

Short communication

Influence of coaxial-rod- and coaxial-blade-type baffles on bed expansion in gas–solid fluidization

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Abstract

Bed expansion data were obtained for unbaffled and two different types of baffled (coaxial rod and coaxial blade) gas–solid fluidized beds for varying operating parameters: fluid mass velocity, particle size, density and initial static bed heights. Correlations have been developed for the prediction of bed expansion. For this, the values of minimum fluidization mass velocity (G_{mf}) and settling mass velocity (G_s , considered as hindered settling) have been calculated with the help of available equations. The correlations developed are modified versions of those of Beranek and Sokol, where mass velocity ratio (G_R) has been used in place of velocity (U):

$$1/R = f(G_R), \text{ where } G_R = (G_f - G_{mf}) / (G_s - G_{mf})$$

Here, the entire range of G_R has been divided into two regimes: $0 < G_R \leq 0.15$ and $0.15 < G_R \leq 1.0$. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

The expansion of a gas–solid fluidized bed depends on the excess fluid velocity over the minimum. This can be conveniently expressed as a ratio, the denominator of which is the difference between the maximum (i.e. terminal, u_t) and the minimum fluidizing (u_{mf}) velocities. These two quantities are dependent on the system parameters and can be predicted from available correlations. The ratio of the above two velocities, defined as the velocity ratio (U) by Beranek and Sokol [1] has been correlated to the reciprocal of the bed expansion, $1/R$ by Ramesh and Ganguly [2]. Based on experimental investigations, correlations have been proposed by Krishnamurthy et al. [3], Agarwal and Roy [4], and Kar [5] for the prediction of height fluctuation ratio (i.e. the ratio between the maximum and minimum bed heights) in gas–solid fluidized beds using coaxial rod and blade types of baffles. With the experimental data of Kar (loc. lit.), an attempt has been made in this communication to correlate the bed expansion data according to the example

of Beranek and Sokol with the use of mass velocity ratio (G_R) in place of velocity ratio (U) for unbaffled and baffled (with two different types of internals) gas–solid fluidized beds. For a uniform suspension, the settling velocity (u_s) and thereafter settling mass velocity (G_s) can be estimated from the terminal velocity (u_t) for an isolated particle using the equation of Richardson and Zaki [6], which is given as,

$$u_s = u_t(\varepsilon)^n$$

The values of the exponent n changes from about 4.6 in the Stokes' law range to about 2.5 in the Newton's law range. The theoretical values of u_{mf} (and hence G_{mf}) have been calculated using the formula suggested by Wen and Yu [7].

2. Experimental

The fluidizer is a transparent perspex column of 5 cm i.d. and 100 cm length provided with a calming section for uniform distribution of the fluidizing medium, which is supplied from an air compressor. Two different types of coaxial baffles—one of rod type and the other of blade type (refer to Fig. 1) have been used. These are held in position

