

IDENTIFICATION OF THE POTASSIUM CHLORIDE DRYING PROCESS

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Annotation. *This article analyzes the process of drying potassium chloride in drum dryers and the issues of identifying its main technological and physicochemical properties. To increase the efficiency of drying potassium fertilizers in drum dryers, the speed of the drying agent, the geometric and parametric dimensions of the drum, the rotation speed, and the movement characteristics of the material were taken into account. Based on mathematical models and calculation formulas of the drying process, the retention time of the wet material in the drum, the particle velocity, the porosity coefficient, the interaction velocity between the drying agent and the particle, and the Reynolds number were determined. The size of the granules and the conditions of heat and mass transfer in the dryer significantly influence the process. The article also provides the identification of important factors determining the physical parameters of the wet concentrate and the drying efficiency in the drum dryer. Based on the research results, the possibilities of automation and optimization of the drying system are substantiated. This scientific work is aimed at improving the technology of energy-saving drying of potassium chloride on an industrial scale and is of practical importance in the chemical industry and the field of automation of technological processes.*

Keyword: *Potassium chloride, drum dryer, automation, gas phase, differential equation, wet material, drying agent, mass flow rate.*

Introduction. Potassium chloride (KCl) is considered one of the main components in the production of mineral fertilizers. Its industrial-scale production, especially the drying stage, determines the energy and technological efficiency of the process. The main purpose of drying is to bring potassium chloride to a suitable and necessary technological state for storage and transportation. Today, drum dryers are widely used for drying potassium chloride, which enables the automation of the process.

However, for effective drying, accurate determination (i.e., identification) of the parameters is of great importance. In recent years, drum dryers have been used in the drying of potassium chloride in the mineral fertilizer production industry. Due to the possibility of fully automating the drying process in drum dryers, it is also possible to

dry potassium chloride with high moisture content [1-3]. In the dryer, due to the longer residence time of the wet concentrate, productivity gradually decreases. This is because the wet concentrate moves in parallel with the drying agent, which reduces the drying zone and decreases the drying intensity. To prevent the fine fraction in the material being dried from being carried away, the velocity of the drying agent driven by the fan should not exceed 3 m/s.

Drying of potassium chloride in a rotary dryer is a process based on heat and mass transfer, where free moisture is evaporated through the interaction between the gas phase and solid particles [3-5]. In this process, heat is transferred from the drying agent to the material, resulting in the evaporation of moisture from the surface of the particles and thereby accomplishing the drying.

The decrease in moisture over time can be expressed by the following differential equation.

$$\frac{dX(t)}{dt} = -\frac{k_x \cdot A}{m_s} (X(t) - X_{nn}(t)) \quad (1)$$

Where:

$X(t)$ – current moisture content;

$X_{nn}(t)$ – equilibrium moisture content;

k_x – mass transfer coefficient [$kg/m^2 \cdot s$];

A – drying surface [m^2];

m_s – dry mass of the material [kg].

This expression (1) is a first-order differential equation, and its solution is given by the following form of the equation:

$$X(t) = X_{nn} + (X_0 - X_{nn}) \cdot e^{-\frac{k_x A}{m_s} t} \quad (2)$$

The calculation of rotary dryers is carried out based on the drying time of potassium chloride or the specific moisture removal rate [6].

When the movement directions of potassium chloride and the drying agent are parallel [7-9], the residence time of the moist material in the drum is calculated using the following equation:

$$t = \frac{D}{S^k \left[R \cdot \operatorname{tg} \alpha \left(n + \frac{c}{\psi} \cdot \frac{b}{R} \right) \right] - \frac{860 \cdot e}{\tau_n \cdot r_3} \cdot (\tau_n \cdot g_{TT})^f} \quad (3)$$

Where: K – drum length, [M]; b – drum rotation speed, [circ/min]; R – drum diameter, [M]; α – drum inclination angle, [rad]; l – average length of the lifters (paddles), [M]; ψ – drum filling degree, [%]; τ_n – bulk density of the material, [kg/m^3];

r_s – equivalent diameter of the particles, [mm]; g_{IT} – gas velocity, [m/c]; k, n, c, e, f – parameters depending on the type of packing.

Figure 1 below illustrates the exponential decrease in moisture content of the material over time. This model can be used to determine the drying duration and evaluate the optimal drying time.

