University of Babylon

College of Materials Engineering

Department of Engineering of Polymer and Petrochemical Industries

Strength of Materials

B.Sc. Course for Second stage

By

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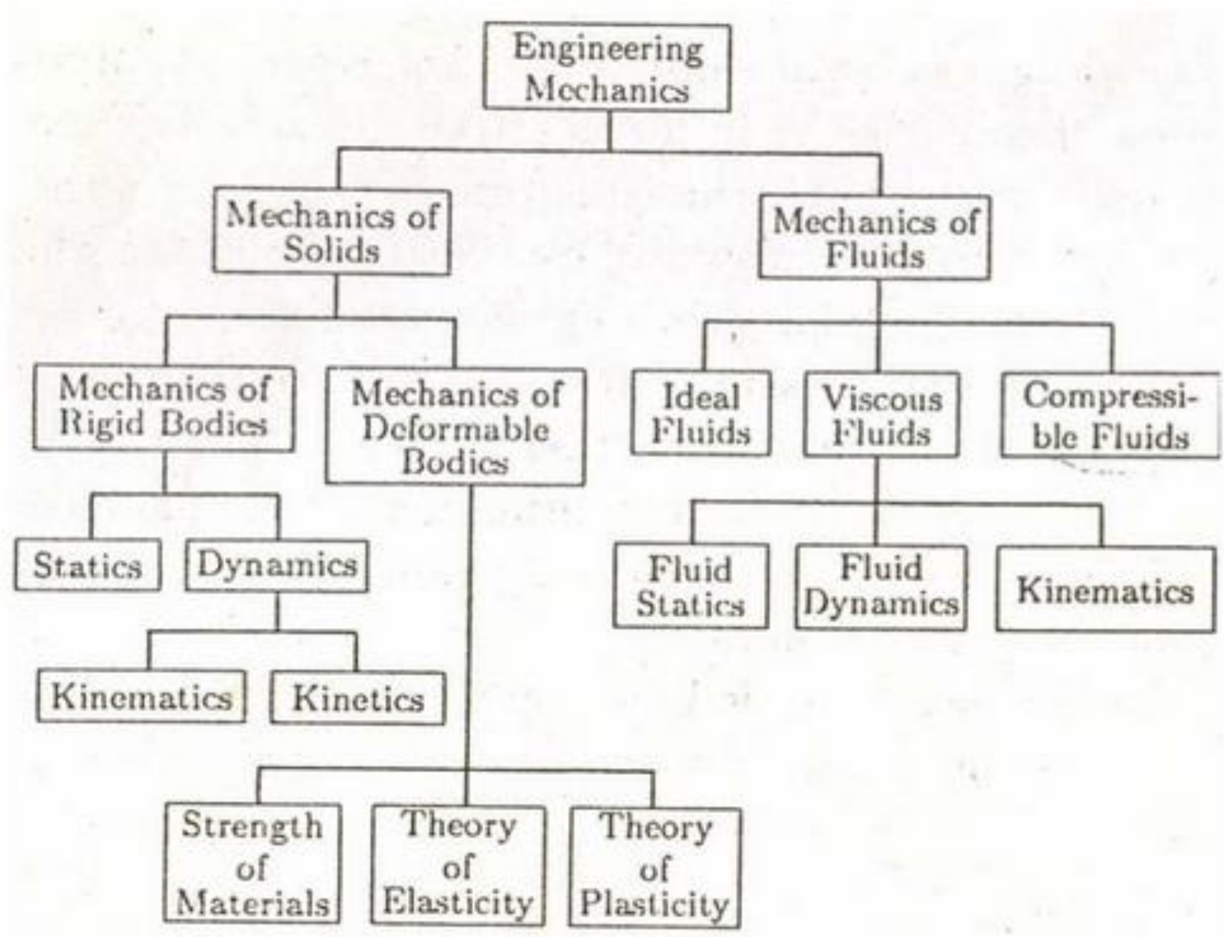
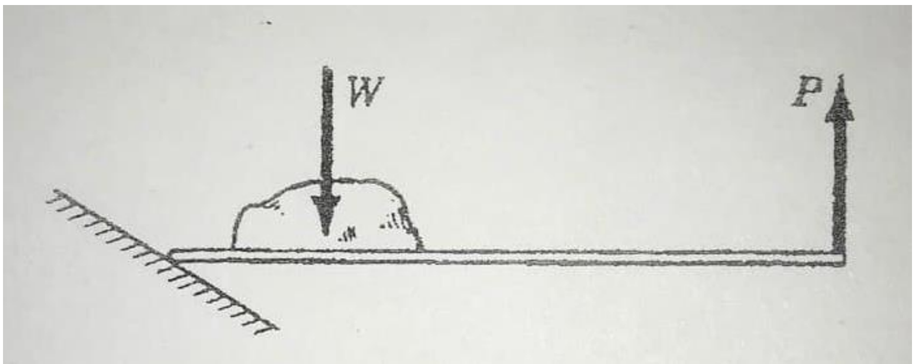
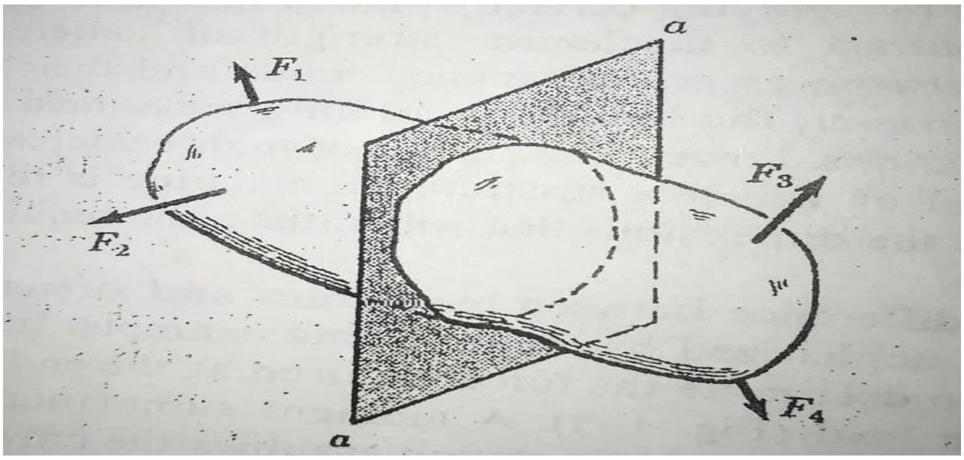
Lecture 1: Simple Stress

