Buletinul Ştiinţific al Universităţii "Politehnica" din Timisoara, ROMÂNIA
Seria CHIMIE ŞI INGINERIA MEDIULUI
Chem. Bull. "POLITEHNICA" Univ. (Timişoara) *Volume 53(67), 1-2, 2008*

Influence of Geometrical and Material Characteristics upon Dynamic Parameters at Granular Material in Spouted Bed Processing

M. Mares, G. Isopencu, G. Jinescu

Chemical Engineering Department, Applied Chemistry and Material Science Faculty, Politehnica University of Bucharest, Polizu St., Bucharest.

Abstract: The paper presents the influence of geometrical characteristics of the system and material properties upon the main dynamic parameters of the granular material in spouted bed. It is used inorganically materials with different sizes, shapes and densities. The materials are classified in group D, according with Geldart classification, adequate to the spouted bed processing. The main dynamic parameters studied were: the minimum spouted velocity, the minimum pressure drop, maximum spouted bed height. By experimental data processing it was obtained empirical relationships specific to the studied system. The obtained relations can be used at spouted bed apparatus design.

Keywords: spouted bed, granular material, dynamic parameters.

1. Introduction

The granular materials processing imply the different operation using (coating operations, drying, etc.) with the purpose to improve the material quality or to ensure the optimal storage conditions. These operations are based on the mass and heat transfer phenomena. To ensure a great property transfer surface, at granular material processing are used intensification techniques.

Like intensification technique for the particulate materials is consecrate the fluidized bed. But, granular materials are a group of materials which include particles larger than 1 mm. According to the Geldart classification this material group can't by efficiently processed in fluidized bed. The intensification techniques recommended for this materials is spouted bed.

The spouted bed is considered like a particulate case of heterogeneous fluidized bed realized in special dynamic and geometrical conditions. The references from specialized literature [1, 2] indicate that fluidized bed can be obtained in conical apparatus and is characterized by a slope angle at column base, θ, and by a well developed fluidized bed zone. The size of this zone is function of con angle, the cylindrical zone diameter, d_c, and central gas inlet orifice, d_0, ratio and material bed height, H_0. The literature data [3, 4] shown that during con angle and bed height decreasing, the central zone with fluidized bed aspect diameter equals the column diameter. Thus, at $\theta = 10^o$ con angle and $D/d_0 = (1,3\ ;\ 1,7)$ ratio, the bed is fluidized on the entire apparatus section. At $\theta > 20^o$ con angle and $D/d_0 = 2$ ratio, in bed are evidenced clearly the two zone: the central zone with fluidized aspect and periphery annular zone, less mobile.

For the cylinder-conical apparatus, characterized by con angle $\theta > 60^o$ and $D/d_0 \geq 4$ ratio, the spouted fluid (gas) is introduce like jet through a central orifice placed at diffuser base and it is obtained the conventional spouted bed [5].

The higher gas velocity in central zone and the non uniform distribution of the gas on the cross-sectional of apparatus determine different characteristics of spouted bed from fluidized bed.

2. Experimental

To realize the experimental study upon the behavior from the dynamic point of view of the granular materials in spouted bed it was conceive and realize an experimental laboratory plant (figure 1).

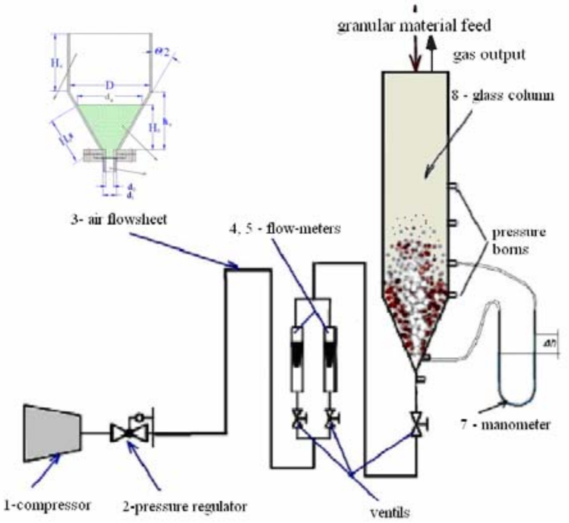

Figure 1. The laboratory experimental installation scheme

The cylinder-conical column is confectioned from glass and has two zone, with different cross section:

- the troncone zone, at the bottom, with dimensional characteristics:

TABLE 1. The constructive characteristics of the troncone zone for the experimental columns

Symbol	d_0, *mm*	θ , *deg*	h_c , *mm*
C1	9	30	90
C2	7	40	70
C3	10	60	75

The stable operation regime of the cylinder-conical columns is determined of the con angle, θ, of sizes, shape and densities of the solid particle.

- the cylindrical zone, at the top, with dimensional characteristics:

TABLE 2. The constructive characteristics of the cylindrical zone for the experimental columns

Symbol	D_c, *mm*	H_c, *mm*
C1	56	25
C2	56	25
C3	96	35

The experimental installation was realized to allow the flexible and secure operation during experiments, which are considerate discontinuous processes [6, 7].

3. The used granular materials characterization

The granular materials are inorganically (glass and polymers). These are characterized by different sizes, densities and shapes, how is shown in table 3.

TABLE 3. The main physical properties of used granular materials.

No crt.	Solid granular material	Material symbol	Particle			Bed	
			d_p 10^3	ρ_p	Ψ	ρ_v	ε_0
UM			*m*	*kg/m³*	-	*kg/m³*	-
1	*Sand*	S	1.5	2623	1	1223	0.53
2	*Glass*	G	2	3152	1	1413	0.55
3	*Nylon*	Ny	2	739	0.62	647	0.30
4	*PVC*	PVC	3.5	936	0.99	566	0.40
5	*Polyethylene*	PE	3.5	834	0.67	594	0.30

For the spouted bed dynamic was used like spouted agent the atmospheric air at surrounding temperature characterized of $\rho_g = 1.28\,kg/m^3$ $\eta_g = 1.8 \cdot 10^{-5}$ $Pa \cdot s$, at flow-rates between 0-10^5 l/h.

4. The experimental results regarding the spouted bed dynamics

The experimental study regarding the spouted bed dynamics has follows the granular materials behavior under ascending air jet, feed at the bottom of the column, obtained from the inlet feeding orifice.

It was follows the spouted bed characteristic dynamic parameters determination, such as: minimum spouting velocity, w_{ms}, minimum spouting pressure drop, Δp_{ms}, maximum bed height, H_M.

The dynamic parameters measurement was made for the next situations:

- for columns with different geometries;
- for the materials with different sizes, densities and shapes;
- for different geometrical ratio: H_0 / D_c; d_0 / D_c.

The minimum spouting velocity was determined by two methods:

- from pressure drop versus gas velocity in inlet column orifice diagram;
- visually, by correlation the observations regarding the dynamic bed structure modification during the experiment with the spouting phases consecrated in literature.

By experimental data processing using linear regression method, it was obtained for the minimum spouting velocity through Reynolds criteria, a relationship valuable for all material types function of material properties, through Arhimede criteria, geometrical simplex H_0 / D_c; d_0 / D_c and con angle (equation 1):

$$Re_{ms} = 1.087 \cdot Ar^{0.401} \cdot \left(\frac{H_0}{D_c}\right)^{0.835} \cdot \left(\frac{d_0}{D_c}\right)^{-1.044} \cdot \cdot \left(tg\frac{\theta}{2}\right)^{-0.089} \cdot \Psi^{-0.991} \quad (1)$$

Relation (1) indicates:

- the significantly influence of the column and bed geometry, the particle properties and shape on the flow regim at minimum spouting ;
- a smaller influence on the spouting regime has the con angle from the feeding spouting agent zone.

