Effect of Co-axial Rod-promoter on the Pressure Drop in a Batch Liquid-solid Fluidized Bed

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This paper deals with experimentation conducted to obtain pressure drop and bed expansion data in liquid-solid fluidized beds under varying conditions. The rate of flow, bed height, particle size and density have been altered and the resulting pressure drop and the bed expansion have been measured. The data have been correlated in terms of Euler number. Expressions relating the Euler number with system parameters have been obtained in case of beds with and without promoter. The predicted and experimental values of Euler number have been found to agree fairly well.
Keywords : Co-axial rod-promoter. Pressure drop, Fluidized bed.

NOTATION

c_1 and c_2	:	intercepts of regression lines, dimensionless
D_c	:	diameter of the conduit (fluidizer), m
D_p	:	particle diameter, m
Eu	:	Euler number, $\Delta p/\left(\rho_f v_f^2\right)$, dimensionless
H_e	:	expanded bed height, m
H_s	:	static bed height, m
n_1 and n_2	:	slopes of regression lines, dimensionless
Δp	:	pressure drop across the bed, Nm^{-2}
v_f	:	velocity of flow of water through fluidizer, ms^{-1}
ρ_f	:	density of fluid (water), kg/m^3
ρ_s	:	density of solids, kg/m^3

INTRODUCTION

The quality of fluidization can largely be improved by introducing a suitable turbulence promoter in a fluidizer. Investigations have been made to study the effect of turbulence promoters of different shapes, sizes, roughness and configuration on the quality of fluidization in gas-solid and liquid-solid fluidized beds. Different types of promoters used are the slotted baffles, tubes, horizontal and vertical baffles', vertical and stirrer type baffle[2], a number of disc mounted over a copper rod at equal spacing[3], twisted strips, baffles and wire coils[4], co-axially placed cones[5]-[6], ring promoter assembly[7,8], string of spheres[9], and mesh and brush inserts'". Effects of twisted tapes on friction factor in a fluidized bed was studied by Sujatha[11]. Effect of spiral coils and helical tape on friction factor in fluidized bed was studied by Prasad'[2] and Koteswara Rao, *et al*[13].

A co-axial triangular-shaped turbulence promoter with a central rod (Fig 1) has been used to impart circumferential as well as central influence in liquid-solid fluidized beds.

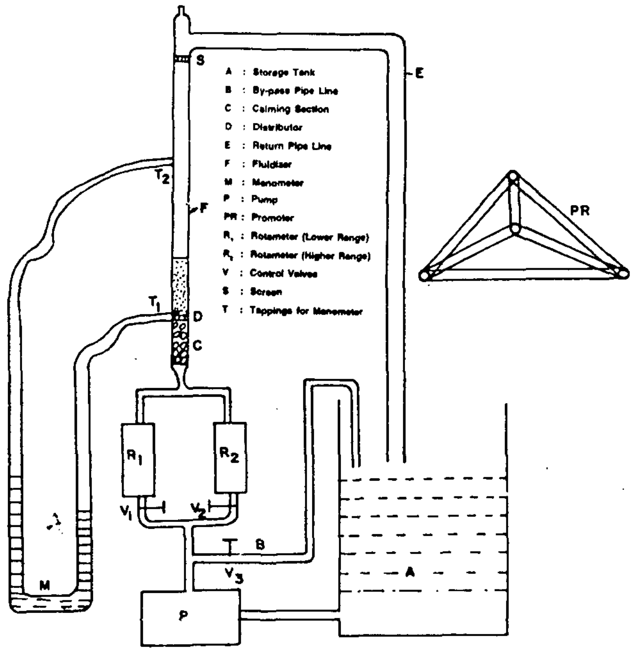

Fig 1 Experimental set-up

EXPERIMENTATION

The experimental set-up (Fig 1) used in the experiment consists of a storage tank of 1m^3 capacity, a 0.5hp/cenlrifugal pump, two rotameters of range 0-2 and 0-20 USGPM and a graduated perspex fluidizer (0.05 m inner dia), with a calming section and a multi-orifice distributor. A differential manometer records the pressure drop across the bed. The turbulence promoter consisted of four numbers of 6 mm diameter and 0.75m long steel rods, three of which are

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'placed on the vertices of an equilateral triangle and the fourth one is placed centrally as shown in the figure. The turbulence promoter was kept in position in the fluidizer with the central rod fixed rigidly on to the top. Control valves V_1, V_2, and V_3 are used to adjust a particular flowrate fluidizer. Rotameter of smaller range was used to measure flowrate of lower range while the other one was used for the higher range. For a particular run, variation of pressure drop was noted with the gradual increase of water flowrate. For fluidized bed condition, bed expansion data were also noted. Experimental runs were repeated with the varying initial static bed height, bed material and particle size. The scope of the experiments is given in Table 1.

