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## COMPUTER SIMULATION OF FLOW IN CORRUGATED CHANNEL OF PLATE HEAT EXCHANGER

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**Statement of the problem.** The heat exchange process occurring in a modified corrugated interplate channel of an intensified plate heat exchanger with an increased turbulence of the heat carrier is discussed. A computer model of the coolant movement in the speed range of 0.1—1.5 m/s is developed and the turbulence coefficient of the plate heat exchanger is determined.

**Results.** The article presents the results of computer modeling of the coolant movement in the interplate corrugated channel of the original plate heat exchanger using the Ansys software package. The criteria of system stability are defined. 3D modeling of the channel formed by corrugated plates is performed. In the study of the process of turbulence several high-speed modes of movement of the coolant were considered. The turbulence coefficient  $Tu$ , % is determined.

**Conclusions.** As a result of computer simulation, an increase in the heat transfer coefficient  $K$ ,  $W/(m^2 \text{ } ^\circ C)$  was found due to an increased turbulization of the flow, which leads to a decrease in metal consumption and a decrease in the cost of heat exchange equipment.

**Keywords:** computer simulation, heat transfer coefficient, plate heat exchanger, corrugated surface and the coefficient of turbulence.

**Introduction.** The development of computer technology and its takeover of all spheres of human life and work has become an essential part of technological progress. The ANSYS engineering analysis software is commonly used for performing thermal engineering and hydrodynamic investigations. The complex enables one not only to conduct qualitative modeling of systems of various physical nature, but also to examine the response of these systems to external

influences in the form of distribution of temperatures, stresses, velocities, etc. The use of such programs helps design organizations to reduce the development cycle as well as the cost of products and improve product quality [4].

Currently, plate heat exchangers are commonly employed in the chemical, food industries, heat power engineering and a range of other industries. Their introduction has become cutting-edge in the energy sector of housing and communal services. This is due to the high technical and economic performance of the plate heat exchange equipment. Hence the problem of modernizing and improving the technical characteristics of such equipment is extremely relevant.

The objective of the study is to develop a computer model of the movement of a coolant with increased turbulization based on a 3D model of a corrugated channel of an intensified plate heat exchanger for housing and communal services.

**1. Computer simulation of the movement of the coolant.** Based on the “Practical Guide to the *Ansys* software package [6] for modeling heat exchange processes in an intensified plate heat exchanger, we set forth the following system stability criteria:

- the isothermal process of heat exchange with the environment is considered; *Petrolimex* 60/70 bitumen in accordance with the requirements of TCVN 7493-2005;
- the liquid is incompressible;
- density of the liquid  $\rho$ ,  $\text{kg/m}^3 = \text{const}$  (along the length of the surface);
- fluid movement occurs under the influence of gravity ( $g = 9.81 \text{ m/s}^2$ );
- $W_1 = 0.1\text{—}1.5 \text{ m/s}$  where  $W_1$  is the fluid velocity at the inlet to the heat exchanger;
- liquid temperature  $70^\circ \text{C}$  at an ambient temperature of  $-23^\circ \text{C}$  (according to the temperature schedule of heat energy supply for Belgorod region);
- $p = 0.9 \text{ MPa}$ ,  $p$  is the pressure at the beginning of the considered section of the heat exchange surface;
- convergence of the solution of the model equations is  $10^{-3}$ .

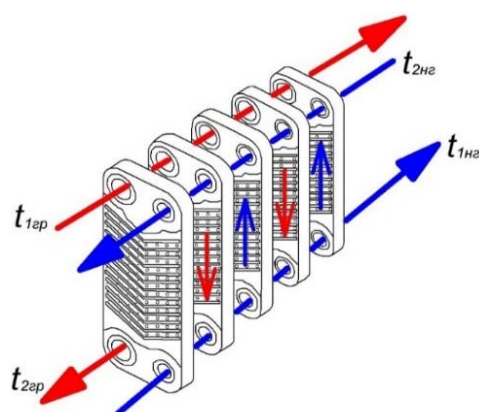
All the methods of intensifying the heat exchange process are designed to increase the heat transfer coefficient  $K$ ,  $\text{W}/(\text{m}^2 \text{ } ^\circ\text{C})$  [5, 11] which for plate heat exchangers is given by the formula:

