SOME BASIC CONCEPTS OF RHEOLOGY

Lecture 10

PFE-2.4.5

By:

ER. K. R. Jethva

Assistant Professor,

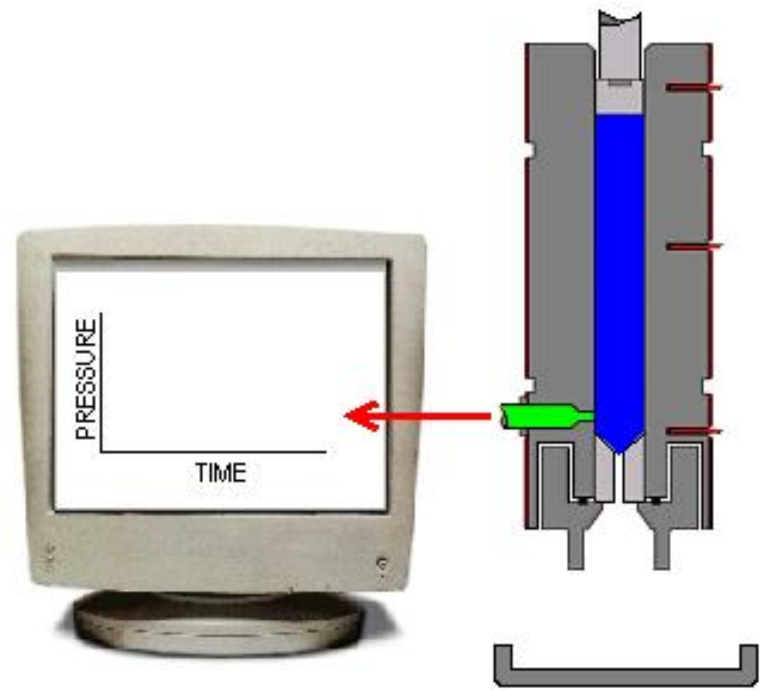
PFE Department, CAET, Godhra

Application

- Design / select equipment such as pumps, pipe lines, extruders, mixers, heat exchangers etc.
- Rheological behavior relates to food texture and sensory data
- To determine ingredient functionality in product development
- Shelf life testing
- To obtain some information about atomic and molecular scale phenomena
- To obtain constitutive relations

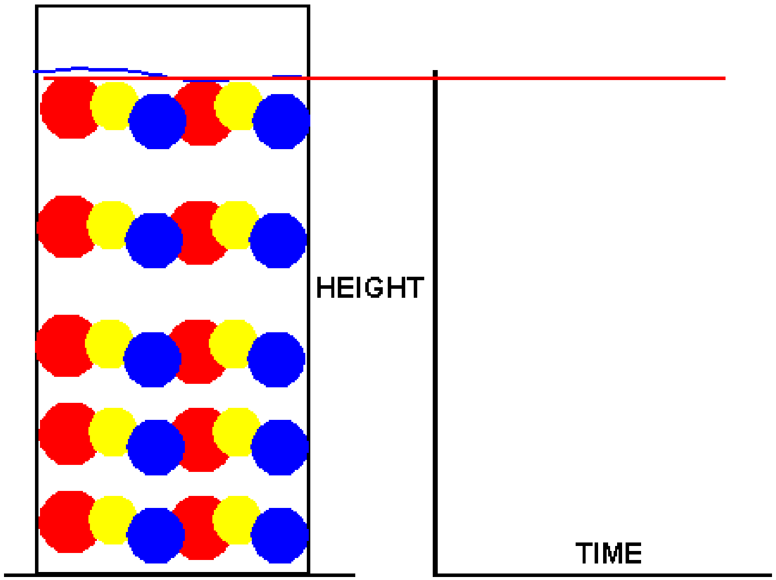
Rheology

- **Rheology** has been defined as" **a science devoted to the study of deformation and flow under applied load.**



Rheology

- When the action of forces result in deformation and flow in the material, the mechanical properties will be referred-to as rheological properties. Moreover, rheology considers the time effect during the loading of a body.

