PHYSICS OF TABLET COMPRESSION

Introduction

- Tablets constitutes of almost 70-80% of the all dosage forms.
- Tablets are generally manufactured by 3 main processes.
- Compaction represent one of the most important unit operations in the pharmaceutical industry.
- Compaction is the situation in which materials are subjected to some level of mechanical force.
- The physics behind the compaction is stated as the compression and consolidation of the two phase system due to applied force.
- While considering the compaction and compression of tablets we had to taken the properties of powder into the consideration as they are involve in the process of the compression and compaction.

- Derived properties of powder: Volume, density, porosity, Flow properties, angle of repose etc., help in quantification of important variables.
- ***<u>Definitions:</u>***
- **<u>What is Compression:</u>**
- Compression means reduction of bulk volume of material as a result of the removal of gaseous phase (air) by applied pressure.

- **<u>What is Consolidation:</u>**
- Consolidation is an increase in mechanical strength of material resulting from particle-particle interactions.

- **<u>What is Compaction:</u>**
- Compaction of the powder is the term is used to describe the situation in which the materials are subjected to some level of mechanical forces.

- **Compaction =compression + consolidation** of two phases (solid-gas) on application of force.

Physics of Tablet Compression:

- Steps involved in the compression of Tablet.

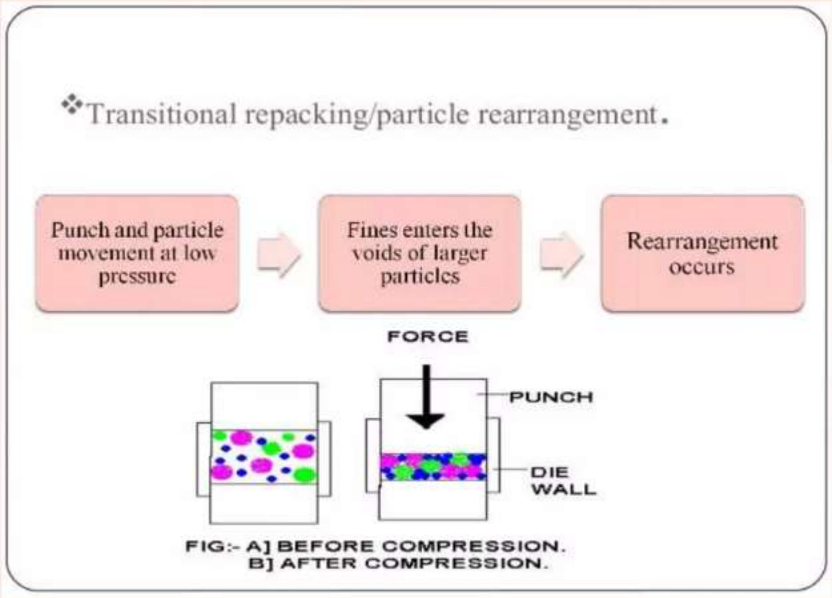
1. Transitional repacking or particle rearrangement.
2. Deformation
3. Fragmentation
4. Bonding (here removal of process)
5. Deformation of solid body
6. Ejection.

Chart showing the steps and process behind the tablet compression

Process of Tablet Compression:

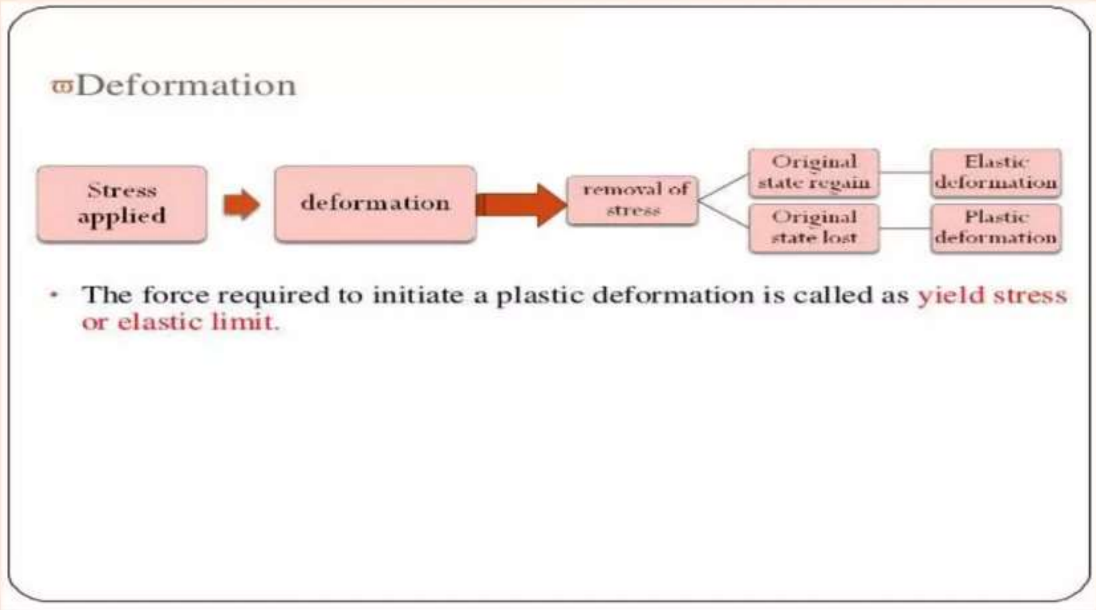
1. Transitional Repacking or Particle rearrangement:

- When a powder is compressed initially the particles are rearranged under low compaction pressures to form a closer packing structure.
- The finer particles enter the voids between the larger ones and give a closer packing arrangement.
- In this process, the energy is evolved, as a result of inter particulate friction and there is an increase in the amount of particle surface area capable of forming inter particulate bonds.



