

# Powder flow

ال tablet يتحضر بكان اعد dies

عبارة عن مزاج بوزن ال powder عار dies وبتكيس

الحبة ، لما بي بعين Volume متن وزن ، ما بوزن قبل

نبط مطبوخ لحد ما بقى حجم ال dies ، فكل زم يتحبا صبح

لحد الغلابة عشان ال Dose تكون Correct

إذا في ماعى با Flow يكون في مشكلة با Dose

Dr. Isra Dmour

Credit: Prof. Nizar Al-Zoubi

لنا اهم الاسباب اللى بدرس عشانها Flow

ال tabletability / compressibility / ما يصير خال الخنة stickiness

ال Flow با tanks و pipes كدما بيحصل ال Flowing

## 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.

تكونة particles بينهم

Adhesives

↓  
Formula  
↓  
Dose (diff component)

Flow با لى بقم با Flow

بما نضف ال powder ، ال tablet ، ال hopper و ال container و ال machine  
Filling machine

### Importance of free powder flow

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.

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.



2) لا لفرطنا نزل ع ال powder صوا ، بيجن الصوا ، ضمكن particles ، لما نكسب الة ينكسب الصوا ولها نزيح الكيس الصوا راج يتقصد فراح بجنس جزء من ال tablet زى اللى بالهورة  
After removing of the compression force - air expansion

3) مرادف التمشيح لدرم يكون ال Flow مناسب

# Particle properties

## Adhesion and cohesion

- Cohesive and adhesive forces are composed mainly from:

- ① Short range non specific van der Waals forces:
  - Increase as particle size decreases and is affected by relative humidity
- ② Surface tensional forces arising from adsorbed layer of liquid
- ③ Electrostatic forces arising from contact or frictional charging

zero net charge

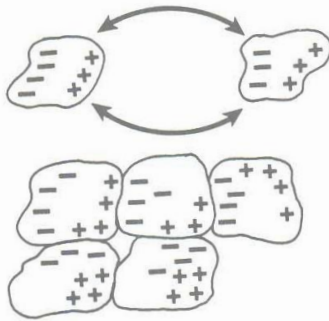


Figure 22 Effect of electrical forces on fine particles.

بالاصول particle  
NEUTRAL PARTICLE (electrical charge evenly distributed over particle)

PROCESSING AND/OR DRY PARTICLE MOVEMENT CAUSES POLARIZATION OF FINE PARTICLES (static electric forces)

POLARIZATION CAUSES AGGLOMERATION OF FINE PARTICLES (electrical charges induced by one particle on another van der Waals forces)

تكتلة

لبس يجرير milling مثلاً  
اد Mixing بصير في Friction  
polarization يحث  
S.A لا Charge دالا  
عالية و high energy و هاد غير  
محتول لازم ال energy لتوكل

للصير، كيفي؟ ال particles بتقرب من بعض  
و تعداد ال charge ، بليتنا ب particles small  
و وكتلة large  
irregular agglomerate

# Powder properties affecting bulk flow

## Particle size

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

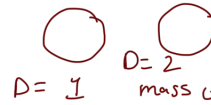
## Particle shape

- Spherical particles have minimum interparticle contact and therefore optimal flow properties.

## Particle density (True density)

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

لو من مادتين نفس الـ size و الـ shape



جاء mass اقل  
لانه الـ Cohesion عالية يعني المادة  
تزيد تماسها  
\* لو نفس الـ Cohesion عالية، قديما يقل Cohesion other particles اقل

Cohesion بزيادة كدالة عالية  
فانجيل Cohesion هو غيرها

$$D = \frac{mass}{V}$$

# Powder properties affecting bulk flow

## Surface roughness of particles

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

لو الـ smooth surfaces كل فان كانت خشنة التوقع اقل

## Moisture content

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

الـ moisture اذا عالية راح يقل

## Electrostatic charge

- Electrostatic charge increases cohesion and adhesion and reduces flowability.

interfacial tension ↓ الـ flow

clumping يكتسب رطل Cohesion



bad flow

solid و void مصفوف

## Mass-Volume relationship for powders

- A powder bed is composed of particles and voids. ②
- Voids are:
  - Interparticulate voids: The air space between individual particles
  - Intraparticulate voids: Those within a single particle
    - Open to the (external environment) → atmospheric: O<sub>2</sub> mainly
    - Closed to the external environment

