Particle Technology
Week 1

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Why Study Particle Technology?

Particulate materials, powders or bulk solids are used widely in all areas of the process industries:

Food Processing	Metallurgical
Pharmaceutical	Detergent
Biotechnology	Power Generation
Oil	
Chemical	
Mineral Processing	

Unit operations

Some examples of unit operations involving particles and powder:

- Crystallization
- Precipitation
- Granulation
- Spray Drying
- Tableting
- Extrusion
- Grinding

Fluids and Particle Technology

Difference between other process materials:

- Gases and liquids – properties are readily measured, tabulated, or calculated
- Particulate solids – properties depend on the particle size distribution, shape, surface properties, humidity of the atmosphere, state of compaction of the powder.

Particle Size Analysis

- In many powder handling and processing operations particle size and size distribution play a key role in determining the bulk properties of the powder.
- Describing the size distribution of the particles making up a powder is therefore central in characterizing the powder.

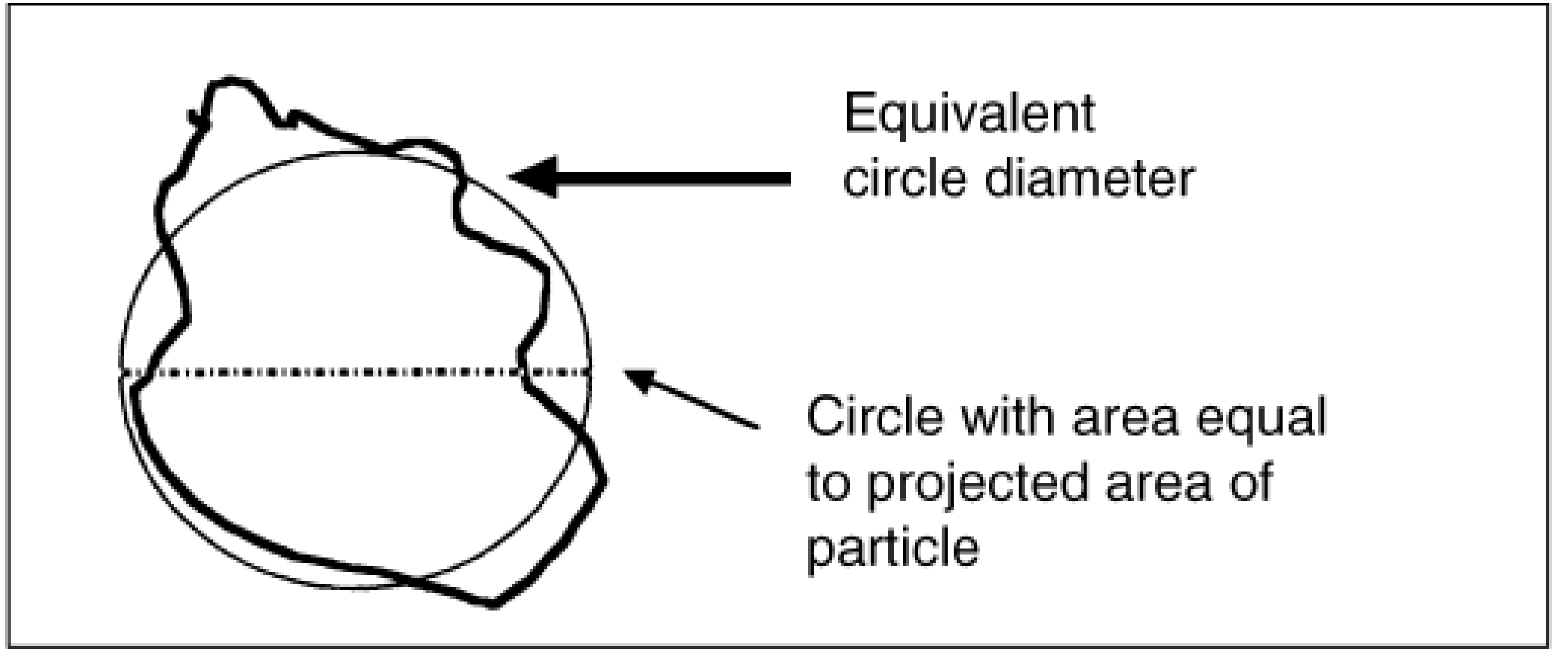
Describing the size of a single particle

Shape	Sphere	Cube	Cylinder	Cuboid	Cone
Dimension	Radius	Side Length	Radius and height	Three sides lengths	Radius and height

