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Prediction of Fluctuation Ratio for Binary Mixtures of Non-Spherical Particles in Conical Beds

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Based on experimental investigations a correlation has been developed for the prediction of fluctuation ratio for conical gas-solid fluidized beds of mixed particles. Values computed from the developed correlation compare well with the experimental ones.

THE advantages of a conical fluidized bed have been detailed in the literature.[1,2] Significant amongst these is the adaptability of the bed to mixed-size fluidization which is of relevance to the gas-solid catalysed reactions of chemical process industries.

Static and dynamic characteristics of conical conduits differ significantly from the cylindrical ones. It is imperative to be well-acquainted with the system' characteristics prior to its application in actual processes. Although some information for gas-solid fluidization of mono-size particles is available[2-8] very little work relating to mixed particle systems in a conical bed has been reported.[9] The present experiemental investigation has been undertaken for the prediction of the fluctuation ratio in conical fluidized beds of mixed particle systems.

Fluctuation Ratio

It is the ratio of the highest to the lowest levels which the lop of the fluidized bed occupies for any gas flow rate and is a quantification of the so-called fluidization quality. A lower value of fluctuation ratio is indicative of improved fluidization quality with less fluctuation at the top of the bed in fluidized condition. *Biswal, et al.*[3,7,8] have presented empirical equations for the prediction of the fluctuation ratio in conical fluidized beds of mono-sized regular and irregular particles. Equations for the fluctuation ratio have been developed by Agarwal[6] for cylindrical, baffled-cylindrical and conical beds of regular particles with a view to project a comparative picture of their fluidization quality.

Mixed Particle Fluidization in Conical Beds

The only work in mixed particle fluidization in conical beds is that of Biswal, *et al.*[9] It presents the following correlations for bed fluctuation in the case of homogeneous and heterogeneous binary mixtures of spherical particles.
For homogeneous mixtures;

$$r = 9.8 \times 10^2 \left(\frac{G_f}{G_{mf}}\right)^{1.06} \left(\frac{D_o}{d_{pm}}\right)^{-1.97} \left(\frac{h_s}{D_o}\right)^{-0.25} (\tan\alpha)^{-0.25} \quad ....(1)$$

For heterogeneous mixtures ;

$$r = 0.44 \left(\frac{G_f}{G_{mf}}\right)^{0.58} \left(\frac{d_p}{D_o}\right)^{-0.06} \left(\frac{\rho_{sm}}{\rho_f}\right)^{-0.10} (\tan\alpha)^{-0.17} \quad ....(2)$$

In this communication a relation has been proposed for bed fluctuation in conical fluidized beds of both heterogeneous and homogeneous binaries involving irregular particles.

Experiemental

The experimental set-up used in the present study has been detailed elsewhere.[7] A weighed amount of material was charged to the fluidizer and the slant static bed height was recorded. Air flow rale was gradually increased and the expanded slant bed heights were noted. As the bed fluctuated between two limits, typical of gas-solid fludization, heights of the upper and the lower surfaces of the fluctuating bed were recorded for each fluid velocity higher than the minimum fluidizing ones. The fluctuation ratio was then calculated. This procedure was repeated for different bed heights of varying particle sizes and different cone angles. Investigations have been made with different cone angles, static bed heights and mixture proportions (with respect to both particle size and particle density). The ranges of variables studied arc presented in *Table-I.* In case of homogeneous mixtures the size ratio of particles used was 1.08 while for the heterogeneous mixture desity range was 2614 t 4948 kg/m3.

The shape factor factor was determined by equation,[10]

$$(1-\epsilon)/\phi_s = 0.231 \log D_p + 1.417,$$

where D_p is the diameter of the particle in fect and ϵ is the void fraction of the bed. The range of ϕ_s was found to be 0.69 to 0.93 in the present case.

TABLE 1

RANGES OF EXPERIMENTAL VARIABLES

(∝) degree	d_p m X 10^4	h_s mX10^2	ρ_{sm} kg. m.$^{-3}$
8.86	5.765	6.0	2751
14.77	5.345	6.3	3336
19.62	4.980	7.0	3853
32.00	4.666	7.2	3887
43.20	4.387	7.7	4050
		8.4	4570
		8.5	
		9.5	
		10.5	

Results **and** Discussion

The fluctuation ratio is found to be a function of the sialic properties : particle size, inlet diameter of conduit, static bed height, particle and fluid density, and the dynamic properies: the fluid velocities at the onset of fluidization and fluidized conditions.

From dimensional analysis the following correlation has been developed for the prediction of fluctuation ratio,

$$r = 3.42\left(\frac{D_o}{d_{pm}}\right)^{-0.180}\left(\frac{h_s}{D_o}\right)^{0.033}\left(\frac{\rho_{sm}}{\rho_f}\right)^{-0.023}\left(\frac{G_f - G_{mf}}{G_{mf}}\right)^{-0.02} \quad \ldots\ldots (3)$$

Out of the two Do terms in equation (3) one accounts for the particle size effect while the other with h_s accounts for the cone angle effect.

