Straitened Movement of the Granules in a Vortex Granulator

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Abstract* – The model of calculation of residence time of granule in vortex granulator in straitened movement mode is proposed. According the study of movement granules in changing its mass and interaction between each other conditions coefficient of conciseness for individual zones of vortex granulator is calculated.

Key words – vortex granulator, straitened motion, residence time.

I. Introduction

Free movement of granules is observed only at low volume content of dispersed phase in two-phase system (ψ <0,1). In this case, the distance between the granules to avoid collisions and mutual influence of granules at each other. If ψ> 0,1 distance between the surfaces of granules (size of passes) are smaller than its diameter, granules can easily slip between the other two. In this case, we should take into account the effect of collisions granules together. Clash of granules in two-phase system can also occur when the dispersed phase consists of polydisperse granules or granules with different density or mass (moisture content). In addition the movement of the granules in gaseous environment creates the speed and pressure fields. Other granules that make up the so-called ensemble and the walls of granulator, in turn, make a hydrodynamic effect on granule.

Considering this hydrodynamic situation and calculation of movement speed of particle (or the time of its staying in device) in straitened movement mode is an important factor in describing the hydrodynamics of two-phase vortex flows.

II. Theoretical basis

In our research we propose to consider straitened movement conditions when calculating residence time of particles in device workspace by such ratio

$$\tau_{sm} = \tau f_{e\tau}(\psi), \qquad (1)$$

where τ_{sm} is the time of straitened movement of granules; τ - time of movement of single granule; $f_{e\tau}(\psi)$ - empirical function of conciseness influence to granules residence time in device workspace.

Function $f_{e\tau}(\psi)$:

$$f_{e\tau}(\psi) = (1-\psi)^{-m}, \qquad (2)$$

where m is empirical indicator of rate (conciseness coefficient for time calculation).

Currently there are no published data concerning determination of empirical index m in formulas (1) and (2) in case of vortex weighted layer. The definition of empirical indicators also is difficult because of the suspension in vortex layer separate zones in height with varying intensity and primary granules movement direction (fig. 1).

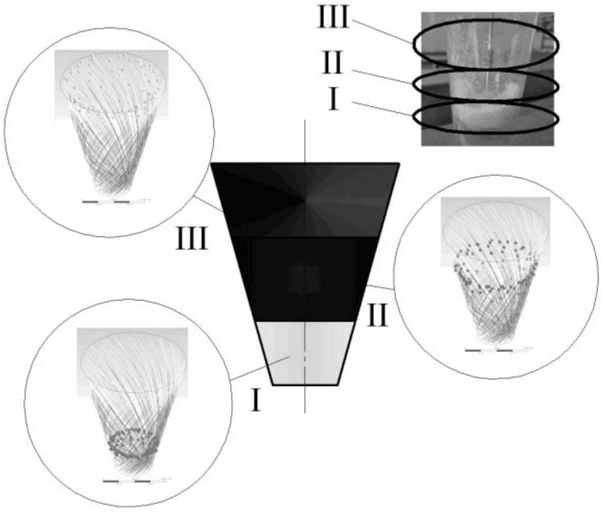


Fig. 1. Main zone movement of granules in a vortex granulator:
I - zone of dominant vortex movement of granules;
II - combined area of vortex and upward movement of granules;
III - dominant area of rising movement of granules

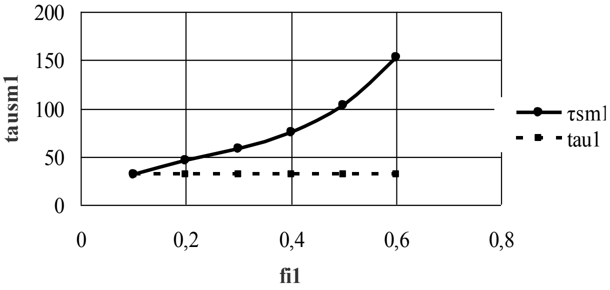
In previous studies [1,2] we shows the change of difference of weighted vortex layer in height. Using in calculating residence time of granules in vortex granulator working space the verage value of contents of dispersed phase to two-phase system ψ leads to significant error in calculations of time of granules staying according to formula (1).

Experimental studies were conducted for granules of ammonium nitrate with varying degrees of polydispersity (containing from 75 to 95% granules with diameter d = 2-3 mm), U_{in} = 0,01-0,02 kg moisture / kg of material and U_{fin} = 0,001-0,003 kg moisture / kg of material at T_C =100-120°C in angles range of opening cone of granulator workspace within φ = 10-15°.

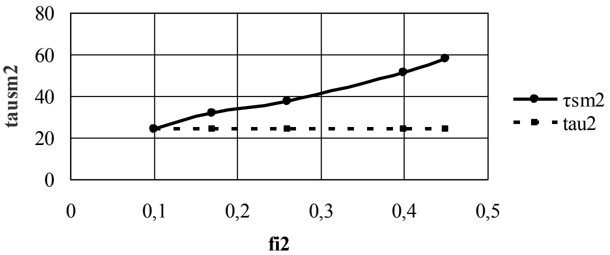
III. Results

In Fig. 2 we shows the experimental studies results of granule`s time spent with defined moisture parameters in workspace of vortex granulator in free movement (ψ≤0,1) and straitened movement mode. Experimental studies were conducted with the application of gas distribution device of blade type.

