Effect of Co-Axial Rod Promoters on the Dynamics of a Batch Gas-Solid Fluidized Bed

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Gas-solid fluidization often suffers from inherent drawbacks like channeling, bubbling and slugging which affect the quality of fluidization. Efforts have been made in this paper to improve the quality of fluidization in gas-solid fluidized beds by using two different types of co-axial rod promoters. The effects of fluid and solid properties, bed characteristics and the promoters on fluidization quality (in terms of fluctuation ratio) and bed pressure drop (in terms of Euler Number) have been presented in the form of correlations. The predicted and experimental values of fluctuation ratio and Euler number have been found to agree fairly well.

GAS-SOLID fluidized beds suffer from certain inherent drawbacks like channeling, bubbling and slugging which result in poor homogeneity of the bed, thereby affecting the quality of fluidization. Investigations have been made to study the effect of turbulence promoters of different shapes, size and configuration on the quality of fluidization and bed pressure drop. Different types of bed internals such as diplegs, nozzles, immersed objects, slotted baffles, tubes, horizontal and vertical baffles are used for improving the quality of fluidization.

Overcashier *et* al[1], Glass and Harrison[2] and Rowe & Everett[3] studied the effect of horizontal baffles on the quality of fluidization. Volk *et al*[4] suggested that vertical tubular surfaces should be inserted in large diameter beds in order to prevent the development of very large bubbles. Krishnamurthy *et al*[5] proposed the following correlation for the prediction of fluctuation ratio for gas-fluidized beds using horizontal baffles.

$$r = 0.59(Gf / Gmf)^{1.01} (D_p / D_c)^{-0.12} (Dc / Hs)^{-0.20} (\rho_s / \rho_f)^{-0.02} \quad (1)$$

Agarwal *et al*[6] studied the effect of stirrer type baffles on fluidization quality and proposed a correlation for the prediction of fluctuation ratio :

$$r = 2.49(Gf / Gmf)^{1.75} (Dp / Dc)^{-0.07} (Dc / Hs)^{-0.29} (\rho_s / \rho_f)^{-0.25} \quad (2)$$

Singh[7] studied the effect of various system parameters on fluctuation ratio in case of unpromoted non-colummar beds, viz square, hexagonal and semicylindrical ones and proposed the following correlations.

For semicylindrical bed :

$$r = 2.3 (Dp / Dc)^{0.08} [(Dc / Hs) \times (\rho_f / \rho_s)]^{0.04} [(Gf - Gmf) / Gmf]^{0.07} \quad (3)$$

For hexagonal bed :

$$r = 2.3 (Dp / Dc)^{0.06} [(Dc / Hs) \times (\rho_f / \rho_s)]^{0.05} [(Gf - Gmf) / Gmf]^{0.06} \quad (4)$$

For square bed :

$$r = 2.55 (Dp / Dc)^{0.09} [(Dc / Hs) \times (\rho_f / \rho_s)]^{0.04} [(Gf - Gmf) / Gmf]^{0.08} \quad (5)$$

Other studies relating to bed dynamics in promoted gas-solid fluidized beds include disc promoter by Ravi *et al*[8], twisted strips and wire coils by Colburn and King[9], co-axially placed cones by Sarveswara Rao *et al*[10,11], ring promoter assembly by Ramabramham *et* al[12,13], string of spheres by Sitaraman[14], mesh and brush insert by Magerlin *et al*[15], Sujatha[16], Prasad[17] and Koteswara Rao *et al*[18]. In the present communication, an attempt has been made to report the bed dynamics of gas-solid fluidized beds using two different types of rod promoters in terms of correlations developed for fluctuation ratio (for fluidization quality) and Euler number (for bed pressure drop).

Experimental

The experimental setup used has been detailed elsewhere[19]. For a particular run, bed pressure drop (for fixed and fluidized bed conditions) and bed expansion and fluctuation (for fluidized condition) have been noted with varying fluid flow rate. The procedure has been repeated for different bed material of varying particle size and static bed height and also for two types of promoters, viz. the rod type and the disc type. The scope *of* the experiment is given in table-1.

