# IDENTIFICATION OF THE GRANULATION PROCESS IN THE FLUIDIZED BED

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## ABSTRACT

The article describes an algorithm identification process of dehydration and granulation in a fluidized bed in the preparation of granulated product specified particulate composition. The conditions characterize the kinetics of stable continuous granulation process with increasing the mass fraction of a given granule diameter by 40%. As a result of calculations after the foregoing algorithm with the initial value of the coefficient $K_1$=0,009, we got $K_1$ values, by which the granules mass distribution function changes in accordance with the set equivalent diameter of granules $d_{esd}$=2,5 mm. At the transitional process duration of 3 s, the main changes of the $K_1$ coefficient take place during the last 30 s and they are characterized by the significant reduction of the $K_1$ coefficient, which results to the reduction of granules unloading of the set equivalent diameter from the apparatus. After the realization of the identification algorithm, the granules mass fraction of the set size of $d_{eзд}$=2, 5 mm increase from 0, 26 to 0, 45, which substantially improved the granules size composition of the final product. As a result of the research, the identification algorithm of the dehydration and granulation processes of mineral fertilizers in the apparatus with a fluidized bed is developed. The defined conditions characterize a stable kinetics of nonrecyclable continuous granulation process with the mass fraction increasing of granules diameter of 2,5 mm by 40%.

**Keywords:** identification, mineral fertilizers, mathematical model, dehydration, granulation, fluidized bed.

## INTRODUCTION

The increasing of humanity necessities in food sets requirements to manufacturers in the increasing of the basic agricultural crops productivity. For the achievement of this aim, the agrarian sector needs to actively use the different types of new generation mineral fertilizers. The chemical production belongs to the most innovative and knowledge-based branch of industry. At the annual demand increasing for mineral fertilizers by 5-8%, the special attention is paid to the final product quality, which is determined by even distribution of macro and micro components on the entire volume of granules, the sizes of which are within the limits of 1, 8-4, 5 mm and have the robustness more than 10 H per granule. Granules with the best structure and agrochemical properties have a size from 2 to 3 mm.

Mineral fertilizers, which are modified by necessary mineral and organic admixtures with the set properties, are most appropriate to get by dehydration and granulation in the apparatus with a fluidized bed. The mathematical model of dehydration and granulation processes in the fluidized bed is developed [1-9]. Granulation in the fluidized bed is accompanied by the multifactor heat and mass transfer processes of granules growth. The kinetics stability of non recyclable granulation process is determined by the mechanism of large granules parts shredding in the apparatus, which is related to the formation of granulation new centers and increasing the size of solid particles due to the creation of microcrystals layer on its surface [10].

Therefore, there was a necessity of parametric identification of dehydration and granulation process. The emulsive phase thermal diffusivity coefficient, the heat and mass transfer coefficients are among the determinant parameters of the process. But the absence of a possibility of the permanent temperature measuring and providing a large number of sensors in the apparatus with a fluidized bed considerably complicates the task of identification by the temperature regime. The aim of the process is an acquiring of the final product of the set dispersible composition, continuous determination of which is the difficult task to implement. But the presence of optical devices for determination of equivalent granules diameter allows identifying the dehydration and granulation process in a fluidized bed by granules size composition.

Currently, there are a lot of mathematical model parameters calculation methods of the processes in the fluidized bed. There are known analytical [11] and numeral methods. Numeral methods are based on the construction of identification tasks to boundary tasks for ordinary differential equations. These solutions are based on the methods of optimal management theory with the use of object dynamic equations and conjugate equations [12-15]. The necessary condition for stationary functionality is often used for identification [16, 17]. So as this condition is local, then for nonlinear tasks the identification algorithm can be reduced to a local extremum.

## THE PURPOSE OF THE WORK

The article shows the identification algorithm of dehydration and granulation processes in the fluidized bed in obtaining a granular product of the set dispersible composition.

## MATERIALS AND METHODS

The identification task is formulated as a task of minimization of functional residual, which looks like:

$$I = \frac{1}{2}\int_0^{d_m} q(D)\cdot\left[\frac{g(D,t_f)}{D} - \frac{1}{d_{esd}}\right]^2 dD \to \min; \qquad (1)$$

where $g(D, t_f)$ – function of granules mass distribution by the sizes, 1/mm; $D$ - granules diameter, mm; $d_{esd}$ - equivalent set diameter of granules, mm; $q(D)$ - weighting coefficients.

