Dynamics of liquid–solid semifluidization

III. Relation between onset of semifluidization and minimum fluidization velocity

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Data on semifluidization characteristics for a few liquid–solid systems have been reported. A correlation relating the onset of semifluidization with the minimum fluidization velocity has been developed in terms of various system parameters.

In our earlier work, correlations have been developed for the prediction of the onset and the maximum semifluidization velocities and the packed-bed formation for liquid–solid systems. In the present paper, a correlation has been developed which relates the ratio of the minimum semifluidization velocity to the minimum fluidization velocity with the system parameter. The experimental setup used in the present study is described in detail in an earlier paper. Altogether 104 sets of runs have been taken. Four non-spherical materials, viz. dolomite, stone chips, coal and iron ore of sizes 6/8 and 14/16 BSS, and one spherical material, viz. glass beads of size 0.0164 ft (0.5 cm dia), have been studied. The lowest and highest specific gravities of solids used are 1.58 and 5.05, respectively.

Prediction of minimum semifluidization velocity from minimum fluidization velocity

The onset of fluidization and semifluidization are two consecutive events in the sequence of operations of the semifluidization phenomenon. While the former corresponds to the initiation of particle movement in a fluid–solid bed, the latter indicates the fluid velocity at which the bed first touches the top restraint of the semifluidizer. There are many correlations for the prediction of minimum fluidization velocity from a knowledge of the fluid and solid properties. Hence the ratio of the minimum semifluidization to the minimum fluidization velocity can be related through the various parameters of the system.

Both in semifluidization and fluidization, the properties of the fluid and the solid as well as the geometry of the system will determine the onset conditions for the respective operations. Important among the variables are: \( h_s, D_c, d_p, \rho_s, \rho_t \) and \( R \). Writing in the form of dimensionless groups one may get,

\[
\frac{G_{osf}}{G_{mf}} = \psi \left[ \frac{h_s}{D_c}, \frac{D_c}{d_p}, \frac{\rho_s}{\rho_t}, R \right]
\]

(1)

Since the column diameter has not been changed in the present study, the effect of the group \( h_s/D_c \) is not relevant. Consequently we consider an expression

\[
\frac{G_{osf}}{G_{mf}} = A (D_c/d_p)^{a_1} (\rho_s/\rho_t)^{a_2} (R)^{a_3}
\]

(2)

where \( a_1, a_2 \) and \( a_3 \) are exponents.

The effects of the individual parameters have been studied and the exponents evaluated. Substituting these exponents, eqn. (2) becomes,

\[
\frac{G_{osf}}{G_{mf}} = A [(D_c/d_p)^{0.266} (\rho_s/\rho_t)^{-0.228} (R)^{0.585}]^B
\]

(3)

Fig. 1 presents a log-log plot of \( G_{osf}/G_{mf} \) against \( (D_c/d_p)^{0.266} (\rho_s/\rho_t)^{-0.228} (R)^{0.585} \). Two parallel straight lines, one for the spherical and the other for the non-spherical particles, have been obtained. The equations for these lines can be written, for non-spherical particles:

\[
\frac{G_{osf}}{G_{mf}} = 1.625 (D_c/d_p)^{0.266} (\rho_s/\rho_t)^{-0.228} (R)^{0.585}
\]

(4a)

and for spherical particles:

\[
\frac{G_{osf}}{G_{mf}} = 1.875 (D_c/d_p)^{0.266} (\rho_s/\rho_t)^{-0.228} (R)^{0.585}
\]

(4b)

The onset of fluidization velocity, \( G_{mf} \), has been calculated from Leva’s simplified equation:

\[
G_{mf} = 688 d_p^{0.52} \frac{10 \pi (\rho_s - \rho_t)^{0.94}}{\mu^{0.38}}
\]

(5)

The values of \( G_{osf} \) calculated from the above two equations have been found to be in good agreement with the experimental data. The individual deviations are given in Table 1. All the deviations lie within ±6%. However, it is felt that spherical particles need to be studied more exhaustively to make the correlation more generalized.
Fig. 1. Relation of $G_{osf}/G_{mf}$ with system variables.

