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INCREASING THE EFFICIENCY OF TRANSFER PROCESSES WHEN USING INHOMOGENEOUS FLUIDIZATION

The processes of dehydration and granulation are associated with the heat transfer to the solid particles from the gas coolant, which acts as a fluidizing agent and causes the stochastic movement of the granular material in the apparatus. To implement the layered structure mechanism of granulation of organic-mineral fertilizers it is necessary to ensure intensive circulation of granular material with intensive gradual passage through the appropriate technological zones of the apparatus. The main problem is the low efficiency of interphase exchange in the gas-liquid-solid system and the formation of agglomerates during granulation with the injection of a liquid heterogeneous solution into the bed of solid granular material.
In this work the conditions for increasing the efficiency of the transfer processes when using an inhomogeneous jet-pulsating mode of fluidization were determined.
Analysis of the intensity of renewal of the contact surface of the phases when using inhomogeneous jet-pulsating fluidization in the self-oscillating mode was carried out. It was established that the use of this mode of fluidization allows getting a significant intensification of heat and mass transfer processes due to the activation of diffusion-controlled processes and an increase in the dynamics of interphase contact exchange by 1.9÷2.9 m²/s, which is 27÷41% of the total surface of the material in device.

Keywords: *fluidized bed, hydrodynamics, jet-pulsating mode, inhomogeneous fluidization.*

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Formulation of the problem. The processes of dehydration and granulation are associated with the transfer of heat to the solid particles from the gaseous coolant, which is at the same time a fluidizing agent and causes stochastic movement of the sloid granular material in the apparatus. At the same time, with the use of a mechanical device, a liquid phase is dispersed in the fluidized bed, which is distributed in the form of a thin liquid film on the surface of the granules due to adhesion and sorption forces. To implement the layer-by-layer granulation mechanism, the mass of the falling on the granule solution shouldn't be more than 10% of the mass of the dry granule [1].

At the same time, the heat supplied to the film of the liquid phase located on the surface of the granules should be sufficient for the evaporation of the solvent, and the temperature of the granules should not drop below the wet bulb temperature. Failure to meet this condition leads to a sharp decrease in the strength of the granules, which will cause them to wear out and increase the removal of micro components of dry substances in the form of dust.

Analysis of previous studies. The heat for heating is supplied to the granules from the heated coolant (fluidizing agent). For values of the Reynolds criterion 1.0≤Re≤2500, it is most appropriate to use the correlation dependence proposed by Kinzer and Gunn:

$$\mathrm{Nu} = 2 + 0.57\mathrm{Re}^{0.5}\mathrm{Pr}^{0.33} \tag{1}$$

The relationship between heat and mass transfer coefficients at significant temperature drops is known as the Lewis equation:

$$\frac{\alpha}{\beta} = C \cdot \rho \frac{P - p_{\mathrm{H_2O}}}{P} \tag{2}$$

where C – isobaric heat capacity of liquid, kJ/kg; ρ – density of liquid, kg/m ^{3}; P – total pressure in the system, Pa; $p_{\mathrm{H_2O}}$ – partial pressure of water vapor in a gaseous medium, Pa.

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Thus, the values of coefficients α and β have significant limitations due to the impossibility of increasing the speed of the gas coolant, which can lead to an increase in the removal of solid particles from the device.

Experimentally established [1] the conditions for the evaporation of the solvent on a separate granule for the implementation of the layered structure mechanism:

$$M_{\mathrm{H_2O}} r = M_{granule} C_{granule} (T_{bed} - T_{\mathrm{м}}), \quad (3)$$

where M_{H_2O} – the amount of water that is in the film on the surface of the granule, kg; r – specific heat of evaporation of water, kJ/kg; $M_{granule}$ – mass of single granule, kg; $C_{granule}$ – heat capacity of granule, kJ/(kg·K); T_{bed}, T_W – respectively, temperature of bed of solids and wet bulb temperature, K.

In addition, it is necessary to ensure the presence of the driving force of mass exchange between the moistened surface of the granule and the gas coolant not only in the zone of intensive heat exchange, which is formed on the surface of the gas distribution device, but also in the zone of dispersion of the liquid phase.

Creating conditions for intensive removal of moistened granules from the dispersion zone will eliminate the risk of local formation of agglomerates with unpredictable sizes.

In a general form, the mass transfer equation for moisture removal can be represented as follows:

$$M = \beta \Delta P^*_{i.c.} F_{i.c.}, \quad (4)$$

where M – productivity of the apparatus by evaporated moisture, kg/s; β – mass transfer coefficient within one phase, kg/(m^{2}s); $F_{i.c.}$ – the minimum required interphase contact surface in the device, м^2; $\Delta P^*_{i.c.}$ – the difference in partial pressures of water vapor over the surface of the moistened granule $P^*_{sat.}$ and in the gas coolant P_a, Pa:

$$\Delta P^*_{i.c.} = P^*_{sat.} - P_a \quad (5)$$

Taking into account the above, in addition to the trivial interaction of the gas coolant with granular material during bubbling hydrodynamics, it is necessary to create the movement of macro clusters of granular material from the irrigation zone to other technological zones of the granulator chamber.

Therefore, in the general case, the minimum mass transfer surface for moisture removal will be determined as, m^2:

$$F_{i.c.} = \frac{M}{\beta \Delta P^*_{i.c.}} \quad (6)$$

In particular, for a fluidized bed with an equivalent diameter d_e, this surface will be determined as, m ^{2}:

$$F_{i.c.} = \frac{6 \Delta P_{bed} S_0}{d_e \rho_{bed} g} \quad (7)$$

where ΔP_{bed} – hydrostatic pressure of the bed of granular material in the apparatus in a stationary state in the gas distributing device zone, Pa; S_0 – horizontal cross-sectional area of the granulator chamber in the area of the gas distribution device, m ^{2}; d_e – equivalent diameter of granules in the apparatus, m; ρ_{bed} – density of granules, kg/m^3; g – acceleration of gravity, m/s^2.

