Liquid-solid semi-fluidization of heterogeneous mixtures

II: Prediction of the minimum semi-fluidization velocity

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Data on liquid-solid semi-fluidization characteristics for heterogeneous mixtures are reported. Values of the minimum semi-fluidization velocity obtained from experimental investigations are compared with those calculated from a modification of a theoretical equation developed earlier for single-sized particles.

Although considerable information is available on the dynamics of liquid-solid semi-fluidization of close-cut particles, literature relating to the behaviour of mixed particle systems is very limited. In a recent communication, a correlation was suggested for the prediction of the maximum semi-fluidization velocity for heterogeneous mixtures. In this paper a correlation is developed which relates the ratio of minimum and maximum semi-fluidization velocities to the system parameters. The apparatus used in the present study is described in detail in an earlier paper. Altogether 32 sets of observations were made using five different combinations of dolomite, chromite, baryte and iron ore particles, all of size 36/44 BSS (British Standard Sieve).

Prediction of minimum semi-fluidization velocity

Based on his experimental investigations, Roy presented the following correlation for prediction of the minimum semi-fluidization velocity of pure components in liquid-solid systems:

\[
\frac{G_{\text{msf}}}{G_{\text{osf}}} = 0.473 \left( \frac{D_c}{d_p} \right)^{-0.20} \left( \frac{\rho_s}{\rho_t} \right)^{0.17} R^{0.38}
\]  

(1)

\[G_{\text{msf}} = 1.85 \times 10^4 d_p^{0.65} \left( \rho_s - \rho_t \right) \mu^{0.55} \]

(2)

The particle density in eqns. (1) and (2) is replaced by \((\rho_s)_{mv}\) for mixtures, where

\[(\rho_s)_{mv} = \Sigma W_i \frac{\rho_i}{\rho_s}
\]

(3)

The experimental values of \(G_{\text{osf}}\) were obtained from plots of the bed pressure drop versus fluid mass velocity and are presented in Table 1. It has been observed that the minimum semi-fluidization velocity is little influenced by the initial static bed height (Fig. 1) and hence an average value of the velocity can be used for different bed heights. However, with an increase in bed expansion ratio, the values of \(G_{\text{osf}}\) also increase (Fig. 2). Similarly the characteristics of the mixture have a marked influence on the minimum semi-fluidization velocity. Increase in the density of the mixture increases the above values (Fig. 3).

The experimental values of \(G_{\text{osf}}\) have been compared (Table 1) with those obtained using eqns. (1) and (2), modified to account for the mixture density. The deviations lie within 0 to 10%. It is observed that in all these cases the experimental values are lower than the calculated ones. Average values of the particle density have been used for calculation, whereas in an actual semi-fluidization experiment with mixtures it is always possible that the lighter components will move at a faster rate than the heavier ones and will reach the top restraint earlier. This will give a value of \(G_{\text{osf}}\) that is smaller than the value calculated on the basis of the average density. Nevertheless, the equation developed for pure components can be used for solid binaries without great error, as shown above.

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NOMENCLATURE

- \(d_p\): particle diameter, L
- \(D_c\): diameter of the semi-fluidizer, L
- \(G\): mass velocity of the fluid, ML^{-2}T^{-1}
- \(h\): height of the semi-fluidized bed, L
- \(h_s\): height of the initial static bed, L
### TABLE 1
Comparison of minimum semi-fluidization velocity for heterogeneous mixtures

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Mixture density (kg m(^{-3}))</th>
<th>(G_{\text{mef}}) (from eqn. (2)) (kg h(^{-1}) m(^{-2}))</th>
<th>(R)</th>
<th>(G_{\text{of}}) (kg h(^{-1}) m(^{-2}))</th>
<th>% deviation from expt.</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td>(\text{calc.})</td>
<td>(\text{expt.})</td>
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<td>Dolomite-chromite</td>
<td>3 210</td>
<td>309 000</td>
<td>2.0</td>
<td>100 000</td>
<td>94 750</td>
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<td>2.5</td>
<td>109 000</td>
<td>105 250</td>
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<td>3.5</td>
<td>124 000</td>
<td>120 000</td>
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<td>Dolomite-baryte</td>
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<td>100 000</td>
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<td>3.5</td>
<td>134 000</td>
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<tr>
<td>Dolomite-iron ore</td>
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<td>112 500</td>
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<td>3.5</td>
<td>139 500</td>
<td>128 000</td>
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<tr>
<td>Iron ore-chromite</td>
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<td>384 000</td>
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<td>120 000</td>
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<td>3.5</td>
<td>163 500</td>
<td>155 000</td>
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<tr>
<td>Iron ore-baryte</td>
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<td>176 500</td>
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</table>

Mixture characteristics: 36/44 BSS size; 50:50 binary.

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**Fig. 1.** Effect of the initial static bed height on the onset of semi-fluidization velocity.
MIXTURE CHARACTERISTICS —
IRON ORE : CHROMITE : 50 : 50
STATIC BED HEIGHT : 6CMS
SIZE OF THE PARTICLES : -36 + 44

LEGEND
SYMBOL BED EXPANSION RATIO R
O R1 = 2.0
A R2 = 2.5
□ R3 = 3.0
Φ R4 = 3.5

Fig. 2. Effect of the bed expansion ratio on the onset of semi-fluidization velocity.

STATIC BED HEIGHT : 6 CMS
BED EXPANSION RATIO : 2 : 0
SIZE OF THE PARTICLES : -36 + 44

LEGEND
SYMBOL MIXTURE CHARACTERISTICS
O DOLOMITE CHROMITE (50 : 50)
A DOLOMITE BARYTE (50 : 50)
□ DOLOMITE IRON-ORE (50 : 50)
Φ IRON ORE-CHROMITE (50 : 50)
■ IRON ORE-BARYTE (50 : 50)

Fig. 3. Effect of the mixture characteristics on the onset of semi-fluidization velocity.
\[ \Delta P \] pressure drop across the semi-fluidized bed, \( FL^{-2} \)

\[ R \] \( h/h_s \), bed expansion ratio in semi-fluidization, dimensionless

\( W_1, W_2 \ldots \) weights of the components of the mixture

\( x \) mass fraction of the components of the mixture

**Greek symbols**

\( \rho \) density, \( ML^{-3} \)

\( \mu \) viscosity, \( ML^{-1}T^{-1} \)

**Subscripts**

\( av \) average

\( f \) fluid

\( msf \) maximum semi-fluidization condition

\( osf \) minimum semi-fluidization condition

\( s \) solid

**REFERENCES**