$$K = \frac{\beta}{\frac{1}{\alpha_1} + \frac{1}{\alpha_2} + \frac{\delta_{CT}}{\lambda_{CT}}}, \quad (1)$$

where  $\beta$  is the coefficient considering the decrease in the heat transfer coefficient due to the thermal resistance of scale and impurities on the plate depending on the quality of the water is

taken equal to 0.7—0.85;  $\alpha_1$  is the coefficient of heat transfer from the heating water to the plate wall,  $W/(m^2 \cdot ^\circ C)$ ;  $\alpha_2$  is the coefficient of heat absorption from the wall of the plate to the heated water,  $W/(m^2 \cdot ^\circ C)$ ;  $\delta_{CT}$  is the thickness of the heat exchange plate, m;  $\lambda_{CT}$  is the coefficient of thermal conductivity of the plate material,  $W/(m^2 \cdot ^\circ C)$ .

The direction of the flow of heat carriers in the heating and heated circuits is taken in compliance with SP 41-101-95 “Designing Heat Points” counter-current as the most effective for operation in heat supply systems of housing and communal services [10, 14]. The flow diagram of the coolants in the heat exchanger is shown in Fig.1.



**Fig. 1.** Scheme of movement of heat carriers in intensified lamellar heat exchanger:

$t_{1gr}$  is the initial temperature of the heating circuit coolant;  
 $t_{2gr}$  is the final temperature of the heating circuit coolant;  
 $t_{1ng}$  is the initial temperature of the coolant of the heated circuit;  
 $t_{2ng}$  is the final temperature of the heating agent of the heated circuit

In the process of studying the values of the velocities of the coolant movement in the interplate channel of the intensified plate heat exchanger, the following were taken:

- 0.4 m/s as the optimal speed while calculating plate water heaters (this value was established during the review of regulatory documents for the design of heat exchange equipment [8]);
- 1 m/s is taken as the maximum for the standard size of the investigated heat exchanger in compliance with SP 41-101-95 “Designing of Heat Points”;
- 1.5 m/s is the maximum possible speed according to *Ridan* studies.

The liquid pressure at the beginning of the surface was taken as 0.9 MPa, since, according to the normative documentation for the equipment in operation in the internal heating and hot water supply systems of housing and communal services, this value does not exceed 1 MPa.

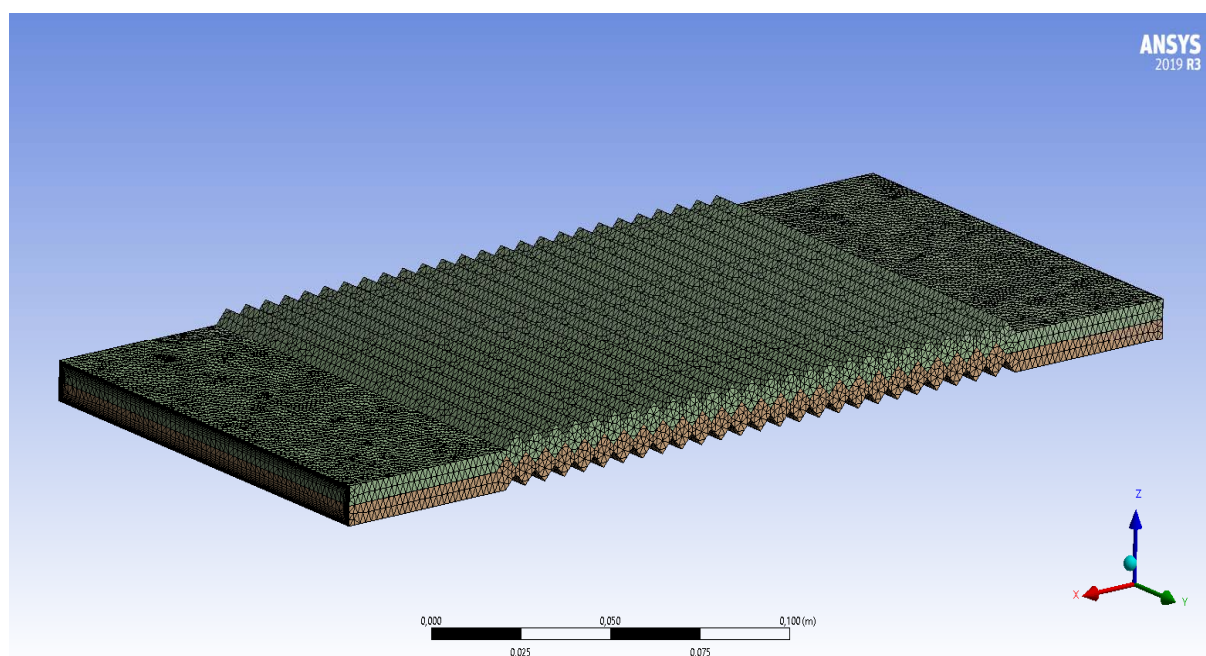
**2. Model of the modified corrugated channel.** We have suggested an original design of an intensified lamellar apparatus whose feature are corrugated plates with spherical depressions, located according to a linear law on the areas between the corrugations [12].

