Deformation of solids

Stress

When an external force acts on a body, it undergoes deformation. At the same time the body resists deformation. The magnitude of the resisting force is numerically equal to the applied force. This internal resisting force per unit area is called stress.

Stress = Force/Area, $\sigma = P/A$ (unit is N/m^2)

Strain

When a body is subjected to an external force, there is some change of dimension in the body. Numerically the strain is equal to the ratio of change in length to the original length of the body.

Strain = Change in length/Original length, $e = \partial L/L$

Young's modulus

The ratio of stress and strain is constant with in the elastic limit. This constant is known as Young‟s modulus.

$$E = \text{Stress}/\text{Strain}$$

The Heckel equation

The Heckel equation was derived assuming that the particles undergo plastic deformation under pressure, whereby the volume reduction of the powder is assumed to obey first-order kinetics in which the pores constitute the reactant.This equation is one of the most useful equations for describing the compaction properties of pharmaceutical powders. Important material properties (e.g., yield strength) of powders can be derived using Heckel analysis.

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

Where V= volume at the applied pressure P
V_o= original volume of the powder including the voids
$V\alpha$= volume of the powder excluding the voids
K = constant related to the yield pressure of the powder
P = Applied pressure

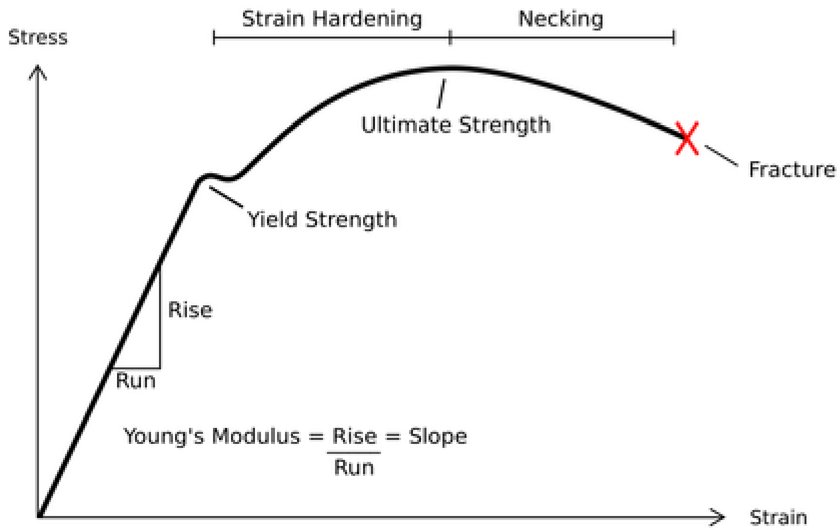
Elastic Deformation

It is reversible process, when the forces are removed, the object tends to come its original shape.

Elastomers and shape memory metals such as nitinol exhibit large elastic deformation ranges as
does rubber. Elasticity is non linear. Metals and ceramics show linear elasticity. Linear elastic deformation is governed by Hooke's Law

$$\sigma = E \varepsilon$$

Where σ is applied stress, E is material constant called young's modulus or elastic modulus and E is the resulting strain.



The relationship indicates that the slope of stress vs. strain curve can be used to find the elastic or young modulus E. The elastic range ends when the material reaches its yield strength.

At this point plastic deformation begins.

Plastic 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. An example of a material with a large plastic deformation range is a wet chewing gum which can be stretched dozens of its times its original length. Hard thermosetting plastics, rubber and ceramics have minimal plastic deformation ranges.

Under the tensile stress plastic deformation is characterized as

1. Strain hardening region – material becomes stronger through the movement of atomic dislocations
2. Necking region – reduction in cross sectional area of specimen. It begins after the ultimate strength is reached. Material can no longer withstand the maximum stress and strain in the specimen rapidly increases.
3. Fracture- indicates the end of the plastic deformation