Mechanical properties of metals:

Factors to be considered:

1) Nature of load
2) Duration of load
3) Environmental conditions

measured using ASTM.

Processes performed on metals:

1) Forging
2) Bending
3) Welding, Machining, Grinding drilling
4) Non-Uniform ~~cooling~~ heating
5) Non uniform cooling
6) Extrusion
7) Rolling
8) Phase change

This causes change in:

1) Deformation
2) Change in grain size, orientation, shap
3) Phase change
4) Energy is stored
5) Dislocation density increases.
6) Stress is induced

Materials can be strengthen by:

1) Grain size refinement

2) Solid solution strengthening

3) Strain hardening.

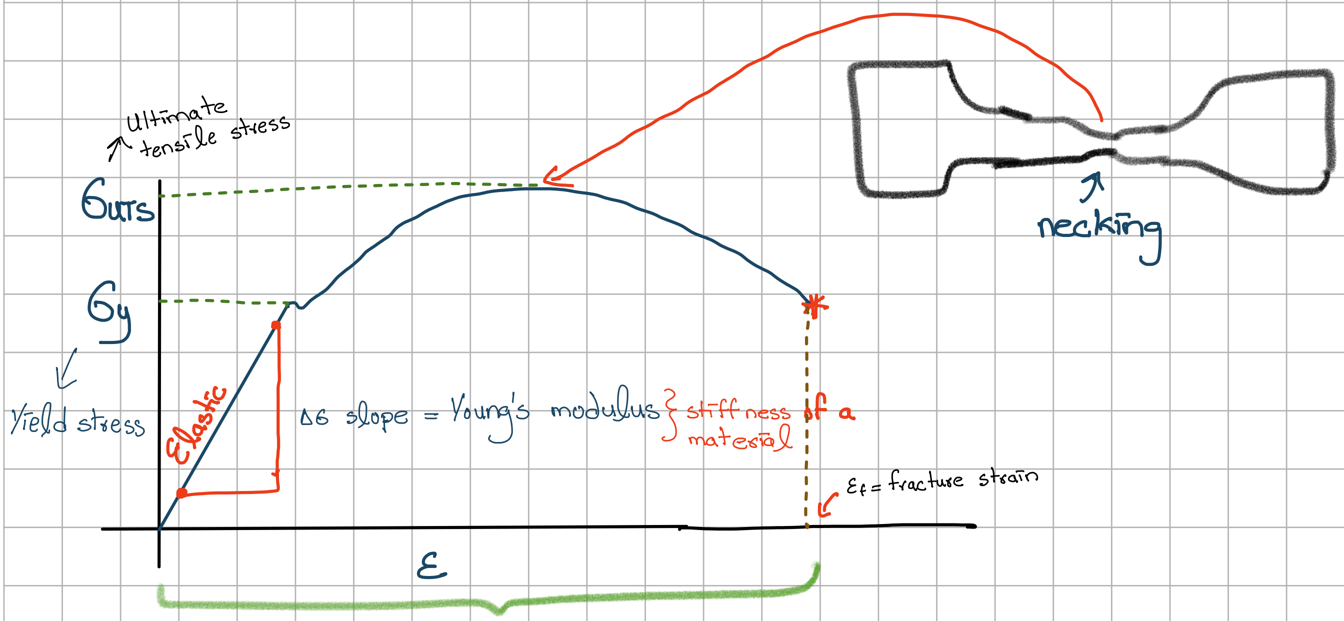
Engineering stress: What a material feels when subjected externally applied force

