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STATIC AND DYNAMIC CHARACTERISTICS OF TRANSPORT PROCESSES IN DISPERSE SYSTEMS

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In this paper describs a mathematical model the static and dynamic characteristics of the process in a fluidised bed granulation and shows the change in coolant temperature and fluidized bed during the heat-mass transfer processes in moving granular material through appropriate technological zone in the apparatus, which providing granular product with the desired properties.

Keywords: mathematical model, granulation, fluidized bed, static characteristics, dynamic characteristics.

Розглянуто математичну модель, що описує статичні та динамічні характеристики процесу гранулоутворення у псевдозрідженому шарі та показує зміну температури теплоносія та псевдозрідженого шару під час проведення тепло-масообмінних процесів при русі зернистого матеріалу через відповідні технологічні зони в апараті, що забезпечує одержання гранульованого продукту із заданими властивостями.

Ключові слова: математична модель, гранулювання, псевдозріджений шар, статичні характеристики, динамічні характеристики.

Introduction

Community development in modern conditions depends on the development and implementation of energy efficient environmentally friendly technologies. Application of technique of fluidisation for obtaining solid composites with desired properties in the presence of phase transitions allows to combine a number of technological stages by the thermal coefficient of more than 60 %. The creation of mathematical models for the purpose of creation modern systems of management processes in disperse systems is relevant. In recent decades, a large number of mathematical models of transport processes in disperse systems with different levels of detailization was developed [1].

Granulation processes are different both in the methods of implementation, and in the hardware design. One of the promising methods is an obtaining of a granular product in a fluidized bed apparatus. The essence of this method is in bringing of the liquid phase onto the surface of fluidized bed. The solution is being dispersed inside the fluidized bed or distributed over its surface with the previous evaporation in the flare spraying or without it. In some cases, such as by granulation of mineral fertilizers simultaneously with evaporation of the solvent the reactions of neutralization progress, followed by crystallization and drying processes.

This makes it possible to combine several stages of the process (neutralization, evaporation, crystallization, drying and granulation) in one device that determines the significant technical and economic effect. It can maximize the heat of chemical reactions, which further determines the economic feasibility of the method.

The statement of the problem

The aim of the article is to study the static and dynamic characteristics of the mathematical model of a fluidized bed granulator during the intensive heat and mass transfer processes in the manufacture mineral fertilizers.

The main material

Feature of the process of formation of solid humic-mineral composites is uniform distribution of mineral and humic substances throughout the volume of grain and in physical and mechanical properties: spherical shape, diameter 1.5–4.5 mm, strength ≥ 10 N/grain. This solution dispersed in two-phase system: granular material — gas coolant (Fig. 1).

Liquid phase by the action of adhesive and sorption forces sticks to the surface of solid particles in a superfine film.

The porous structure of granules causes partial diffusion of moisture. To films from hot solid particles and gas coolant supplied heat.

This leads to intense evaporation of the solvent resulting in the surface of solid particles formed a thin layer of microcrystals mineral substance and deposited between colloidal particles of humic compounds.

Further microcrystals serve as centers of crystallization of minerals with another liquid film, resulting in increasing the size of granules (Fig. 2).

This leads to the formation of a porous carcass of a mineral component in the cavities of which are particulate organic matter.There are several approaches to the mathematical modeling of dehydration and granulation in fluidized bed.

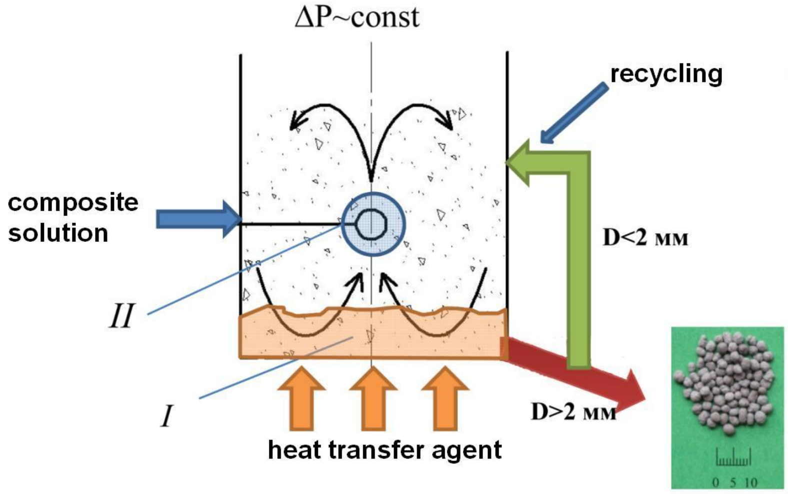

Fig. 1. The scheme of granulation humic-mineral composites:
I — zone of intense heat transfer; *II* — zone moisture

