KINETICS OF DRYING OF SPRAY MATERIALS

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Annotation:
The rate of evaporation of moisture from the material, that is, the results of the kinetics of drying are obtained experimentally without changing the parameters of the drying agent (temperature, moisture retention and speed) during the experiment. During the experiment, the material is weighed continuously or continuously (using the method of taking a sample) and its moisture content is determined. The temperature of the material must also be continuously measured. Experimentally determined kinetic lines of drying can provide accurate information for a specific material, including various physical factors of drying under given conditions. However, these kinetic curves are considered reliable for the experimental conditions.
Keywords: drying limit ,process, drying agent, difficult problem, speed of rotation, kinetic lines of drying

Introduction

During the first period of drying, the diffusion resistance of the water vapor formed on the surface of the material to the flow of the drying agent determines the drying rate. During this period, since the large capillaries are filled with liquid, the resistance to the movement of the liquid in the capillary-porous material in the capillaries is small. During drying, the moisture in large capillaries evaporates, their liquid decreases, and in the process of evaporation, liquid evaporation begins in small capillaries with high hydraulic resistance. Due to the fact that the liquid movement in the capillaries cannot provide the flow of the evaporating liquid, the drying speed decreases, and the internal resistance of the moisture movement in the structure of the capillary-porous material increases. The drying limit goes to the inner layers of the material. In the second period of drying, the temperature of the material being dried increases and asymptotically approaches the temperature of the drying agent. The moisture retention of the material also asymptotically approaches the equilibrium moisture retention of the drying agent. The wet storage at the end of the constant drying rate period is the critical Ukr, where the internal and external resistances to moisture transfer are equal. The initial drying line is changed to the drying rate line for clarity. In this figure, the horizontal line is during the period of constant drying rate, and the second period of decreasing drying rate varies depending on the structure of the capillary-porous material. During this period, the numerical value of the drying time depended on the structure and thickness of the material. If we define the drying rate in the second period of drying as a straight line, we get the following equations for the duration of drying and the current moisture content.

$$U = U_0 - Nt, U_{KP} \le U \le U_0 \quad (1)$$

$$U = U^* + (U_{KP} - U^*)\exp(-Kt), U_{KP} \le U \le U_0 \quad (2)$$

Drying rate coefficients N and K are found experimentally.

The value of critical Ukr wet storage depends on the parameters of the drying agent except for the porous structure and thickness of the material. The parameters of the drying agent are affected by the internal and external resistance of the wet transfer. The total drying time is equal to the time of the first period of drying tkr and the time from the beginning of the second period of drying until the moisture content of the material reaches U.

$$t_{ум} = t_{кр} + t_k = \frac{1}{N}\left[(U_0 - U_{KP}) + (U_{KP} - U^*)\ln\frac{U_{KP} - U^*}{U_K - U^*}\right] \quad (3)$$

where: coefficient K is determined by N on the condition that the drying rates at the end of the first period and the beginning of the second period are equal. Experimental results are not always straight lines. Therefore, we can define the rate of drying for cases not in the first period in a more complicated form as follows:

$$-\frac{1}{N}\frac{dU}{dt}=\frac{(U-U^{*})^{m}}{A+B(U-U^{*})^{m}} \quad (4)$$

where: A, V and m are approximation coefficients. The indicator m depends on the methods of contact with moisture and moisture transfer ability of the material. Coefficients A and V depend on the shape and dimensions of the material being dried. To generalize the experimental drying lines for different external parameters and for the material at the same initial moisture storage, it is brought to one coordinate (U – U*) – Nt and a single drying line is obtained for the material.

$$N_1t_1 = N_2t_2 = ... = N_nt_n = const \quad (5)$$

where: t1, t2, …, tn are the drying intervals of the material for different drying regimes from Ubosh wet storage to specified humidity. For each mode, the constant N=exact value is correct.

In the case where the first period of drying is absent (Ubosh < Ukr), there is the following method of summarizing the experimental results:

$$\frac{t_1}{t_{m1}} = \frac{t_2}{t_{m2}} = ... = \frac{t_n}{t_{mn}} = const \quad (6)$$

where: tm1, tm2, ..., tmn is the drying time of the material from Ubosh to Uox in different external conditions.

