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PELLETIZING IN POWDER MATERIALS WITH THE USE OF "FATTENING" TECHNOLOGY

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The pelletizing process in plate granulators with the use of "fattening" technology has been investigated. A mathematical description of various process versions including pellet nucleation and their fragmentation is presented.

Keywords: *pelletizing, encapsulation, mathematical modeling.*

The advancement of add-on palletizing technology is related primarily to the necessity to obtain pellets of larger size with considerably higher quality indices than those to be reached in granulation towers. [1, 2]. Melts, solutions, powders with or without a binder may be used for original pellet fattening [3]. In this case it is possible to change the composition of the product being palletized or encapsulate the pellets obtained [3].

The process is carried out in paddle or screw mixers, rotary drums, inclined axle plates [3] and pelletizer types [2].

Fattening is the process used for add-on original pellets (often produced by prilling and, therefore, not strong enough) with a powder (with or without a binder) by palletizing in apperatus including those of plate type [3].

In the course of the process it is necessary to avoid pellet nucleation and their fragmentation. As the process of pellet size gain is a random one Fokker-Planck equation is used for a description of prill size distribution [4]:

$$\frac{\partial n(r,\tau)}{\partial \tau} = \frac{\partial}{\partial r}\left[-v_+ n(r,\tau) + (D_+ + D_-)\frac{\partial n(r,\tau)}{\partial r}\right], \qquad (1)$$

where v_+ – average rate of prill size variation; D_+, D_- – the coefficients of prill size variation rate, n – prill size distribution density, τ – time.

The initial condition: $n(r,0) = n_0(r)$; boundary condition: $n(0,\tau) = 0;\ n(\infty,\tau) = 0$;

and the normalization condition:

$$\int_0^\infty n(r,\tau)dr = 1;$$

The solution can be written as [5]:

$$n(r,\tau) = \frac{1}{\sqrt{2\pi}\sigma}\int_0^\infty \left[\exp\left[-\frac{1}{2}\left(\frac{re^{(\mu_- - \mu_+)\tau} - 1}{\sigma}\right)^2\right] - \exp\left[-\frac{1}{2}\left(\frac{re^{(\mu_- - \mu_+)\tau} + 1}{\sigma}\right)^2\right]\right] n_0(\xi)d\xi, \qquad (2)$$

where $\sigma^2 = \frac{D_+ + D_-}{\mu_- - \mu_+}\left[e^{2(\mu_- - \mu_+)\tau} - 1\right]$, $\mu_\pm = \frac{v_\pm}{r}$ – the frequency of particle detachment (breaking away) and attachment, $v_\pm$ – prill growth (breakage) rate.

The equation (1) is solved by means of numerical and graphical-analytical methods.

In calculation by the finite differences method the simplified equation version (1) has being solved [6]:

$$\frac{d\psi(x,\tau)}{d\tau} + \frac{d}{dx}\left[\lambda(x,\tau)\psi(x,\tau)\right] = 0, \qquad (3)$$

where $\psi \equiv n,\ x \equiv r,\ \lambda \equiv v_l,\ (D_+ + D_-) \equiv 0$.

As a basis of the initial data the prill size distribution for ammonium nitrate as per GOST 2-85 has been used [1]:

Table 1

$d_{гр}$, mm	0-1	1-2	2-3	3-4	4-5
n, %	3	12.5	70	12.5	2

The linear growth rate of calcium ammonium nitrate has been used as a result of the experimental data obtained from the procedure for its calculation proposed by the authors [3, 7].

In this case prill breakage and agglomeration are ignored. From the practicle point of view this is an ideal variant of carrying out the "fattening" process.

As in the previous case it is assumed that prill nucleation does not occur but their partial breakage takes place (with φ fraction). As it follows Fokker-Planck equation is modified taking into account the obvious relationship of the law of conservation of substance and the expression for time derivative of the integral of the unknown function n(r, τ) over the movable volume V(τ) which is closed by the surface S(τ) assuming that as a result of breakage there are two fragments:

$$\frac{d}{d\tau}\int_{S(\tau)} ndV = \int_{S(\tau)} q_\pm dS + \int_{S(\tau)} \varphi q_n dS + \int_{S'(\tau)} 2\varphi q_n dS \Rightarrow$$

$$\Rightarrow \int_{V(\tau)}\left[\frac{dn}{d\tau} + div(v_l n)\right]dV = \int_{V(\tau)} divq_\pm dV + \qquad (4)$$

