Powder flow

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Powder flow

Powders are generally considered to be composed of solid particles of the same or different chemical compositions having equivalent diameters less than 1000 µm. حجمها اقل من 1000µm

Importance of free powder flow الأهمية ؟

A. Reproducible and uniform filling of tablet dies and capsules, which is necessary for weight uniformity of these dosage forms, requires free flowing of the powder from the feeder.

الهواء المحبوس في الباودر

B. Uneven powder flow can result in excess entrapped air within powders, which may promote problems (capping and lamination).

C. Many industrial processes that require powder movement from one location to another (such as mixing, feeding, transfer, and fluidization) are affected by powder flow properties.

التصاق الجزيئات بأسطح اخرى

Particle properties

Adhesion and cohesion → ترابط الجزيئات مع بعض

- Cohesive and adhesive forces are composed mainly from: مصادرها
  - Short range non specific van der Waals forces:
    - Increase as particle size decreases and is affected by relative humidity ↓ particle size ↑ van der Waals
  - قوة الشد السطحي Surface tensional forces arising from adsorbed layer of liquid
  - Electrostatic forces arising from contact or frictional charging
    الكهرباء الساكنة تنتج من الاحتكاك

Adesion force is ≈ بتس adsorbed layer

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الشحنات موزعة بشكل متساوٍ

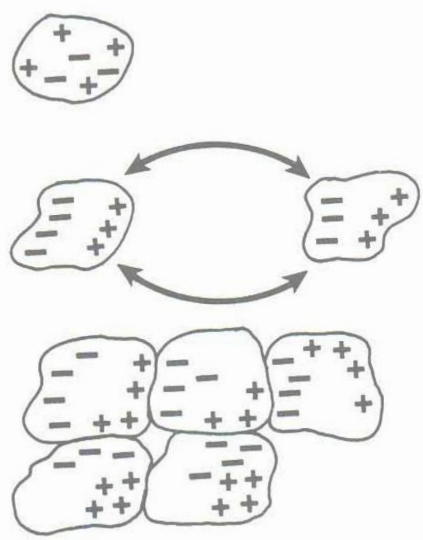

Figure 22 Effect of electrical forces on fine particles.

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* كل ما يصغر particle size كل bad flowability أكثر

خصائص powder الي بتأثر على flow

Powder properties affecting bulk flow

1 *Particle size* سطحها كبير بالنسبة إلى كتلتها

- Fine particles have high surface to mass ratios and are more cohesive (bad flowability). حجم particles كثير صغير

2 *Particle shape* اقل احتكاك

الكروية
- Spherical particles have minimum interparticle contact and therefore optimal flow properties. → flow↓ ← irregular shape

3 *Particle density (True density)*

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

-الاعلى كثافة اقل **cohesive** واحسن **flow**.

-الاقل كثافة اعلى **cohesive** واضعف **flow**.

Powder properties affecting bulk flow

4 *Surface roughness of particles* خشونة السطح

- Rough surface of particles lead to bad flowability of powders.

* كل ما زادت الخشونة قل flow

5 *Moisture content*

- High moisture content causes increase surface-tensional cohesive forces and reduced flowability.

* الرطوبة بتزيد من cohesive وبتقلل من flow

6 *Electrostatic charge*

- Electrostatic charge increases cohesion and adhesion and reduces flowability.

* الكهرباء الساكنة بتزيد من cohesion & adhesion

وبتقلل flow

1- particles
2- Voids

powder بتكون من

Mass-Volume relationship for powders

- A powder bed is composed of particles and voids.
- Voids are:

الفراغات بين الجزيئات ← Interparticulate voids: The air space between individual particles

الفراغات داخل الجزيئات نفسها ← Intraparticulate voids: Those within a single particle

الها نوعين :-

  - Open to the external environment
  - Closed to the external environment

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محبوسة داخل الجزيء وما الها فتحة برا.
تحتفظ بالهواء جواتها

الها مدخل من الخارج .
والهواء والماء ممكن يدخلوا فيها.