Irregular shaped particle

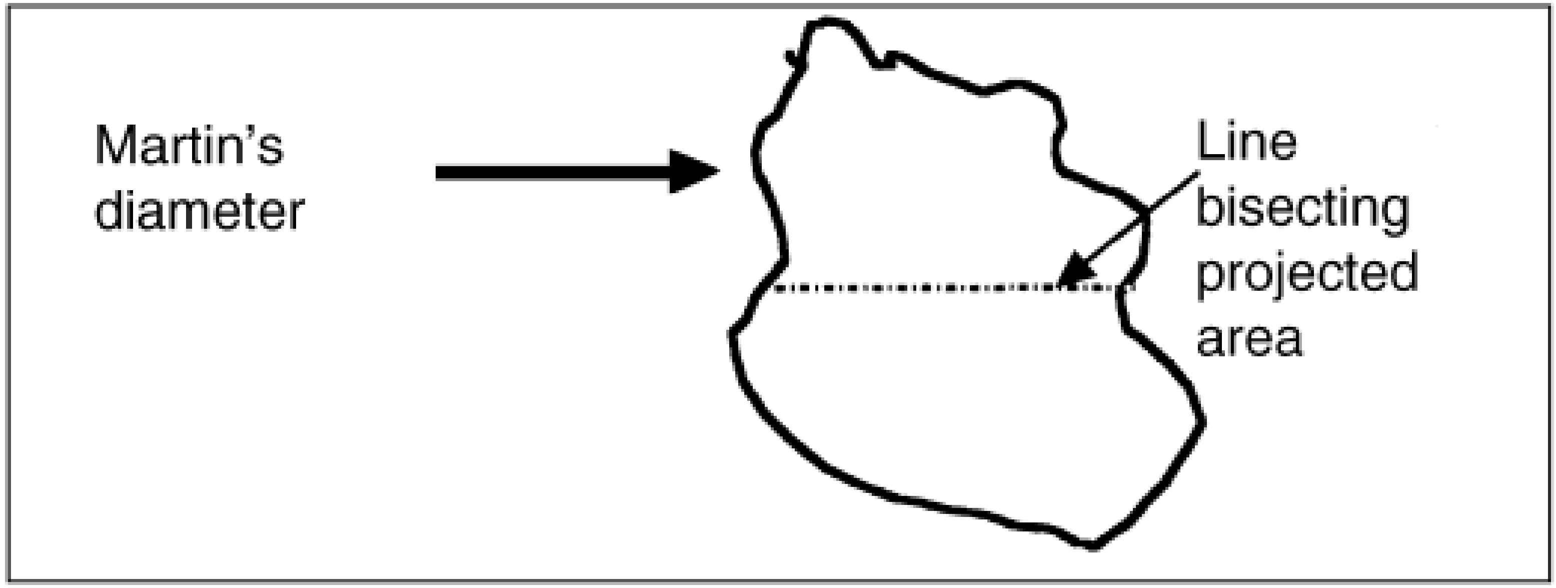
1. Equivalent circle diameter
2. Martin’s diameter
3. Feret’s diameter
4. Shear diameter