The function of equivalent diameter is offered in an order not to enter non-linearity on mass fraction.

The equivalent diameter of particles in the fluidized bed is determined by the expression:

$$d_e = \frac{1}{\sum \frac{g_i}{D_i}}; \qquad (2)$$

where $g_i$ - mass fraction of i's fraction, 1/mm; $D_i$ - average diameter of i's fraction, mm.

For the identification task, the mathematical model of granules mass distribution function by their sizes is used $g(D, t)$ at the flowing of drying process in the first period [9]:

$$\frac{\partial g(D,t)}{\partial t} + 2\left(v\frac{\partial g(D,t)}{\partial D} - 3\frac{g(D,t)v}{D}\right) = = -S\eta K_r g(D,t) + \Phi(D); \qquad (3)$$

with the initial and boundary conditions:

$$g(D,0) = g^b;\ g(0,t) = g^0; \qquad (4)$$

where ν - linear speed of granules increasing, mm/s; $D$ – granules diameter of i's fraction, mm; η - granulation coefficient, $\eta = \frac{G_B}{G_M}$, $G_B$ - productivity of the granular product kg/s, $G_M$ - amount of dry substances, that comes to apparatus with the solution, kg/s, $S$ – separator function, that takes into account a selective unloading from the apparatus; $K_r$ - an unloading constant, 1/s; $\Phi(D)$ - function, that takes into account the particles flow due to unloading from the apparatus and grinding the part of large granules, i.e. it is an algebraic sum of integrals of flow and source, 1/mm·s.

It is experimentally established that unloading constant $K_r$ depends on the temperature difference of a heat carrier on the apparatus entrance and particles temperature in emulsive phase. So, in the fluidized bed, with the change of temperature $T_1$ granules mass distribution will change by their sizes. The unloading constant can be written in the form:

$$K_r = K_1\cdot(T_{20} - T_1); \qquad (5)$$

where $K_1$ - a coefficient, that influences on the unloading constant, 1/K·s.

Distribution equation of granules by the size with taking into account the dependence of the unloading coefficient on the temperature difference of the heat carrier on the apparatus entrance $T_{20}$ and particles temperature in emulsive phase $T_1$:

$$\frac{\partial g(D,t)}{\partial t} = -2\left(v\cdot\frac{\partial g(D,t)}{\partial D} - 3\cdot\frac{g(D,t)\cdot v}{D}\right) - -S\cdot\eta\cdot K_1\cdot(T_{20} - T_1)\cdot g(D,t) + \Phi(D). \qquad (6)$$

Thus, for different temperature regimes on the layer height, it is possible to calculate the granules mass distribution by diameters.

For identification the parameter $K_1$, the variational approach to the construction of estimation algorithm is used. The advantage of such approach consists in the possibility of obtaining more exact parameters estimations in comparison with other methods, in particular, with a least-squares method.

In the optimality criterion, a mathematical model is taken into account:

$$I = \frac{1}{2}\int_0^{d_m} q(D)\cdot\left[\frac{g(D,t_f)}{D} - \frac{1}{d_{езд}}\right]^2 dD + +\int_0^{t_f}\int_0^{d_m} \lambda\cdot(-\frac{\partial g(D,t)}{\partial t} - 2v\cdot\frac{\partial g(D,t)}{\partial D} + 6\frac{g(D,t)\cdot v}{D} - -S\cdot\eta\cdot K_1\cdot(T_{20} - T_1)\cdot g(D,t) + \Phi(D))dDdt; \qquad (7)$$

Lagrangian of the absolute minimization task:

$$L(K_1) = \lambda(D,t)\cdot(-\frac{\partial g(D,t)}{\partial t} - 2v\cdot\frac{\partial g(D,t)}{\partial D} + +6\frac{g(D,t)\cdot v}{D} - S\cdot\eta\cdot K_1\cdot(T_{20} - T_1)\cdot g(D,t) + \Phi(D)). \qquad (8)$$

The aim of identification is a determination for the equation (5) of such $K_1^*$, for which the condition $I(K_1^*) \le I(K_1)$ would be true at any legitimate value of $K_1$.