$$\sigma = \frac{F}{A_0}$$

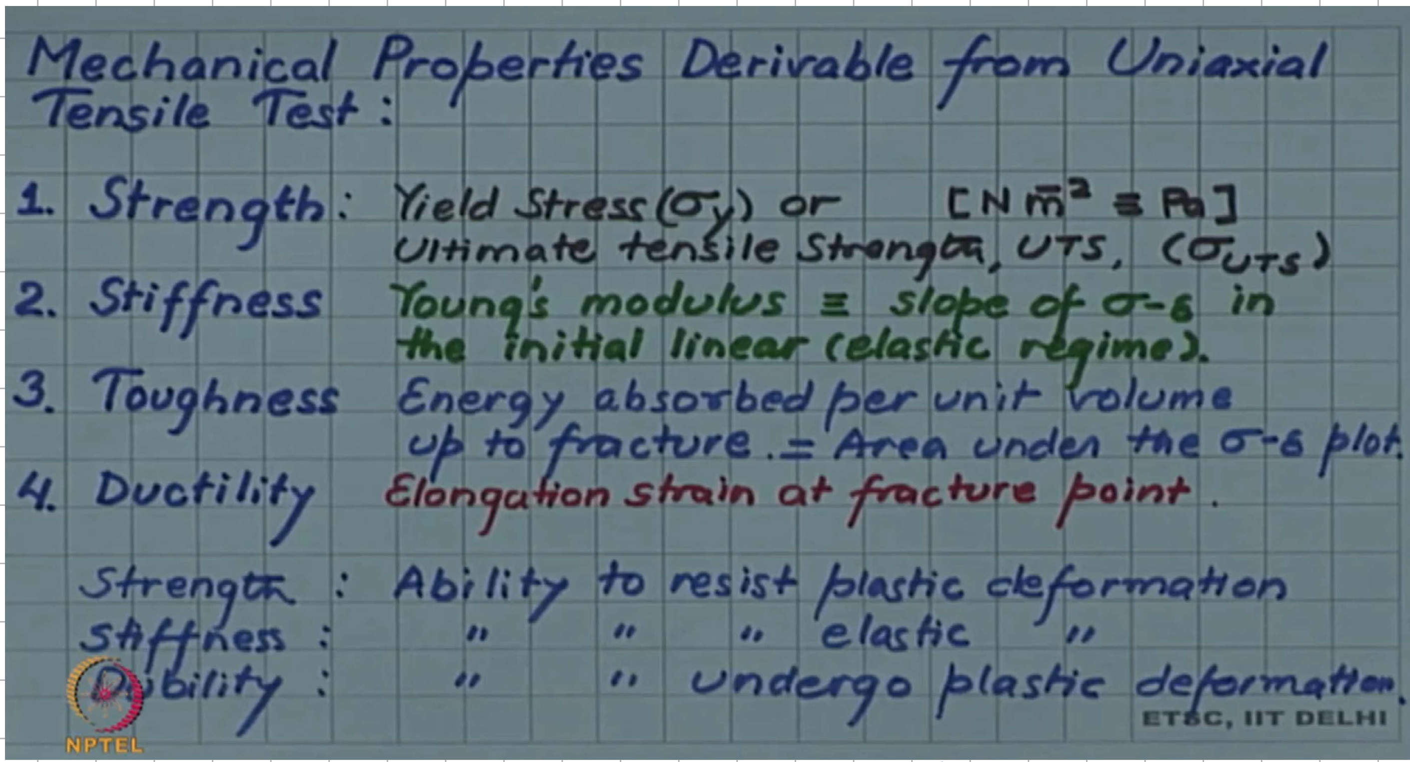
Engineering strain: Deformation of a material from stress

$$\varepsilon = \frac{\Delta L}{L}$$

NOTE:
Further deformation will occur at neck



Energy required to fracture material } Area under the curve = toughness N/m^2 or J/m^3



45 — 40

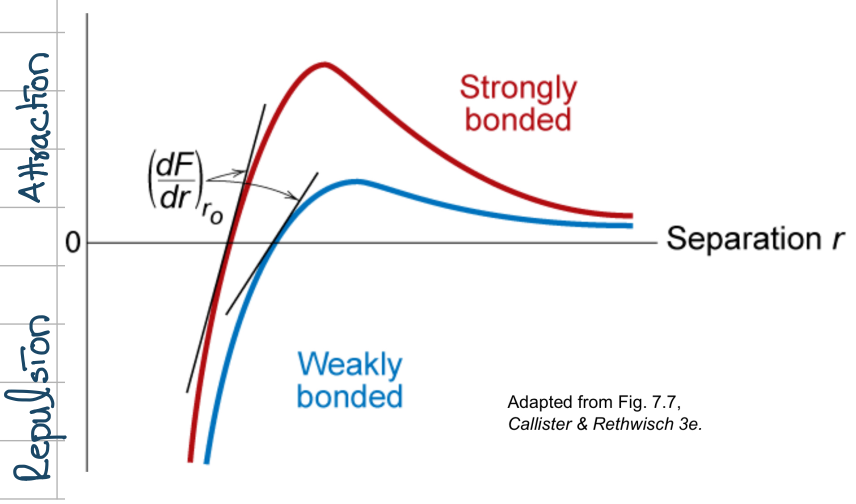
Stress-Strain : $\sigma = E\varepsilon$

Elastic deformation:

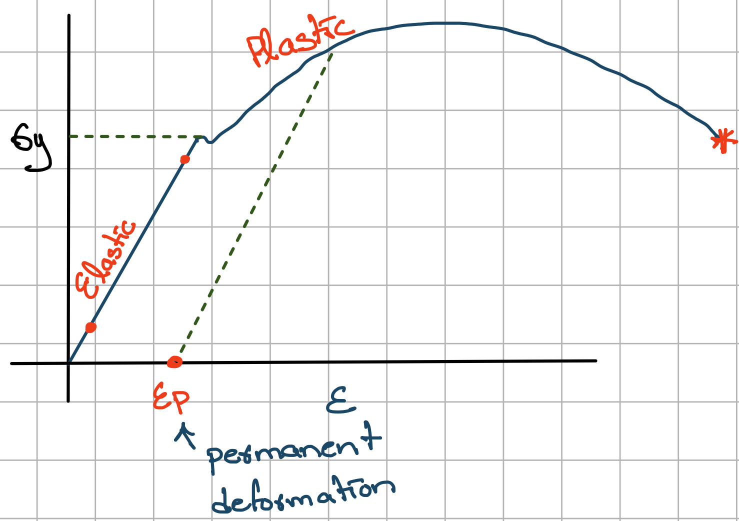
Stress – strain plot is normally linear. But for gray cast iron, concrete and many polymers, it is not linear.

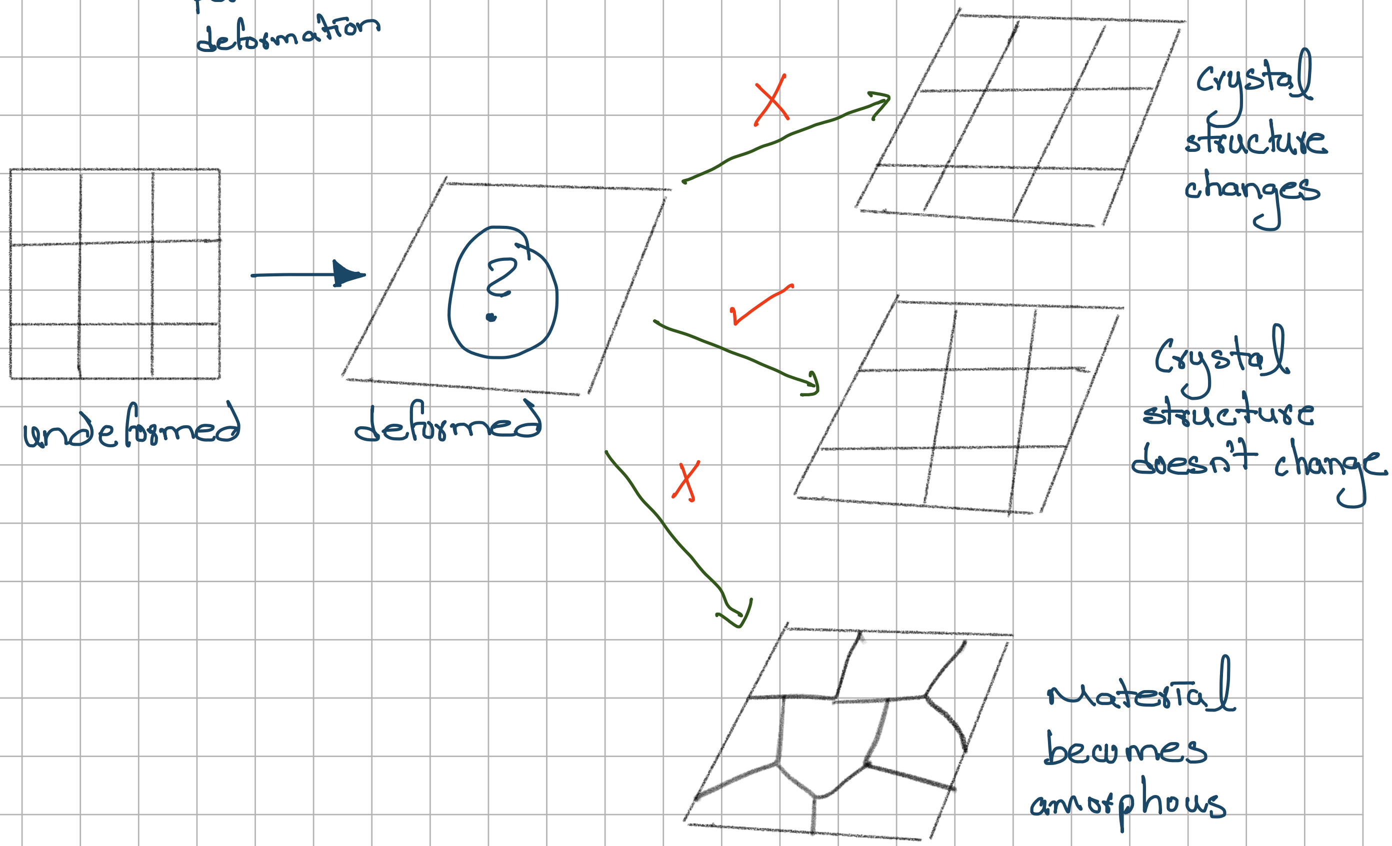
On macroscopic elastic strain, small changes in inter-atomic spacing and stretching of interatomic bonds.