Equivalent Circle Diameter

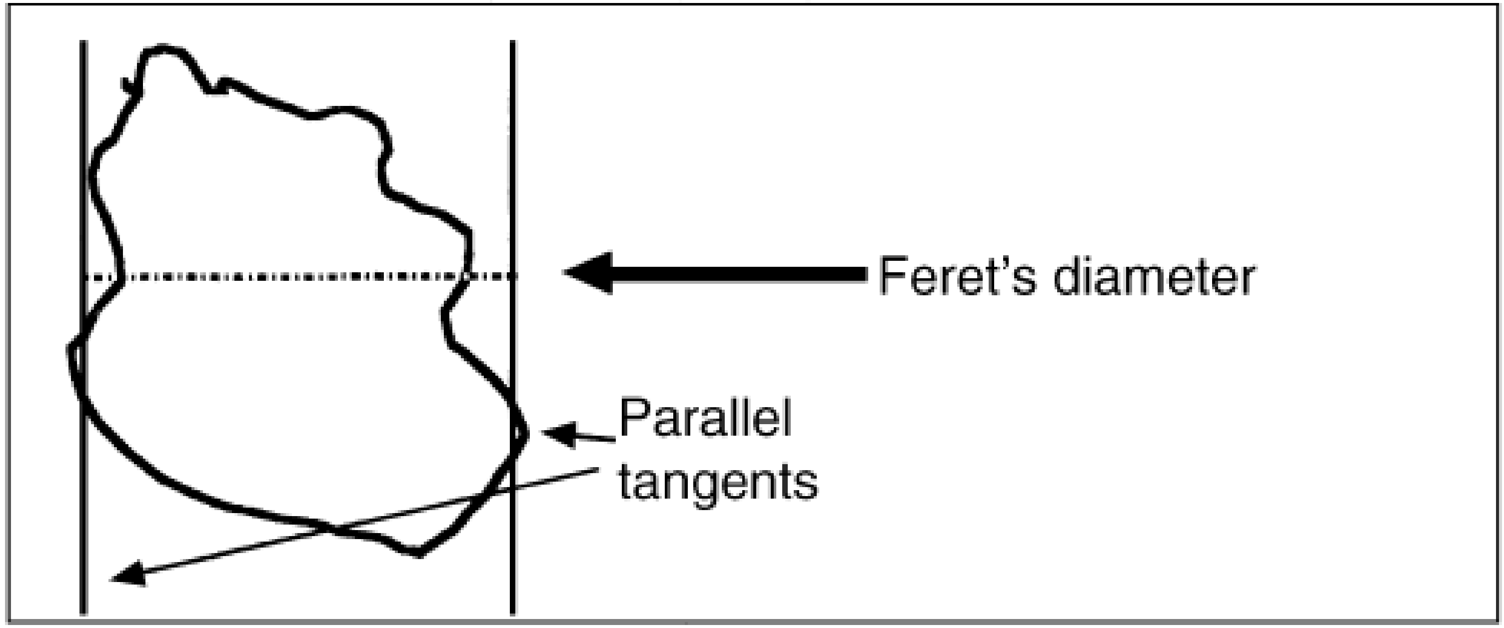


$$A = \frac{\pi}{4} d^2 \qquad d = \sqrt{\frac{4A}{\pi}}$$

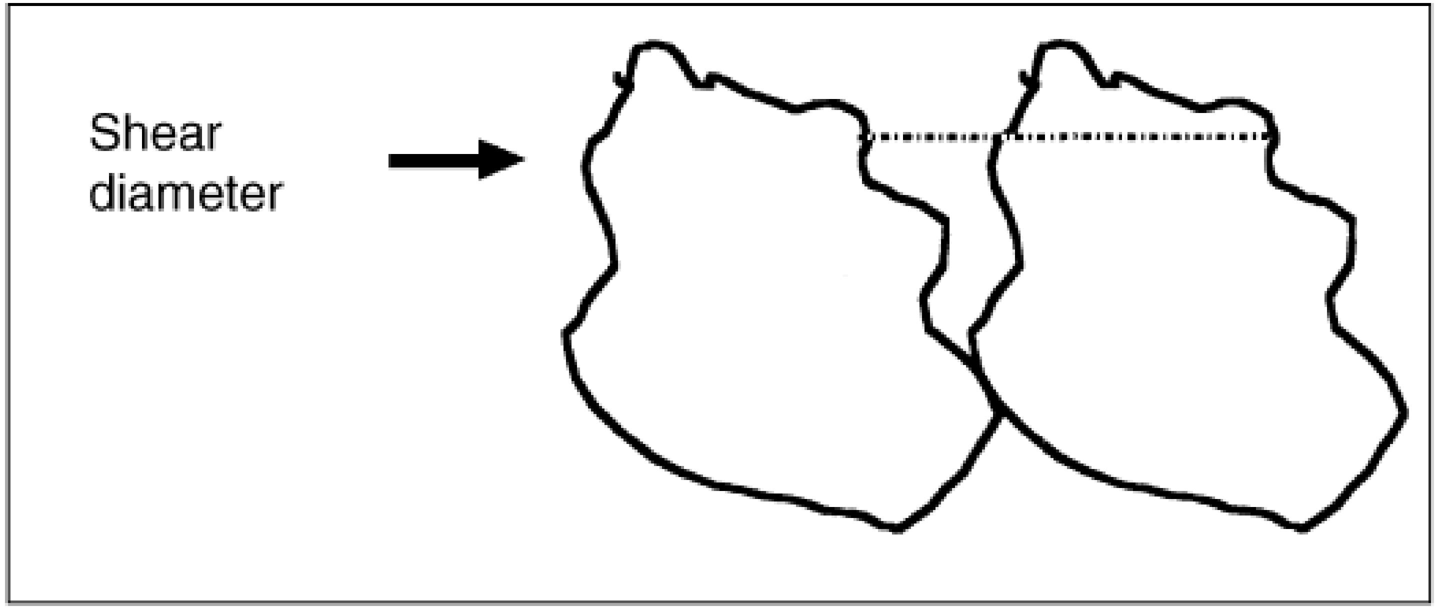
Martin’s Diameter



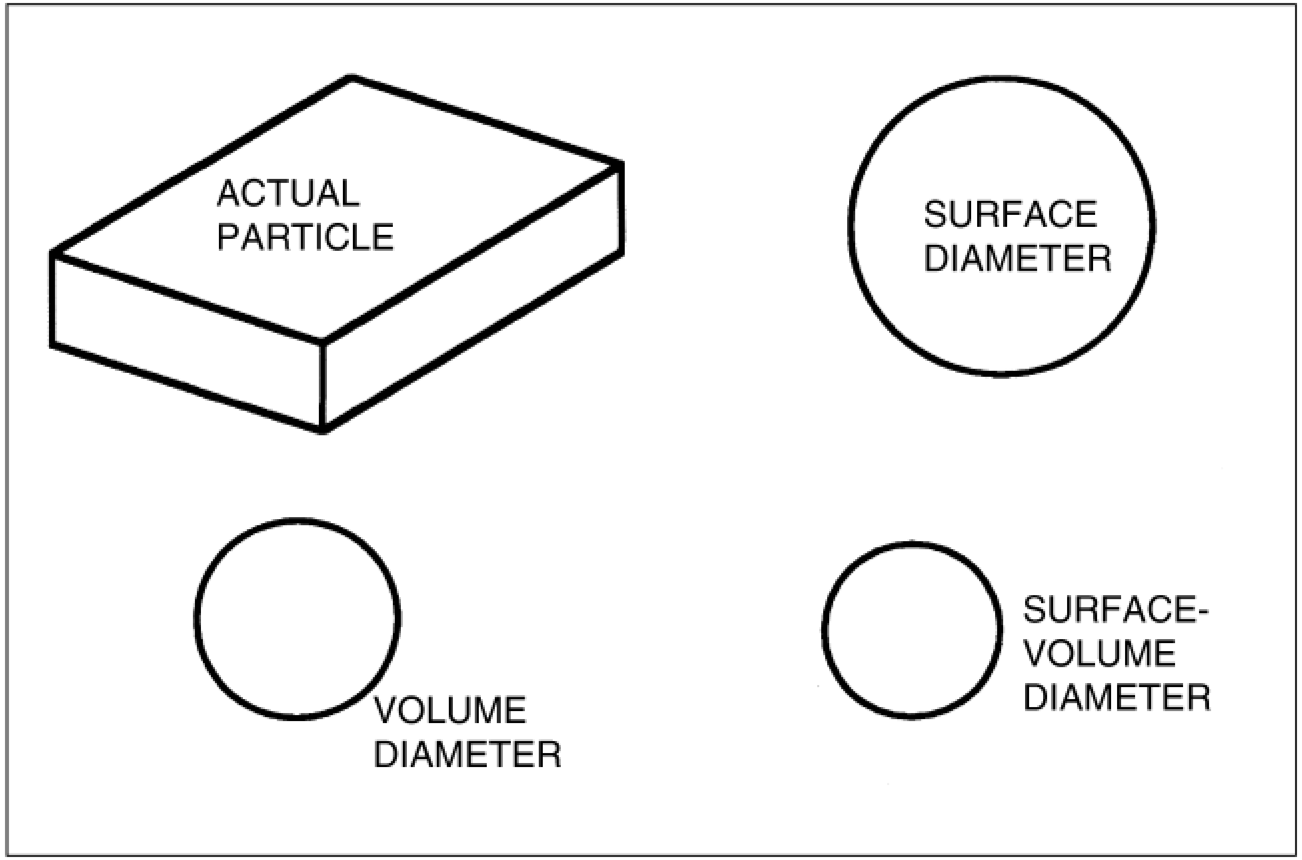
Feret's Diameter



Shear Diameter



Comparative Diameter



Example 1

Calculate the equivalent volume sphere diameter xv and the surface-volume equivalent sphere diameter x_{sv} of a cuboid particle of side length 1, 2, 4 mm.

