STUDY OF LONGITUDINAL MIXING IN A DRUM APPARATUS

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Annotation

In the process of convective drying of chemical fertilizers, drum dryers are widely used, their simplicity of construction and high technical and economic indicators have ensured their widespread use in the industry compared to other types of dryers. The final results of their drying depend on the nature of the movement of the agents involved in the process, and the solutions of the material and heat balance equations in the process are determined by the hydrodynamics of the environment. The movement of currents in drum devices is extremely complex, and it is a difficult problem to mathematically model it and find exact solutions covering all aspects of the process. Therefore, the description of such processes is shown by various hydrodynamic models. Ignoring the movement properties of the material leads to an incorrect assessment of the hydrodynamic situation in the apparatus.

Keywords: process, drying agent, difficult problem, speed of rotation.

Introduction

Scientific research in this direction led to the development of much simpler models of the structure of flows in devices, and although they are semi-empirical in nature, they allowed to obtain models that reflect the real drying process with a certain accuracy [1-4]. Heat and mass transfer processes in a drum dryer depend on its structural characteristics (dimensions, number

and profile of nozzles), technological parameters (drum rotation speed, device inclination angle, flow rate, air temperature and humidity, etc.) and mineral fertilizer properties [5-9].
Given the nature of the movement of the drying agent in the drum apparatus, it should be noted that it has a chaotic nature. This is due to the turbulence of the flow and the randomness of the movement of individual volumes of the flow by the material particles that are scattered inside the drum. The chaotic movement of the particles of the sprayed material occurs along the length of the drum [10-17]. The movement of material particles in the opposite direction to the movement of the entire flow occurs due to the opposite movement of the drying agent, that is, the hot air moving inside the drum blows away a certain part of the material particles and moves them opposite to the main flow [18-25]. This movement of the flow has a certain similarity with the description of the chaotic movement of individual molecules presented in the molecular-kinetic theory of gases. In this theory, this movement is estimated using Fick's first law, the molecular diffusion coefficient. That is, if we consider the movement of the material in the drying drum to be similar to the diffusion model, we can describe the flow structure with an equation similar to the molecular diffusion equation. We can take the model parameter as the longitudinal mixing coefficient or the reverse mixing coefficient, similar to the molecular diffusion coefficient [26-34].

Analytical research method

In order to calculate the drying process as a separate physico-chemical system, the hydrodynamic structure of the flows in the technological apparatus is considered as a basis, and the characteristics of the time distribution of the particles of the dried material in the drying apparatus are considered [35-39].

Visual and preliminary experimental studies showed that the distribution of material in the longitudinal part of the drying apparatus significantly depends on the construction of internal devices, the speed of rotation of the drum and the angle of inclination, the speed of the heating air in the apparatus, which in turn affects the time the material particles stay in the drying zone.

There are many studies on the effect of temperature, humidity and drying speed, angle of inclination and rotation speed of the drum on the process of filling the drum with material. However, these studies did not take into account the effect of internal spraying elements - nozzles.

In addition, the influence of the longitudinal mixing level of different spraying devices on the final results of drying was not taken into account [40-47]. Thus, we determined the effect of different internal nozzles on the material residence time, longitudinal mixing and filling coefficients. When analyzing the movement of the drying agent and material in the studied apparatus, its structural characteristics are considered constant, and since the stationary mode is taken into account, the process parameters in each separate section of the drum are also considered unchanged. With such limitations, we somewhat simplify the movement of particles in the drying drum, based on the physical model of the device, taking into account several factors and the flow zone of ideal mixing.

$$\bar{\tau} = (1+R)\left[\frac{M_1}{(1+R)\nu} + \frac{\beta M_2}{\beta(1+R)\nu}\right] = \frac{M_1 + M_2}{\nu} = \frac{M}{\nu}, \quad (1)$$

Here: M is the total mass of the layer, M1, M2- respectively, the mass of the material in the flow and stagnant zones, kg; n - mass flow rate at the inlet and outlet of the device; Rn is the mass velocity of the recirculation flow, where R is the recirculation parameter; b(1+R) n is the mass flow rate of a part of the flow coming to or leaving the stagnant zone; b is exchange intensity, 0≤b≤1.