$$+ \int_{V(\tau)} div\varphi q_n dV + \int_{V(\tau)} div 2\varphi q_n dV,$$

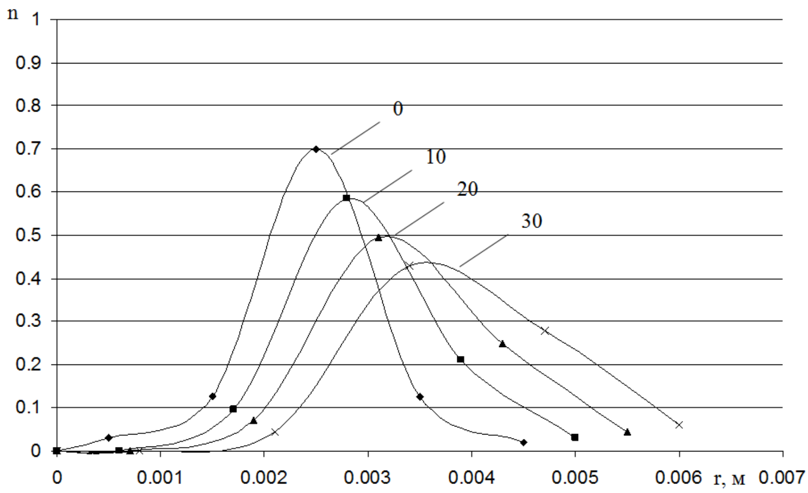

Fig. 1. Changing the distribution density of the calcium ammonium nitrate granules in size with time n. The numbers on the curves – time, s.

where $q_{\pm} = (D_{+} + D_{-})\nabla n$, $q_n = v_л n$, v_l – linear growth rate of prills, ∇ – the Hamiltonian operator;

Turning to differential form of the equation (4), we obtain

$$\frac{\partial n(r,\tau)}{\partial \tau} = \frac{\partial}{\partial r}\left[-(1-\varphi)v_{+}n(r,\tau) + (D_{+}+D_{-})\frac{\partial n(r,\tau)}{\partial r}\right] + \frac{\partial}{\partial r'}(2\varphi v_l n(r,\tau)), \quad (5)$$

wherein r – current for spherical or r '– equivalent to non-spherical radius of the fragments, in general, if fragmentation occurs at ξ fragments, $r' = r/\sqrt[3]{\xi}$, equation (5) becomes:

$$\frac{\partial n}{\partial \tau} = \frac{\partial}{\partial r}\left[-(1-\varphi)(1-2\sqrt[3]{\xi})v_l(r)n + \left[D_{+}(r)+D_{-}(r)\right]\frac{\partial n}{\partial r}\right] \quad (6)$$

The numerical solution of the equation (6) by the method of finite differences [8] with the use of the implicit scheme when prills are broken into two fragments of equal size with the fraction of prills being broken φ equal 0.5 is presented in fig. 2. When compared with the case given in fig. 1 there is a "drift" of time distribution density observed in fig. 2. An increase in polydispersity of the product being produced is evident when breakage of the prills being processed is not prevented by the technological means. This correlates well with practice. The calculation results disagree with experiment not more than 10±2% with probability equal to 95%.

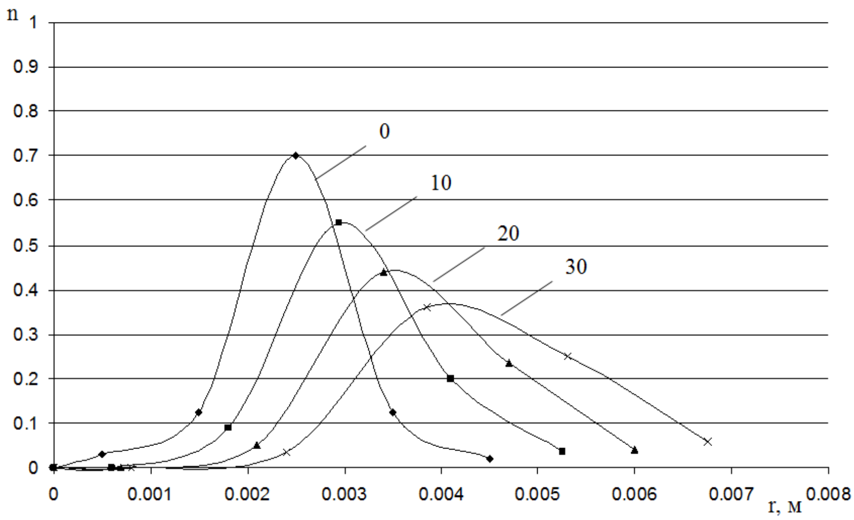

Fig. 2. Changing the distribution density of the calcium ammonium nitrate granules in size with time n. The numbers on the curves - time, s.

Apart from the above we have also investigated other process variants including the variants in which nucleation of new prills from the powder exists with both breakage or non-breakage of some prills formed. In addition, the program for algorithm implementation that takes into account the influence of breakage and agglomeration of prills in orbitrary proportions has been developed.

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ГРАНУЛООБРАЗОВАНИЕ В ПОРОШКООБРАЗНЫХ МАТЕРИАЛАХ ПРИ ИСПОЛЬЗОВАНИ ТЕХНОЛОГИИ “FATTENING”

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Рассмотрен процесс гранулообразования при использовании технологии “fattening” в грануляторах тарельчатого типа. Дано математическое описание различных вариантов протекания процесса, в том числе с учетом зарождения гранул и их возможного дробления.

Ключевые слова: *гранулирование, капсулирование, математическое моделирование.*