METHOD OF THERMAL CALCULATION OF A MULTIZONE ENDOTHERMIC ROASTING FURNACE IN A FLUIDIZED BED

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A method of approximate thermal calculation of an endothermic roasting furnace with stepped heating and cooling zones is presented.

The method of calculation proposed in [1] serves for determining the specific flow rate of fuel V/G and the optimal number of steps of the heating zone n and cooling zone m. The quantity V/G depends on the degree of utilization of the heat in the heating and cooling zones and consequently on n and m. The minimum value of V/G or, what is slightly more accurate, the minimum of the total energy expenditures ΣQ (fuel for roasting plus the electrical energy for the blast and draft) is obtained with an optimal combination of n and m. The optimal n is determined by the most advantageous temperature t_n of the outgoing gases of the furnace or accordingly by the most advantageous temperature t_2 of the solid material pouring over from the heating zone to the roasting zone. Similarly the optimal m is found from the optimal temperature t_m of the product at the furnace exit or accordingly from the optimal temperature t_{2c} of the air passing from the cooling zone to the roasting zone.

The problem of finding V/G, n, and m was solved in [1] by a complex graph– analytic method. Formulas and graphs were obtained from three equations of the heat balance of the heating, roasting, and cooling zones – Eqs. (1), (2), and (3) (the notations and numeration of the equations are written as in [1]).

The problem can be solved only by means of the indicated three equations. Actually, if we assign, as in [1], the values of t_2 and t_{2c}, then V/G is calculated directly by Eq. (2). Then by means of Eq. (1) we find successively, from the bottom up, the temperatures of all steps of heating. We find the temperature t_n of the last (upper) step from the known temperature t_0 of the solid material entering the furnace, which closes the calculation. We thereby obtain n. We find m in the same manner. Calculation of the temperatures of the cooling zones is done successively from the top down to the temperature of the last (lower) step, at which the calculation is closed by the known temperature t_0 of the air entering the furnace. If we assign another pair of values of t_2 and t_{2c}, we obtain new values of V/G, n, and m.

An inverse relation exists between temperatures t_2 and t_n and accordingly between temperatures t_{2c} and t_m. The minimum value of V/G will be obtained at the maximum values of t_2 and t_{2c} or accordingly at the minimum values of t_n and t_m. Owing to the operating conditions it is most often necessary to assign the values of t_n and t_m. Then the calculation is performed by assigning the values of these temperatures and not of temperatures t_2 and t_{2c}. In this case the calculation of the temperatures of the steps is done in the reverse order and is closed by the roasting temperature t_1, which is known. If we make the calculation with assigning temperatures t_2 and t_{2c}, then, repeating the calculation once or twice and in some cases a greater number of times, we obtain those values of n and m at which the most advantageous temperatures t_n and t_m, and so, the practical minimum of V/G are reached.

The total specific consumption of energy ΣQ consists of the consumption of the heat of the fuel Q/G and consumption of electrical energy E in terms of heat with consideration of efficiency with respect to production η_p and transport η_{tr} of electrical energy (η_{tr} is not taken into account in [1]). Since in ΣQ the term E does not exceed 10%, it is sufficient to limit ourselves to finding the minimum value of Q/G = f(n, m). If we strive for greater accuracy and take into account E, the calculation becomes too cumbersome.

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Thus, in the example given in [1] for n = 1-10 and m = 1-10 it is necessary to make 100 variants of the calculations and construct 10 curves for Q/G = f(n, m) and the same number of curves for E = f(n, m) and for ΣQ = f(n, m), i.e., 30 curves in all (in [1] 23 curves are plotted in Fig. 5). It turned out that there was no need for these variant calculations, since the selection of the optimal number of n and m with respect to the minimum value of ΣQ and minimum value of Q/G gave the same results.

We note that in a refined calculation it is necessary to take into account: 1) the heat of vaporization of the moisture of the solid material in the heat balance of the steps of the heating zone; 2) change of the weight of the solid material in the heating and roasting zones as a consequence of the conversion of part of the solid material to gas and vapor as a result of chemical reactions and vaporization of the moisture; 3) the corresponding change of the volume of gases.

The assumption of equality of the temperatures of the gases and solid material at the exit from each step of the heating zone and equality of the temperature of the air and finished product at the exit from each step of the cooling zone is substantiated if the process of heat transfer is completed at each step. This requires a sufficient height of the fluidized bed and appropriate organization of the kinetics of the process.

NOTATION

V, G	are the flow rates of the gas (fuel) and finished product, standard m^3/h;
n	is the number of steps of the heating zone;
m	is the number of steps of the cooling zone;
ΣQ, E	are the total specific consumptions of energy (heat of fuel and electrical energy) and of electrical energy, kJ/kg;
t_0, t_1, t_2, t_{2c}, t_n, t_m	are the temperatures of: the solid material and air entering the furnace; roasting; solid material flowing from the heating zone to the roasting zone; air passing from the cooling zone to the roasting zone; gases leaving the furnace; product at the furnace exit, °C.

LITERATURE CITED

1. V. M. Dement'ev, Inzh.-Fiz. Zh., 11, No. 6 (1966).