Solvent أو المذيبات  
environmental mixing  
إذا كان يخلط مع البيئة  
liquid

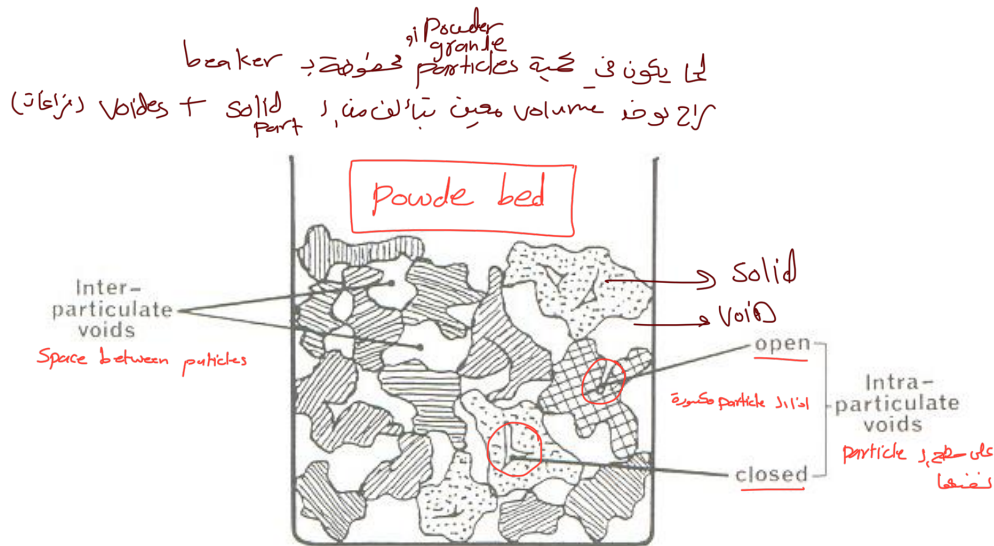


FIG. 4-4. Diagram of various intraparticulate and interparticulate air spaces in a bed of powder.

$$Volume = \text{Solid volume} + \text{intra particulate} + \text{interparticulate}$$



نرخ د  $\rho$  density  
Volume

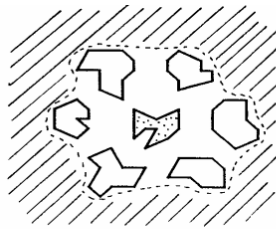
## Mass-Volume relationship for powders

Three interpretation of powder volume may be proposed:

- The true volume ( $V_t$ ): The total volume of the solid particles, which excludes all space greater than molecular dimension.
- The granular volume (particle volume) ( $V_g$ ): The volume occupied by particles and all intraparticle voids.
- The bulk volume ( $V_b$ ): The total volume occupied by the entire powder mass (i.e. particles and intraparticle and interparticle voids)

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اذا صحت bulk ب beaker (Container) راج تداخل مكان حقیق یعنی در Solid و void با هم bulk Volume  
و قسمی از mass است bulk Density

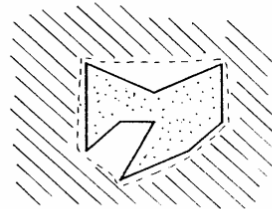


(a)



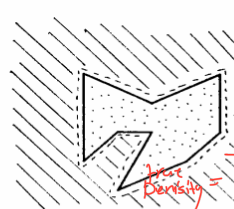
(b)

tapping عمل (تقریباً) فشرده  
جزء از voids به پر شدن particles  
more compact  
New Volume = Solid + Voids



(c)

اذا این one particle حقیق است  
البته یکن حجم از Solid و particle نمیباشد  
open void + intra



(d)

صورت فشرده  
تماماً من کل voids  
intra + inter  
mass  
true density = mass / volume  
قبل فقط Solid یعنی

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

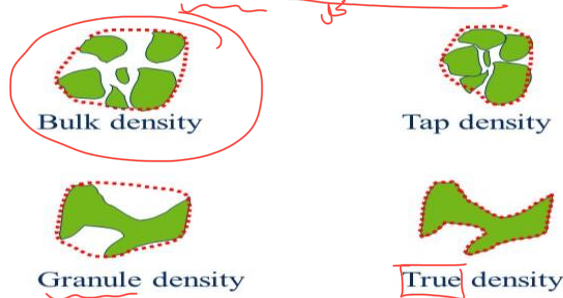
Solid + Voids  
intra intra

Solid + Voids

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## Mass-Volume relationship for powders

- True density = mass / true volume
- Granular density = mass / <sup>(particle)</sup> 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).

voids ← عتق اقصا

- Packing geometry can be characterized by: →

### Bulk density

- It is the mass of powder occupying a known volume.
- A powder can have many different bulk densities depending on the way in which the particles are packed.
- 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.