Table 1 : Scope of Experiments

A. Materials used

Bed Materials	Particle density ρ_s, Kg/m³	Initial bed height Hs×10²m	Particle size Dp×10²m
Coal (M1)	1430	6.0	0.0925
Coal+Dolomite (M2)	1950	9.0	0.0780
Sand (M3)	2610	12.0	0.0605
Dolomite (M4)	2760	15.0	0.0428
Manganese (M5)	4836		

B. Promoters used

1. Rod type promoter (P1)
   Diameter of the rods = 0.6
2. Blade type promoter (P2)
   No. of blades/disc = 4
   Disc spacing = 5 cm
   Disc diameter = 4.4cm

Development of Correlations for Bed-dynamics

(i) Correlation for pressure drop :

Using dimensional analysis approach pressure drop for batch gas-fluidized beds with and without turbulence, promoters has been correlated in the form of Euler number with various non-dimensional system parameters representing bed and material properties. These parameters are expressed with the Euler number (EU) as:

$$EU = f(Hs/Dc, He/Dc, Dp/Dc, \rho_s/\rho_f) \quad (6)$$

or. $$EU = c_1 (Hs/Dc)^a (He/Dc)^b (Dp/Dc)^c (\rho_s/\rho_f)^d \quad (7)$$

Analysing the experimental data for the effect of individual parameter, following correlations have been obtained with the help of least square fit :

For unpromoted bed :

$$\Delta P/\rho_f U^2 = 0.0124 (Hs/Dc)^{2.8} (He/Dc)^{-1.51} (Dp/Dc)^{-1.45} (\rho_s/\rho_f)^{0.66} \quad (8)$$

For bed with co-axial rod type promoter :

$$\Delta P/\rho_f U^2 = 0.003 (Hs/Dc)^{2.19} (He/Dc)^{-2.15} (Dp/Dc)^{-1.3} (\rho_s/\rho_f)^{1.02} \quad (9)$$

For bed with co-axial disc type promoter :

$$\Delta P/\rho_f U^2 = 1.842 (Hs/Dc)^{1.86} (He/Dc)^{-0.93} (Dp/Dc)^{-0.57} (\rho_s/\rho_f)^{0.34} \quad (10)$$

(ii) Correlation for fluctuation ratio :

Fluctuation ratio used as a criterion for the measurement of fluidization quality has been related to different static and dynamic parameters of the system, viz. aspect ratio excess velocity ratio, wall effect and. density ratio. Following the aforesaid method, the correlations obtained are as follows :

For unpromoted bed :

$$r = 0.003 (Hs/Dc)^{0.11} (Dp/Dc)^{-0.05} (\rho_s/\rho_f)^{1.08} [(Gf - Gmf)/Gmf]^{0.35} \quad (11)$$

For bed with co-axial rod type promoter :

$$r = 0.004 (Hs/Dc)^{0.15} (Dp/Dc)^{-0.29} (\rho_s/\rho_f)^{0.29} [(Gf - Gmf)/Gmf]^{0.30} \quad (12)$$

For bed with co-axial disc type promoter :

$$r = 0.87 (Hs/Dc)^{0.04} (Dp/Dc)^{-0.04} (\rho_s/\rho_f)^{0.02} [(Gf - Gmf)/Gmf]^{0.04} \quad (13)$$

Results and Discussion

The effects of fluid and solid properties, bed characteristics (i.e. wall effect, bed expansion and aspect ratio) and two different types of promoters on bed pressure drop (equations 8 to 10) and bed fluctuation (equations 11 to 13) have been obtained.

***Bed pressure drop*:**

The bed pressure drop has been found to increase with the increase in initial static bed height, particle size and density. The values of Euler number calculated from the proposed correlations (equations 8 to 10) agree fairly well with those obtained from experiments as is evident from figure 1 (a, b and c). The mean and standard deviations calculated for unpromoted bed and bed with co-axial rod and disc promoters have been 4.54 arid 8.07. 6.89 and 7.82 and 6.44 and 7.29 respectively. Further it is observed that in case of co-axial rod type promoter, there is an increasing trend in pressure drop when compared to an unpromoted bed. The increase in pressure drop indicates that some channels of the fluidized bed

" have been broken since the three rods of the rod type promoter are at three different positions of the bed. However, in case of co-axial disc type promoter, a decrease in pressure drop has been observed. In this case the effect of the promoter is restricted to the central region only. Hence channeling has been partly reduced in the centre but increased simultaneously in the annular region (w.r.t. the promoter) thus resulting in a decrease in pressure drop when compared to an unpromoted bed.