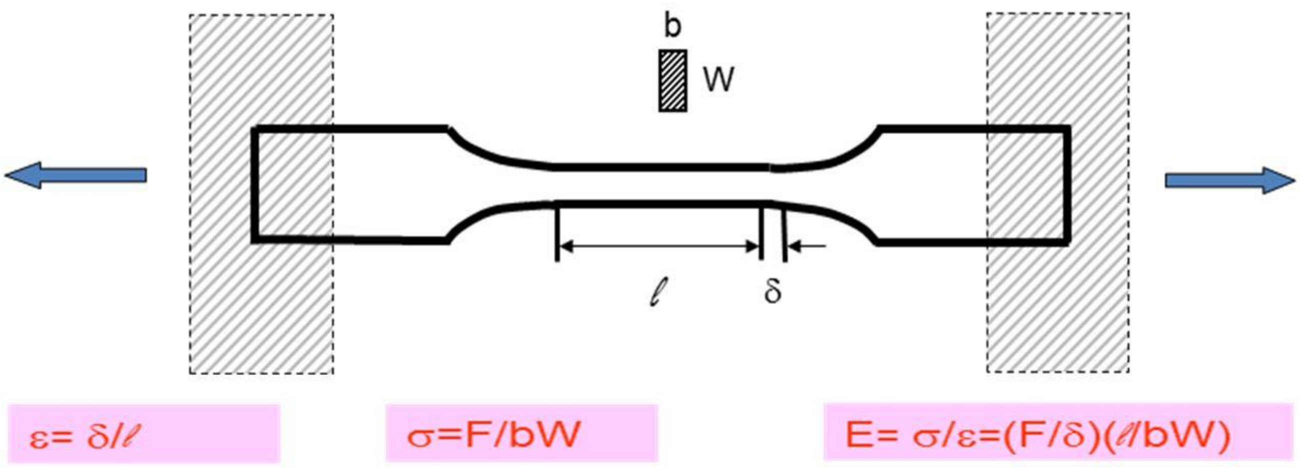


Stress and Strain

- Stress" is defined as force components acting on a body per unit cross-sectional area or area of the deformed specimen (SI units in Pa).
- "Strain" is the change in size or shape (SI units in mm or percentage) of a body in response to the applied force (at a certain time or during continuous change as stress is applied)

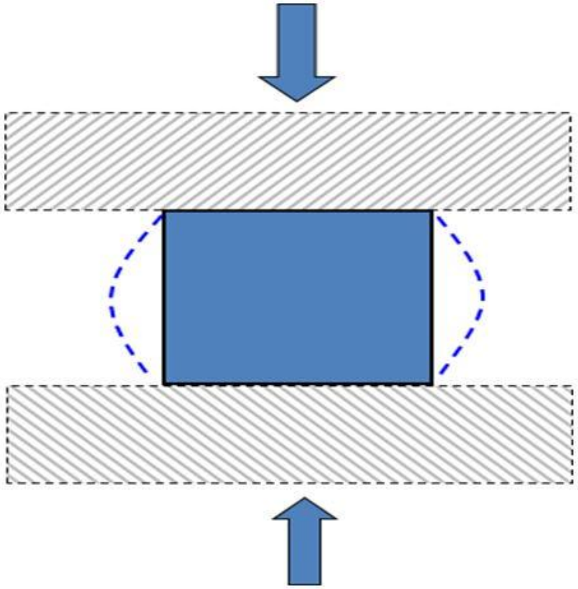
Tensile stress

- it is the normal stress due to forces directed away from the plane on which they act.