كيف بجي المكان ركنه (particle) بتوزع منه ماد بعل (diff.)

← د بتوزع د packing ركنه

high bulk \* د: packing ركنه no porosity close

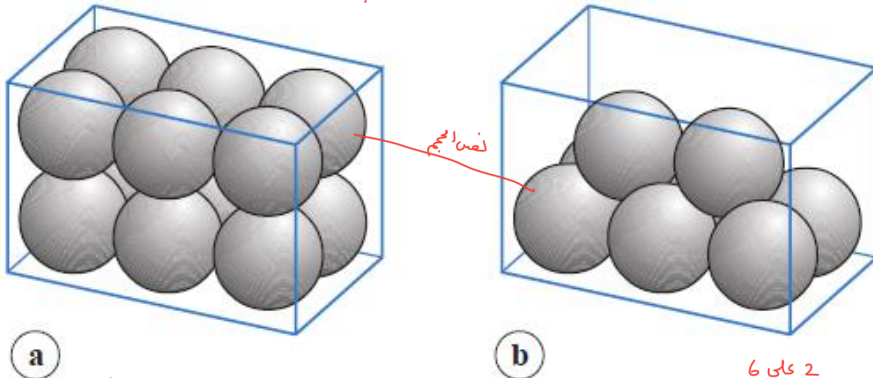
\* د: packing ركنه true

\* لا يمكن ان يكون د: packing ركنه fine particles

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# Geometry

لفظ اذ ل A بـ A سpheric 2 مافري لاديني sphere مبدية باق (volume) لها  
B بـ 8



(a)

(a) Cubic packing.

(b)

(b) Rhombohedral packing.

Different geometric packings of spherical particles

75% Particles اذلى تحبة  
25% Voids / با

المجموع 1

2 على 6

64% particle  
36% voids

ادعوا سلا 17

الصوا سوا اذلى منه 13

## Packing geometry

1 Packing fraction (Fractional solid content,  $k$ )

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

الرقم ف ك دالاً اقل من واحد

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

اذلى با mass  
لفظا  
بجفتي المعكوي

Void  
ما بقى من الفراغ Porosity (Fractional void content,  $e$ )

$$\text{Porosity (e)} = 1 - K \quad \text{ex } 1 - 75\% = 25\% \text{ porosity}$$

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

على سلا 18

# 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

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

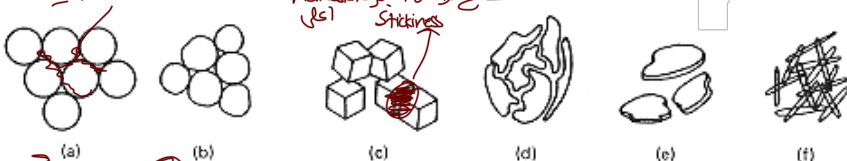
## 3) Surface properties

- 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

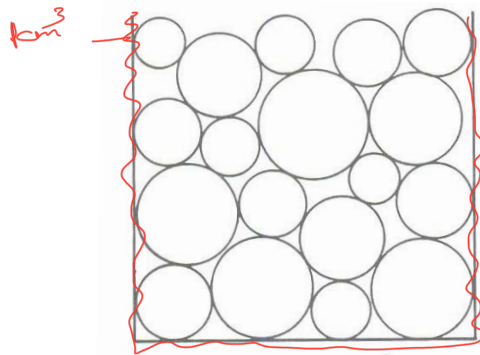
Contact حصة خال Cohesive اقل



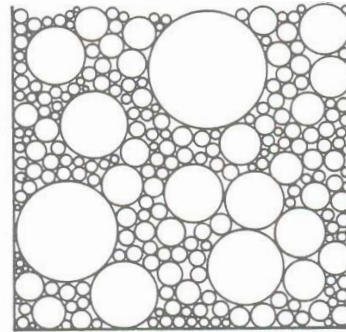
### General particle shapes and their effect on power flow.

- Spherical particles normally flows easily,
- oblong shapes with smooth edges normally flows easily
- equidimensionally shaped sharp edges such as cubes does not flow as readily as (a) or (b).
- Irregularly shaped interlocking particles normally shows poor flow and easily bridges.
- irregularly shaped two-dimensional particles such as flakes normally shows fair flow and may cause bridges.
- 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.