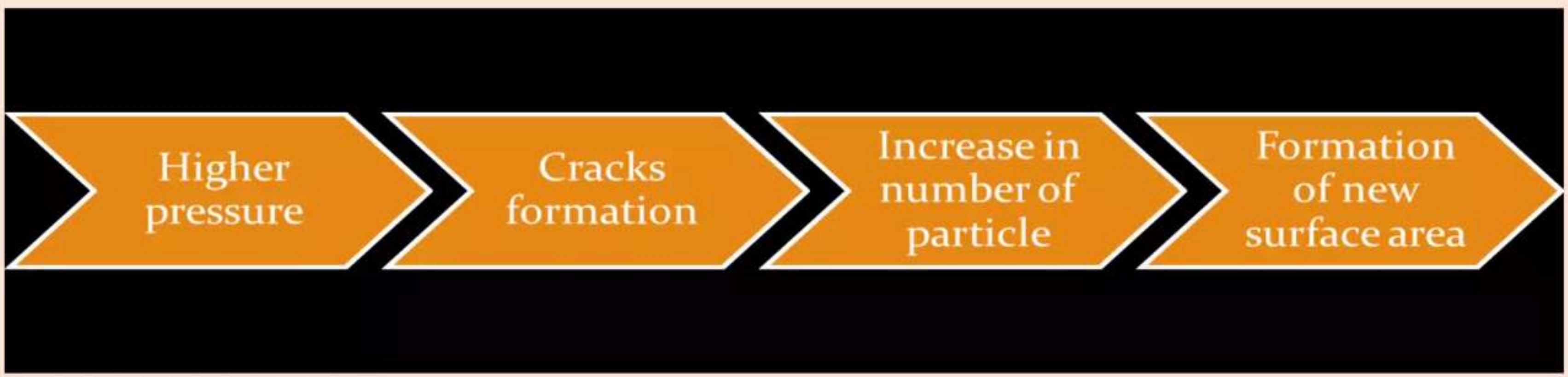
2. Deformation:

- When the particles of granulation are so closely packed that no further filing of voids can occur, a further increase in the compression force causes deformation at that point of contact
- Change in shape of material occurs. At certain points the packing characteristics of the particles reduced space or porosity of inter-particulate friction will prevent any further rearrangement of particles.
- At this point further reduction in the compact volume results in elastic or plastic deformation.



3.Fragmentation:

- As compression force increases deformed particles start fragmentation due to high load, particles breaks into smaller fragments leading to formation of new bonding areas.
- The fragment undergo densification with infiltration of small fragments into voids.
- Some particles undergo structural break down called as brittle fracture.



4.Bonding of Particles:

- After the fragmentation of the particles, as the pressure increases, formation of new bonds between the particles at that contact area occurs. The hypothesis favoring for increase in mechanical strength of bed of powder when subjected rising compressive forces can be explained by following theories.

a) Liquid surface film theory

b) Intermolecular theory

c) The mechanical theory.

- **Liquid surface theory:** This theory attributes bonding to the presence of a thin liquid film which may be the consequences of fusion or solution at the surface of the particles. This theory is a combination of Solid bridge, Hot welding and Cold welding theory.
- **The Mechanical Theory**: It occurs between irregularly shape particles and increase no of point of contact between the particles. This theory proposes that under pressure the individual particles undergo elastic or plastic deformation and edges of particle intermesh deforming a mechanical bond.

5. Deformation of the solid body:

- As the applied force /pressure is further increased the bonded solid is consolidated towards a limiting density by plastic/ elastic deformation of the tablet within the die.

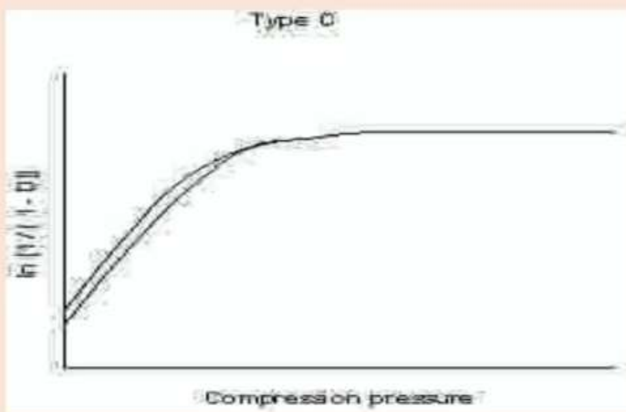
6. Ejection:

- The last stage in compression cycle is ejection from die.
- The force necessary to eject a tablet involves the distinctive peak force required to initiate ejection, by breaking of die wall– tablet adhesion. The second stage involves the force required to push the tablet up the die wall, and the last force is required for ejection.

Compaction Equations:

1.Heckel equation: The Heckel equation is based on the assumption that densification of the bulk powder under force follows first-order kinetics.

- The Heckel equation is expressed as; In **[1/1-D] = KP +A**
- Where, D is the relative density of the tablet (the ratio of tablet density to true density of powder) at applied pressure P, and K is the slope of straight line portion of the Heckel plot.



2.Kawakita equation: The basis for Kawakita equation for powder compression is that the particles are subjected to compressive load in equilibrium at all stages of compression, so that the product of pressure term and volume term is constant.

- Pa/C = 1/ab +Pa/a

Where,

Pa= Applied pressure,

a= degree of volume of reduction for bed particles.

b= Constant inversely proportional to yield strength.

C= Degree of Volume of reduction.