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SIMULATION OF DYNAMICS OF PROCESS IN THE ROTARY DRUM DRYER-GRANULATOR

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Key Words and phrases: grain composition of the obtained product; granular material migration; longitudinal mixing; process of granulating and drying; return particles; rotary drum dryer-granulator.

Abstract: The presented model allows for the influence of the main geometrical parameters of the drum design, its technological characteristics, technological characteristics of the spray device on the process and it can be used for calculation of the rotary drum dryer-granulator and when solving problems of optimal organization of granulating and drying processes.

Obtaining the product of set grain composition is one of the main purposes of the granulating process in the Rotary Drum Dryer-Granulator. In this connection analytical relations for forecasting grain composition of the product in the Rotary Drum Dryer-Granulator are considered to be of great practical and theoretical concern.

The consumption and grain composition of return particles, pulp spray uniformity, uniformity of falling solid particles and flow pattern of a solid phase in the device (longitudinal and transversal mixing, in particular) are known to have a considerable influence on grain composition of the obtained product. If the time being of all granules in the rotary drum were equal, if there were no transversal mixing and other terms were equal solid particles would grow on identical value. Actually there is longitudinal and transversal mixing in the rotary drum, which has a great influence on the time being and, therefore, on time of gas-liquid stream and falling solid particles interaction and grain composition of the product.

The influence of both consumption and grain composition of return particles, and flow pattern of a solid phase on solid particles growing and distribution of solid particles of the product on diameters should be taken into consideration in the mathematical model of the process in the Rotary Drum Dryer-Granulator.

In connection with above-mentioned facts the typical scheme of granular material migration in the rotary drum was developed. Thus, we have picked out the following basic stages of particle migration, which recur many times when material advances along the axis of the rotary drum: movement in a sliding layer of the material which is formed at the bottom of the rotary drum; filling the rotary drum blades; migration in the static bed of volume fraction relatively to the rotary drum; falling from the barrel blades; motion in the flow of heat carrier; motion and growth in a plume of the sprayed pulp; falling in the material in the rotary drum.

The analysis has shown, that longitudinal mixing of the granular substance occurs at all stages. It should be taken into account at model making of granulating and drying in the Rotary Drum Dryer-Granulator. The mixing of dispersible materials in the rotary drum device with a blade-lifting attachment is well described by a diffusive model. Having set the goal to simulate dynamics of granulating and drying processes along the rotary drum axis, we have used more simple one-parameter model for the description of mixing. Experimental results have corroborated its applicability for engineering practice [1]. The specificity of a solid phase flow pattern in the device of the design under consideration was allowed for, by adding some more components in the diffusive model, which reflect how the interactive effects between the granules and gas liquid flow of the sprayed pulp influence on the flow pattern formation.

When implementing processes of granulating and drying in the Rotary Drum Dryer-Granulator, return particles and sprayed pulp supply is brought from one butt-end of the rotary drum, and product discharge and scooping of return particles from another one.

During such a filling some increase of the loading coefficient at the beginning of a zone "plume - curtain" and some reduction at the end of the plume are observed, further on, along the drum length the loading coefficient is a constant value [2]. Consequently, we consider the change of the loading coefficient along the rotary drum length to be known and it corresponds to the above-mentioned experimental data [2].

Having supposed, that the function I_l of the loading material distribution along the drum length is known (fig. 1), we have calculated the longitudinal velocity U_j of the material in the filling in a *j*- section of the device according to the formula

$$U_j = \frac{4}{\rho(1-\varepsilon)\pi D^2 \beta} \int_x^{x+\Delta x} (I_l + I_{l1}) dx .$$

The following differential equation describes a convective transfer and longitudinal mixing of a target fraction granules in the rotary drum dryer-granulator on condition that there is no granule growing [1]:

$$\frac{\partial c}{\partial t} = \frac{\partial (Uc)}{\partial x} + D_{ls} \frac{\partial^2 c}{\partial x^2} + \frac{4 c_r}{\beta \pi D^2} I_l, \qquad 0 \le x \le L, \tag{1}$$

where c, $\tilde{n}_r$ - current concentration of an i-component and concentration in return particles accordingly; D_{ls} - coefficient of longitudinal stirring; β - loading coefficient.

