جامعة الجزيرة الخاصة
ALJAZEERA PRIVATE UNIVERSITY

Powder flow

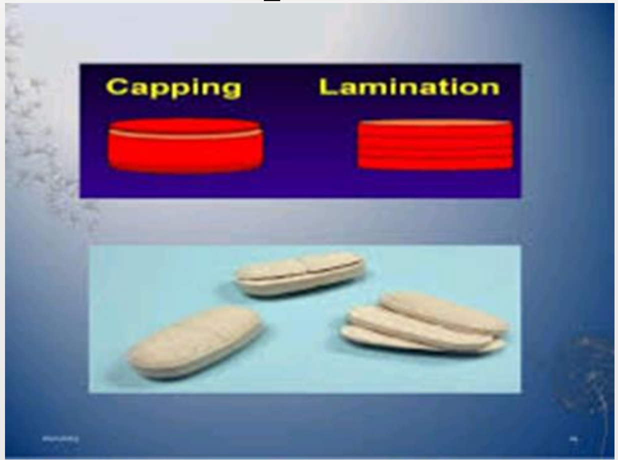
Importance of powder flow

- The largest use of powders pharmaceutically is to produce tablets and capsules.
- The flowability of a powder is of critical importance in the production of pharmaceutical dosage forms.
- Pharmaceutical powders should be of **good**, **rapid** and **regular** flowability, i.e. free flowing.

Importance of powder flow

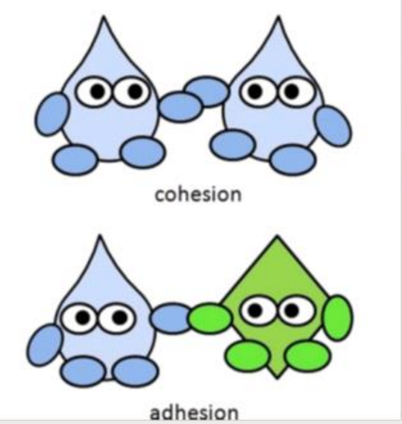
Some of the reasons for producing free-flowing pharmaceutical powders include:

1. Uniform feed from storage containers or machine hoppers into the tablet dies and capsule dosators, allowing uniform particle filling which maintains weight uniformity.
2. Uneven powder flow can result in excess entrapped air within powders, which may cause capping or lamination of tablets.
3. Flowability of powders also influences mixing.



Adhesion and Cohesion

- The presence of attractive forces produces a tendency for solid particles to stick to themselves (cohesion) and to other surfaces (adhesion).
- Cohesion occurs between like surfaces, such as component particles of a bulk solid.
- Adhesion occurs between two unlike surfaces, for example, between a particle and a hopper wall.
- Adhesion and cohesion are important factors that **can limit powder flow**.



