HEAT TRANSFER OF RECTANGULAR ELEMENT IN FROTH LAYER

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Heat transfer of tube bundles and single cylindrical surfaces in a froth layer was studied in [1,2]. In this paper we describe a study of heat transfer for a rectangular element (Fig. 1). The brass heat-exchange element 1 with the internal electric heater 2 and the six thermocouples 3 was installed for the surface temperature measurements in a plexiglas column, which was equipped with a gas-distributing grid. Power was supplied by wires in the water-resistant insulation 5 through the fittings 4. In all the experiments the gas phase was air and the liquid was water.

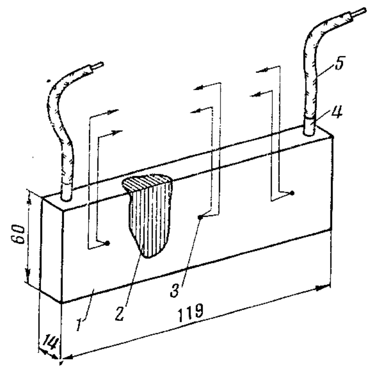

Fig. 1

Analysis of the physical picture of the process in question makes it possible to obtain with good approximation for given pressure P (bars) in the column and heat flux q (W) the relation for the heat transfer coefficient

$$\alpha = \frac{V}{F}\,\frac{\rho_1 d_S r}{\Delta t \tau} \tag{1}$$

Here ρ_1 is the air density (kg/m^3), d_S is the moisture content at saturation (kg/kg of dry air), r is the latent heat of vaporization (J/kg), Δt is the average temperature head (°C), τ is the time for air passage through the froth layer (sec), V is the froth layer volume (m^3), and F is the active surface of the heat-exchange element (m^2).

The experimental study made by the present authors and studies of others make it possible to state that in this case the variation of the quantity $\rho_1 d_S r/\Delta t\tau$ is not significant, and therefore the heat transfer coefficient can be written in the form

$$\alpha \approx f\,(V\,/\,F) \tag{2}$$

We term the ratio V/F the effective linear dimension of the system. Such a relation $\alpha = f_1(F/V)$ was first presented by Poll and Smith in [3].

In our study different values of the effective linear dimension were obtained by using a set of columns which differed in area of the free section for the same height of the froth layer.

The experiments were conducted with V/F = 0.25, 0.14, 0.09, 0.05 m and air velocity in the free section of the column W = 2.0 m/sec [4].

Figure 2 shows the relation $\alpha = f(V/F)$, from which it follows that with increase of V/F the heat transfer coefficient α increases. This is explained by the increase of the interphase heat transfer surface area in the froth layer, as a result of which the vaporization process is intensified and therefore the heat transfer coefficient increases.

The numerical values of α obtained in the experiments confirm the high intensity of the heat transfer in the froth layer.

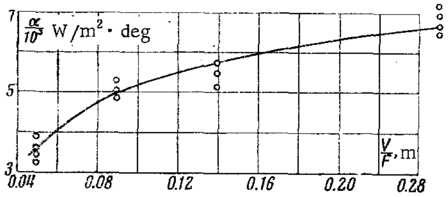

Fig. 2

Figure 3 shows the element surface temperature relation $t_w = f(V/F, q)$. For a fixed value of the heat flux q the wall temperature t_w is determined by the temperature of the froth surrounding the heat-exchange element. The froth temperature depends in turn on the intensity of the vaporization process, and the latter is seen from the discussion above to depend indirectly on the volume of the froth layer. Thus, the larger V/F the lower the surface temperature. For given values of t_w and q, by means of Fig. 3, we can find the ratio V/F, which defines the dimensions of the heat exchange apparatus. We also see from the figure that there is no significant reduction of the surface temperature for $V/F > 0.125$ m.

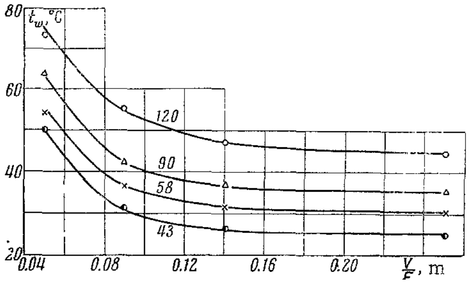

Fig. 3

Experiments were made with a fixed value $V/F = 0.1$ to clarify the influence of the air flow rate on t_w. In these experiments the specific air flow rate g_1 (kg/kW · h) was varied for various heat fluxes. The experimental results are shown in Fig. 4.

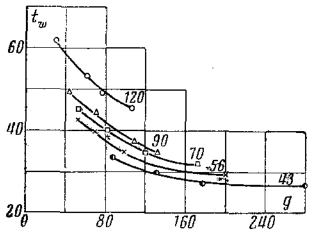

Fig. 4

We see from the figure that there is no marked reduction of the temperature t_w for heat fluxes $q < 70$ kW/m² and air flow rates $g_1 \geq 160$ kg/kW · h, i. e., the effect of temperature reduction with increase of the air flow rate disappears. We note that the specific flow rates $g_1 = 130-140$ kg/kW · h correspond to the usually recommended air velocity $W = 2$ m/sec.

In our study a check was also made of the possibility of intensification of the heat transfer of a flat element with vertical fins mounted on the side surfaces.

Figure 5 shows the relation $q = f(K, t_w)$ for the case $W = 1.45$ m/sec and $V/F = 0.25$ m.

In the experiments the fin coefficient $K = (F + F_p)/F$ was varied from 1.0 to 1.3, which corresponds to the installation on each side of the element of five brass ribs of height 2, 3, 4, 5.5 mm and rib thickness 1.5 mm. The heat flux q naturally increases more slowly than K; the 30% increase of the heat transfer surface area F as a result of installing the fins leads to about a 12% increase of the heat flux.

The rectangular elements studied can be used in heat exchangers with heat removal into a froth layer.

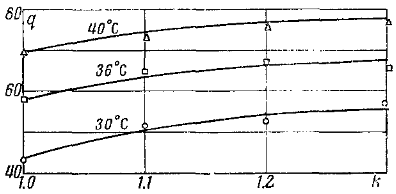

Fig. 5

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