Strength of Materials

Tutor

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Mechanical Properties of Metals

Mechanical Properties refers to the behavior of material when external forces are applied

Stress and strain $\Rightarrow$ fracture

For engineering point of view: allows to predict the ability of a component or a structure to withstand the forces applied to it

For science point of view: what makes materials strong $\rightarrow$ helps us to design a better new one

Learn basic concepts for metals, which have the simplest behavior

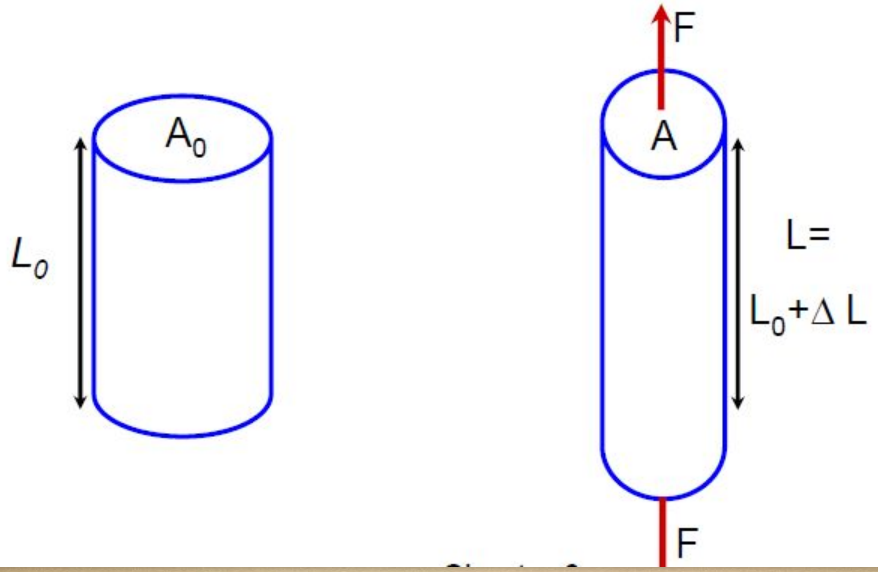
Main properties of Materials

- Elasticity
- Plasticity
- Ductility
- Hardness
- Toughness
- Creep
- Fatigue
- Fracture

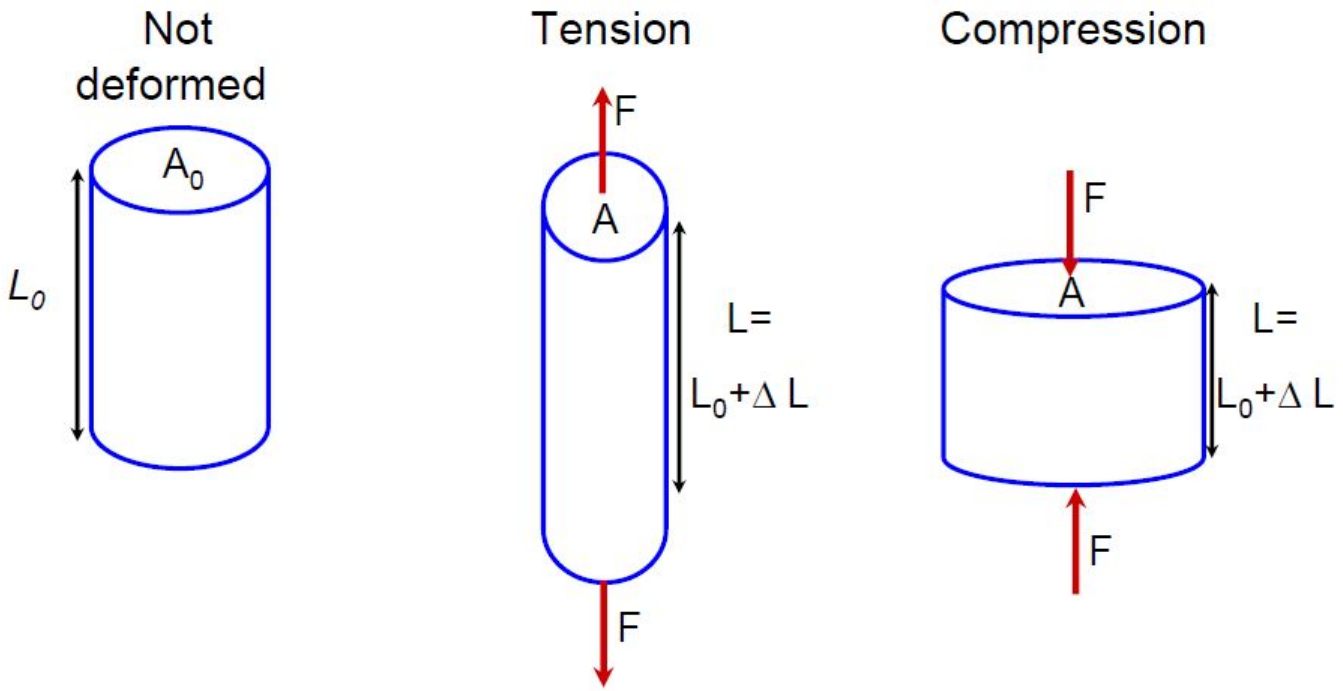
- Metal piece is subjected to a uniaxial force ⇒ deformation occurs
- When force is removed:

