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Design of a Grid for Preparation of high Density Granules from Dispersed Materials

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***Abstract*—**New design of a grid for preparation of high density granules with enhanced mechanical strength by granulation of dispersed materials is suggested.

A method for hydrodynamic dimensioning of the grid depending on granulation conditions, hydrodynamic regime of the operation, dispersity and physicochemical characteristics of the materials to be granulated was suggested.

The aim of the grid design is to solve the problems arising by the granulation of disperse materials.

***Keywords*—**fluidized bed reactor, granulation, porous silicate materials.

I. Introduction

GRANULATION comprises a series of physicochemical and physicomechanical processes giving particles of certain shape, size, structure and physical properties. It involves the following technological processes: preparation of the initial product, dosing and mixing of the component, formation of granules (agglomeration, layering, crystallization, densification, etc.), formation of their structure (Drying, sintering, polymerization, etc.), sorting (separation of the particles by size) and splitting of the larger fractions into smaller ones by further separation.

In chemical, food production and other industries, fluidized bed granulators are most often used for granulation of powdery materials [1,2,3].

An advantage of this granulation technique is that the devices have simple design, do not require sophisticated infrastructure and the investments tend to be smaller. Furthermore, due to the intense stirring, the phase distribution and granules structure is better. But the main advantage of these devices is that granules of defined size can easily be obtained.

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The aim of the present work is to design a grid with which granules of higher density can be prepared from powdery materials.

II. Theoretical Background

The formation of granules in a classic fluidized bed reactor is achieved by spraying wetting liquid through nozzles. The wetting liquid can be water or solution of binding substances in organic solvent.

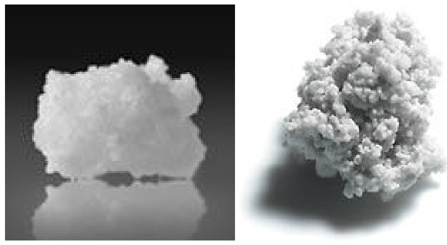

Fig. 1 Granule with “snowflake” shaped structure

The granules obtained by this method are usually with “snowflake” structure (Fig.1) and, depending on the physico-mechanical properties of the substance and disperse composition of the blend.

To prepare granules of higher strength, a process of granule formation is employed involving wetting with special binding substances - so called encapsulation – but the granules obtained have smaller active surface due to the specific features of the binding process to form the granule. This drawback resulted in limited usage of encapsulation especially in technological processes requiring large active specific area of the granules.

Another approach for preparation of granules of higher strength is granulation in devices equipped with special grids (fig.2,4) which generate stable vortex in the bed [4] resulting in mechanical densification and smoothing of the granules.

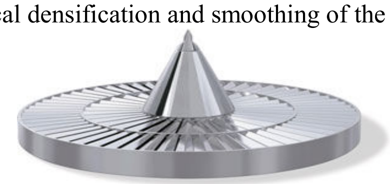

Fig. 2 Grid SpinFlow®

Fig. 2 shows vortex grid SpinFlow® though this type of grids have certain disadvantages. First, the granule rotat areoun only one axis (Fig.3).

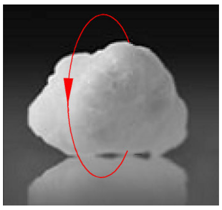

Fig. 3 Formation of a granule

Second, the grid design suggests formation of dead zones beside reactor walls and in the centeral part around the cone where the resistance is higher and the hydrodynamic regime is less stable. Fif.4 shows a grid with tangential injection of the fluidizing gas into the chamber.

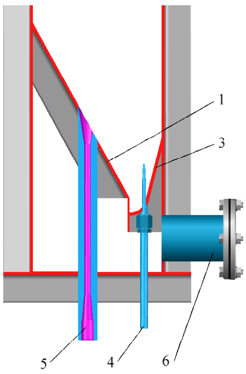

Fig. 4 Grid with tangential injection of the fluidizing gas into the chamber

With this type of grid, due to the high speed of the gas at the entrance, the motion is more intense and the probability of material sticking to the walls and formation of slug zones is lower but the rotation is still around one axis.

III. Discussion

A. Grid design

To solve the problem of preparation of granules of higher density, mechanical strength and stability, a new design is suggested for the grid of an apparatus working by the method of equilibrium layer.

The design is presented in Fig.5 and consists of a guiding device, central cone and wall cone.

The fluidizing gas is injected from the lower part of the grid, passes through guides and enters the fluidized layer where it generates screw-like vortex rotating around the central axis of the cone.

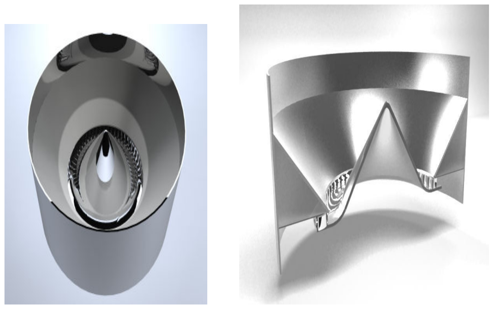

Fig. 5 Grid with screw-like motion of the layer

The design suggested can be characterized by the fact that it establishes hydrodynamic regime in the bed by which the fluidizing gas flow (as well as the granules) rotates around two axes – one tangentially to the gas inlet, thus creating vortex-like flow upwards the facing cone and downwards the wall cone (Fig.5), and another one parallel to the grid vertical axis.