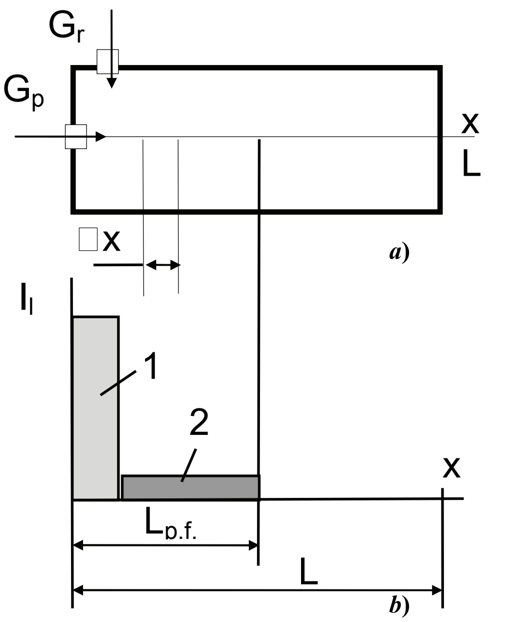

Fig 1. The function of the loading material distribution along the drum length:
a) the scheme of the drum;
b) the loading material: *1* - dot in butt-end of the drum;
2 - at the expense of granule growing

The boundary conditions for butt ends of the rotary drum were formulated in the usual way, which reflects the absence of a diffusive flow through the butt-end walls:

$$\left.\frac{\partial c}{\partial x}\right|_{x=0} = 0, \qquad \left.\frac{\partial c}{\partial x}\right|_{x=L} = 0.$$

The initial distribution of the i-component in the filling along the drum length was assumed identical and corresponding to the distribution of fragments in return particles: $c(0,x)=c_0=\text{const}$ which corresponds to conditions of setting the device in motion in full measure.

Let's consider an element of the material filling based on coordinates x and Δx. At each time step the blade-lifting attachment selects from this volume Q_x of the granulated material:

$$Q_x = \frac{\omega}{2\pi} n_b F_b \Delta x,$$

where F_b - cross-sectional area of a granule filling on a blade, which is easily determined by a semigraphical method.

Taking into account the obtained expression and analogy between operation of the blade-lifting attachment and negative source of the i-fraction we have determined volumetric power of negative source i-fraction in the following way

$$I_v^- = \frac{2\omega n_b F_b}{\pi^2 \beta D^2} c(t,x)k, \qquad (2)$$

where $c(t, x)$ - concentration of a i-fraction on coordinate x of the rotary drum length at the time moment t; k - coefficient which takes into account fraction and structure of granules, contacting with the plume of sprayed pulp. It is calculated according to the formula in view of experimental data on distribution of curtain particles in a drum cross section [3]

$$k = \int_{-R_p}^{R_p} f(y)dy \Big/ \int_{-R_p}^{R_p} f(y)dy,$$

where R_p - radius of a plume of the sprayed liquid.

It was assumed that the granules, dropping from blades without interaction with the plume of sprayed pulp, migrate without drift.

The granule flow, pouring from blades, falls in the plume of the sprayed pulp and interacts with it. The analysis of this interaction was carried out and is shown in [4, 5], a calculating method of new granules distribution on the sizes after a single interaction of flows is also described there. In accordance with the explained method the concentration of the i-component c_1 in a flow, dropping in a filling, was determined as a function of initial distribution of granules on a blade $\varphi(\tilde{n}_N)$ on coordinate x, which corresponds to the trajectory of the granule motion. Subsequently we supposed, that this relation is described in the following way $c_1(t,x) = f(\varphi c_N)$.

After interaction of flows some more material $m_1(t, \Delta x)$ is fed in the filling, in view of the increase of granules weight on value $\Delta \grave{I}$.

Then volumetric power of a positive source of the i-fraction component is determined as:

$$I_v^+ = \frac{6m_1(t,\Delta x)}{\pi D^3 \beta\rho \Delta x} c_1(t,x) \qquad (3)$$

When determining the dynamics of change in grain composition of the i-fraction concentration it was assumed, that during the drying the granules lose some moisture, but their volume (size) does not change. It is grounded on the results, adduced in [6].

The equalities (2) and (3) with the equation of substance transferring (1) were reviewed jointly. We have received a dynamic equation of the i-component distribution in the rotary drum dryer-granulator:

$$\frac{\partial c(t,x)}{\partial t} = \frac{\partial Uc(t,x)}{\partial x} + D_{ls}\frac{\partial^2 c(t,x)}{\partial x^2} + \frac{4c_r}{\beta\pi D^2} I_l + I_v^+ + I_v^- . \tag{4}$$

For implementation on a computer of the introduced above mathematical model of the rotary drum dryer-granulator it was necessary to reduce a differential partial equation (4) to algebraic equations. With this purpose each member of the equation was substituted for its differencial analogue. We have received the differencial equations on the basis of Krank-Nikolson's scheme.

Having substituted the obtained expressions in the equation (4) and the collecting terms in view of boundary conditions in the differencial form we have received a system consisting of n+1 simple equations with n+1 unknown:

$$-a_j c_{j-1}^{\gamma+1} + p_j c_j^{\gamma+1} - q_j c_{j+1}^{\gamma+1} = f_j, \quad j = 0,1,2...n,$$

where a_0=0, q_n=0.