The radius of the spherical indentations  $r_0$  in order to maintain the rigidity of the plate must have a value (0.1 ÷ 0.7) of the plate thickness. The recommended value is 0.35 mm. The dis-

tance between the spherical recesses located in the channels formed by the corrugations, according to the fundamental research of Zukauskas [5],  $(6 \div 12) r_0$  is recommended. This distance ensures the formation of a continuous turbulent wake.

It is recommended that structural and operating methods are employed together, in a complex manner in order to obtain optimal conditions for the heat exchange process. This conclusion is confirmed by theoretical and practical research by A. A. Gukhman [3], since the major process of heat transfer occurs in the boundary layer [1, 19], and hence the development of effective methods for influencing the wall region promotes turbulization of the coolant flow [9, 7, 16].

The main stage in modeling heat exchange processes in the *Ansys* software package is the creation of a 3D model shown in Fig. 2.

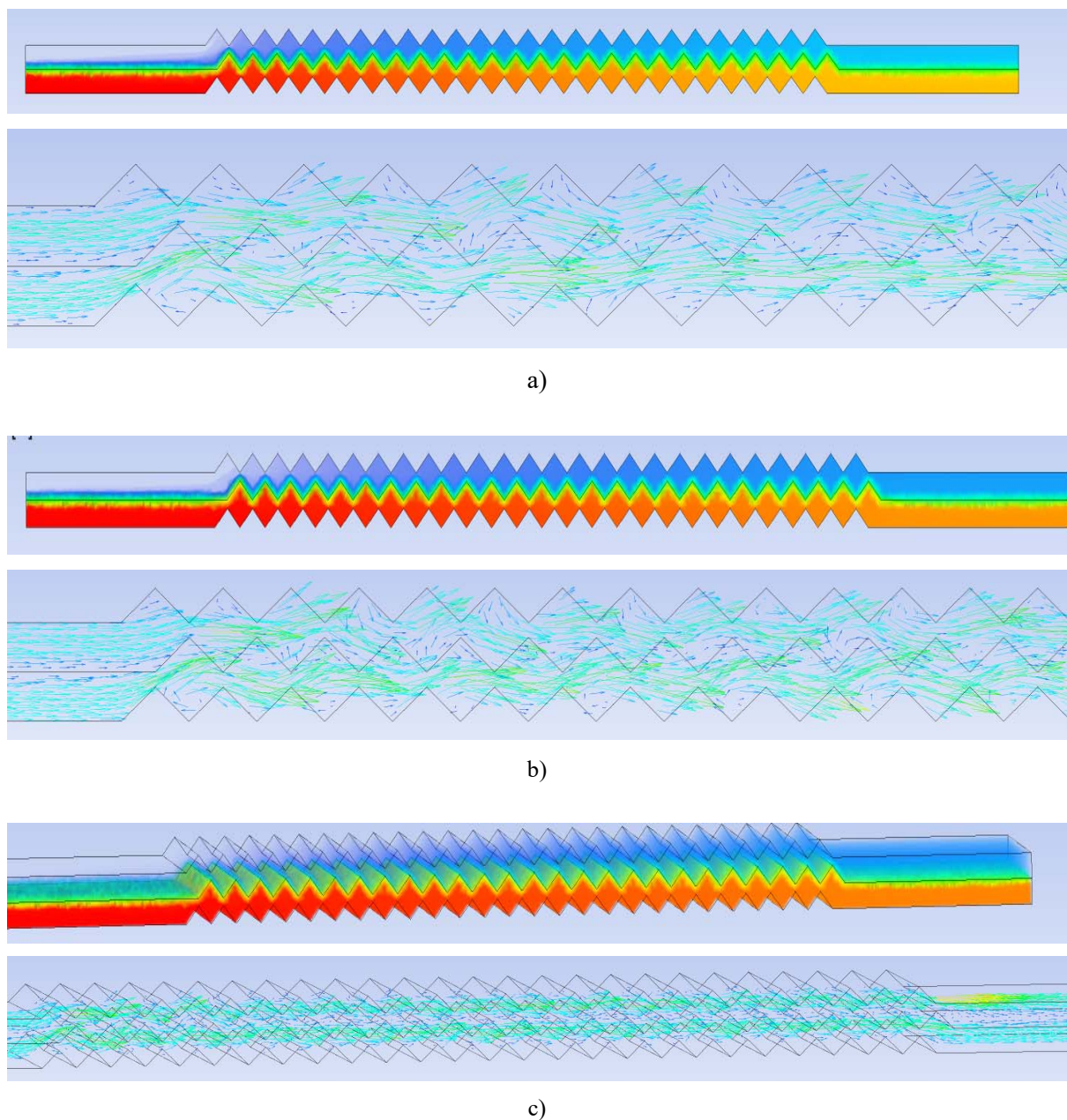


**Fig. 2.** 3D-model of modified corrugated plates

This 3D model of the modified corrugated plates makes it possible to visually identify the turbulence areas located in the temperature boundary layer.

According to the scientific research by X. Kexin, S. Robin, P. Kumar, employees of an engineering center located in New Delhi, a high level of heat transfer in the boundary layer is facilitated by an enhanced renewal of vortex formations, i.e. rapid mixing of some volumes with different temperatures and speeds with others. An increase in the difference between the temperature distribution and the speed of movement of the coolant near the heat-transferring wall with a modified geometry contributes to that in the intensity of heat transfer [15, 17, 18,