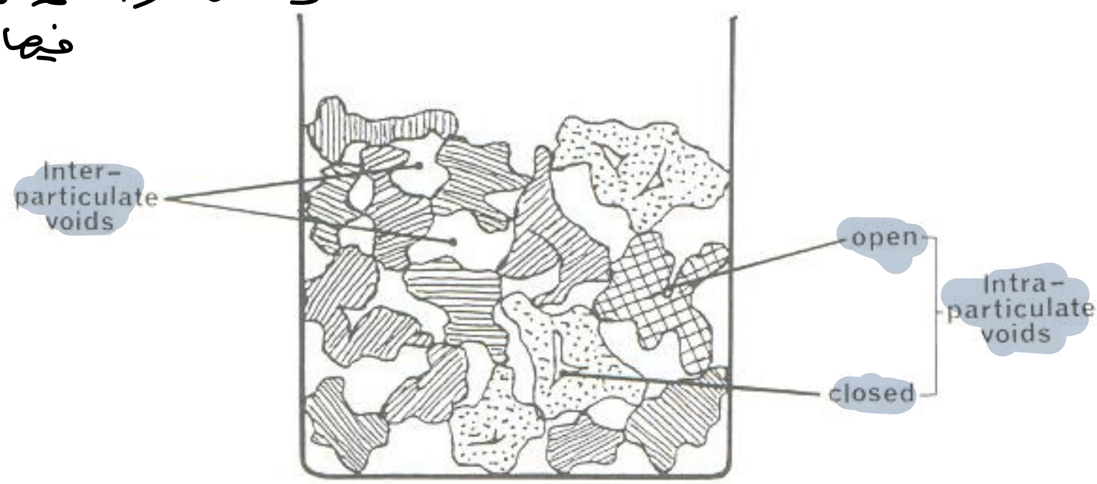

FIG. 4-4. *Diagram of various intraparticulate and inter-particulate air spaces in a bed of powder.*

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True volume: (بدون الفراغات) حجم المادة فقط

Granular volume: intraparticulate حجم الجزيئات مع الفراغات

Bulk volume: هو اكبر واحد ويشمل حجم كل شي (particles, voids سواء inter او intra)

Mass-Volume relationship for powders

Three interpretation of powder volume may be proposed:

اصغر حجم ← • The true volume (V_t): The total volume of the solid particles, which excludes all space greater than molecular dimension.

اكبر من True واصغر من Bulk ← • The granular volume (particle volume) (V_g): The volume occupied by particles and all **intraparticular** voids.

اكبر حجم ← • The bulk volume (V_b): The total volume occupied by the entire powder mass (i.e. particles and intraparticulate and **interparticulate** voids)

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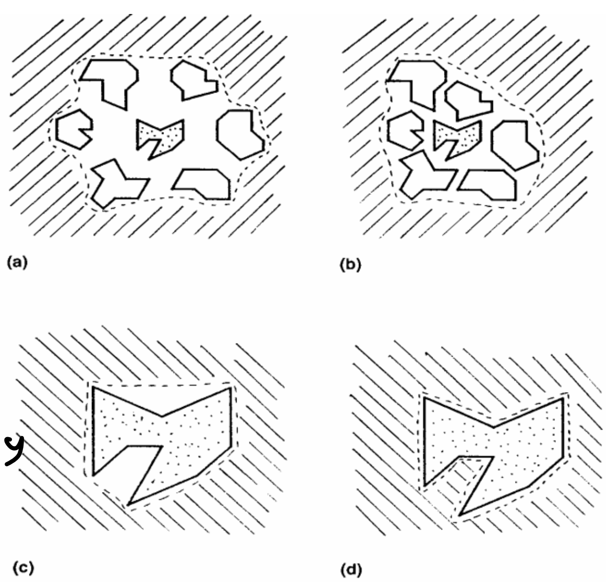
bulk density

tapped density

particle density (granular)

true density



The different types of densities a) bulk density b) tapped density c) particle density d) true density

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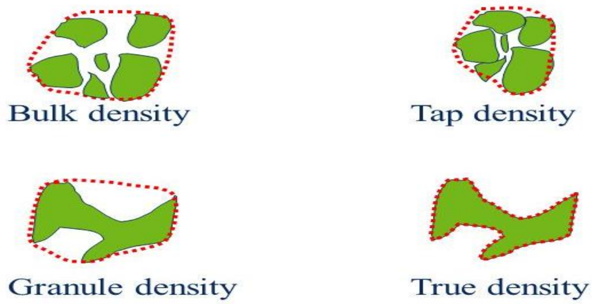
Mass-Volume relationship for powders

- True density = mass / true volume
- Granular density = mass / granular volume
- Bulk density = mass / bulk volume



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Packing geometry

- The apparent volume (or density) of a powder can be changed by rearrangement of the packing geometry of particles (by vibration for example).
- Packing geometry can be characterized by:

Bulk density

- It is the mass of powder occupying a known volume. → كتلة البودرة إلي بتحتل حجم معين
- A powder can have many different bulk densities depending on the way in which the particles are packed. → نفس البودرة ممكن يكون الها bulk densities مختلفة حسب طريقة ترتيب الجسيمات.
- However, a high bulk density value does not necessarily imply a close-packed low-porosity bed, as bulk density is directly proportional to true density.

