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HEAT EXCHANGE PROCESSES IN A SHELL-AND-TUBE HEAT EXCHANGER

Husanov Nurmukhammad
Senior lecturer
Sh.B. Abdukhalilova
AssistantFerghana Polytechnic Institute

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Abstract. *the article presents methods for calculating heat exchangers by design, size and surfaces.*

Keywords: *heat exchangers, shell-and-tube heat exchanger, geometry of the heat exchange surface, heat transfer coefficient, thermal and hydraulic calculations*

ТЕПЛООБМЕННЫЕ ПРОЦЕССЫ В КОРПУСНО-ТРУБНОМ ТЕПЛООБМЕННИКЕ

Аннотация. *В статье представлены методы расчета теплообменников по конструкции, размерам и поверхностям.*

Ключевые слова: *теплообменники, кожухотрубный теплообменник, геометрия поверхности теплообмена, коэффициент теплопередачи, тепловые и гидравлические расчеты.*

INTRODUCTION

Based on the analysis of various geometries of heat exchange surfaces, it is possible to distinguish the heat exchange surfaces of the following geometry (Figure 3):

- flat surface;
- round surface (convex or concave).

Figure 3 – Geometry of heat transfer surfaces: a – flat surface; b – round surface

In the heat exchanger proposed by us (see Figure 2), as a heat exchange surface, there are both surfaces of circular geometry (ribs, tube) and flat (plates).

To determine the heat transfer coefficient of a liquid, it is advisable to investigate the process of heat exchange between the heated liquid and the heat exchange surface (rib and plate). It is necessary to determine the temperature distribution over the surface of the rib and plate.

MATERIALS AND METHODS

Mathematical modeling

It is known that the coefficient of heat transfer from a heated solid (for example, a plate, a cylinder) to a liquid, W / (mI• K), is determined by the formula [1]:

$$\alpha = \frac{\lambda_{ж} Nu}{l}, \qquad (1.2)$$

where the coefficient of thermal conductivity of the liquid, W / (m • K), Nu is the Nusselt number, l is the defining geometric parameter of the surface (for the plate – length, m, and for the cylinder – its diameter), m.

The fundamental research of the heat transfer process, for example, from a heated solid surface of a certain geometry, was carried out by prominent Soviet scientists - academicians Mikheev M.A. and Kutatelladze S.S. [2].

The Nusselt number Nu, used by them to calculate the heat transfer coefficient α, W/(m2K), from a heated surface to a cold liquid, contained the criterion values of the Reynolds (Re) and Prandtl (Pr) numbers.

RESULTS

Mikheev M.A. proposed to use the ratio [2] to determine the coefficient of heat transfer from a flat plate to a liquid:

$$\overline{Nu} = 0,037\,\mathrm{Re}^{0,8}\,\mathrm{Pr}_{ж}^{\;0,43}\left(\mathrm{Pr}_{ж} / \mathrm{Pr}_{cm}\right)^{0,25}. \qquad (1.3)$$

It should be noted that the multiplier (Rg / Rg) 0.25 is an amendment that takes into account the effect of changes in the physical parameters of the coolant with a change in temperature on heat transfer. This multiplier characterizes the dependence of heat transfer on the magnitude of the heat flow. This ratio is applicable when the temperature of the plate does not change along the length.

However, when calculating the Nusselt number for the design of the proposed heat exchanger, it is necessary to take into account the turbulence value of the fluid flow.

With the transverse flow of a single pipe (cylinder) in the vicinity of the frontal point, the heat transfer coefficient is calculated:

$$\alpha_{\varphi=0} = 1,04\lambda_{ж}(U_0 / \nu d)^{0,5}\,\mathrm{Pr}_{ж}^{\;1/3}, \qquad (1.4)$$

Where U0 is the velocity at the frontal point of the cylinder, m/s, d is its diameter, M.

Kutatelladze S.S. to determine the average heat transfer coefficient of the plate, he also proposed a dependence that differs somewhat from the ratio of M.A. Mikheev (1.1) by a multiplier before the number Pr and the value of the exponent at the numbers Pr and Re, as well as the absence of the multiplier (Rgj / Rgst) is 0.25 [3].

DISCUSSION

Kutateladze S.S. proposed to calculate the heat transfer of a single cylinder to determine the number Nu by the formula:

$$Nu \approx 1,14C\,\mathrm{Pr}_{ж}^{\;0,4}\,\mathrm{Re}^{m}, \qquad (1.5)$$

where the coefficients C and m depend on the values of the number Re [4].

Zhukauskas A.A. obtained a dependence for calculating the number Nu, also with other coefficients for the numbers Pr and Re [5]. He took into account the turbulence of the flow when flowing around a single cylinder at the frontal point.

$$Nu = 0,43\,\mathrm{Re}^{0,6}\,\mathrm{Pr}_{ж}^{0,35}\,Tu^{0,15}(\mathrm{Pr}_{ж} / \mathrm{Pr}_{cm})^{0,25}. \qquad (1.6)$$

To determine the heat transfer coefficient of the liquid α1, we need to investigate the process of heat exchange between the heated liquid and the heat exchange surface (rib and plate).It is necessary to obtain a temperature distribution over the surface of the rib and plate.

Thus, in order to determine the heat transfer coefficient from the outer surface of the heat exchange tube α2, when calculating the Nusselt number characterizing heat exchange at the wall–liquid interface, it is necessary to investigate the turbulence of the liquid flow and obtain the value of the turbulence coefficient Tu, %.

CONCLUSION

1. Shell-and-tube heat exchangers are used at thermal power plants, thermal power plants, nuclear power plants, steam and hot water boilers, central and individual heating points.

2. Intensification of thermal processes of shell-and-tube apparatuses is an important task, since the dimensions, the number of sections and the cost of the heat exchanger depend on them.

3. One of the promising ways to intensify heat exchange processes in shell-and-tube heat exchangers is to change the geometry of the heat exchange surface.

4. A patent-protected design of a shell-and-tube heat exchanger with increased turbulence of the heated liquid flow and heat exchange intensity is proposed.

5. Based on the analysis of work on modeling thermal and hydraulic processes, the purpose and objectives of the research are formulated.

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