Table 1 Scope of experiments

Bed Materials	Particle Size, $D_p \times 10^3$, m	Particle Density, ρ_s, kg/m³	Initial Bed Height, $H_s \times 10^2$, m
Dolomite	1.850	2720 }	8.0
Dolomite	1.350	2720 }	12.0 16.0
Dolomite	0.800	2720 }	20.0
Dolomite	0.550	2720	8.0
Coal	1.350	1430	8.0
Iron Ore	1.350	4254	8.0
Iron Chips	1.350	5790	8.0

DEVELOPMENT OF CORRELATIONS

Pressure drop for batch fluidized bed has been correlated in form of Euler number with various system parameters from a dimensional analysis approach. The following two correlations have been developed-one for a normal fluidized bed and the other for a bed with a turbulence promoter.

For a fluidized bed without promoter

$$Eu = c_1[(H_s/D_c)^{3.03}(H_e/D_c)^{-3.42}(\rho_s/\rho_f)^{-0.46}(D_p/D_c)^{-1.23}]^{n1}. \quad (1)$$

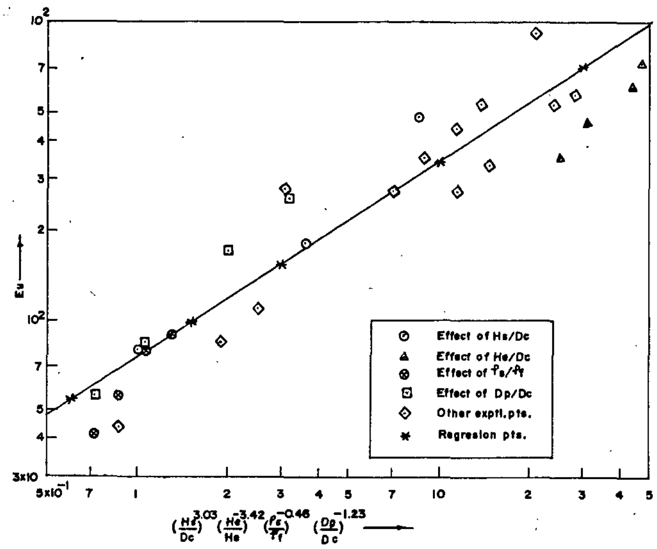

Fig 2 Variation of Eu with system variables (without promoter)

For a fluidized bed with promoter

$$Eu = c_2[(H_s/D_c)^{3.25}(H_e/D_c)^{-2.57}(\rho_s/\rho_f)^{-0.77}(D_p/D_c)^{-1.44}]^{n2}. \quad (2)$$

The values of c_1 and n_1 of equation (1) and c_2 and n_2 of equation (2) have been obtained from the regression analysis of the data shown in Figs 2 and 3 respectively. The final correlations arc :

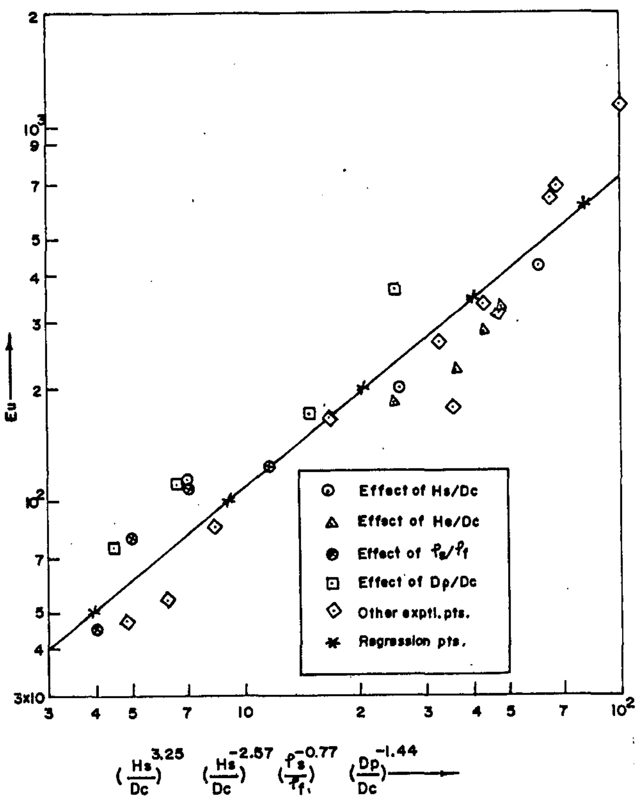

Fig 3 Variation of Eu with system variables (with promoter)

for a batch liquid fluidized bed without promoter

$$Eu = 74(H_s/D_c)^{1.98}(H_e/D_c)^{-2.23}(\rho_s/\rho_f)^{-0.3}(D_p/D_c)^{-0.8}. \quad (3)$$

for a batch liquid fluidized bed with promoter

$$Eu = 15(H_s/D_c)^{2.79}(H_e/D_c)^{-2.2}(\rho_s/\rho_f)^{-0.66}(D_p/D_c)^{-1.23} \quad (4)$$

RESULTS AND DISCUSSION

Calculated values of Euler number obtained with the help of equations (3) and (4) have been compared with their respective experimental values as given in Tables 2 and 3 for beds without and with promoter respectively. Fairly good agreement has been found between the experimental and the calculated values of Euler number [Figs 4 and 5].