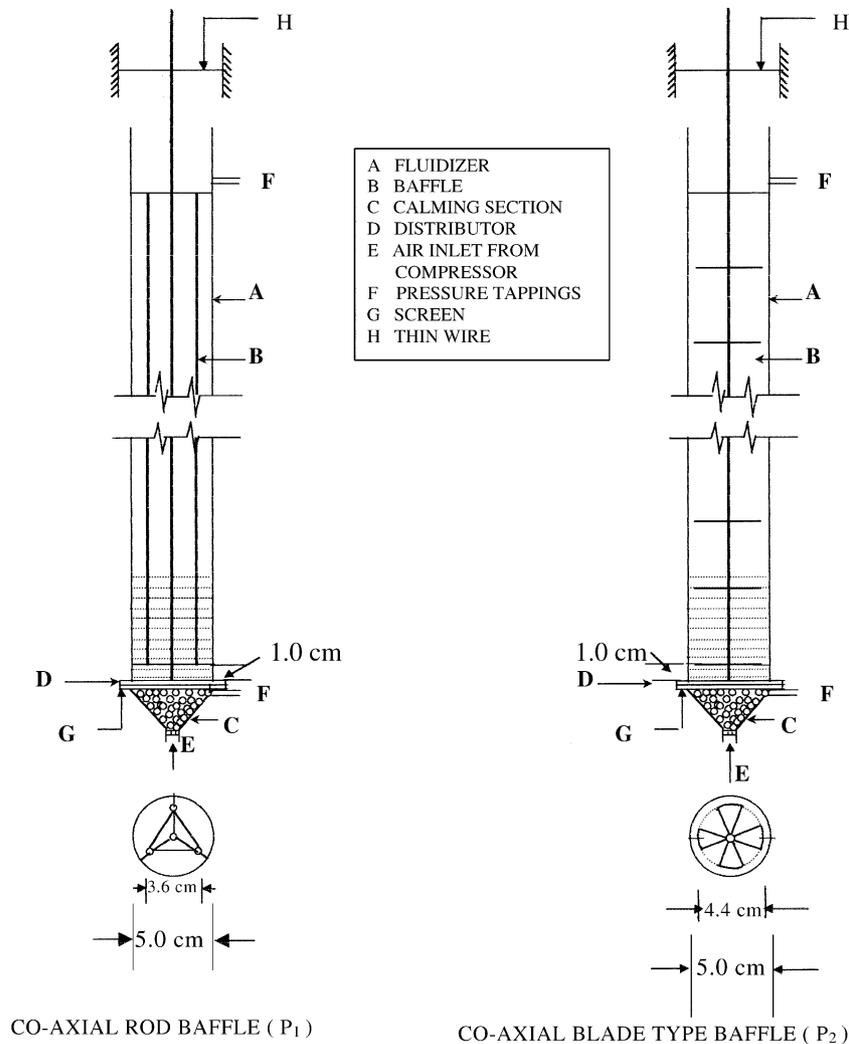


Fig. 1. Details and positioning of baffles.

in the bed with the help of two thin wires. Experimental observations consist of recording the expansion and height fluctuation of the bed for velocities above the minimum

Table 1
Scope of the experiments

A. Materials used			
Bed materials	Particle size, D_p ($\times 10^2$ m)	Particle density, ρ_s (kg/m^3)	Initial static bed heights, H_s ($\times 10^2$ m)
Coal + dolomite	0.0925	1950	6
Sand	0.0780	2610	9
Dolomite	0.0605	2760	12
Manganese	0.0428	4836	15

B. Baffles used	
(1) Rod-type baffle (P_1)	Diameter of the rod = 0.6 cm
(2) Blade-type baffle (P_2)	Number of blades/disc = 4
	Disc spacing = 5 cm
	Disc diameter = 4.4 cm

fluidizing value, for a given static bed height, both for an unbaffled bed and a bed with baffles. The above observations are repeated with change in variables: the particle size and density and the initial static bed height. The scope of the experiments is given in Table 1.

3. Results and discussion

The calculated values of the mass velocity ratio (G_R) have been plotted against experimental values of the reciprocal of bed expansion ratio ($1/R$) for unbaffled and baffled beds in Fig. 2. From this plot, the entire range of G_R has been divided into two regimes, viz. $0 < G_R \leq 0.15$ and $0.15 < G_R \leq 1.0$. The correlations developed by the method of least squares are:

In the range $0 < G_R \leq 0.15$:

For beds with and without baffles,

$$1/R = 0.433(G_R)^{-0.28} \quad (1)$$

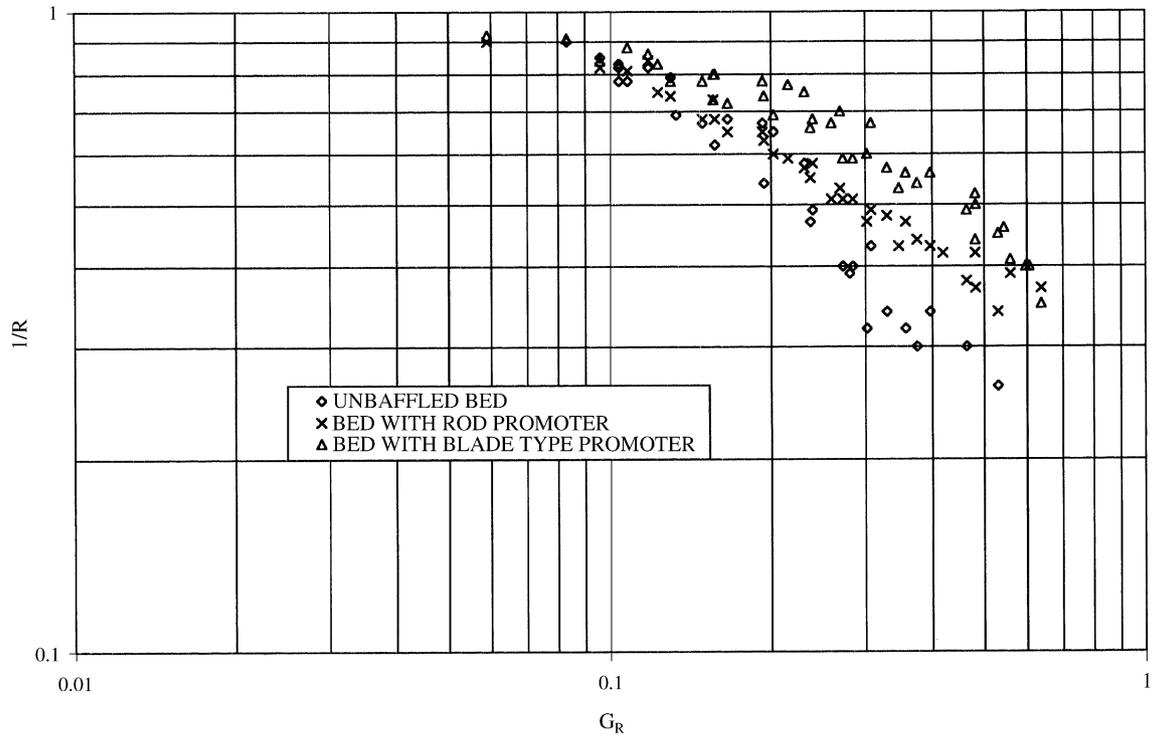


Fig. 2. Variation of $1/R$ with G_R .

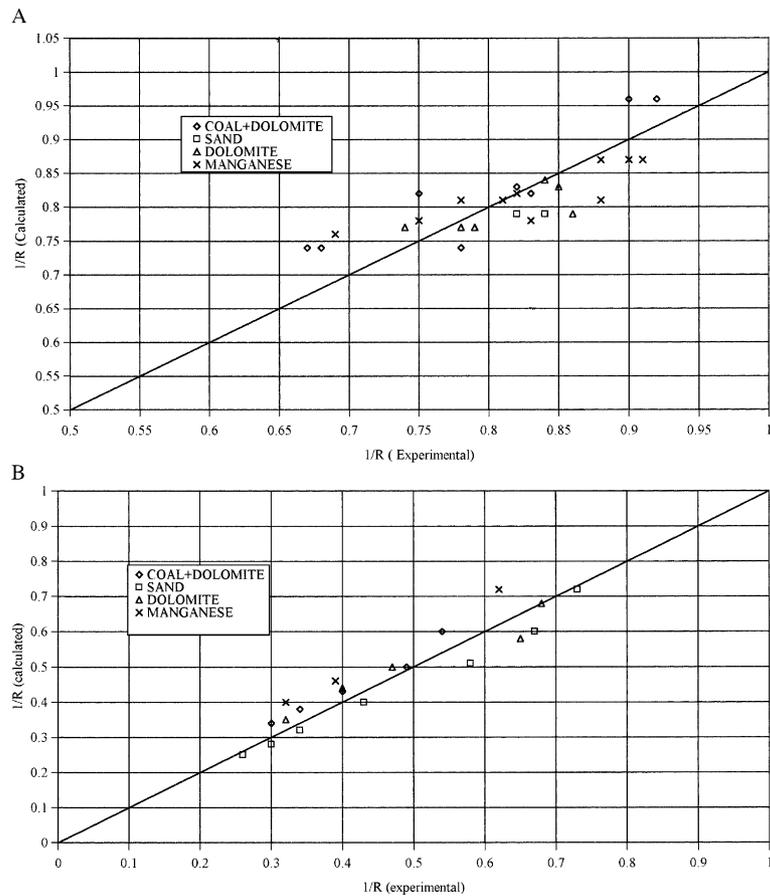


Fig. 3. (A) Comparison of calculated and experimental values of $1/R$ in un baffled and baffled beds (range: $0 < G_R \leq 0.15$). (B) Comparison of calculated and experimental values of $1/R$ in un baffled bed (range: $0.15 < G_R \leq 1.0$). (C) Comparison of calculated and experimental values of $1/R$ in bed with rod-type baffle (P_1) (range: $0.1 < G_R \leq 1.0$). (D) Comparison of calculated and experimental values of $1/R$ in bed with blade-type baffle (P_2) (range: $0.15 < G_R \leq 1.0$).