Bridging



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



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

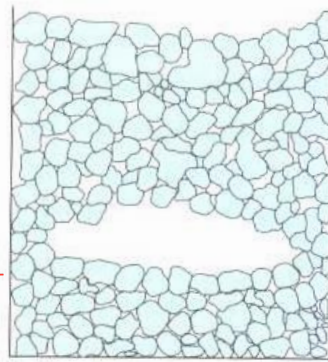
ال ٥٠٧ من ١٠٠ fine particle  
 عن ان تخلص من هذه  
 او الصوا  
 ثلاثة بوجه من جهة واحدة  
 oxidation

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

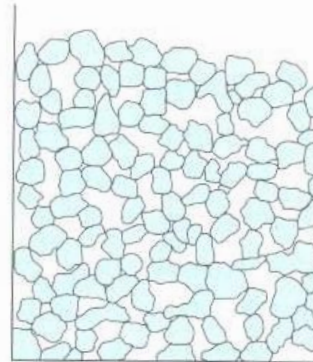
ارجوا سلاية ١٢

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لض عن الفراغات



A



B

not condens

← هو مشكلة لانه Ark  
 بعقبات flow

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

ال ٢ من امثلة ووصوله  
 A → B ← كل الفراغات بنفس المكان  
 packing void (ark)

الفراغات متوزعة

loss - fluty powder

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ارجوا سلاية ١٥

لض عن Shape وليس الزاوية حجم بئر packing مختلف

## 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 ...

قصر بوبل من  
حجرات الجوارح حتى يصل

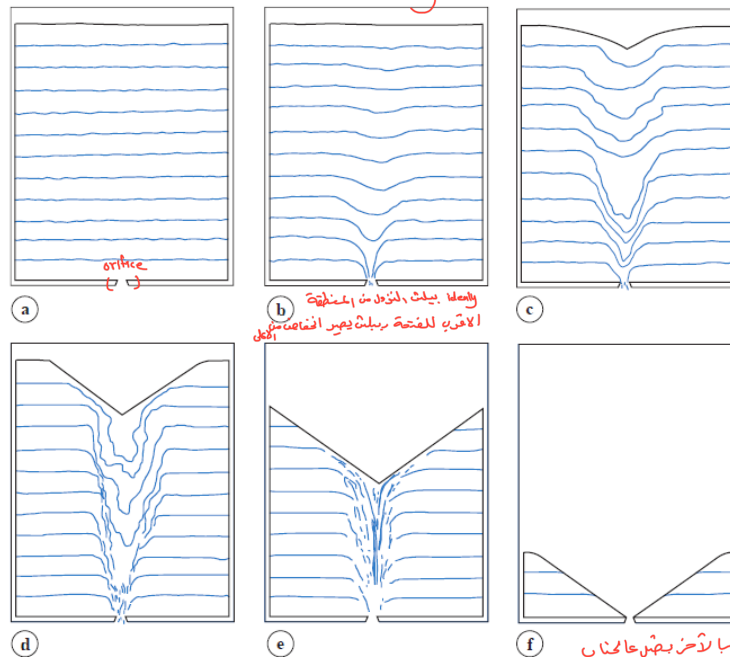
tableting machine  
ادار capsule machine

Container

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كيف لنزول powder

radially



Development of flow through an orifice

فتحة

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## Flow rate through an orifice

- This flow through orifices is affected by:

1. Orifice diameter ↑ ↑ Flow لور سببھا

(amount of powder / time)

- (Flow rate) is proportional to orifice diameter

**2. Hopper width** العرض / ارتفاع

powder الى خوقل office الماخونا  
والعائق على office كما استغل width  
صا الوزن اذ النقل يكون اعلى (مفيدة) بن  
لرمتو يحدد Diameter يعني مابين الزننجير  
والفتحة محبزة لانه راجح فتحة على رية لحد  
ما ينزل الى جانب الانحاف اجبر عن الفتحة  
يعني  $\uparrow$  width  $\downarrow$  النقل  $\uparrow$  الى على اواني  
ممكن

3. Adhesion to the walls of hopper → adhesion (التصاق) Stickness (اللزوجة) powder (الغبار) vibrator (الترديد) hopper (الطاحونة) → adhesion (التصاق) Stickness (اللزوجة) powder (الغبار) vibrator (الترديد) hopper (الطاحونة)

