DESIGN OF LIQUID-SOLID SEMIFLUIDIZER

— G. K. ROY

Semi-fluidization is a compromise between the packed and the fluidized bed operations, where certain drawbacks of both are eliminated. Based on correlations developed earlier (4,5,6) for predicting the minimum and the maximum semi-fluidization velocities, packed bed formation and pressure drop across semi-fluidized bed, a method is suggested for the design of a liquid-solid semi-fluidizer.

A semifluidized bed overcomes some of the inherent disadvantages of both the fixed and the fludized bed. The principle of semi-fluidization can be applied to the design of MT reactors(1) (mixed and tubular) for obtaining an optimum performance in case of fast exothermic reactions. Application of this technique in the studies of mass transfer has been quite encouraging (2). Thus semi-fluidization is a very useful technique of fluid-solid contacting, which can be of wide applicability in the fields of heat transfer, mass transfer and reaction kinetics.

Illustrations:—

In course of studies of semifluidization characteristics of different solids with water at 25 °C as the medium, the following observations have been made in case of dolomite-water system:

For semifluidizer —

Diameter (I.D.) = 6.0 inches.
Height of top restraint = 2 x initial static bed height.

Height of packed section (in semifluidization) = $\frac{1}{2}$ x initial static bed height.

For water,

ρ = 62.4 Lb/ft^3
μ = 0.8 cp.

For dolomite,

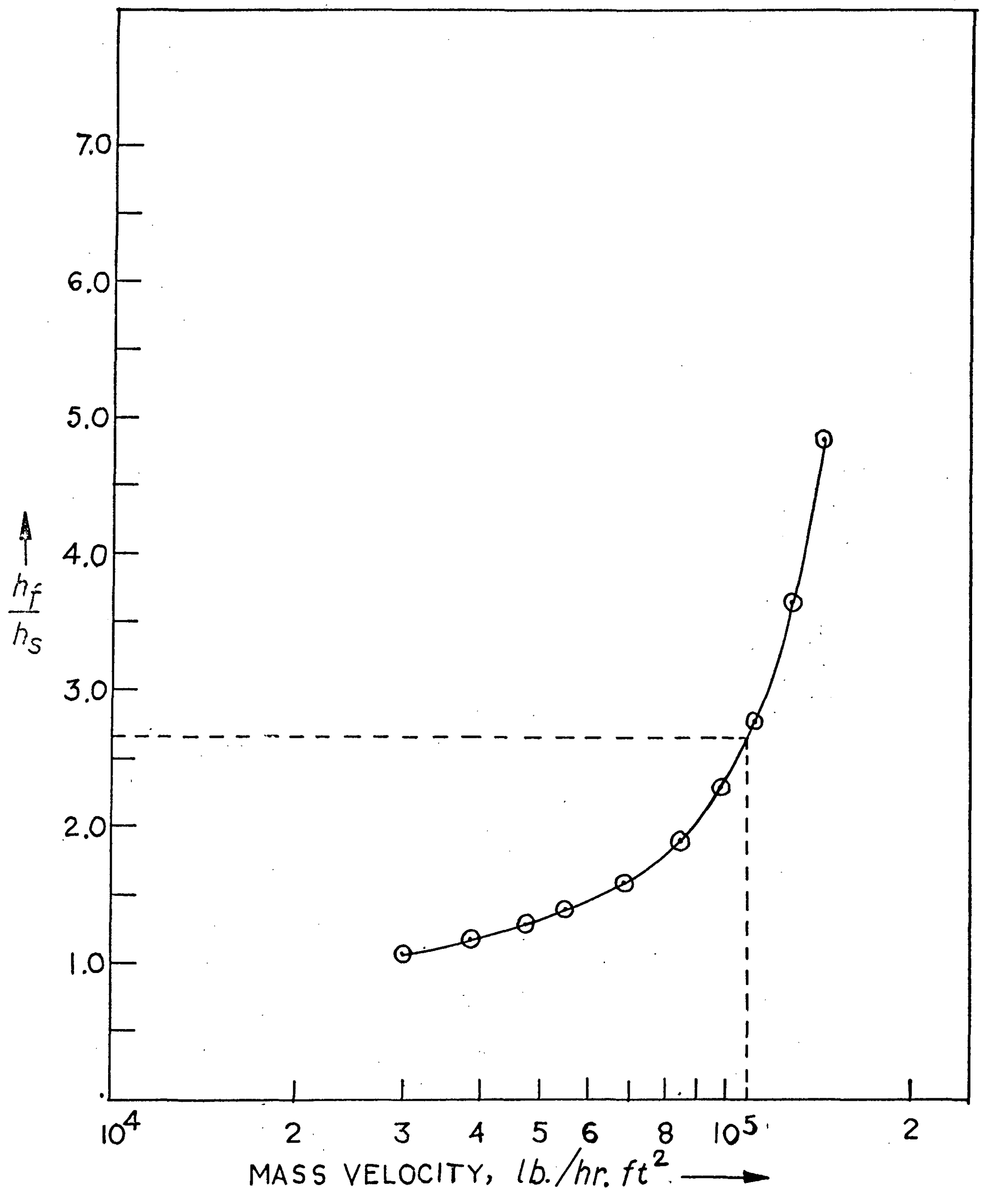
Shape = irregular.
Weight = 20.0 Lbs.
d_p = 0.008 ft.
εP_a = 0.539
ρ = 172.2 lb/ft^3