* density العالية مش معناها دايمًا انه powder
هو packed منيح لأنه bulk density مرتبطة بـ true density كمان.

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الفراغ هو air

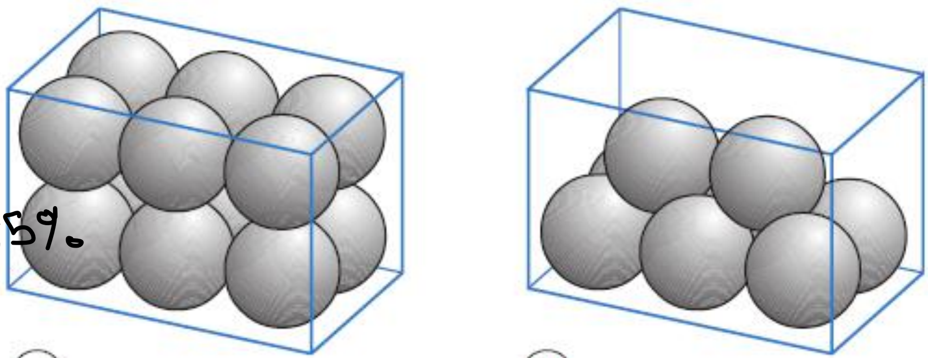
هذا الشكل يعطي اعلى تعبئة

75%

(e) = 1 - 75%

الفراغات

%65



a

b

(a) Cubic packing.

(b) Rhombohedral packing.

Different geometric packings of spherical particles

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نسبة البودرة بدون الفراغات

Packing geometry

① particle size
② shape

Packing fraction (Fractional solid content, k)

- It is the bulk density divided by true density of the solid.

$$K = \frac{\text{True volume}}{\text{Bulk volume}} = \frac{\text{Bulk density}}{\text{True density}}$$

الفراغات

Porosity (Fractional void content, e)

Porosity (e) = 1 - K

- Porosity represents the fractional void content of a powder bed.

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الفراغات بين الحبيبات الكبيرة رح تعبيها fine particles ويصير closer packing.

Factors affecting packing geometry

1) Particle size and size distribution

- Void spaces between coarse particles may be filled with **fine** particles in a powder with a wide size range, resulting in closer packing.

2) Particle shape and textures

الي شكلها كروي بتنزل وتتراص بسهولة،اما الغير منتظمة بتعلق ببعض.

- Arches within the powder bed will be formed more readily through the interlocking of non-isometric, highly textured particles

3) Surface properties

شحنات كهربائية ممكن تخلي الحبيبات تلتصق او تتنافر ،بتأثر بال packing.

- The presence of electrostatic forces can promote closer particle packing

4) Handling and processing conditions

- The way in which a powder has been handled prior to flow or packing affects the type of packing geometry

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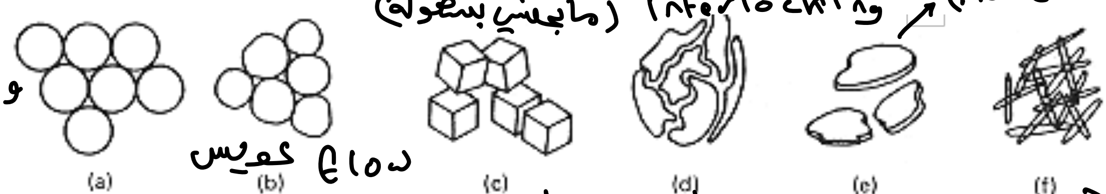
اذا هزينا البودرة رح تتراص اكثر ،واذا سكبناها بسرعة بتكون اقل تراص.

spherical
flow أفضل واسهل بالحركة
oblong
كويس flow
cubic (مابمشي بسهولة)
irregular interlocking
بعمل bridge وبعلق
flakes متوسط وبعمل مشاكل flow)
Fibrous (أسوأ اشي)
بعمل bridge و blockage



General particle shapes and their effect on power flow.

(a) Spherical particles normally flows easily,

(b) oblong shapes with smooth edges normally flows easily

,(c) equidimensionally shaped sharp edges such as cubes does not flow as readily as (a) or (b),

(d) Irregularly shaped interlocking particles normally shows poor flow and easily bridges,

(e) irregularly shaped two-dimensional particles such as flakes normally shows fair flow and may cause bridges,

(f) Fibrous particles very poor flow, and bridges easily. Bridging refers to the stoppage of powder flow as a result of particles which have formed a semirigid or rigid structure within the powder bulk.

