M is the effect of compressible turbulent pulsation expansion on the total dissipation rate; t is time, unit is S; μ is turbulent viscosity in units $kg/(m \cdot s)$; p is fluid density in units kg/m^3, The empirical constant is $G_{1\varepsilon}=1.44$, $C_{3\varepsilon}=1$, $C_\mu=0.09$; k is turbulent kinetic energy, u_i is speed, unit m/s, u_t is turbulent viscosity in units $Pa \cdot s$.

Results and discussion

The heat exchanger is made of structural steel. Two fluids flow through the heat exchanger. The first fluid Water flows through the tube, and the second fluid (air) flows in the shell of the heat exchanger. The initial temperature is different when flowing into the heat exchanger, but after cycling in the heat exchanger, the temperature of the two is close to a balance Temperature. The presence of baffle plates leads to lateral flow of air, which increases the heat exchange area. Other using baffles one advantage is that vibration due to fluid flow can be reduced.

Figure 2 shows the uplift distance of the upper wall. This is the wall lift distance in the tube, which may be the most critical area in terms of grid resolution. It is about 10% of the radius of the tube, which is enough.

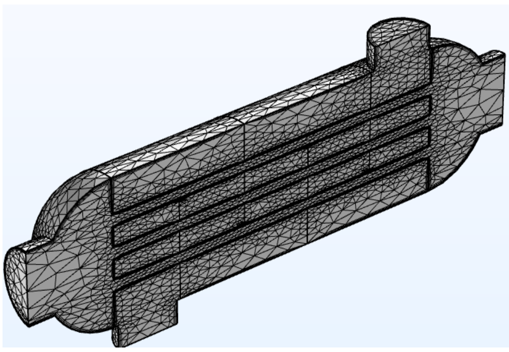

Figure 1. Mesh of tube-shell heat exchanger model.

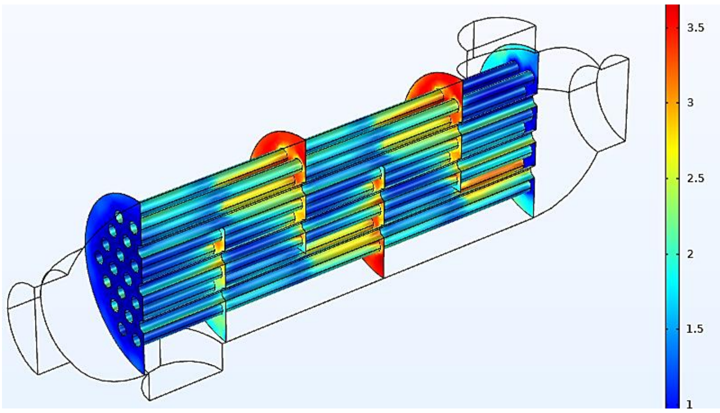

Figure 2. Wall lifting distance of the tube.

The velocity of the tube path indicates that the velocity distribution in the tube is very uniform. Before the water flows into the pipe, there is a reflux zone. Streamline color indicates the temperature, we can see that the temperature of the two exits is very close.

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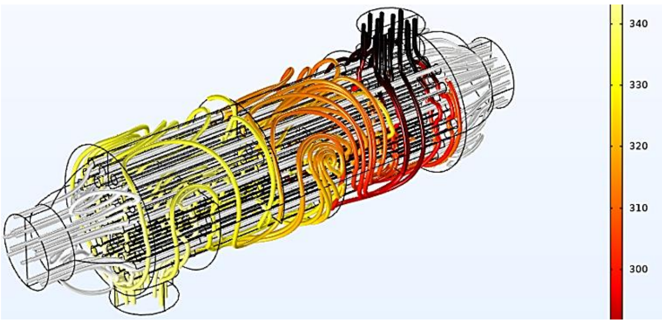

Figure 3. Streamline diagram.

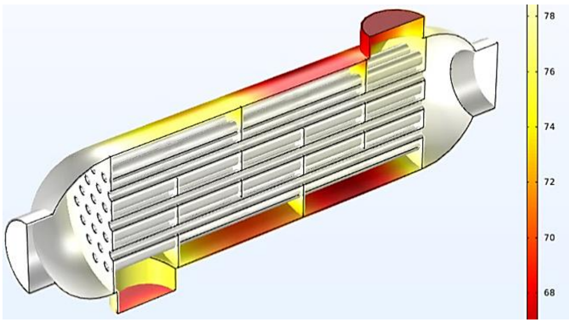

Figure 4. Temperature on the heat exchanger boundary.

We use several physical quantities to describe the characteristics and efficiency of heat exchangers, one of which is the equivalent heat transfer coefficient, expressed as

$$h_{eq} = \frac{P}{A(T_{hot} - T_{cold})} \tag{3}$$

Among them, where P is the total switching power and A is the surface area through which the P flows. In this model, the value of h_{eq} is 5.5 $W/(m^2 \cdot K)$. The pressure drop of tube side is about 38 Pa, shell side is about 13 Pa.

Conclusion

Based on the numerical simulation of tube-shell baffle with COMSOL software, the following conclusions can be drawn by analyzing velocity field, pressure field and temperature field:

1) In the shell flow field of the tube-shell baffle heat exchanger, the back of the baffle is easy to form a retention zone, which results in uneven distribution of temperature, velocity and pressure, which has a certain negative effect on the heat transfer performance of the tube-shell baffle heat exchanger.

2) With the continuous improvement of inlet velocity, the retention area of the back of the baffle plate is also increasing. Compared with the open baffle plate, the open baffle plate can effectively reduce the retention area, make the distribution of temperature field and pressure field more uniform, and play a positive role in improving the heat transfer performance of-shell heat exchanger.

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