Types of stresses

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Factor of Safety

Structural members or machines must be designed such that the working stresses are less than the ultimate strength of the material.

$$FS = \text{Factor of safety}$$

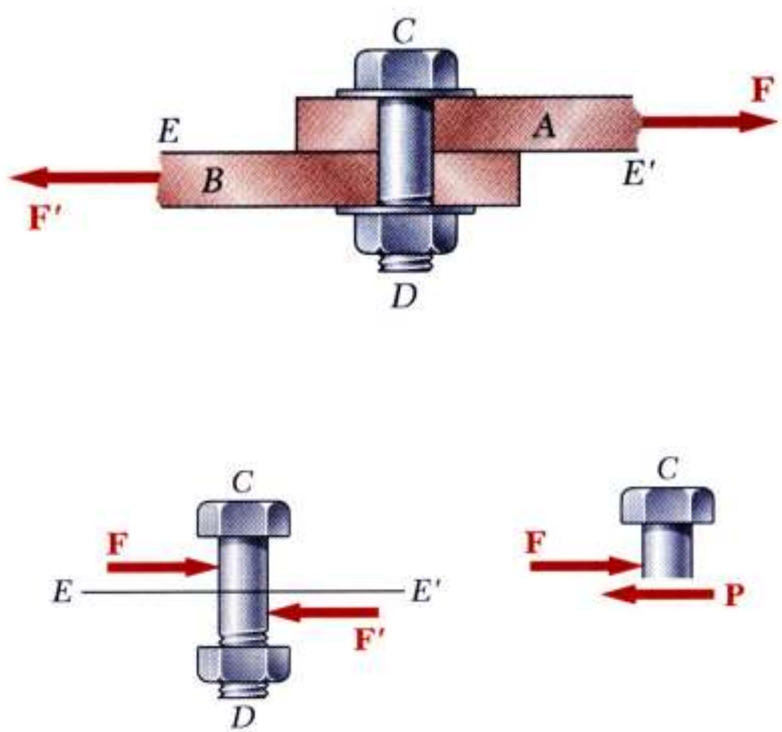
$$FS = \frac{\sigma_u}{\sigma_{all}} = \frac{\text{ultimate stress}}{\text{allowable stress}}$$

Factor of safety considerations:

- uncertainty in material properties
- uncertainty of loadings
- uncertainty of analyses
- number of loading cycles
- types of failure
- maintenance requirements and deterioration effects
- importance of member to structures integrity
- risk to life and property
- influence on machine function

