METHODOLOGY OF TEACHING AND OBTAINING CRITERIA DEPENDENCIES IN THE COURSE OF SPECIAL DISCIPLINES OF THERMAL ENGINEERING PROFILE

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ANNOTATION: *In the context of integration of science, education and technology, in order to prepare specialists in the heat and power engineering profile, information is needed on theoretical and experimental research methods, on methods of processing results used in this field of science. It is necessary to emphasize that the main attention should be paid to the disclosure of the theory, tasks, types and forms and the basics of planning the experiment. This work proposes a methodology for teaching the above-mentioned topic and obtaining criteria, as well as dependencies characterizing heat and mass transfer processes in industrial heat exchangers.*

Key words: *education, technology, differentiation and integration, heat and mass transfer , industrial power engineering, machine tools, film condensation, gaseous state, Nusselt criteria, Peclet criterion, Stanton criterion*

In the context of the integration of science, education and technology, in order to prepare specialists in the heat and power engineering profile, information is needed on theoretical and experimental research methods, on the methods of processing the results used in this field of science. As shown by many years of experience in teaching special disciplines in the heat engineering profile and practice, the solution of many scientific and technical problems is simplified by applying the theory of dimensionality, similarity and modeling. [1,2]. It should be emphasized that the main attention should be paid to the disclosure of the theory, tasks, types and forms and the basics of planning the experiment. The processing of the results of the experimental study is carried out on the basis of the methods of graphical processing of experimental data, graphical differentiation and integration. Then, mathematical descriptions of the process under study are performed, empirical formulas are selected, conclusions and proposals are formulated.

This paper proposes a methodology for teaching the above-mentioned topic and obtaining criteria, as well as dependencies characterizing heat and mass transfer processes in industrial heat exchange devices.

The educational and training task is to explain the physical nature of thermal conductivity , convective heat and mass transfer and teach students to conduct experiments , measure thermophysical parameters, and perform calculations in heat and mass exchange devices of power plants. Of greatest practical interest is film condensation, which is mainly encountered in various types of industrial heat exchange devices, where there is forced movement of steam along rough wetted cooling surfaces . The study of the heat transfer process during film condensation is actually reduced to the study of the process of heat exchange of a liquid film with the wall surface, i.e. heat exchange between a solid and a single-phase medium. However, the peculiarity of the process under study is that the process of film formation itself is caused by the transition of the medium from a gaseous state to a liquid one. The essence of the theory of film condensation of steam is as follows [3,4]. When steam comes into contact with a wall, the temperature of which is below the saturation temperature t_n , the steam condenses, a film is formed on the surface of the wall, and if its movement mode is laminar, then the heat released during steam condensation is distributed by thermal conductivity through the thickness. In this case,

$$q_x = \lambda \frac{t_н - t_{cm}}{\delta_x} \quad (1),$$

$$q_x = (t_н - t_{cn}) \quad (2),$$

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$$\alpha_x = \frac{\lambda}{\delta_x} \quad (3)$$

Where α_x is the heat transfer coefficient during steam condensation on the surface of the cooled wall in section *X; λ is* the thermal conductivity coefficient of the condensate; δ_x is the thickness of the condensate film in section *x.*

From the first three equations we obtain the criteria known to us

$$Nu = \frac{\alpha l}{\lambda}, \quad (4)$$

$$Pe = \frac{\omega l}{a} = \mathrm{Re}\,\mathrm{Pr}, \quad (5)$$

$$Fr = \frac{gl}{\omega^2}, \quad (6)$$

$$Ga = Fr\,\mathrm{Re}^2 = \frac{gl^3}{\nu^2}, \quad (7)$$

and from the heat balance equation

$rdM = c\,M_1\,dt$,

where $rdM = dQ$ is the elementary amount of heat transferred from the vapor to the liquid during condensation of the amount of vapor dM ; $dQ = cM_1\,dt$ is the elementary amount of heat received by the mass of liquid M_1 and causing an increase in its temperature by dt . If we process the heat balance equation using the methods of similarity theory, we obtain the Kutateladze criterion $K = r / c\,\Delta t$ -phase transition where r is the heat of evaporation; *c is* the heat capacity of the condensate,

a $\Delta t = t_n - t_{cm}$. Since in the laminar regime the nature of the fluid motion does not depend on the speed, the Re criterion drops out and the criterion the equation for heat transfer during condensation of steam takes the form

$$Nu= \int(Ga; Pr ; K)= \varphi (Ko),$$

Where Ko= Ga Pr K is called the condensation criterion.