### TABLE 1
Comparison of minimum semifluidization velocity

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>System</th>
<th>$G_{mf}$ (lb./h ft$^2$)</th>
<th>$G_{osf}$ (lb./h ft$^2$)</th>
<th>From Calc.</th>
<th>From experiment</th>
<th>% deviation from expt. value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Dolomite-water</td>
<td>20600</td>
<td>84000</td>
<td>84000</td>
<td>95600</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>($d_p = 0.0080$ ft.)</td>
<td></td>
<td></td>
<td>105800</td>
<td>108000</td>
<td>-2.04</td>
</tr>
<tr>
<td>2.</td>
<td>Dolomite-water</td>
<td>9440</td>
<td>47500</td>
<td>54100</td>
<td>53600</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>($d_p = 0.0036$ ft.)</td>
<td></td>
<td></td>
<td>60100</td>
<td>60600</td>
<td>-0.82</td>
</tr>
<tr>
<td>3.</td>
<td>Stone chips-water</td>
<td>19800</td>
<td>81500</td>
<td>92600</td>
<td>92500</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>($d_p = 0.0080$ ft.)</td>
<td></td>
<td></td>
<td>103300</td>
<td>104000</td>
<td>-0.67</td>
</tr>
<tr>
<td>4.</td>
<td>Stone chips-water</td>
<td>9100</td>
<td>46100</td>
<td>52600</td>
<td>50200</td>
<td>4.79</td>
</tr>
<tr>
<td></td>
<td>($d_p = 0.0036$ ft.)</td>
<td></td>
<td></td>
<td>58500</td>
<td>56200</td>
<td>4.10</td>
</tr>
<tr>
<td>5.</td>
<td>Iron ore-water</td>
<td>33800</td>
<td>119800</td>
<td>136800</td>
<td>130500</td>
<td>4.83</td>
</tr>
<tr>
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<td>($d_p = 0.0080$ ft.)</td>
<td></td>
<td></td>
<td>152000</td>
<td>152000</td>
<td>0.00</td>
</tr>
<tr>
<td>6.</td>
<td>Iron ore-water</td>
<td>17200</td>
<td>75500</td>
<td>86000</td>
<td>85500</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>($d_p = 0.0036$ ft.)</td>
<td></td>
<td></td>
<td>93500</td>
<td>96000</td>
<td>-0.52</td>
</tr>
<tr>
<td>7.</td>
<td>Coal-water</td>
<td>3970</td>
<td>22600</td>
<td>25800</td>
<td>26700</td>
<td>-3.37</td>
</tr>
<tr>
<td></td>
<td>($d_p = 0.0036$ ft.)</td>
<td></td>
<td></td>
<td>28700</td>
<td>30200</td>
<td>-4.96</td>
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<tr>
<td>8.</td>
<td>Glass beads-water</td>
<td>30500</td>
<td>122000</td>
<td>138500</td>
<td>137000</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>($d_p = 0.0164$ ft.)</td>
<td></td>
<td></td>
<td>154400</td>
<td>154000</td>
<td>0.26</td>
</tr>
</tbody>
</table>
Nomenclature

$D_c$ diameter of column (semifluidizer), [L]

$d_p$ particle diameter, [L]

$G$ mass velocity of fluid, [M$\Theta^{-1}$ L$^{-2}$]

$G_{mf}$ minimum fluidization velocity, [M$\Theta^{-1}$ L$^{-2}$]

$G_{osf}$ minimum semifluidization velocity, [M$\Theta^{-1}$ L$^{-2}$]

$h_s$ height of initial static bed, [L]

$R$ bed expansion ratio in semifluidization, dimensionless

Subscripts

$c$ column

$f$ fluid

$mf$ minimum fluidization conditions

$osf$ minimum semifluidization conditions

$s$ solid.

Greek letters

$\psi$ function

$\mu$ viscosity, [M$\Theta^{-1}$ L$^{-1}$]

$\rho$ density, [ML$^{-3}$]

References