② vibrator تحریک کے لئے hopper کے ساتھ موقوف ال پاور

#### 4. Head size/height

- This is the height of powder bed above the orifice

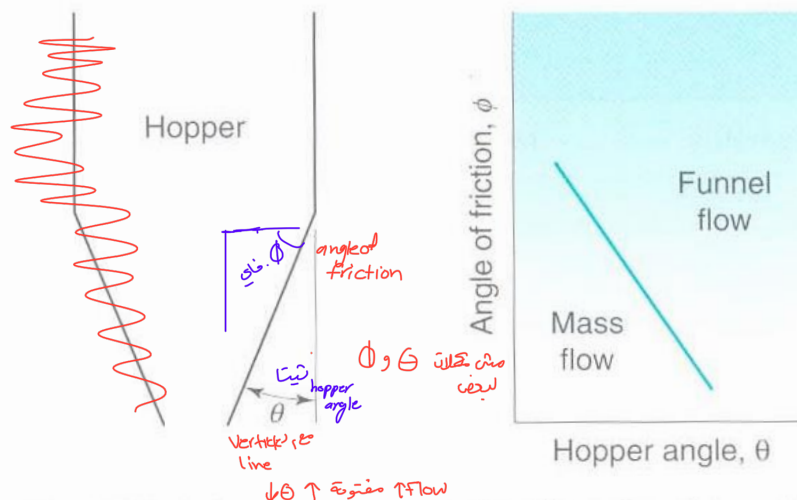
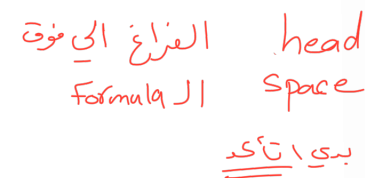
ارتفاع الج powder

### 5. Hopper wall angle احد

- As the angle decreases, flow rate increases 

Length ↑ Flow

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

٢٢- لما يكون  $\Phi$  عالية و  $\theta$  صغيرة  $\text{Massflow} = 1$  و  $\text{Flow}$  اعلى ما يكون

