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Intensification of the Process of Hydrodynamics and Kinetics of Drying Dispersed Materials in Vortex Dry Camera

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ABSTRACT: This highly efficient vortex drying chamber allows you to hold the rotating layer of particles without self-transporting them with the gas flow. In the work, the trajectories of the motion of the gas and solid phase systems in the vortex chamber and the kinetics of drying of dispersed materials are considered. The tangential velocity of the gas depends on the vortex radius and characterizes the ratio of thermal resistances inside and on the surface of the particle, when the material is heated.

KEY WORDS: Water treatment plant, thermal power plant, the electrochemical method, circulating water supply systems, purification, clarification of water.

I.INTRODUCTION

The main direction of these studies is the development of one of the most promising methods of drying - drying in swirling threads - as applied to cotton cellulose, due to the acute need of textile and related industries in this product, the need to improve its quality. Thus, the total annual production of only two types of products: paper and fibber's based on cellulosic raw materials is about 140 million tons, which is approximately three times higher than the output of synthetic polymeric materials.

Vortex dryers belong to the apparatuses with swirling gas flows. The advantages of swirling flow before direct flow is as follows: increased retention capacity of the material in the apparatus, high relative speeds, an increase in the range of operating speeds, an expansion of the effective volume, the presence of recirculation zones, which contribute to the stabilization of hydrodynamics and intensive mass transfer.

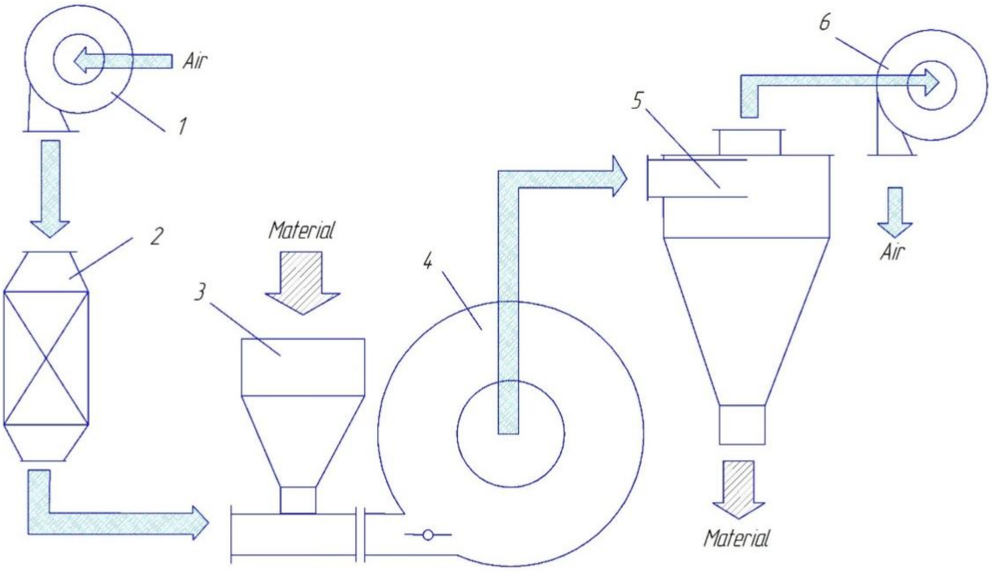

Figure 1. Schematic diagram of the laboratory vortex dryer. 1- fan; 2-heater; 3-feeder; 4-vortex dryer; 5-cyclone; 6 - suction fan.

II. SIGNIFICANCE OF THE SYSTEM

For a number of years, work has been done on the study of hydrodynamics and heat and mass transfer of dispersed media in swirling gas flows. As a result of these studies, a vortex chamber was created, which allows to keep the rotating layer of particles without their self-arbitrary removal with the gas flow. The processing of dispersed material, in particular cellulose acetate, in the vortex chamber leads to the intensification of heat-mass transfer processes, because as a result of centrifugal force, the gas filtration rate through the layer may exceed the cellulose acetate soaring rate several times.

III. LITERATURE SURVEY

To carry out the tasks we have carried out literary analysis and research on the illuminated materials.Features of the aerodynamics of the vortex and cyclone chambers for a number of high-temperature technological processes are currently investigated in sufficient detail. These studies indicate a close relationship between the characteristics of a rotating flow and the geometrical shape of the vortex chamber, with the method of supply and exhaust air, with the ratios of its defining geometrical dimensions. The design features of the drying chamber create an aerodynamic setting in it that is different from the aerodynamics of the known apparatus of the vortex and cyclone type. Below are the results of experimental studies on the choice of design parameters of a vortex dryer.

IV. METHODOLOGY

The Biot criterion, which characterizes the ratio of thermal resistances inside the particle and the surface, when the material is heated in a vortex chamber is

$$Bi = \alpha R / \lambda = 0.1,$$

which indicates the possibility of intensifying the process of heating the dispersed material by increasing the speed of the blower.

