CONSOLIDATION

An increase in the mechanical strength of the material resulting from particle or particle interaction. (Increasing in mechanical strength of the mass)

Consolidation Process

- ***Cold welding: When the surface of two particles approach each other closely*** enough, (e.g. at separation of less than 50nm) their free surface energies result in strong attractive force, this process known as cold welding.

- ***Fusion bonding: Contacts of particles at multiple points upon application of load,*** produces heat which causes fusion or melting. If this heat is not dissipated, the local rise in temperature could be sufficient to cause melting of the contact area of the particles.

Factors Affecting Consolidation

- Both “cold" and "fusion" welding, the process is influenced by several factors, including:

1. The chemical nature of the materials
2. The extent of the available surface
3. The presence of surface contaminants
4. The inter-surface distances

- Various forces involved in the Compression,
  - Frictional force
  - Distributional force
  - Radial force
  - Ejectional force

Frictional force

- Frictional forces are interparticulate friction & die wall friction. Interparticulate friction forces occur due to particle-particle contact & it is more significant at low applied load . These forces are reduced by using glidants e.g. colloidal silica .

- Die wall friction forces occur from material pressed against die wall & moved it is dominant at high applied load These forces are reduced using lubricants e.g. magnesium stearate.

EFFECT OF FRICTION

At least two major components to the frictional forces can be distinguished.

1. Interparticulate friction:

   This arises at particle/particle contact and can be expressed in tearms of a coefficient of interparticulate friction; it is more significant at low applied loads. Materials that reduce this effect are referred to as glidants. Colloidal silica is a common example .

2. Die-wall friction:

This results from material being pressed against the die wall and moved down it; it is expressed Mcg the coefficient of die-wall friction. This effect becomes dominant at high applied forces when particle rearrangement has ceased and is particularly important in tabletting operations. Most tablets contain a small amount of an additive designed to reduce die-wall friction; such additives are called lubricants. Magnesium stearate is a common choice.

Dributional Force

- The fundamentals of tabletting have been carried out on single-station press or even on isolated punch & punches with hydraulic press.

- When force is being applied to top of a cylindric powder mass, the following basic relationship applies, since there must be an axial (vertical) balance of forces.

- Most investigations of fundamentals of tableting have been carried out on single punch press or even isolated dies & punches with hydraulic press A force is applied on top of cylinder of powder mass consicder single isolated punch.

$$FA = FL + FD$$

FA = Force applied to upper punch
FL = Force transmitted to lower punch
FD = Reaction at die wall due to friction at surface.

Because of this inherent difference between the force applied at the upper punch and that affecting material close to the lower punch, a mean compaction force, F_M, has been proposed,

$$F_M = \frac{F_A + F_L}{2}$$

F_A = Force applied to upper punch

F_L = Force transmitted to lower punch

F_M = Mean force

A recent report confirms that F_M offers a practical friction independent measure of compaction load, which is generally more relevant than F_A.

The geometric mean force (F_G):

$$F_G = (F_A \times F_L)^{1/2}$$

RADIAL FORCE :

- As the compression force increased and any repacking of the tabletting mass is completed, the material may be regarded to some extent as a single solid body.
- Then as with other solid, compressive force applied in one direction (e.g. vertical) result in decrease ΔH in the height, i.e. a compressive stress.
- In The case of an unconfined solid body, this would be accompanied by an expansion in the horizontal direction of ΔD.
- The ratio of these two dimensional changes is known as poisson ratio of the material, $\lambda = \frac{\Delta D}{\Delta H}$

EJECTION FORCE :

Radial die wall forces and die wall friction also affects ejection of the compressed tablet can be removed from the die. The force necessary to eject the finished tablet is known as ejection force.

This force can eject tablet by breaking tablet/die wall adhesion, variation also occurs in ejection force when lubrication is inadequate.

COMPACTION PROFILES

- Many attempts have been made to minimize the amount of applied force transmitted radially to the die walls. All such investigations lead to characteristic hysteresis curves called as compaction profiles. Radial pressure is developed due to the attempt of material to expand horizontally. The plot of radial pressure against axial pressure leads to hysteresis curve called as compaction profile.

- When the elastic limit of the material is high, elastic deformation may make the major contribution, and on removal of the applied load, the extent of the elastic relaxation depends on the value of the material's modules of elasticity (young's modulus).

