Mechanical Properties

Basic concepts

- stress and strain
  - tensile and shear
  - engineering and true
- Poisson's ratio
- Modulus

Deformation

- plastic and elastic

Stress and Strain

Stress

ratio of the normal force applied to a specimen divided by its original cross sectional area.

Formally called engineering stress

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

Stress is measured in units of megapascals (MPa)

Stress and Strain

Strain

- the ratio of change in length due to deformation to the original length of the specimen
  - formally called engineering strain

$$\varepsilon = \frac{l_i - l_o}{l_o} = \frac{\Delta l}{l_o}$$

  - strain is unitless, but often units of m/m are used.

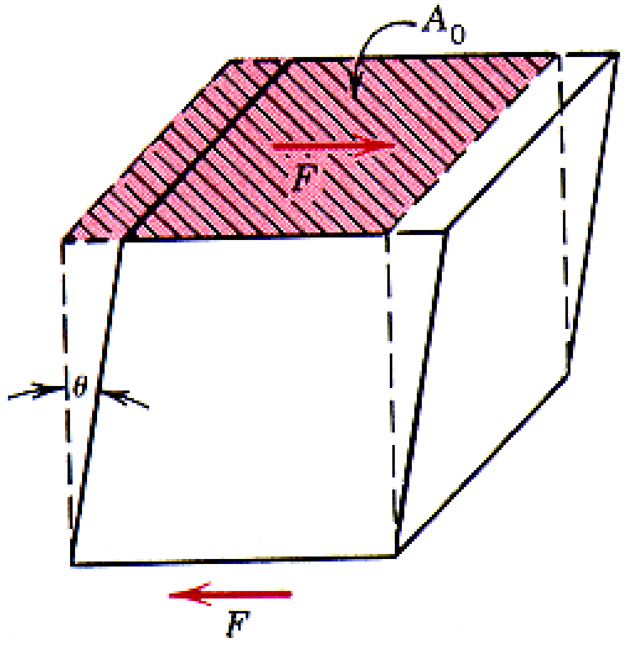
Shear Stress and Strain

Tensile stress is used in cases where purely shear force is applied to a specimen and is given the symbol τ.

- Formula for calculation and units remain the same as tensile stress.
- Differs from tensile stress only in the direction of the applied force (parallel for shear and perpendicular for tensile)

Shear Stress and Strain

Shear strain (γ) is defined as the tangent of the angle θ, and, in essence, determines to what extent the plane was displaced.



Stress-Strain Relationship

Hooke's Law

for materials stressed in tension, at relatively low levels, stress and strain are proportional through:

$$\sigma = \mathbf{E}\,\varepsilon$$

constant $\mathbf{E}$ is known as the modulus of elasticity, or Young's modulus.

Measured in MPa and can range in values from ~$4.5\text{x}10^4$ - $40\text{x}10^7$ MPa

Stress-Strain Relationship

Shear stress and strain are related in a similar manner, but with a different constant of proportionality

$$\tau = \mathbf{G}\gamma$$

the constant **G** is called the shear modulus and relates the shear stress and strain in the elastic region.

Poisson's Ratio

When a material is placed under a tensile stress, an accompanying strain is created in the same direction.

As a result of this elongation, there will be constrictions in the other two directions.

Poisson's ratio, ν, is the ratio of the lateral to axial strains.

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

Poisson's Ratio

Theoretically, isotropic materials will have a value for Poisson's ratio of 0.25.

The maximum value of ν is 0.5

denotes no volume change during deformation.

Most metals exhibit values between 0.25 and 0.35

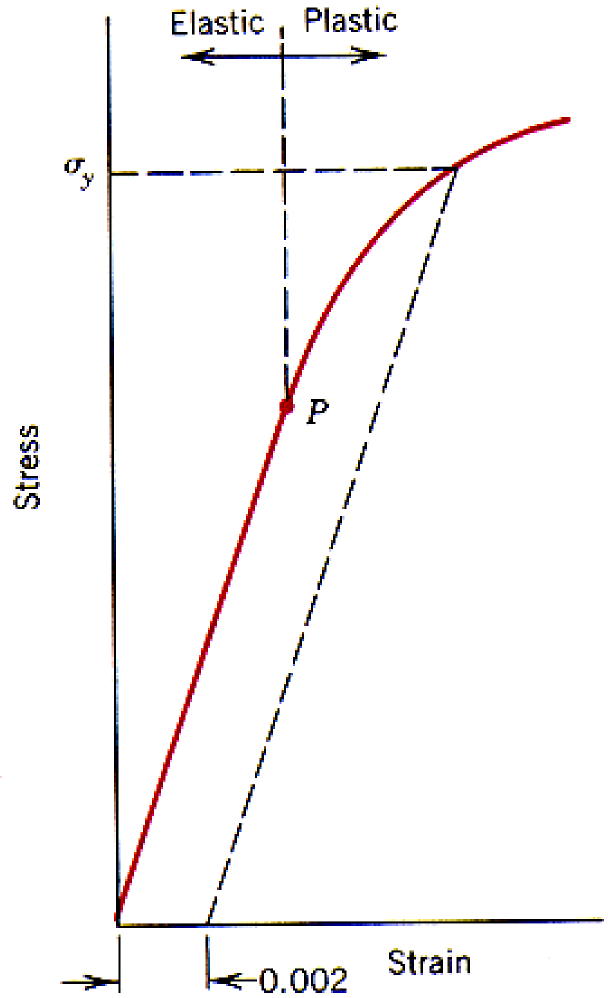
It is also used to relate shear and elastic moduli

