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Dynamics of Gas-Solid Fluidization of Regular Particles in Conical Vessels

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The relative merits of conical vessels over conventional cylindrical ones have been highlighted in this paper. The necessity of a generalized correlation for prediction of fluctuation ratio in case of gas-solid fluidization in conical beds has been emphasized. Data on fluidization for glass bead-air system with varying cone angles have been presented. A correlation in terms of system parameters has been developed for prediction of the fluctuation ratio and its calculated and experimental values compared.

NOMENCLATURE

D_c = mean diameter of cone, m

D_o = inlet diameter of the cone, m

d_p = particle diameter, m

G = mass velocity of fluid, kg/m²h

G_f = mass velocity of fluid at fluidization condition, kg/m²h

G_{mf} = mass velocity of fluid at minimum fluidization, kg/m²h

h_s = static bed height, m

ρ_s = density of the solid, kg/m³

ρ_f = density of the fluid, kg/m³

r = fluctuation ratio, dimensionless

INTRODUCTION

Fluidization as an established fluid-solid contacting technique has found extensive applications in carbonization, gasification, combusiton and many other process industries during the last four decades. Inspite of the various advantages, the efficiency and quality of large scale and deep fluidized beds are adversely affected by bubbling, slugging, channeling behaviour at gas velocities higher than the minimum fluidization velocity. Various techniques including introduction of baffles, operation in a multistage unit, imparting vibrations and alterations in bed geometry have been advocated from time to time to tackle such problems. Introduction of a conical fluidizer instead of a conventional cylindrical one is an alternative technique in gas-solid fluidization. Better solid-fluid mixing and improved quality of fluidization can be achieved in a conical fluidizer. The gradual decrease in superficial fluid mass velocity due to the varying cross-sectional area entails the use of continuously decreasing sized particles for smooth and stable operation of such a fluidizer. Considering this operation it will be of importance where a gradual decrease of particles is encountered like that of solid fuel combusion and gasification. Prior to its application in actual processes it is essential to be well aquainted with the dynamics of fluidization in conical beds. Although some information for liquid-solid system in conical vessel is available,[1-4] very little work relating to gas-solid fluidization in conical vessel is available.[5] The present experimental investigation have been undertaken for prediction of the 'fluctuation ratio' in conical. vessels.

EXPERIMENTAL SET-UP

APPARATUS

The schematic diagram of the apparatus used in the investigations is shown in Fig 1. The cone was made up of a thick Perspex sheet. The angles of the cone were 10°, 30°, 45° and 60° and the inlet diameter 4 cm.

The grid had a screen of 60 mesh. Below this was a conical section packed with glass beads which served as the calming section. Air, used as the fluidizing medium, was supplied from a compressor through a constant pressure reservoir. Drying of air was done by passing it through a silica gel tower. Two rotameters, one for lower and the other for the higher range, measured the flow rates of air. Bed pressure drop was noted with the help of two manometers, one for lower and the other for the higher rate of flow.