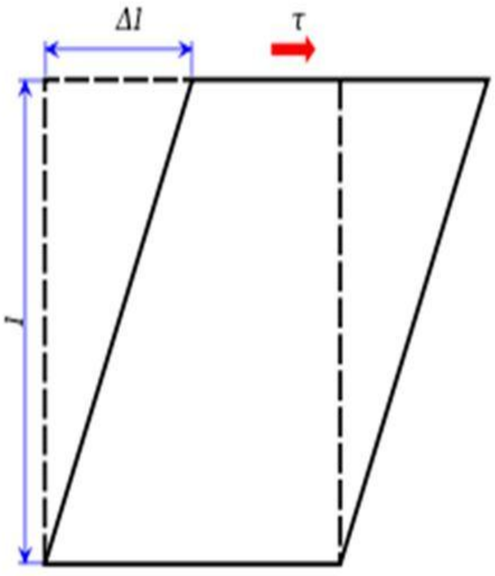
Compressive stress

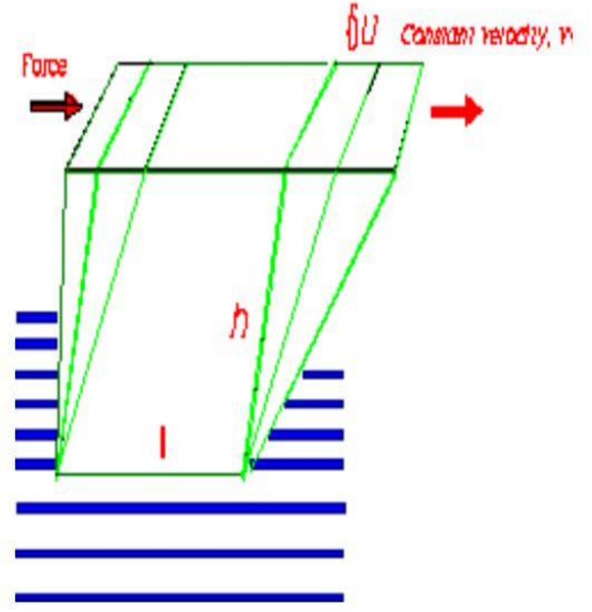
- it is the normal stress due to forces directed toward the plane on which they act.



Shear stress

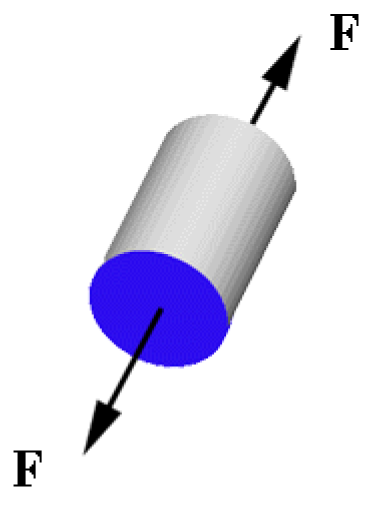
- Stress component tangential to the plane on which the forces act.





Strain

- The unit change , due to force, in the size or shape of a body referred to its original size or shape. Strain is non-dimensional quantity, but it is frequently expressed centimeter per centimeter, m/m, mm/mm etc.



Types of strains

- **Linear (tensile/ compressive) strain**: the change per unit length due to force in an original linear dimension
- **Axial strain**: linear strain in a plane parallel to the longitudinal of the specimen.
- **Transverse strain**: linear strain in a plane perpendicular to the axis of the specimen.
- **Shear strain (angular strain)**: the tangent of the angular change, due to force, between two lines originally perpendicular to each other through a point in a body.

Strength

- The resistance to applied force (kg/cm)
- **Tensile strength:** the maximum tensile stress that a material is capable of sustaining. Tensile strength is calculated from the maximum load during a tension test carried to rupture and the original cross sectional area of specimen.
- **Compressive strength:** the maximum compressive stress that a material is capable of sustaining. Compressive strength is calculated from the maximum load during a compression test and the original cross sectional area of specimen

Ultimate strength

Yield/ Bioyield strength: the stress corresponding to the bioyield point.

Ultimate strength: the stress corresponding to the rupture point (kg/cm^2)

