

\[ N_{\text{vsi}} = \text{viscosity group}, \mu d^{1/3}/\sigma \]
\[ N_{\text{we}} = \text{Weber number}, \rho d u^2 / \sigma \]
\[ n_r = \text{impeller speed} \]
\[ \Delta P(d,t) = \text{dynamic pressure difference} \]
\[ \Delta \bar{P} = \text{average magnitude of } \Delta P(d,t) \]
\[ T = \text{mean period of } \Delta P(d,t) \]
\[ t = \text{time} \]
\[ \bar{u}^2(d) = \text{mean square of the difference of the velocities at distance } d \]
\[ \varepsilon = \text{energy dissipation rate per unit mass} \]
\[ \eta = \text{Kolmogoroff length}, (\nu/\sigma)^{1/4} \]
\[ \theta = \text{spring elongation or magnitude of the deformation} \]
\[ \mu = \text{viscosity} \]
\[ \nu = \text{kinematic viscosity} \]
\[ \omega = \text{dimensionless time}, t/T \]
\[ \rho = \text{density} \]
\[ \sigma = \text{interfacial tension} \]
\[ \phi = \text{dispersed phase volume fraction} \]

\(<\text{Subscripts}>\)
\[ c = \text{continuous phase} \]
\[ d = \text{dispersed phase} \]
\[ \text{crit} = \text{critical} \]
\[ \text{max} = \text{maximum} \]
\[ \psi = \text{volume-average} \]

Literature Cited

SHORT COMMUNICATIONS

PREDICTION OF SEMIFLUIDIZATION VELOCITY AND PACKED BED FORMATION FOR HETEROGENEOUS MIXTURES IN LIQUID-SOLID SYSTEMS

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Introduction

Semifluidization is a new type of solid-fluid contacting technique, which has been reported in the last decade only. It is claimed to be a compromise between the packed and the fluidized bed operations and can be achieved in a conventional fluidizer by incorporating certain modifications to the column construction. The special features of such a bed have been reported in literature\(^{11}\).

A glance into semi-fluidization literature reveals that various aspects of liquid-solid semi-fluidization viz. the prediction of minimum and maximum semi-fluidization velocities\(^{1-7}\), packed bed formation\(^{1,3,8}\), and pressure drop\(^9\) have been exhaustively investi-

Received January 24, 1977. Correspondence concerning this article should be addressed to G. K. Roy.
Results and Discussions

Altogether 32 sets of runs have been taken using five different 50:50 binary mixtures of dolomite, chromite, iron ore and baryte particles of 36/44 BSS size. Characteristics of mixtures and ranges of variables studied are given in Table 1.

Prediction of semi-fluidization velocity and packed bed formation: Based on experimental investigations, Roy has given the following correlation for the prediction of semifluidization velocity for pure components in case of liquid-solid systems:

\[ \frac{G_{sf}}{G_{msf}} = 0.925 \left( \frac{D_c}{d_p} \right)^{-0.2} \left( \frac{\rho_s}{\rho_f} \right)^{-0.12} \left( \frac{h_p}{h_s} \right)^{0.22} \]  

\[ G_{msf} = 1.85 \times 10^4 d_p^{0.05} \left( \rho_s (\rho_s - \rho_f) \right)^{0.55} \]  

The particle density in the above equations has been replaced by \((\rho_s)_h\), for the mixtures and this has been calculated as:

\[ (\rho_s)_h = \frac{\sum W}{\sum (W/\rho_s)} \]  

With the help of Eqs. (1)–(3), values of semi-fluidization velocity can be calculated for desired packed bed formations. On the other hand, the same equations can also predict the relative distribution of particles in the two regimes of operation viz. the packed and the fluidized zones for a definite semi-fluidization velocity.

The values of semi-fluidization velocity calculated from above have been compared with the experimental values. It is observed that excepting a few cases all, the deviations lie within +10.0 to -25.0%. The mean and standard deviations for a set of 165 values have been found to be 8.40 and 9.71%, respectively. Further it is found that in most of the cases experimental values are higher than the calculated ones. (Fig. 1) This is due to the fact that in case of calculation, average values of density have been used for the mixtures, whereas in actual semi-fluidization experiment with heterogeneous mixtures the lighter components will reach the top restraint earlier, thereby indicating lower calculated values, as the semi-fluidization velocity ratio \((G_{sf}/G_{msf})\) is inversely proportional to the particle density (fluid density remaining constant). In the second phase of the phenomenon, while dealing with the heavier components at higher fluid mass velocities, the effect of compaction of the top packed bed becomes more prominent as compared to the density effect. Hence, for a required top formation actual (experimental) values of semi-fluidization velocity will be higher than those calculated by the equations. However, the correlation for pure components with density modification is useful for the prediction of either the semi-fluidization velocity or the packed bed formation for solid binaries.

