SYSTEM ANALYSIS, DETERMINISTIC-STOCHASTIC MODELING AND OPTIMIZATION OF PROCESSES OF GRANULATION OF POWDERED MATERIALS

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The granulation process in the drum granulator is accompanied with charge fractional composition change. It is necessary to update and intensify granulation processes in terms of development of scientific foundations for designing, optimization and control with the purpose of increasing output product quality and quantity indices.

Impossibility of phenomena precision partitioning, simultaneously occurring in the drum granulator, leads to the necessity of the approximate estimation of interaction different stages effect and stipulates approximate mathematical models creation of the drum granulator as the sufficiently large system, consisting of separate subsystems, on the system analysis principle base.

According to the system approach, applied for the processes research in the drum granulator, it is necessary to consider the whole population of these processes on the hierarchic system base. The pointed hierarchy of levels can be taken as the basis for the mathematical model development and is represented at the definite hierarchy level.

The first level description base comprises relations, accounting physical-chemical and physical-mechanical phenomena proceeding in a particle. The complex interpartical processes mechanisms disclosure and their representation in the general form, this level research problem.

The performed nowadays researches show that the processes, carring in granule formation, are so complex that the use of these researches for practical tasks is very difficult. So, the generalized kinetic model of powdered materials particles growth is used when simulating the drum granulator. The subsequent levels of the granulation processes hierarchy in the granulator are connected with the general mathematical model elements development on the functioning macrolevel.

These elements equivalence and necessary constant values are estimated using production data. The regularity of binding material and diffusive effects influences the granule formation process is studied in these investigations.

The next stage of the mathematical model development is connected with the formalization of the hierarchy level interconnecting with the kinetic model. The relations defining particles mixing conditions in the granulator, the agglomeration degree, lumps destruction features and their plastic deformation degree in the system, are estimated at this stage.

Agglomeration, packing, particles deterioration and grinding form the granule distribution according to sizes for different drum lengths.

The granulation process model is formed, as a whole, in the drum granulator (the hierarchic system 4 th level) on the base of considered third level blocks for packing, grinding, mass transfer models accounting the particles growth kinetics model of granules.

The 5-th level mathematical models of the hierarchic system is formed on the drum granulation process model base in the drum granulator and can be used for the optimization characterizing quantitative (standard granules output increase) and qualitative (hardness, sphericity etc) process part and represents the systems generalized mathematical description of parallel connected granulators accounting the residual (retura) and can be used to solve the load distribution optimization problem according to the crude. Thus, the powdered materials granulation processes multistage allows to create more full deterministic-stochastic models:

$$\begin{cases} \dfrac{da}{d\tau} = \dfrac{2R\omega\beta a_0}{\pi}\dfrac{\delta}{a} - ka \\ \dfrac{d\delta}{d\tau} = \dfrac{1}{6m_0(1+2\delta)^2}\left[k_1 G_n \varphi_n \varphi_B - \dfrac{\pi a^3}{6}\rho(1-\theta)\Delta P/\xi_m - \varepsilon\pi\rho a^4 \sigma_D (1-\delta)^2 \upsilon_0 / 2\right] \\ \dfrac{d\theta}{d\tau} = -(1-\theta)\dfrac{\sigma_D}{\xi_m} \\ \dfrac{\varphi_n}{d\tau} = -k_2 \varphi_n \varphi_B \\ \dfrac{\partial P}{\partial t} = -\dfrac{\partial}{\partial a}\left[\dfrac{da}{dt}P(a,t)\right] + B\dfrac{\partial^2 P}{\partial a^2} \end{cases} \tag{1}$$

The distribution experimental curves are received as the result of the statistical processing. The experimental and theoretical curves in Fig.1 show the industrial description adequacy.

The mathematical model availability of powdered superphosphate granulation process gives the possibility to state and solve the process optimization problem.

The granulation process optimization requires to define the binding material quantity optimal distribution along the granulator length under the corresponding restrictions in order to increase the standard granules output.

Standard granules output increase is equivalent to the square maximization restricted with the distribution curve at the output, i.e.