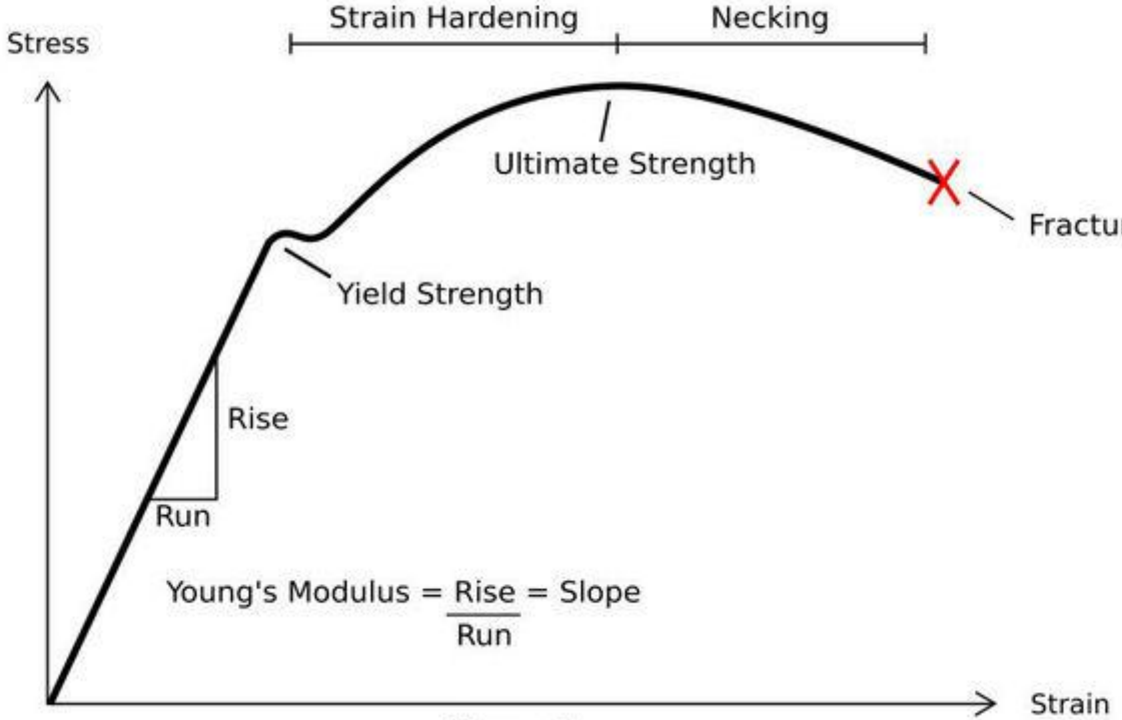
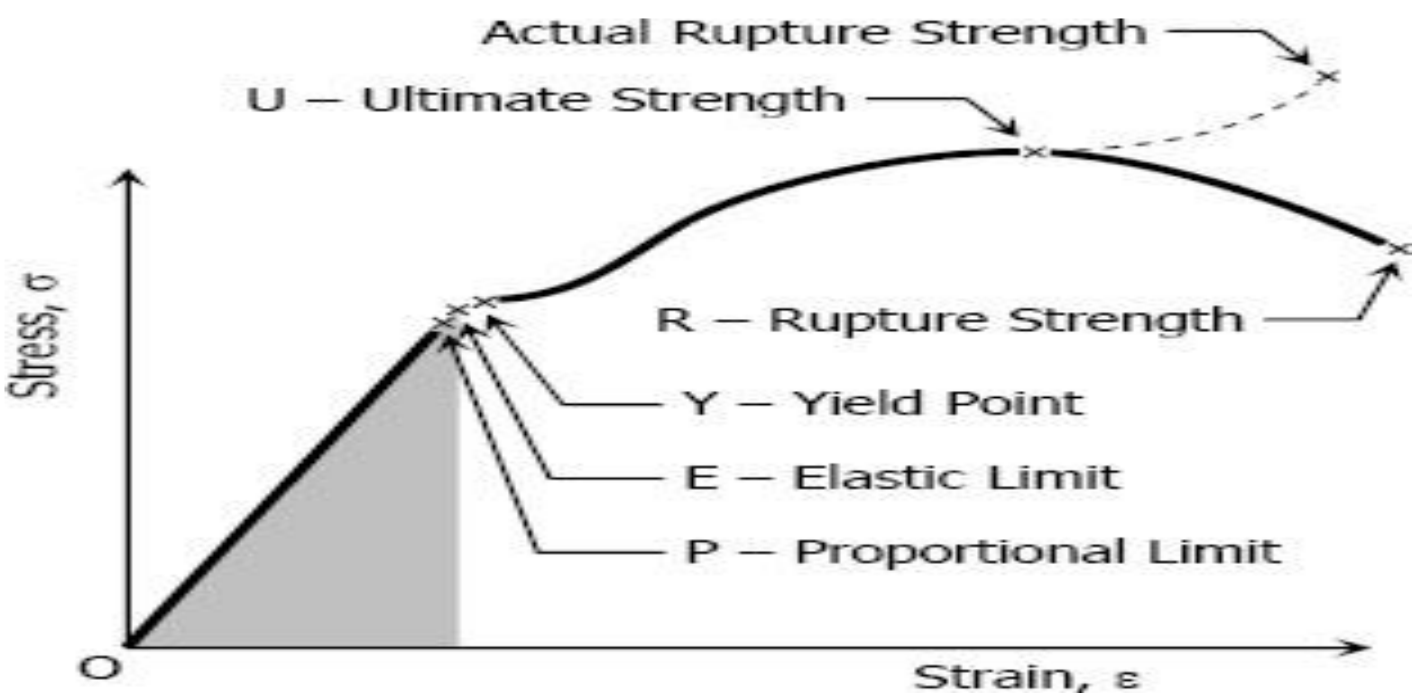