$$\mathbf{E} = 2\mathbf{G}(1 + \nu)$$

Plastic Deformation

- Elastic deformation only occurs to strains of about 0.005.
  - After this point, plastic (non-recoverable) deformation occurs, and Hooke’s Law is no longer valid.
- On an atomic level, plastic deformation is caused by *slip*, where atomic bonds are broken by dislocation motion, and new bonds are formed.

Plastic Deformation



Yield Strength

denoted by σ_y, it is the strain corresponding to the elastic-plastic transition.

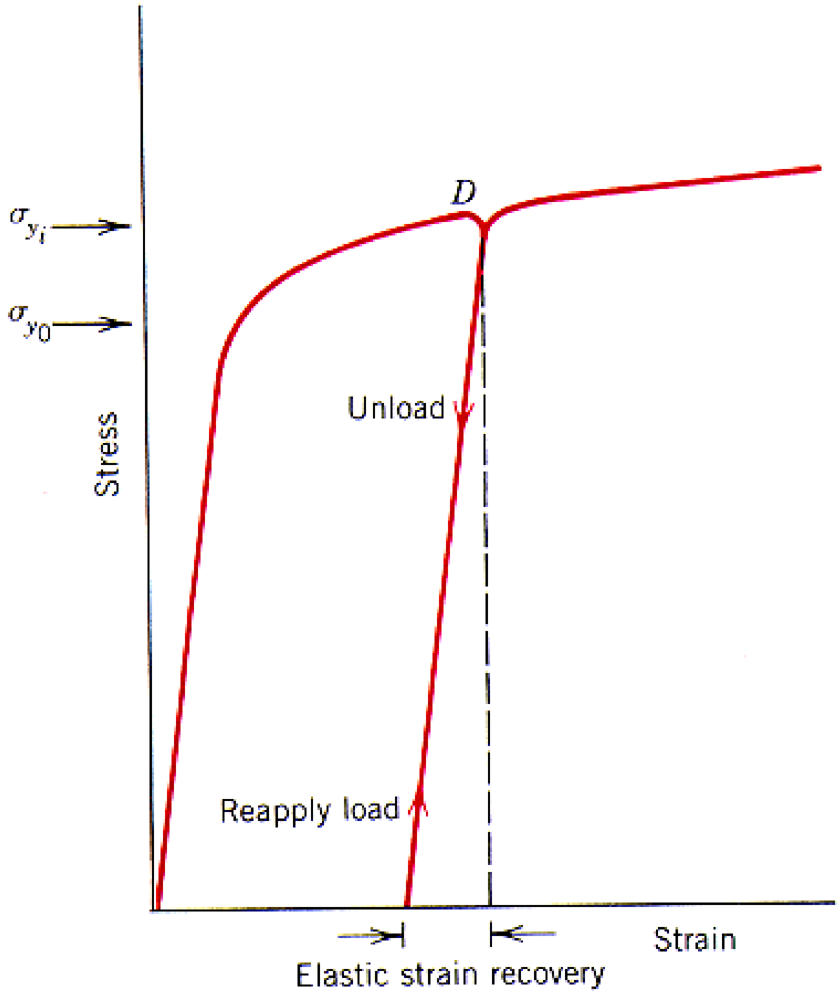
Calculated from a 0.002 strain offset from the origin, intersecting with the stress-strain curve.

Elastic Recovery

After a load is released from a stress-strain test, some of the total deformation is recovered as elastic deformation.

- During unloading, the curve traces a nearly identical straight line path from the unloading point
  - parallel to the initial elastic portion of the curve
- The recovered strain is calculated as the strain at unloading minus the strain after the load is totally released.

Elastic Recovery



Ductility

Ductility is a measure of the degree of plastic deformation at fracture

expressed as percent elongation

$$\%\mathbf{EL} = (\frac{l_f - l_0}{l_0})*100$$

also expressed as percent area reduction

$$\%\mathbf{AR} = (\frac{A_0 - A_f}{A_0})*100$$

l_f and A_f are length and area at fracture