As a result of generalization of experimental data conducted with various liquids, the following calculation formulas were obtained for determining the average heat transfer coefficient during steam condensation:

A vertical wall or pipe of height H, $Nu = 0{,}42 Ko^{0,28}\left(\frac{Pr}{Pr_{cm}}\right)^{0,25}$; (11)

The determining dimension in these equations for vertical walls and pipes is their height, and for horizontal pipes – their diameter. The determining temperature is the saturation temperature t_H .

Similarity criteria can be modified by considering them together in order to bring them to a form most convenient for describing specific problems. Thus, when studying the motion caused by different densities of individual particles of a liquid without moving its entire volume by an external source of motion, the flow velocity cannot be measured. In this case, it is more convenient to combine them in such a way as to isolate a new criterion that would include the difference in densities of individual particles (layers) of the liquid, which is the cause of the motion, and the flow velocity would be excluded. To do this, Fr is multiplied by Re^2 and by the relative difference in flow densities $(p-p_0)/p_0$, where p and p_0 are the densities of different particles (layers) of the liquid:

$$Fr\,Re^2\,\frac{\rho-\rho_0}{\rho_0}=\frac{gl}{\omega^2}\frac{\omega^2 l^2}{\nu^2}\frac{\rho-\rho_0}{\rho_0}=\frac{gl^3}{\nu^2}\frac{\rho-\rho_0}{\rho_0}. \quad (13)$$

Полученный безразмерный комплекс $\frac{\rho-\rho_0}{\rho_0}\frac{gl^3}{\nu^2}=Ar$ (14)

It is called the Archimedes criterion.

Finally, if the difference in densities of different layers of liquid is determined by the difference in their temperatures Δt , as is the case with natural convection, the expression $(p-p_0)/p_0$ can be replaced by the product $\beta\Delta t$, in accordance with the equation $p=p_0[1-\beta(t-t_0)]$, where β is the coefficient of volumetric expansion of the liquid; i.e. $(p-p_0)/p_0 = \beta\Delta t$. Substituting this value into equation (14) we obtain the Grashof criterion :

$$Gr = g\, l^3 \beta\Delta t / v^2$$

(15) r Criterion Gr characterizes the ratio of inertial forces and gravity of the lifting force in the absence of forced fluid movement and is most convenient for describing free movement (natural convection).

It is known that the complex $\omega\, l / a$ is called the Peclet criterion:

$$\omega\, l/a = Pe \qquad (16)$$

If we expand the value of the thermal conductivity coefficient $a = \lambda/(c\rho)$ and multiply the numerator and denominator of the expression of the Pe criterion by the temperature difference Δ t between some points of the flow, then the criterion can be presented in the following form:

$$Pe = \frac{\rho c \omega \Delta t}{\lambda \Delta t / l}; \qquad (17)$$

From which follows the physical meaning of the Peclet criterion, i.e. the Pe number is the ratio of the density of the heat flow transferred by convection from one point in space to another to the density of the heat flow transferred between these same points by conduction. As is known, convective heat transfer, the characteristic of which is the Pe criterion, is precisely the combined action of the two specified heat transfer mechanisms. It is advisable to transform the Pe criterion in order to exclude from it the flow velocity ω as quantities that have already been included in other similarity criteria (for example Re). To do this, we divide Re by Re :

$$\frac{Pe}{Re} = \frac{\omega l / a}{\omega l / \nu} = \frac{\nu}{a} \qquad (18)$$

The resulting dimensionless complex is called the Prandtl criterion: $\nu / a = Pr$.(19)

The Prandtl criterion, which contains only thermophysical parameters , characterizes the influence of the physical properties of liquids on convective heat exchange. Substituting the value of the factors of such a transformation, we obtain.

$\alpha' l' / \lambda' = \alpha l / \lambda = idem$.

This dimensionless complex is called the Nusselt criterion:

A $l/\lambda = Nu$.

Note that the Nu criterion includes the heat transfer coefficient α, which is usually the desired value when studying convective heat exchange processes. Thus, with thermal similarity of two or more systems, the equality criterion Pe (or Pr), Nu takes place .

In some problems of convective heat transfer, the complex Stanton criterion is used :

$$St = \frac{Nu}{Re\,Pr} = \frac{\alpha}{\rho c_p \omega} . \qquad (22)$$

It should be recalled that a necessary condition for thermal similarity is also hydrodynamic similarity, i.e. with thermal similarity, Re (or Gr), Eu are also equal . Thus, heat and mass transfer are widely used in practice, the significance of their laws is of primary importance for thermal and nuclear power engineering, industrial thermal power engineering, power engineering, aviation, astronautics, rocket engineering, etc.

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