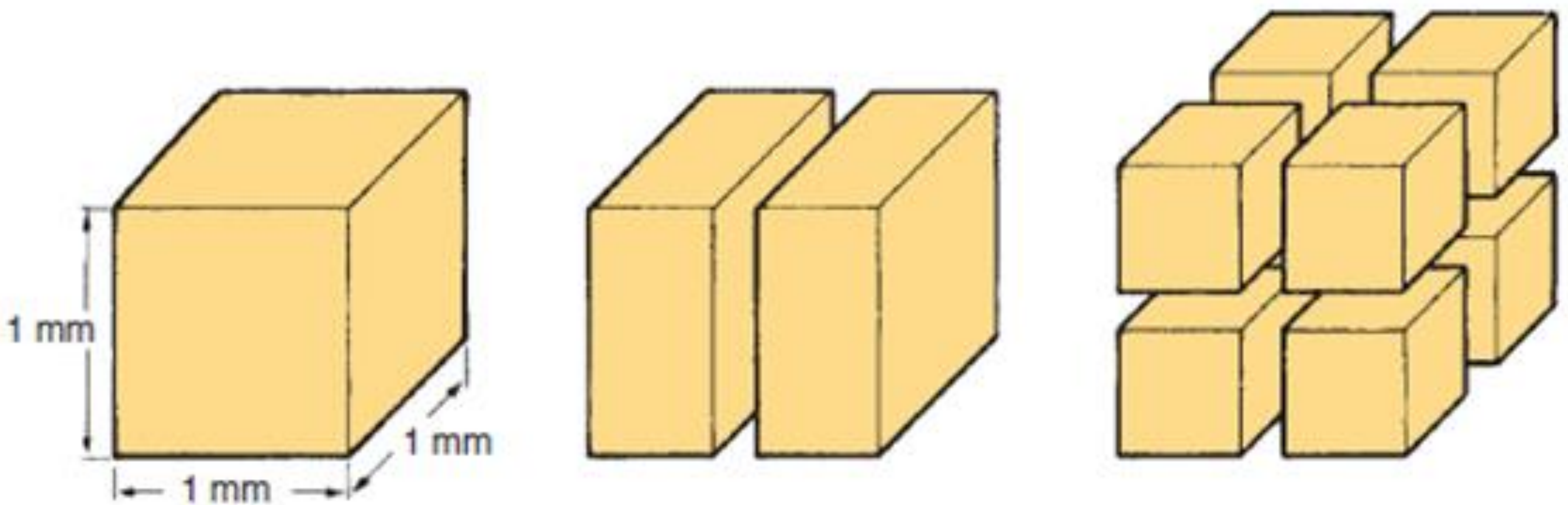
Factors affecting powder flow

- Most important factors affecting adhesion/cohesion and flow of powders:
  1. Particle size.
  2. Particle shape.
  3. Particle density.

Factors affecting powder flow

1. **Particle size**

- ❑ Attractive forces (responsible for adhesion and cohesion) occur at the surface of particles.
- ❑ In a batch of powder generally:
- ✓ the smaller the particle size → the greater the surface area per unit mass (specific surface area) → the greater the attraction forces between particles → higher adhesion/cohesion.



Volume	1 mm^3	1 mm^3	1 mm^3
No of pieces	1	2	8
Total surface area	6 mm^2	8 mm^2	12 mm^2

As the particle size decreases the specific surface area increases.

Factors affecting powder flow

1. **Particle size**

- Particles larger than 250 micron are usually relatively free flowing,
- Particles below 100 micron powders become cohesive and flow problems are likely to occur.
- Powders having a particle size less than 10 micron are usually extremely cohesive and resist flow under gravity.

Factors affecting powder flow

2. **Particle shape**

- ❑ Powders with similar particle sizes but dissimilar shapes can have different flow properties.
- ❑ This is due to differences in interparticle contact areas.

For example:

- ✓ a **group of spheres** has minimum interparticle contact and generally optimal flow properties,.
- ✓ a **group of particle flakes** has a very high surface-to-volume ratio and poorer flow properties.

Factors affecting powder flow

2. **Particle shape**

- Moreover, in addition to adhesional and cohesional forces, irregularly shaped particles may experience mechanical interlocking.

Factors affecting powder flow

3. **Particle density**

- Given particles of the same size and shape, dense particles are generally less cohesive than less dense particles.

- This is because powders normally flow under the influence of gravity. Therefore particles of the same size and shape having the same surface area but different density (and therefore mass) tend to have different flow properties:

  - ✓ the more dense particle will flow better than the less dense.

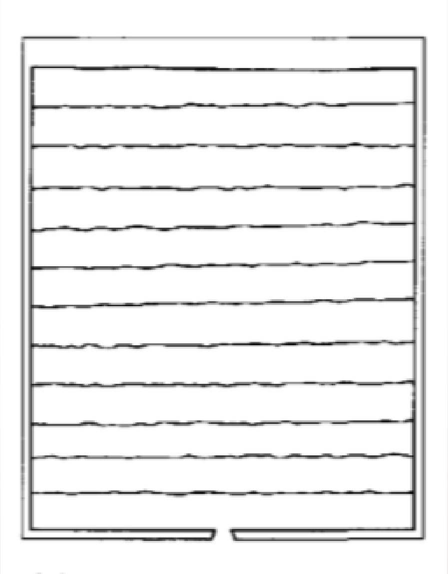
Flow through an orifice

- In the manufacture of pharmaceutical solid dosage forms, there are many examples of flow of powders through an orifice.
  - ✓ For example when granules or powders flow through the opening in a hopper used to feed powder to tabletting machines, capsule-filling machines or sachet-filling machines.
- Efficient flow through an orifice is important in producing unit doses containing the same or very similar powder masses. Therefore, the behaviour of particles being fed through orifices has been extensively studied.