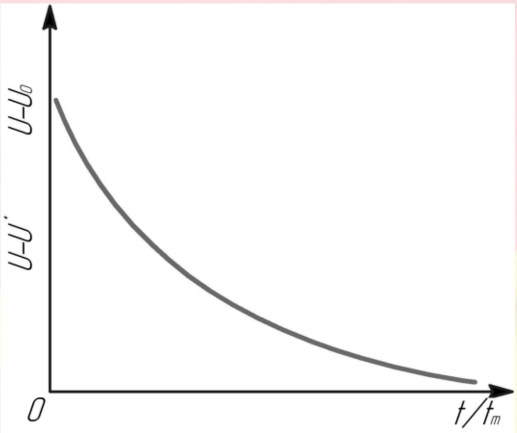

Figure 1. Generalized drying lines of the material during the period of decreasing drying speed

Experimental determination of the numerical values of the constant in equation (5) allows to calculate the drying process for the studied material through generalized drying lines at different temperature, moisture storage and speed indicators.

Some researchers give the wet storage value as a fractional-linear function:

$$U = U_0 - \frac{t}{A_1 + B_1 t}$$

Here, the experimental coefficients A1 and V1 depend on the material and the drying regime. In the second period, the following form is given for the points where the drying speed line is S-shaped.

$$-\frac{dU}{dt} = K_c(U_{мув} - U)(U - U^*) \qquad (7)$$

where: Umuv is the equilibrium moisture content of the material equal to water vapor at the wet bulb temperature Ks is an experimentally determined constant. Equation (7) was used by researchers for polymeric materials.

Heating of wet material depends on drying kinetics. Heat supplied to the materialQ(t) is used to evaporate moisture and heat the wet material. The amount of heat used for evaporation is equal to the product of the heat of evaporation and the rate of drying:

$$r_k\left(-\frac{dU}{dt}\right).$$

The amount of heat used to heat the dry content of the material and to heat the remaining moisture in the material:

$$(C_T + C_E U)\left(\frac{d\vartheta}{dt}\right),$$

where the heat capacity of the dry material and the liquid. In this case:

$$q(t) = r_k p_m R_V \left|\frac{dU}{dt}\right|\left(1 + \frac{\bar{c}}{r_k}\frac{d\vartheta}{dU}\right) \qquad (8)$$

here: $\bar{c}$ = st+svU – wet material heat capacity;

$$R_V = \frac{V}{S}$$

- the ratio of the volume of the material being dried to its outer surface.

Dimensionless complex

$$(c_T + c_E U)\frac{d\vartheta}{|r_k dU|} = Rb$$

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Rebinder number is the ratio of the amount of heat used to heat the wet material to the amount of heat evaporated from it. In the first period of drying, when the temperature of the material TM does not change, the value of the Rebinder number Rb=0. The value of Rb number for the second period of drying is found from the experimental results. As a result of the reduction of moisture content in wet material, Rb and $\frac{d\vartheta}{dU}$ the reason for the increase in values is that the amount of heat for vaporization of moisture decreases in small values, and the amount of heat used to increase the temperature of the material increases. The criterion Rb=U and the temperature of the drying agent T has the following approximate form:

$$Rb = A_2 \exp\left[-n(U - U^m)\right]$$

where n depends on the material properties and shape. A2 - temperature dependence of the drying agent, when calculating the linear dependence of its wet storage and temperature on the entire thickness of the material being dried, for a one-dimensional problem with an internal x coordinate, the following was obtained:

$$\vartheta(x,t) = \vartheta_b + b_T U(x,t) \quad (9)$$

here: ϑ_b - the basic indicator of the temperature of the material is the coupling coefficient. If the linear relation (9) is not correct in the entire range of humidity changes, the linear approximation is carried out for small parts.

According to relation (9), the problem of non-stationary humidity and temperature inside a wet material can be reduced to the non-stationary equation of heat transfer:

$$\frac{d\vartheta}{dt} = \alpha_{эке}\left(\frac{d^2\vartheta}{dx^2} + \frac{\Gamma}{x}\frac{d\vartheta}{dx}\right) \quad (9)$$

here: $\alpha_{экв} = \frac{\lambda}{c_{экв} p_T}$ - equivalent temperature conductivity of wet material; $c_{экв} = c_T + E\frac{r_k}{b_T} = c_T\frac{Rb + E}{Rb}$

- equivalent heat capacity of wet material (calculated as heat of vaporization); $E = \frac{dU_{буг}}{dU_{ум}}$ evaporation coefficient, the ratio of evaporated moisture to total moisture.

If G= 0; When 1 and 2, equation (10) is for the body form infinite plate, infinite and sphere. Solutions of Eq. (10) in eigenproperties for Rb and E, whose experimental value is constant, are also given.

For thin materials, the solution of the problem becomes easier if the surface temperature is taken to be equal to the average temperature of the material for the cases where temperature-moisture bonds are determined.

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