Calculate — (a) the range for the semi fluidization operation (b) the height of the packed and the fluidized sections (c) the semi fluidization velocity and (d) the power required for the above case.

The bed expansion data for dolomite—water system is shown in Table 1.

Bed Expansion Data For Dolomite-Water System

G_1 lb/hr.ft^2	29700	38600	47400	55000	68250	84800	98000	112200	127800	144300
εf	0.580	0.613	0.645	0.673	0.710	0.757	0.800	0.834	0.875	0.906
h_f / h_s	1.070	1.185	1.295	1.410	1.590	1.890	2.300	2.780	3.650	4.850



Fig' 1 : Variation of Bed Expansion Ratio with Fluid Mass Velocity

Solution;-

In order to design a liquid-solid semifluidizer, the study of the characteristics of semifluidized beds differing in size as well as density is necessary. Co-relations have been developed for the prediction of the minimum and the maximum semifludization velocity,[4] packed bed formation[5] and semifluidized bed pressure drop.[6]

Part (a)

The range for - the semifluidization operation is marked by the minimum and the maximum semifluidization velocities.

Maximum semi fluidization velocity:—

$$Re_{msf} = 0.30\,(Ar)^{0.58}$$

where,
$$Re_{msf} = \frac{d_p\, G_{msf}}{\mu}$$

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

So, $Ar = (0.008)^3 \times 32.2 \times 172.2 (172.2-62.4)$
$= 1.08 \times 10^6$

$$Re_{msf} = 0.30 (1.08 \times 10^6)^{0.58}$$
$$= 0.30 \times 3150 = 945$$

$$\therefore G_{msf} = 945 \times \frac{\mu}{d_p}$$
$$= 945 \times \frac{1.926}{0.008} = 229000 \text{ Lb/hr.ft}^2.$$

Minimum semi-fluidization velocity :—

The following equation [1] relates the ratio of the minimum and the maximum semi-fluidization velocity to the system parameters.

$$\frac{G_{osf}}{G_{msf}} = 0.105R + \frac{\log (Ar.) + 2.456}{52}$$
$$= 0.105 (2.0) \frac{\log (1.08 \times 10^6) + 2.456}{52}$$
$$= 0.210 + 0.1635 = 0.3735$$
$$G_{osf} = 0.3735 \times 229200 = 85500 \text{ lb/hr. ft}^2$$

So, semi-fluidization occures between fluid mass velocity of 85500 — 229200 lbs/hr.ft².

Part (b)

Calculation of initial static bed —

weight of solid = 20.0 lbs.

Area of cross section $= \frac{\pi}{4} \left(\frac{6}{12}\right)^2$
$= 0.196 \text{ ft.}^2$

If h_s = initial static bed height

$$A h_s (1-\varepsilon_{pa}) \rho_s = 20.0$$
$$h_s = \frac{20}{A(1-\varepsilon_{pa})\rho_s}$$
$$= \frac{20}{0.196 (1-0.539) 172.2}$$
$$= 1.283 \text{ ft.} = 15.4 \text{ inches.}$$

$R = 2.0$

So, height of semi-fluidized bed = 2 x 15.4 = 30.8"

Height of packed section = $\frac{1}{2} \times h_s$ = 7.7"

Height of fluidized section = 30.8 — 7.7 = 23.1"

Part (c)

It was felt necessary to have an equation for the prediction of semi-fluidization velocity for a given packed bed height and a relation [5] of the following type was developed.

$$\frac{G_{sf}}{G_{msf}} = 0.945 \left(\frac{D_c}{d_p}\right)^{-0.15} \left(\frac{\rho_s}{\rho_f}\right)^{-0.11} (R)^{0.57} \left(\frac{h_s}{D_c}\right)^{0.10} \left(\frac{h_{pa}}{h_s}\right)^{0.66}$$

