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Effect of Distributor Parameters on the Quality of Fluidization

(Ms.) Prasanti Swain, Prasant K. Nayak & G.K.Roy
Department of Chemical Engineering
Regional Engineering College
Rourkela 769008,INDIA

Abstract

The importance of bed fluctuation in the context of uniform gas-solid fluidization has been highlighted. Correlations for the prediction of fluctuation ratio and bed pressure drop have been developed and (heir applications critically discussed.

Introduction

The flow of gas in a gas-solid fluidized bed is characterised by the predominance of bubbles which lead to considerable bed fluctuation at fluid velocity higher than that at the minimum fluidization. Consequently, an instability in the operation results which affects the fluidization quality adversely.

Fluctuation Ratio and Fluidization Quality

Of the two methods, namely the uniformity index and fluctuation ratio, r the latter has been widely used to assess the fluidization quality. It is defined as the ratio of the highest and the lowest levels which the top of a fluidized bed occupies for any particular gas flow rate above the minimum fluidization velocity. Thus, Leva(1) suggested

$$r = e^{m} (G_f - G_{mf})/G_{mf} \quad (1)$$

The slope 'm' was related to particle diameter.

Beyond certain limiting value of $(G_f-G_{mf})/G_{mf}$ the top oscillations may be caused by slugging. Since slugging is affected by the 'aspect ratio', the fluctuation ratio should be dependent on it as well.

Bed fluctuation and fluidization quality being inter-related, previous investigations on the quality were aimed at the development of correlations for fluctuation ratio in terms of static and dynamic parameters. In this context, it is noteworthy to mention the work reported for cylindrical (Agarwal et. al."), baffled-cylindrical [Krishnamurty et al.,[3] Agarwal et. al, [2]]and conical beds [Agarwal et al.[2] , Biswal et al[4]. and Singh et al.] using spherical as well as non-spherical particles of monosize and mixed sizes of materials [Biswal et al. [4] and Singh et al.]. Dimensionless groups like d_p/D_t (dpm in case of mixtures), h_s/D_t (aspect ratio).ρ_s/ρ_f (ρ_{sm} in case of mixtures), velocity (G_f/G_{mf}) or excess velocity $(G_f-G_{mf})/G_{mf}$ ratio and the tangent of the cone angle (in case of conical bed) have been used in the aforesaid correlations. Two broad conclusions have been made:

1. A substantial decrease in the fluctuation ratio (and hence an increase in the fluidization quality) was observed in baffled-cylindrical and conical beds as compared to a columnar one.
2. Less bed fluctuation was marked in case of homogeneous and heterogeneous mixtures, as compared to the monosize material under similar experimental conditions.

A review of the earlier work shows that notwithstanding a lot of publications in the field, proper emphasis has not been put on the effect of distributor like the percent open area and the distribution of the open area (central or annular zones). More open area in the central zone promotes 'spouting' and a relatively large open area in the peripherial (annular) zone of the distributor induces 'gulf stream circulation' in the bed. By the use of improved distributors with requisite orifice area and their appropriate distribution in the two zones, the gas flow pattern can considerably be improved with consequent dampening in the bed fluctuation, thereby resulting in the" quality enhancement of bed performance (6,7). The present work highlights this aspect and discusses the findings therefrom.

Experimental

Set-up : A schematic diagram of the set-up is presented in Fig. 1. It is a conventional unit having air