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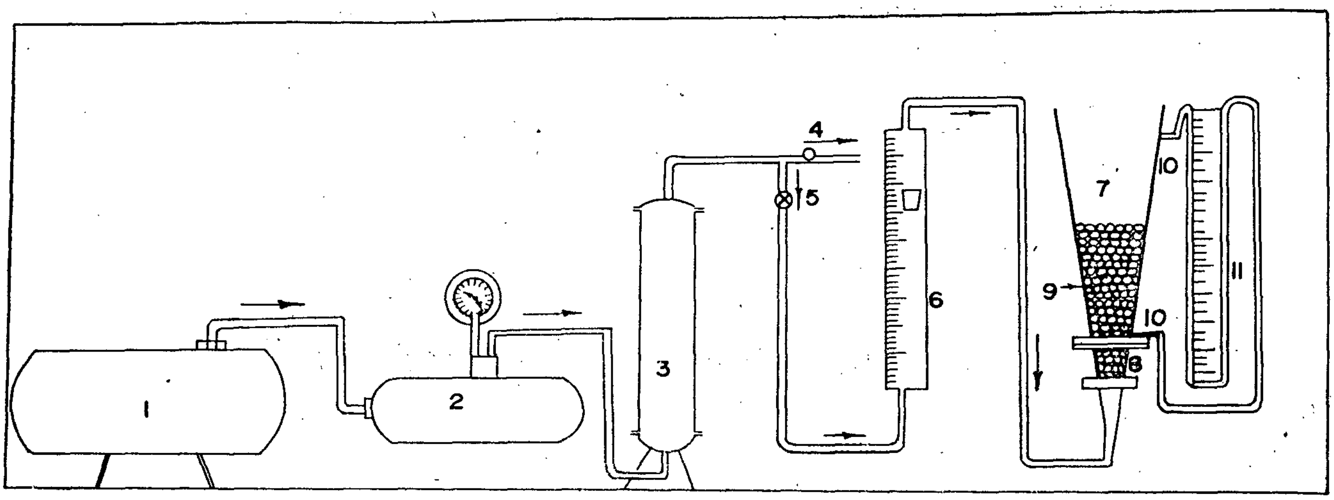

1. COMPRESSOR
2. RECEIVER
3. SILICA GEL TOWER
4. BY-PASS VALVE
5. LINE VALVE
6. ROTAMETER
7. CONICAL FLUIDIZER
8. GLASS BEAD PACKING
9. GLASS BEADS IN FLUIDIZATION STATE
10. PRESSURE TAPPINGS TO MANOMETER
11. MANOMETER

Fig 1 Experimental set-up

PROCEDURE

A weighed amount of material was charged to the fluidizer and the slant static bed height was recorded. Air flow rate was gradually increased and the corresponding bed pressure drops were noted. After the point of incipient fluidization the expanded slant bed heights were also noted. As the bed fluctuated between two limits typical of gas-solid fluidization, 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. The properties of the fluidized materials are presented in Table 1. Results of a typical experimental run is given in Table 2.

TABLE 1 RANGES OF VARIABLES STUDIED

Material — Glass Beads

Shape — Spherical

Density — 2300 kg/m^3

Cone Angle, C°	Particle Size, m	Static Bed Height m
10	0.5×10^{-3}	9.2×10^{-2}
30	1.0×10^{-3}	10.7×10^{-2}
45	1.5×10^{-3}	13.0×10^{-2}
45	2.0×10^{-3}	15.4×10^{-2}
60	2.5×10^{-3}	

TABLE 2 VARIATION OF r WITH FLUID MASS VELOCITY

r (dimensionless)	G_f (kg/m^{2}h)
1.053	3198.8
1.217	4277.6
1.417	5001.2
1.525	5705.0
1.638	6416.0
1.648	7133.0
1.660	7640.0
1.688	8660.3
1.725	10 186.0
1.815	11 126.5
1.833	12 733.5
1.835	14 246.0

RESULTS AND DISCUSSIONS

The fluctuation ratio, r, is defined as the quotient of the highest and the lowest levels, which the top of the bed occupies for any particular fluid flow rate."

The variation of r with fluid mass velocity is evident from Table 2. From dimensional analysis the fluctuation ratio can be related to the system parameters in terms of dimensionless groups as

$$r = f\left(\frac{D_c}{h_s}, \frac{h_s}{D_o}, \frac{d_p}{D_o}, \frac{G_f - G_{mf}}{G_{mf}}\right) \quad (1)$$

Equation (1) can be written as

$$r = k\left[\left(\frac{D_c}{h_s}\right)^a \left(\frac{h_s}{D_o}\right)^b \left(\frac{d_p}{D_o}\right)^c \left(\frac{G_f - G_{mf}}{G_{mf}}\right)^d\right] \quad (2)$$

where k is the co-efficient and a, b, c, d are the exponents. The effect of individual groups on r has been separately evaluated and the values of the exponents determined. Incorporating these values, in equaion (2), it becomes

$$r = k\left[\left(\frac{D_c}{h_s}\right)^{-0.2620} \left(\frac{h_s}{D_o}\right)^{-0.3920} \left(\frac{d_p}{D_o}\right)^{0.2243} \left(\frac{G_f - G_{mf}}{G_{mf}}\right)^{0.2744}\right]^n \quad (3)$$

where k is the correlation coefficient, and n the correlation exponent.