- *Lower the modulus higher will be the elastic relaxation. Then there will be the danger of structural failure. Higher the modulus value results in low decompression hence lesser risk of structural failure.*

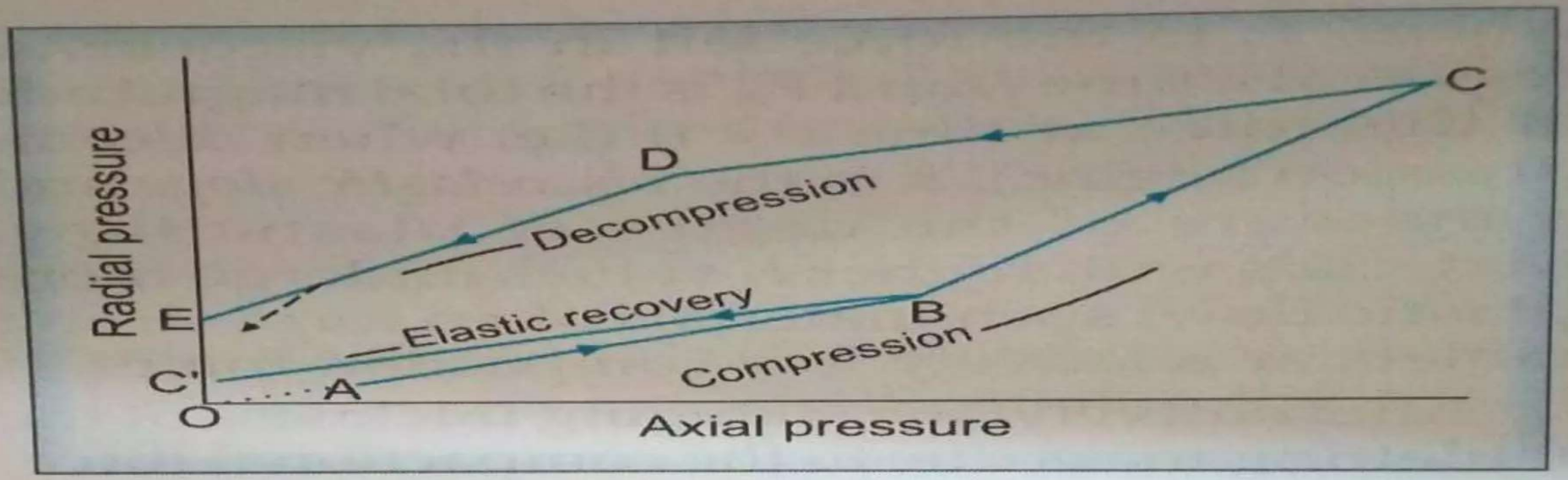


Fig. 13.48: Examples of compaction profiles. Dotted line O to A represents a highly variable response due to repacking, while at A, elastic deformation becomes dominant and continues until the elastic limit B is reached. From B to the point of maximum compression C, deformation is predominantly plastic, or brittle fracture is taking place. The decompression process C to D is accompanied by elastic recovery, and if a second yield point (D) is reached, by plastic deformation or brittle fracture D to E. The decompression line B to C represents the behavior of a largely elastic material

Compression phase:

- OA – Represents repacking of granules or powders.
- AB – Represents elastic deformation which continues up to B (elastic limit).
- BC –Represents plastic deformation and brittle fracture. Point C indicates the maximum compression force.

Decompression phase :

- CD –Represents elastic recovery on the removal of applied force.
- DE –Represents recovery from plastic deformation
- E –Represents residual force, which holds the compact in the sides of the die.
- Ejection force must be greater than residual force.

How they are measured?

It is analyzed by compaction simulators, these are attached to punching machines which collect or measure the data from forces on punches, displacement of punches, die wall friction, ejection force and temperature change.