CAPSULE FILLING MACHINE

Flow through an orifice

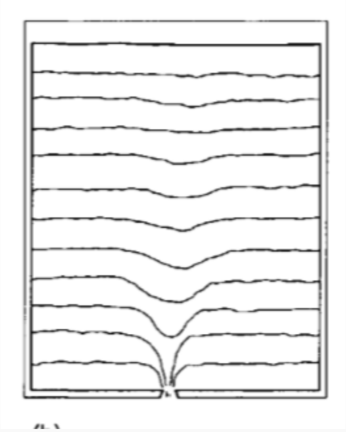
- A hopper can be modelled as a tall cylindrical container having a closed orifice in the base and initially full of a free-flowing powder.



Flow through an orifice

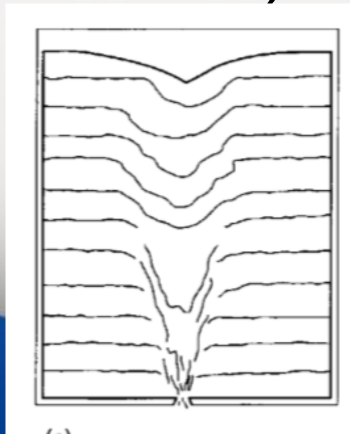
1. On opening the orifice there is no instantaneous movement at the surface, but particles just above the orifice fall freely through it (a)

(a)

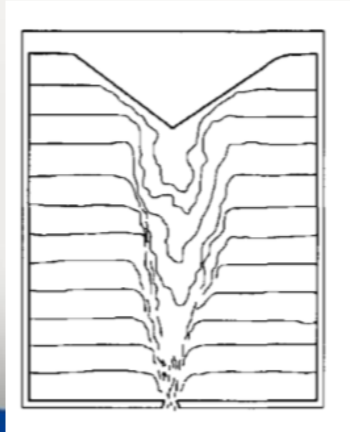


2. A depression forms at the upper surface and spreads outwards to the sides of the hopper (b1 and b2).

(b1)



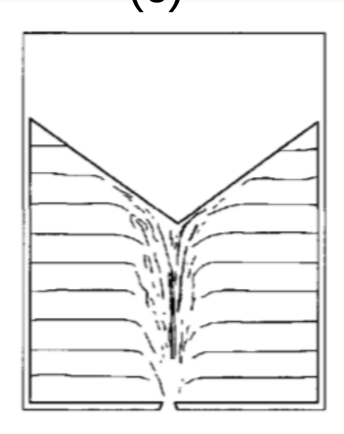
(b2)

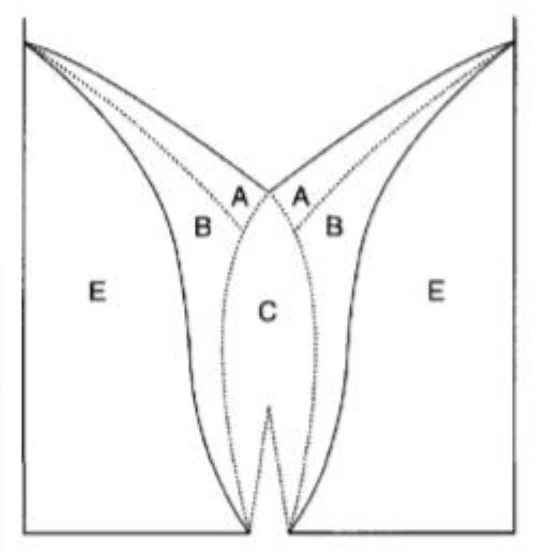


Flow through an orifice

3. Provided that the container is tall and not too narrow, the flow pattern illustrated (c) is rapidly established.

(c)





- ✓ Particles in zone E, remain stationary.
- ✓ Particles in zone A slide rapidly over the slower moving particles in zone B, The particles in zone A feed into zone C, where they move quickly downwards and out through the orifice.
- ✓ The more slowly moving particles in zone B do not enter zone C.
- ✓ Both powder streams in zones B and C converge just above the orifice, from where they exit.