In addition to the evaporation of water from the film of the solution, a layer of microcrystals is formed on the surface of the granule, which is a limiting factor. It was experimentally established [1-3, 6] that the actual surface of the interphase contacts when dispersing the liquid phase using a cup disperser is 3÷4 times greater than the calculated surface of the interphase contact determined by formula (1) [2].

Therefore, it is rational to effectively increase the productivity of the apparatus for evaporated moisture due to an increase in the surface of the particles in the fluidized bed, which is associated with an increase in the initial height of the stationary bed in the apparatus, m:

$$H_0 = \frac{4 F_{i.c.} d_e}{6 S_0 (1 - \varepsilon_0)} \quad (8)$$

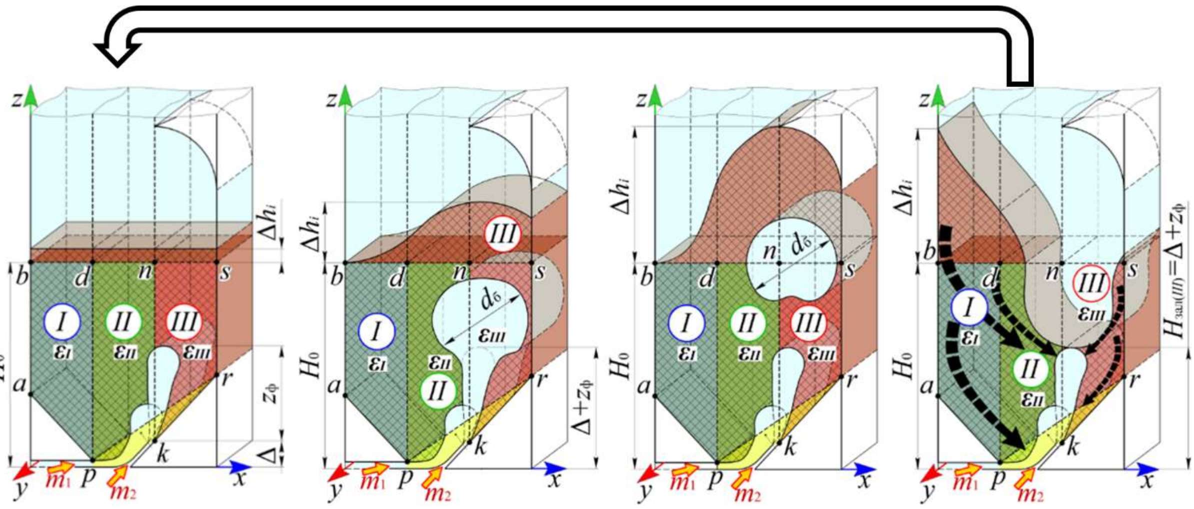
where ε_0 – porosity of the fixed bed of solids. It is assumed that the bed of granular material consists of solid particles of spherical shape, therefore ε_0=0.4.

Under such conditions, fluidization goes into the bubbling mode, in which mixing is insufficient, which negatively affects the kinetics of the granulation process when spraying liquid systems. In addition, stagnant zones of granular material are formed on the perforated gas distribution grids, which makes it impossible to carry out the granulation process using a high-temperature coolant, the temperature of which exceeds the melting point of the components of the granules.

The purpose of the article is determination of the conditions for increasing the efficiency of transfer processes during granulation of organic-mineral humic fertilizers using a inhomogeneous jet-pulsation mode of fluidization.

Presentation of the main material. Almost complete elimination of these shortcomings was achieved in works [3-5] due to the application of inhomogeneous jet-pulsation fluidization in the self-oscillating mode, Fig. 1.

In the proposed method of interaction of the gas coolant with the granular material in the fluidized bed, it was possible to achieve a significant movement of the material beyond the initial bed of solids and through the irrigation zone, as well as to minimize the size of the slow moving zones of the granular material on the horizontal surface of the gas distributing device (GDD) [6], Fig. 2, where K_w – number of fluidization; d_e – equivalent diameter of solid particles in the bed, mm; $H_{bed}/H_0=i_h$ – index of increase in the total height of the granular material bed.



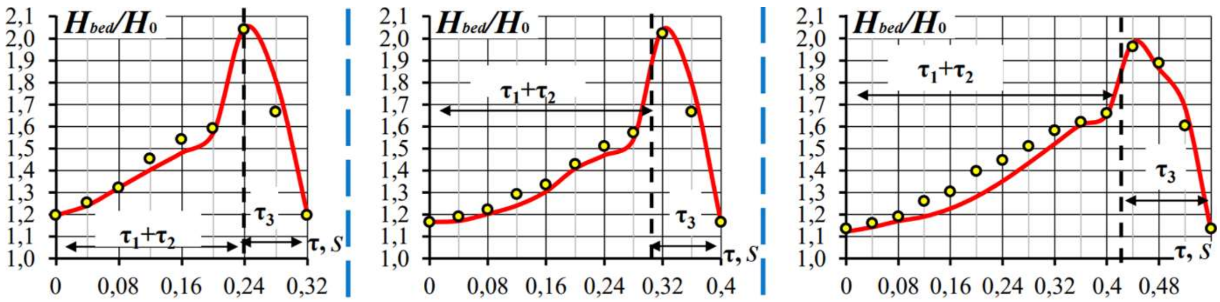
a) τ=0; ***b***) $\tau_i \leq \tau_1$; ***c***) $\tau_1<\tau_i<\tau_1+\tau_2$; ***d***) $\tau_i=\tau_{1+}\tau_2$