Types of compaction profiles :

- Force –time profile
- Force –displacement profile
- Die wall force profile

1) Force time profile:

Compression force time profiles are used to characterize the compression behavior of the active ingredients, excipients and formulations with respect to their plastic and elastic deformation.

a) Compression phase
b) Dwell time
c) Decompression/relaxation phase

a) Compression phase:

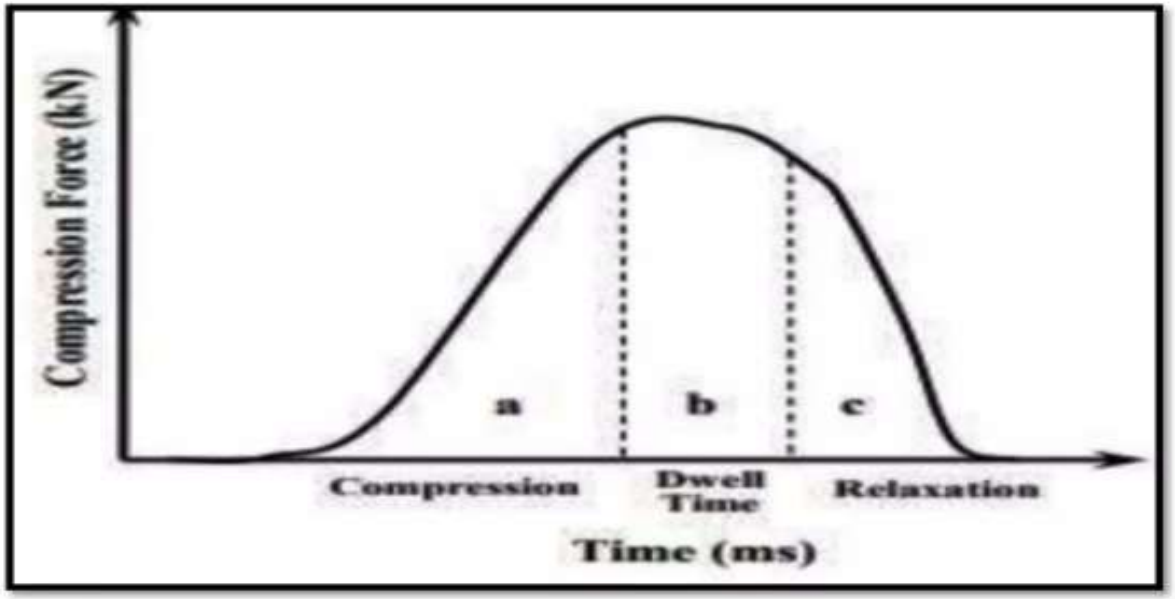
Compression is the process in which maximum force is applied powdered bed in order to reduce its volume.

b) Dwell phase:

when compression force reaches a maximum value, this maximum force is maintained for prolonged period before decompression. The time period b/w the compression phase and decompression phase is known as dwell time.

c) Decompression phase:

Removal of applied force on powder bed i.e., both punches moving away from upper and lower surfaces.