The solution of the parametric identification task is realized in the determined formulation. Herewith, necessary conditions of identification task look like:

$$\frac{\partial L(K_1)}{\partial K_1} = -S\cdot\eta\cdot(T_{20} - T_1)\cdot g(D,t)\cdot\lambda(D,t); \qquad (9)$$

where $L(K_1)$ – Lagrangian of the absolute minimization task; $\lambda(D,t)$- a solution of a conjugate task of the kind:

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$$\frac{\partial\lambda(D,t)}{\partial t}=-2v\cdot\frac{\partial\lambda(D,t)}{\partial D}+ \\ +\lambda(D,t)\cdot\left(-6\frac{v}{D}+S\cdot\eta\cdot K_1\cdot(T_{20}-T_1)\right); \quad (10)$$

with the final and boundary conditions:

$$\lambda(D,t_f)=q(D)\cdot\left[\frac{g(D,t_f)}{D^2}-\frac{1}{d_{esd}\cdot D}\right]; \\ \lambda(d_m,t)=0. \quad (11)$$

Identification algorithm of the coefficient $K_1$, which influences on the unloading constant, has the following form:

a) An initial value of the parameter $K_1$ is $K_1^s=K_1^0$, where $s$ - index of iteration cycle and then we calculate g($D,t$) in accordance with (6) and the value of criterion $I$ in accordance with (1).

b) With the use of set $K_1$ value, we find the derivative value $\frac{\partial L(K_1)}{\partial K_1}$ by using the correlation (9) and solving the conjugate equation (10) with taking (11) into account.

c) New estimation of the parameter, which is identified, is determined by:

$$K_1^{s+1}=K_1^s-\varepsilon_1\cdot\frac{\partial L(K_1)}{\partial K_1}; \quad (12)$$

where $\varepsilon_1$ - a step of a gradient procedure.

d) Then, a condition is verified

$$\frac{\left|I(K_1^{s+1})-I(K_1^s)\right|}{I(K_1^s)}\le\varepsilon; \quad (13)$$

where $\varepsilon$ - the defined error of parameter $K_1$ calculation. If this condition is true, then by the calculated coefficient value, which influences on the unloading constant, $K_1^{s+1}$ is accepted and the identification procedure is completed. Otherwise, go back to the paragraph 2.

For the solution of the identification task, the researches of granulator work with the fluidized bed during the dehydration and granulation of ammonium sulfate were used.

## RESULTS AND DISCUSSIONS

As a result of calculations after the foregoing algorithm with the initial value of the coefficient $K_1$=0,009, we got $K_1$ values, by which the granules mass distribution function changes in accordance with the set equivalent diameter of granules $d_{esd}$=2,5 mm. The results of $K_1$ coefficient calculations are shown on the Figure-1. At the transitional process duration of 3 s, the main changes of the $K_1$ coefficient take place during the last 30 s and they are characterized by the significant reduction of the $K_1$ coefficient, which results to the reduction of granules unloading of the set equivalent diameter from the apparatus.

The change of granules mass distribution by the sizes as a result of parametric identification is shown on the Figure-2. After the realization of the identification algorithm, the granules mass fraction of the set size of $d_{esд}$=2, 5 mm increase from 0, 26 to 0, 45, which substantially improved the granules size composition of the final product.

The change of quality criterion (1) as a result of parametric identification is shown on Figure-3. The results of identification mostly depend on the choice of the step of the gradient procedure, that’s why the realization of identification for 19 iterations indicates the effective work of the algorithm. The quality criterion decreases significantly during the first three iterations.

The granules equivalent diameter changes after experimental researches results, which are calculated by using the mathematical model (6), and after parametric identification results are shown on the Figure-4.