  - metal returns to its original dimensions ⇒ **elastic** deformation (atoms return to their *original position*)

  - metal deformed to an extent that it cannot fully recover its original dimensions ⇒ **plastic** deformation (shape of the material changes, atoms are *permanently displaced* from their positions)



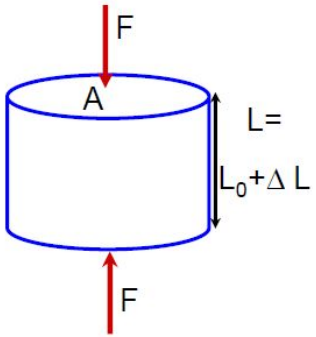
Load can be applied to the material by applying axial forces:



ΔL can be measured as a function of the applied force; area A_0 changes in response

Stress (σ) and Strain (ε)

Block of metal



Stress (σ)

- defining F is not enough (F and A can vary)
- Stress σ stays constant

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

- Units

  Force / area = N / m^2 = Pa

  usually in MPa or GPa

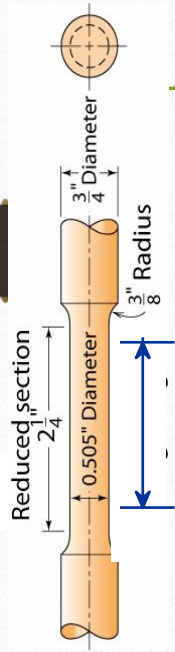
Strain (ε) – result of stress

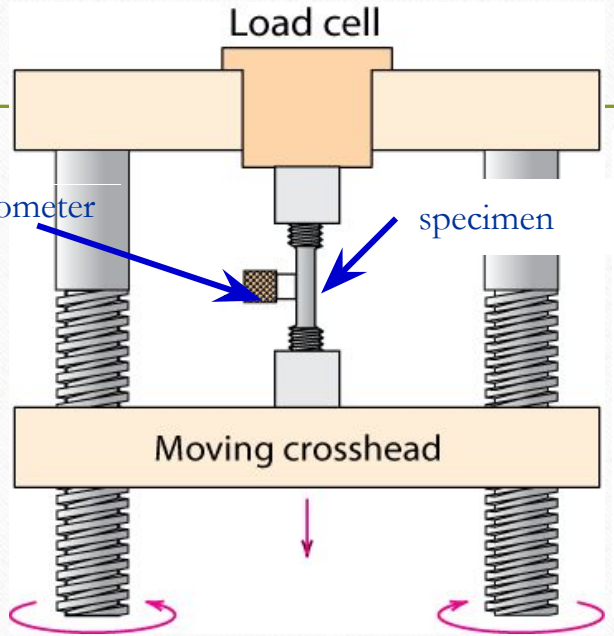
- For tension and compression: change in length of a sample divided by the **original** length of sample