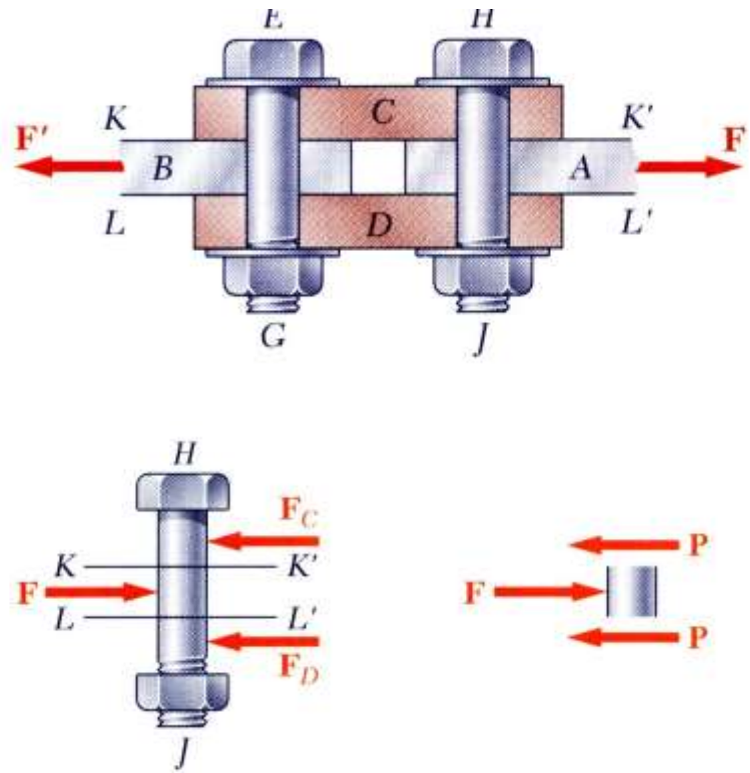
Shearing Stress Examples

Single Shear



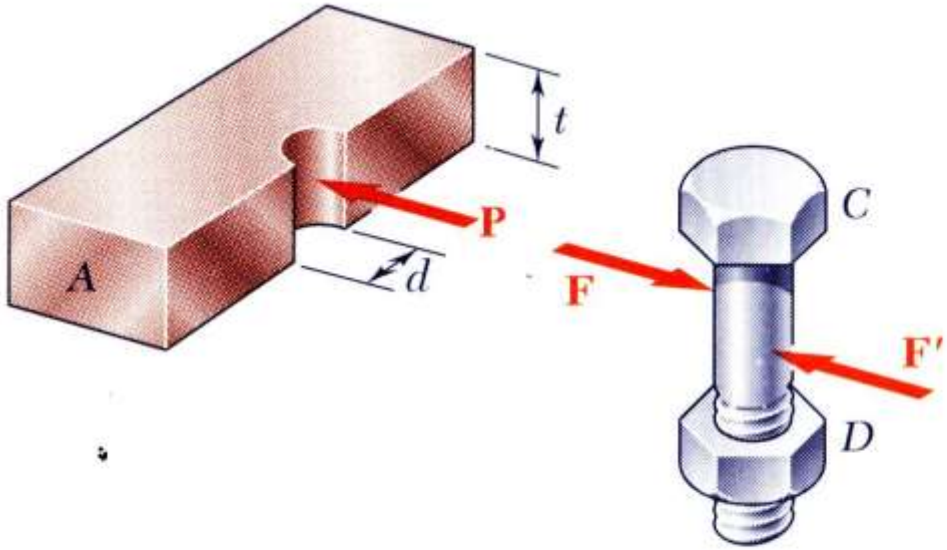
$$\tau_{\text{ave}} = \frac{P}{A} = \frac{F}{A}$$

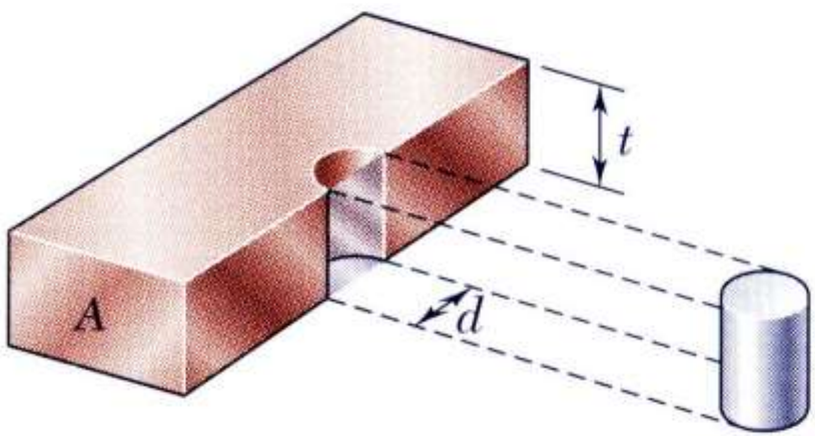
Double Shear



$$\tau_{\text{ave}} = \frac{P}{A} = \frac{F}{2A}$$

Bearing Stress in Connections





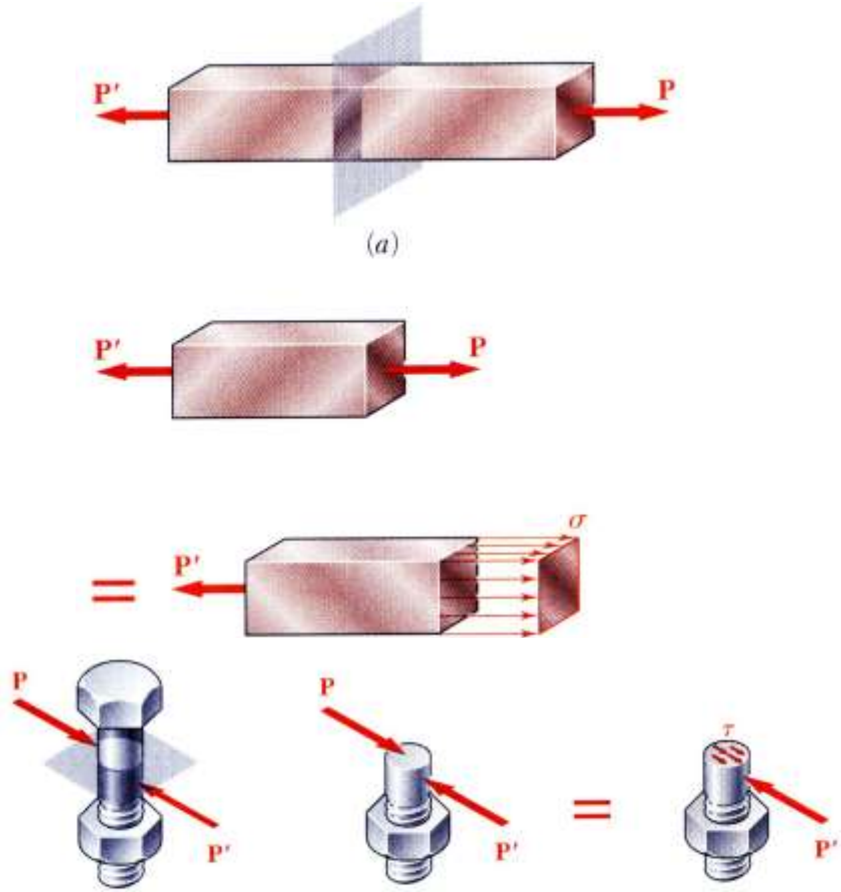
- Bolts, rivets, and pins create stresses on the points of contact or *bearing surfaces* of the members they connect.

