The Minimum Fluidization Velocity and Bed Fluctuation Ratio in Air-Solid Systems

A. Suryanarayana¹, B. Lakshman², G. Manohar³, T. Hanumanth⁴, M. Ramadevi⁵

Abstract—There are many equations available to predict minimum fluidization velocities of solid particles in air-solid systems in cylindrical columns. Experiments were carried out for minimum fluidization velocities of solid particles and compared with existing equations. Based on error, conclusions are drawn for which type of materials, which equations are agreeing well. Based on Rayleigh’s method and dimensional analysis and experiments, an equation is formulated to predict the fluctuation ratio of single size particles in cylindrical columns.

I. INTRODUCTION

Fluidization(1): Minimum fluidization velocity is an important parameter used to characterize the hydrodynamic behaviour of a material inside the fluidized bed. The density and size change the minimum fluidization velocity. In fluidization, fine granular solids are transformed into a fluid like state through contact with a fluid. When a liquid or gas is passed at low velocity up through a bed of solid particles, the particles do not move. If the fluid velocity is increased slowly, the pressure drop and the drag on individual particles increases and eventually the particles start to move (minimum fluidization velocity) and become suspended in the fluid.

1. Wen and Yu: \( U_{mf} = \mu / [(1135.7 + 0.048Ar)^{1/2} - 33.7]/(\rho g d_p) \)
2. Leva et al.: \( U_{mf} = 7.39d_p^{1.82}(p_g - p_\phi)^{0.94}/\rho_\phi^{0.94} \)
3. Goroshoko et al.: \( U_{mf} = \mu / [(p_g d_p)] \times [0.00138Ar/(Ar+19)^{0.11}] \)
4. Bena: \( U_{mf} = [\mu/(p_\phi d_p)] \times [0.00138Ar/(Ar+19)^{0.11}] \)
5. Rowe and Henwood: \( U_{mf} = 0.008d_p^{2}(p_g - p_\phi)g/\mu_\phi \)
6. Miller and Logwinuk: \( U_{mf} = 0.00125d_p^{2}(p_g - p_\phi)g/p_\phi^{0.10} \mu_\phi \)
7. Frantz: \( U_{mf} = 0.00106d_p^{2}(p_g - p_\phi)g/\mu_\phi \)
8. Davies and Richardson: \( U_{mf} = 0.00078d_p^{2}(p_g - p_\phi)g/\mu_\phi \)
9. Pillai and Raja Rao: \( U_{mf} = 0.000701d_p^{2}(p_g - p_\phi)g/\mu_\phi \)
10. Saxena and Vogel: \( U_{mf} = \mu / [(25.28 + 0.0571 Ar)^{3/2} - 25.25]/(p_\phi d_p) \)
11. Babu: \( U_{mf} = \mu [(25.25^2 + 0.0651 Ar)^{1/2} - 25.25]/(p_\phi d_p) \)
12. Richardson and Dast Jeromino: \( U_{mf} = \mu [(25.7^2 - 0.0365 Ar)^{1/2} - 25.7]/(p_\phi d_p) \)

The chief advantages of fluidization are: It ensures contact of the fluid with all parts of solid particles, prevents segregation of the particles by thoroughly agitating the bed, minimizing the temperature variations even in larger reactor and ensure high heat and mass transfer rates. Fluidization finds applications: In the catalytic cracking of reactors in petroleum industry, drying and sizing of crystals, transportation of solids, coating of metal surfaces with plastic materials, in roasting of ores and synthesis reaction. The disadvantages of fluidization are: Greater power requirement, high beakage of solid particles, serious erosion of pipe lines, containers and for bigger size reactors.

II. FLUCTUATION RATIO

It is the ratio of highest level to lowest level which the top of the fluidized bed occupies for any gas flow rate and is a quantification of the fluidization quality. A lower value of the fluctuation ratio is indicative of improved fluidization quality with less fluctuation ratio at the top of the bed in fluidized condition.