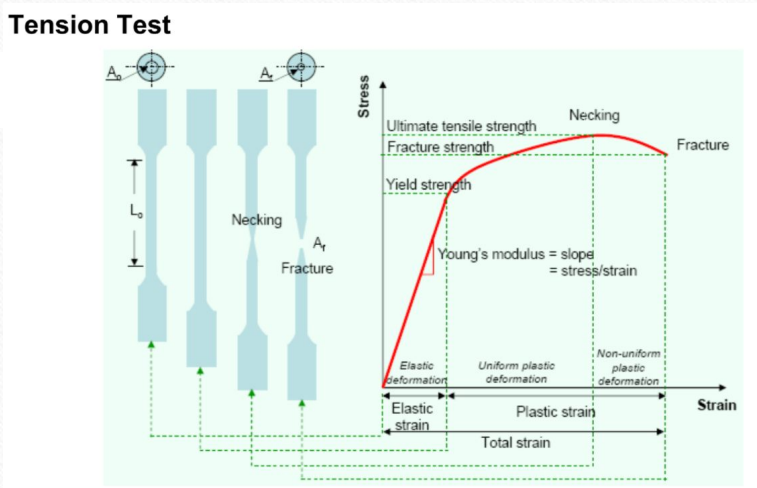
$$\varepsilon = \frac{\Delta L}{L}$$

Stress-Strain Testing

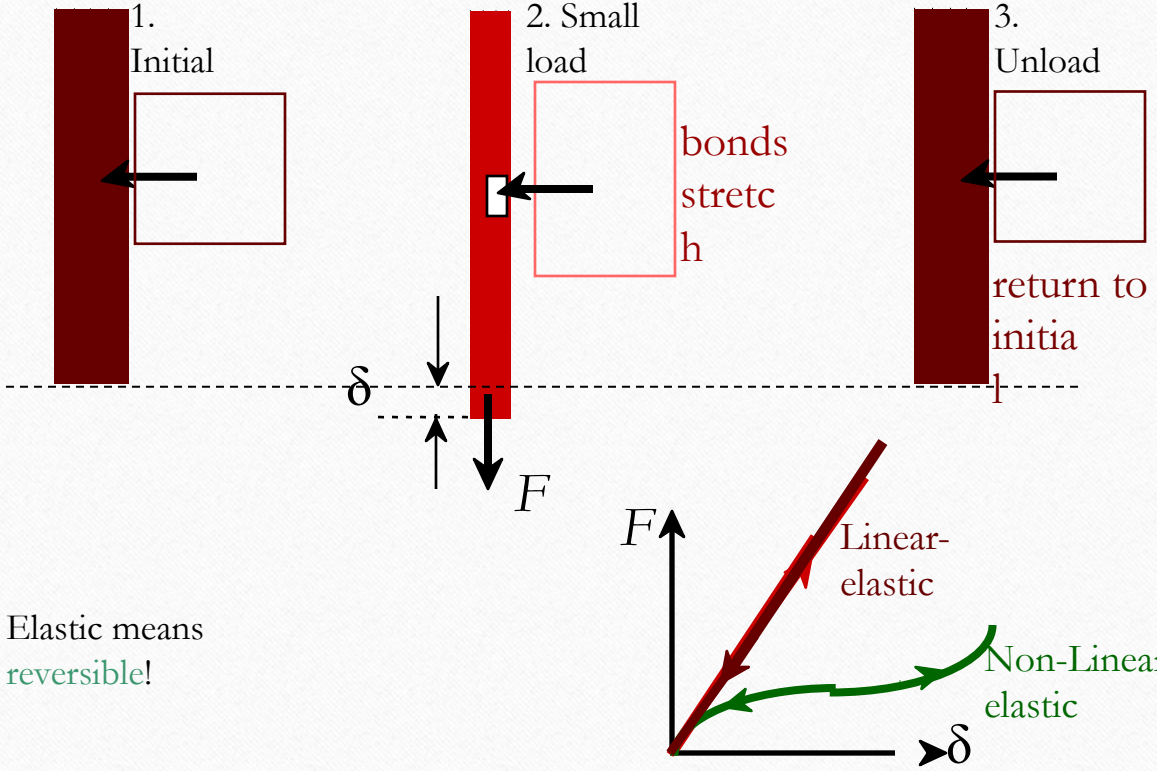
- Typical tensile specimen
- Typical tensile test machine