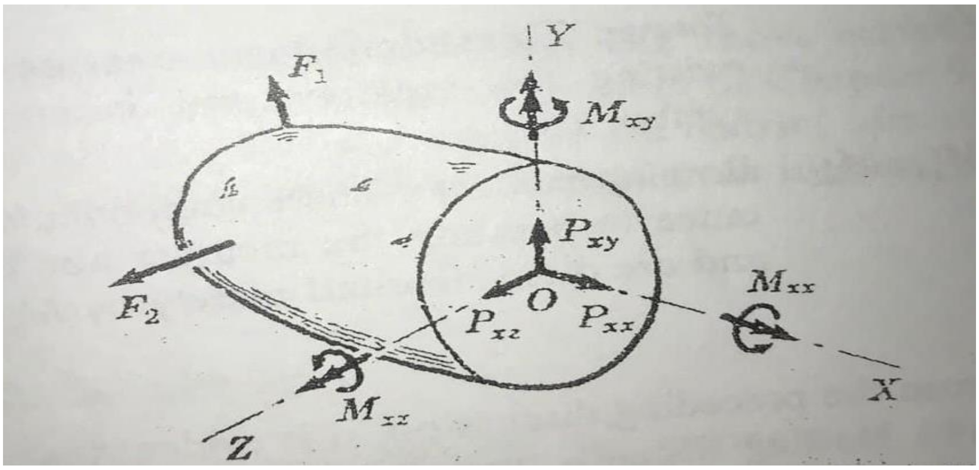
Introduction:





Analysis of Internal Forces





P_{xx} : Axial force. This component measures the pulling (tensile tends to elongation) or pushing (compressive tends to shorten) action over the section, it is denoted by ***P***.

