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# Prediction of Minimum and Maximum Semi-fluidization Velocities for Gas-Solid Systems by Nomographs

Dr G K Roy, *Associate Member*

Dr P Sen Gupta, *Non-member*

*The technique of semi-fluidization has been briefly reviewed and the correlations developed for the prediction of minimum and maximum semi-fluidization velocities for the gas-solid systems are presented. Based on the two correlations, two nomographs have been prepared for rapid estimation of the values of velocities. The accuracy of the nomographs has also been given.*

## NOTATIONS

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

$D_c$ = diameter of column (semi-fluidizer, $L$)

$d_p$ = diameter of particle ($L$)

$G_{msf}$, $G_{osf}$ = maximum and minimum semi-fluidization velocity respectively ($ML^{-2}\,\theta^{-1}$)

$g_c$ = gravitational constant ($L\theta^{-2}$)

$R$ = bed expansion ratio in the case of semi-fluidization, that is, ratio of the top restraint height from the bottom grid to the initial static bed height

$\rho_f$, $\rho_s$ = density of fluid and solid, respectively ($ML^{-3}$)

$\mu$ = viscosity of fluid ($ML^{-1}\,\theta^{-1}$)

## INTRODUCTION

Semi-fluidization is a new and novel technique of contacting solids with fluid. This can be viewed as a combination of batch fluidized bed at the bottom and 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] that it combines the merits of packed as well as fluidized bed, which are essential for the design of mixed and tubular (MT) reactors[1].

## 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-solid and gas-solid systems involving close size range of particles. They suggested a dimensionless correlation for the formation of semi-fluidized bed in terms of minimum fluidization, semi-fluidization and maximum semi-fluidization velocities. Based on theoretical considerations, Poddar and Dutt[5] reported equations for predicting the minimum and the maximum semi-fluidization velocities for liquid-solid systems. Roy and Sarma[6] have given correlations valid for liquid solid systems for the direct prediction of the maximum semi-fluidization velocity where from the minimum semi-fluidization velocity can be calculated. Two nomographs have been suggested[7] based on the above correlations. Little work on gas-solid semi-fluidization however, has been reported. Two correlations for the direct prediction of the maximum and the minimum semi-fluidization velocities have been developed[8,9] related with system parameters. Thus

(i) For maximum semi-fluidization velocity ($G_{msf}$), the correlation suggested is

$$G_{msf} = 1.15 \times 10^{-3}\,(Ar)^{0.676}\left(\frac{\mu}{d_p}\right) \tag{1a}$$

With air as the fluidizing medium the equation reduces to

$$G_{msf} = 9.1 \times 10^{2}\,(d_p)^{1.03}\,[\rho_s(\rho_s - \rho_f)]^{0.676} \tag{1b}$$

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

$$\frac{G_{osf}}{G_{msf}} = 48.0\left(\frac{D_c}{d_p}\right)^{0.38}\left(\frac{\rho_s}{\rho_f}\right)^{-1.05}(R)^{0.64} \tag{2}$$

Based on the above two equations, the two nomographs have been prepared for rapid estimation of the maximum and minimum semi-fluidization velocities with the help of (Figs 1 and 2).

Dr G K Roy is with Regional Engineering College, Rourkela and Dr P Sen Gupta is with MT, Kharagpur.

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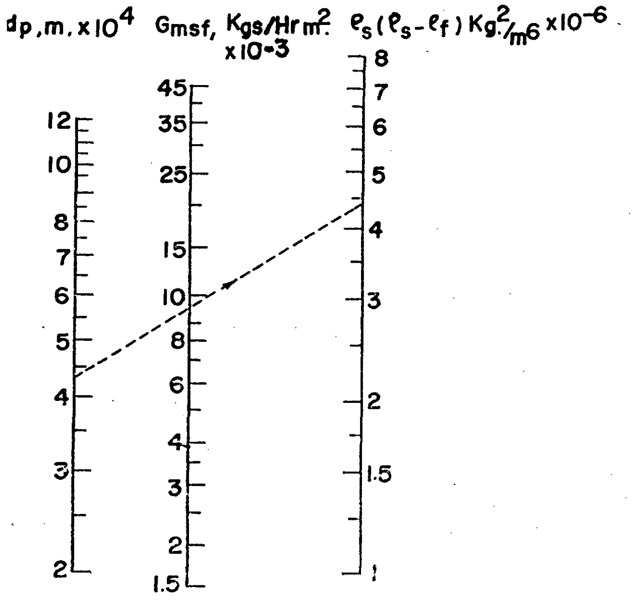