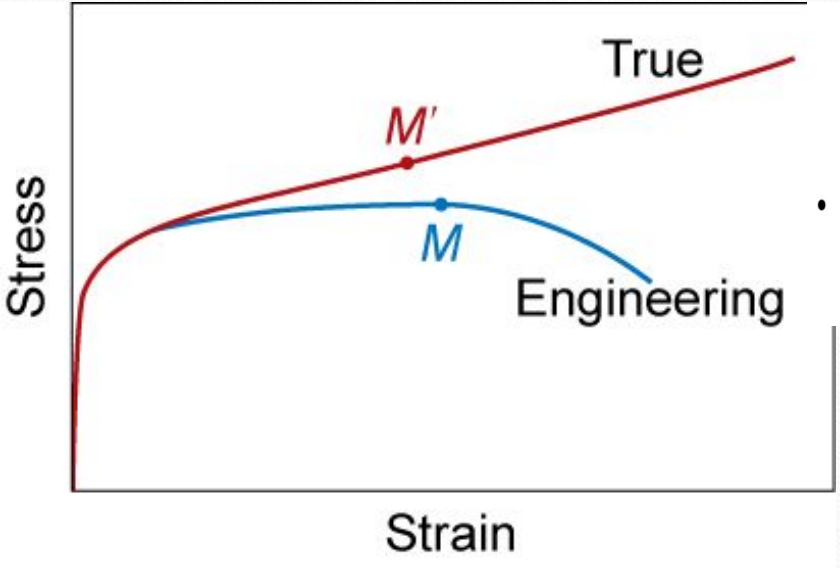


Elastic Loading



Elastic means reversible!

True Stress & Strain



The true stress is defined as the ratio of the load to the cross section area at any instant.

$$(\sigma_T) = \frac{\text{load}}{\text{Instantaneous area}} = \sigma(1+\varepsilon)$$

Where σ and ε is the engineering stress and engineering strain respectively.

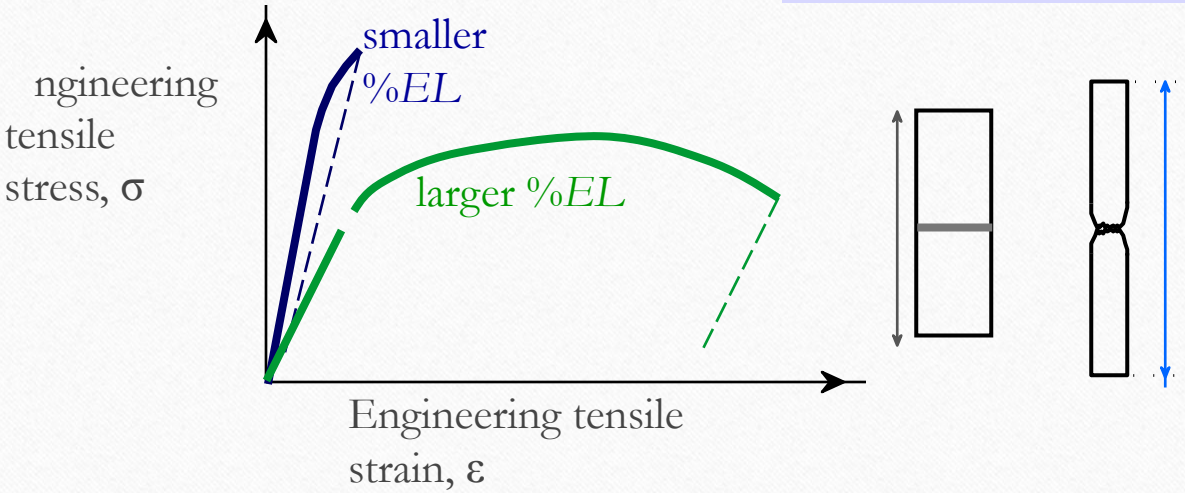
- **True strain**

$$(\varepsilon_T) = \int_{L_o}^{L} \frac{dl}{l} = \ln\left(\frac{L}{L_o}\right) = \ln(1+\varepsilon) = \ln\left(\frac{A_o}{A}\right) = 2\ln\left(\frac{d_o}{d}\right)$$