P_{xy} and P_{xz}: Shear force. This components measures the total resistance to sliding; the shear force is designed by ***V.***

M_{xx} : Torque. This component measures the resistance to twisting the member and given the symbol ***T.***

M_{xy} and M_{xz}: Bending moments. These components measures the resistance to bending the member about Y and Z axes and given the symbol $\boldsymbol{M_y}$ *or* $\boldsymbol{M_z}$*.*

Simple Stresses

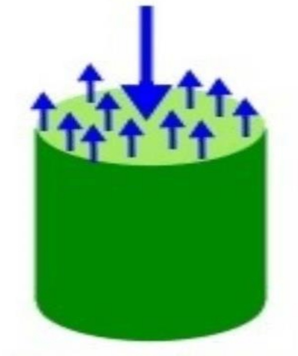
Simple stresses are expressed as the ratio of the applied force divided by the resisting area or

σ = Force / Area.

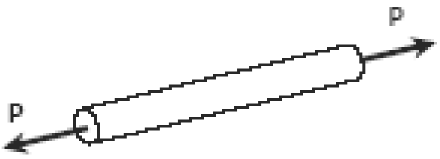
Simple stress can be classified as *normal stress*, *shear stress*, and *bearing stress*.

1- **Normal stress** develops when a force is applied perpendicular to the cross-sectional

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

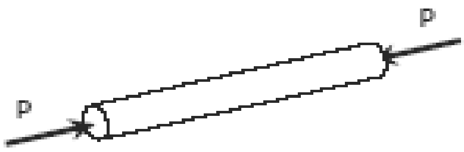


- tensile stress



Bar in Tension

- compressive stress



Bar in Compression

Units of Stress

P in (N), A in (m^2) so, $\sigma = \frac{N}{m^2}$ = Pa

or $\sigma = \frac{N}{mm^2}$ = Pa × 10^6 or MPa

or $\sigma = \frac{kN}{mm^2}$ = Pa × 10^9 or GPa

101. An aluminum tube is rigidly fastened between a bronze rod and a steel rod as shown in Fig. 1–8a. Axial loads are applied at the positions indicated. Determine the stress in each material.