Acknowledgment

The authors are thankful to the B. S. & I. R., Orissa for providing necessary finance to carry out this work.

Nomenclature

B. S. S. = British Standard Sieve
\( D_c \) = diameter of the semifluidized particle [L]
\( d_p \) = particle diameter [L]
\( G_{msf} \) = maximum semi-fluidization mass velocity [ML^{-1}, T^{-1}]

Table 1 Characteristics of mixtures and ranges of variables studied

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Mixture components</th>
<th>Mixture nomenclature</th>
<th>((\rho_s)_h) [kg/m^3]</th>
<th>( h_s ) [cm]</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Dolomite-chromite</td>
<td>D-C</td>
<td>3.21 \times 10^3</td>
<td>6.0, 8.0</td>
<td>2.0, 2.5</td>
</tr>
<tr>
<td>2.</td>
<td>Dolomite-baryte</td>
<td>D-B</td>
<td>3.45 \times 10^3</td>
<td>10.0, 12.0</td>
<td>&quot;</td>
</tr>
<tr>
<td>3.</td>
<td>Dolomite-iron ore</td>
<td>D-I</td>
<td>3.67 \times 10^3</td>
<td>6.0</td>
<td>&quot;</td>
</tr>
<tr>
<td>4.</td>
<td>Iron ore-chromite</td>
<td>I-C</td>
<td>4.34 \times 10^3</td>
<td>6.0</td>
<td>&quot;</td>
</tr>
<tr>
<td>5.</td>
<td>Iron-ore-baryte</td>
<td>I-B</td>
<td>4.80 \times 10^3</td>
<td>6.0</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

Fig. 1 Comparison of semifluidization velocity for heterogeneous mixtures
LOCAL H.T.U. IN PACKED DISTILLATION COLUMN

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Hitherto the mass transfer in distillation has almost been treated as a straightforward process of mass diffusion; however, the temperature difference between bulk vapor and liquid has attracted the attention of several investigators\(^1\). Recently, Yamada et al.\(^3\) suggested a transfer model in which the mass transfer depends upon the heat transfer caused by the temperature difference between bulk vapor and liquid be considered as well as the ordinary mass diffusion. In the following paper, this model has been applied to examine the local H.T.U. in the packed distillation column, where a constant molar rate is assumed.

I. Local H.T.U.

According to the transfer model\(^7\), the component material balance in the differential hight of packing \(dz\) is given by

\[
V \frac{dy_i}{dz} = k_{v,di} a_p (y_i^p-y_i^l) + \frac{h_a}{\lambda} \left( y_i^p - y_i^l \right) (T^v - T^l) \tag{1}
\]

where the first term shows the component mass transfer rate by the ordinary diffusion and the second term by the thermal effect. Then, the definition of local H.T.U. leads to

\[
H_i = \left[ \frac{dy_i}{dz} \right]^{-1} = \left[ k_{v,di} a_p R_i \right]^{-1} \tag{2}
\]

where \(k_{v,di} a_p\) and \(R_i\) are defined by

\[
f_{v,di} = k_{v,di} a_p \quad f_{v,di} = \frac{h_a}{\lambda k_{v,di} a_p} \quad R_i = 1 + \frac{f_{v,di}}{f_{v,di}} \left( y_i^p - y_i^l \right) \left( T^v - T^l \right) \tag{3}
\]

where \(y_i^p \equiv (y_i^p - y_i)(T^v - T^l)\), \(T^v\) and \(T^l\) are kept at the bubble and the dew points respectively. \(f_{v,di}\) is the well-known parameter, whereas \(f_{v,di}\) is a new parameter involving the thermal effect, which means the ratio of [molar rate of partial condensation per unit temperature difference][molar rate of ordinary mass diffusion per unit diffusional driving force]. Moreover, \(R_i\) denotes the ratio of component local N.T.U. with and without the thermal effect as suggested by Liang et al.\(^3\). Equation (2) has two parameters, \(f_{v,di}\) and \(f_{v,di}\), this equation is characterized by \(f_{v,di}\), because if \(f_{v,di}\) is out of consideration, Eq. (2) is reduced to the ordinary equation to express \(H_i\). Furthermore, \(\lim_{i \to v} R_i = 1\), where no thermal effect occurs.

2. Numerical Examples and Discussion

As mentioned in the studies on gas-liquid operation\(^9\), it is considered that the effective film resistance to both mass and heat transfers are equally affected

Received December 24, 1976. Correspondence concerning this article should be addressed to I. Yamada. M. Sawada is with Mitsui ship building & Eng. Co., Ltd., Osaka 559.

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