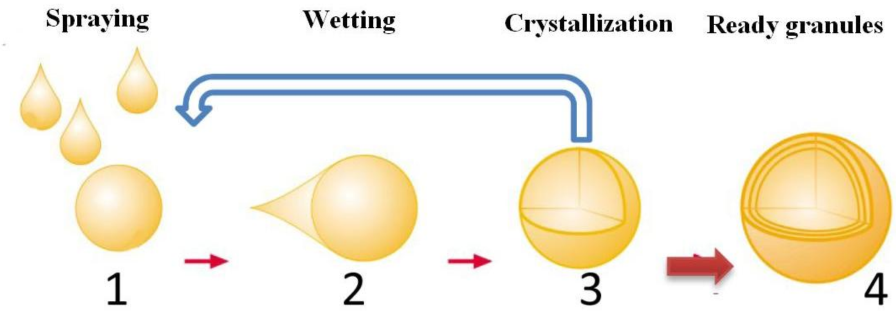

Fig. 2. Mechanism of granulationGranular material is fluidised chaotic system

Experimental research confirmed that local areas cavity pressure and concentrations are random fluctuations associated with nonlinear dynamics. Therefore, using the chaos can describe the dynamics of fluidized bed processes and examine the machine for different hydrodynamic regimes. Deterministic chaos can occur in a fluidised bed as a result of nonlinear interaction of gas bubbles with granular material. For the mathematical modeling of fluidized bed apparatus is also chaotic hydrodynamics [2]. Stochastic mathematical models applied to systems with random processes or complex systems where the randomness is used to facilitate necessary. When modeling fluidized bed stochastic approach allows for local fluctuations in hydrodynamics and interfacial exchange. When managing apparatus with fluidized bed most paramateriv that measured with random fluctuations of relatively high amplitude.

Very effective are attempts to explore the hydrodynamics of multiphase processes in a fluidized bed apparatus using mikrobalance models. These mathematical models solved to bind the equation of conservation of energy considering the interfacial interaction. For multivariate modeling processes of dehydration and granulation in fluidized bed using two-phase Euler-Euler model [3]. For each phase account for mass transfer between phases, availability and lift forces acting on a particle - friction, pressure forces, gravity forces Archimedes adhesion of particles on the phase boundary.

Transport equation of temperature granules taken into account convective heat transfer, solid phase voltage, flow fluctuation energy scattering energy collisions, the energy exchange between the phases. It is possible to determine the intensity of the interaction of the gas (solid) environment and solid particles (dispersed phase) at different hydrodynamic regimes and the corresponding temperature change granules during dehydration and granulation [4].

Mathematical model [4] fully takes into account the process, but a large amount of calculation time complicates its use in driving the process of dehydration and granulation in fluidised bed in real conditions.

Therefore, use slightly simplified mathematical model of its structure corresponds to the model described above, but significantly improves its adaptation in driving the process of dehydration and granulation in a fluidized bed.

This mathematical model takes into account the complex of the process, which is accompanied by a phase transition, is complicated by the formation of a liquid phase on the surface of the granules with the subsequent release of the liquid phase and the formation by mass crystallization layer of microcrystals of the soluble phase.

In this approximation, the two phases — solid and dispersed — modeled as two interpenetrating solid. Phases interact continuously in time and space. This principle is applied in the continuous averaging to local instantaneous momentum and energy equations.

According to the results of experimental researches it was found that for the kinetics of the process of obtaining a stable final product with desired physical and chemical properties in fluidised bed granulation prerequisite is respect given temperature in the layer. Therefore, to research the static and dynamic characteristics of selected mathematical model with lumped parameters — the ultimate coolant temperature and temperature fluidized bed.

We identified two storage tanks:

– The capacity of motion coolant;

– The capacity of particle motion in a fluidised bed.

Were made the following assumptions:

– Heat transfer between the coolant and the particles in the fluidized bed is due to convection;

– A solution for getting a piece evaporates and resulting in crystallization on the surface of a heat release.

The dynamics of thermal balance coolant-air can be described by the following equation:

$$\begin{gathered} V_a \cdot \rho_a \cdot C_a \frac{dT_{af}}{dt} = G_a \cdot C_a \; T_{as} - T_{af} \; - \\ -\alpha \cdot F \; T_{af} - T_1 \; , \end{gathered} \tag{1}$$

where T_{as}, T_{af} — initial and final air temperature, К; T_{l} — temperature layer, К; F— surface mass transfer, м^2; α — heat transfer coefficient, W/м^2·К; G_a — air flow, м^3/с ; C_a — heat capacity of air, J/kg·К; V_a — the air volume, м^3; ρ_a — air density, kg/м^3.