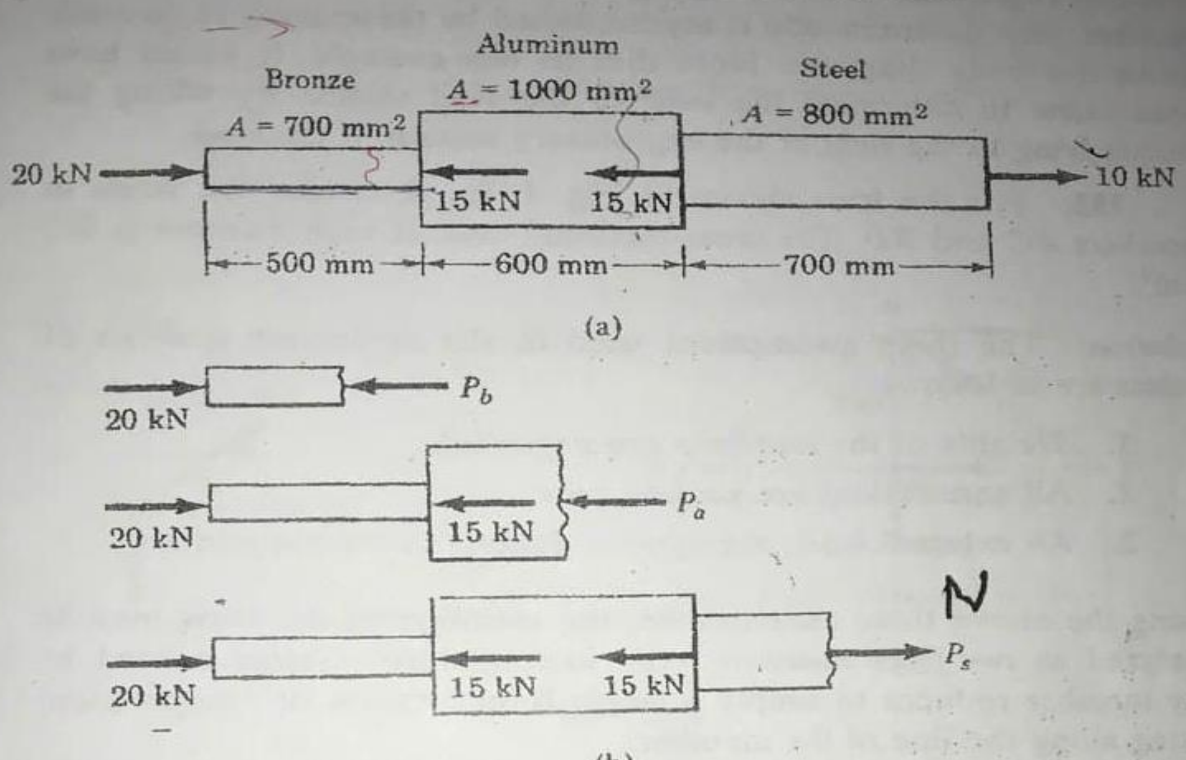


Figure 1–8.

Solution: To calculate the stress in each section, we must first determine the axial load in each section. The appropriate free-body diagrams are shown in Fig. 1-8b, from which we determine the axial load in each section to be $P_b = 20$ kN (compression), $P_a = 5$ kN (compression), and $P_s = 10$ kN (tension). The stresses in each section are

$$\left[\sigma = \frac{P}{A}\right] \qquad \sigma_b = \frac{20\text{ kN}}{700\text{ mm}^2} = \frac{20 \times 10^3\text{ N}}{700 \times 10^{-6}\text{ m}^2}$$

$$= 28.6 \times 10^6\text{ N/m}^2 = 28.6\text{ MPa} \qquad \textit{Ans.}$$

$$\sigma_a = \frac{5\text{ kN}}{1000\text{ mm}^2} = \frac{5 \times 10^3\text{ N}}{1000 \times 10^{-6}\text{ m}^2}$$

$$= 5 \times 10^6\text{ N/m}^2 = 5\text{ MPa} \qquad \textit{Ans.}$$

$$\sigma_s = \frac{10\text{ kN}}{800\text{ mm}^2} = \frac{10 \times 10^3\text{ N}}{800 \times 10^{-6}\text{ m}^2}$$

$$= 12.5 \times 10^6\text{ N/m}^2 = 12.5\text{ MPa} \qquad \textit{Ans.}$$

EX: A hollow steel tube with an inside diameter of 100 mm must carry a tensile load of 400 kN. Determine the outside diameter of the tube if the stress is limited to 120 MN/m^2.

$P = \sigma A$

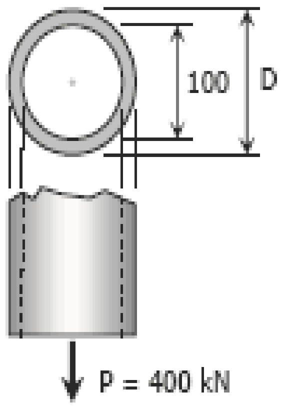
where:

$P = 400\text{ kN} = 400\,000\text{ N}$

$\sigma = 120\text{ MPa}$

$A = \frac{1}{4}\pi D^2 - \frac{1}{4}\pi(100^2)$

$= \frac{1}{4}\pi(D^2 - 10\,000)$



thus,

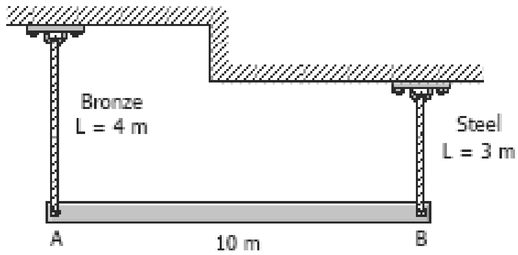
$400\,000 = 120[\frac{1}{4}\pi(D^2 - 10\,000)]$

$400\,000 = 30\pi D^2 - 300\,000\pi$

$$D^2 = \frac{400\,000 + 300\,000\pi}{30\pi}$$

$D = 119.35\text{ mm}$

Ex: A homogeneous 800 kg bar AB is supported at either end by a cable as shown in Fig. Calculate the smallest area of each cable if the stress is not to exceed 90 MPa in bronze and 120 MPa in steel.