The system was solved with the help of the factorization method.

The presented computational scheme was realised in the calculation program of the dynamics process in the rotary drum dryer-granulator on a computer.

The adequacy of the designed model of granulating process in the rotary drum dryer-granulator was checked by comparing outcomes of simulation with experimental data. The experimental data were obtained on the industrial rotary drum dryer-granulator in the production of granulated ammophos. To define the size of ammophos granules at the orifice of the rotary drum we selected the samples, which were subjected to mesh (sieve) analysis. Then grain composition of the product was determined by the results of mesh (sieve) analysis.

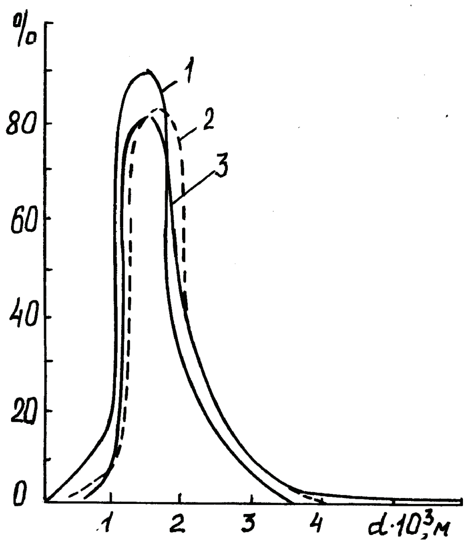

Fig.2. The comparison of computational and experimental outcomes on dynamics of process in the rotary drum dryer-granulator:
1 - return particles; grain composition of the obtained product; *2* - experimental; *3* - computational

When simulating the substantial industrial device it was necessary to define the value of the longitudinal mixing D_{ls} coefficient. In [1] the semiempirical formula for calculation of value D_{ls} is obtained which depends on such parameters as a diameter of the rotary drum D, quantity of lifting blades n_b, angular rate of rotation n, coefficient of the rotary drum filling β and width of a blade l:

$$D_{ls} = 12{,}5 \cdot 10^{-5} D^{1{,}37} e^{1{,}12 n_b} \left[D tg\alpha_x \left(169 + \frac{1000}{\beta}\left(\frac{l}{D}\right)\right)\right],$$

where α – angle of the rotary drum slope to horizon. According to this formula $D_{ls} \cong 1\cdot10^{-3}$ m^2/seconds.

The comparison of computational and experimental outcomes on dynamics of process in the rotary drum dryer-granulator (fig. 2) allows to draw a conclusion that the calculating values correspond to the experimental data adequately.

The designed model allows for the influence of the main geometrical parameters of the drum design (diameter, sizes of blades and their quantity), its technological characteristics (rotation rate and coefficient of the rotary drum filling), technological characteristics of the spray device (speed of a gas liquid flow, drops dispersity of a fluid phase, the arrangement of the device) etc. on the process and it can be used for technological calculation of the rotary drum dryer-granulator and when solving problems of optimal organization of granulating and drying processes.

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Моделирование динамики процесса гранулирования в барабанных грануляторах-сушилках

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Ключевые слова и фразы: гранулометрический состав продукта; движение гранул; продольное перемешивание; процесс гранулирования и сушки; ретур; барабанный гранулятор-сушилка.

Аннотация: Представлена модель, учитывающая влияние на процесс гранулирования в барабанных грануляторах-сушилках основных геометрических параметров аппарата, его технологических характеристик, технологических характеристик распыливающего устройства, которая может быть использована для расчета аппарата и при решении задач оптимальной организации процесса гранулирования и сушки.

Modellierung der Dynamik des Prozesses der Granulierung im Trommeltrockengranulator

Zusammenfassung: Es ist das Modell, das die Einwirkung der hauptsächlichen geometrischen Parameter der Konstruktionen des Apparats, seiner technologischen Charakteristiken, technologischer Charakteristiken der zerstäubenden Anlage auf den Prozeß der Granulation im Trommeltrockengranulator (TTG) dargestellt. Das Modell kann man für die technologische Berechnung des Apparats des TTGs und bei der Lösung der Aufgaben der optimalen Organisierung des Prozesses der Granulation und der Trockung gebrauchen.

Simulation de la dynamique du processus de la granulation dans les granulateurs-sécheuses à tambour

Résumé: On a présenté le modèle qui prend en compte l'influence des essentiels paramètres de la construction de l'appareil, de ses caractéristiques technologiques ainsi que des caractéristiques technologiques des granulateurs-sécheuses à tambour sur le processus de la granulation. Ce modèle peut être utilisé au cours du calcul technologique de l'appareil ainsi que pendant la résolution des problèmes de l'organisation optimale du processus de la granulation et du séchage.