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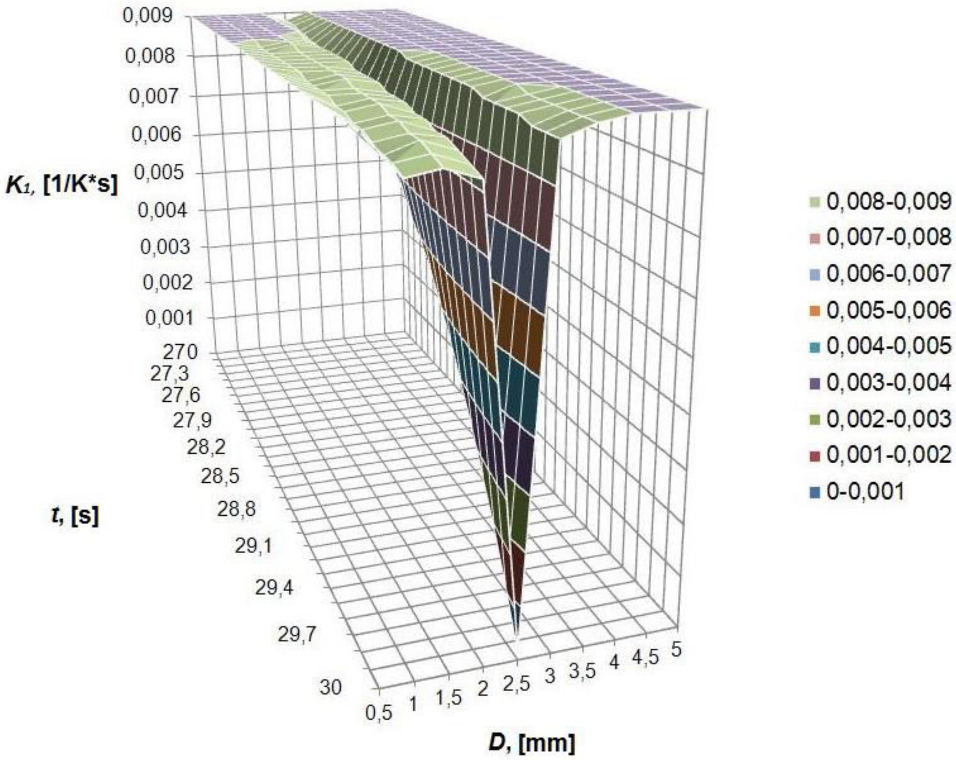


**Figure-1.** The values of the $K_1$ coefficient as a result of parametric identification.

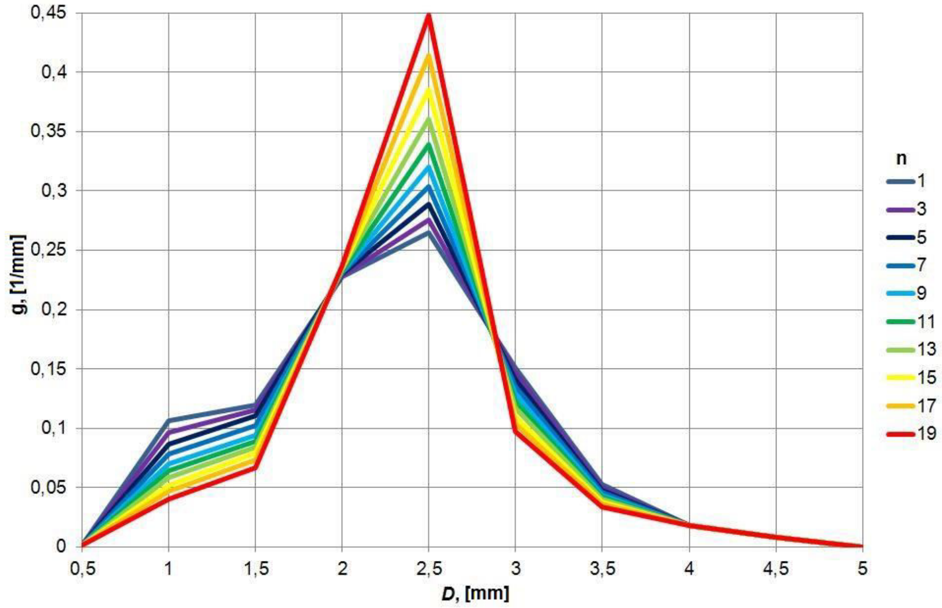


**Figure-2.** The change of granules mass distribution by the sizes as a result of parametric identification for 19 iterations.