Funnel flow



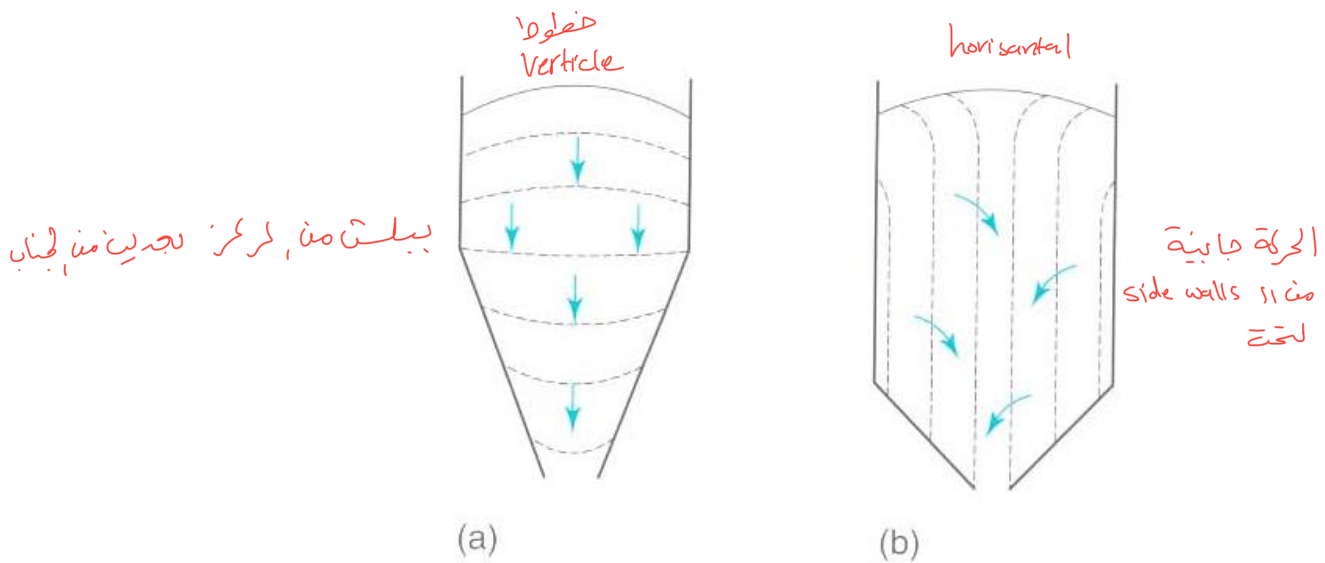
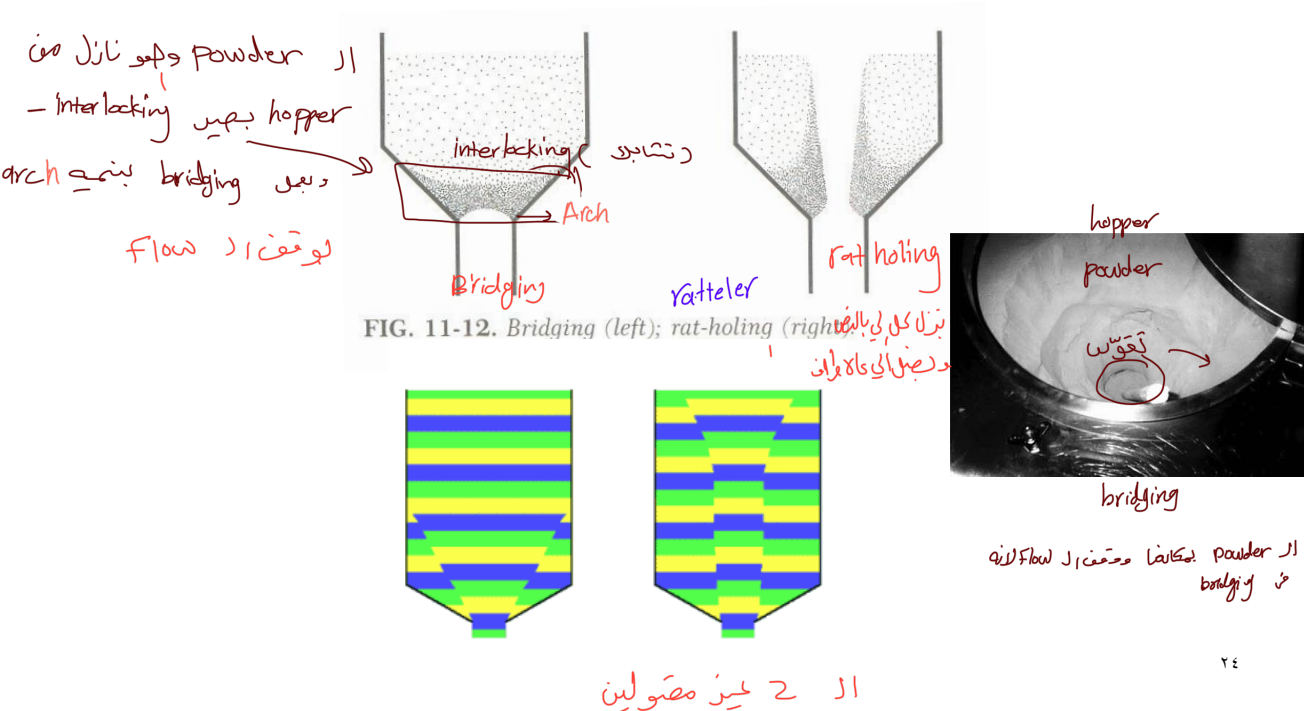


Fig. 13.12 (a) Mass flow hopper. (b) Funnel flow hopper.

سؤال بعد كثر  
الصحة ينزل ويصير في خلايا  
اصيان



وقف بسبب وزن powder بقطام فوق ووقف  
فقط vibrator او shaker

# Flow كيفية احسن ال Characterization of powder flow

## Indirect methods (Measurement of adhesive/cohesive properties)

استخدامنا Conical Funnel في powder

### 1) Angle of repose indirect method

بشكلها بعبارة

- 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.

بشكلها بعبارة  
تزيد قوة التماسك بين الجزيئات  
تزيد قوة التماسك بين الجزيئات  
التي تؤدي إلى زيادة في  
الزاوية الزاوية

وفي ارتفاع معين لل Funnel، يكون  
عندئذ الزاوية تكون هي angle

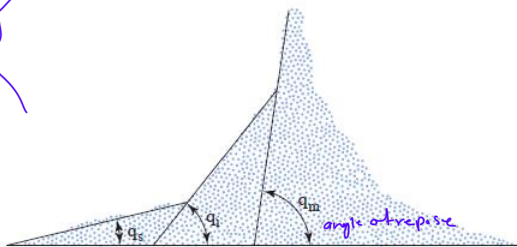
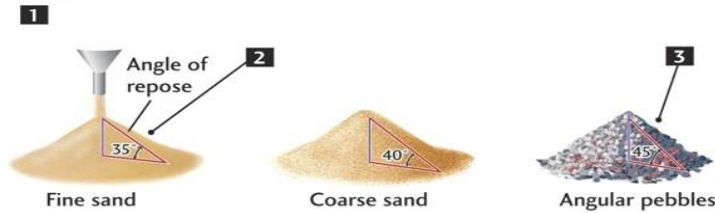
إذا كان Powder نازلاً سريعاً يعني الزاوية  
كثيرة قليلة، والى سطح عالي، غالباً  
spherical not cohesive