$D_c / d_p = 0.5/0.008 = 62.5$

$\rho_s / \rho_f = 172.2/62.4 = 2.76$

$R = 2.0$

$h_s / D_c = 15.4/6.0 = 2.57$

$h_{pa} / h_s = 0.5$

$$\frac{G_{sf}}{G_{msf}} = 0.945 (62.5)^{-0.15} (2.76)^{-0.11} (2.0)^{0.57} (2.57)^{0.10} (0.5)^{0.66}$$
$$= 0.470$$
$$G_{sf} = 0.470\ G_{msf}$$
$$= 0.470 \times 229200 = 107800 \text{ lbs/hr. ft}^2.$$

Part (d)

The power required can be calculated from a knowledge of the semifluidized bed pressure drop. The correlation suggested for pressure drop is :

$$\frac{(\Delta P_t) \text{ actual}}{(\Delta P_t) \text{ calculated}} = 16.7 \quad (D_c/d_p)^{-0.59} (\rho_s/\rho_f)^{0.67} (h_s/D_c)^{-0.43} (h_{pa}/h_s)^{0.08} (R)^{0.08}$$

$$= 16.7 \quad (6.25)^{-0.59} (2.76)^{0.67} (2.57)^{-0.43} (0.5)^{0.08} (2.0)^{0.08} = 1.9^1$$

$$(\Delta P_t) \text{ calculated} = \left[150 \frac{(1-E_{pa})^2}{E_{pa}^3} \frac{\mu u}{d_p^2} + 1.75 \frac{(1-E_{pa})}{E_{pa}^3} \frac{Gu}{d_p} \right]$$

$$\left[(h_f - h) \frac{(1-E_f)}{E_f - E_{pa}} \frac{1}{g_c} + \left[h_f - \frac{(1-E_{pa})\ (h_f - h)}{E_f - E_{pa}} \right] \right.$$
$$(1-E_f)\ (\rho_s - \rho_f)$$

$$G_{sf} = 107800 \text{ lbs/hr. ft}^2$$

$$u = \frac{107800}{62.4} = 1725 \text{ ft/hr.}$$

$$\frac{h_f}{h_s} = 2.65 \text{ (from fig. 1)}$$

$$h_f = 2.65\ h_s = 2.65 \times 15.4 = 40.9'$$

$$E_f = 0.827 \text{ (from fig. 2).}$$

$$(\Delta P_t) \text{ calculated} = \left[150 \cdot \frac{(1-0.530)^2}{0.539^3} \cdot \frac{(1.936)(1725)}{(0.008)^2} + 1.75 \cdot \frac{(1-0.539)}{0.539^3} \cdot \frac{(107800)(1725)}{0.008} \right] \frac{1}{4.17 \times 10^8}$$

$$\left[\frac{1}{12} \quad \frac{(40.9-30.8)(1-0.827)}{(0.827-0.539)} \right]$$

$$+ \frac{1}{12} \left[40.9 - \frac{(1-0.539)(40.9-30.8)}{0.822-0.539} \right] (1-0.827)(172.2-62.4)$$

$$= \left[(6.17 \times 10^6 \times 1725) + (0.646 \times 10^3 \times 107800 \times 1725) \right]$$

$$\left[(0.505) \frac{1}{4.17 \times 10^8} \right] + \frac{1}{12} (40.9-16.2)(0.173)(109.8)$$

$$= (106.5 + 1291.0) \frac{(0.505)}{4.17} + 1/12 \times 24.7 \times 0.173 \times 109.8$$

$$= 158.2 + 39.4 = 197.6 \text{ lbs / ft}^2.$$

$$\frac{(\Delta P_t) \text{ actual}}{(\Delta P_t) \text{ calculated}} = 1.91$$

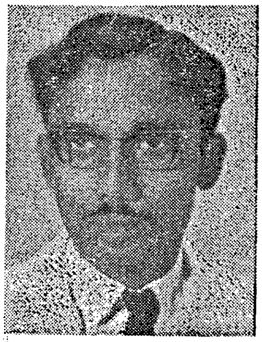
$$(\Delta P_t)_{\text{actual}} = 1.91 \times 197.6 = 378 \text{ lbs / ft}^2.$$

$$\text{Flow rate} = A\,u$$

$$= 0.196 \times 1725 = 338 \text{ ft}^3\text{ / hr.}$$

$$\text{HP required} = \frac{378 \times 338}{30000 \times 60} = 0.0646.$$

THE AUTHOR



Mr. G K. Roy is attached to the Department of Chemical Engineering, Regional Engineering College, Rourkela-8. (Orissa).