Fig. 1 – Physical model of inhomogeneous jet-pulsating fluidization

The potential of the index of material mass removal beyond the initial bed of solids depends on the maximum pressure drop in one cycle of pulsations and was determined by the expression that actually determines the intensity of interphase contact exchange, Fig. 3:

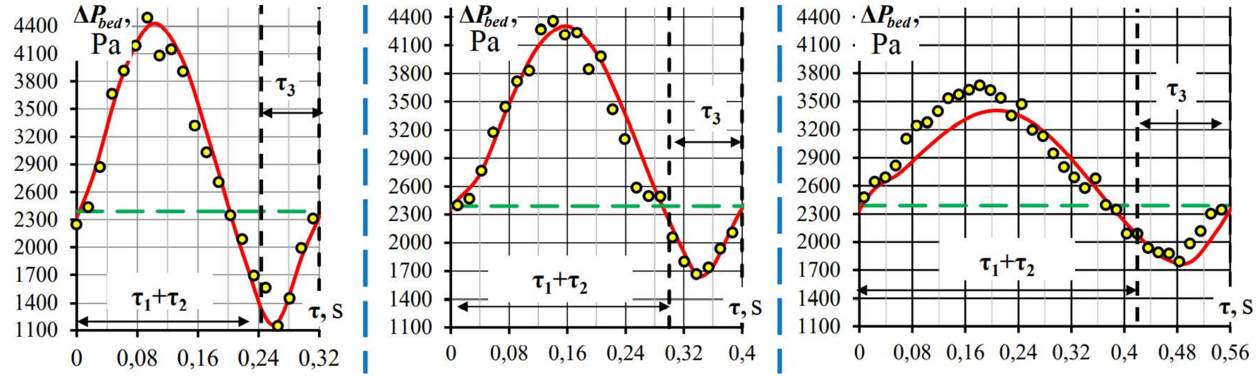
$$j_{\Delta p} = \frac{(\Delta P_{\max} - \Delta P_0)}{\Delta P_0} \tag{9}$$

where $\Delta P_{\max}$ and ΔP_0 – respectively, the maximum hydraulic resistance of the bed of solids during the formation of a gas bubble and the hydrostatic resistance of the initial bed, Pa.



a) R=0.9818; d_e=1.5 mm; K_w=2.66 ***b***) R=0.9878; d_e=2.5 mm; K_w=2.03 ***c***) R=0.9866; d_e=4.0 mm; K_w=1.43

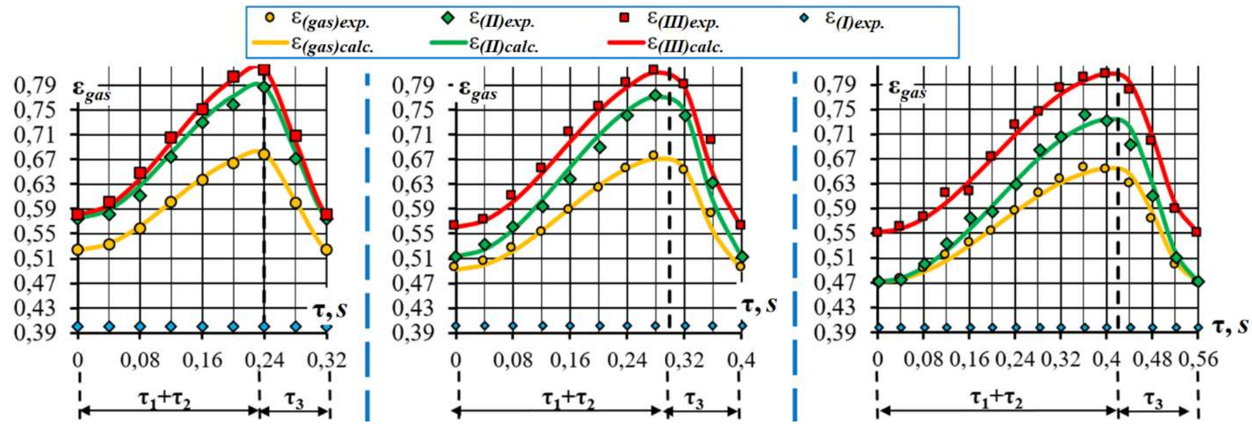
Fig. 2 – Dynamics of change of the index of increase of the total height of the bed of solids at H_0=0.32 m for different values of d_e



a) d_e=1.5 mm; K_w=2.66 ***b***) d_e=2.5 mm; K_w=2.03 ***c***) d_e=4.0 mm; K_w=1.43

Fig. 3 – Dynamics of changes in the pressure drop in the bed of solids at H_0=0.32 m for different values of d_e

The dynamics of changes in porosity in the zones of the initial volume of the bed of solids, according to Fig. 1, are shown in Fig. 4.



a) d_e=1.5 mm; K_w=2.66 ***b***) d_e=2.5 mm; K_w=2.03 ***c***) d_e=4.0 mm; K_w=1.43

Fig. 4 – Dynamics of changes in porosity in the zones of the initial bed of solids at H_0=0.32 m for different values of d_e