*Fig 1 Prediction of maximum semi-fluidization velocity*

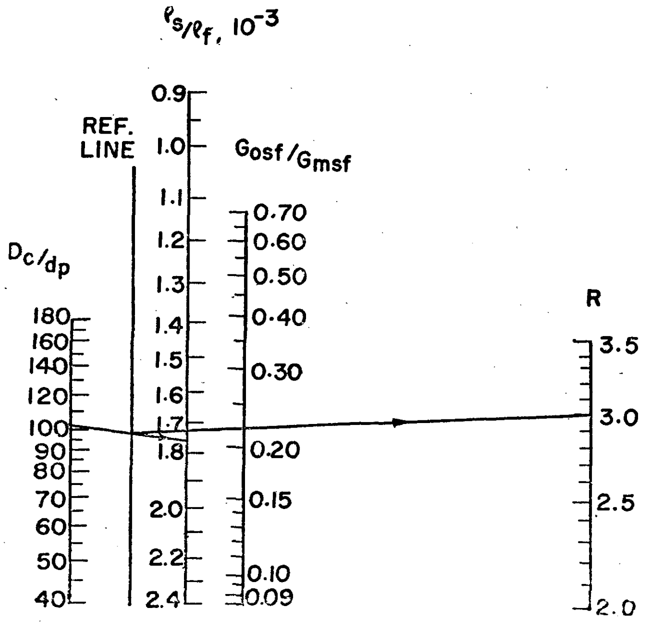


*Fig 2 Prediction of velocity ratio*

## ACCURACY OF THE NOMOGRAPHS

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

## EXAMPLE

*System*: *Table Salt-Air*

$D_c$ = 0.045 m

$d_p$ = 0.000 442 m

$P_s$ = 2 100 kg/m³

$\rho_f$ = 1.2 kg/m³

$\mu$ = 0.000 18 p

$R$ = 3.0

MAXIMUM SEMI-FLUIDIZATION VELOCITY

(i) From the equation

$$G_{msf} = 10\ 120 \text{ kg/hr } m^2$$

(ii) From the nomograph

$$G_{msf} = 9\ 600 \text{ kg/hr } m^2$$

(iii) From the experiment

$$G_{msf} = 10\ 500 \text{ kg/hr } m^2$$

MINIMUM SEMI-FLUIDIZATION VELOCITY

(i) From the equation

$$\frac{G_{osf}}{G_{msf}} = 48.0\left(\frac{0.045}{0.000\ 442}\right)^{0.38}\left(\frac{2\ 100}{1.2}\right)^{-1.05}(3.0)^{0.64} = 0.2\ 192$$

$$G_{osf} = 0.2\ 192 \times G_{msf} = 2\ 220 \text{ kg/hr } m^2$$

(ii) From experiment

$$G_{osf} = 2\ 275 \text{ kg/hr } m^2$$

(iii) From nomograph

$$\frac{G_{osf}}{G_{msf}} = 0.22$$

$$G_{msf} = 9\ 600 \text{ kg/hr } m^2 \text{ (Fig. 1)}$$

$$G_{osf} = 0.22 \times 9\ 600 = 2\ 112 \text{ kg/hr } m^2$$

## CONCLUSION

The values of minimum and maximum semi-fluidization velocities obtained from nomographs compare favourably well with the calculated and the experimental values. The deviations were less than 9 % (Tables 1 and 2).

TABLE 1 COMPARISON OF $G_{msf}$ VALUES

| Values of $G_{msf}$,-kg/hr m² | | | Percentage deviation of nomograph values | |
|---|---|---|---|---|
| Nomograph | Experimental | Calculated | From experimental value | From calculated value |
| 9 600 | 10 500 | 10 120 | —8.56 | —5.13 |

TABLE 2 COMPARISON OF $G_{osf}$ VALUES

| Values of $G_{osf}$,-kg/hr m² | | | Percentage deviation of nomograph value | |
|---|---|---|---|---|
| Nomograph | Experimental | Calculated | From experimental value | From calculated value |
| 2 112 | 2 275 | 2 220 | —7.17 | —4.86 |

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