FLOW PROPERTIES OF

SOLIDS

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- Flow prop's are employed as the flow measurements of the effect that the interparticulate forces acting at once

- Flow prop's are imp for formation of stable tablets, since it requires continuous and uniform flow of granules.

- Based on flow prop's, powders are classified as
  - Free flow powders
  - Cohesive powders

- Flow prop's are effected by changes in particle size, shape, density, electrostatic charge and absorb moisture

- Flow prop's of solids have great impact on the tabletting and encapsulation process

- Weight variation and uniform content properties depends upon the uniform & rapid flow of powders

FACTORS INFLUENCING THE FLOW PROPERTIES

- Nature of powders and granulation
- Particle size and size distribution
- Shape factors and surface morphology
- Moisture and static charge
- Powder cohesion and storage conditions
- Effect of temperature

NATURE OF POWDERS AND GRANULATION

- Powders are two phase assemblies of discrete particles with interactions b/w gas & solid internal phases

- Powders differ from other physical states of matter, no-homogeneous…consists discrete solid particles of diff sizes & shapes

- Powders expand / contract when stresses and don't flow…..on too small stresses…..stresses are not dependent on rate of flow.

- Solids handling properties are influenced by factors that have effect on particle particle interactions

- Factors associated with nature of particles and their surfaces such as..

  Size, Shape, Surface morphology, Packing conditions, Interparticulate forces

- Interparticulate forces are of several types …….

  - ✓Mechanical forces
  - ✓Surface tension
  - ✓Electrstatic forces
  - ✓Vanderwall's forces
  - ✓Solid bridge forces

- Properties and phenomena associated with assembly of particles are…….

  - ✓Particle size & shape distribution
  - ✓Cohesion, strength & adhesion
  - ✓Packing properties
  - ✓Flowability
  - ✓Segregation
  - ✓Angle of internal friction

PARTICLE SIZE AND SIZE DISTRIBUTION

♪Dimensions of particles increases and particles changes in nature and forces acting on them also changes

♪Fine powder particles

Less than 100μm	~governed by surface forces
Above 1000μm	~governed by gravitational forces

♪Balance of interaction forces determines the powder behaviour

♪Flow through an orifice – restricted by small particles…. Cohesive forces b/w particles are same as gravitational forces

♪As particle size increases, flow facilitated….if too large…arching...blocks flow

♪Finest fraction of powders….poorest flow, larger fraction…best flow

♪Increase in fines, increases the flow rate…further increase , decreases the flow rate

♪Flow rate increases as diameter of fines increases to 90μm

♪Decrease in particle size and its distribution decreases the angle of internal flow

SHAPE FACTORS AND SURFACE MORPHOLOGY

- Various shape factors includes sphericity, circularity, surface shape coefficient, volume shape coefficient and surface volume shape coefficient

- Flowability of powders decreases as shape of particles becomes more irregular

- Flowability of powders increases with increasing spericity

- Shape of components has great impact on mixing rate and physical stability

MOISTURE AND STATIC CHARGE

- Adsorbed moisture in solids exists in unbound state or part of the crystal structure
- Moisture exerts its effect by changing the surface prop's of particles
- Moisture effects flow prop's indirectly and permanently through formation of granules, which are held together by solid bridges generated by hydration and dehydration of powder / binder
- Moisture influences powder flowability by forming liquid bridges
- Effect of moisture varies depending on degree of packing and porosity of powder bed
- For cohesive & porous materials flowability is effected by moisture, since it penetrates
- Increased moisture content (exceeding 5%) decreases flow prop's and even very low moisture hinders flow prop's

POWDER COHESION & STORAGE CONDITIONS

- Storage conditions of powder influences greater effect on flow characteristics
- As solid remains at rest, the cohesiveness or difficult flowing of powders occurs
- Load levels, time on storage, temperature of storage alters the flow properties
- Increased time & temperature of storage causes decrease in flow properties

EFFECT OF TEMPERATURE

- Cohesion of powder decreases as temperature is decreased and hence flow rates decreases with the increasing temperature

- The low melting point solids have more flow properties than higher melting point solids

FLOW PROPERTIES & THEIR MEASUREMENT

Various flow properties determined for powders and granules are……

- Cohesion
- Angle of Repose (Ø)
- Powder Bulk Density
- Particle Density
- Compressibility Index (I)

COHESION

✓Defined as Stress necessary to shear a bed of powder under conditions or zero normal load

✓Measurement of cohesion is done by various methods…

Using Shear Cell (Quantitative method)
Rate of Sieving (Qualitative method)
Mobility Test (Qualitative method)

Using Shear Cell….

