ELECTROTHERMAL ANALOGIES AND THE RESULTANT
HEAT FLUX ABSORBED BY A POROUS COLLOID
DURING DRYING

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Measurements are reported on the effective thermal conductivities and resultant heat fluxes in the drying of potato starch.

Design calculations on drying systems and proper organization of drying require a knowledge of the heat-flux kinetics \(q(\tau)\) at the material, in particular, to analyze heat and mass transfer.

Direct measurement of heat fluxes requires special detectors in conjunction with a knowledge of the optical parameters of the material; in general, there are serious experimental difficulties.

For this reason, considerable interest attaches to the use of an electrothermal analog, which requires a knowledge of the effective thermal conductivity \(\lambda_{ef}\) as a function of position.

We have examined the problem with an \(\text{ЭИПН-3/66}\) electrical integrator used with an RC network model based on R-33 resistance boxes, which were used to simulate \(\lambda_{ef}\), together with sets of nonpolar film capacitors type MPGT, which simulated the bulk specific heat \(c_\gamma\) [1].

To calculate \(q(\tau)\) we used measurements on the drying of unaltered potato starch by infrared radiation applied from one side, with natural convection in air. The radiation flux at the surface of the starch was 4300 \(W/m^2\), while the layer thickness was 15 mm. The temperatures in the layers were measured with copper-Constantan thermocouples working into an \(\text{ЭПП-09МI}\) chart recorder. Special balances were used to record the mass loss by the moist starch, with automatic recording [2].

Figure 1 shows the temperatures in layers during drying of starch with an initial water content \(U_0=30\%\); these curves were used with the method of [3] to determine the \(\lambda_{ef}\), and parts a and b of Fig. 2 show the variations with time in the layers.

It is clear the \(\lambda_{ef}\) varies in a complex fashion during drying, which is due to the general trends in the internal heat and water transport, the rise in \(\lambda_{ef}\) for layers close to the middle is due to rapid thermal diffusion, which occurs roughly for 30 min during drying and extends down to \(x=9\) mm depth. The rise in \(\lambda_{ef}\) is also due to the heating; the fall in \(\lambda_{ef}\) in the surface layers is clearly due to the water loss by evaporation.

The shape of the \(\lambda_{ef}=f(x)\) curves alters considerably for times greater than 30 min; the marked increase in \(\lambda_{ef}\) above 30 min (Fig. 2a) is ascribed to the virtually horizontal disposition of the curves above 30 min, i.e., for \(x>10\) mm the...
Fig. 2. Variation in $\lambda_{ef}$ (W/m·deg) with position in drying starch for $\tau$ (min) of: a) 5-35; b) 50-130.

Temperatures in the layers are identical. As a consequence, $\lambda_{ef}$ increases considerably in response to the marked reduction in $\text{grad } t$ as $q = -\lambda_{\text{grad } t}$ (for restricted values of $q$).

The values of $U$ in the surface layers were considerably lower, which means that there is little water transport by thermal diffusion in these layers, since a water monolayer is not thermally active [4]. This suppresses the peaks on the $\lambda_{ef}=f(x)$ curves. A subsequent slight increase in $\lambda_{ef}$ for the surface layers is due to diffusion of water to the surface. The considerable fall in $\lambda_{ef}$ in the lower layers at the end of drying is clearly due to rapid evaporation from these layers and heat transport by molecular means to the surface via the extensive pore structure.

These results on $\lambda_{ef}$ were used in calculating $q(\tau)$; the heat flux going to heat the material $q_1(\tau)$ was represented as an equivalent current in the model. The relation between $q_1$ and $I$ is

$$q_1 = \frac{R_{bc}\lambda_{ef}R_{max}}{U} \quad (1)$$

The method of determining $q_1(\tau)$ is as follows. The drying period was split up into intervals $\Delta\tau$ that corresponded to the $\Delta\tau$ in temperature recording within the material. For each $\Delta\tau$ we selected resistors corresponding to the $\lambda_{ef}$ for the individual layers. A special instrument was used to set the boundary conditions of the second kind, and a current was passed to the boundary through a limiting resistor $R_{bc-II}$; we adjusted $R_{bc-II}$ to set the current through the model to be such that the temperature at the boundary varied in a known fashion for the given interval.

The currents were calculated from

$$I = \frac{U_{bc} - U}{2R_{bc-II}} \quad (2)$$