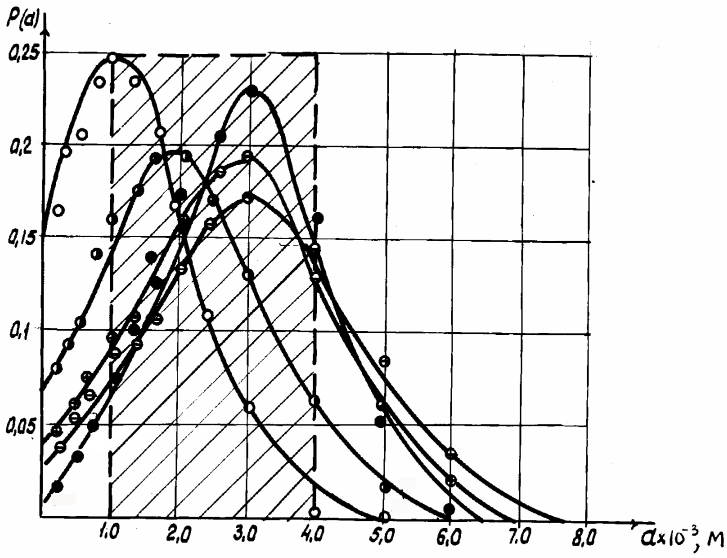

Fig. 1 Evolution of granules distribution function on sizes for the drum different length:

○ - L = 1 M, ◐ - L = 2 M, ⊖ L = 4 M, ⊕ L = 6 M,

● - L = 8 M.

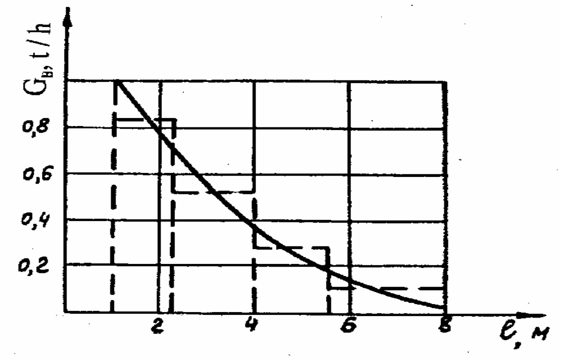

Fig. 2 Optimal distribution of binding material (water) flowrate along the granulator length (dotted lines are discrete feed of binding material in different points)

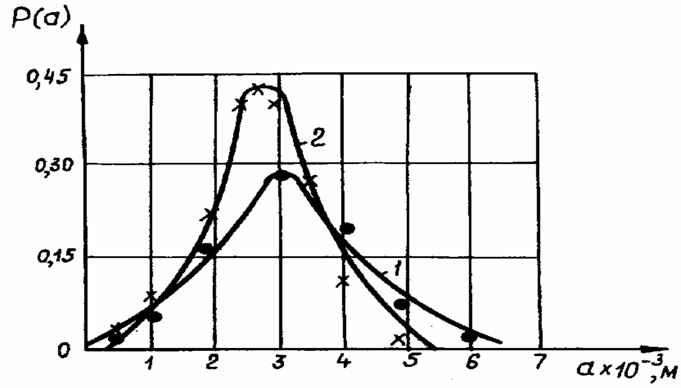

Fig. 3 Granules distribution function on sizes at the granulator output: 1 is the curve of production data; 2 is the optimal curve.

$$\max_{C_B \in \bar{C}_B} J = \int_1^4 P(a)da = \max\left\{\frac{1}{2}\left[erf\left(\frac{4-\mu_a}{\sqrt{2\pi}\sigma}\right) - erf\left(\frac{1-\mu_a}{\sqrt{2\pi}\sigma}\right)\right]\right\} \qquad (2)$$

The optimization problem is formulated as follows:

It is required to select such binding material optimal distribution along the granulator length that the functional (2) has maximal value when satisfying restrictions given in the model form (1) and in the form:

$$\int_0^{\tau_k} C_B(\tau)d\tau \le 1{,}68 \qquad (3)$$

As the granulation process mathematical models, described with the equations (1) and (3), are nonlinear then the granulation process optimization problem in the statement (1-3) is the typical nonlinear programming problem.

The criterion values were discovered in the special form.

The binding material distribution was set with different explicit functions. The function, providing the criterion most maximal value (2), was the distribution of the form:

$$C_B = C_B^0 e^{-m\tau} \tag{4}$$

where C_B^0 and m were made more accurate with the nonlinear programming methods.

The obtained equation accounting coefficients ($C_B^0 = 1{,}0t/h, m = 31{,}6h^{-1}$) is the optimal control algorithm of the powered materials granulation process.

The binding material optimal distribution along the granulator length and granules distribution function are given in Figs. 2 and 3 according to the sizes at the apparatus output.

Notation:

a - granular mean size m

σ_D- deforming stress kg/m^2

θ - granule porosity

λ - the layer thickness m

$\delta = \lambda / a_0$ - value characterizing granule stratification

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