World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:5, No:11, 2011

Distributor Plate Design and a System for Collection of Granules in a Device with a Vortex Fluidized Bed

Bogdan Il. Bogdanov, Dimitar R.Rusev, Yancho H. Hristov, Irena G. Markovska, Dimitar P.Georgiev

Open Science Index, Materials and Metallurgical Engineering Vol:5, No:11, 2011 publications.waset.org/4626.pdf

Abstract**—**A newly designed gas-distributor for granulation of powdery materials in equilibrated fluidized bed and a system for collecting the granules prepared are suggested.

The aim of these designs is to solve the problems arising by the granulation of powdery materials in fluidized bed devices. The gas-distributor and the collection system proved to be reliable at operation; they reduce the size of still zones, effectively disperse the binding solution in the bed and ensure the collection of granules of given diameter.

Keywords**—**Distributor plate design; Granulation; System design

I. INTRODUCTION

GRANULATION is a process allowing particles of certain shape, size, structure and physical properties to be formed by bonding primary fine powders into large grains through heating, compaction or addition of binding liquids [1]. Granulation is widely encountered process pf particle enlargement in chemical industry, food processing and biotechnology [1-4].

The advantages of the granulation as a method of particle enlargement are mainly in the simple designs of the equipments used, the easily controllable process conditions allowing grains of desired size, shape and structure to be obtained.

Generally, fluidized bed based devices are used to perform granulation process [4] as it shown by the examples in Fig. 1 with either rectangular (Fig. 1a) or circular (Fig. 1b) cross-sections.

Commonly the initial product is fed into the apparatus through a nipple and fluidized by fluidizing gas (most often – air) fed under the gas-distributor.

B. Il. Bogdanov - Department of inorganic substances and silicates, Assen Zlatarov University, 1 Prof. Yakimov Str., 8010 Bourgas, Bulgaria, e-mail: bogdanov_b@abv.bg

D. R. Rusev - Department of Material science and technology, Assen Zlatarov University, 1 Prof. Yakimov Str., 8010 Bourgas, Bulgaria, , e-mail: dr_rusev@mail.bg

Y. H. Hristov - Department of Material science and technology, Assen Zlatarov University, 1 Prof. Yakimov Str., 8010 Bourgas, Bulgaria, e-mail: janchrist@abv.bg

I. G. Markovska - Department of inorganic substances and silicates, Assen Zlatarov University, 1 Prof. Yakimov Str., 8010 Bourgas, Bulgaria, e-mail: imarkovska@abv.bg

Dimitar P.Georgiev - Department of Material science and technology, Assen Zlatarov University, 1 Prof. Yakimov Str., 8010 Bourgas, Bulgaria, e-mail: dgeorgiev@btu.bg

The solution to be granulized is spread over the layer (Fig.1a, c) or into the layer (Fig.1b) through nozzles. The granules are pulled out of the device through the outlet nipple.

The devices shown in Fig. 1a, b, c have with horizontal perforated gas-distributors requiring careful adjustments because the wide cross-sectional area leads to dead zones with non-fluidized particles [5]. The dead zones could be avoided by swirling of the gas flow by means of tangential gas input as it is illustrated in Fig. 1d.

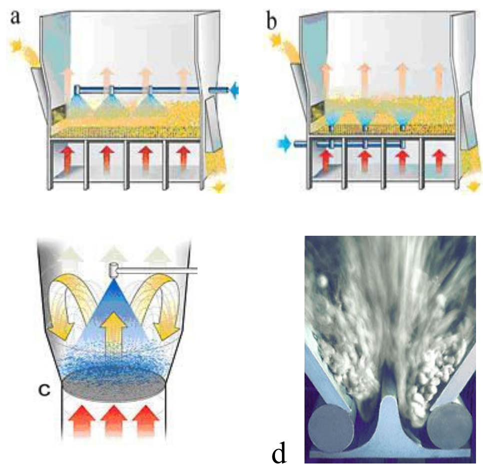

Fig. 1 Typical fluidized bed granulators: a – prismatic apparatus where the solution is sprayed over the layer; b – prismatic apparatus where the solution is sprayed into the layer; c – cylindrical apparatus where the solution is sprayed over the layer; d- gas distributor with tangential gas flow. Present author's schematic designs

The principle disadvantage the granulators based on fluidized beds is that non-granulated powder can leave the device as a result of the intensive mixing and bubbling. The latter yields granulated product with wide distribution of the grain in size. Commonly, this can be avoided by collection of the granulation product though a central tube connected to the gas-distributor (Fig. 2) where additional gas flow controls the downward flow of the granules. Another, principle problem emerging in the operation of the granulation devices is the nozzle fouling (Fig. 3).