- The resultant of the force distribution on the surface is equal and opposite to the force exerted on the pin.

- Corresponding average force intensity is called the bearing stress,

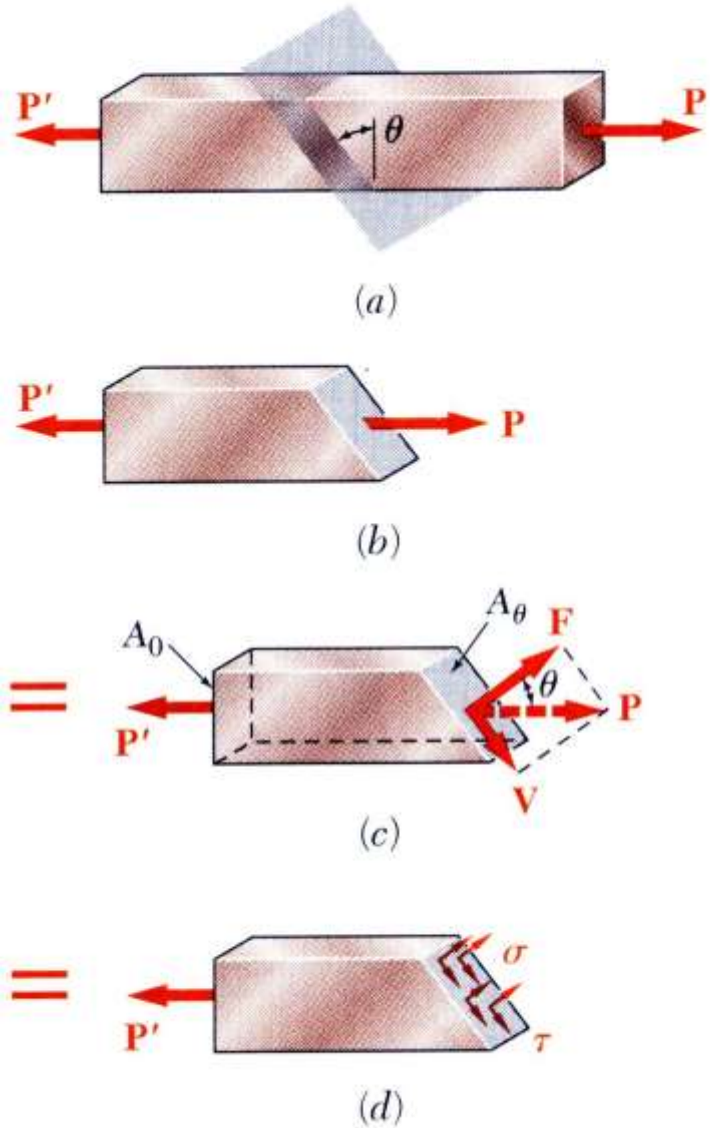
$$\sigma_b = \frac{P}{A} = \frac{P}{t\,d}$$

Stress in Two Force Members



- Axial forces on a two force member result in only normal stresses on a plane cut perpendicular to the member axis.
- Transverse forces on bolts and pins result in only shear stresses on the plane perpendicular to bolt or pin axis.
- Will show that either axial or transverse forces may produce both normal and shear stresses with respect to a plane other than one cut perpendicular to the member axis.

Stress on an Oblique Plane



- Pass a section through the member forming an angle θ with the normal plane.