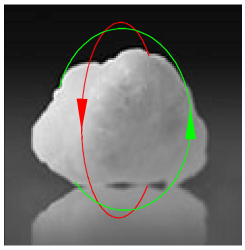

Fig. 6 Formation of granules with the grid design suggested

The advantages of the rotation around two axes (Fig.6) are the higher density of granule structure and improvement of its mechanical strength, as well as the significantly shorter time for granulation.

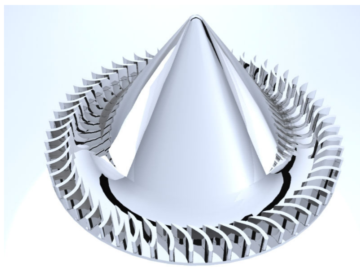

Fig. 7 Guiding device and central cone of the grid

B. Hydrodynamic dimensioning of the grid

The main characteristics of the grid designed, the guiding device, working angles and blade profiles were determined using hydrodynamic calculations.

The aim of the hydrodynamic calculations is to determine the minimal and working velocities of the gas flow across the grid, determine overall size of the apparatus, layer height, hydrodynamic resistance of the layer and the grid and the total resistance of the apparatus under optimal regime of the process. These calculations based on the determination of the average equivalent diameter of the particles were carried out by the following order.

- Determination of the equivalent particles.

The determination of the equivalent diameter of the particles in a polydisperse system is a key moment in the calculation of the process of equilibration.

The diameter was determined according to eqs.(1) using data obtained from laboratory analyses and taking the average values of the physical characteristics for the different layer compositions [5].

$$d_E = \sum_{n=1}^{i} X_i . d_i$$

Or, by the weight method

$$d_E = \sqrt[3]{\frac{6.M}{\pi.\rho_M.N}} \qquad (1)$$

where: M - particle mass, kg; ρ_M - density of particles material, kg/m^3; N - number of particles in the fraction.

- Determination of Archimedes criterion.

$$Ar = \frac{d_Э^3.(\rho_M - \rho_C).g}{\nu_C^2.\rho_C}$$

or

$$Ar = \frac{6.M.g}{\pi.\rho_C.\nu_C^2} \qquad (2)$$

where: ρ_C - fluidizing gas density under the temperature conditions in the reactor, kg/m^3; ν_C - fluidizing gas kinematic viscosity under the temperature conditions in the reactor, m^2/s.

- Determination of the criterion of Reynolds and the hovering velocity.

$$\mathrm{Re}_{EQ} = \frac{Ar}{18 + 0{,}61.\sqrt{Ar}};$$

$$W_{EQ} = \frac{\mathrm{Re}_{EQ}.\nu_c}{d_Э} \qquad (3)$$

Coefficient of resistance (ζ):

$$\zeta = \frac{4}{3}.\frac{Ar}{\mathrm{Re}_{EQ}^2}$$

- Determination of the geometric characteristic of the layer

- average relatively free cross-section of the layer f_{RF}.

At initial layer porosity less or equal to $\varepsilon_O \le 0{,}435$ (according to the physical model assumed), the average relatively free cross-section of the layer $f_{RF} = f_{ARC} = 0{,}188$ at minimal working velocity of the fluidizing flow [5].

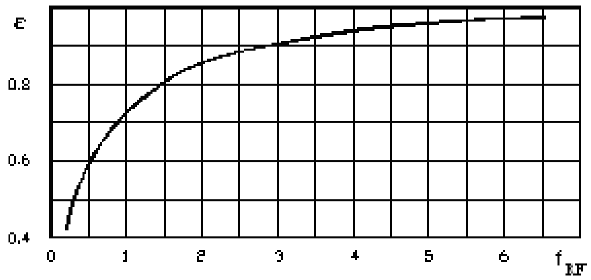

Fig. 8 Plot for the determination of the relatively free cross-section

In the cases when the initial porosity ε_O is higher than 0,435, the average relatively free cross-section f_{RF} was determined either using graphical dependence (Fig.8) or calculated by the equation:

$$f_{RF} = \left(0{,}73/(1-\varepsilon)\right)^{2/3} - 1 \qquad (4)$$

- Determination of the working region and regimes of the layer.

The working region of the equilibrated layer was selected on the basis of the hydrodynamic stability condition, ubiquitous agitation and minimal energy consumption for fluidization. The fluidized layer working regimes are presented in Fig.9.