Minimum Fluidization velocity Equations Available in literature For Cylindrical Columns (2)
III. FLUCTUATION RATIO EQUATION

Based on Rayleigh’s method and dimensional analysis, the fluctuation ratio in cylindrical fluidized column is a function of the variables: \(G_{of}, G_{mf}, D_c, d_p, h_s, p_r, \mu \). The final equation is:

\[
R = 1.432 \left( \frac{G_{of}}{G_{mf}} \right)^{0.034} \left( \frac{D_c}{h_s} \right)^{0.00627} \left( \frac{d_p}{h_s} \right)^{0.0211} \left( \frac{p_r}{p_r_0} \right)^{0.042} 
\]

Earlier equation is \( R = 1.95 \left( \frac{d_p}{D_c} \right)^{0.04} \left( \frac{D_c}{h_s} \right)^{0.04} \left( \frac{p_r}{p_r_0} \right)^{0.04} \left( \frac{G_{of}}{G_{mf}} \right)^{0.05} \).

IV. EXPERIMENTAL

The various parts in the experimental set up are: 1-Blower/compressor (for air input); 2-Air flow control valve; 3-Mesh covered at the bottom of the column (not to allow solids to fall down from the bottom of the column); 4-U-Tube manometer (for measuring air flow rate); 5-Mesh cover at the top of the column (not to allow the particles to go out of the column).

PROCEDURE: 1- Fill the column to a height of 20 cm with the solid particles from the top of the column; 2-Use blower or compressor to get the desired flow rate of air; 3-Adjust the flow rate of air using the air flow control valve until the solid particles just vibrate in the column (minimum fluidization); 4-Note the manometer reading (gives the flow rate of air); Switch off the blower or compressor, change the material in the column and continue for next observation; 6- The height of the bed is not affecting the minimum fluidization velocity.

V. RESULTS

The observations of cereals are shown in Table 1. The observations of dals are shown in Table 2. The observations of seeds are shown in Table 3. The observations of metals are shown in Table 4. The observations of ores are shown in Table 5. The observations of crystals are shown in Table 6. The scope of experiments are shown in Table 7. The comparison of experimental fluctuation ratios and equation values are shown in Table 8.

VI. CONCLUSIONS: CEREALS

The equations of Pillai, Miller, Wen and Yu and Frantz are agreeing well (less than 10% error). DALS: The equations of Davies, Saxena, Babu, Wen and Yu and Richardson and Thong Limp are agreeing well. SEEDS: The equations of Bena, Goroshko, Richardson, Wen and Yu and Babu are agreeing well. METALS: The equations of Saxena, Babu and Franz are agreeing well.

ORES: The equations of Bena, Doichev and Miller are agreeing well. CRYSTALS: The equations of Babu and Leva are agreeing well.

In general for all types of materials, there is no single equation agreeing well for minimum fluidization velocity with less than 10% error.

The error in fluctuation ratio equation is less than 10%.

REFERENCES

**About the Authors**

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**TABLE-1:**

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<th>U_{mf} Equ.</th>
<th>% Error</th>
<th>Equation</th>
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<td>2.90</td>
<td>Bena</td>
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<td>14.2</td>
<td>Miller</td>
</tr>
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### TABLE—6 : CRYSTALS

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<tr>
<th>Material</th>
<th>Diameter,m</th>
<th>$U_{mf}$ Expt.</th>
<th>$U_{mf}$ Equ.</th>
<th>% Error</th>
<th>Equation</th>
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<tbody>
<tr>
<td>Sodium Chloride</td>
<td>0.00475</td>
<td>2.434</td>
<td>2.216</td>
<td>9.0</td>
<td>Babu</td>
</tr>
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<td>15.0</td>
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<td>1.392</td>
<td>9.6</td>
<td>Babu</td>
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**TABLE—8 : COMPARISION OF FLUCUATION RATIOS**

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<th>$G_{mf}$</th>
<th>$D_c$</th>
<th>$h_s$</th>
<th>$h_{min}$</th>
<th>$h_{max}$</th>
<th>$d_p$</th>
<th>$P_p$</th>
<th>$P_f$</th>
<th>$r_{exp}$</th>
<th>$r_{eq}$</th>
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