Ductility

- Plastic tensile strain at failure:

$$\%EL = \frac{L_f - L_o}{L_o} \times 100$$



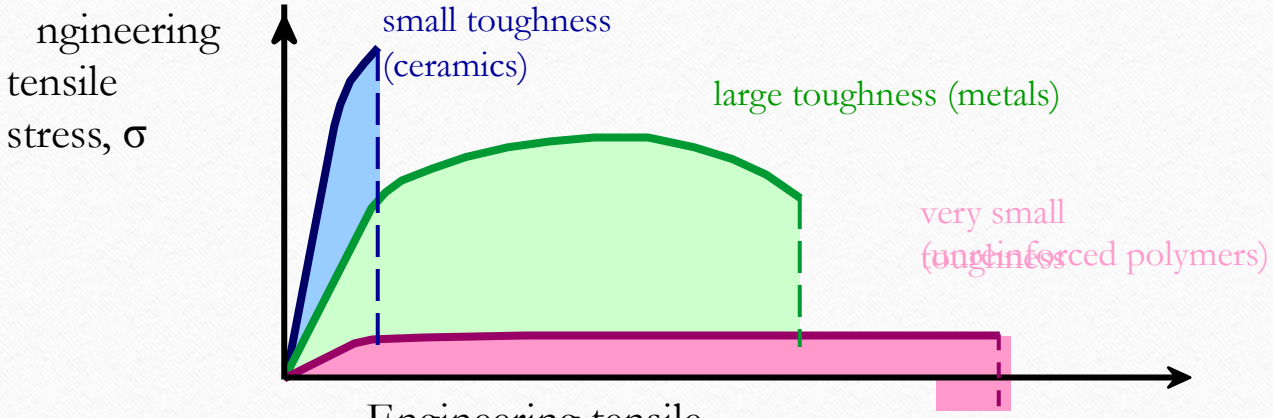
- Another ductility measure:

$$\%RA = \frac{A_o - A_f}{A_o} \times 100$$

E

Toughness

- Energy to break a unit volume of material
- Approximate by the area under the stress-strain curve.

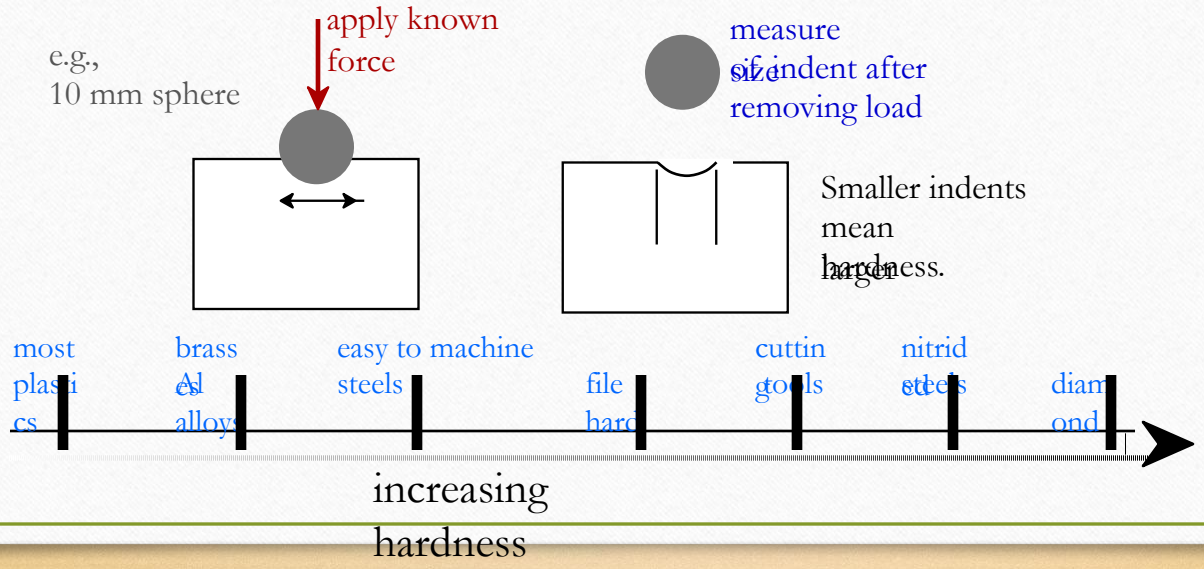


Brittle fracture: elastic energy

Ductile fracture: elastic + plastic energy

Hardness

- Resistance to permanently indenting the surface.
- Large hardness means:
  -- resistance to plastic deformation or cracking in compression.
  -- better wear properties.



Thank You