Dynamics of heat balance particle fluidized bed is described as follows:

$$\begin{gathered} m_g \cdot C_g \frac{dT_1}{dt} = \alpha \cdot F \; T_{af} - T \; - \\ -\beta \frac{M_{\text{H}_2\text{O}}}{RT_{as}} \cdot r \cdot \Delta p + G_p \cdot C_p \cdot T_{ps} - G_p \cdot q; \end{gathered} \tag{2}$$

$$\Delta p = \xi_1 \cdot \Delta T_{af} - \xi_2 \cdot \Delta T_1;$$

$$\xi_1 = \frac{\partial p}{\partial T_{af}}; \quad \xi_2 = \frac{\partial p}{\partial T_1},$$

where β — coefficient of mass recoil, м/s; $M_{\text{H}_2\text{O}}$ — molecular weight of water, kg/mol; F — mass of transfer surface, м^2; F_M — particle surface, м^2; R — universal gas constant, J/(mol·К); m_g — mass of granule, kg; C_g — specific heat of the material granule, J / kg ·К; G_{p} — expenditures of solution, kg/c; Δp — difference of partial pressures, Pa; x_p — moisture content of the material; T_{ps} — initial temperature of the solution, К; C_p — heat capacity of solution, J/kg·К; r — heat of vaporization, J / kg; q — heat released by crystallization solution, J / kg.

Possible channels “expenditures coolant — temperature fluidized bed”, “cost solution — temperature fluidized bed”.

For static characteristics are equation based finite temperature and the temperature of the layer changes the air flow and solution:

$$G_a \cdot C_a \; T_{as} - T_{af} \; - \alpha \cdot F \; T_{af} - T_1 \; = 0; \tag{3}$$

$$\begin{gathered} \alpha \cdot F \; T_{af} - T_1 \; - \beta \frac{M_{\text{H}_2\text{O}} \cdot F_M}{RT_{as}} \cdot r \cdot \Delta p + \\ + G_p \cdot C_p \cdot T_{ps} - G_p \cdot q = 0. \end{gathered} \tag{4}$$

From equations (3)–(4) we obtained an expression for the temperature fluidized bed:

$$\begin{gathered} T_1 = \frac{G_a \cdot C_a \; T_{as} - T_{af} \; + G_p \cdot C_p \cdot T_{ps} - G_p \cdot q}{\beta \frac{M_{\text{H}_2\text{O}} F_M}{RT_{as}} \cdot r \cdot \xi_1} + \\ + \frac{\xi_2 \cdot T_{af}}{\xi_1}. \end{gathered} \tag{5}$$

Fig. 3–4 are static characteristics of temperature change on the layer of air flow and solution at different initial temperatures.

The temperature of fluidized bed changes linear and an increase in primary coolant temperature from 460 K to 475 K is the corresponding linear increase in temperature of the layer. This dependence is due to the fact that the process of dewatering film solution is in a book by the warmth of the problem, as determined by the appropriate value of temperature in granule layer (varies from 363.6 K to 365 K) (Fig. 3). Temperature change layer from 365.9 K to 365.5 K is inversely proportional dependence with increasing solution costs by 30% (Fig. 4).

Dynamic characteristics of the mathematical model (1)—(2) are shown in Fig. 5–6.

Transient response by the channel “cost heat carrier — the ultimate temperature” (Fig. 5) shows that useful temperature difference T = 465 K-395K = = 70 K is realized for the first 2*s*, which confirms the device characteristics of an ideal mixing. The intensity of mixing increases with the mass flow heat carrier channel “cost heat carrier — the ultimate temperature”.