- From equilibrium conditions, the distributed forces (stresses) on the plane must be equivalent to the force *P.*

- Resolve *P* into components normal and tangential to the oblique section,

$$F = P\cos\theta \qquad V = P\sin\theta$$

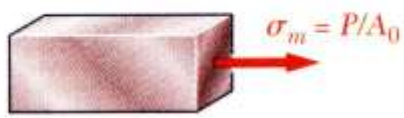
- The average normal and shear stresses on the oblique plane are

$$\sigma = \frac{F}{A_\theta} = \frac{P\cos\theta}{A_0 / \cos\theta} = \frac{P}{A_0}\cos^2\theta$$

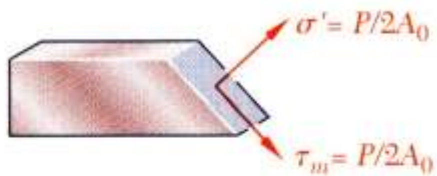
$$\tau = \frac{V}{A_\theta} = \frac{P\sin\theta}{A_0 / \cos\theta} = \frac{P}{A_0}\sin\theta\cos\theta$$

Maximum Stresses

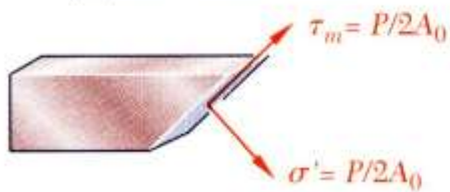
(a) Axial loading



(b) Stresses for $\theta = 0$



(c) Stresses for $\theta = 45°$



(d) Stresses for $\theta = -45°$

- Normal and shearing stresses on an oblique plane

$$\sigma = \frac{P}{A_0}\cos^2\theta \quad \tau = \frac{P}{A_0}\sin\theta\cos\theta$$

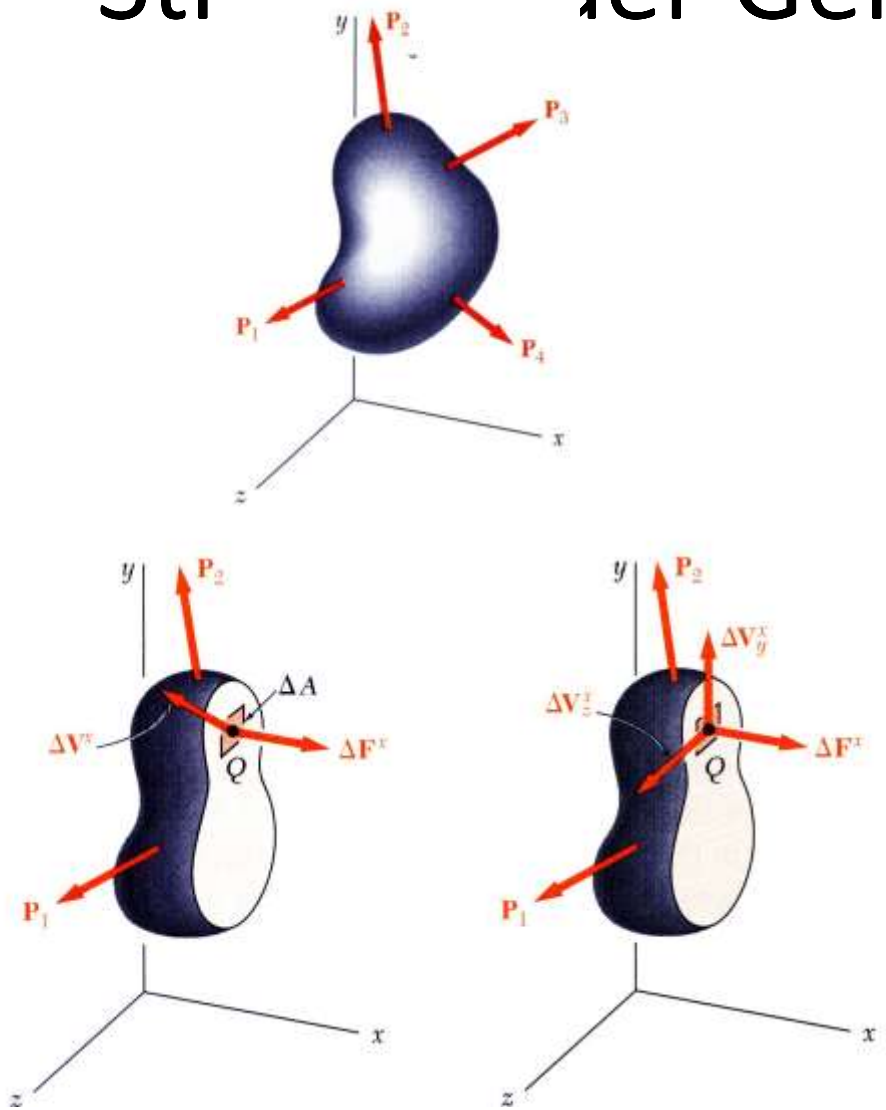
- The maximum normal stress occurs when the reference plane is perpendicular to the member axis,

