Shear Stress

• Tensile and compressive forces along the primary axis will produce stress that are normal to the cross section, as shown in the diagrams.

• There is yet another kind of shear that may be produced, called “shear” and the stresses will be parallel to the plane of the cross-section and also in the plane of the line of action of the force producing them.

• The equation for shear stress is: $s_s = \frac{P}{A}$
  
  Where $s$ is the average shear stress, $P$ is the applied force and $A$ is the area where the shear stress develops.

• Here are some examples of how shear stresses may develop:
Figure 9-10  Shear stress examples.

(a) Shear between two separate bodies

(b) Shear within a body
Punching Shear Stress Examples

(a) Plate prior to punching
(b) Disk removed from plate
Shear in Bolted Connections Example

(a) Joint

(b) Sheared bolts

Sheared surface
Example Calculation of Shear Stress in a Bolt

A tractor drawbar is connected to an implement as shown. The tractor pulls with a force of 50kN that must be transmitted by shear pin.

Calculate:

a) The shear stress in the bolt if the diameter is 19 mm
b) the percent increase in shear stress if the bolt diameter is reduced to 16 mm.
Allowable Shear Stress

Similar to stress from tension/compression, all materials will have a shear strength that cannot be exceeded in design.

• The equation used to size an element being subject to shear is: \[ A = \frac{P}{S_{s(all)}} \]
Deformations: Axial strain (tension/compression)  
Shear Strain (shear)

Axial Strain \( e = \frac{\delta}{L_0} \)  
Shear Strain \( e = \frac{\delta}{L_0} \)
Axial Strain Example

For the bar shown, the total strain was measured to be .00056. Calculate the total deformation of the bar.
For the block shown, P is applied at the top of the block and displaces the top a horizontal distance of .0041 inches. The height of the block is 2.6 inches. Compute the shear strain.
**Material Behavior**

**Ductility** is a mechanical property that describes the extent in which solid materials can be *plastically* deformed without *fracture*. Examples of ductile material include

**Malleability**, a similar concept, refers to a material's ability to deform under compressive stress; this is often characterized by the material's ability to form a thin sheet by hammering or rolling. Ductility and malleability do not always correlate with each other; for instance, gold is both ductile and malleable, but lead is only malleable.

Schematic appearance of round metal bars after tensile testing.
(a) Brittle fracture  
(b) Ductile fracture  
(c) Completely ductile fracture
For elastic materials, each incremental increase in stress will produce a proportional increase in strain. This results in a straight line on a stress/strain diagram. Material will fully rebound.

Proportional Limit is the stress at which this relationship will not longer hold true and the line will begin to curve. Exceeding this limit will also result in permanent deformation (not full rebound).

Elastic Limit is stress at which the material will continue to deform plastically with no increase in stress (load).

Strain Hardening: Strengthening that occurs because of movements within the crystal structure of the material.

Ultimate Stress: Limit of the strain hardening region when necking begins to occur.

Fracture: Sample finally ruptures/fractures

THE SLOPE OF THE LINE IN THE ELASTIC REGION IS CALLED "E" AND KNOWN AS THE MODULUS OF ELASTICITY OR YOUNG'S MODULUS.

\[ E = \frac{\text{stress/strain}}{\text{strain}} = \frac{s}{e} \]
A tensile member is subjected to a 5000 lb load. The member is 30 inches long and made from steel. Compute the tensile stress and the total axial deformation. Assume $E=30,000,000$ psi.