The deviation of the values calculated with relation (1) versus experimental values is represented in figure (2); the deviation is determined mainly of the different shape of the used particles.

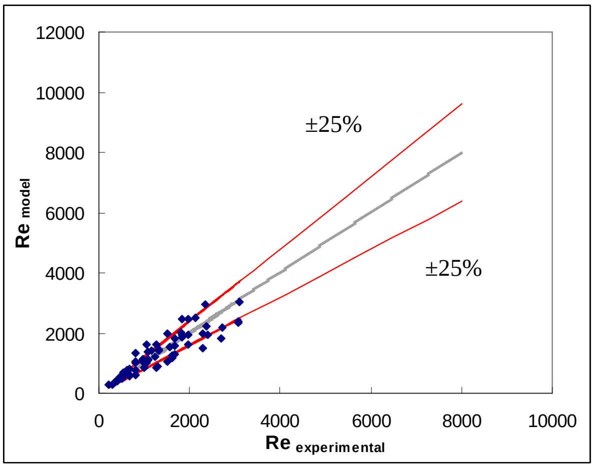

Figure 2. The deviation of the eq (1) calculated values versus experimental values for the Re_{ms}

The pressure drop in spouted bed, is measured in mm water with and differential manometer connected to the pressure borne dispose under the feeding column zone, respectively on the column cylindrical zone, above the material bed. Initially is determined the pressure drop in empty column, Δp_g . After that, during the experiments is measured the total pressure drop. The pressure drop in the spouted bed is determined by the next equation:

$$\Delta p_s = \Delta p_t - \Delta p_g \qquad (2)$$

The experimental data obtained for the minimum spouting pressure drop was correlated in an empirical equation function of Arhimede criteria which introduce the physical properties of the solid particles and of the spouting agent and function of the usual geometrical simplex used in spouted bed characterization. The method of the correlation was linear regression applied to the all materials used:

$$\frac{\Delta p_{ms}}{\rho_p \cdot g \cdot H_0} = 1.089 \cdot Ar^{-0.088} \cdot \left(\frac{H_0}{D}\right)^{0.28} \cdot \left(\frac{d_0}{D}\right)^{-0.316} \cdot \left(tg\frac{\theta}{2}\right)^{-0.798} \cdot \Psi^{-3.535} \qquad (3)$$

In the figure 3 is presented *the deviation of the calculated* values with equation (3) versus experimental values for the minimum spouting pressure drop

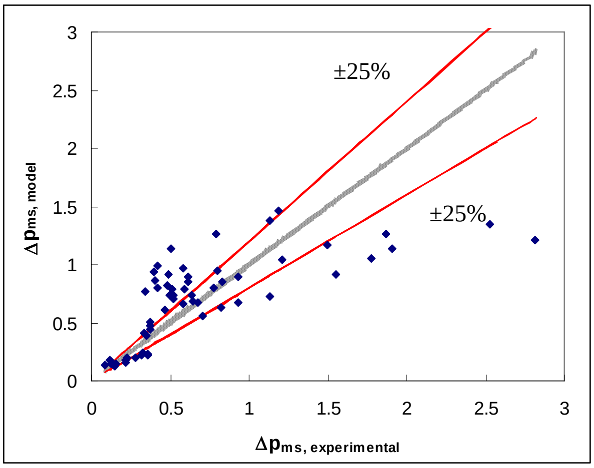

Figure 3. The deviation of the eq. (3) calculated values versus experimental values for the minimum spouting pressure drop

The maximum bed height, H_M, obtained in stable spouting bed conditions is a value which depends of solid particle nature, of column walls effect and column base angle upon bed dynamic. On the correlation analysis by linear regression method it was obtain for the maximum bed height the next equation:

$$H_M = 0.304 \cdot \left(\frac{H_0}{D_c}\right)^{0.784} \cdot \left(\frac{\rho_p}{\rho_g}\right)^{0.031} \cdot \left(tg\frac{\theta}{2}\right)^{-1.095} \qquad (4)$$

In figure 4 is represented the deviation of the calculated values with equation (4) versus experimental values in variation domain of $\pm 25\%$.