When describing the motion of the “gas-solid particles” system in vortex dryers, the interaction of the gas and solid phases is of great importance. Such interaction, first of all, is expressed by the fact that the particles of the material take away a part of the amount of motion from the gas, which leads to a decrease in the angular coordinate of the twist of the gas flow.

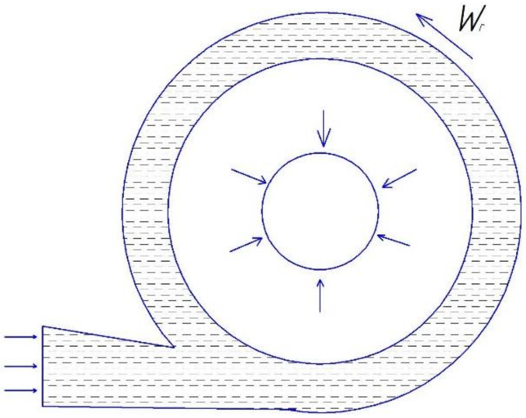

Fig. 2. To modelling the movement of material particles in a vortex chamber.

V. EXPERIMENTAL RESULTS

Experiments have shown that the form of the dependence of the tangential gas velocity υφ on the current radius r is extremely. υφ with increasing r first monotonously increases to its maximum value at the point r = rr, then monotonously decreases to zero when r = R. The dependence υφ = υφ (r, φ) is described by the expression

$$A1\ (\varphi)\ r\ n \text{ with } r \leqslant r\ *$$

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$\upsilon\varphi (r, \varphi) = \{$

$A_2 (\varphi) r^{-m}$ with $r \geqslant r *$

The exponents “n” and “m” are found by the least squares method from the experimentally determined field of tangential gas velocity components n = 1.3; m = 0.8.

Often the drying process is divided into three periods: the warm-up period, the constant drying speed period, the falling drying speed period. Considered during the drying process under the action of two driving forces.

$$dU / d\tau = - K (A - U) (U - B)$$

A and B - the initial and final equilibrium moisture content of the material. It is assumed that the drying process is a transfer of material from a certain equilibrium state to another state as a result of a change in the equilibrium conditions. Solution of the equation for the initial condition: $\tau = 0$

{looks like:

$$U = U_n$$

$$\tau = 1/(K (A - B)) \ln ((U - B) (A - U))/((A - U) (U - B))$$

The parameter K * of the generalized curve depends on the material and is independent of the mode.

K * defines the U = U (Nτ) curve over the entire drying range.

The parameter “B” is a finite equilibrium moisture content; it can be found from the desorption isotherm.

The parameter “A” can be found through the parameter B and the moisture content value Un at the inflection point of the curve U = U (Nτ)

$$A = 2U * - B$$

The value of N is determined from the warm balance for the cylindrical particles of the material, taking into account the fact that all the supplied heat goes to evaporation of moisture in the material, and the temperature is equal to the temperature of the wet thermometer Ɵn.

$$\alpha (t - \Theta_m) [\pi dh + \pi d / 2] = m\, r_n N$$

α is the coefficient of heat transfer from gases to the material; t is the temperature of the coolant; rn is the specific heat of the phase transition.

$$N = (\alpha (t- \Theta) \pi d (h + d / 2)) / (m r)$$

Thus, the kinetics of drying can be considered known if the kinetic drying curve, taken for a single mode, is known. The maximum drying rate N is determined according to both the parameters of the drying mode and the parameters of the material.

The paper presents the results of theoretical and experimental studies of the process of heat and mass transfer of a rotating layer of material with hot air. In experiments, air with a temperature of 70 °C through a twisting apparatus entered the working volume of the chamber formed by tangential inlets. The dispersed material to be processed was fed from the bunker by means of a pneumatic trip to the chamber, where under the action of centrifugal force it formed a rotating layer with a thickness of up to 0.025 m and a weight of up to 1 kg. At the same time, the air flow rate through the layer varied in the range of 0.2-0.35 kg/s, which ensured the speed of ash of the dry material from 11 to 22 m/s. The contact time of hot air with the material varied from 2 s to 11 s.

In the experiments, the air velocity was measured at the inlet and outlet of the layer of material being processed, the speed of rotation of the layer, as well as the air temperature at the entrance and exit of the layer and the temperature of the material before and after treatment in the chamber. The figure shows the dependence of the dimensionless temperature of the dispersed material

$T = (t - t_o) (t_в - t_o)$ from the criterion $Fo = \alpha\tau/R^2$

proportional to the time of contact of the material with air for air filtration rates of 10 m/s and 16 m/s.