The values of the fluctuation ratio have been calculated by using the above equation and compared with experimental values *(Figure 1).*

Mean and standard deviations for fifty cases have been found to be 5.17 per cent and 7.04 per cent respectively,

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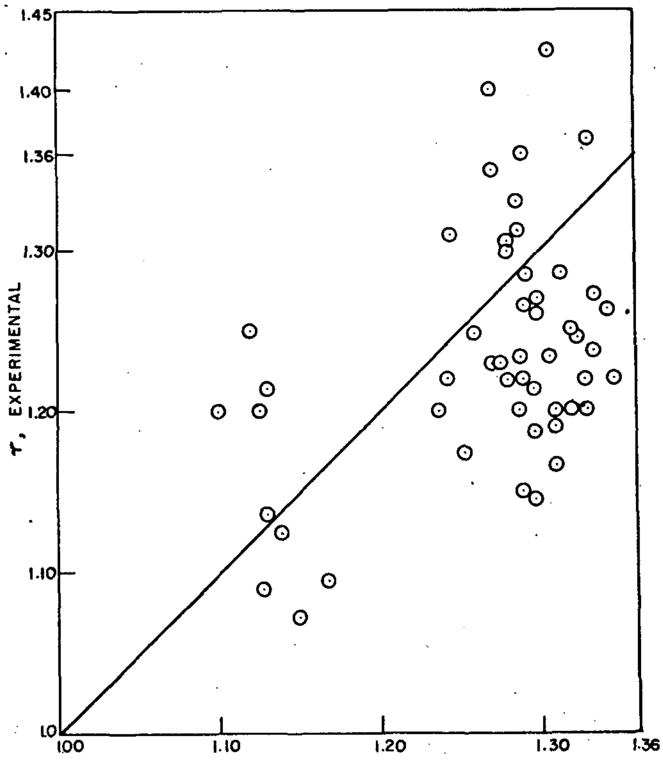

Fig. 1 Comparison of 'r' Values

indicating thereby a fairly good agreement between the calculated values (with equation 3) and the experimental ones. The fluctuation ratio was plotted against reduced mass velocity. It was observed that the behaviour is different from a cylindrical bed having mono-size particles. It was observed that the fluctuation ratio increases for low values of reduced mass velocity and then decreases to a constant value. The fluctuation ratio values, calculated using an empirical equation, given in Fluidization by Leva, are more than the observed ones by about 30 per cent. The probable reason for this deviation may be particle - particle interaction.

Two different correlations (equations 1 and 2) were developed by one of the authors for homogenous and heterogenous mixtures of spherical particles in conical beds. The present correlation is for irregular binaries of both a homogeneous and a heterogeneous naure where the cone-angle effec has been incorporated in he dimensionless group of h_s/D_o The correlation is more akin to equation 2 with the angle effect of tan α being replaced by h_s/D_o and the homogeneity being incorporated by the group D_o/d_{pm} in place of d_p/D_o of the earlier equation 2. Thus, the developed correlation becomes more versatile with respect to its use for different binaries of non-spherical particles. This equation is valid for well - fluidized beds($G_f>G_{mf}$)

Prediction of fluctuation ratio is of significance for gas-solid fluidization as its numerical value quantifies the fluidization quality. In addition, a knowledge of bed fluctuation fixes the bed height in the case of the design of a gas-solid fluidized system.

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NOMENCLATURE

D_o	inlet diameter of cone, L
d_p	particle diameter, L
d_{pm}	mean particle diameter for mixture, L, $1/\Sigma\left(\frac{x_i}{d_{pi}}\right)$
G_f	mass velocity of fluid at fluidization condition $ML^{-2}\text{ø}^{-1}$
G_{mf}	mass velocity of fluid at minimum fluidization conditon $ML^{-2}\text{ø}^{-1}$
h_s	static bed height, L
r	fluctuation raio, dimensionless
X_i	weight fraction, dimensionless

Greek Letters

$\propto$	apex angle of cone, degree
ϵ	porosity
ϕ_s	sphericity factor
ρ_f	density of fluid, ML^{-3}
ρ_{sm}	Mean particle densiy for mixture, ML-3 ($\Sigma\ \rho_{si}\ x_i$)

REFERENCES

1. Shri, Y.F., Yu, Y.S. and Fan, L.T., *Ind. Eng. Chem. Fundam.*, 23, 484 (1984)
2. Agarwal, S.K. and Roy G.K., *Ind. Chem. Engr.*, Vol. XXX No. 3 (1988)
3. Biswal, K.C., Sahu, S. and Roy, G.K., *The Chem. Eng. J.*, 23, 97 (1982)
4. Biswal, K.C., Bhowmic, T. and Roy, G.K., *The Chem. EngJ.*, 29, 47 (1984)
5. Biswal, K.C., Bhowmic, T. and Roy, G.K., *The Chem. Engg. J.*, 30, 57 (1985)
6. Agarwal, S.K., A Quantitative Study of Fluidization Quality in Various Conduits, M.Sc. Engg. thesis, Sambalpur University (1983)
7. Biswal, K.C., Samal, B.B. and Roy, G.K., *J. of I.E. (India)*, 65, pt. Ch-1,15 (1984)
8. Biswal, K.C. and Roy, G.K., *J. of I.E. (India)*, 65, Pt. Ch-2,32 (1985)
9. Biswal, K.C., Singh, R.K. and Roy, G.K., *Proceedings of the 4th National Convention of Chemical Engineers of the Institution of Engineers (India)*, Roorkee, Oct. 3-4. (1988)
10. Narsimhan, G., *A.I. Che. E.J.*, 11(3), 550 (1965)