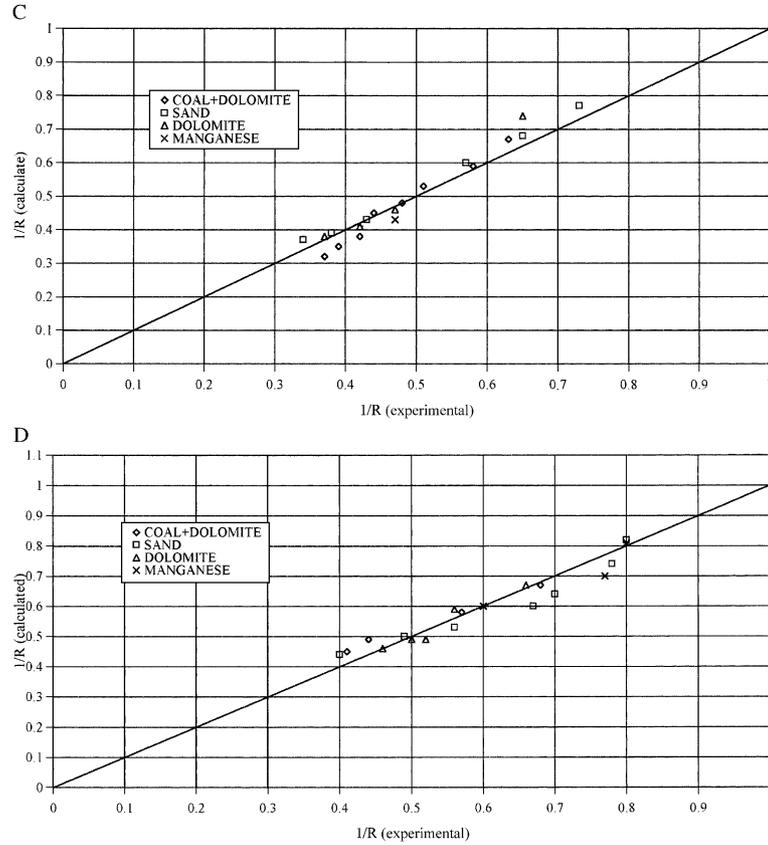


Fig. 3 (continued).

In the range $0.15 < G_R \leq 1.0$:

$$\text{For unbaffled bed,} \\ 1/R = 0.141(G_R)^{-0.88} \quad (2)$$

$$\text{For bed with coaxial-rod-type baffle,} \\ 1/R = 0.239(G_R)^{-0.63} \quad (3)$$

$$\text{For bed with coaxial-blade-type baffle,} \\ 1/R = 0.348(G_R)^{-0.46} \quad (4)$$

The experimental values of $1/R$ have been compared with the calculated values obtained with the help of the above correlations in Fig. 3A–D and have been found to agree fairly well. For unbaffled beds, the mean and standard deviations are 4.34 and 5.50, respectively, for the first regime and 9.43 and 10.46, respectively, for the second regime.

In case of baffled beds, the mean and standard deviation are, respectively, 5.34 and 6.55 for the bed with baffle P_1 and 4.67 and 6.07 for the bed with baffle P_2 with respect to the second regime.

4. Conclusion

It has been found that the effect of baffle is small in the range, $0 < G_R = 0.15$ whereas there is a marked increase in

$1/R$ (i.e. decrease in bed expansion) in the range, $0.15 < G_R = 1.0$. The percentage reduction in bed expansion for baffled beds compared to unbaffled ones ranges from 10 to 40 for beds with baffle P_1 and 20 to 60 for bed with baffle P_2 , respectively, in the range of the experiment.

Thus, the use of coaxial rod and coaxial blade types of baffles is quite effective in damping the bed fluctuation and thereby reduce the expanded bed heights when compared with an unbaffled gas–solid fluidized bed with identical operating parameters, which would be of practical relevance in the design of gas–solid fluidized bed systems. The dampening effect of the coaxial-blade-type baffle has been found to be more significant as compared to the coaxial-rod-type baffle.

List of symbols

D_p	particle size (m)
G_f	mass velocity of fluid ($\text{kg/m}^2 \text{ h}$)
G_{mf}	mass velocity at minimum fluidization ($\text{kg/m}^2 \text{ h}$)
G_R	mass velocity ratio $[(G_f - G_{mf}) / (G_S - G_{mf})]$
G_S	terminal settling mass velocity, for hindered settling ($\text{kg/m}^2 \text{ h}$)
H_e	expanded bed height (m)
H_s	initial static bed height (m)
P_1	coaxial-rod-type baffle

P_2	coaxial-blade-type baffle
R	bed expansion ratio (H_e/H_s)
U	velocity ratio $[(u_f - u_{mf})/(u_t - u_{mf})]$
u_f	superficial fluid velocity (m/s)
u_{mf}	minimum fluidization velocity (m/s)
UP	unbaffled bed
u_s	terminal settling velocity, hindered settling (m/s)
u_t	terminal settling velocity (m/s)
ε	expanded bed voidage
ρ_s	density of solid (kg/m^3)

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