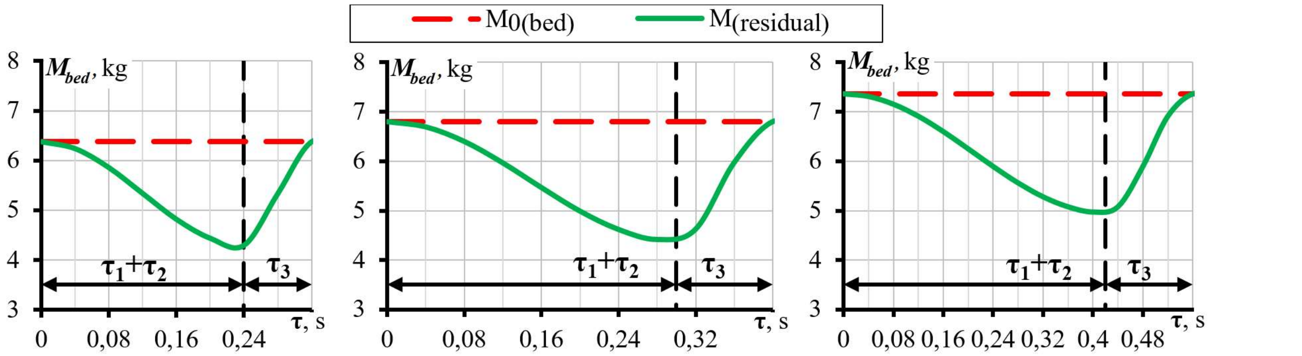
The mass of granular material carried beyond the initial bed of solids, Fig. 5, depends on the porosity and the initial volume of the bed, kg:

$$\Delta M = V_0 \rho_{solids} (\varepsilon_{gas} - \varepsilon_0) \tag{10}$$

where V_0 – the initial volume of the bed of solids at τ=0, m^3; ρ_{solids} – density of solid particles, kg/m^3; ε_{gas} – the current average value of porosity in the initial volume of the entire bed of solids.

The total mass of a bed of granular material moving beyond the initial bed of solids for a part of the time interval of one cycle of pulsations τcycle contacts with the gas coolant in the case of direct-flow phase contact $0<\tau<\tau_1+\tau_2$ and in counter-flow phase contact $\tau_1+\tau_2<\tau<\tau_{cycle}$, Fig. 1. When in this case, direct current contact between phases occurs during the time $\tau_1+\tau_2=0.75\tau_{cycle}$, Fig. 1, which corresponds to the movement of solid particles in the direction opposite to the action of gravity during the formation of a gas bubble in the bed of solids and the removal of particles into the space above the initial bed, with height H_0. The countercurrent contact between the phases occurs during the reverse movement of solid particles until the voids in the bed of solids, which arose in the first periods during the time of $0.25\tau_{cycle}$ are filled. Then the mass of material that was carried beyond the initial bed of solids is equal to the mass of the bed that returned to the borders of the initial bed of solids with height H_0:

$$-\Delta M_{ejected} = +\Delta M_{returned} \tag{11}$$



a) d_e=1.5 mm; K_w=2.66 ***b)*** d_e=2.5 mm; K_w=2.03 ***c)*** d_e=4.0 mm; K_w=1.43

Fig. 5 – Dynamics of changes in the mass of a bed of granular material carried beyond the initial bed of solids in one cycle at H_0=0.32 m for different values of d_e

Then the total mass of displaced solid particles of the bed of solids (ejected beyond the boundaries of the initial layer and returned to the initial volume of the bed of solids with a height of H_0) within one cycle (during one self-oscillation τ_{cycle} with inhomogeneous fluidization) in the chamber of the apparatus, kg:

$$\sum \Delta M_{total} = \int_0^{0.75\tau_{cycle}} dM_{ejected}\, d\tau + \int_{0.75\tau_{cycle}}^{\tau_{cycle}} dM_{returned}\, d\tau. \tag{12}$$

So, for one cycle in the vertical plane outside the initial bed of solids depending on the equivalent diameter d_e=1.5÷4.0 mm, Fig. 5, the intensity of mixing is determined as, kg/s:

$$J_M = \frac{\sum \Delta M_{total}}{\tau_{cycle}}. \tag{13}$$

At the pulsation frequency f=1/τ_{cycle}, the total mass of material movement in the apparatus chamber will be determined as, kg/s:

$$\sum\sum \Delta M_{total} = \sum \Delta M_{total}\, f. \tag{14}$$

Therefore, the predicted time of complete mass exchange of the initial bed of solids is, s:

$$\tau_{M\,total} = \frac{M_0}{J_M} = \frac{M_0}{\sum\sum \Delta M_{total}} \tag{15}$$

The results of calculations for the bed of granular material with a height of H_0=0.32 m with d_e=1.5÷4.0 mm under the conditions of ensuring a high-quality inhomogeneous jet-pulsation mode [6] are shown in Table 1.

Table 1 – Results of calculations of the intensity of bed of solids mass renewal

Parameter	**Equivalent diameter of solid particles of the bed d_e, mm**		
	1.5	**2.5**	**4.0**
τ_{cycle}, s	0.32	0.4	0.560
f, Hz	3.125	2.5	1.786
$\sum \Delta M_{residual}$, kg	0.864 (11.7%M_0)	0.976 (13.2%M_0)	1.050 (14.3%M_0)
J_M, kg/s	2.699 (36.6%M_0)	2.439 (33.1%M_0)	1.875 (25.5%M_0)
$\tau_{M\,total}$, s	2.362	2.789	3.928

In the general case, for spherical particles, the surface of the initial bed of solids will be defined as:

$$F_0 = \frac{6M_0}{d_e \rho_{solids}}, \tag{16}$$

where M_0– mass of the initial bed of solids, kg; d_e – equivalent diameter of solid particles, m:

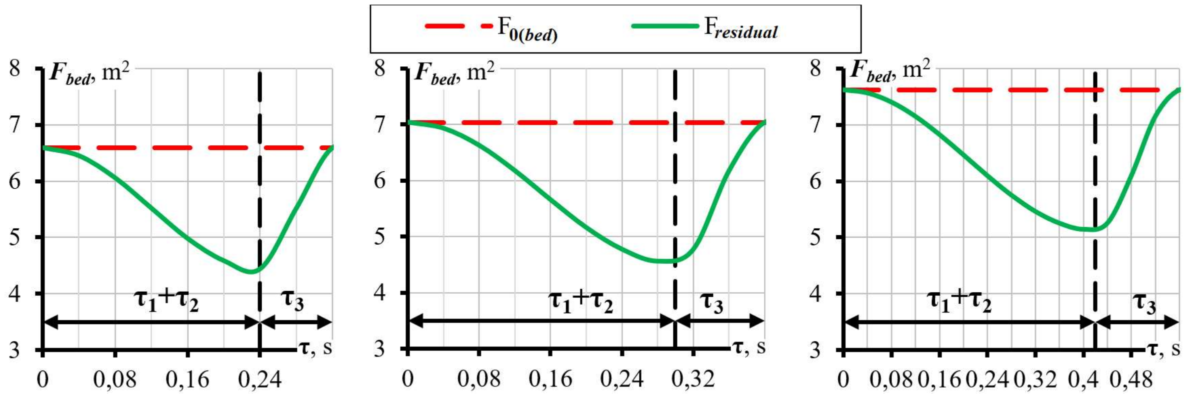
$$d_e = \frac{1}{\sum \frac{x_i}{d_i}}, \tag{17}$$

where x_i – mass proportion of the i-th fraction; d_i – average geometric size of the i-th fraction, m.
The residual surface of solid particles in the bed will be, Fig. 6, m^2:

$$F_{\boldsymbol{residual}} = \frac{6\Delta M_{\boldsymbol{residual}}}{d_e \rho_{solids}} \tag{18}$$

The surface of the granular material carried out of the initial bed of solids within one cycle of pulsations, Fig. 6, m^2:

$$\Delta F_{ejected} = F_{solids} - F_{residual} \tag{19}$$



a) d_e=1.5 mm; K_w=2.66 **b)** d_e=2.5 mm; K_w=2.03 **c)** d_e=4.0 mm; K_w=1.43

Fig. 6 – Dynamics of changes in the interphase surface of the bed of solids in the chamber of the apparatus with satisfactory quality of hydrodynamics of jet-pulsation fluidization

Then the total surface of the moved bed of solid particles in one cycle of pulsations, similarly to the mass, m^2:

$$\sum \Delta F_{total} = \int_0^{0.75\tau_{cycle}} dF_{ejected}\, d\tau + \int_{0.75\tau_{cycle}}^{\tau_{cycle}} dF_{surface}\, d\tau \tag{20}$$

Taking into account (17) and (13), equation (21) can be presented in the form, m^2:

$$\sum \Delta F_{total} = \frac{6\sum \Delta M_{total}}{d_e \rho_{solids}}. \tag{21}$$

Then the frequency of updating the contact surface of the phases will be m^2/s:

$$J_F = \frac{\sum \Delta F_{total}}{\tau_{cycle}} = \sum \Delta F_{total} f \tag{22}$$

Therefore, the calculated time of complete exchange of the bed of solids surface is, s:

$$\tau_{F\,total} = \frac{F_{solids}}{J_F} = \frac{F_{solids}}{\sum \Delta F_{total} f} \tag{23}$$

The results of calculations for a bed of granular material with a height of H_0=0.32 m with d_e=1.5÷4.0 mm under the conditions of ensuring a high-quality inhomogeneous jet-pulsating mode of fluidization, Table 2, are correlated with the obtained results given in Table 1.

So, with this method of implementing inhomogeneous fluidization, the device works in a mixed mode: ideal mixing and ideal movement of the material.

At the same time, the averaged dynamics of changes in the movement of solid particles [1], Fig. 7, confirms that the device implements forward and counter-current movement of the granular material relative to the movement of the gas coolant. This leads to significant turbulence of the diffusion sublayer and on the micro-level intensifies the exchange of the interphase surface and, accordingly, to the significant intensity of the interphase exchange in the gas-liquid-solid system.

Table 2 – Results of calculations of the intensity of bed of solids surface renewal

Parameter	**Equivalent diameter of solid particles of the bed d_e, mm**		
	1.5	**2.5**	**4.0**
τ_{cycle}, c	0.32	0.4	0.560
$F_{pulsation}$, Hz	3.125	2.5	1.786
$\sum \Delta F_{total}$, m^2	0.893 (11.7%F_0)	1.009 (13.2%F_0)	1.086 (14.3%F_0)
J_F, m^2/s	2.792 (36.6%F_0)	2.523 (33.1%F_0)	1.940 (25.5%F_0)
$\tau_{F\,total}$, c	2.362	2.789	3.928

According to the Lewis model, Fig. 8, this nature of the interaction of the gas coolant with granular material confirmed the hypothesis regarding the intensification of diffusion-controlled processes during dehydration and granulation of liquid heterogeneous systems [6].