The volume of cuboid = 1 x 2 x 4 = 8 mm^3

The surface area of the particle = (1x2)+(1x2)+(1+2+1+2)x4 = 28 mm^2

The volume of sphere of diameter x_v is $[\pi(x_v)^3] / 6$

Hence, diameter of a sphere having a volume of 8 mm^3; x_v = 2.481mm

The *equivalent volume sphere diameter* x_v of the cuboid particle is therefore

<u>x_v = 2.481mm</u>

Example 1

The surface to volume ratio of the cuboid particle = 28 / 8 = 3.5 mm^2 / mm^3

The surface to volume ratio for a sphere of diameter x_{sv} is therefore $6/x_{sv}$

Hence, the diameter of a sphere having the same surface to volume ratio as the particle = 6 / 3.5 = 1.714 mm

The surface-volume equivalent sphere diameter of the cuboid, x_{sv} = 1.714 mm

Specific Surface

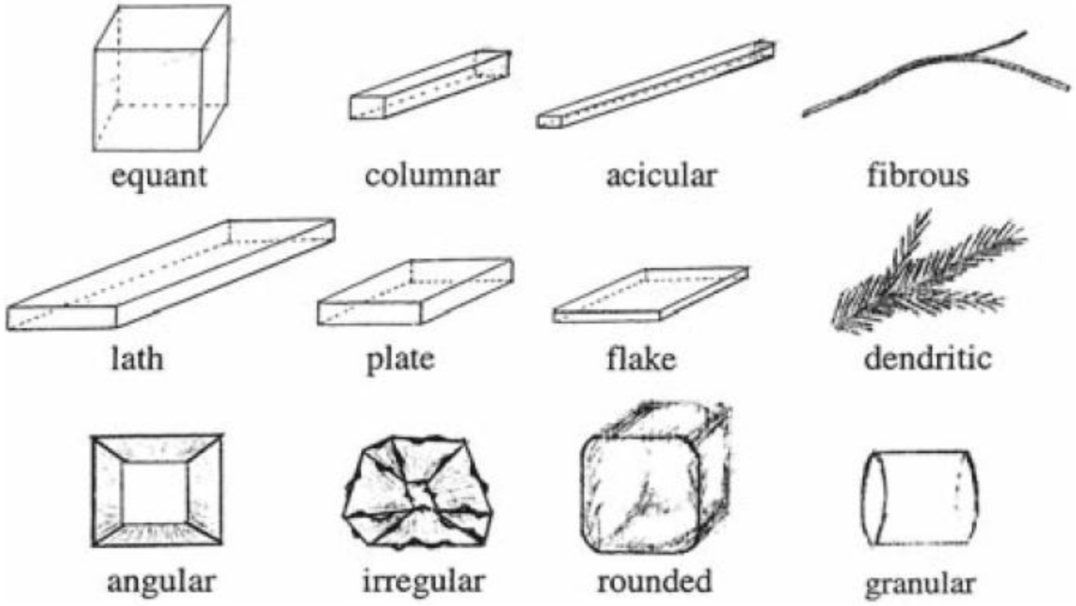
Specific surface is the surface area of the particle per unit volume

$$S_v = \frac{A_p}{V_p}$$

Particle Shape

Qualitative

BS 2955:1993



Particle Shape

Quantitative descriptors:

Elongation

Flakiness

Aspect Ratio

Chunkiness

Sphericity

Wadell Sphericity or Sphericity measures how closely a particle resembles a perfect sphere:

$$\Psi = \frac{A_s}{A_p} = \frac{\pi^{1/3}\left(6V_p\right)^{2/3}}{A_p}$$

Sphericity

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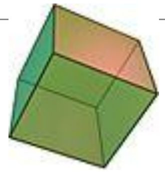
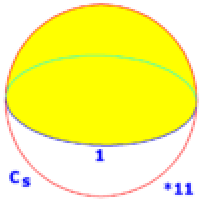
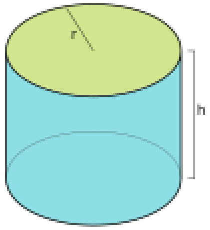