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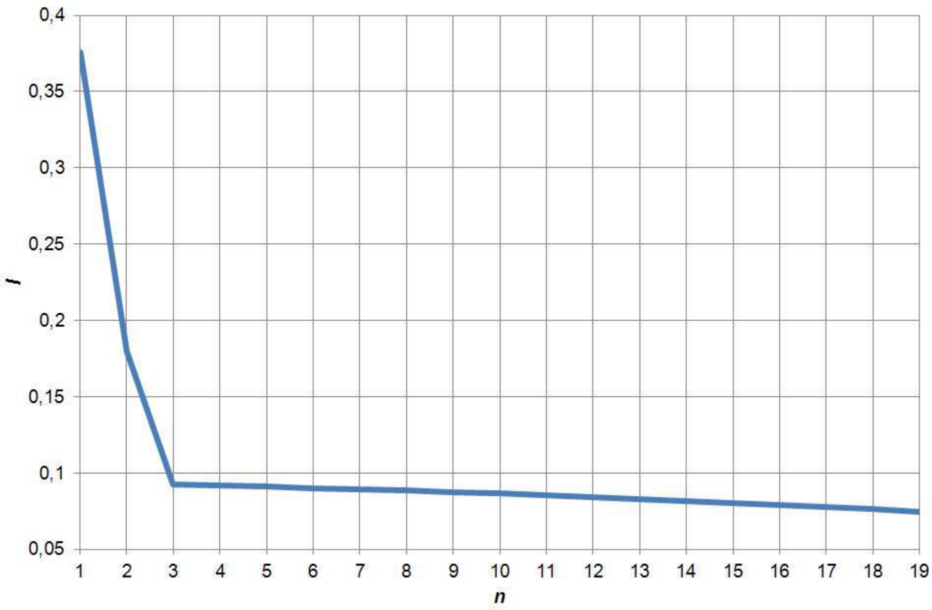


**Figure-3.** The change of quality criterion by the iterations amount.

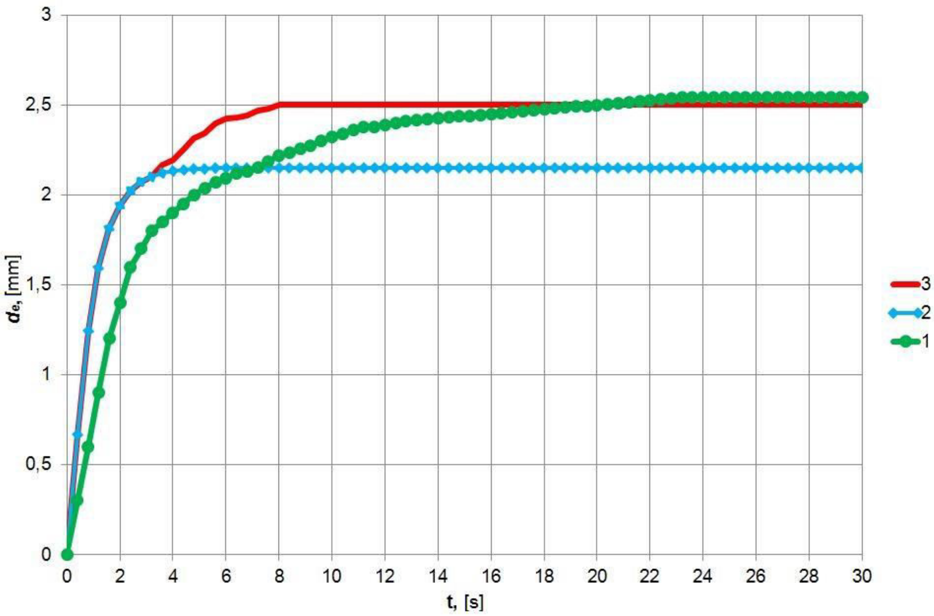


**Figure-4.** The change of granules equivalent diameter in time of: 1 - the result of experimental researches; 2 - the result of calculations after a mathematical model; 3 - the result of parametric identification

## CONCLUSIONS

As a result of the research, the identification algorithm of the dehydration and granulation processes of mineral fertilizers in the apparatus with a fluidized bed is developed. The defined conditions characterize a stable kinetics of nonrecyclable continuous granulation process with the mass fraction increasing of granules diameter of 2, 5 mm by 40%.

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