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SHORT COMMUNICATION

Packed and Fluidized Bed Pressure Drops In Non-Cylindrical Conduits

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Abstract- With the help of Ergun's equation packed and fluidized bed pressure drop equations are formulated for square, semi-cylindrical and hexagonal conduits based on experimental data.

Theoretical Analysis

Ergun equation (l) can be written in general form for cylindrical conduits as.

$$\frac{\Delta P}{L}\frac{\varepsilon^3\phi_s d_p}{\rho u^2(1-\varepsilon)} = \frac{K_1(1-\varepsilon)}{N_{Re}} + K_2 = f_u \qquad (1)$$

At low Reynolds numbers, K, is neglected (Kozeny-carman equation) and K is obtained as intercept by plotting experimental data of f_u versus $N_{Re}/(l-\varepsilon)$ on log-log coordinates. The values of constant K_1 obtained for various conduits and particle shapes are listed in the paper (Table-1).

Table - 1 : Experimental K_1 values

Bed Configuration	Particle Shape	K_1
Cylindrical	Spherical	150
Cylindrical	Non-spherical	150
Hexagonal	Spherical	200
Hexagonal	Non-spherical	150
Square	Spherical	300
Square	Non-spherical	150
Semi-cylinder	Spherical	250
Semi-cylinder	Non-spherical	150

Ergun equation can also be put in the form as,

$$\frac{\Delta P}{L_u}\frac{\phi_s^2 d_p^2 \varepsilon^3}{u(1-\varepsilon)^2} = K_1 + K_2\frac{N_{Re}}{(1-\varepsilon)} = f_v \qquad (2)$$

At high Reynolds number, K_1 is neglected (Burke-Plummer equation) and K_2 is obtained as intercept by plotting experimental data of f_v versus $N_{Re}/(l-\varepsilon)$ on log-log coordinates (3). The values of constant K_2 obtained for various conduits and particle shapes are listed in this paper (Table 2).

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Table - 2 : Experimental K_2 values

Bed Configuration	Particle Shape	K_2
Cylindrical	Spherical	2.5
	Non-spherical	3.5
Hexagonal	Spherical	3.0
	Non-spherical	3.5
Square	Spherical	4.5
	Non-spherical	3.5
Semi-cylindrical	Spherical	3.5
	Non-spherical	3.5

Experimental Section

The cylindrical and all the non-cylindrical beds viz. the semi-cylindrical, square and hexagonal ones were made of transparent acrylic resin so that the solids behaviour could be observed clearly. For proper distribution of air a calming section packed with glass beads was used at the entrance of column. Above the glass beads, a copper screen of 48 mesh was used.

The dimensions of the beds employed, properties of the beds and the fluidized particles are listed elsewhere (4). Ambient air (approximately at 30°C) dehydrated through silica gel tower was used as the medium. The flow rate was measured by a rotameter and the pressure drop by a manometer. The grid pressure drop was found to be negligible.

A known weight of the particles was poured into the bed. The loading of particles for each experiment ranged from 0.5 to 1.5 kg. The values of fluid velocity and bed pressure drop were recorded, first for the packed bed and later for the fluidized bed regime. The shape factor was determined using the following equation (2),

$$\frac{\Delta P}{L} = Ku(1-\varepsilon)^2 / (d_p\phi_s)^2\varepsilon^3 \qquad (3)$$

Results and Discussion

The experimental data of f_u versus $N_{Re}/(l-\varepsilon)$ and f_v versus $N_{Re}/(l-\varepsilon)$ are shown in Figures l and 2 respectively for semi-cylindrical bed. Similarly, plots were made for other conduits also.