By symmetry:

$P_{br} = P_{st} = \frac{1}{2}(7848)$

$= 3924\text{ N}$

For bronze cable:

$P_{br} = \sigma_{br} A_{br}$

$3924 = 90 A_{br}$

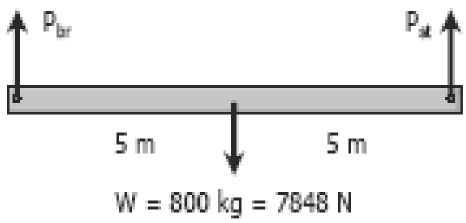
$A_{br} = 43.6\text{ mm}^2$

For steel cable:

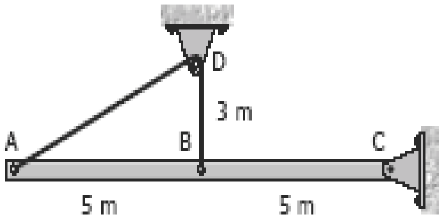
$P_{st} = \sigma_{st} A_{st}$

$3924 = 120 A_{st}$

$A_{st} = 32.7\text{ mm}^2$

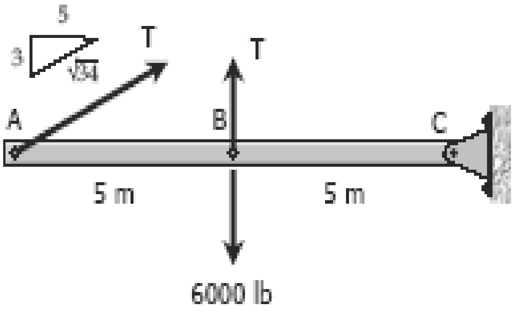


EX: The homogeneous bar shown in Fig. is supported by a smooth pin at C and a cable that runs from A to B around the smooth peg at D. Find the stress in the cable if its diameter is 0.6 inch and the bar weighs 6000 lb.



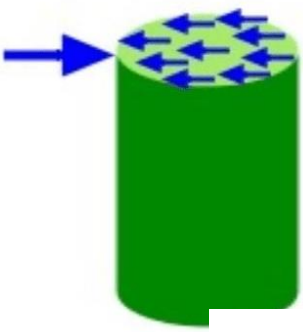
$$\sum M_C = 0$$
$$5T + 10\left(\frac{3}{\sqrt{34}}T\right) = 5(6000)$$
$$T = 2957.13 \text{ lb}$$

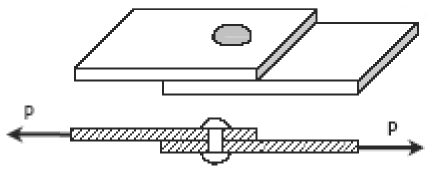
$$T = \sigma A$$
$$2957.13 = \sigma\left[\tfrac{1}{4}\pi(0.6^2)\right]$$
$$\sigma = 10\,458.72 \text{ psi}$$



2- **Shear stress** is developed if the applied force is parallel to the resisting area.

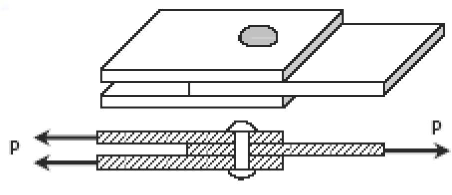
$$\tau = \frac{V}{A}$$





Single Shear

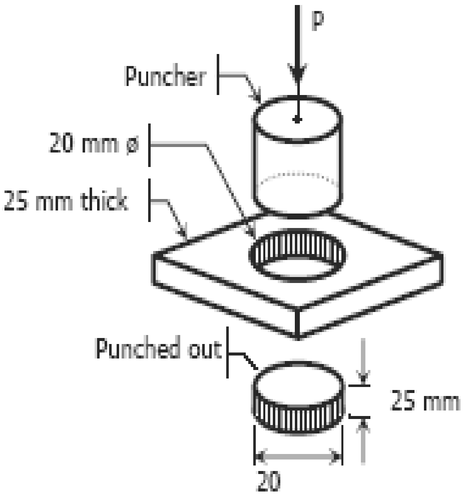
$$\tau = \frac{V}{A}$$



Double Shear

$$\tau = \frac{V}{2A}$$

EX: What force is required to punch a 20-mm-diameter hole in a plate that is 25 mm thick? The shear strength is 350 MN/m2.