Increasing of residence time of granule in each zone occurs with different intensity, given the change in weighted layer and different direction vector of total gas flow speed of height of device. The granule is mainly located in area of vortex motion of granules, which coincides with the "active" zone, in which most moisture is removing in constant speed drying mode. In second and third zones of granulator where granule residence time below the first zone 3-5 (Fig. 3), moisture removal is happening in flowing speed drying. The assumption of coincidence zones granules in vortex motion with periods of drying is confirmed by determining the speed of drying in height of unit (ammonium nitrate drying curve is shown in Fig. 4). In the first zone 60% of required moisture are removed, in the second zone – up to 30%, the third zone is characterized by the slow moisture removal and has more hydrodynamic function - function of separation zone and zone of lead of small or easy granules to implement internal circulation of seeding agent.



a



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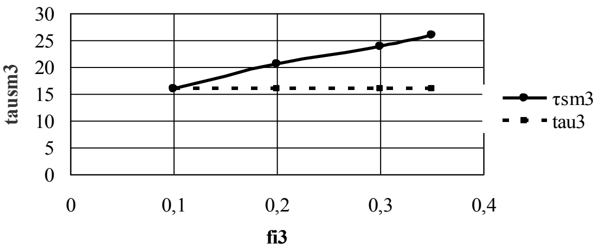

c

Fig. 2. Residence time of ammonium nitrate granules (polydisperse system consisting of 75-80% granules with diameter d = 2-3 mm) with U_{in} =0,02 kg moisture / kg of material and U_{fin} =0,001 kg moisture / kg of material at T_C =100°C in certain granulator areas (according to Fig. 1): a - zone I; b - zone II; c - zone III

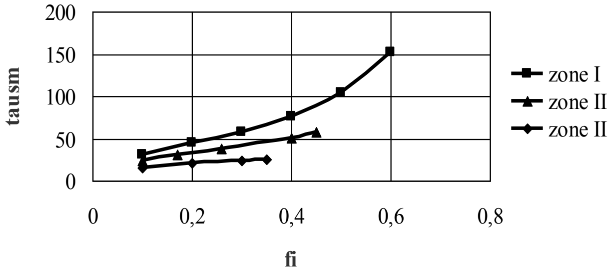

Fig. 3. Determination of staying time granules in certain areas of vortex granulator working space

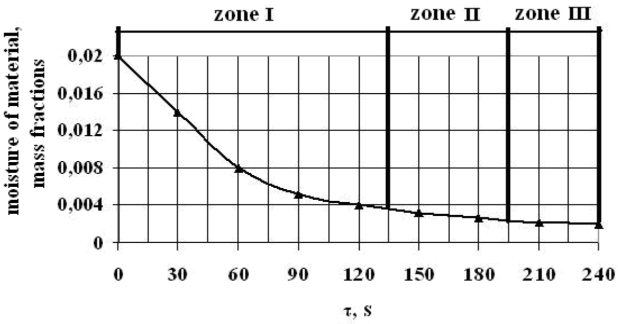

Fig. 4. Ammonium nitrate drying curve: T_C =100°C, U_{in}=0,02 kg moisture / kg of material, U_{fin}=0,001 moisture / kg of material, d=2 mm

Research results allowed to us to define the range of values of *m* in each zone granulator according to formula (2):

– zone I – *m*=1,7-1,74;
– zone II – *m*=1,46-1,49;
– zone III – *m*=1,1-1,13.

Thus, the total time of granules stay in straitened mode movement is determined by

$$\sum \tau_{cm} = \tau^{I}_{cm} + \tau^{II}_{cm} + \tau^{III}_{cm} = \tau^{I}(1-\psi^{I})^{-m^{I}} + \\ +\tau^{II}(1-\psi^{II})^{-m^{II}} + \tau^{III}(1-\psi^{III})^{-m^{III}}, \quad (3)$$

where the average value of ψ in each zone depends on the average difference of weighted layer ε [] and is given by

$$\psi_i = 1 - \varepsilon_i. \quad (4)$$

According to experimental studies to determine the optimal design of gas-distributing unit and its impact on stability of vortex weighted layer we offered the following ranges of average values ψ in each vortex granulator zone to be applied in engineering calculation of average power device: zone I – ψ =0,48-0,53; zone II – ψ =0,35-0,4; zone III – ψ =0,2-0,24.

Conclusion

Given the fact that for dehydration process of granular material specified time has to be discharged, the introduction ratio of conciseness in calculations for each granulator zone and timing of alone stay granules in each granulator zone will achieve optimal conditions for heat treatment of granules without overheating or presence of residual, more than the minimum necessary, amount of moisture.

References

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