PREDICTION OF MINIMUM AND MAXIMUM SEMIFLUIDIZATION VELOCITIES BY NOMOGRAPHS.

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Semi-fluidization is a new and novel technique of contacting solids with fluid. This can be viewed as a combination of a batch fluidized bed at the bottom and a fixed bed at the top. Such a bed can be obtained by providing sufficient space for the free expansion of the bed and then arresting the escape of the particles out of the system by means of a top restraint. A bed of this nature has the unique advantage[2] in that it combines the merits of packed as well as fluidized bed, which are very essential for the design of mixed and tubular reactors[1] (MT reactors).

Minimum and Maximum Semi-fluidization velocities:

Minimum semi-fluidization velocity is the fluid velocity at which the first particle of the bed touches the top restraint. The velocity, at which all the particles of the bed accumulate below the top restraint is defined as the maximum semi-fluidization velocity. Fan et al[3,4] studied both liquid-and gas-solid systems involving closed size range of particles. They have suggested a dimensionless correlation for the formation of semi-fluidized bed in terms of minimum fluidization velocity, semi-fluidization and maximum semi-fluidization velocities. Poddar and Dutt[5] have recently reported equations based on theoretical considerations to predict the minimum and maximum semi-fluidization velocities for liquid - solid systems. Based on their experimental data, Roy and Sarma[6] have given correlations for the direct prediction of the maximum semi-fluidization velocity, from which the minimum semi-fluidization velocity can be calculated knowing the properties of the liquid and the solid particles and the position of the restraining screen. The proposed correlations are:

(i) For maximum semi-fluidization velocity (G_{msf}) the suggested equation is:

$$G_{msf} = 0.3\ (Ar)^{0.58}\ \left(\frac{\mu}{d_p}\right) \quad \ldots\ldots\ldots\ldots (1a)$$

With water as the medium the equation reduces to—

$$G_{msf} = 2.675\times10^{4}\ (d_p)^{0.74}\ [\rho_s\ (\rho_s - \rho_f)\ ]^{0.58} \ldots (1b)$$

(ii) For minimum semi-fluidization velocity (G_{osf}) the equation is —

$$\frac{G_{osf}}{G_{msf}} = 0.105R + \frac{\log\ (Ar) + 2.456}{52} \quad \ldots \quad (2a)$$

For water-solid system this becomes

$$\frac{G_{osf}}{G_{msf}} = 0.105R + 0.0577 \log d_p + 0.0192 \log [\rho_s\ (\rho_s - \rho_f)] + 0.2018 \quad \ldots\ldots\ldots\ldots (2b)$$

Based on the above two equations, the two, following, nomographs have been prepared for direct prediction of the maximum (from figure No. 1) and minimum (from figure No. 2 with the help of figure No. 1) semi-fluidization velocities.

Accuracy of the nomograph.

The values found from the nomographs were compared with the respective values obtained by the other two methods, viz, from the equations and the actual experiments. The percentage deviations were also calculated.

Example:

System:- dolomite - water

Particle size (d_p) - 0.008 ft. Particle density (ρ_s) -172.2 lb/ft^3

Fluid density (ρ_s) - 62.4 lb/ft^3. Fluid viscosity (μ) 0.8 CP.

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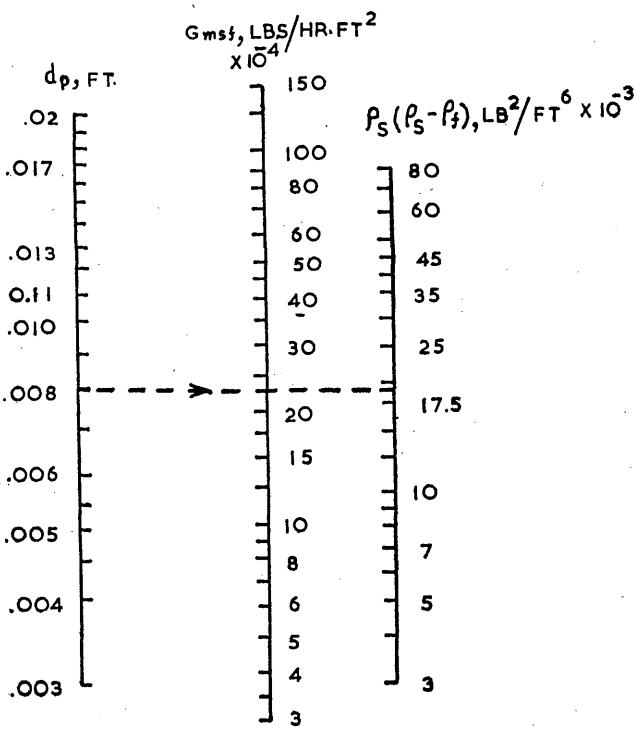

FIG. I. PREDICTION OF MAXIMUM SEMIFLUIDIZATION VELOCITY.