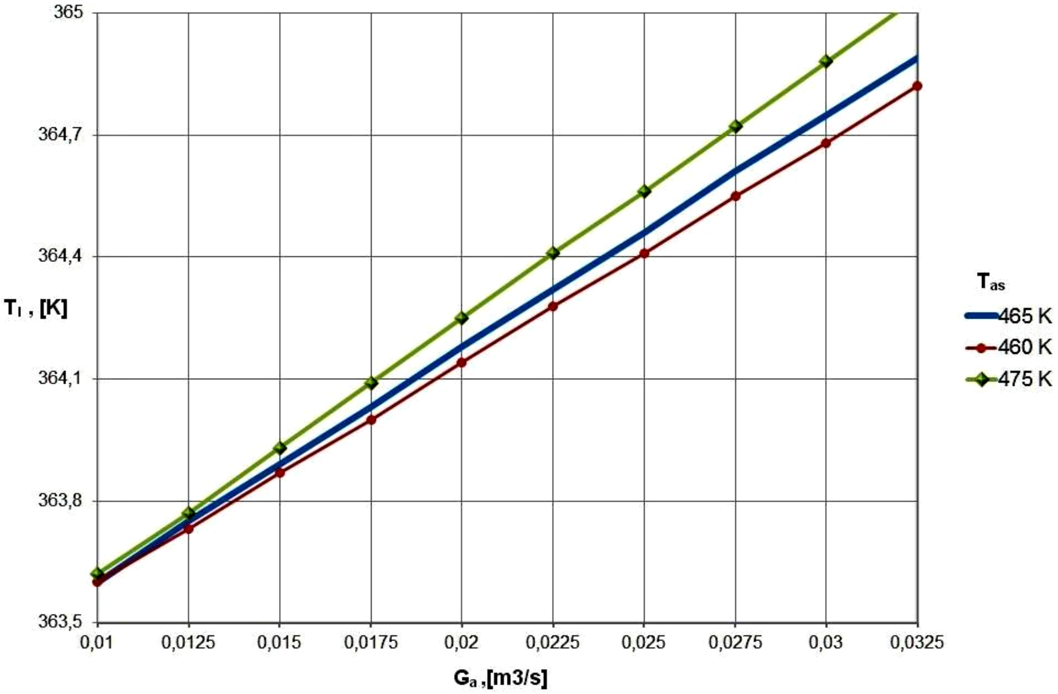

Fig. 3. Static characteristic of temperature change on the layer
of air changes at different initial temperatures

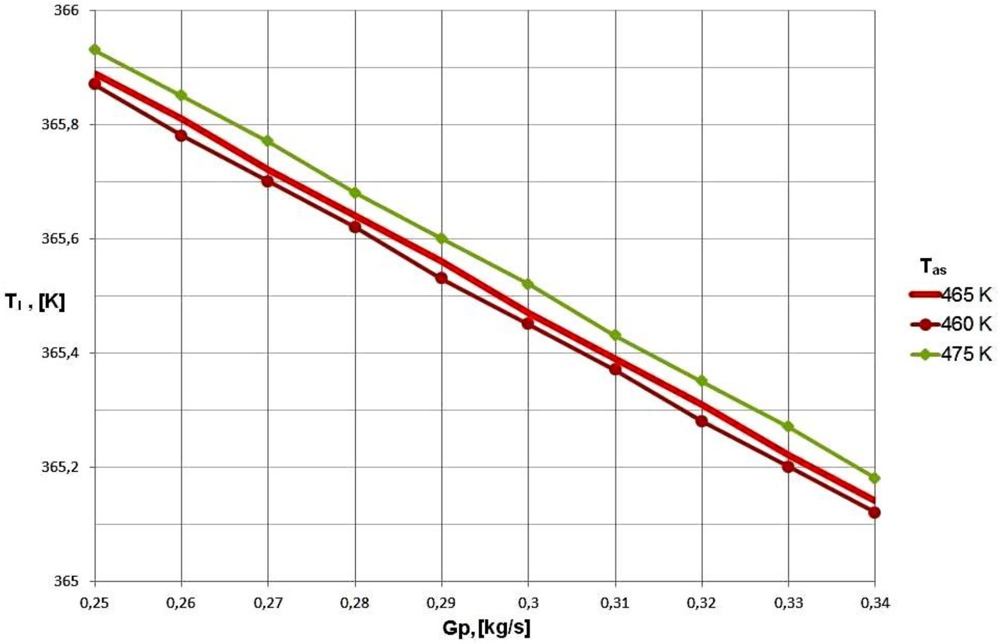

Fig. 4. Static characteristic of temperature change on the layer
change cost solution at different initial temperatures

Transient response by the channel “costs heat carrier — temperature fluidized bed” shows that stabilization of temperature in the layer occurs at 25 s within the temperature changes from 365 K to 366.25 K (Fig. 6). This dynamic change in coolant temperature in the layer confirms the mixing intensity.

Conclusions

This mathematical model describes the static and dynamic characteristics of the process in a fluidised bed granulation and shows the change in coolant temperature and fluidized bed during the heat-mass transfer processes in moving granular material through appropriate technological zone in the apparatus, which providing granular product with the desired properties.

The variation of temperature determines the granulation kinetics and physical and mechanical properties of the pellets. Therefore, the proposed mathematical model can be used to create an effective system of managing the process of formation of mineral fertilizers in the fluidized bed with liquid dehydration systems.