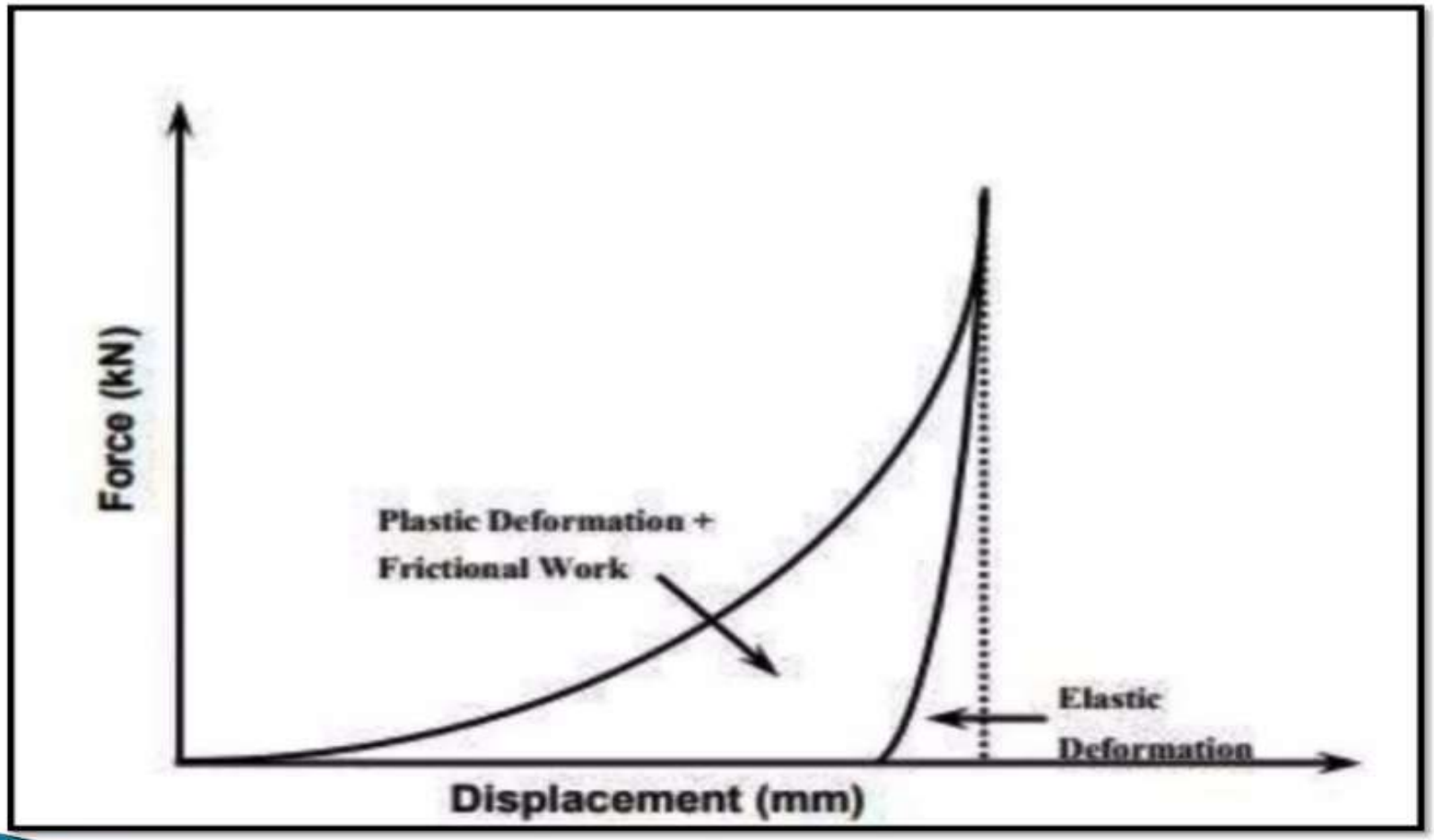
a) Compression phase (horizontal and vertical punch movement)

b) Dwell time (plane punch head area is under compression roller)

c) Decompression phase (both punches move away from upper and lower surfaces)

2) Force –displacement profiles:

- Assessment of the compaction behavior of materials is done by force –displacement profile .
- Force –displacement profile can be used to determine the behavior of plastic and elastic materials.
- Stress relaxation is observe to be minimal in case of plastic deformation; where as the material that undergoes elastic deformation tend to relax to a greater extent during and/or after compression.
- At a given f_{max} the displacement area of plastic deformation is more when compared to the displacement area of elastic deformation.


Force (kN)
Plastic Deformation +
Frictional Work
Elastic
Deformation
Displacement (mm)

3) Die wall force profile:

- During tableting, friction arises b/w the material and the die wall which is called Die wall force friction.
- The die wall force reaches maximum just after the maximum upper and lower force, and a constant residual value after upper and lower forces become zero.
- The high die wall force during ejection is a sign of adhesion of powders to the die.

Sr. no.	material	Residual die wall force
1	Plastic	Large
2	Brittle	Medium
3	Elastic	Low

Energy involved in compaction:

- Tablet machines, roller compactors, and similar types of equipment required a high input of mechanical work.
- The work involve in various phase of tablets operation includes.
- That necessary to overcome friction between particles.
- That necessary to overcome friction between the particles and machine parts.
- That required to induce elastic and/ plastic deformation of the materials.
- That required to cause brittle fracture within the materials.
- That associated with the mechanical operation of various machine parts

SOLUBILITY :

Solubility is defined as Quantitative terms as concentration of solute in concentration of solute in concentrated solution at a certain temperature, and in qualitative way it can be defined as a spontaneous interaction of two or more substance to form a homogeneous molecular dispersion.

Importance of solubility :

- Therapeutics effectiveness of a drug depends upon the bioavailability and ultimately upon the solubility of drug molecule.
- It is important parameter to achieve desired concentration of drug in systemic circulation for pharmacological response to be shown.
- Any drug to be absorbed must be soluble or present in the form of an aqueous solution at the site of absorption.