Properties and Handling of particulate Solids

- The small particle is the most important on chemical engineering standpoint of all

- An understanding of the characteristics of masses of particulate ~~matter~~ solids is necessary in designing processes and equipment for dealing with streams containing such solids

Characterization of solid particles

- solid particles characterized by size, shape & density

- Homogeneous solids have the same density as the bulk material.

- particles obtained by breaking up a composite solid, such as metal ore, have various densities, usually different from the density of the bulk material.

- Size and shape are easily specified for regular particles, such as spheres and cubes,

- for irregular particles (sand grains or mica flak the terms size and shape are not so clear must be arbitrarily defined.

[Flow through bed of solids]

particle shape:-

Sphericity ϕ_s = Surface-volume ratio for a sphere of dia D_p / Surface-volume ratio for the particle whose nominal size is D_p

$$\phi_s = \frac{6/D_p}{S_p/v_p}$$

$$S_p = \pi D_p^2 \qquad v_p = \frac{1}{6}\pi D_p^3$$

$$\boxed{\frac{S_p}{v_p} = \frac{6}{\phi_s D_p}}$$

Sphericity of miscellaneous materials

Material	sphericity
Sphere, cubes, short cylinder ($L \doteq D_p$)	1.0
Rasching Ring ($L = D_p$)	
$L = D_o$, $D_i = 0.5 D$	0.58
$L = D_o$, $D_i = 0.75 D_o$	0.33
Berl Saddle	0.3
Ottawa Sand	0.95
Rounded sand	0.83
Coal Dust	0.73
Flint Sand	0.65
Crushed glass	0.65
Mica flak	0.28

Although cubes and short cylinders have same sphericity of 1.0, they have more surface area than spheres of the same volume.

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The shape of individual particle is commonly expressed in term of sphericity ϕ_s, which is independent of size.

for a spherical particle of diameter D_p, $\phi_s = 1$; for a non spherical particle the sphericity is defined by the relation

$$\phi_s = \frac{6/D_p}{S_p v_p}$$

D_p = nominal diameter of pipe
S_p = Surface area of one particle
v_p = volume of one particle.

Equivalent Diameter:- The diameter of a sphere of equal volume.

→ For fine granular materials, it is difficult to determine the exact volume and surface area of the particle, and D_p is usually taken to be the nominal size based on screen analyses or microscopic examination

→ The surface area may be found from the pressure drop in the bed of particles

for non porous ~~mat~~ particles, from adsorption measurements used to calculate ϕ_s.

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particle size:-

Diameter — For equidimensional particle

Coarse particles : inches / millimeters
Fine particle : screen size
Very fine particle : micrometers / nanometers
Ultrafine particle : surface area / unit mass (m^2/g)

Mixed particle sizes and size Analysis:-

→ In a sample of uniform particles of diameter D_p the total volume of the particles is m/ρ_p,

$m \rightarrow$ mass of the sample
$\rho_p \rightarrow$ Density of the particles

volume of one particle V_p

The no. of particle in sample 'N' :

$$N = \left(\frac{m}{\rho_p}\right) / V_p$$

$$N = \frac{m}{\rho_p V_p}$$

Total surface area of the particle

$$A = N S_p = \frac{6m}{\Phi_s \rho_p D_p}$$

$$= \frac{m}{\rho_p V_p} \times \frac{6 V_p}{\Phi_s D_p} = \frac{6m}{\Phi_s D_p \rho_p}$$

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Specific surface of mixture

particle density ρ_p, sphericity ϕ_s are known

specific surface

$$A_w = \frac{6x_1}{\phi_s \rho_p \bar{D}_{p1}} + \frac{6x_2}{\phi_s \rho_p \bar{D}_{p2}} + \cdots \frac{6x_n}{\phi_s \rho_p \bar{D}_{pn}}$$

If ρ_p & ϕ_s are const

$$= \frac{6}{\phi_s \rho_p} \sum_{i=1}^{n} \frac{x_i}{\bar{D}_{p_i}}$$

x_i = mass fraction in a given increment
n = number of increment
$\bar{D}_{p_i}$ = average particle diameter [Arithmetic average of smallest and largest particle diameter in increment]