- The force required to shear the bed can be measured

- Shear stress is found by driving this force by cross-section area of bed and increases as bed is compressed by increasing load.

- Types of Shear cell…
  - Jenike shear cell
  - Plate type shear cell
  - Ring or Annular cell
  - Bi & Triaxial Shear cell

Rate of Sieving…

- The rate of sieving is influenced by cohesion due to the formation of aggregates & bridges

- Smaller size fractions passes through mesh and cohesion particles first impedes and finally prevents passage through sieves

PARTICLE SIZE (μm)	RATE OF SEIVING (g/s)
306	0.603
165	0.312
90	Blocked

Mobility Test…

✓Fine particles are more cohesive than coarser, cohesion of bulk powder reduced by adding coarser fraction

✓Mobility test finds the minimum quantity of a coarse component that is trequired for free flowing properties of cohesive powder

FACTORS INFLUENCING COHESION OF POWDERS

1, Average particle size – Cohesion is a surface effect, fine powders are more cohesive and below 10μm powders are extremely cohesive

2, Particle density – Density substances are less cohesive since weight of particles for a given volume is increased

3, Nature of surface

ANGLE OF REPOSE

- The maximum angle possible between surface of a pile of powder and horizontal plane is known as Angle of Repose

- It is the common way of expressing the flow characteristics of powders and granules

- Through this, frictional forces of powders / granules are measured

$$\text{Tan } \varnothing = h / r$$

$$\varnothing = \text{Tan } {}^{-1} h / r$$

ANGLE OF REPOSE	FLOW PROPERTY
0 – 25°	Excellent
25 -35°	Good
35 - 45°	Moderate
> 45°	Poor

Angle of repose is determined by various methods…

- ✓Funnel Method
- ✓Open Cylinder method
- ✓Pilpel method

COMPRESSIBILITY INDEX

- The simple indication of ease with which a material can be induced to flow is given by application of Compressibility Index.
- C.I is denoted by….

$$I = [1 - V / V_o] \times 100$$

Problems Occurring in Determining I

- In case of powders containing non- isometric particles, they take more time for packing due to…
- Arches & Bridges are formed by the interlocking of particles, which need to break down and disperse
- Smaller particles have to move into voids between the larger particles, hence this movement needs time to occur.

I VALUES	FLOW PROPERTY
Below 15%	Good
15-25%	Moderate
Above 25%	Poor

POWDER DENSITY

- The ratio of mass to volume is known as the density of material

- Types of densities…

  True Density , Granular Density, Bulk Density, Relative Density

- True Volume – The total volume of the solid particles, which excludes all spaces greater than molecular dimensions.

- Granular Volume – The cumulative volume occupies by particles including all interparticulate voids

- Bulk Volume – The total volume occupied by entire powder mass under particular packing conditions.

PARTICLE DENSITY

- The particle density is defined as the weight of particle divided by its volume

- It is always greater than bulk density, since part of bed will consists of voids.

METHODS OF IMPROVING FLOW PROPERTIES

- Increasing the average particle size
- By producing the powder in the form of spherical particles
- By use of additives

INCREASING THE AVERAGE PARTICLE SIZE

- The larger particles are less cohesive than smaller ones and the optimium size for free flow exists and also a distinct disadvantages in using a finer grade is noted.

- Hence granules are used in many cases than powder forms and also the addition of coarser fraction to fine powder improves its flow property.

BY PRODUCING THE POWDER IN THE FORM OF SPHERICAL PARTICLES

- By using this type of powder, it packs down and flows wasily since particles roll over one another.

BY USE OF ADDITIVES

Commonly used additives to increase the flow properties of the powders are flow enhancers

They are generally used in low conc's and the optimum conc of all glidants varies from 1% to 2% and above this conc, the flow properties of powders decreases.

Various mechanisms of glidant action

✓Dispersion of static charge from surface of host particles

✓Distribution of glidants in host particles

✓Adsorption of gases and vapours are adsorbed onto host particles

✓Physical separation of particles and reduction in vanderwaal's interaction.

✓Adsorption of glidant particles to granulation surfaces so that friction between particles and surfaces are minimized.

✓Disruption of water film formed between the particles, when they are exposed to air, due to increased humidity.

✓The effect of glidant depends on may factors such as…

1, Physical & chemical affinity of powder

2, Average particle size & shape

3, Concentration of glidant

4, Degree of mixing

5, Moisture content

✓Glidants generally has mechanical action …they adhere to surface of host powders and reducing their tendency to interlock mechanically during movement and flow.

✓In general 100μm powder requires about 3% of 1 μm glidant