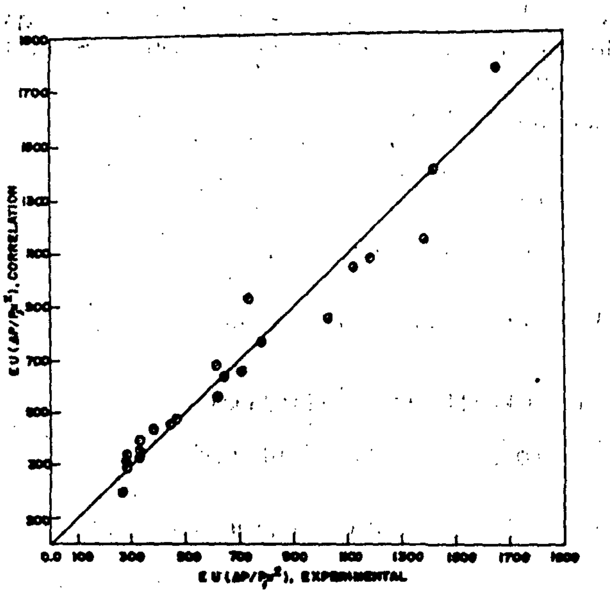


Fig. 1a : Comparison of Euler Number for an Unpromoted Bed

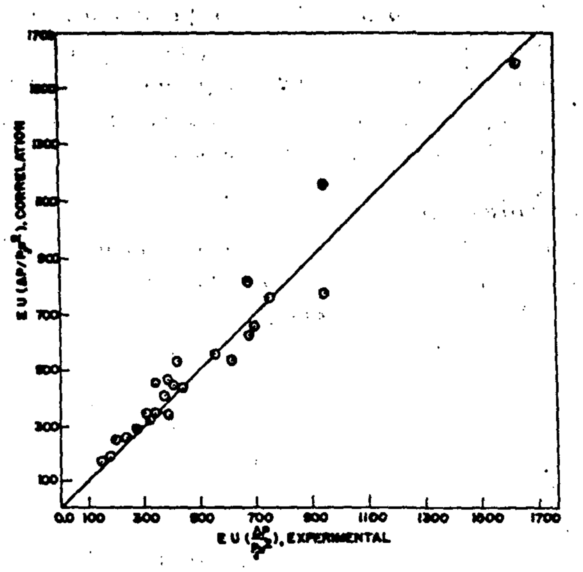


Fig. 1b : Comparison of Euler Number for a Bed with Rod Type promoter (P1)

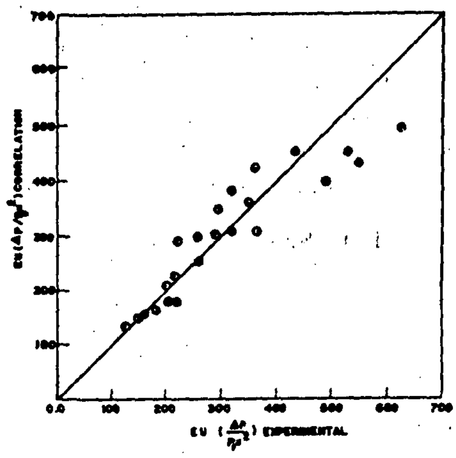


Fig. 1c : Comparison of Euler Number for a Bed with Disc Type Promoter (P2)

Bed fluctuation and fluidization quality :

It is observed that fluctuation ratio increases with initial static bed height and decreases with increase in particle size and density. The values of fluctuation ratio calculated from the developed correlations (equations .11 to 13). agree fairly well with those obtained from experiments , (figures 2.a, b and c). The mean and standard deviations calculated for the unprom6ted bed and bed with co-axial rod and disc promoters have been 3.00 and 3.48, 6.00 and 5.34 and 2.54 and 3.01 respectively.