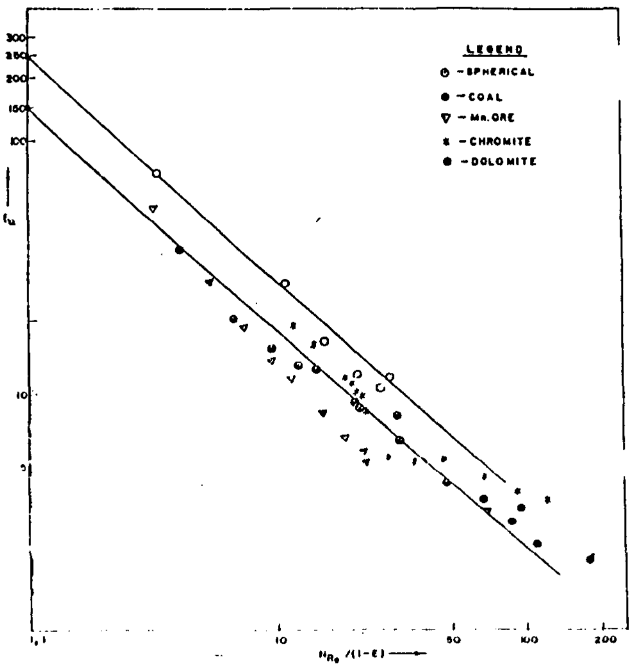

Fig. 1 : f_u vs $N_{Re}/(1-\epsilon)$ for semicylindrical bed

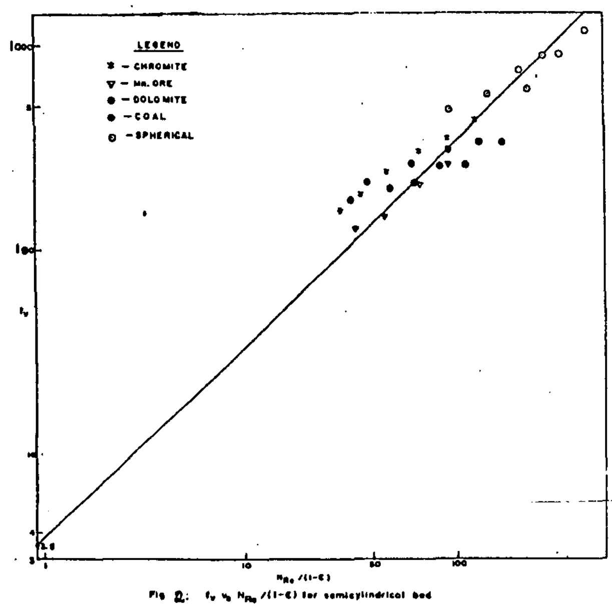

Fig. 2: f_v vs $N_{Re}/(1-\epsilon)$ for semicylindrical bed

The constant (K_1) in case of fixed bed obtained for different conduits and shapes of particles are listed in Table-I. The constant (K_2) obtained for fluidized bed in case of different conduits and shapes of particles are listed in Table -2.

It is observed that the values of constant is independent of the shapes of conduit and remain unchanged for non-spherical particles. On the other hand, for spherical bed materials, the values of the constant increase steadily from cylindrical to square bed through hexagonal and semi-cylindrical ones. Bed pressure drop in packed condition is primarily dependent on function of sphericity $(1/\phi_s^2)$ and porosity $(1-\varepsilon)^2/\varepsilon^3$ for non-spherical particles, while it depends on porosity function, $(1-\varepsilon)^2/\varepsilon^3$ only for the non-spherical particles. The effect of above two functions neutralized each other for non-spherical particles thereby giving a single numerical constant for all the four different bed configurations. On the other hand, the effect of porosity function becomes predominant in case of spherical particles (the effect of sphericity function being absent) resulting in varied numerical constants for different bed configurations depending on their respective fixed bed porosity. A similar explanation may also be valid for a single numerical constant obtained in case of non-spherical particles and varied numerical Constants for spherical particles for fluidized bed pressure drop in beds of different geometry.

The mean and standard deviations between the experimental and calculated values of packed and fluidized bed pressure drops for various conduits are presented in Table 3 and 4 respectively. Thus the modified (i.e. with modified numerical constants) Kozeny-Carman and Burke - Plummer equations can used with fairly good accuracy lor the prediction of pressure drop in the packed and fluidized beds respectively for non-cylindrical conduits.

Table - 3 : Mean and Standard Deviations for Packed Bed Pressure Drop

Bed Configuration	Particle shape	No. of observation	Mean Deviation.%	Standard Deviation.%
Cylindrical	Spherical	6	21.36	4.95
	Non-spherical	30	10.35	18.33
Hexagonal	Spherical	23	15.18	27.55
	Non-spherical	36	13.97	28.49
Square	Spherical	7	11.41	21.34
	Non-spherical	16	16.59	23.24
Semi-cylinder	Spherical	30	12.83	18.87
	Non-spherical	26	12.11	11.94

Table - 4 : Mean and Standard Deviation for Fluidized Bed Pressure Drop

Bed Configuration	Particle Shape	No.of Observation.	Mean Deviation.%	Standard Deviation.%
Cylindrical	Spherical	4	4.49	10.67
	Non-spherical	32	17.11	27.42
Semi-cylinder	Spherical	—	—	—
	Non-spherical	23	14.21	21.37
Hexagonal	Spherical	23	12.72	24.19
	Non-spherical	24	16.57	31.11
Square	Spherical	4	11.98	27.69
	Non-spherical	29	17.71	30.05

Nomenclature

d_p – Particle diameter, m

f_u, f_v – Modified friction factors for packed

		bed and fluidized bed respectively.
K, K_1, K_2	=	Constants
L	=	Length of bed, m
ΔP	=	Pressure drop
N'_{Re}	=	Reynolds number
u	=	Superficial fluid velocity measured at average pressure, m/s

Greek Letters

ε	=	Porosity of bed
ϕ_s	=	Sphericity factor
ρ	=	Density of fluid, kg/m^3
μ	=	Viscosity of fluid, kg/m.s.

References

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