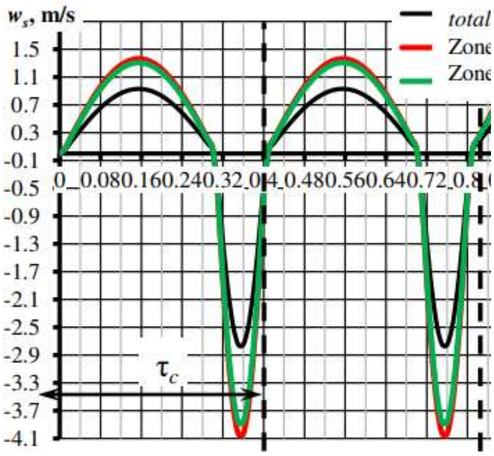


Fig. 7 – Averaged dynamics of changes in the movement of solid particles (d_e=2.5 mm; $w_{gas(average)}$=1.6 m/s; K_w=2.05)

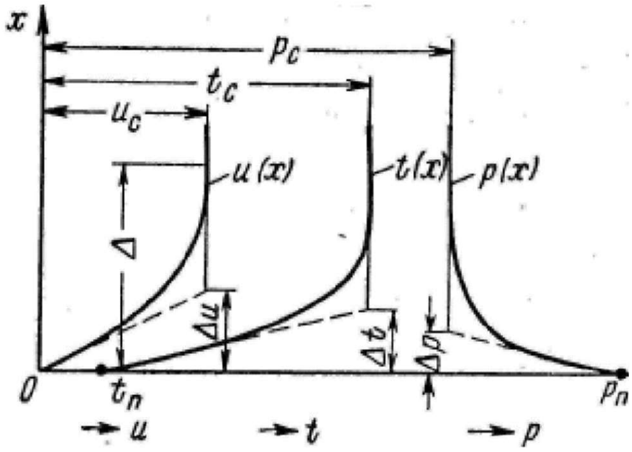
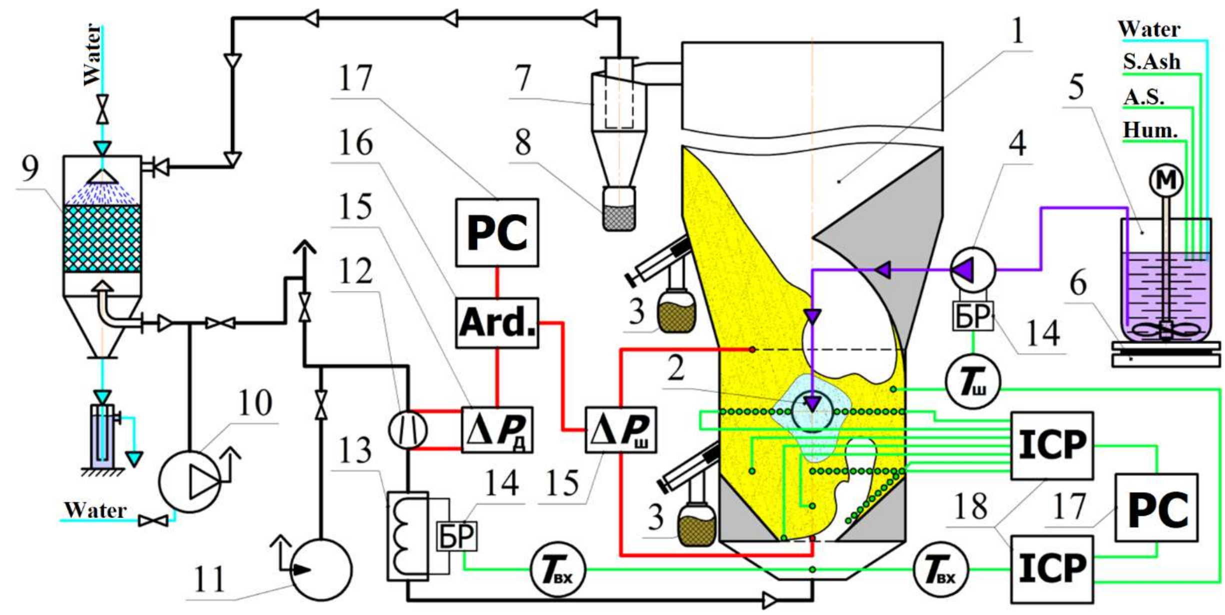


Fig. 8 – Velocity, temperature and partial pressure distribution curves

The study of the processes of interphase exchange during the granulation of organic-mineral humic fertilizers was carried out in two stages at the pilot plant [6], the scheme of which is shown in Fig. 9.



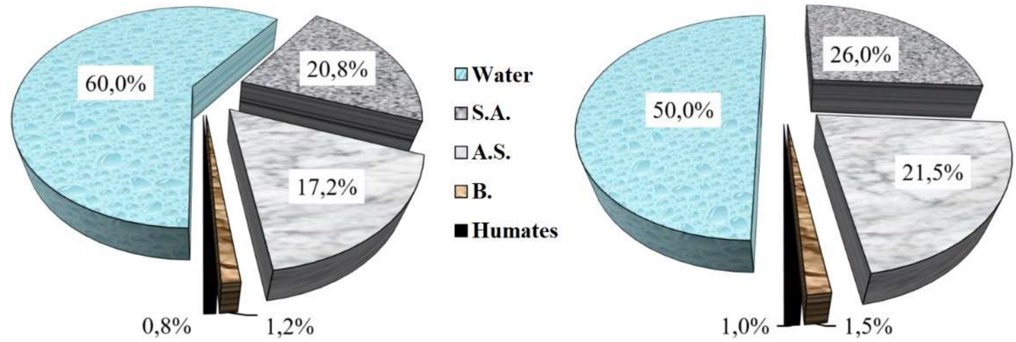
1– granulator; 2 – mechanical dispersant; 3 – containers for the finished product; 4 – pump; 5 – mixer; 6 – scales; 7 – cyclone; 8 – dust container; 9 – scrubber; 10 – vacuum pump; 11 – gas blower; 12 – diaphragm; 13 – heater; 14 – control unit; 15 – pressure transducers (MPXV7007DP); 16 – controller (Arduino Pro Mini); 17 – computer; 18– temperature controller (ICP-7018)

Fig. 9 – Scheme of the pilot plant

In experiments 1 and 2, the concentration of dry substances in the working liquid phase supplied to dehydration was 40% (wt), and in experiments 3 and 4 it was increased to 50% (wt).