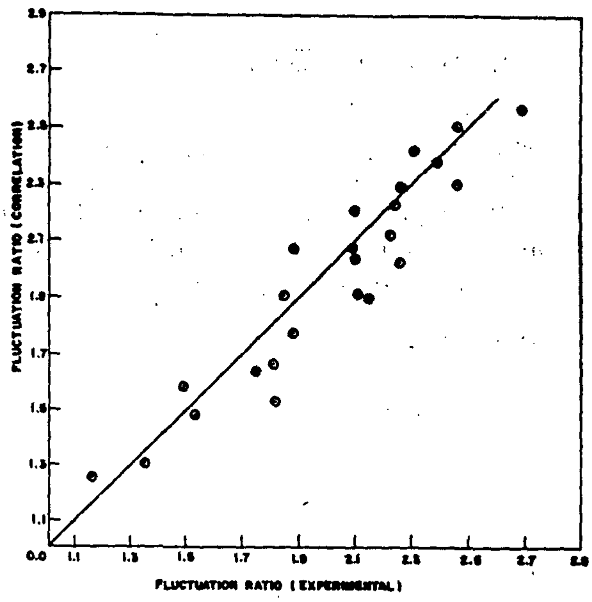
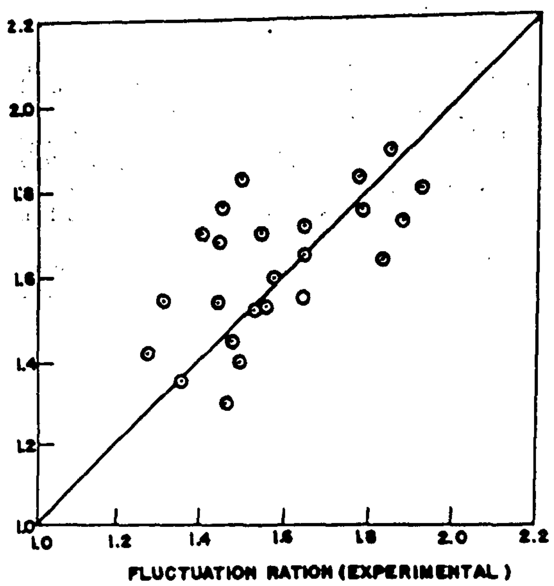
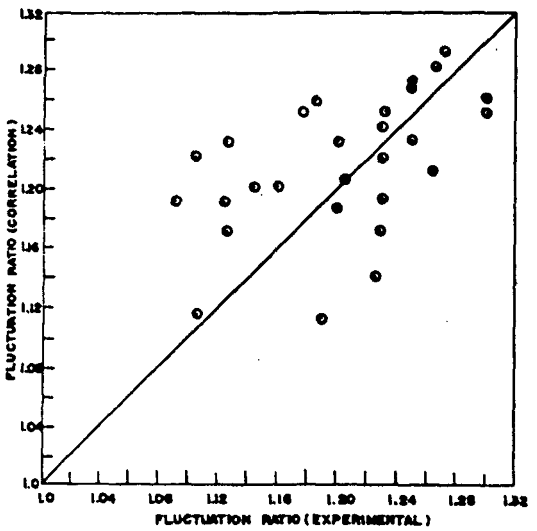


Fig. 2a : Comparison of Eluctuation Ratio for an Unpromoted Bed



b : Comparison of Fluctuation Ratio for a Bed with Rod Type Promoter (P1)



: Comparison of Fluctuation Ratio for a Bed with Disc Type Promoter (P2)

A few representative values of bed fluctuation ratio been presented in table-2 for beds with and without oters. As compared to bed with promoters, the ation ratio for an unpromoted bed was quite high ating a poor quality of fluidization. For identical m parameters, fluctuation ratio has been found to case for the rod type and disc type promoters with ium values for the latter one. This may be due to combined effects of the breaking up of channels and hindrance to the coalescence of bubbles in the central region of the bed where the discs of the" promoters are present.

Table 2 : Comparison of Fluctuation Ratio
(Fluid mass velocity = 508 kg/hr. m^2)

Sl No.	Material	Hs Cm.	Dp×10^2 m	ρ_s kg/m^3	Fluctuation ratio, r UP	Bed with P1	Bed with P2
1	M4	6.0	0.0780	2760	1.48	1.37	1.18
2	M4	9.0	0.0780	2760	1.68	1.50	1.22
3	M4	12.0	0.0780	2760	1.87	1.59	1.16
4	M4	15.0	0.0780	2760	1.95	1.63	1.12
5	M4	9.0	0.0925	2760	1.35	1.14	1.07
6	M4	9.0	0.0605	2760	1.78	1.53	1.19
7	M4	9.0	0.0428	2760	1.94	1.56	1.25
8	M1	9.0	0.0605	1420	2.00	1.36	1.18
9	M2	9.0	0.0605	1950	1.88	1.53	1.19
10	M3	9.0	0.0605	2610	1.81	1.51	1.03
11	M3	9.0	0.0605	4835	1.52	1.34	1.16

The developed correlations can be used effectively to predict the bed dynamics and fluidization quality for gas-solid systems in the ranges of variables investigated. In view of comparatively low bed pressure drop and fluctuation ratio for the disc type promoter, further work in this direction may be useful for a better understanding of the promoted gas-solid fluidized bed.

Nomenclature

Dp	=	Particle size, m
Dc	=	Diameter of the bed, m
EU	=	Euler number, $\Delta P/\rho_f U^2$, dimensionless
Gf	=	Mass velocity of fluid, Kg/hr. m^2
Gmf	=	Mass velocity at minimum fluidization condition, Kg/hr. m^2
He	=	Expanded bed height, m
Hs	=	Initial static bed height, m
P1	=	Co-axial rod type promoter
P2	=	Co-axial disc type promoter
ΔP	=	Bed pressure drop, N/m^2
r	=	Fluctuation ratio, dimensionless
U	=	Linear velocity of fluid, m/s
UP	=	Unpromoted bed
ρ_s	=	Density of solid, kg/m^3
ρ_f	=	Density of fluid, kg/m^3

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