BP 403T. Physical Pharmaceutics-II (Theory)

Unit1 (Part II)

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UNIT-II 10 Hours

Rheology: Newtonian systems, law of flow, kinematic viscosity, effect of temperature, non-Newtonian systems, pseudoplastic, dilatant, plastic, thixotropy, thixotropy in formulation, determination of viscosity, capillary, falling Sphere, rotational viscometers Deformation of solids: Plastic and elastic deformation, Heckel equation, Stress, Strain, Elastic Modulus

DEFORMATION OF SOLIDS

It is possible to change the shape or size (or both) of an object through the application of external forces It is described as strain. As deformation occurs internal inter molecular forces arise that oppose the applied force.

If the applied force is not too great these internal forces are sufficient to completely resists the applied force and allow the object to assume a new equilibrium state and to return to its original state when the load is removed.

A larger applied force may lead to a permanent deformation of the object or even to its structure failure.

Stress is the measure of the force required to cause deformation.

Stress = Force/Area

$\sigma = P/A$ (unit is N/mm^2)

A **strain** is the measure of the degree of deformation.

Strain = Change in length/Original length

$e = \partial L/L$

The ratio of stress to strain is known as elastic modulus. Elastic modulus defines the amount of force required per unit deformation.

Elastic Deformation (Temporary Deformation): It is reversible. When the forces are removed, the object tends to its original shape.

An object is **elastic** when it comes back to its original size and shape when the load is no longer present. Physical reasons for elastic behavior vary among materials and depend on the microscopic structure of the material.

For example, the elasticity of polymers and rubbers is caused by stretching polymer chains under an applied force.

In contrast, the elasticity of metals is caused by resizing and reshaping the crystalline cells of the lattices (which are the material structures of metals) under the action of externally applied forces.

There are two parameters that determine the elasticity of materials:

- Elastic modulus
- Elastic limit.

Elastic modulus:

The Elastic Modulus is the measure of the stiffness of a material. In other words, it is a measure of how easily any material can be bend or stretch.

λ =stress/strain

- A low elastic modulus is typical for materials that are easily deformed under a load; for example, a rubber band.
- If the stress under a load becomes too high, then when the load is removed, the material no longer comes back to its original shape and size, but relaxes to a different shape and size: The material becomes permanently deformed.

Elastic deformation is reversible i.e. recoverable. Up to a certain limit of the applied stress, strain experienced by the material will be the kind of recoverable i.e. elastic in nature.

This elastic strain is proportional to the stress applied. The proportional relation between the stress and the elastic strain is given by **Hooke's law**, which can be written as:

$\sigma \propto \varepsilon$ and $\sigma = E\varepsilon$ (where the constant E is the modulus of elasticity or **Young's modulus.)**

E**lastic limit:** is the stress value beyond which the material no longer behaves elastically but becomes permanently deformed.

Applications of the Elastic modulus:

It is used in engineering as well as medical science.

- To calculate how much a material will stretch and also how much potential energy will be stored.
- The elastic modulus allows you to determine how a given material will respond to Stress.
- Elastic modulus is used to characterize biological materials like cartilage and bone as well.

Plastic Deformation (Permanent Deformation): It is irreversible. Object in plastic deformation range will first have undergone elastic deformation which is reversible so the object will partly return to its original shape. Soft thermoplastic materials have rather large plastic deformation range as do ductile metals such as copper, silver and gold.

For stresses beyond the elastic limit, a material exhibits **plastic behavior**.

This means the material deforms irreversibly and does not return to its original shape and size, even when the load is removed.

When stress is gradually increased beyond the elastic limit, the material undergoes plastic deformation. When a material is subjected to applied forces, the material experiences elastic deformation followed by plastic deformation. The transition from elastic to plastic state is characterized by the yield strength of the material.

Heckel Equation: The Heckel equation is one of the most useful equations for describing the compaction properties of pharmaceutical powders. Heckel measured that decline in the voids follows the first order kinetics connection with applied pressure.

For compression method heckel has suggested following equation:

$\ln(V/V- V\alpha) = KP + (Vo/ Vo- V\alpha)$

Where V= volume at the applied pressure P

Vo= original volume of the powder including the voids.

Vα= volume of the powder excluding the voids

K = constant related to the yield pressure of the powder

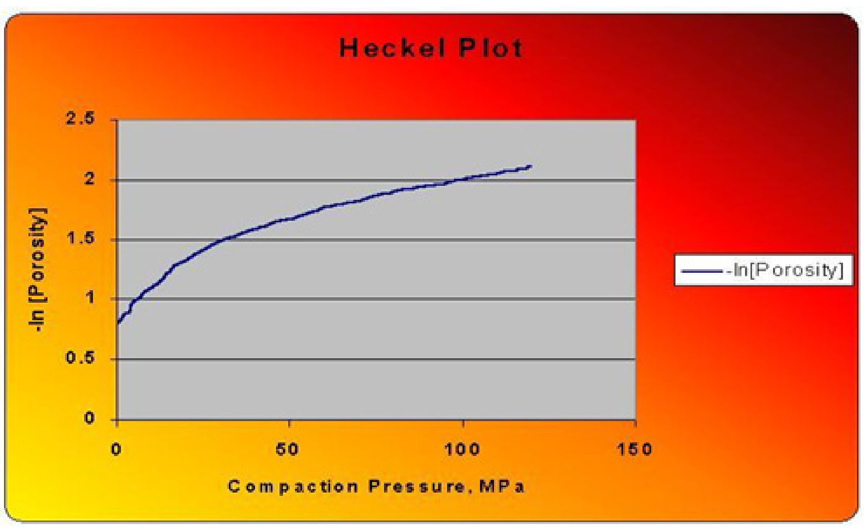
P = Applied pressure as we know porosity

E is the ratio of the total volume of the void space to the bulk volume of the powdered material E= V- Vα / V

Replacing the value in previous equation it becomes:

$\ln(1/E) = KP + (Vo/ Vo- V\alpha)$

Heckel established a linear relationship between the relative porosity of a powder and the applied pressure.



The slope of the linear regression is the Heckel constant, a material dependent parameter inversely proportional to the mean yield pressure (the minimum pressure required to cause deformation of the material undergoing compression).

Large values of the Heckel constant indicate susceptibility to plastic deformation at low pressures, when the tablet strength depends on the particle size of the original powder. The intercept of the line indicates the degree of densification by particle rearrangement.