Figure 1

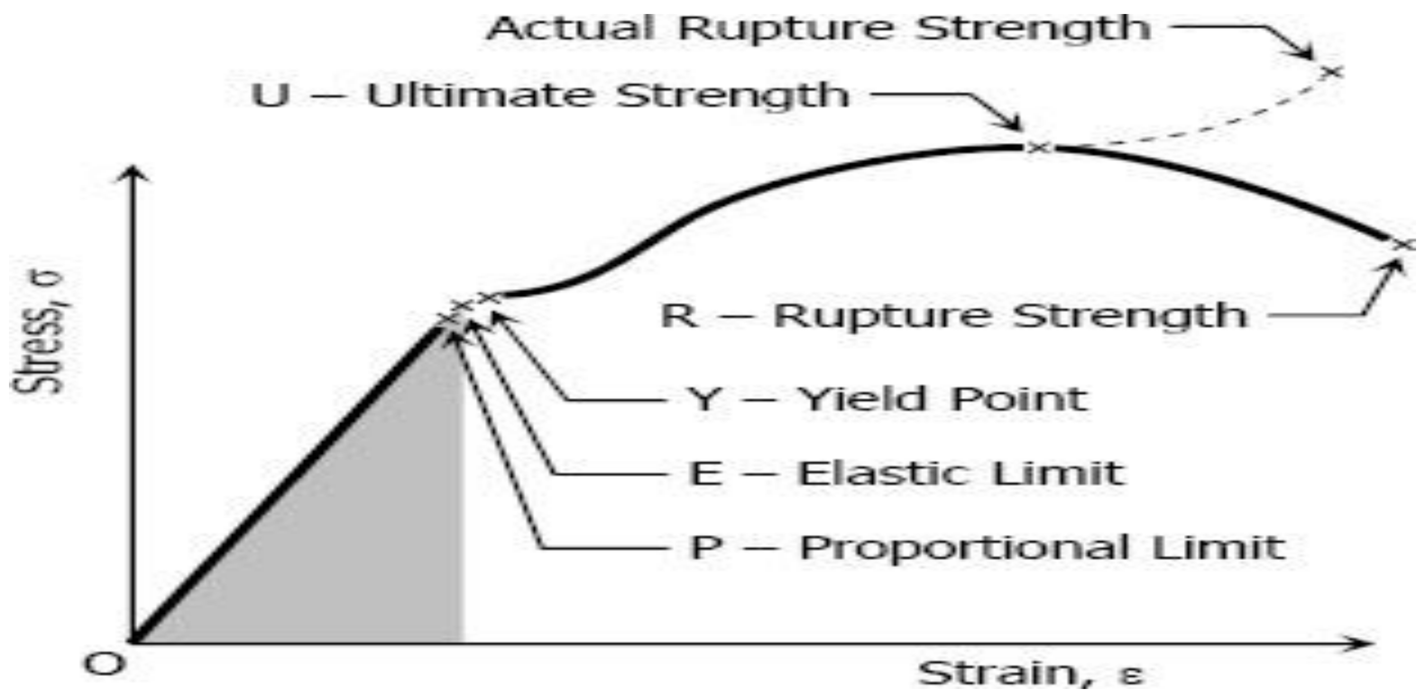
Limits

- **Elastic limit:** the greatest stress which a materials is capable of sustaining without any permanent strain remaining upon release of the stress.
- **Proportional limit:** the greatest stress which a materials is capable of sustaining without any deviation from proportionality of stress to strain (Hooke's law).