إذا كان نازلاً وتوقفت في مكانه  
معتدلة بين بهما تحسين

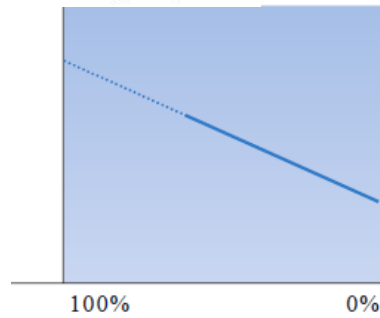
إذا كان نازلاً وتوقفت في مكانه  
معتدلة بين بهما تحسين  
(الزاوية بين الجزيئات)  
↓  
حركة جزيئات  
في Flow  
زاوية قليلة

↑ coh ↓ flow ↑ angle

MASS MOVEMENT DEPENDS ON THE NATURE OF MATERIAL, WATER CONTENT, AND SLOPE STEEPNESS



Cohesive powder poured in a heap



Determination of angle of repose for very cohesive powders.

زاوية  
منخفضة  
↓  
flowable

↓ coh

Defined : remaining powder  
 راجع انجیل ۵

Angle of repose  
 ↓

Drainage method  
 ↓

Apparatus	Method	Angle defined	Apparatus	Method	Angle defined
	Fixed height cone	Angle of repose static		Ledge	Drained angle of repose
	Fixed base cone	Angle of repose static		Grater	Drained angle of repose
	Tilting table	Angle of repose static		Platform	Drained angle of repose
	Rotating cylinder	Dynamic angle of repose			

بکون في breaker او رعا سکتیل في ال  
 فستة بکون ال powder و بکون angle

التمريف من انبوب، ال انقباض ال powder بول  
 و بکون زاوية (الفرقة بکون انقباض)  
 و بالانحداد ال فرق خلاص

اعمال ال carbonates بنسب منجزي ال Stand

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۵) کمال powder ب cylinder

مردی بکون شفاف transparent

لحیة امک ال powder بار cylinder

واسف ک بکون Diameter جا ال cylinder

بکون powder بکون

عال Triangle ال Stand  
 صاف بکون قسین و

نیوضه لغزات و - دوات و لغز اقرب و

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

Flow ↑ Angle ↓  
 powder ↑

بکون احتی بکون ال powder  
 و بالانحداد ال فرق خلاص

الغزات

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# Characterization of powder flow

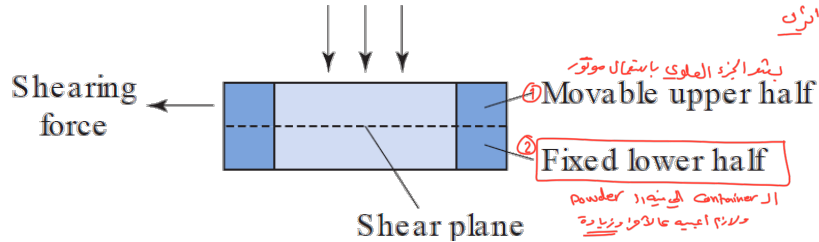
## Indirect methods (Measurement of adhesive/cohesive properties)

Shear: two parallel surfaces  
در دو سطح موازی

### 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

load or stress  
بار یا تنش



Diagrammatic representation of Jenike shear cell.

ظرف از powder و container متحرک و ثابت

واحدی که در آن shear force اعمال می شود

نیمه ای که با نیروی عمودی بارگذاری می شود

۲۹ - Cohesion: نیروی چسبندگی بین ذرات پودر است. Shear: نیروی لغزش بین ذرات پودر است. Jenike shear cell: دستگاهی برای اندازه گیری خواص چسبندگی و لغزش پودر.

درک ما از چسبندگی و لغزش پودر، به کمک دو پارامتر Coh و Shear می باشد.

# Characterization of powder flow

## Indirect methods (Measurement of adhesive/cohesive properties)

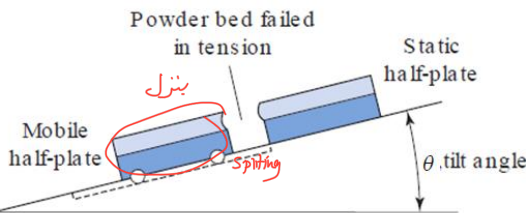
تست برش  
↓

### 3) Tensile strength determination

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

تست برش  
↓

همان که در تست برش، پودر را از یکدیگر جدا می کنند.



