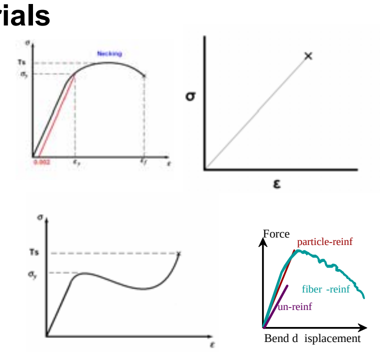
Class 1b: Stress Strain Behavior in Materials



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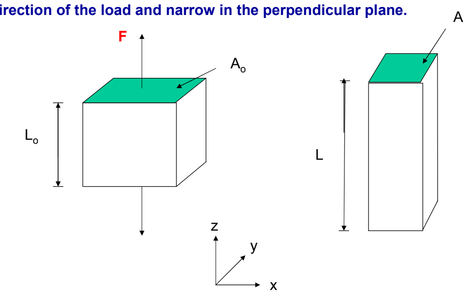
Stress strain behavior of a material describe how the sample shape changes when a load is applied.

When a tensile load is applied, most materials stretch in the direction of the load and narrow in the perpendicular plane.



Definition of stress, strain, Young's modulus, and Poisson's ratio are independent of the material type

Engineering Tensile Stress

$$\sigma = \frac{F}{A_o}\left[\text{Pa} = \frac{\text{N}}{\text{m}^2}\right]$$

Engineering Tensile Strain

$$\varepsilon = \frac{L - L_o}{L_o}[\text{unitless}]$$

Hooke's Law

$\sigma_Z = \varepsilon_Z E$ [Pa]
E = modulus of elasticity or Young's Modulus

Poisson's Ratio: A measure of volume change

$$\upsilon = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\varepsilon_y}{\varepsilon_z}[\text{unitless}]$$

metals: ν ~ 0.33
ceramics: ~0.25
polymers: ~0.40

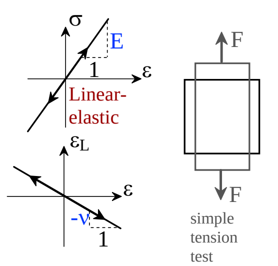


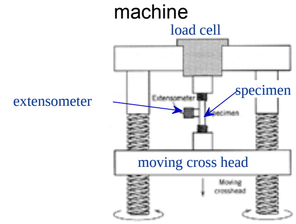
Figure adapted from Callister

Stress strain tests are set by ASTM standards

American Society for Testing and Materials (ASTM) sets standards for testing of materials which includes

- **sample size and shape**
- **pull rates**
- **instructions on loading samples**

Typical tensile test machine



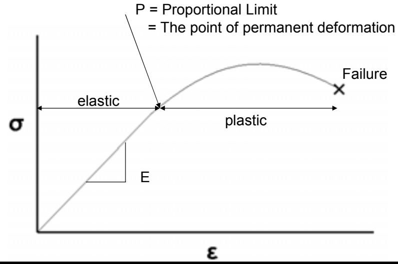
Adapted from Fig. 6.3, *Callister 6e.* (Fig. 6.3 is taken from H.W. Hayden, W.G. Moffatt, and J. Wulff, *The Structure and Properties of Materials*, Vol. III, *Mechanical Behavior*, p. 2, John Wiley and Sons, New York, 1965.)

In general, stress strain curves give information on elastic and plastic deformation regimes

In the elastic regime, deformation to an applied stress is temporary

In the plastic regime, an applied stress causes permanent deformation

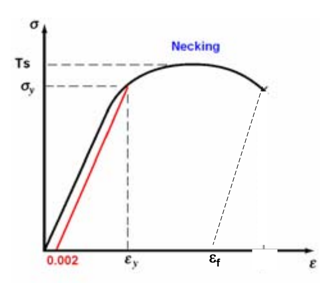
P = Proportional Limit
= The point of permanent deformation



From a stress strain curve for a typical metal, tensile strength, 0.2% yield strength, and fracture strain can be defined

The main points on a stress strain curve for metals are

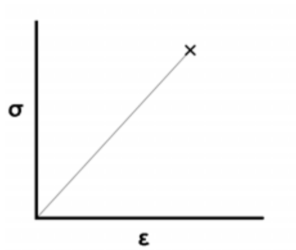
- **σ_y = yield stress = 0.2% offset yield**
- **ε_y = yield strain**
- **TS = Tensile Strength**
- **ε_f = fracture strain or ductility**
- **% elongation (ductility) = ε_f * 100**
- **Toughness = energy to fracture= area under curve**



A typical stress strain curve for a ceramic has only elastic deformation

Ceramics typically fail in a brittle manner (that is without plastic deformation).

This is because the ionic nature of the bonds prevent slip (dislocation motion).



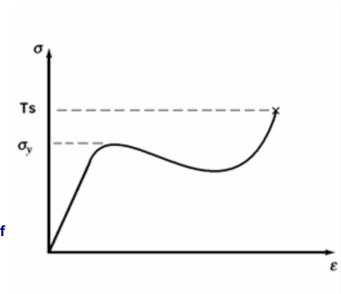
Yield stress and tensile strength in polymers is defined differently than metals

In polymers, plastic deformation takes place from chains untangling. There are no dislocations in polymers!

The yield stress is the maximum on the curve which occurs just beyond the linear-elastic region.

The TS is the stress at which fracture occurs.

The tensile modulus (modulus of elasticity) and ductility are defined the same as in metals.



Composites have the combined properties of the matrix and reinforcement

The mechanical properties of the composite depend on the properties of the matrix and reinforcement.

The effect also depends critically on the reinforcement shape and how it is aligned relative to the load

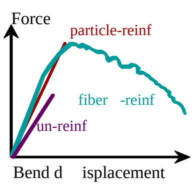


Figure from Callister overheads

In summary, the stress strain properties depend on the material type

ASTM standards exist to properly test metals, ceramics, polymers, and composites

The stress strain plot for metals give information on yield stress, Young's modulus, TS, ductility, and toughness

Ceramics tend to fail in a brittle manner (without plastic deformation).

Polymers do not deform by slip. The yield stress and TS are defined differently than in metals.

The stress strain plots for composites depend on the matrix and reinforcement