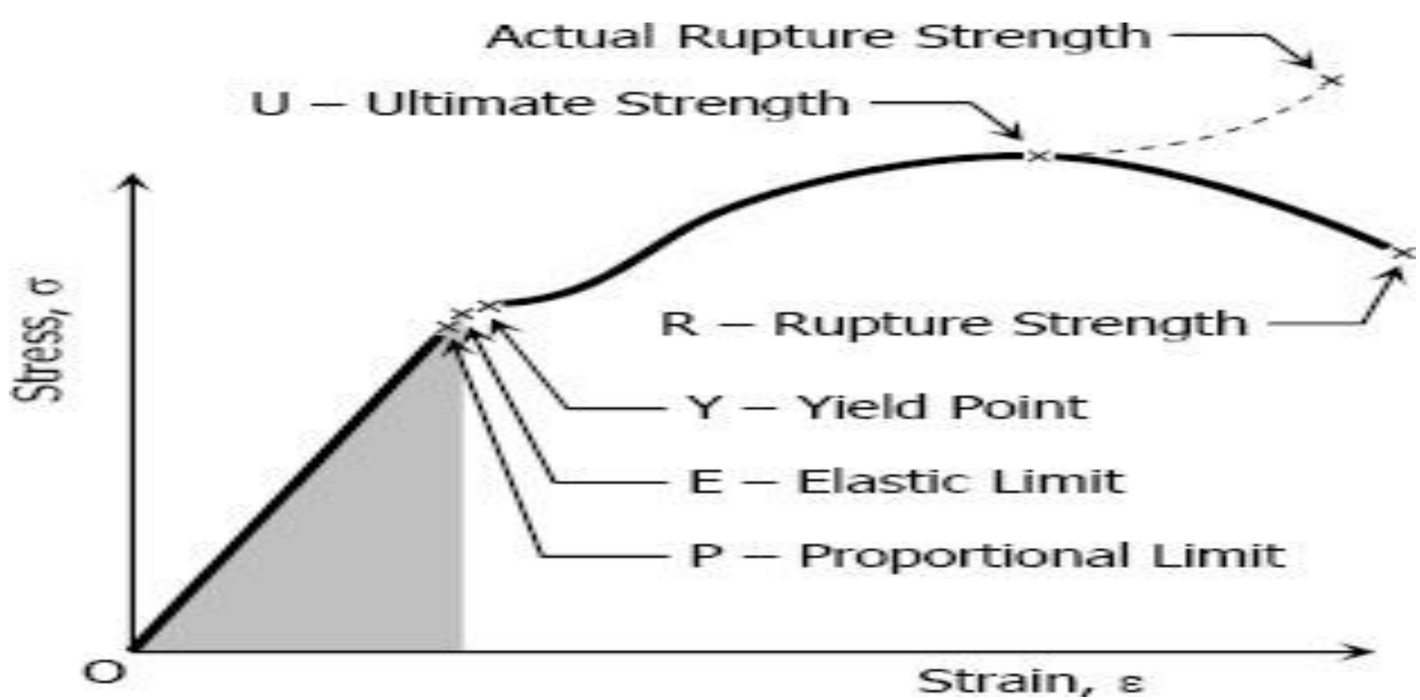
Points

- **Yield point:** the first stress in a material, less than the maximum attainable stress, at which an increase in strain occurs without an increase in stress.
- **Bioyield point:** a point, as y on the stress-strain or force-deformation curve at which there occurs an increase in deformation with a decrease or no change of force. In some agricultural products, the presence of this bioyield point is an indicative of initial cell rupture in the cellular structure of the material.



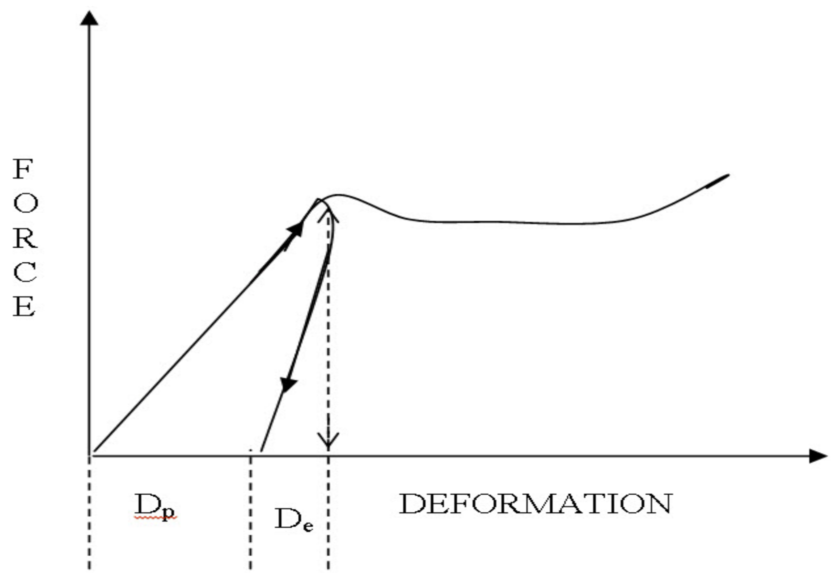
Points

- **Rupture point:** a point on the stress-strain or force-deformation curve at which the axially loaded specimen ruptures under a load. In biological materials, rupture may cause puncture of shell or skin, cracking or fracture planes.