World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:5, No:11, 2011

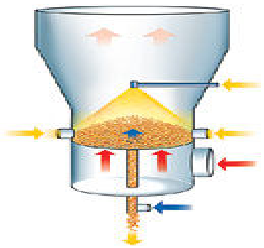

Fig. 2 Apparatus with central tube for collecting the product

Fig. 3 Fouling of the nozzle injecting the binding solution

II. Design System for Selection of Granules from a Layer

The experimental set-up is shown schematically in Fig.5. The granulation solution enters the device through the nozzle 1 located in the zone of intensive fluidizing upflow (see Fig.1d) with a vortex along distributor plate. This vortex prevents the nozzle fouling.

The present work addresses application of special nozzle (see Fig. 4) designed to avoid the above mentioned problems. More over, new design of the gas-distributor plate and a system of granule collection are conceived that allow obtaining granules in a narrow fraction and avoiding the nozzle fouling.

The granules are collected from the bed in two stages by a system consisting of a central tube (2) for initial separation, hopper (3), a dispenser with sectors (4), a tube for precise separation (5) and a hopper (6) for final collections of the grains. According to Romankov [6] the vortex distributor design is suitable for technologies where the solids precipitation is limited by the available space. The hydrodynamic conditions in system are controlled by regulating valves mounted in the tubes for supplying the technological gas. The distributor plate design is shown in Fig. 6. It was developed on the basis of a distributor plate with tangential feeding the gas into the layer, but with additional nozzle for injection of the granulated solution - 4 and nipple for collection of the granules obtained - 5. The nozzle is mounted in the center of the vortex zone of the fluidized layer. The experimental studies revealed that the location of this center depends on the equivalent diameter of the particles in the layer. The nipple for collecting the granules was mounted at distributor plate front side (position 1). Its mounting height depends on the intensity if the hydrodynamic conditions and the segregation of the granules in the layer. The fluidizing gas is fed through nipple 6 and on entering the layer it is distributed through the openings in the vertical plate (position 2).

Fig. 4 Special nozzle of Glatt Group [5]. Top- general view of the assembled nozzle. Bottom – nozzle details

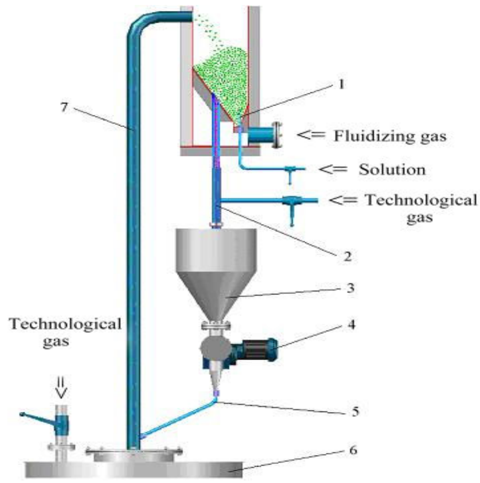

Fig. 5 System for collection of granules from the layer:
1 - nozzle; 2 – central tube for initial separation; 3 – hopper; 4 – sectored dispenser; 5 - tube for precise separation;
6 - hopper for the collected granules