The resisting area is the shaded area along the perimeter and the shear force V is equal to the punching force P.

$$V = \tau A$$

$$P = 350[\pi(20)(25)]$$

$$= 549\,778.7 \text{ N}$$

$$= \mathbf{549.8 \text{ kN}}$$

EX: As in Fig., a hole is to be punched out of a plate having a shearing strength of 40 ksi. The compressive stress in the punch is limited to 50 ksi. (**a**) Compute the maximum thickness of plate in which a hole 2.5 inches in diameter can be punched. (**b**) If the plate is 0.25 inch thick, determine the diameter of the smallest hole that can be punched.

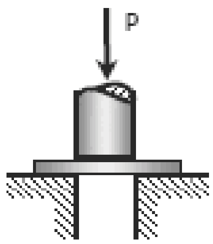


Figure 1-11c

(a) Maximum thickness of plate:

Based on puncher strength:

$$P = \sigma A$$

$$= 50[\tfrac{1}{4}\pi(2.5^2)]$$

$$= 78.125\pi \text{ kips}$$ → Equivalent shear force of the plate

Based on shear strength of plate:

$$V = \tau A$$ → V = P

$$78.125\pi = 40[\pi(2.5t)]$$

$$t = 0.781 \text{ inch}$$

(b) Diameter of smallest hole:

Based on compression of puncher:

$$P = \sigma A$$

$$= 50(\tfrac{1}{4}\pi d^2)$$

$$= 12.5\pi d^2$$ → Equivalent shear force for plate

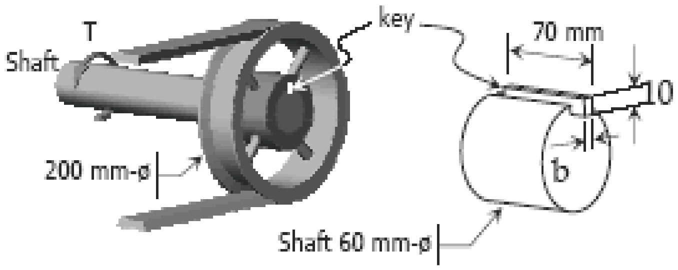
Based on shearing of plate:

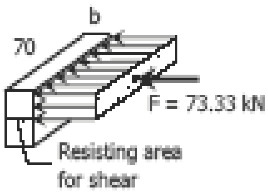
$$V = \tau A$$ → V = P

$$12.5\pi d^2 = 40[\pi d(0.25)]$$

$$d = \mathbf{0.8 \text{ in}}$$

EX: A 200-mm-diameter pulley is prevented from rotating relative to 60-mm-diameter shaft by a 70-mm-long key, as shown in Fig. If a torque T = 2.2 kN·m is applied to the shaft, determine the width b if the allowable shearing stress in the key is 60 MPa.





FBD of Pin

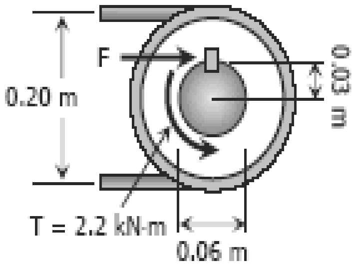
$$T = 0.03F$$
$$2.2 = 0.03F$$
$$F = 73.33 \text{ kN}$$