The composition of a liquid heterogeneous system with different water content is shown in Fig. 10 [6].

Chemical composition of the working solution (by dry components) and, accordingly, of the granulated product [Humates]:[K]:[S]:[N]:[Ca]:[Mg]:[P]=[1.5]:[21.5]:[13.8]:[9.1]:[4.6]:[3.2]:[1.8].



a) experiments 1 and 2 (Exp.1, Exp.2) ***b***) experiments 3 and 4 (Exp.3, Exp.4)

Fig. 10 – Composition of the liquid phase (wt.%)

As initial granulation centers were used ammonium sulfate granules with admixtures of humic substances with equivalent diameter of granules d_e=1.85 mm. The initial height of the stationary bed of solids was H_0=0.32 m and the mass of the bed of granular material M_{bed}=7.83 kg was kept constant during the experiments due to the constant unloading of the bed when $\Delta P_{hydrost(0)}$=2389 Pa was exceeded at 400 Pa. The liquid phase was fed into the bed of solids and dispersed using a mechanical bowl disperser [6].

When using the inhomogeneous jet-pulsating mode of fluidization, according to the physical model, Fig. 1, a monotonous growth of the equivalent diameter was observed: experiment №1 – from 1.85 mm to 2.15 mm, experiment №2 – from 2.46 mm to 2.9 mm, experiment №3 – from 2.86 mm to 3.58 mm, experiment №4 – from 3.18 mm to 3.58 mm with an average growth rate of granules: $\lambda_{Exp.1}$=0.182 mm/h, $\lambda_{Exp.2}$=0.243 mm/h, $\lambda_{Exp.3}$=0.297 mm/h, $\lambda_{Exp.4}$=0.301 mm/h, which indicates stable kinetics of the process with a layered structure granulation mechanism, Fig. 11.

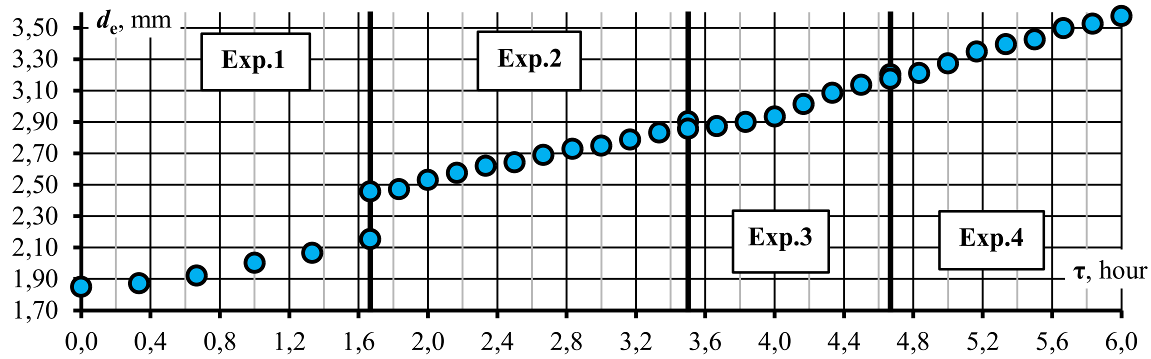


Fig. 11 – Dynamics of changes in the equivalent diameter of granules $d_e = f(\tau)$

The basic assessment of the intensity of heat-mass exchange processes during dehydration and granulation is the specific load of the surface of the bed by moisture, which characterizes the effective renewal of the interphase surface and the preservation of the driving force for mass exchange.

It was experimentally confirmed that the specific load of the surface of the bed of solids by the moisture is at least 1.5 times bigger compared to the bubbling mode when producing organic-mineral (humic-potassium-nitrogen-calcium-sulfur-containing fertilizers with magnesium and phosphorus impurities) with composition [Humates]:[K]:[N]:[Ca]:[S]:[Mg]:[P]= =[1.5]:[21.5]:[13.8]:[4.6]:[21.5]:[4.6]:[3.2].

The comparisons of the specific load by moisture shown on Fig. 12 confirm a significant advantage when using inhomogeneous fluidization, compared to the usual bubbling homogeneous mode.

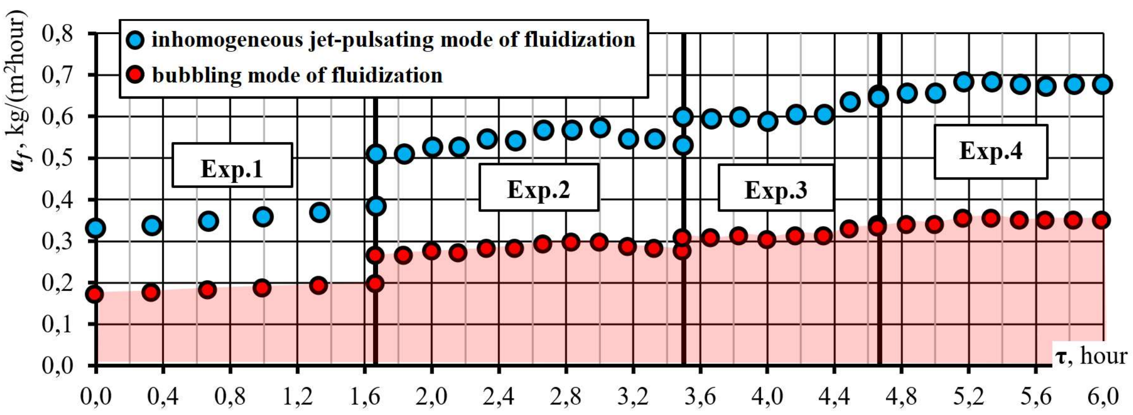


Fig. 12 – Comparison of the dynamics of changes in the specific load of the surface of the bed by moisture in the case of inhomogeneous jet-pulsating and bubbling hydrodynamic modes of fluidization

At the same time, the kinetics of the granulation process was stable, which is confirmed by the dynamics of changes in the granulation coefficient - a coefficient that shows how many percent of the dry substances contained in the initial liquid phase (which was fed to the granulation apparatus) was used to form a granulated product, Fig. 13.