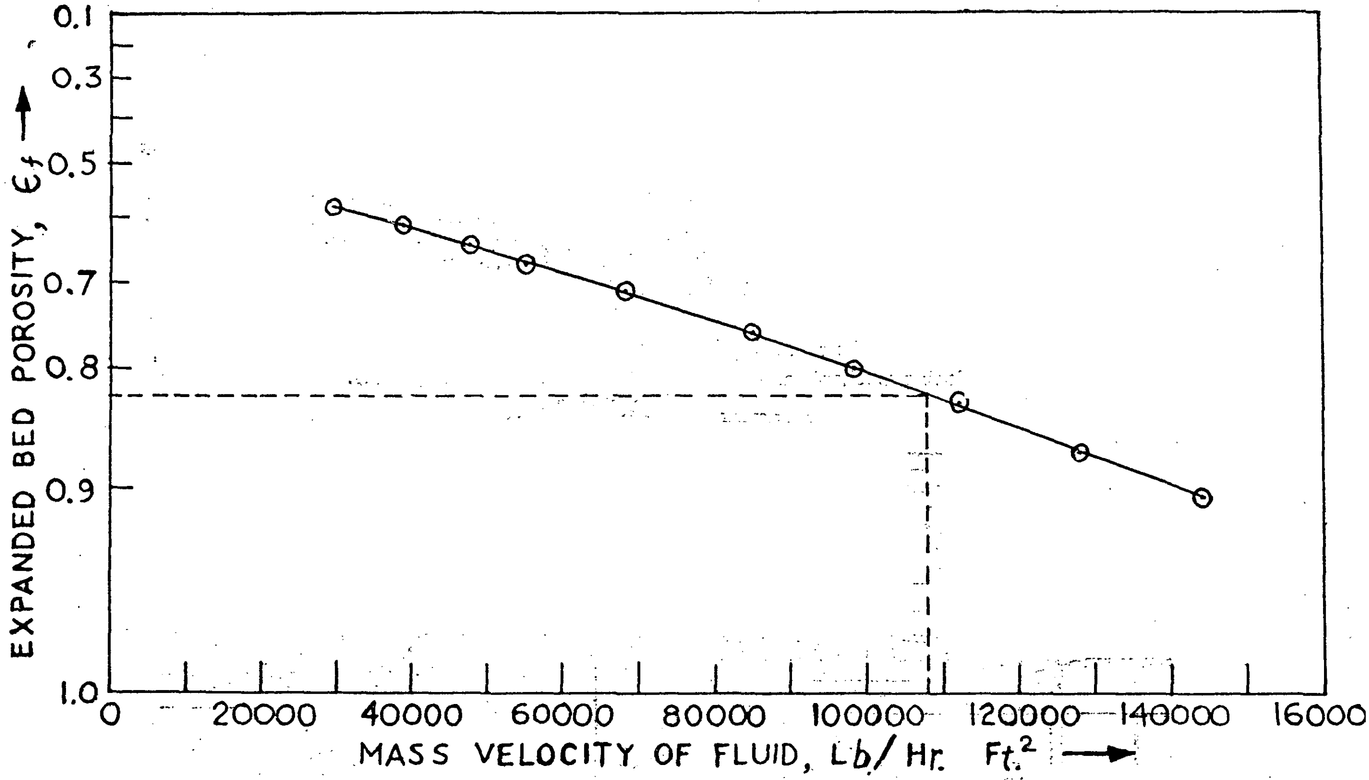


Fig. 2: Variation of Expanded Bed Porosity with Fluid Mass Velocity

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NOMENCLATURE

A = Area of cross section of the semi-fluidizer, L^2.

Ar = Archimedes number, dimension less group,

$$d_p^3 \, g_c \, \rho_s \, (\rho_s - \rho_f) / \mu^2$$

D_c = Diameter of column (or semifluidizer). L.

d_p = Particle diameter, L

g_c = Acceleration due to gravity, $L \theta^{-2}$

G_{osf} = **Minimum Semi - fluidization vetocity**, $ML^{-2} \theta^{-1}$

G_{msf} = Minimum Semi-fluidization velocity, $ML^{-2} \theta^{-1}$

G_{sf} = Semi--fluidization velocity, $ML^{-2}\theta^{-1}$

h = Overall height of column (or semi-fluidized bed), L

hf = Height of fluidized bed, L

h Pa = Height of packed section in semi-fluidization, L

h_s = Height of initial static bed, L.

(ΔP_t) = Total pressure drop across semi-fluidized bed, FL^{-2}.

R = Bed expansion ratio in case of fluidization, h/hs.

Re_{msf} = Particle Reynolds number corresponding to the maximum semi-fluidization condition, $\frac{d_p G_{msf}}{\mu}$

u =Linear velocity of fluid, $L \theta^{-1}$

Greek letters

Ef = Porosity of fluidized section or porosity of fully fluidized bed.

E Pa = Porosity of packed section

μ = Viscosity of fluid, $M \theta^{-1} L^{-1}$

ρ_f = Density of fluid, ML^{-3}

ρ_s = Density of solid, ML^{-3}

ϕ_s = Shape factor

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