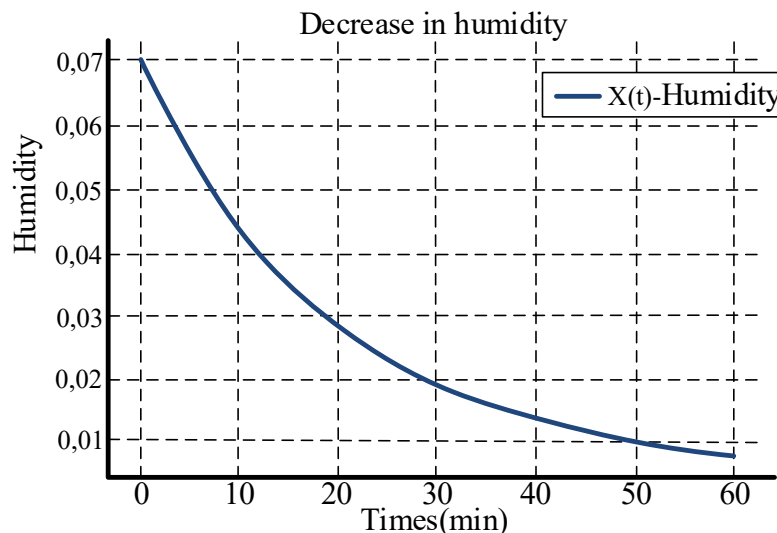


Figure 1. Determination of drying duration and evaluation of optimal time

Based on the method presented in [8-10], we will consider the technological parameters that affect the quality of potassium chloride in relation to its mass flow rate and the technological process and physical transformations occurring in the rotary drying unit. The average particle size of potassium chloride granules should fall within the range of 1 to 4 [mm]; the mass flow rate of potassium chloride fed into the dryer is 50 [tons/hour]. After the flotation process, where certain minerals are separated from the ore using water or a saturated salt solution, the moisture content of potassium chloride typically reaches an average of 6 to 7 [%]. The velocity of the drying agent inside the drum depends on the particle size, density, and the movement direction of the wet concentrate. For potassium chloride, the average velocity of the drying agent ranges from 1.5 to 3 [m/s]. In the dryer, the relative velocity g_{HT} between the heat carrier and the wet concentrate is equal to the difference in their respective velocities and is described by the following formula:

$$g_{HT} = g_{KT} - g_{HK} \quad (4)$$

As the gas velocity increases, the residence time of the material in the drum decreases. Figure 2 clearly illustrates this relationship and helps to determine the optimal gas velocity.

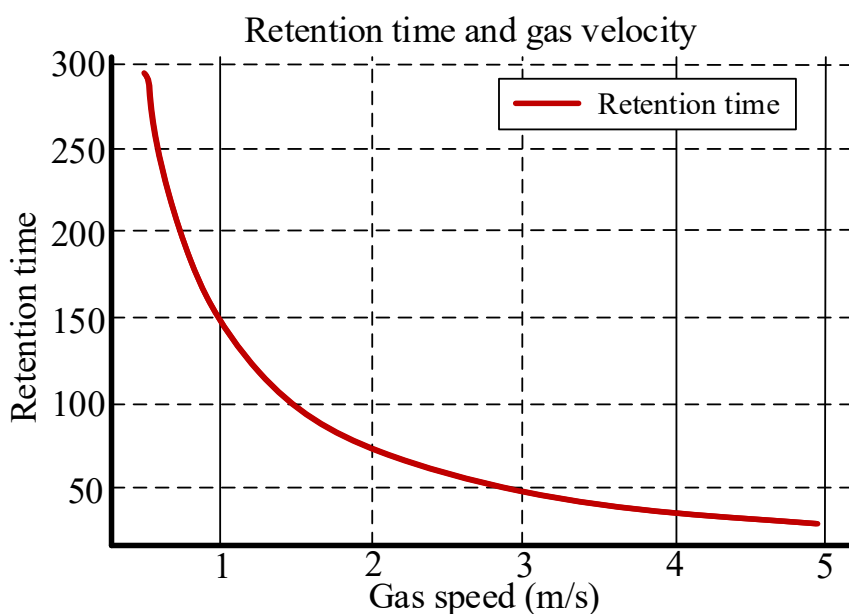


Figure 2. Determination of the Optimal Gas Velocity

To avoid complications during the drying process, the linear velocity of the rotating drum is not taken into account when considering the movement of the wet concentrate. The impact velocity of the potassium chloride particles, which make up the material, in relation to all states of the drying agent, is determined using the formula provided below [10].

$$R_e = \frac{\mu_r}{18 + 0,6\sqrt{\mu_r}} \quad (4)$$

Overall, the contact velocity between the drying agent and potassium chloride particles with an average calculated size of 4 mm is 2.345 m/s.

Rotary drum dryers are designed for drying potassium chloride with granule sizes ranging from 1 to 4 mm and porosity values between 0.65 and 0.85. The porosity is calculated using the following formula:

$$\chi = 1 - \lambda_{\text{кон}} \cdot \frac{g_{KT}}{g_{HK}} \cdot \frac{\rho_{\Gamma}}{\rho_B} \quad (5)$$

The movement velocity of wet concentrate particles inside the drum ranges from 0.0055 to 0.009 [m/s], and the relative velocity of the drying agent with respect to the wet concentrate $g_{HT} = 3,2$ [m/s], as well as the value of the Reynolds number $R_e = 24,83$, are determined accordingly.

Conclusion

In recent years, the efficient drying of potassium chloride has been recognized as one of the key technological stages in the production of mineral fertilizers. This article

analyzes the technological and physicochemical characteristics of the potassium chloride drying process in a rotary drum dryer. It was found that the direction and speed of the drying agent, the geometric and parametric dimensions of the drum, its rotation speed, as well as the size of the granules have a significant impact on the efficiency of the process. Studies have shown that the parallel movement of the drying agent and the wet concentrate in rotary dryers leads to a reduction in the drying area, and consequently, a decrease in drying intensity. During the drying process, the movement of particles, the porosity level inside the dryer, and the heat and mass transfer characteristics were evaluated based on mathematical equations. It was determined that the optimal velocity of the drying agent should be within the range of 1.5 to 3 m/s, while the particle velocity should be approximately between 0.0055 and 0.009 m/s. The average contact velocity was established to be 2.345 m/s.

Based on the retention time of potassium chloride in the drum, the volume of the drying zone, and the limitation of the drying agent's velocity, an optimal set of parameters for efficient drying was developed. Furthermore, it was substantiated that, by calculating and identifying these parameters, it is possible to automate the drying process and enhance energy efficiency.

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