As can be seen from equation (1), the average residence time of particles in the system does not depend on the rate of exchange between the flowing and stagnant zones or the fraction of recirculation.

The proposed equation was compared with the experimental data to verify its suitability for the real drying process and is presented in the results section.

Experimental results

An experimental analysis of the distribution functions of the material residence time in the apparatus was carried out for two modifications of the developed design of the drum nozzle during direct drying of quartz sand.. Experiencein order to determine the average time of the dispersion material in the apparatus and the longitudinal mixing coefficient, the non-stop flow of the material was influenced by the method of stimulating a certain section of it (the entrance to the drum). In this case, the impact signal has the character of an impulse. Hydrodynamic parameters of the system (S-deviation) are determined based on the result of signal response functions.Quartz sand was used as the main dispersed layer during the experiments. An experimental copy of the laboratory device with a Ø0.4×2.0 meter drum was prepared at the "Technological machines and equipment" department of the Fergana Polytechnic Institute. Experimental studies were carried out in a drying drum at the training ground of the department. During the experiments, the number of rotations of the drum was in the range of n= 3.0 - 6.0 rev/min, and the productivity of the quartz sand considered as the main material was in the range of 0.02-0.05 kg/s.

Material treated in a specially prepared homogenous mixture of sodium chloride was used as a tracer for the flow of quartz sand. The granulometric composition of the mixture was the same as the granulometric indicators of the base material. The method of obtaining experimental response curves (C-curves) was carried out as follows. After the drying drum reached a certain temperature and hydrodynamic mode, a part of the indicator was introduced into the material loading area through a special device, almost instantly. At the same time, the stopwatch was turned on and the product coming out of the apparatus was taken by the sampler at the outlet of the drying drum. Sampling was carried out continuously in a glass measuring cylinder and was arranged according to the sampling time. Then a certain weight of the obtained sample was taken and mixed and dissolved in distilled water. 10 ml of the resulting solution was taken, and the mass of the indicator (NaCl) was determined by titration according to Mor's method. The appointed time $\Delta\tau_i$ The concentration of the indicator in the sample taken after [g/g] was calculated as a fraction of the mass of the indicator divided by the total weight of the sample.

When processing the experimental results, the estimated average residence time of the material in the layer was determined by the expression:

$$\bar{\tau} = \frac{\Sigma C_i \tau_i}{\Sigma C_i} \qquad (2)$$

The measured value of the differential function of the average residence time of the material in the apparatus was calculated by the following equation:

$$C(\tau_i) = \frac{C_i}{\Sigma C_i \Delta\tau_i} \qquad (3)$$

The dimensionless value of the distribution of the average residence time of the material in the apparatus was determined by the following equation:

$$C(\theta_i) = C(\tau_i)\bar{\tau} \qquad (4)$$

Summary

The determination of the obtained model (1) with the experimental data of the results of impulse exposure to a continuous flow of material to obtain its unknown parameters was carried out by obtaining theoretical and experimental C-curves.

The experimentally obtained results correspond to the solutions of equation (1), the difference between the theoretical and experimentally obtained data does not exceed 7%. It can be seen that the average residence time of particles in the system does not depend on the rate of exchange between the flowing and stagnant zones, nor on the ratio of the recirculation flow, which is generally consistent with the conclusions. As a result, the following recommended model parameters were obtained:

$$\bar{\tau} = 2{,}5 - 5{,}7\,мин;\ \beta = 0{,}02 - 0{,}5;\ R = 0{,}6 - 3{,}2;\ \tau_2 / \tau_1 = 3 - 5.$$

Summarizing the above, the parameters obtained during the experiment can be used to determine the time of drying material in the apparatus and to calculate the overall drying process based on this.

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