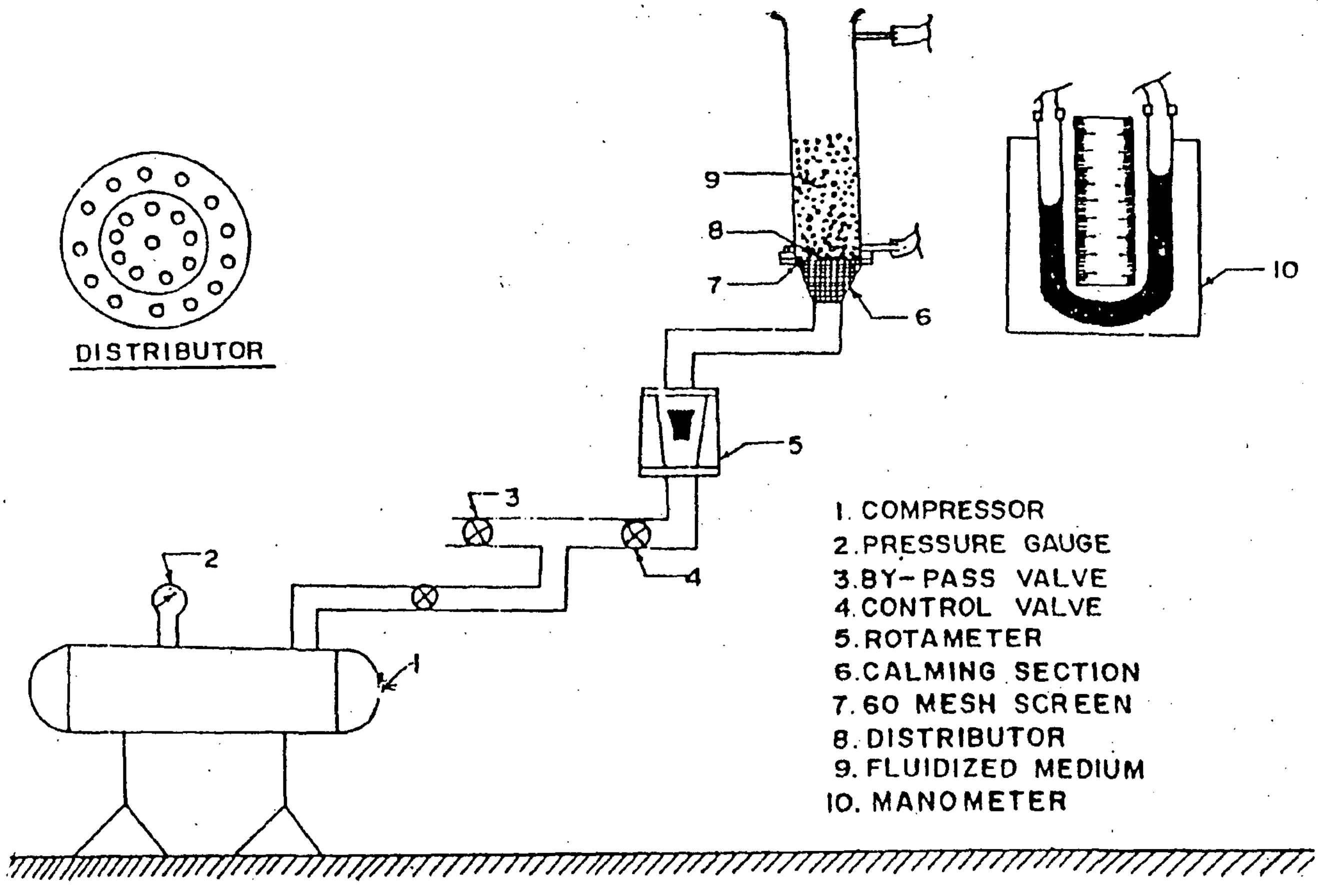

Figure 1. Schematic Diagram of the Experimental Set-Up

compressor, rotameter, fluidizer (10.5 cm i.d. and 100 cm long) alongwith the distributor and a manometer.

The distributor is made of 1 mm thick G.I.Plate, being divided equally into annular and central zones and having requisite number of 3 mm diameter holes drilled in each zone. Distributors with percent open area of 2.28%, 4%, 5% and 6.36% of the column cross section have been used. Open area distribution of 1:1 for the annular and the central zones have been used (for each of the above cases). In addition, distributors with area distribution in the ratios of 1:1.5, 1:2.8 and 2.8:1 for a total opening area of 4% of the column cross-section have also been employed.

Procedure:

A weighed amount of solid was taken, in the fluidizer. The air flow rate was then increased gradually through the bed. The rate of flow of air and the corresponding total bed pressure drop (inclusive of distributor drop) were noted. After the onset of fluidization, the maximum and minimum heights of the expanded bed were also recorded.

The above procedure was repeated for different experimental conditions like the initial static bed height, particle size, bed material and distributor types. (Table 1).

Table 1 : Experimental Conditions & Scope of Experiment (Physical properties of solids and system parameters)

Particle density (ρ_s/ρ_{sm}) Kg.m^{-3}	Particle size (d_p/d_{pm}) m x 10^3	Opening area (% of column area)	Area distribution ($A_A : A_I$)	Initial static bed height (h_s) m
1124	3.35	2.28	0.357	0.06
1938	4.28	4.00	0.667	0.08
2285	6.05	5.00	1.000	0.10
2740	7.80	6.36	2.800	0.12
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Development of Correlations

Fluctuation ratio:

A dimensional analysis of the parameters investigated shows that the fluctuation ratio can be related to the static and dynamic properties of the fluidized bed as under (Figure 2):

$$r = f_1\left(G_f/G_{mf},\ H_s/D_t,\ d_p/D_t,\ A_o/A_T,\ A_A/A_I,\ \rho_s/\rho_f\right) \quad (2)$$