$\downarrow E \propto \frac{1}{T}$



Adapted from Fig. 7.7, *Callister & Rethwisch 3e.*





Types of stress:

1) Compressive stress:

Not very common, for brittle materials, stress is taken to be negative, strain is already negative.

Compressive σ > Tensile σ

2. Shear stress:

F applied to upper & lower faces h distance apart.

3. Torsion stress:

Applied to shaft or axies in rotation.

$$\tau = G \cdot \gamma \qquad \gamma = \frac{a}{h} = \tan\theta$$

Poisson Ratio: → Tells how material deforms in lateral

lateral → x, y direction

Axial → z direction

$$\text{Poisson ratio} = \frac{\text{Lateral}}{\text{Axial}}$$

$$= -\frac{\varepsilon_x}{\varepsilon_z}$$

$$= -\frac{\varepsilon_y}{\varepsilon_z}$$

$$E = 2G(1+v)$$

$$0 \leq v \leq \frac{1}{2}$$

Anelasticity:

→ Not important metals
→ Important for polymers

elastic deformation time dependent.

OR Viscoelasticity

True stress & strain:

$$\sigma_T = \frac{F}{A}$$

$$\varepsilon_T = \ln \frac{l_i}{l_0}$$

$$\left.\begin{aligned} \sigma_T &= \sigma(1+e) \\ \varepsilon_T &= \ln(1+\varepsilon) \end{aligned}\right\}$$ Relation b/w stress, strain & true stress, strain

Ductility: Measure of deformation at fracture

$\uparrow$ Ductility $\propto T \uparrow$

$$\%EL = \frac{l - l_0}{l_0} \times 100$$ → % of elongation

$$\%RA = \frac{A_0 - A_f}{A_0} \times 100$$ → % Reduction in Area

Resilience:

$$U_r = \int_0^{\varepsilon_y} \sigma \, d\varepsilon$$

The capacity of material to absorb energy during elastic deformed. Recovered on unloading

$$U_r = \frac{1}{2} \sigma_y \varepsilon_y$$

$$U_r = \frac{1}{2} \sigma_y \left(\frac{\sigma_y}{E} \right)$$

$$= \frac{\sigma_y^2}{2E}$$

Unit: J/m^3 , Pa

$l_0 = 305 mm$ $E = 110 GPa$

$\sigma = 276 MPa$

$\Delta l = ?$

$$\sigma = E \epsilon$$

$$\frac{\Delta l}{l_0} = \frac{\sigma}{E}$$

$$\Delta l = \frac{\sigma}{E} \times l_0$$

Plastic deformation in crystalline (slip) & in amorphous (viscous)

►What happens to bonds during plastic deformation

►Role of dislocation in plastic deformation

►Most materials deform elastically to the extent of

In plastic deformation, atomic bonds are distorted or broken, leading to permanent shape changes.
Dislocations facilitate plastic deformation in crystalline materials by enabling slip between atomic planes.
Materials typically deform elastically (reversibly) until the applied stress exceeds the yield strength, after which plastic (permanent) deformation occurs.