Flow through an orifice

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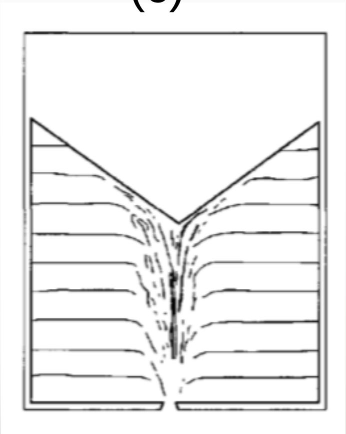
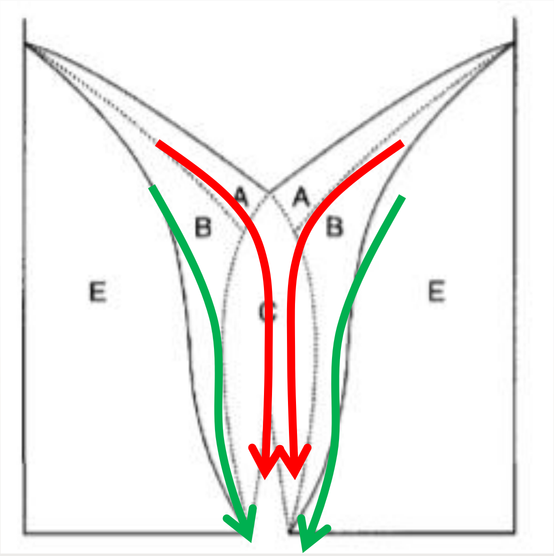
(c)





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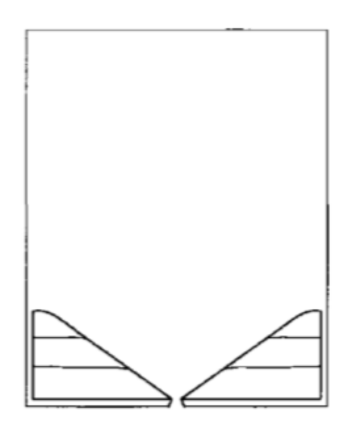
Flow through an orifice

- Important practical consequences of this flow pattern are that if a square-bottomed hopper is repeatedly refilled and partially emptied, the particles in a zone towards the base and sides of the container will not be discharged (d).

(d)



- Thus process hoppers are designed to have a conical lower section, in effect eliminating zone E.

Flow through an orifice

Factors affecting flow rates through orifices

- Powder flow rates through orifices, are dependent on many different factors, some of which are particle related[1] (described before) and some process related[2].
- The most important **process related parameter** is:
  - ✓ Orifice diameter. The larger the orifice, the faster the flow.

Flow through an orifice

Factor not influencing flow rates through orifices

- Provided that the height of the powder bed, called the head of powder, remains considerably greater than the orifice diameter, flow rate is virtually independent of powder head.
- This situation is unlike that relating to liquid flow through an orifice, where the flow rate falls off continuously as the head diminishes.
- **This constant rate of flow for powders means** that if a bulk powder is filled into dies, sachets, capsules or other enclosures, they will receive equal weights if filled for equal times.

Characterization of powder flow

Many different methods have been developed to describe and quantify flow properties of powders.

These includes **indirect methods**:

1. Angle of repose.
2. Measurements based of bulk and tapped density.
3. Critical orifice diameter.

and **direct methods**:

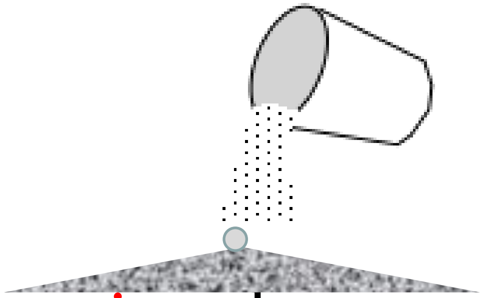
4. Hopper flow rate.
5. Recording flowmeter.