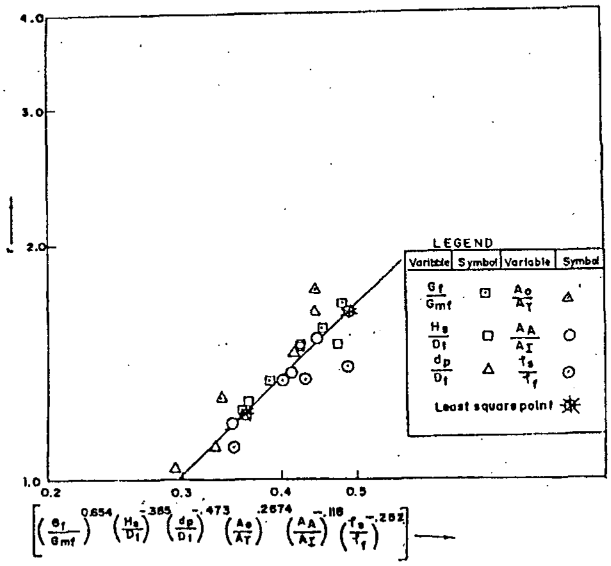

Figure 2. Effect of System Variables on Bed Fluctuation Ratio

Considering the exhaustive experimental data, a correlation has been ontained, namely (Figure 3)

$$r=3.136\,(G_f/G_{mf})^{0.60}\,(H_S/D_t)^{-0.35}\,(d_p/D_t)^{-0.43}\times$$

$$(A_o/A_T)^{0.24}\,(A_A/A_I)^{-0.11}\,(\rho_s/\rho_f)^{-0.23} \quad (3)$$

Bed pressure drop:

The ratio of bed pressure drop to that of the grid (distributor)has been correlated in an identical manner. Then,

$$\frac{\Delta p_b}{\Delta p_d}=2.604\times10^3\,(G_t/G_{mf})^{-0.68}\,(H_S/D_t)^{1.34}\,(d_p/D_t)^{0.75}\times$$

$$(A_o/A_m)^{1.85}\,(A_A/A_I)^{-0.54}\,(\rho_s/\rho_f)^{0.30} \quad (4)$$

Both the correlation give satisfactory agreement with the experimental data.

It has been observed that the fluctuation ratio, for the same air mass velocity, decreases (i.e. quality of fluidization improves) with an increase in the bed height) by keeping all distributor parameters unchanged. Similarly, an increase in the particle size, ratio of free area in the annular to central zone and solid density, lead to better quality of fluidization. An increase in the free flow area for air through the distributor causes more and more non-uniformily in fluidization.

Limitations : The method employed is considered by many as outdated. In recent years, more sophisticated techniques for finding the qualities of fluidization have been developed.

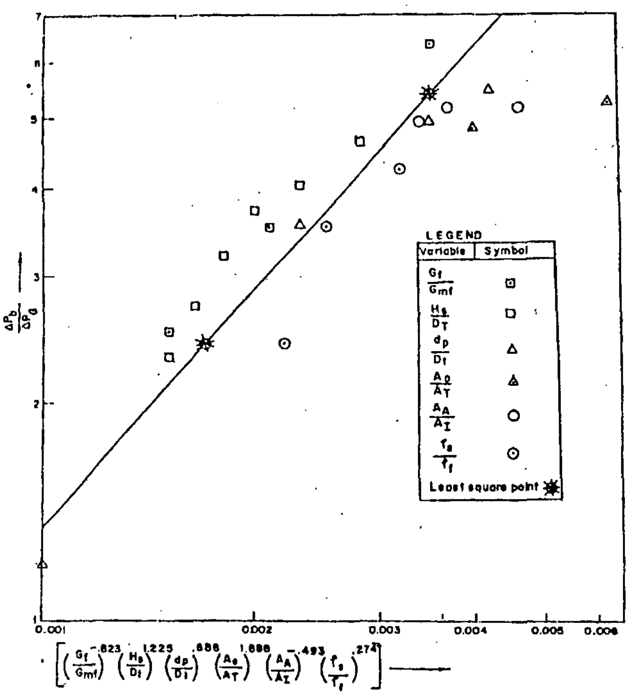

Figure 3. Effect of System Variables on Bed to Distributer Pressure Drop Ratio

Nomenclature

A_A = Annulus opening area of distributor, m^2

A_I = Inside (central) opening area of distributor, m^2

A_o = Total opening area of distributor, m^2

A_T = Inside cross-sectional area of fluidizer, m^2

d_p = Average particle diameter, m

d_{pm} = Average particle diameter of mixture, m

D_t = Inner diameter of fluidizer, m

f_1, f_2 = functions

G_f = Fluid mass velocity for fluidization, $kg/hr.m^2$

G_{mf} = Minimum fluid mass velocity for fluidization, $kg/hr.m^2$

H_S = Initial static bed height, m

Δp_b = Bed pressure drop, N/m^2

Δp_d = Distributor pressure drop, N/m^2

r = Fluctuation ratio, dimensionless

ρ_f = Density of fluid, kg/m^3

ρ_s = Density of solid, kg/m^3

ρ_{sm} = Average density of solid in mixture kg/m^3

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