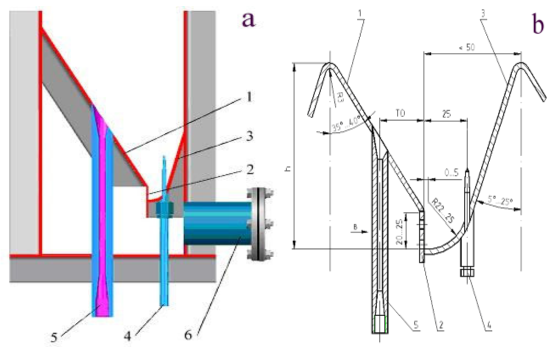

Fig. 6 Distributor plate design: a) General sketch. b) Details in the design (all dimensions are in millimeters). Elements : 1- front side; 2- vertical plate; 3- back side; 4- nozzle; 5, 6 - nipples

III. Hydrodynamic Model

The hydrodynamic model developed considers exchange of mechanical energy between the gas flow and the solids arranged in an aggregate (see Fig. 7) consisting of 1 or N particles and existing at mechanical equilibrium. For

Open Science Index, Materials and Metallurgical Engineering Vol:5, No:11, 2011 publications.waset.org/4626.pdf

Open Science Index, Materials and Metallurgical Engineering Vol:5, No:11, 2011 publications.waset.org/4626.pdf

simplicity, the particles are considered as spherical in shape. The aggregate is considered at rest and streamlined along the vertical Z axis by gas flow.

The particle is smooth and it is placed in a channel with cross-section $f_C = f_D + f_F$. To determine the fluid drag R_A the force balance condition

$$\sum_{i=1}^{n} P_i = G - A + P_R - P_P - P_{DH} - R_A = 0 \qquad (1)$$

can be applied The force P_p due to the pressure differences can be expressed as

$$P_P = (p_1 - p_2) f_D = (G - A)\frac{1}{1+f_{RF}} \qquad (2)$$

Where: $f_{RF} = f_F / f_D$ - the free cross-section ratio.

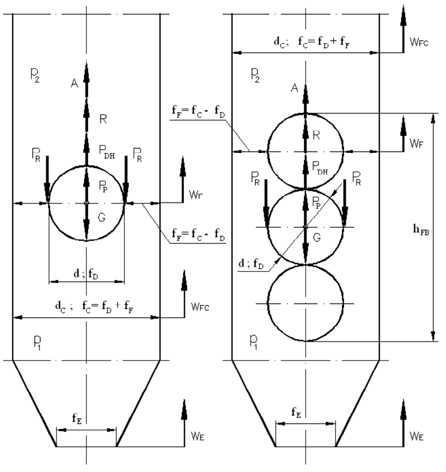

Fig. 7 Equilibrium of 1 and N particles placed within a limited space: G – particle gravity; A – Archimedes buoyancy; P_P – force acting due to pressure difference before and after the particle; P_{dh} – force of the dynamic head of the flow; P_R – force of the reaction tot he flow between the particle and channel wall; R_C – resulting resistance of the flow

The dynamic force acting on the particles is

$$P_{DH} = \Delta P f_D = \frac{(G-A)}{\zeta_A}\frac{f_{RF}}{1+f_{RF}} \qquad (3)$$

while the fluid drag force in the throat formed by the aggregate and the channel wall is

$$P_R = (G-A)\frac{1}{\zeta_A}\frac{f_{RF}}{1+f_{RF}}(1-\zeta_A) \qquad (4)$$

Substitution of (2), (3) and (4) in (1) yields

$$R_A = (G-A)\frac{1}{\zeta_A}\frac{f_{RF}}{1+f_{RF}}\left(1-\frac{\zeta_A}{f_{RF}}\right) \qquad (5)$$

At the equilibrium we have

$$R_A = 2(G-A) \qquad (6)$$

$$G - A = \frac{\pi . d^3}{6}(\rho_B - \rho_0) g \qquad (7)$$

From (1) (5) and (7) and some algebra we have relationships valid within different ranges defined by the Archimedes number, namely

- for $Ar \geq 5.10^3$ or $\zeta \leq 1$

$$\frac{U_{FC}}{U_{EQ}} = \frac{X_0}{1+f_{RF}} \qquad (8)$$

- for $Ar \leq 5.10^3$ or $\zeta \geq 1$

$$\frac{U_{FC}}{U_{EQ}} = \frac{X_0}{1+X_0} \qquad (9)$$

where:

$$X_0 = f_{RF}\sqrt{\frac{f_{RF}}{1+f_{RF}}.\left(1+\frac{\zeta}{f_{RF}}\right)} \qquad (10)$$

The relationships (8) and (9) allow the minimum gas velocity at the point of mechanical equilibrium to be determined. However, this theoretical assumption is violated by the chaotic particle motions and collisions in the fluidized layer; as results particles in a wide distribution in size enter the collection tube.