Characterization of powder flow

1. Angle of repose - principles

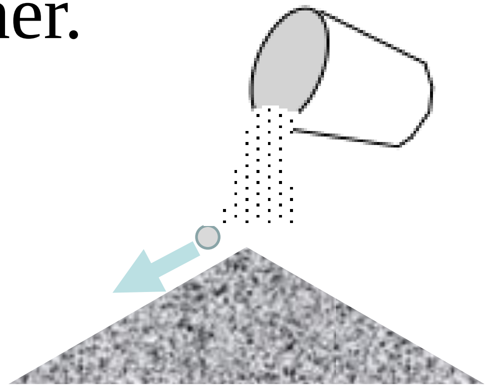
A powder poured from a container on to a horizontal surface forms a heap:

1. Initially the particles stack



- ✓ Cohesive forces greater than gravitational forces due to angle of inclination.
- ✓ Any added particle does not slide down.

2. At some point, the approach angle for subsequent particles joining the stack is large enough to overcome cohesive forces, and the particles slip and roll over each other.



- ✓ Cohesive forces smaller than gravitational forces due to angle of inclination.
- ✓ Added particle slides down.

Characterization of powder flow

1. Angle of repose - principles

- The sides of the heap formed in this way make an angle with the horizontal surface which is called the angle of repose and is a characteristic of the cohesion of the particles.

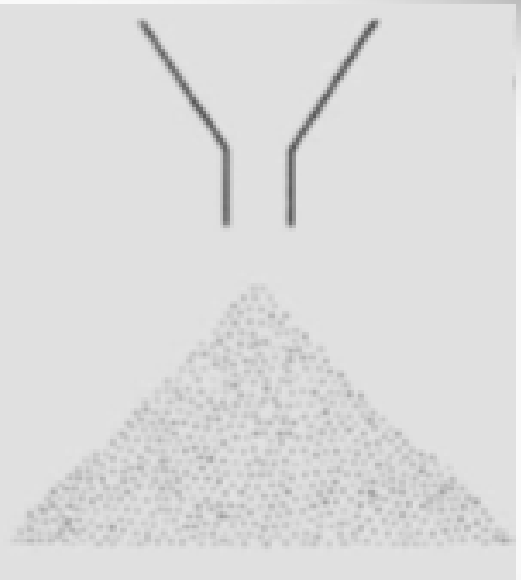
- The value of the angle of repose will be high if the powder is cohesive and low if the powder is non-cohesive.

Characterization of powder flow

1. Angle of repose – method of measurement

- There are different methods to measure the angle of repose.

✓ One of the most commonly used consists in pouring the powder from a funnel at a fixed height and then measuring the angle of repose.



- It is possible to correlate the angle of repose obtained with the flow properties of the powder.

Flow Character	Angle of Repose
Excellent	25-30°
Good	31-35°
Fair	36-40°
Passable	41-45°
Poor	46-55°
Very Poor	56-65°
Very, Very Poor	≥66°

Characterization of powder flow

2. Measurements based on bulk and tapped density

Bulk density

- ✓ The bulk density of a powder is the ratio of the mass of an untapped powder sample and its volume including the contribution of the interparticulate void volume.

Tapped density

- ✓ The tapped density is an increased bulk density obtained after mechanically tapping a container containing the powder sample.

Characterization of powder flow

2. Measurements based on bulk and tapped density

Correlation with powder flow

- Interparticulate interactions influence in the same way:
  - ✓ the bulking properties of a powder.
  - ✓ the powder flow.
- A comparison of the bulk and tapped densities can give a measure of the relative importance of these interactions in a given powder.
- Therefore comparison of bulk and tapped density are often used as an index of the ability of the powder to flow.