20, 21]. In order to identify the turbulization coefficient  $Tu$ , %, the major range of variation of the coolant velocity (from 0.1 m/s to 1.5 m/s) in the modified interplate channel was examined. Limiting mode, 1.5 m/s is not employed in housing and communal services due to the increased flow rate of the coolant, but it presents theoretical interest. The outcomes of the study are presented in the form of the temperature distribution of the coolant in the interplate channel formed by two modified corrugated plates (Fig. 3).



**Fig. 3.** Graphical distributions of the degree of flow turbulization at different flow rates around the modified heat transfer surface: coolant speed — 0.4 m/s (a), 1 m/s (b), 1.5 m/s (c)

When analyzing the results of the graphical distribution of the degree of flow turbulization at different speeds of the coolant, vortex formation zones were identified that contribute to an increase in the efficiency of heat transfer and the heat transfer coefficient  $K$ ,  $W / (m^2 \cdot ^\circ C)$ . Ultimately, a high value of  $K$  will lead to a decrease in metal consumption and a decrease in economic costs.

As a result of computer simulation of the movement of the coolant, the following parameters of the fluid flow were identified:

- 1) the degree of flow turbulization in the entire section of the turbulization zone;
- 2) the length of the turbulization zone (the turbulization zone ends when the turbulence of the flow of the vortex zone and the major fluid flow is equal);
- 3) the height of the turbulization zone.