$$\left(\frac{\pi}{6}\right)^{\frac{1}{3}} \approx 0.806$$

$$\left(\frac{\pi}{6\sqrt{3}}\right)^{\frac{1}{3}} \approx 0.671$$



$$\left(\frac{16}{27}\right)^{\frac{1}{3}} \approx 0.840$$



$$\left(\frac{2}{3}\right)^{\frac{1}{3}} \approx 0.874$$

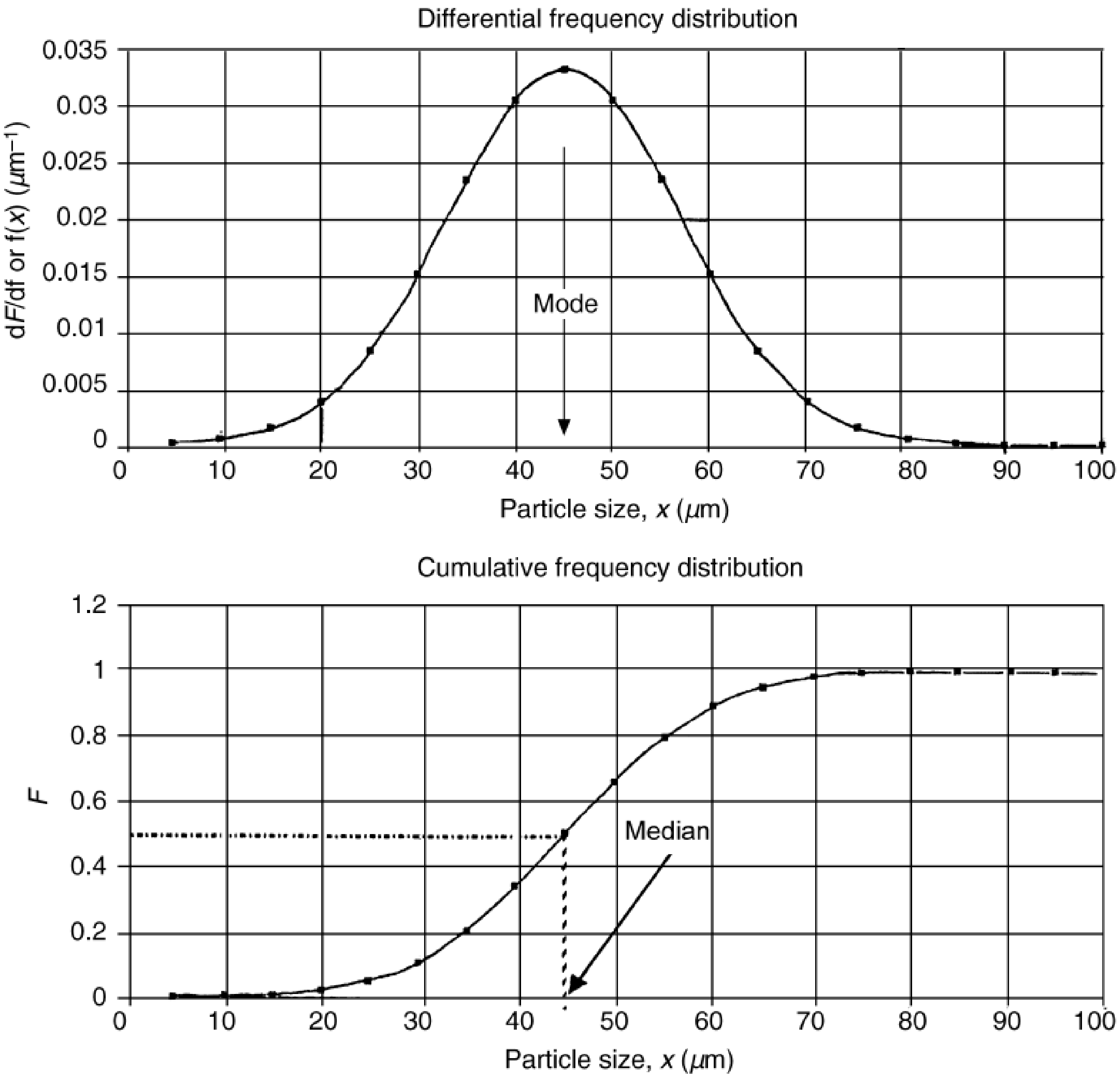
Particle Size Distribution

A collection of particles always shows a PSD, since there are always some deviations during their generation or production.

Sometimes, these deviations are small and all particles have nearly the same size

Particle Size Distribution

- Frequency Distribution (Differential Frequency Distribution)
- Cumulative Distribution (Cumulative Frequency Distribution)


Differential frequency distribution
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
dF/df or f(x) (μm⁻¹)
Mode
0 10 20 30 40 50 60 70 80 90 100
Particle size, x (μm)
Cumulative frequency distribution
1.2
1
0.8
0.6
0.4
0.2
0
F
Median
0 10 20 30 40 50 60 70 80 90 100
Particle size, x (μm)

Any questions?