The values of k and n have been obtained by plottin the correlation factor against the fluctuation ratio in Fig 2. The final correlatiion is

$$r = 3.168\left[\left(\frac{D_c}{h_s}\right)^{-0.16} \left(\frac{h_s}{D_o}\right)^{-0.24} \left(\frac{d_p}{D_o}\right)^{0.14} \left(\frac{G_f - G_{mf}}{G_{mf}}\right)^{0.17}\right] \quad (4)$$

Using this relationship, the fluctuation ratio, r, has been calculated and compared with the esperimental ones. It has been found that most of the calculated values agree fairly well with the experimental values

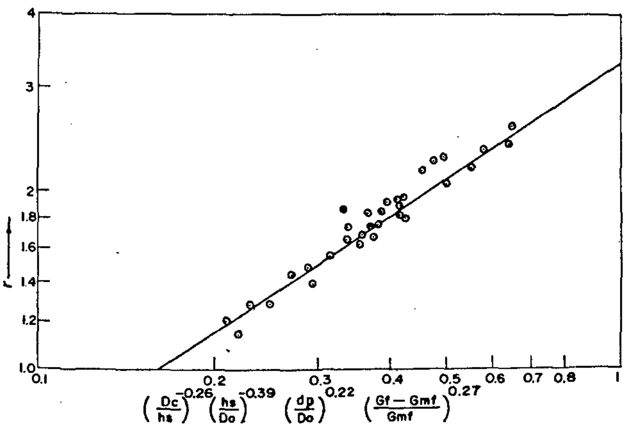

Fig 2 Variation of 'r' with system parameters

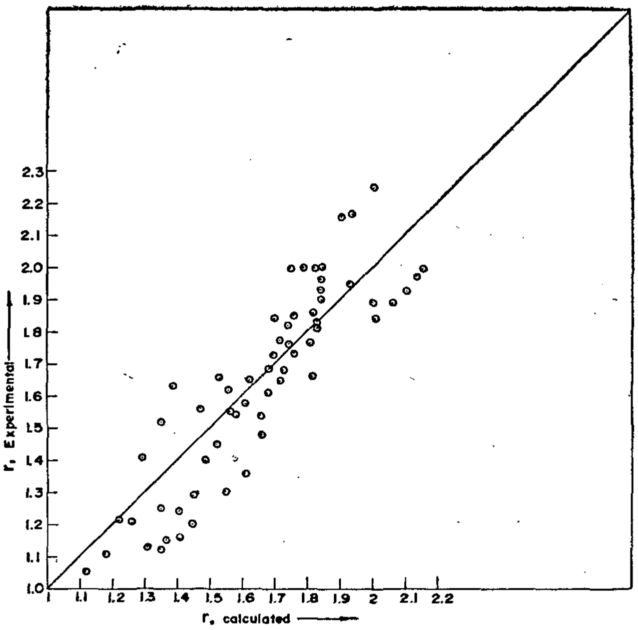

Fig 3 Comparison of experimental and calculated values of 'r'

(Fig 3). The mean and standard deviations for 80 readings have been calculated to be 10.10 and 12.25 respectively.

CONCLUSION

A knowledge of fluctuation ratio, r, in gas-solid fluidization is of importance in the design of fluidized bed reactors, gasifiers and combustors, specifically for calculation of height. This gives the value of the fluctuation ratio for spherical particles in conical fluidized beds of varying cone angle with fair accuracy and can be used in the design of gas-solid fluidized systems.

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