INVESTIGATION OF THE HEAT EXCHANGE OF A FLAT ELEMENT IN A DYNAMIC TWO-PHASE LAYER

A. N. Khoze, A. P. Burdukov,
B. G. Pokusaev, and V. A. Kuz'min

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The local coefficients of mass transfer of a flat element in a dynamic two-phase layer are investigated by using an electrochemical method.

Despite the fact that a significant quantity of research has been devoted to the question of studying the heat exchange in a dynamic two-phase layer, the results of various authors are contradictory and the computation formulas are often unjustifiedly complex and require knowledge of medium parameters which are difficult to determine. Thus, it is necessary [1] to know the frequency of gas bubble passage and the gas content in order to perform computations to determine the heat-exchange coefficient $\bar{\alpha}'$. The graphical dependences $\bar{\alpha}' = f(W_0'')$ obtained in [2] for W_0' = var yield a stratification in $\bar{\alpha}'$ as a function of W_0', and also the existence of a minimum, where there is no similarity number, constructed by means of W_0', in the functional dependence obtained, and the existence of the minimum is not shown in the formula. The dependence of $\bar{\alpha}'$ on the number Pr', obtained by the authors, also has an inadequate foundation.

Our experiments studying the hydrodynamics and heat exchange for cylindrical elements and tube bundles, performed by an electrochemical method, have been published in [3]. Hence, only experiments for flat elements and their analysis are considered below.

Experiments to determine the local coefficients of mass transfer (see Fig. 1) were performed by an electrochemical method in the first series of tests to establish the possibility of using a dependence such as

$$\bar{St}^* = f(Re^*, Fr'', Pr') \tag{1}$$

for separate flat vertical elements, as well as to clarify the regularities of convective heat exchange on a flat wall. The plate under investigation was from nickel foil, mounted on a Plexiglas substrate. Part of the nickel foil, the cathode, was covered successively by a thin paraffin layer during the experiment. Consequently, local mass transfer coefficients were determined successfully at 10.5, 32.5, 54.5, and 88.0 mm distances from the frontal point of the element. It follows from the figure that the experimental results (excluding the data for x = 10.5 mm, i.e., in the neighborhood of the frontal point) are described completely satisfactorily by the dependence

$$\bar{St}_D = 0.086\,(Re^*)^{-0.28}(Fr'')^{-0.28}(Pr_D)^{-0.56}. \tag{2}$$

It is known that the hydrodynamic structure of gas-liquid flows is quite complex; we had established earlier [4] that there is no steady circulatory motion of the liquid phase in a dynamic two-phase layer with a nonrunning heavy phase, and only the existence of fluid microflows is possible directly at the heat-exchange surface. A measuring

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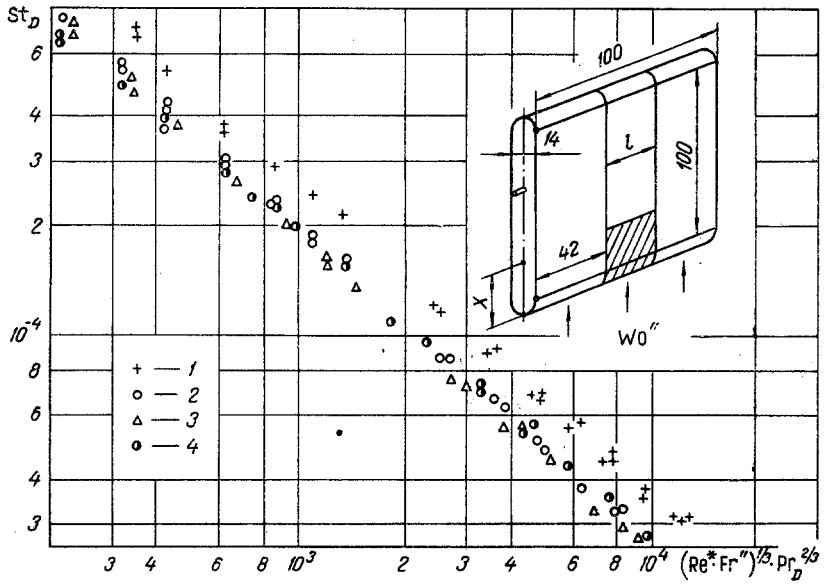

Fig. 1. The dependence $\bar{St}_D = f[Re^*Fr'']^{1/3}Pr_D^{2/3}$: 1) $l \times X$ = 194 × 10.5 mm; 2) 17.5 × 32.5; 3) 16.5 × 54.4; 4) 18.3 × 88 mm.

element structure with protected sections was used to verify the influence of the effects on the faces of the measuring element. The main measuring element was 29.5 mm wide and the protective shields were 10 mm wide each. Special attention was hence turned to the fact of maintaining a relatively small and constant gap between the measuring element and the protective shields. A gap of less than 50 μm was obtained in the foil sheet by using an electrical spark method; then the sheet with the slots was glued to the element, fastened by screws and self-hardening plastic; the slots were cut into the foil by a milling machine.

The measuring element and protective shields (cathodes) were supplied from a common source (potentiostat) operating in the dc voltage domain and maintaining a strictly constant voltage between the anode and cathodes despite the current fluctuations.

The experiments were performed for a constant initial fluid level (150 mm) and reduced gas velocities exactly as in the preceding researches [3]. Consequently, no influence of the side surfaces was detected in practice, and their results are processed well by the correlation dependence (2).

Therefore, the functional dependence (1) used earlier to compute the mass-transfer coefficient in the case of cylindrical surfaces and tube bundles is sufficiently universal and can be recommended for the case of heat transfer of plates and surfaces.

NOTATION

$Re^* \equiv W_0''d/\nu'$ is the Reynolds number referred to the kinematic viscosity of the liquid phase; $Fr'' \equiv W_0''^2/gd$ is the Froude number; $Pr' \equiv \nu'/a$ is the Prandtl number; $\bar{St}^* \equiv \bar{\alpha}'/C_p'\rho'W_0''$ is the diffusion Stanton number referred to the velocity of the light phase; $Pr_D \equiv \nu'/D$ is the diffusion Prandtl number; $\bar{St}_D \equiv \bar{\beta}/W_0''$ is the diffusion Stanton number; W_0'' is the reduced velocity of the light phase, m/sec; W_0' is the reduced velocity of the liquid phase, m/sec; ν' is the kinematic coefficient of viscosity of the liquid phase, m^2/sec. The superscripts ', " refer to the liquid and gas phases, respectively.

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