$$\sigma_m = \frac{P}{A_0} \quad \tau' = 0$$

- The maximum shear stress occurs for a plane at $\pm$ 45° with respect to the axis,

$$\tau_m = \frac{P}{A_0}\sin 45 \cos 45 = \frac{P}{2A_0} = \sigma'$$

Stress Under General Loadings



- A member subjected to a general combination of loads is cut into two segments by a plane passing through *Q*

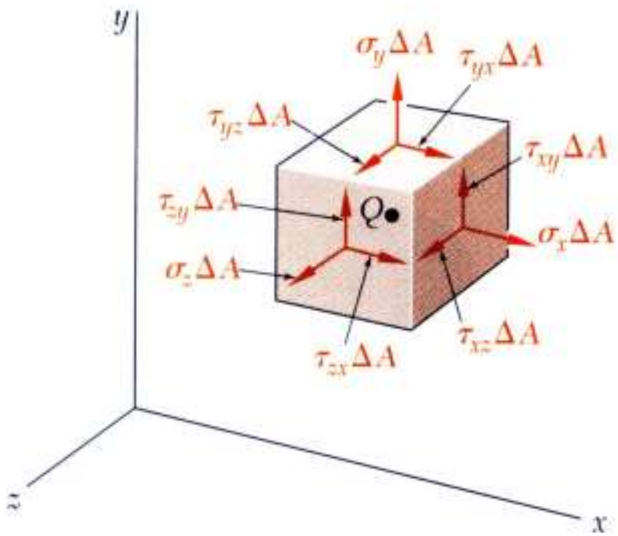
- The distribution of internal stress components may be defined as,

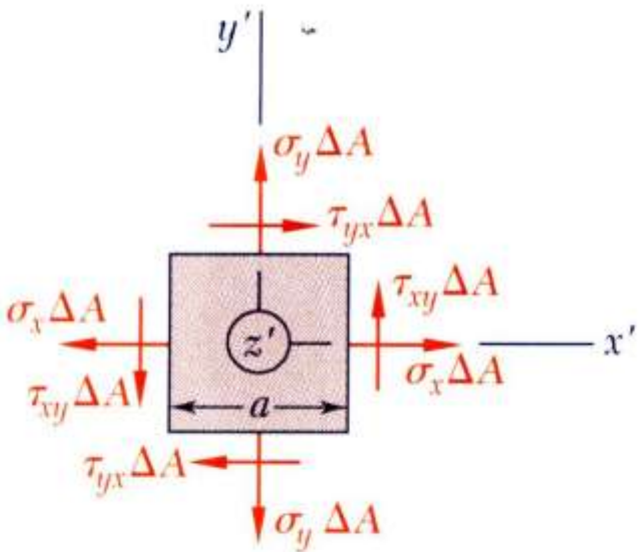
$$\sigma_x = \lim_{\Delta A \to 0} \frac{\Delta F^x}{\Delta A}$$

$$\tau_{xy} = \lim_{\Delta A \to 0} \frac{\Delta V_y^x}{\Delta A} \quad \tau_{xz} = \lim_{\Delta A \to 0} \frac{\Delta V_z^x}{\Delta A}$$

- For equilibrium, an equal and opposite internal force and stress distribution must be exerted on the other segment of the member.

State of Stress





- Stress components are defined for the planes cut parallel to the *x*, *y* and *z* axes. For equilibrium, equal and opposite stresses are exerted on the hidden planes.

- The combination of forces generated by the stresses must satisfy the conditions for equilibrium:

$$\sum F_x = \sum F_y = \sum F_z = 0$$

$$\sum M_x = \sum M_y = \sum M_z = 0$$

- Consider the moments about the *z* axis:

$$\sum M_z = 0 = (\tau_{xy} \Delta A) a - (\tau_{yx} \Delta A) a$$

$$\tau_{xy} = \tau_{yx}$$

similarly, $\tau_{yz} = \tau_{zy}$ and $\tau_{yz} = \tau_{zy}$

- It follows that only 6 components of stress are required to define the complete state of stress

Thank you