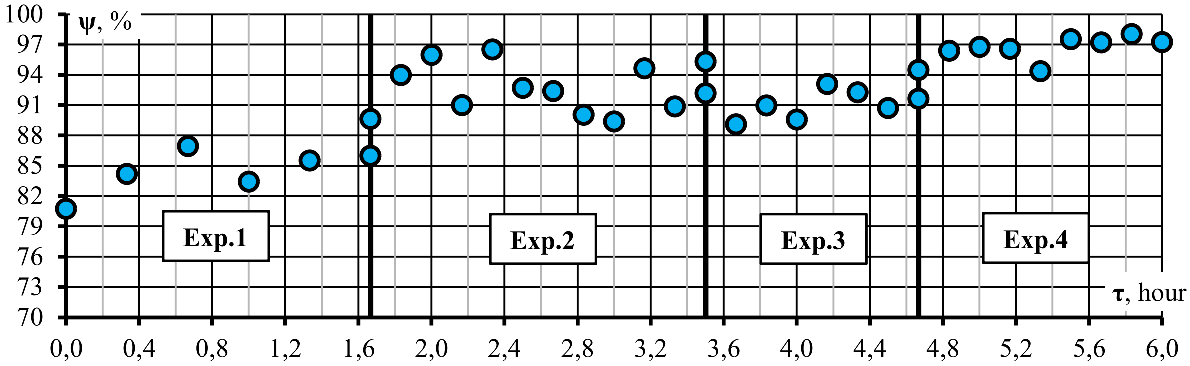


Fig. 13 – Dynamics of changes in the granulation coefficient ψ = *f* (τ)

Conclusions. Thus, the use of inhomogeneous jet-pulsating mode of fluidization makes it possible to significantly intensify the processes of heat and mass transfer due to the activation of diffusion-controlled processes and the increase of the exchange dynamics of the interphase contact 1.9÷2.9 m2/s, which is 27÷41% of the total surface of the material in the apparatus.

This made it possible, under the same conditions of experimental studies of granulation of liquid heterogeneous systems, to increase the productivity of the apparatus in terms of evaporated moisture by 1.5 times with stable kinetics of the layered structure mechanism of granulation with a coefficient of granulation in the stationary mode $\psi \geq 90\%$.

Experimental studies confirm that applying the inhomogeneous jet-pulsating mode of fluidization provide an intensive volumetric mixing with an intensive surface exchange without formation of agglomerates during the process of granulation the humic organic-mineral fertilizers with the injection of a liquid heterogeneous solution into the bed of solid granular material.

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ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ ПРОЦЕСІВ ПЕРЕНЕСЕННЯ ПРИ ЗАСТОСУВАННІ НЕОДНОРІДНОГО ПСЕВДОЗРІДЖЕННЯ

Процеси зневоднення та грануляції пов'язані з перенесенням теплоти до твердих частинок від газового теплоносія, який також виконує роль зріджувального агенту та спричиняє стохастичне переміщення зернистого матеріалу в апараті. Для реалізації пошарового механізму грануляції органо-мінеральних добрив необхідно забезпечити інтенсивну циркуляцію зернистого матеріалу з поступовим проходженням через відповідні технологічні зони апарата: зону інтенсивного теплообміну, зону висхідного потоку, зону зрошення, та зону низхідного руху (релаксації). При цьому за допомогою механічного пристрою у псевдозріджений шар диспергується рідка фаза, яка за рахунок адгезійно-сорбційних сил розподіляється у вигляді тонкої рідкої плівки на поверхні гранул.

Невирішеною науковою проблемою є низька ефективність міжфазового обміну в системі газ-рідина-тверде тіло та утворення агломератів при грануляції з підведенням рідкого гетерогенного розчину в шар зернистого матеріалу. Тому дослідження впливу гідродинамічної обстановки в камері гранулятора на забезпечення умов інтенсивного перемішування та переміщення зернистого матеріалу через встановлені технологічні зони грануляції при неоднорідному псевдозрідження є надзвичайно актуальним.

Метою роботи було визначення умов підвищення ефективності процесів перенесення при застосуванні неоднорідного струменево-пульсаційного режиму псевдозрідження. Для досягнення поставленої мети у даній роботі проведено аналіз інтенсивності оновлення поверхні контакту фаз при застосуванні неоднорідного струменево-пульсаційного псевдозрідження.

Встановлено, що застосування неоднорідного струменево-пульсаційного псевдозрідження в автоколивальному режимі дозволяє суттєво інтенсифікувати процеси тепло-масообміну за рахунок активізації дифузійно-контрольованих процесів та підвищення динаміки обміну міжфазового контакту 1.9÷2.9 м^2/с, що становить 27÷41% від загальної поверхні матеріалу в апараті. Це дало можливість при однакових умовах експериментальних досліджень грануляції рідких гетерогенних систем підвищити продуктивність апарата за випареною вологою в 1.5 рази при стійкій кінетиці пошарового механізму з коефіцієнтом грануляції в стаціонарному режимі більше 90%.

Ключові слова: *псевдозріджений шар, гідродинаміка, струменево-пульсаційний режим, неоднорідне псевдозрідження.*

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