Due to the intense hydrodynamic regime in the bed generated by the unbalanced forces and chaotic moments acting in it, certain number granules of varying diameter fall in the collecting tube. This leads to uncontrollable changes in hydrodynamics and rates of precipitation in the tube (dependencies 8 and 9). This explains the undesirable distribution in size of the final product.

For proper separation of the granules and collection of granules of selected diameter only, an additional precipitating tube 7 (fig.5) was mounted wherein stable hydrodynamic regime is formed providing for the dosed collection of granules effected by a sector dispenser 4 (fig.5). The granules collected, having a diameter determined by the hydrodynamic regime formed in tube 7, are precipitated in the bunker 6. The system hydrodynamics is controlled by a system of vents mounted in the tubes for input and output of the technological gas used.

The nozzle is mounted in the center of the vortex zone of the fluidized bed. The experimental studies showed that the location of this center depends on the equivalent diameter of the bed particles, physicochemical characteristics of the fluidizing gas, radius of the back wall 3 of the gas-ditributor, bed height, etc. Special software was developed to determine the approximate location of the center and the nozzle design allowed it to be mounted at different heights.

The orifice through which the product prepared is carried away is mounted at the front wall 1 of the gas-ditributor. The orifice mounting height is determined by the intensity of the hydrodynamic process and according to the segregation of the granules in the bed. The fluidizing gas is fed through orifice 6 and distributed into the layer through the openings of the vertical plate -2.

IV. Conclusion

A newly designed gas-distributor for granulation of powdery materials in equilibrated fluidized bed and a system for collecting the granules prepared are suggested

The designs suggested are aimed at solving the problems arising by the granulation of powdery materials in fluidized bed devices with equilibrated bed. To solve these problems, as well as for precise separation of the granules, an additional precipitating tube was used where stable hydrodynamic regime is established ensuring dosed collection of the granules.

The gas-ditributor and collection system show reliable performance, they reduce to minimum the still zones in the bed, the binding solution is effectively dispersed into the solution and collection of granules of predetermined diameter is ensured.

Nomenclature

f_D - particle cross-section (m^2)

f_F - free cross-section of the channel between the particle and the channel walls (m^2)

P_P - force acting on the body due to the pressure difference

P_{DH} - dynamic force dues to the flowing gas (N)

U_{EQ} - the gas superficial velocity at the mechanical equilibrium (ms^{-1})

U_E - superficial gas velocity at the channel entrance (ms^{-1})

U_{FC} - superficial gas velocity defined by the full channel cross-section (ms^{-1})

U_F - superficial gas velocity in the free cross-section (ms^{-1})

Acknowledgment

The authors would like to acknowledge for the financial support provided by Bulgarian Ministry of Education and Science, Fund "Scientific Investigation".

References

[1] I. Sekiguchi, Granulation, in: Powder Technology Handbook, 3rd ed., H. Masuda , K. Higashitani and H. Yoshida, eds., pp. 599-613 (CRC Press,
Boca Raton, 2006)

[2] P. V.Klassen, I.G. Grishaev, Basic granulation techniques. (Khimiya, Moscow, 1982)-In Russian

[3] A.I. Kolpashnikov, A.V. Efremov, Granulated materials. (Khimiya, Moscow, 1977) - In Russian.

[4] L.M. Sulimenko, B. S. Albats, Agglomeration processes in the production of construction materials, (Khimiya, Moscow, 1994)- In Russian.

[5] The Glatt Group of Companies, http://www.glatt.com.

[6] P. G. Romankov, N. B. Rashkovskaya, Drying in fluidized bed. (5th edition, Khimiya, Leningrad, 1979)- in Russian.

Open Science Index, Materials and Metallurgical Engineering Vol:5, No:11, 2011 publications.waset.org/4626.pdf