The mean and standard deviations were 12.65% and 14.42% respectively in the case of a bed without promoter. For a bed with turbulence promoter mean and standard deviations were 17.09% and 17.900% respectively.

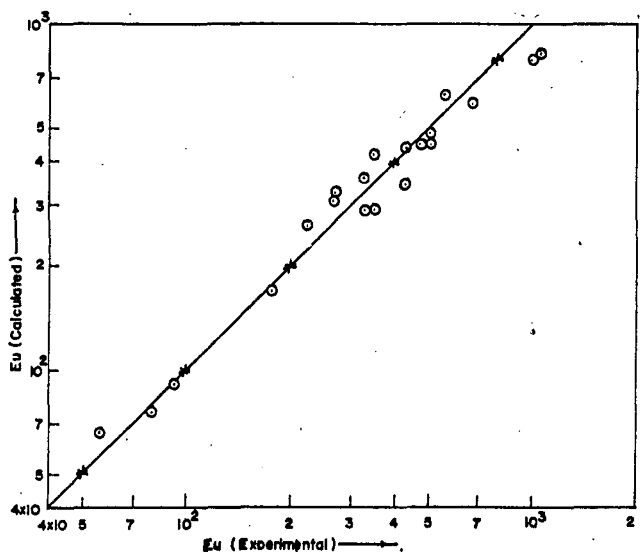

Fig 4 Comparison of Euler number (without promoter)

Table 2 Comparison of Euler number (bed without promoter)

Euler Number		% Deviation
Calculated	Experimental	
442	346	21.97
330	267	23.53
448	514	−12.80
284	323	−12.07
810	1023	−20.82
451	474	−4.85
265	273	−2.93
76	80	−5.00
169	178	−5.06
473	514	−8.00
358	332	7.83
311	268	16.04
293	350	−16.29
337	432	−22.00
91	92	−1.09
66	56	17.86
800	1041	−23.12
593	694	−14.55
443	427	3.75
646	569	−13.53

CONCLUSION

It is apparent that Euler number is significantly influenced by the initial static bed height, particle size, material density as well as with the presence of promoter. Further, improvement of the correlations can be achieved by considering other variables such as fluid viscosity and promoter parameters like shape, size and configuration.

Table 3 Comparison of Euler number values (bed with promoter)

Euler Number		% Deviation
Calculated	Experimental	
305	253	20.55
427	367	16.35
473	511	−7.44
483	387	24.81
532	655	−18.78
571	668	−14.52
297	266	11.88
589	487	20.91
386	454	−14.98
1013	1289	−21.41
588	482	22.00
440	372	18.28
647	771	−16.08
975	1292	−24.54
581	771	−18.97
1355	1739	−22.06
1075	996	7.93
298	392	−23.98
265	243	9.05
141	152	−7.35

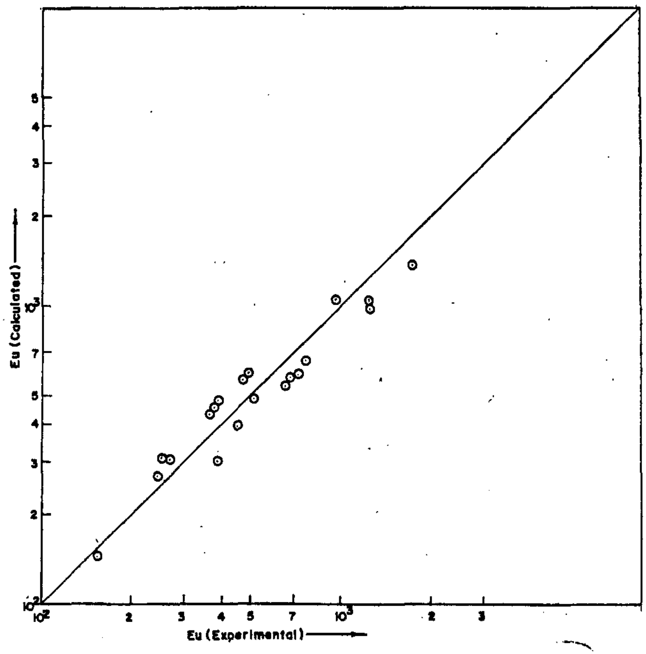

Fig 5 Comparison of Euler number (with promoter)

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