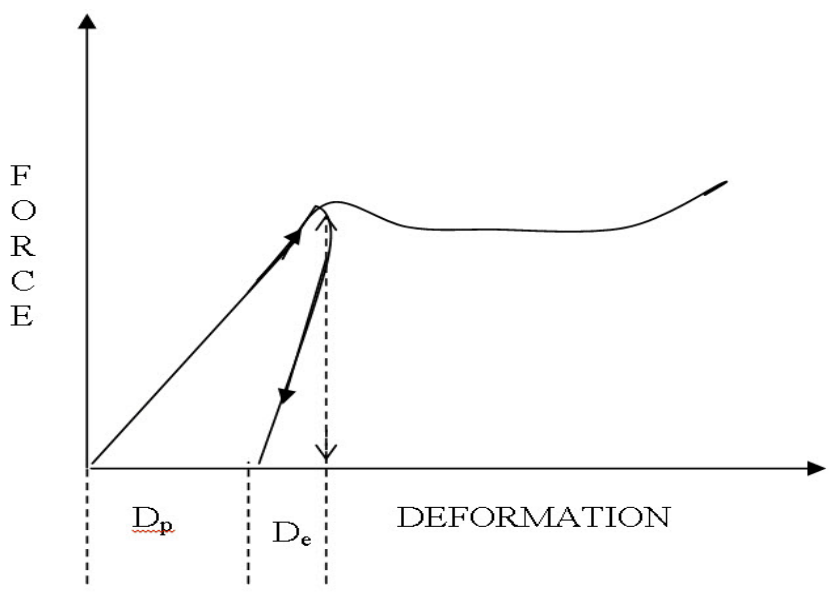
Elasticity

- The capacity of a material for taking elastic or recoverable deformation. In those portions of the curve before the point (Linear limit) LL is reached, elongations are, in large part at least. Recoverable, and are a measure of elastic deformation.



Plasticity

- the capacity of a material for taking plastic or permanent deformation. Since deformations from the bioyield point to the point of rupture are not all recoverable, the recoverable part can be taken as a measure of plastic deformation.



Degree of elasticity

- The ratio of elastic deformation to the sum of elastic and plastic deformation when a material is loaded to a certain load and then unloaded to zero load.

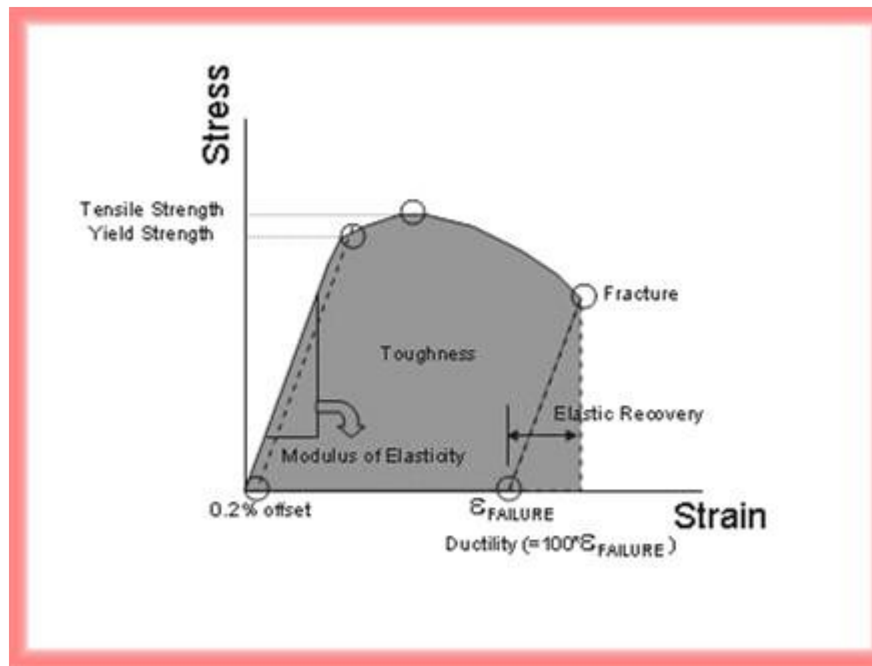
  D_e= elastic or recoverable deformation