The average value of the flow turbulence coefficient for calculating the heat transfer coefficient identified using the *Ansys* program is shown in the table.

Table

Average turbulence coefficient  
at different speeds of the coolant in the interplate channel

Coolant speed, m/s	0.1	0.25	0.5	0.75	1	1.25	1.5
Turbulence coefficient value for modified corrugated plate $Tu, \%$	2.4	4.3	6.9	11.1	14	19.7	24.6

Using the least squares method [2], we obtain linear dependences of the turbulization coefficient on the average fluid velocity of the interplate channel for the modified corrugated plate  $Tu, \%$ .

$$Tu = 13.4 W, \quad (2)$$

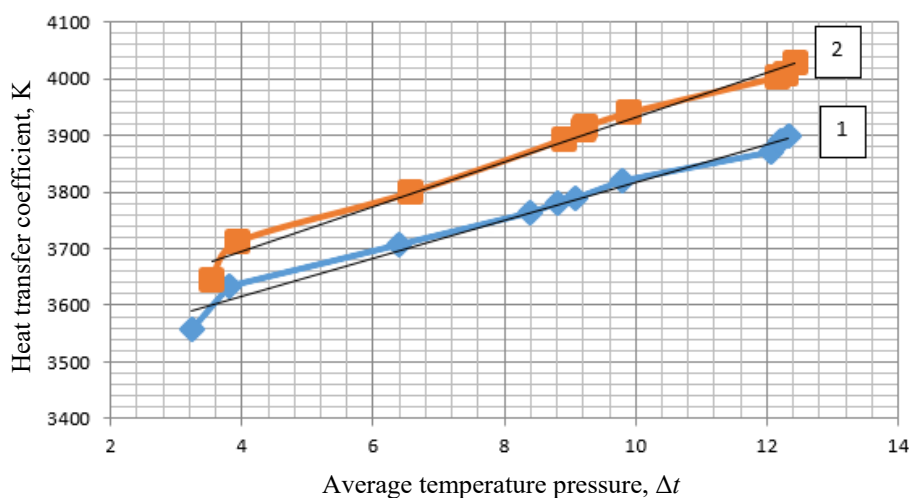
where  $W$  is the coolant velocity in the interplate channel, m/s.

Hence, as a result of computer simulation of the movement of the coolant in the corrugated interplate channel, the turbulization coefficient  $Tu, \%$ , necessary to improve the method of calculating the heat transfer coefficient  $K$ ,  $W/(m^2 \cdot ^\circ C)$ , which is the major characteristic of the efficiency of the heat exchange equipment, was identified. It has been established that the use of original plates with spherical recesses causes an increase in the heat transfer coefficient  $K$ ,  $W/(m^2 \cdot ^\circ C)$  [16]. The results of experimental studies are shown in Fig. 4.

As the graph indicates, the heat transfer coefficient of an intensified plate heat exchanger increases linearly as does the coefficient of a serial plate heat exchanger, but the value  $K$  for the



equipment in question is higher by an average of 5%, which signals the efficiency of employing corrugated plates with spherical recesses located according to the linear law.



**Fig.: 4.** Graph of the dependence of the heat transfer coefficient on the temperature head:  
1 is a plate heat exchanger with corrugated plates; 2 is an intensified plate heat exchanger  
with modified corrugated plates

## Conclusions

1. The above method of intensification of heat exchange processes, i.e., the application of spherical depressions according to a linear law, leads to an increase in the turbulization of the coolant.
2. It has been experimentally established that spherical depressions with a radius of 0.35 mm retain the plate rigidity and cause the appearance of a vortex zone, which promotes more efficient mixing of the coolant.
3. The comparison of the two plate heat exchangers confirms the advantage of employing modified corrugated plates.
4. The height of the turbulization zone was 30% of the accepted radius of the spherical deepening.
5. A high value of the heat transfer coefficient will cause a decrease in the cost of heat exchange equipment, as well as in overall dimensions (metal consumption) and an increase in service life.

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