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Some Aspects Concerning Convective Circulation Mode of Heat Transfer in Furnace to Wood Heat Treatment

The paper presented the most aspects of convective circulate mode of heat transfer : heat transfer through the boundary layer formed at the surface of the heat generator; heat transfer in the heat carrier and heat transfer through the boundary layer formed at the heated surface

1. Introduction

The calculation of a furnace is aimed at determining all the characteristics required for the construction of a furnace and also the characteristics of its thermal operation. Before the calculation, the optimal conditions of furnace operation should be specified. One of the conditions that it is necessary to know is the convective circulation mode of heat transfer.

A feature typical of the convective circulation heat transfer mode is that the temperature of a heat carrier is practically constant in all points of the heated surface. Under steady-state conditions of heat transfer, i.e, when temperature is time-invariable, the heat balance of the process is described by equation:

$$Q_{hg} + Q_{he} + Q_{hl} = 0 \qquad (1)$$

2. Analysis

Let us analyze the simplest case of a circulation mode when heat losses to the surroundings are relatively low. We then have

$$Q_{hg} + Q_{he} = 0 \qquad (2)$$

i.e. the heat given up by the heat generator is transmitted fully to the heated surface. The heat is transmitted by the heat carrier circulating between the heat generator and heated surface. The mutual arrangement of the heat generator and heated surface determines a particular pattern of closed currents of a heat carrier in the volume (circulation contours), Fig.1.

With vigorous circulation, intermixing is quite perfect, so that the state of the heat carrier can be characterized by a definite uniform temperature. If a heat carrier is non-diathermal and is at a low temperature, the phenomenon of heat transfer in it is determined exclusively by mass-exchange processes. Thus, the convective heat transfer in a circulation mode comprises three stages (Fig. 1a):

(1) heat transfer through the boundary layer formed at the surface of the heat generator;
(2) heat transfer in the heat carrier;
(3) heat transfer through the boundary layer formed at the heated surface.

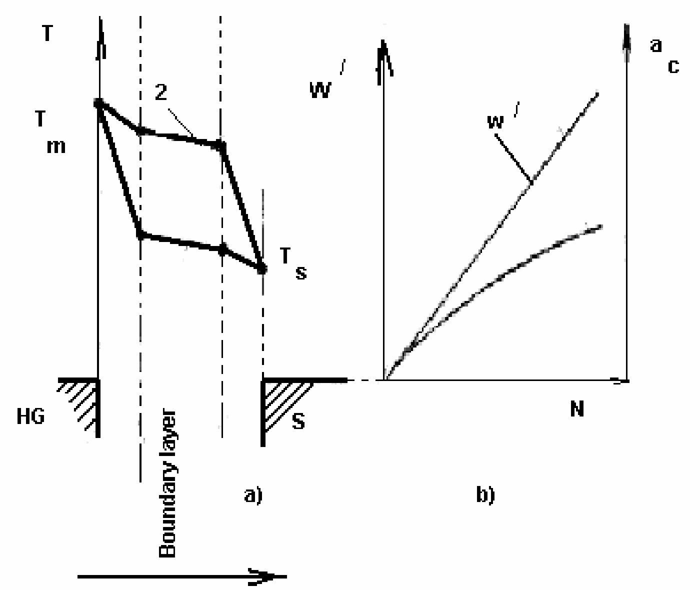

Figure1. Temperature characteristics of a convective circulation mode a) and effect of the power of stirring N on heat transfer in the heat carrier and to the heated surface (b)

The resulting effect depends on the limiting link in this series of heat-transfer processes and the resulting heat transfer can be described by the equation:

$$Q=\frac{1}{\frac{1}{\alpha_c^{!}\frac{F_{hg}}{F_s}}+\frac{\left(T_m^{!}-T_m^{"}\right)}{\beta}+\frac{1}{\alpha_c^{"}}}\left(T_{hg}-T_s\right)F_s \qquad (3)$$

where β is a coefficient characterizing the heat transfer in the heat carrier, W/m^2, $\alpha_c^{!}$ and $\alpha_c^{"}$ are the coefficients of convective heat transfer from the heat source F_{hg} to a heat carrier and from the heat carrier to the heated surface F_s, W/(m^2.K) and $T^!_m$ and $T^»_m$ are the temperatures of the heat carrier at the surfaces of boundary layers.

The normal state of the circulation mode of heat transfer can be characterized by that the process of heat transfer in the layer of a heat carrier does not limit the process of heat transfer as a whole, i.e. $(T'_m - T^»_m)/\beta \rightarrow$ O. Therefore, under steady-state conditions, the heat transfer from the heat generator to heated surface can be determined by the formula:

$$Q=\frac{1}{\frac{1}{\alpha_c^{*}\cdot\frac{F_{hg}}{F_s}}+\frac{1}{\alpha_c^{"}}}\left(T_{hg}-T_s\right)F_s \qquad (4)$$

As follows from fig.1 one and the same heat transfer can be obtained at various temperature conditions of the circulating heat carrier (1 or 2). Circulation modes of heat transfer from favorable conditions for convective heat transfer, since disordered motion of heat carrier minimize the thickness of the boundary layer.

The intensity of circulation of the heat carrier depends on the power spend on stirring. As has noted earlier formula:

$$G_{\mathrm{Re}}=\frac{Nt}{V\nu\rho} \qquad (5)$$

An analogue of Reynolds number can be conveniently used in that case:

$$G_{\mathrm{Re}}=\frac{Nt}{V_m\nu_m\rho_m}=\frac{Ntg}{V_m\eta_m} \qquad (6)$$

For the same value of G_{Re} number, the power of stirring should be higher density of a heat carrier.

There are four principally different methods for making the heat carried to circulate, and therefore, for creating convective heat transfer in the mode considered: mechanical, electromagnetic, pneumatic and gravitational.

4. Conclusion

Expressing the heat transfer coefficient through the power spend on stirring offer great advantages for processing experimental and analytical data, since this power can in many cases be measured quite accurately, while the velocity of the heat carrier in a circulation made may be indeterminate.

Circulation mode of convective heat transfer may take place with various states of heat carrier: liquid, solid, gaseous, or in a fluidized bed.

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