  D_p= plastic or residual deformation

  Degree of elasticity = $D_e / (D_e + D_p)$

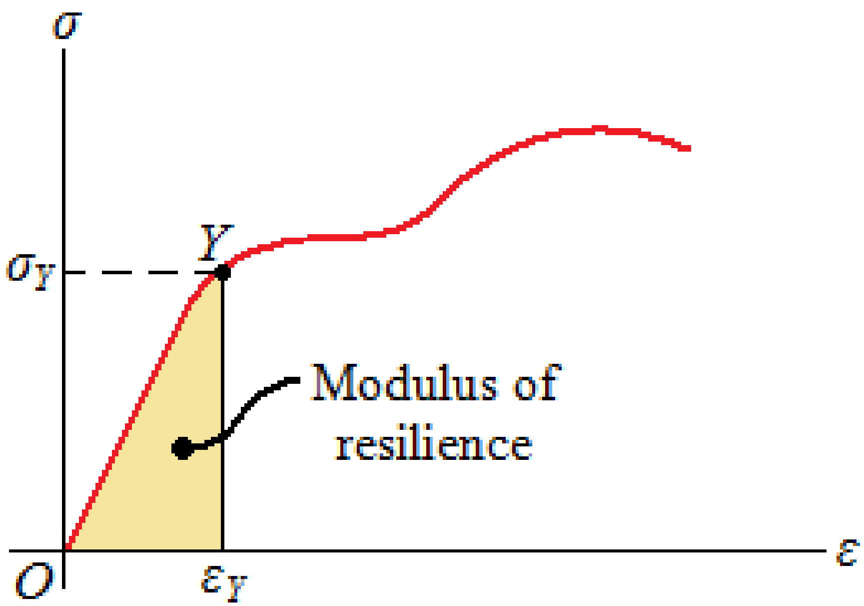
Toughness

- the work required to cause rupture in the material. This can be approximated by the area under the stress-strain or force-deformation curve up to the point selected as the rupture point. If in estimating toughness, a force-deformation curve is uses, the size of the specimen and the loading surface area should be specified.



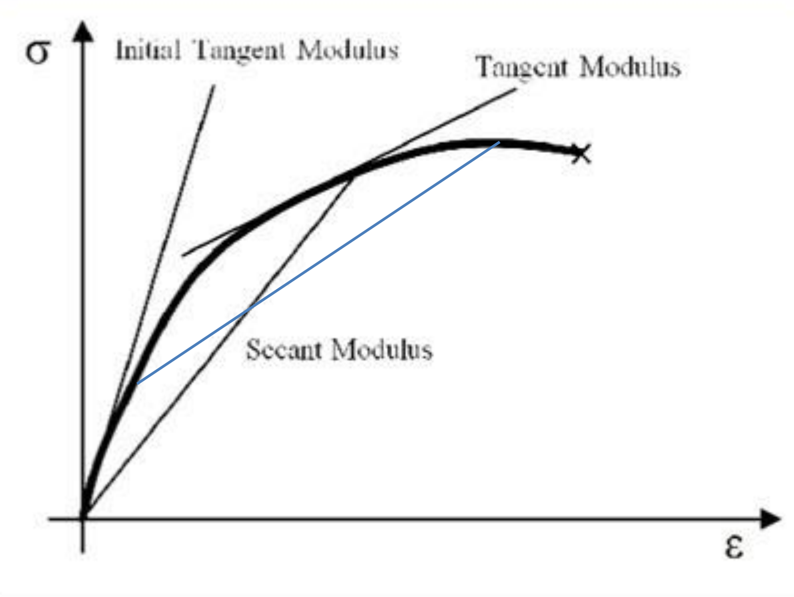
Resilience

- The capacity of a material for storage of strain energy in the elastic range. Thus the area under the unloading curve is a measure of resilience of the material.



- **Initial tangent modulus:** The slope of the stress-strain curve at the origin
- **Tangent modulus:** The slope of the stress-strain curve at any specified stress or strain
- **Secant modulus:** The slope of secant drawn from the origin to any specified point on stress – strain curve
- **Chord modulus:** The slope of chord drawn between any two any specified point on stress – strain curve.

Figure 1 – Different types of modulus of elasticity in the stress-strain curve



Poisons ratio

- the absolute value of the ratio of transverse strain to the corresponding axial strain resulting from uniformly distributed axial stress below the proportional limit of the material.

$$\nu = \frac{lateral - strain}{axial - strain} = \frac{dR / Ro}{dL / Lo}$$