Characterization of powder flow

2. Measurements based on bulk and tapped density

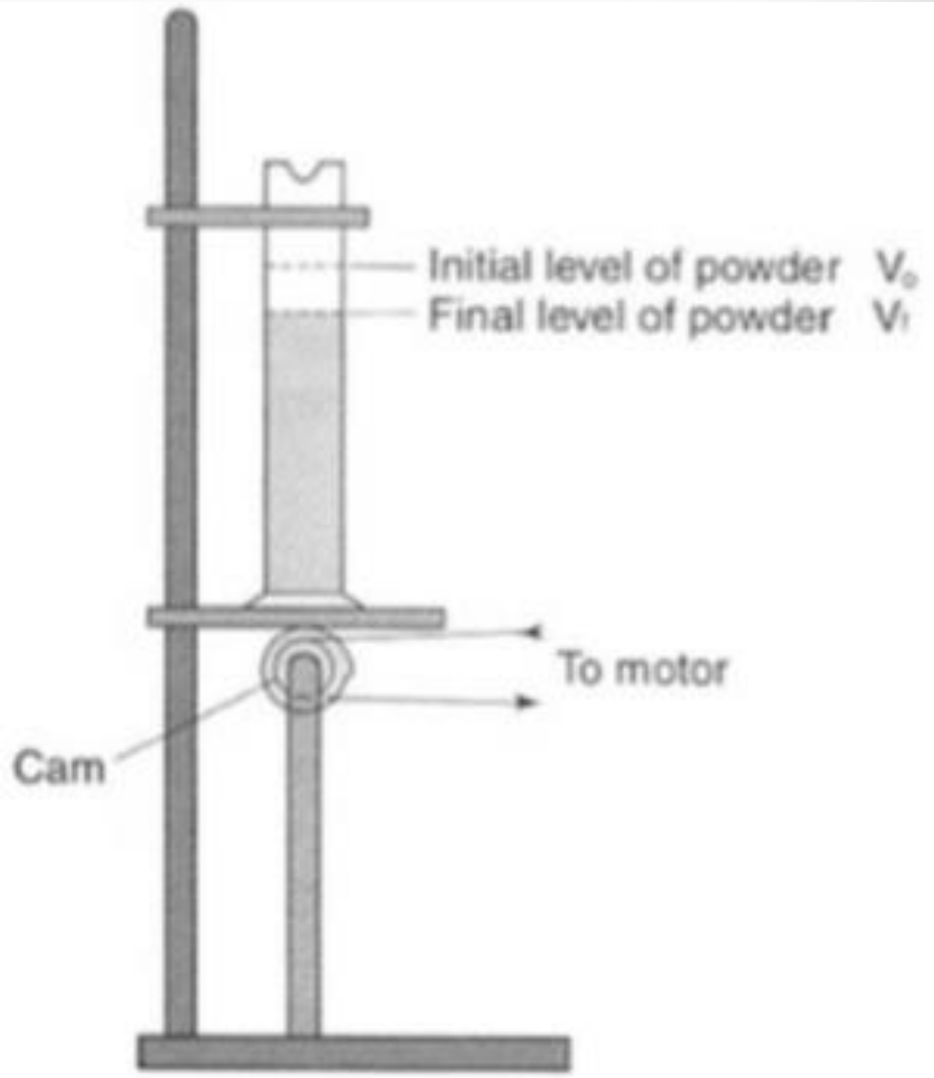
Correlation with powder flow

- In a free flowing powder, such interactions between particles are less significant, and the bulk and tapped densities will be closer in value.
- For poorer flowing materials, there are frequently greater interparticulate interactions, and a greater difference between the bulk and tapped densities will be observed.

Characterization of powder flow

2. Measurement based on bulk and tapped density - procedure

- The figure shows a mechanical tapping device or tapped density tester.
- The powder contained in the measuring cylinder is mechanically tapped by means of a constant velocity rotating cam.
- The powder density increases from an initial bulk density to a final bulk density when it has attained its most stable (i.e. unchanging) arrangement.



Characterization of powder flow

2. Measurement based on bulk and tapped density - procedure

Characterization of powder flow

2. Measurement based on bulk and tapped density - procedure

- Once bulk density and tapped density for a powder have been measured using a tapped density tester, as part of the procedure, comparison between bulk density and tapped density is often carried out using either:
  - ✓ Hausner ratio.
  - ✓ Compressibility index.