$$V = \tau A$$

Where: V = F = 73.33 kN

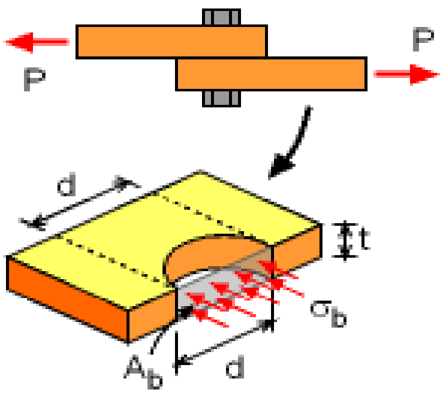
A = 70b; τ = 60 MPa

$$73.33(1000) = 60(70b)$$
$$b = 17.46 \text{ mm}$$

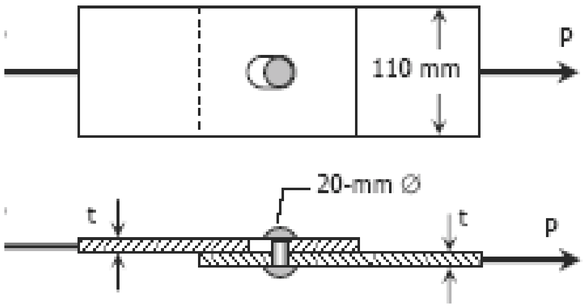


3- **bearing stress,** it is the contact pressure between two bodies. It differs from compressive stress, as it is an internal stress caused by compressive forces.

$$\sigma_b = \frac{P_b}{A_b}$$



EX: In Fig., assume that a 20-mm-diameter rivet joins the plates that are each 110 mm wide. The allowable stresses are 120 MPa for bearing in the plate material and 60 MPa for shearing of rivet. Determine (a) the minimum thickness of each plate; and (b) the largest average tensile stress in the plates.



(a) From shearing of rivet:

$P = \tau A_{rivets}$

$= 60[\frac{1}{4}\pi(20^2)]$

$= 6000\pi$ N

From bearing of plate material:

$P = \sigma_b A_b$

$6000\pi = 120(20t)$

$t = 7.85$ mm

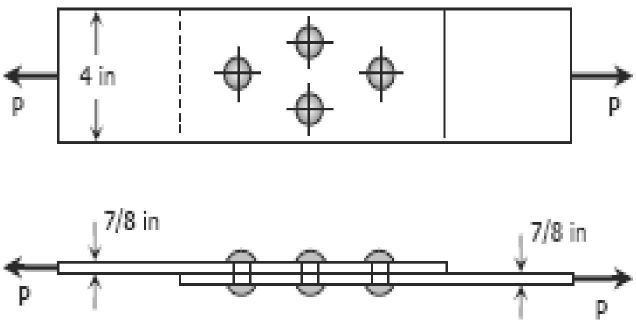
(b) Largest average tensile stress in the plate:

$P = \sigma A$

$6000\pi = \sigma[7.85(110 - 20)]$

$\sigma = 26.67$ MPa

EX: The lap joint shown in Fig. is fastened by four ¾-in.-diameter rivets. Calculate the maximum safe load P that can be applied if the shearing stress in the rivets is limited to 14 ksi and the bearing stress in the plates is limited to 18 ksi. Assume the applied load is uniformly distributed among the four rivets.



Based on shearing of rivets:

$P = \tau A$

$P = 14[4(\frac{1}{4}\pi)(\frac{3}{4})^2]$

$P = 24.74$ kips

Based on bearing of plates:

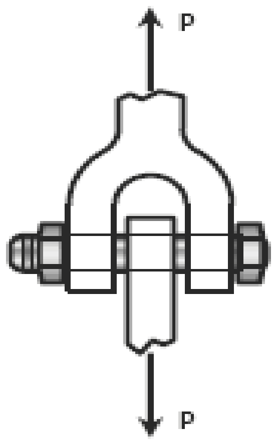
$P = \sigma_b A_b$

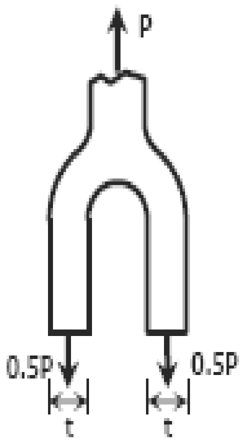
$P = 18[4(\frac{3}{4})(\frac{7}{8})]$

$P = 47.25$ kips

Safe load $P = 24.74$ kips

EX: In the clevis shown in Fig., find the minimum bolt diameter and the minimum thickness of each yoke that will support a load P = 14 kips without exceeding a shearing stress of 12 ksi and a bearing stress of 20 ksi.





For shearing of rivets (double shear)

$P = \tau A$

$14 = 12[2(\frac{1}{4}\pi d^2)]$

$d = 0.8618$ in → diameter of bolt

For bearing of yoke:

$P = \sigma_b A_b$

$14 = 20[2(0.8618t)]$

$t = 0.4061$ in → thickness of yoke