Average particle size:

Volume surface mean diameter

$$\bar{D}_s = \frac{6}{\phi_s A_w \rho_p}$$

$$\bar{D}_s = \frac{1}{\sum_{i=1}^{n} (x_i/\bar{D}_{p_i})}$$

If N_i (no. of particles) is known instead of mass fraction

Arithmetic Mean Diameter

$$D_N = \frac{\sum_{i=1}^{n} (N_i \bar{D}_{p_i})}{\sum_{i=1}^{n} N_i} = \frac{\sum_{i=1}^{n} (N_i \bar{D}_{p_i})}{N_T}$$

N_T → No. of particles in entire sample.

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~~Mass mean~~ diameter

$$\bar{D}_w = \sum_{i=1}^{n} x_i \bar{D}_{pi}$$

Average volume of a particle

$$= \frac{\text{Total volume of sample}}{\text{no. of particles in the mixt}}$$

volume mean diameter $\bar{D}_v$

$$\bar{D}_v = \left[\frac{1}{\sum_{i=1}^{n} (x_i / \bar{D}_{pi}^{-3})} \right]^{1/3}$$

Number of particles in mixture

volume is proportional to its diameter cub

$$v_p = a D_p^3$$

↑ volume shape factor

N_w → total population in one mass unit

'a' is independent of size

$$N_w = \frac{1}{a f_g} \sum_{i=1}^{n} \frac{x_i}{\bar{D}_{pi}^3} = \frac{1}{a f_g \bar{D}_v^{-3}}$$

$$N_w = \frac{1}{a f_g D_p^3}$$

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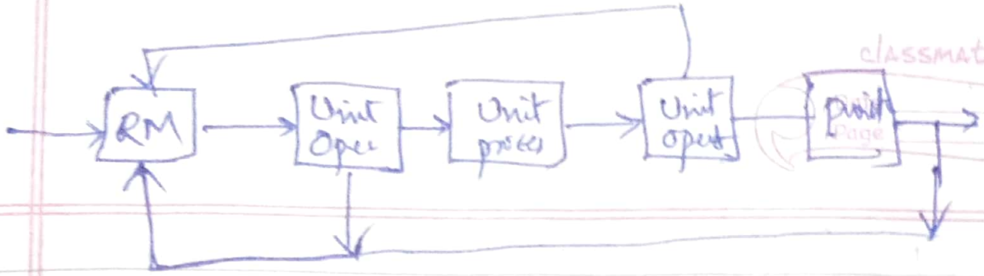

Unit operations :- 1) Mechanical operations ;- size reduction, conveying, filtration etc

2) Fluid flow operations in which pressure diff acts as driving force

3) Heat Transfer in which Temp. differen acts as a driving force eg. evaporation

4) Mass Transfer in which the concn diff acts as a driving force : distillation

→ Unit operations of chemical Engineering are directed towards separating a substance into its component parts.

→ For heterogeneous mixtures, such separations may be entirely mechanical, eg. the separation of solid particles according to their size or the filtration of a solid from a suspension in a liquid.

Many unit operations involve unit operation particulate solids as well as fluids. In many cases, the solids are an integral part of the material being processed/treated.

Ex: Feeding pulverized coal (in air) to a burner

→ Mechanical operations involving particulate solids are

1) Size reduction – crushing and grinding

2) Mixing solid-solid, liquid-liquid, solid-liquid

3) classification – Screening, froth flotation, magnetic separation, electrostatic separation, jigging, tabling and wet classification

4) solid-fluid separation – filtration, sediment and centrifugal separation

5) Gas-solid separation – Dust collection, bag filtration, electrostatic precipitation

6) Solid handling – storage, feeding and conveying

7) Size enlargement – Pelletization, agglomeration, granulation and extrusion

Mechanical Separations:- For heterogeneous mixture

1) Separation of solids from solids

2) Separation of solids from solids in liquid

3) Separation of solids from liquids

4) Separation of solids or liquid drops from gases (5) separation of ... liquid