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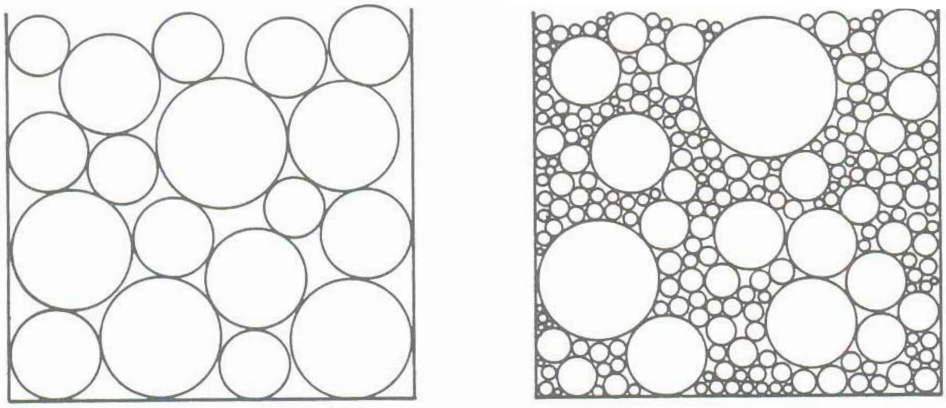
coarse particles بين fine particles



VOLUME = 1 cm^3
WEIGHT = 2 grams

BULK DENSITY = $\frac{2 \text{ grams}}{1 \text{ cm}^3}$ = 2.0

VOLUME = 1 cm^3
WEIGHT = 2.7 grams

BULK DENSITY = $\frac{2.7 \text{ grams}}{1 \text{ cm}^3}$ = 2.7

Figure 24 Effects of particle size distribution on the bulk density of a powder.

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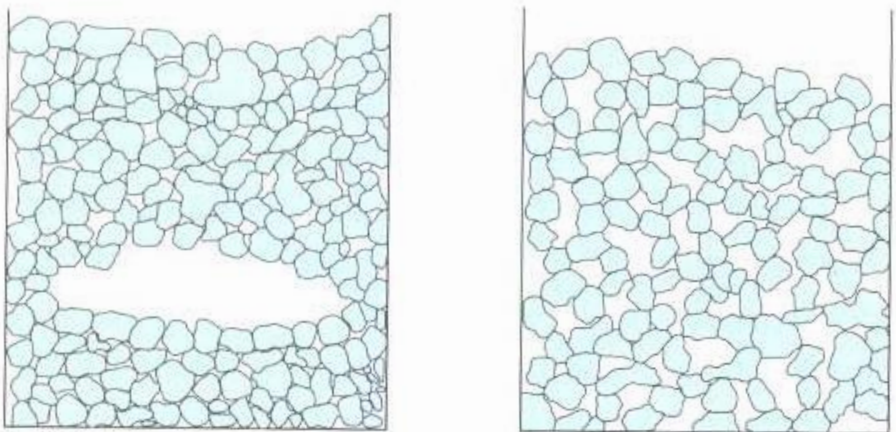
same porosity



A

B → يحشي اكتر في الماكينة

Fig. 13.6 Two equidimensional powders having the same porosity but different packing geometries.

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Flow rate through an orifice

- There are many manufacturing processes of pharmaceutical solid dosage forms that require the powder flow through the opening in a hopper or bin used to feed powder to tableting machine, capsule- filling machine, sachet-filling machines …

في تصنيع **solid dosage forms** مثل**tablets and capsules** لازم **powder** ينزل من الهوبر او **bin** بشكل منتظم عبر فتحة **(orifice)** لتغذية:

1.Machine

2.Capsule-filling machine

3.Sachet-filling machine

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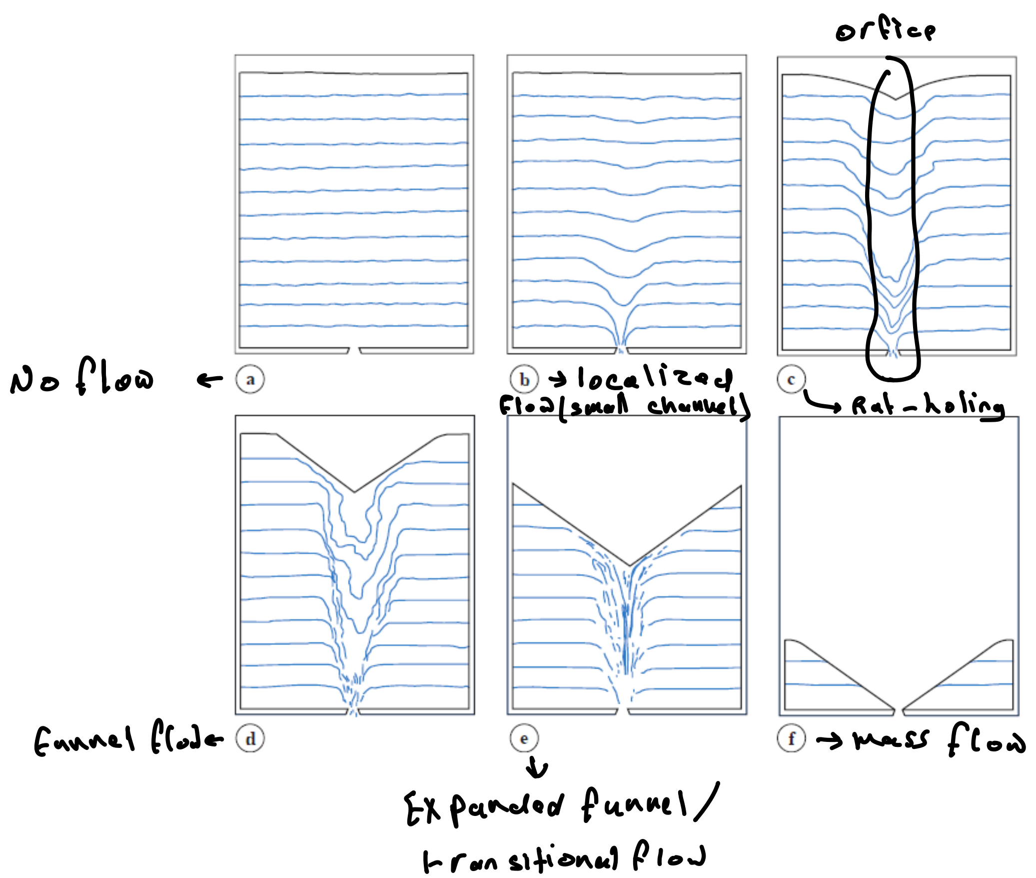

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Flow rate through an orifice

- This flow through orifices is affected by:

1. Orifice diameter طردية

- Flow rate is proportional to orifice diameter

2. Hopper width (عكسية امكن ضغط solid يخف)

3. Adhesion to the walls of hopper

4. Head size كمية solid على orifice

- This is the height of powder bed above the orifice

5. Hopper wall angle عكسية

- As the angle decreases, flow rate increases

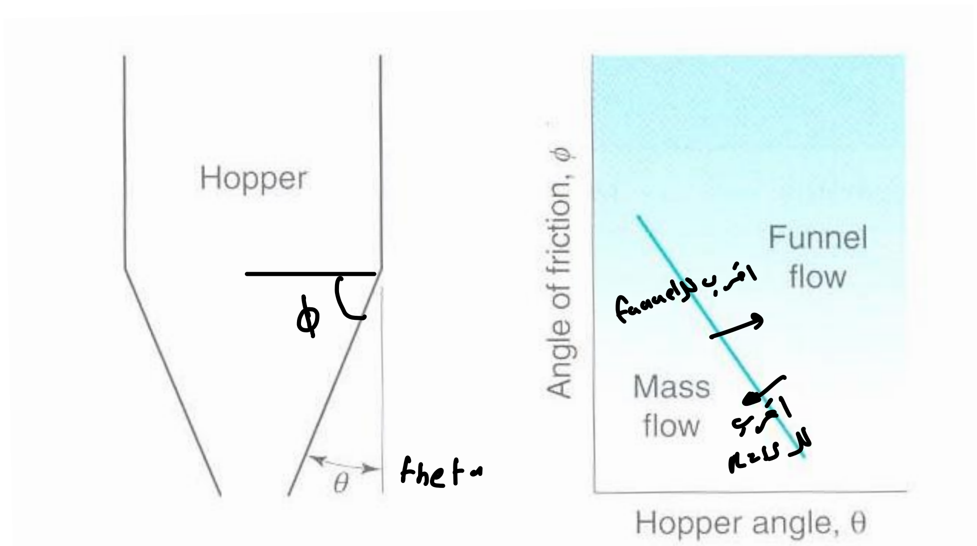
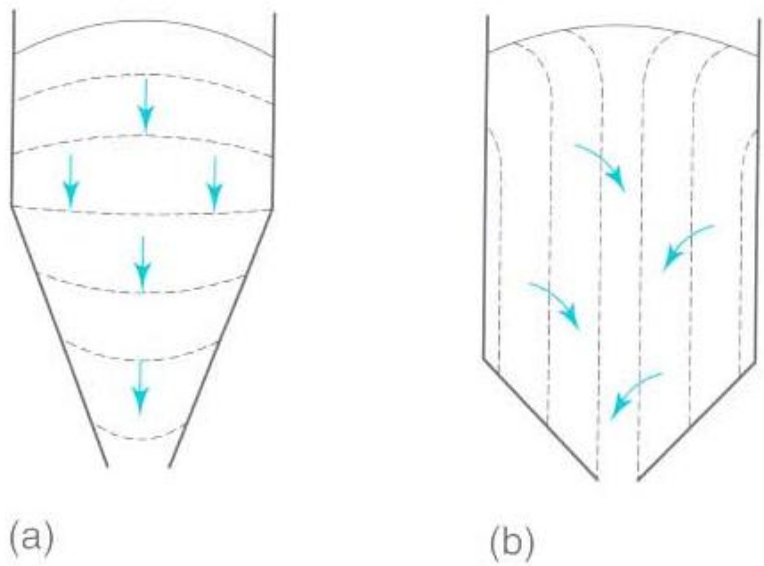