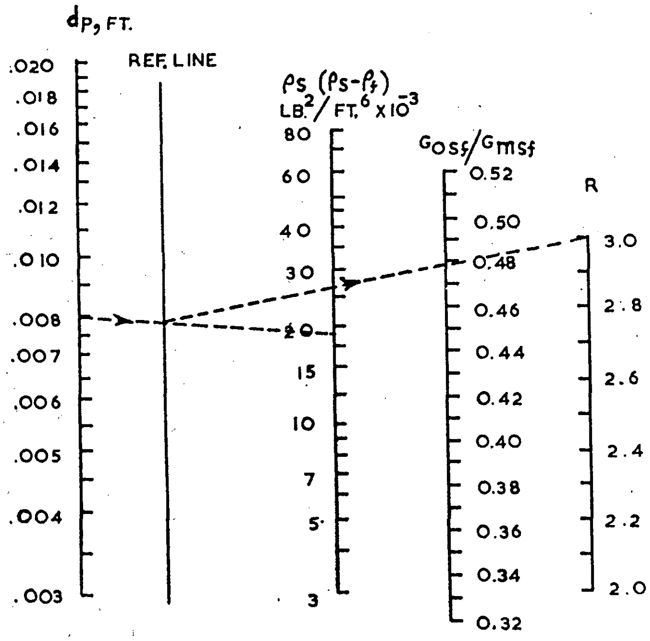

FIG. 2 PREDICTION OF VELOCITY RATIO G_{OSF}/G_{MSF}.

Bed expansion ratio (R) - 3.0

Maximum semi-fluidization velocity:

(i) From equation —

$$Ar = \frac{d_p^3 \, g_c \rho_s (\rho_s - \rho_f)}{\mu^2}$$

$$= \frac{(0.008)^3 \times (32.2) \times (3600)^2 \times 172.2 \times (172.2\text{-}62.4)}{(0.8 \times 2.42)^2}$$

$$= 1.08 \times 10^6$$

$$G_{msf} = 0.3 \, (Ar)^{0.58} \left(\frac{\mu}{d} \right)$$

$$= 0.3 \quad (1.08 \times 10^6)^{0.58} \left(\frac{0.8 \times 2.42}{0.008} \right)$$

$$= 2.3 \times 10^5 \text{ lbs/hr. ft}^2$$

(ii) From experiment —

$G_{msf} = 2.26 \times 10^5$ lbs/hr. ft²

(iii) From nomograph —

$G_{msf} = 2.3 \times 10^5$ lbs/hr. ft²

Minimum semi-fluidization velocity:

(i) From equation —

$$\frac{G_{osf}}{G_{msf}} = 0.105R + \frac{\log (Ar) + 2.456}{52}$$

$$= 0.105 \ (3) + \frac{\log (1.08 \times 10^5) \times 2.456}{52}$$

$$= 0.478$$

$$G_{osf} = 0.478 \times G_{msf}$$

$$= 0.478 \times 2.3 \times 10^5 = 1.099 \times 10^5 \text{ lbs/hr. ft.}^2$$

(ii) From experiment —

$G_{osf} = 1.08 \times 10^5$ lbs/hr. ft²

(iii) From nomograph —

$$\frac{G_{osf}}{G_{msf}} = 0.4775$$

$G_{msf} = 2.3 \times 10^5$ (from fig. No. 1)

$G_{osf} = 0.4775 \times 2.3 \times 10^5$

$= 1.092 \times 10^5$ lbs/hr. ft.²

Table - 1

Comparison of G_{msf} values.

Values of G_{msf}, lbs/hr.ft.²			Percentage deviation	
Nomograph	Experimental	Calculated	From Expt. Value	From Calculated Value
2.3×10^5	2.26×10^5	2.3×10^5	1.77	0.00

Table - 2

Comparison of G_{osf} values

Values of G_{osf}, lbs/hr.ft.^{2}			Percentage deviation	
Nomograph	Experi-mental	Calculated	From Expt. value	From Calcu-lated Value
1.092×10^5	1.08×10^5	1.099×10^5	1.11	0.63

Conclusion:

It is seen that the values of minimum and maximum semi-fluidization velocities obtained from nomographs compare favourably with those calculated by the equations and also with the experimental data. The deviations were found to be less than 2 per cent.

Nomenclature:

Ar — Archimedes number, $d_p^3 g_c \rho_s (\rho_s - \rho_f)/\mu^2$. dimensionless.

d_p — Particle diameter, ft.

G_{osf} — Onset of semi-fluidization velocity or, minimum semifluidization velocity lbs/hr. ft.^{2}

G_{msf} — Maximum semi-fluidization velocity, lbs/hr. ft.^{2}

R — Bed expansion ratio, i.e. ratio of the top restraint height from the bottom restraint to the initial fixed bed height.

Greek letters:

ρ_s — density of solid, lbs/ft.^{3}

ρ_f — density of fluid lbs/ft^3

μ — viscosity of fluid, lb/ft.hr.

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