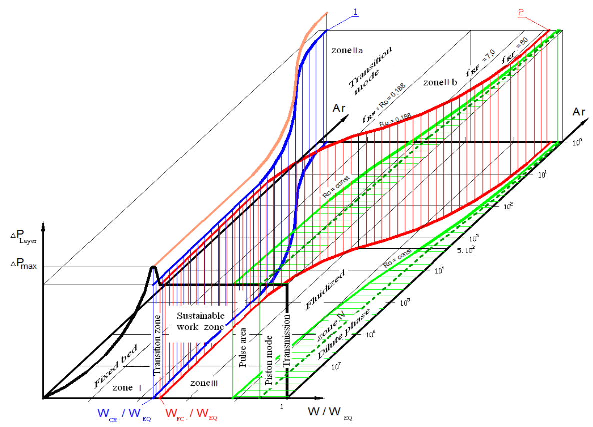

Fig. 9 Working regions of fluidized systems

- Determination of the fluidizing flow minimal velocity across the full cross-section of the layer:

at $Ar \ge 5.10^3$ or $\zeta \le 1$:

$$\frac{W_{FC}}{W_{EQ}} = \frac{X_O}{1 + f_{RF}} \qquad (5)$$

at $Ar \le 5.10^3$ or $\zeta \ge 1$:

$$\frac{W_{FC}}{W_{EQ}} = \frac{X_O}{1 + X_O} \qquad (6)$$

where: $X = f_{RF} \cdot \sqrt{\frac{f_{RF}}{1+f_{RF}} \cdot \left(1+\frac{\zeta_{EQ}}{f_{RF}}\right)}$

Working velocity of the flow at layer surface.

$$W_{work} = (1{,}2 \div 1{,}3).W_{FC} \quad (7)$$

where: $1{,}2 \div 1{,}3$ – coefficient accounting for the deviations from particles shape, unevenness, etc. – which guarantee for the reliable hydrodynamic performance of the fluidized layer.

C. Constructive design of the grid

The grid constructive design was carried out on the basis of the hydrodynamic calculations and the granulometric composition of the particles; it involves determination of grid cross-section, slope angles of the central and wall cone, as well as grid height (Fig.10).

A major issue in the constructive design of the grid is the determination of the angles of the vorticizer blades. Depending on the value of the angle β , the rotational speed of the layer (granule) around one or other axis is determined.

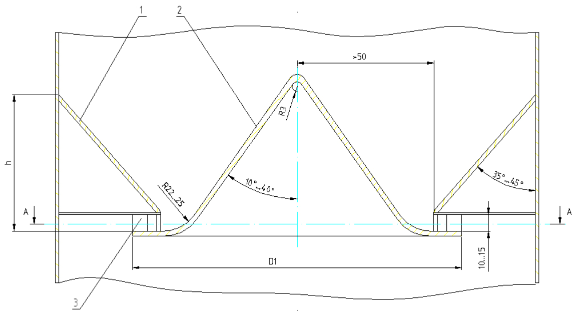

Fig. 10 Constructive design of the grid

The velocity of the gas at the point of injection into the layer is calculated by the equation:

$$\frac{W_{IN}}{W_{EQ}} = \sqrt{\frac{K_1}{1+f_{RF}} \cdot \frac{H_0}{d_E} \cdot \frac{\zeta_{EQ}}{\zeta_{GR}}} \quad (8)$$

where: K_1–coefficient accounting for the ratio between the hydrodynamic resistances of the apparatus and the layer. For the different hydrodynamic regimes of the layer (Fig.9), the values of this coefficients were from 1 to 0.3 [5]; ζ_{GR} – hydrodynamic coefficient of the grid, for prismatic grids $\zeta_{GR} = 1{,}2 \div 1{,}4$; H_0 - layer height.

The cross-section of the vorticizer (gas-distribution grid of the apparatus) was determined from the dependence:

$$F_{IN} = F_{GR}.(W_W / W_{IN}).(\rho_{t_{GR}} / \rho_{t_{IN}}) \quad (9)$$

where: $\rho_{t\ gr.}$, $\rho_{t\ in.}$ are fluid densities at the temperature of the layer and at the temperature at apparatus inlet, respectively.

IV. Conclusion

A new design was suggested for a grid for preparation of granules with high density and improved mechanical strength in the process of granulation of disperse materials.

A method for hydrodynamic dimensioning of the grid depending on the granulation conditions, hydrodynamic regime of the apparatus, disperse composition and physico-chemical characteristics of the material to be granulated.

A method for constructive dimensioning of the grid is also suggested, where the basic characteristics of the grid elements are calculated depending on particles granulometric composition.

The aim of the new grid design is to solve problems arising in the granulation of disperse materials.

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References

[1] Klassen P.V., I.G.Grishaev, Basic methods of granulation, Moscow, Khimiya, p.358, 1982.
[2] Kolpashnikov A.I., A.V.Efremov, Granulated materials, Moscow, Khimiya, p.146, 1977.
[3] Sulimenko L.M., Albats B.S., Agglomeration processes in the production of construction materials, Moscow, Khimiya, p.247, 1994.
[4] Yudaev V.F., Hydromechanical processes in rotor apparatuses with modulation of the pass-through cross-section of the medium treated //Teor.osnovy chim.technol. , v. 28, № 6,. pp. 581 – 590, 1994.
[5] Rusev D.R. Method for technological calculation and constructive design of fluidized bed devices, Annual of Univ. ”Prof.Dr.A.Zlatarov”-Bourgas, v. XXXIV, No1, 2005.