Fig. 13.11 Influence of hopper wall angle and particle–wall friction on powder flow.

بيلش من الاطراف وبتجي للنص

Mass flow

بيلش من النص



Funnel flow

Fig. 13.12 (a) Mass flow hopper. (b) Funnel flow hopper.

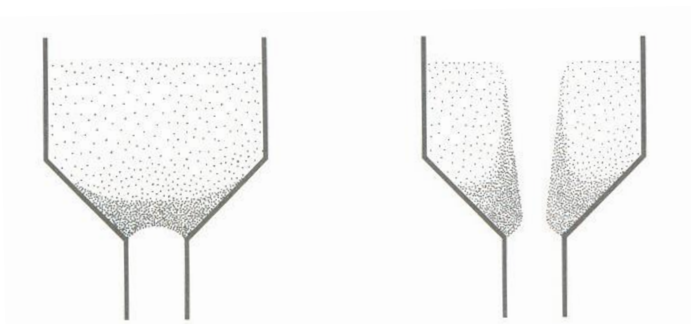
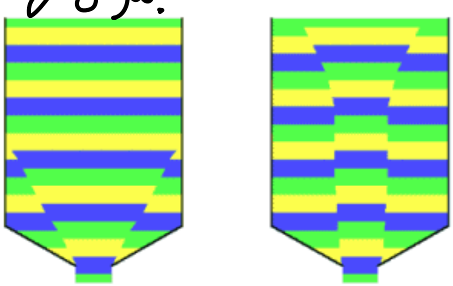


FIG. 11-12. *Bridging (left); rat-holing (right).*

بنزل من الاطراف

ينزل من النص



① direct → بدون معادلات
② indirect → بمعادلات

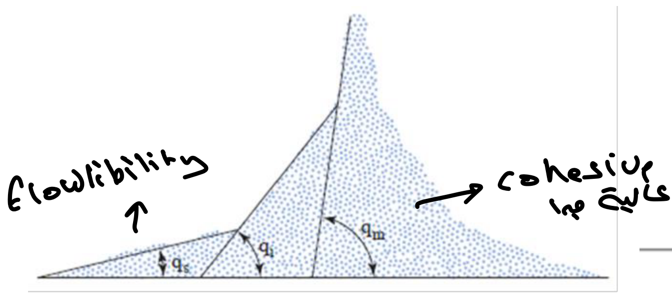
Characterization of powder flow

Indirect methods (Measurement of adhesive/cohesive properties)

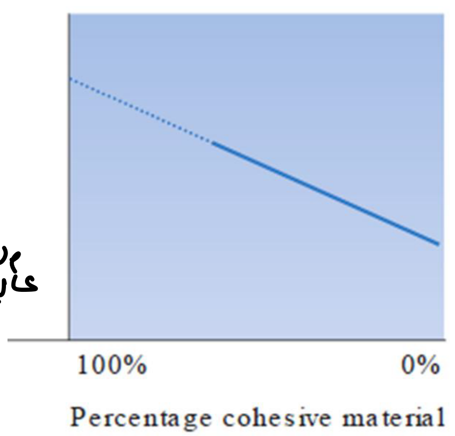
1) Angle of repose (indirect method)

- It represents the balance between frictional/cohesive forces and gravitational force
- Therefore, it describes interparticle cohesion and it is an indirect method for estimating powder flowability.
- There are different methods for determination of angle of repose which may produce different values.
- The high values indicate bad flow properties.