Diagrammatic representation of tilting table method.

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

mass gravity Angle of repose 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)

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

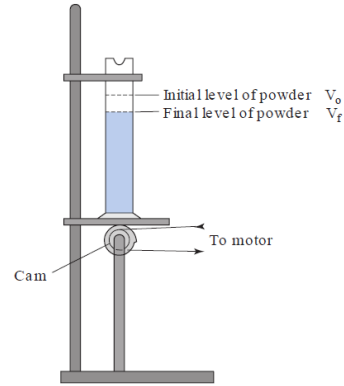
$$\text{Hausner's ratio} = \frac{D_f}{D_0} = \frac{V_0}{V_f}$$

$D_f$  = Final bulk density (tapped density)

$D_0$  = initial bulk density

$V_f$  = Final bulk volume (tapped volume)

$V_0$  = initial bulk volume



Mechanical tapping device

اوونكر  
cylinder powder  
نوعه volume اسطوانة 25g  
bulk volume = 100 ml  
الارتفاع tapping في Volume فيكون ربعين  
والارتفاع المستطاع  
Tapped D : 0.5  
bulk D = 20g  
Volume  
Tapped = 20g  
new / Tapped volume

قابلية powder ايضا تنضغط مراتها من مضغوطة يعني ما ترجع تتفتت  
سواء السبب انما انهم متساوية في اداسها والى  
① قوة الضغط او الكبس  
② coh

في ادوية نيجي tablet وما نيجي cap  
معدل compressibility

↑ coh ↑ comp ↓ flow

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

حدت رحمين حفظهم  
عالمين اولد آخره

# 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

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# Characterization of powder flow

## Direct methods

### 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.

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التي تتدفق flow

## 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.

المزج ماكرامس مضاف من هنا

### 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.

ملاحظة: ماله يتناهي

Free Flow / Spherical / Hemispherical  
تري هليب الاطمان  
عن نهيد فاني لا يصحح زحاي المراه

٣٥ - الاصل، Shape من عملية، Crystallization، بحره، يتحكم بهار solvent / heating / cooling / تحريك لطيف

## Approaches for improvement of powder flow

### Alteration of surface forces

- Electrostatic charges and high moisture content decrease the flowability.

Static charge / اذا زدن كمية الـ water / يتكثف و lumpy aggregate / ماله charge

### 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

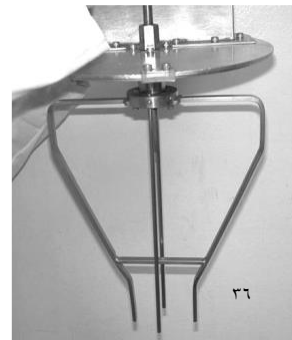
عن نهيد هيبسكس افوتون

منه لافضاد الى زح التعريف

زح الزمير

لعمل قنطرة عن نيزل كم، powder، دما يتوقف

Internal agitator



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## 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.**

- Commonly used glidants include <sup>Inorganic</sup> talc, <sup>Polysaccharide</sup> starch, <sup>Inorganic</sup> colloidal silicon dioxide and <sup>Fatty acid (U.hydro)</sup> magnesium stearate.



تساع  
يعمل ترتيباً و sheet جنبه particle  
تساع  
بنماد Adh و coh

fatty acid (U-hydrophobic) - كل احمضات  
 $\text{CH}_3 - \underset{\text{stacked}}{\text{--- n ---}} - \text{CO}$  حمض الاكسين  
 الاندول لديها ببتل مغالية اذا حصلت معها كمية قليلة  
 myosteatine : بطاكية تـ \_\_\_\_\_ لة ه أ  
 ٣٧  
 orer - v. hydrophobic زبدتها شمير الكادرات  
 lubrication او  
 over mixing  
 Insoluble قليل حن سائس mixing time د وقت  
 mixing مقليل  
 lubricant مقلية  
 كبر

## Mechanisms of action of flow activators

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

1. They make the surface of the particles more smooth. (ستمانته): particle ستمانه, smooth نعيم
2. They reduce electrostatic charges.
3. They interfere with the cohesion or adhesion due to adsorbed moisture layer

38 الطبقة تسمى Stomate بفتح ال Moisture layer مفتح ال Adhesion