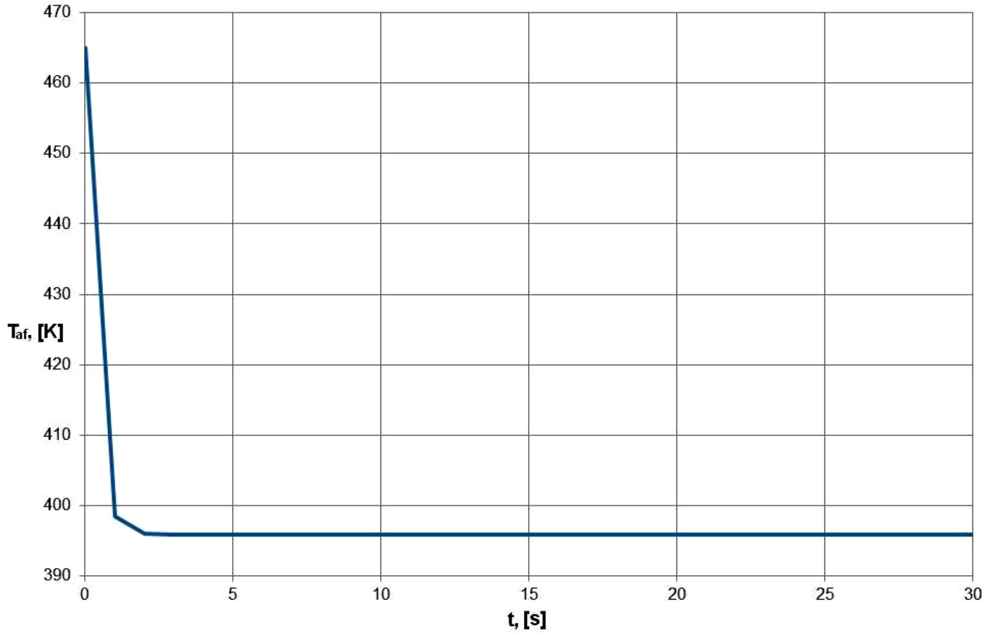

Fig. 5. Transient response by the channel “cost heat carrier ultimate-temperature”

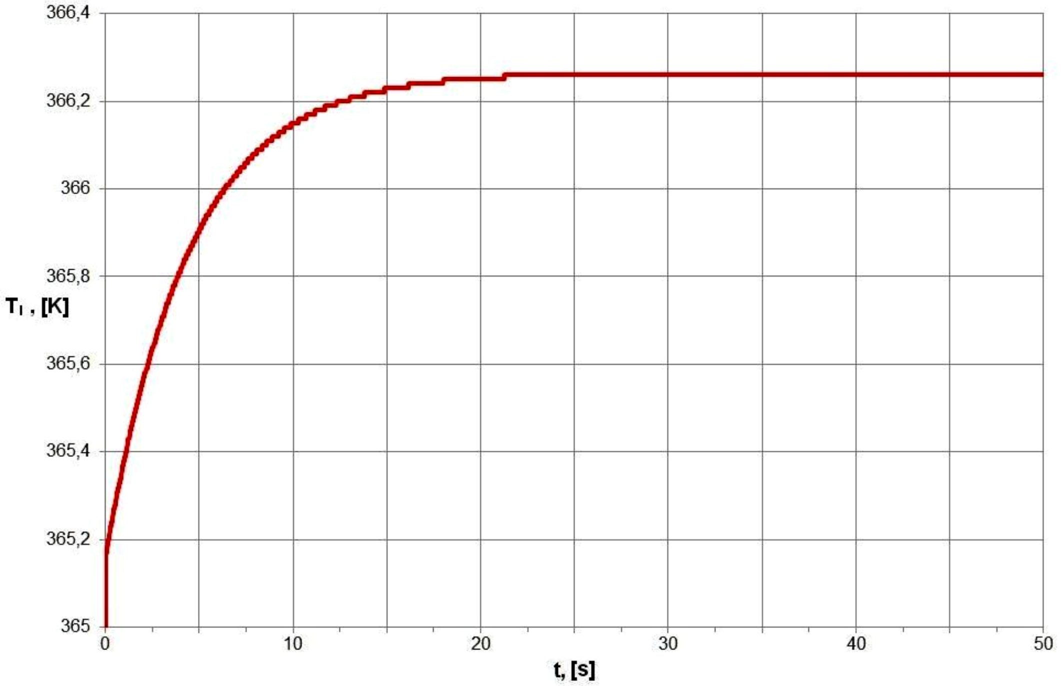

Fig. 6. Transient response by the channel “costs heat carrier-temperature fluidized bed”

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