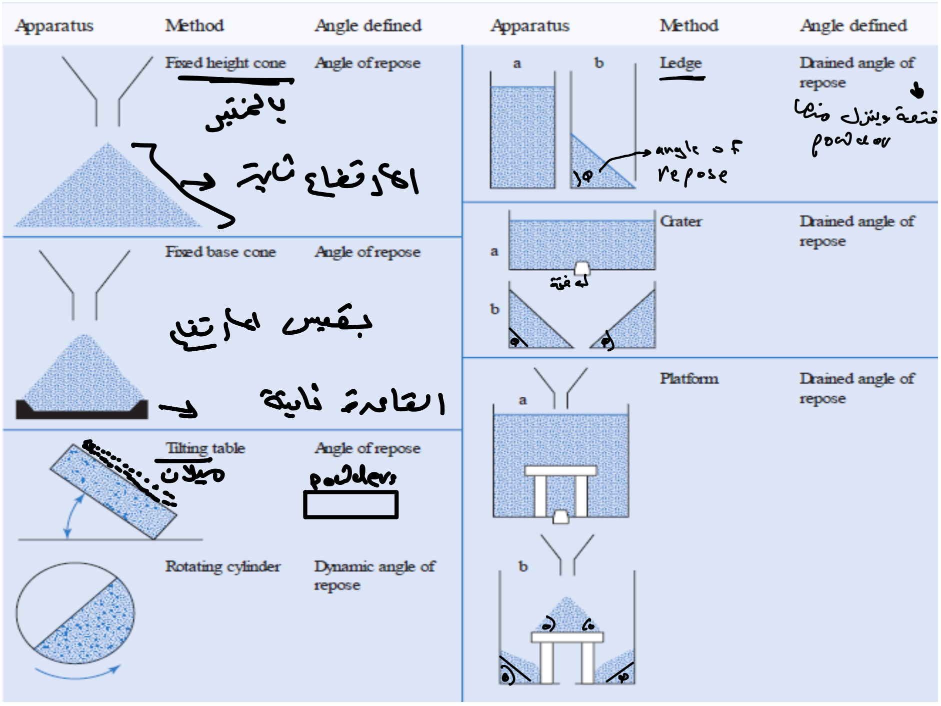
low flow ← very cohesive ← Φ↑ ← زاوية عميقة



Cohesive powder poured in a heap



Determination of angle of repose for very cohesive powders.



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مهم أول 2 و آخر 2

علاقة عكسية

Angle of repose (degrees)	Type of flow
25–30	Excellent
31–35	Good
36–40	Fair (flow aid not needed)
41–45	Passable (may hang up, flow aid might be needed)
46–55	Poor (agitation or vibration needed)
56–65	Very poor

flowbility

cohesive

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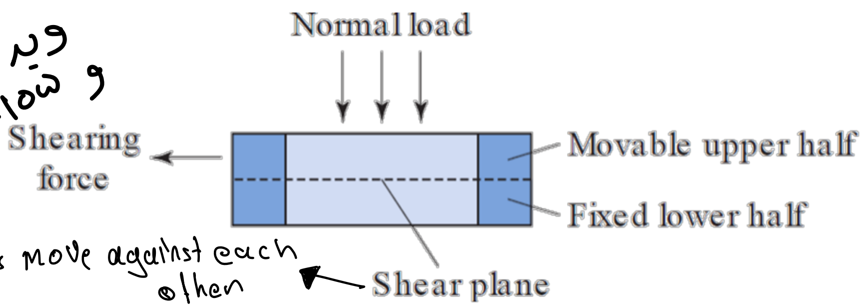
Characterization of powder flow

Indirect methods (Measurement of adhesive/cohesive properties)

2) Shear strength determination

- Cohesion can be defined as stress (force per unit area) necessary to shear the powder bed under conditions of zero normal load

صعب تنزلق
ويدها force أعلى
و flow تبعها
سيء



2 parallel surfaces move against each other

Diagrammatic representation of Jenike shear cell.

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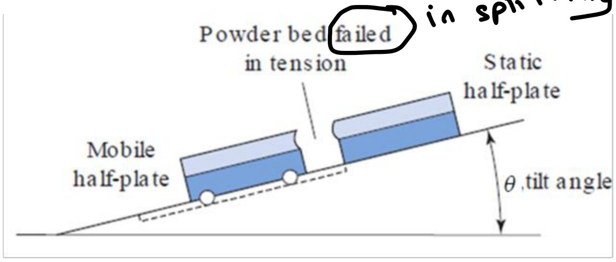
Characterization of powder flow

Indirect methods (Measurement of adhesive/cohesive properties)

نستعمل عشان نشوف مدى مقاومة الوصل.

3) Tensile strength determination → القوة هي الشد عشان نشوف قديش powder ماسك داخلياً.

- The powder bed is caused to fail in tension by splitting.