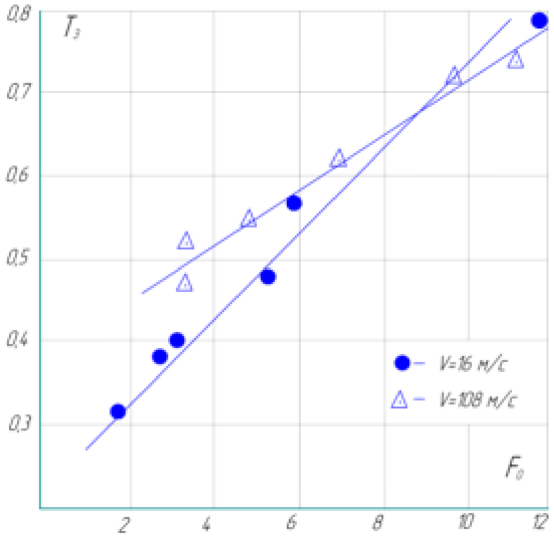

Fig.1. Dependences of the dimensionless temperature of the dispersed material on the Fuhre criterion

The figure shows that with an increase in the rate of air filtration through the layer, the heating rate of the material increases. The experimentally obtained values of the heating rate of cellulose acetate Δt / τ (deg / s) are an order of magnitude higher than those known for the heating processes in a fluidized bed and a fixed bed. A further increase in the filtration rate to 22 m/s did not lead to an increase in the heating rate of the material. Probably, to further increase the heating rate of cellulose acetate, along with an increase in the filtration rate of the coolant, it is necessary to increase its temperature.

Experimental studies of the drying process were also carried out in continuous mode on vortex drying chambers. Installation warmed up, displayed on the desired temperature. According to the flow meter installed in front of the heater, the consumption of the drying agent was determined. Then the feeder engine was turned off; wet material was supplied. Measurements were made at various air flow rates. The temperature of the air supplied to the drying unit was regulated by a voltage transformer in an electric air heater by varying the current intensity. The air temperature at the inlet to the drying unit varied from 100 ° C to 180 ° C. At the outlet of the drying unit, samples were also taken in cups to determine the moisture content of the material. The results of the experiment are shown in table 1.

Table 1.Drying cotton cellulose in a vortex dryer.

Air temperature,°C		Consumption,kg/s		Moisture content of the material, kg/kg		Change in the temperature of the coolant in the dryer, °C			
initial	final	Air, Gг	Material, Gм	initial, Ui	final,Uf	t1	t2	t3	t4
100	87	0,17	0,6	0,55	0,020	97	94	92	89
110	97	0,17	0,6	0,55	0,021,	106	103	101	99
120	108	0,17	0,6	0,57	0,019	118	115	113	110
130	120	0,17	0,6	0,560	0,017	126	125	122	121
140	129	0,17	0,6	0,58	0,016	138	136	133	130
150	138	0,17	0,6	0,58	0,016	148	146	142	140
160	151	0,17	0,6	0,56	0,014	159	157	155	152
170	159	0,17	0,6	0,56	0,010	167	165	163	161

To improve the conditions for introducing the coolant flow and adjusting the effective radius for introducing the coolant, a louver device was adopted. Such a device consists of several blades, petals, which can open or close the passage of gas. Studies have shown that by adjusting the radius of the gas inlet with a louver device, it is possible to adjust the residence time of the material in the vortex chamber and the final moisture content of the finished product.

To improve the twist of the gas flow and a more uniform load of the vortex chamber on the material, you can use a chamber with several tangential inputs. It should be noted that in this case, the manufacture of the vortex chamber is complicated. The operating experience of the vortex chamber showed that even for such a large chamber one input is enough.

The conducted studies of vortex chambers in laboratory and industrial conditions revealed the following rational values of regime-design parameters.

Table 2. Rational values of some mode-design parameters of the vortex chamber.

The input gas flow velocity υ_{in}, m/s.	15 ÷ 20
Expendable concentration of the material, Gm/Gg.	0,02 ÷ 0,04
The ratio of the radius of the outlet to the radius of the camera, $\frac{r}{R}$	0,6 ÷ 0,8
The ratio of the width of the camera to its diameter,$\frac{H}{D}$	0,3 ÷ 0,5
Conventional radial velocity of gas, $\upsilon r\ y = \frac{L}{\pi DH}$	0,9 ÷ 1,2

VI.CONCLUSION AND FUTURE WORK

Tests of experimental samples of the vortex chamber for pre-treatment of cotton cellulose of semi-industrial performance have shown that the processed material increases flow ability and the storage period without spontaneous combustion increases several times. Compared with other dryers swirling flow swirl chambers have several advantages. So, they have several times higher heat output and productivity, the drying mode is soft, which allows them to dry fine-porous materials with high binding energy of moisture to a low residual moisture content, and the material is quickly removed from the drying zone, which guarantees the absence of over drying, overheating of the material and changes in its physical and chemical properties. The advantages of a disk vortex chamber are also simplicity of manufacture, compactness, high economy. The economic efficiency was calculated from the introduction of a vortex drying chamber for drying cotton cellulose with a capacity of 1300 kg/h of dry material mounted in a cotton-cleaning workshop at a production association.

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