Characterization of powder flow

2. Measurement based on bulk and tapped density - procedure

Hausner ratio

It is the ratio between tapped density (D_f)/ bulk density (D_0).

Powders with low interparticle friction, such as coarse spheres, have ratios of approximately 1.2.

More cohesive, less free-flowing powders such as flakes have Hausner ratios greater than 1.6.

Flow Character	Hausner Ratio
Excellent	1.00-1.11
Good	1.12-1.18
Fair	1.19-1.25
Passable	1.26-1.34
Poor	1.35-1.45
Very poor	1.46-1.59
Very, very poor	>1.60

Characterization of powder flow

2. Measurement based on bulk and tapped density - procedure

Compressibility index (Carr's index)

$$\% \text{ compressibility} = \frac{D_f - D_o}{D_f} \times 100$$

Flow Character	Compressibility Index (%)
Excellent	≤10
Good	11-15
Fair	16-20
Passable	21-25
Poor	26-31
Very Poor	32-27
Very, Very Poor	≥38

Where D_f is tapped density

and D_0 is the bulk density.

Characterization of powder flow

3. Critical orifice diameter

- Powder is filled into a shallow tray to a uniform depth.
- The base of the tray is perforated with a graduated series of holes, which are blocked either by resting the tray on a plane surface or by the presence of a simple shutter.
- The critical orifice diameter is the size of the smallest hole through which powder discharges when the tray is lifted or the shutter removed.

Characterization of powder flow

4. Hooper flow rate

The simplest method of determining powder flowability directly is to measure the rate at which powder discharges from a hopper.

Procedure:

1. A simple shutter is placed over the hopper outlet and the hopper filled with powder.
2. The shutter is then removed and the time taken for the powder to discharge completely is recorded.
3. By dividing the discharged powder mass by this time, a flow rate (e.g. g/s) is obtained which can be used for quantitative comparison of different powders.

Characterization of powder flow

5. Recording flowmeter

A recording flowmeter is essentially similar to hopper flow rate method, except that powder is allowed to discharge from a hopper or container directly onto a **balance**.

The continuous increase in powder mass with time is recorded.

Recording flowmeters allow to be determined

1. powder flow rates.
2. uniformity of flow (this cannot be done using the hopper flow rate method).

How to improve powder flow

1. **Alteration of particle size and particle size distribution.**
2. **Alteration of particle shape or texture.**
3. **Alteration of surface forces.**
4. **Addition of formulation additives.**

How to improve powder flow

1. **Alteration of particle size and particle size distribution**

- Because coarse particles are generally less cohesive than fine particles, there is a distinct disadvantage in using a finer grade of powder than is necessary.
  - ✓ The process of granulation (*that you will study in the next Chapter*) consist actually in forming large granules made of finer particles of powder. (i.e. ↑ size = ↑flow)
- The size distribution can also be altered to improve flowability by removing a proportion of the fine particle fraction.

How to improve powder flow

2. Alteration of particle shape or texture

- In general, for a given particle size more spherical particles have better flow properties than more irregular particles.
- The texture of particles may also influence powder flowability, as particles with very rough surfaces will be more cohesive and have a greater tendency to interlock than smooth-surfaced particles.

How to improve powder flow

3. Alteration of surface forces

- Reduction of electrostatic charges can improve powder flowability and this can be achieved by altering process conditions to reduce frictional contacts. For example, when a powder is poured down along pipes, the speed and length of transportation should be minimized.

- The moisture content of particles is also of importance to powder flowability. In cases where moisture content is excessive powders should be dried and, if hygroscopic, stored and processed under low-humidity conditions.

How to improve powder flow

4. **Addition of formulation additives-Flow activators**

- Flow activators are commonly referred to pharmaceutically as 'glidants'.
- Flow activators improve the flowability of powders by reducing adhesion and cohesion.
- Some commonly used glidants include talc, maize starch, magnesium stearate and colloidal silicon dioxide.
- Most flow activators have their effect by reducing electrostatic interactions.

How to improve powder flow

Caution!

Remember from the mixing chapter:

- Alterations made in order to improve powder flow might lead to demixing or segregation.

- Improving powder flow to improve weight uniformity **may reduce content uniformity** through increased **segregation**!