Diagrammatic representation of tilting table method.

signa

$$\sigma_t = \frac{Mg\sin\theta}{A}$$

area

Equation for calculation of tensile strength

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Characterization of powder flow

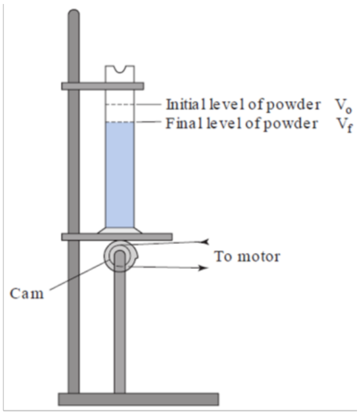
Indirect methods

4) Bulk density measurement (% compressibility and Hausner's ratio)

$$\boxed{\%\ \text{compressibility} = \frac{D_f - D_0}{D_f} \times 100 = \frac{V_0 - V_f}{V_0} \times 100}$$

$$\boxed{\text{Hausner's ratio} = \frac{D_f}{D_0} = \frac{V_0}{V_f}}$$

D_f = Final bulk density (tapped density)
D_o = initial bulk density
V_f = Final bulk volume (tapped volume)
V_o = initial bulk volume



Mechanical tapping device

احفظ اول 2 و آخر 2

عكسية

عكسية

Compressibility index (%) (Carr's index)	Type of flow	Hausner ratio
1–10	Excellent	1.00–1.11
11–15	Good	1.12–1.18
16–20	Fair	1.19–1.25
21–25	Passable	1.26–1.34
26–31	Poor	1.35–1.45
32–37	Very poor	1.46–1.59
>38	Very, very poor	>1.60

Characterization of powder flow

Indirect methods

5) Critical orifice diameter

- Critical orifice diameter is a measure of powder cohesion and arch strength.
- The smallest orifice diameter through which powder can flow

اذا تضيقت اكثر بعمل arch

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Direct

Characterization of powder flow

Direct methods

$$\frac{\text{Mass}}{\text{time}} = \frac{g}{\text{minute}}$$

1) Hopper flow rate

- Simple and direct
- The mass of a powder discharged from a hopper is divided by the time taken for the powder to discharge.

2) Recording flowmeter

- The powder is allowed to discharge onto a balance and the increase of powder mass with time is recorded.

powdor mass Vs Time

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* مشاكل بدنا نحلها *

ازا عندي مشاكل
بال size
milling, granulation

Approaches for improvement of powder flow

Alteration of particle size and size distribution

- Coarse particles are less cohesive and therefore are flowing better than fine particles.

Alteration of particle shape or texture

- Spherical particles have better flowability than irregular particles.
- Particles with smooth surface have better flowability than particles with rough surface.
- Particles with suitable shape can be obtained by spray drying or by controlling crystallization process.

less cohesive ← Coarse
more cohesive ← fine particles

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Approaches for improvement of powder flow

Alteration of surface forces

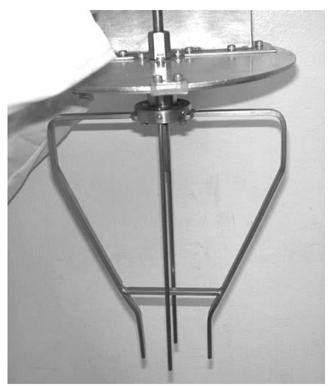
- Electrostatic charges and high moisture content decrease the flowability.

Formulation additives (flow promoters)

- Glidants decrease cohesive and adhesive forces.

Alteration of process conditions

- Use of vibration-assisted or agitated hoppers
- Use of force feeders



Internal agitator

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flowability بحسن +

Flow activators

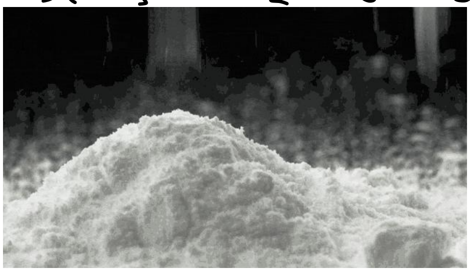
- Flow activators (enhancers, promoters) improve the flowability of powders by reducing adhesion and cohesion.
- They are referred to as glidants.
- Some of them have anti-adherent and lubricant properties.

inorganic ← بيعمل sheets بين الparticles

- Commonly used glidants include talc, maize starch, colloidal silicon dioxide and magnesium stearate.

polysaccharide

fatty acids لا حسن وحده ← بتعمل تخليف للparticles ← بودرة الأطفال



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Mechanisms of action of flow activators

+ كيف Glidants بتحسن flow / عن طريق 3 شغلات:

Glidants improve flowability by one or more of the following mechanisms:

1. They make the surface of the particles more smooth.
2. They reduce electrostatic charges.
3. They interfere with the cohesion or adhesion due to adsorbed moisture layer

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