The maximum bed height is influenced of system geometry, increase proportionally with geometrical simplex H_0/D_c and decrease with the column angle, material and spouting agent properties (ρ_p/ρ_g ratio).

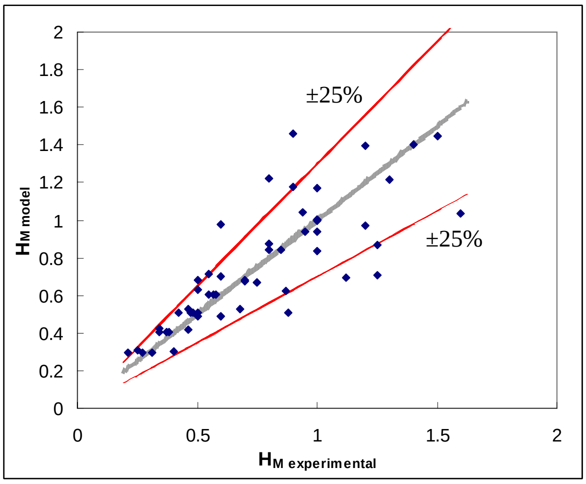

Figure 5. The deviation of the eq. (3) calculated values versus experimental values for H_M

5. Conclusions

The experimental determination follows the dynamic behavior study of the granular particles in spouted bed.

It was determined by regression from experimental data, the original criterial empirical relations for valuable for the spouted bed, in conical columns for materials with different shapes, considering a large domain for the variables (physical properties of the materials, geometrical simplex); the results obtained for the dynamic parameters with empirical equation versus experimental data present a deviation of 25%.

The minimum spouting velocity is proportional with: geometric simplex H_0/D_c (which determine the wall effect), the solid particle diameter, particle density and particle shape. The minimum spouting velocity decrease with d_0/D_c, which characterizes the jet effect.

The minimum pressure drop in bed is directly influenced of granular material nature (sizes, shape factor, density) and of initial bed height of the solid particle bed.

The empirical relations can be used to establish by calculus the optimal operating domain for the dynamic parameters w_{ms}, p_{ms}, H_M function of the system properties solid particle- spouting agent, of apparatus geometry and of charging column degree.

REFERENCES

1. Devahastin, S ., Mujumdar, A. S ., Raghavan, G. S Y., Spouted Beds Research"**at** McGill University, Proceedings of the International Conference on Food Industry techn logy and Energy Applications", Bangkok, Thailand, **1996**, pp. 22-29.
2. Olazar, M., Jose, M.S., Izquierdo, M.A., Salazar, A.O., Bilbao, J., Effect of operating conditions on solid velocity in the spout, annulus and fountain of spouted beds, *CES*, **2001**, 56, pp. 3585-3594.
3. Jose, S., Olazar, M.J., Alvarez, S., Morales, A., Bilbao, J., Local porosity in conical spouted beds consisteing of solids of varying density, *CES*, **2005**, 60, pp. 2017-2025.

4. Lourenco, R.O., Duarte, C.R., Henrique, H.M., Barrozo, M.A.S, Simulation and experimental study of pressure drop fluctuations in a cylindrical spouted bed, **2006**, IDS 2006
5. Floarea O., Jinescu, G., Procedee intensive in operatii unitare de transfer, Ed Tehnica, Bucuresti, **1975**.
6. Mares, M., Vasilescu, P., Jinescu, G., Isopencu, G., Aspects regarding the spouted bed hydrodynamics of granular biomaterials, XIV Roumanian Conference on Chemistry an Chemical Engineering, Bucuresti, Romania, **2005,** pp. 310-318.
7. Monica Mares, Fenomene de transfer de proprietate la uscarea biomaterialelor granulare prin procedee intensive, teza de doctorat, **2008.**