Chemical Engineering and Petroleum Industries

Strength of Material

First stage

Assistant Lec.Elaf Jasim Mohan

2020-2021

Course Syllabus:

1- Definitions and Types of Stress and Strains
Simple stress, Shear stress, Stress in cylinders, Simple strain, Thermal stress, Stress-strain diagram.

2- Proportional Limits
Elastic limit, Stiffness elasticity, Plasticity, Hardness and Working stress, Hook's law.

3- Poissons ratio and Composite stresses
Volumetric stress, Bulk Modulus, Thin walled cylinders.

4- Shear and Bending Moments in Beams
Deformation in beams, Equations of stress and momentum in beams, Curves of stress and moments in beams.

Definitions and Types of Stress and Strains:

If applied force causes change in dimension that material is said to be under stress .This force per unit area is the measurement of stress .Higher the force per unit area, higher is stress. Tensile and compressive stress are known as direct stress. Direct stress is denoted by Greek letter sigma (σ).

σ (Stress) = Force / Area = F/A

where force in N and area in m^2

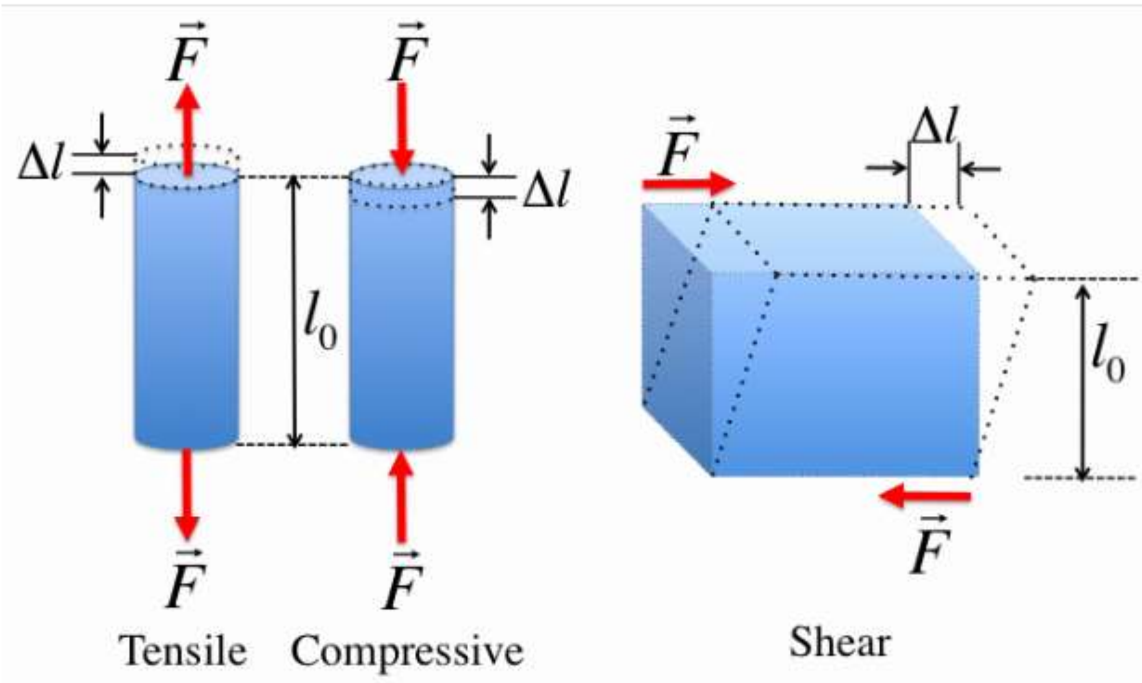
Pascal (Pa). 1 N/m2 = 1 Pa

There are three different nature of stress based on area of application. If the area is perpendicular to applied stress , then the stress can be tensile or compressive as per direction of force .

For shear force ,area parallel to force is considered for calculation of stress ,shear stress is denoted by Greek letter tau (τ).

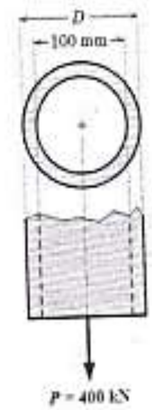
Thus force can be tensile, compressive and shear.

اذا سلطت قوه على مساحه معينه وغيرت في مقاسات النموذج فان القوه (نيوتن) / مقطع المساحة (متر مربع) يسمى اجهاد.
ينقسم الاجهاد الى ثلاثة انواع اما اجهاد شد او سحب او مماس كما في التوضيح التالي:


F
Δl
l0
Δl
F
F
F
Tensile
Compressive
F
Δl
l0
F
Shear

Example 1.

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.



Solution

$d_i = 100\ mm$

$F = 400\ kN$

$\sigma = 120\ MPa$

$d_o = ?$

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

$* A = \frac{\pi}{4}(d_o^2 - d_i^2)$

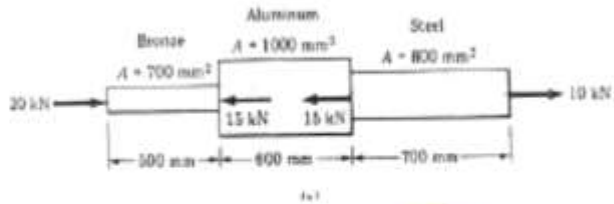
$120 = \frac{400 * 10^3}{\frac{\pi}{4}[d_o^2 - 100^2]}$

$d_o^2 = 14244.13$

$d_o = 119.34\ mm$ → Ans.

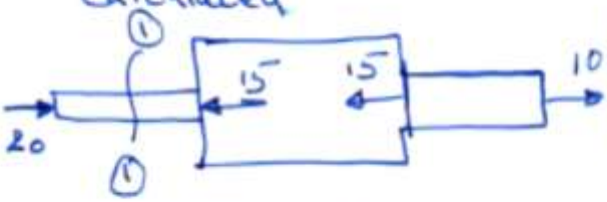
Example 2:

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

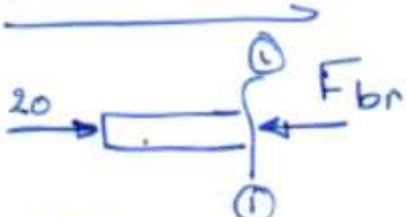


Solution

By superposition method, the force in each section calculated



Section ①—①



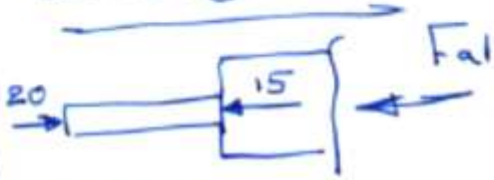
$\Sigma F x = 0$

$F_{br} = 20\,kN$

$$\sigma_{br} = \frac{F_{br}}{A_{br}} = \frac{20 * 10^3}{700}$$

$\sigma_{br} = 28.57\ MPa$

Section ②—②



$\Sigma F x = 0$

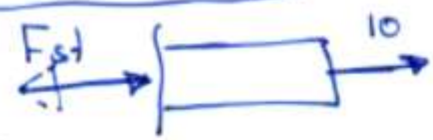
$-F_{al} - 15 + 20 = 0$

$F_{al} = 5\,KN$

$$\sigma_{al} = \frac{F_{al}}{A} = \frac{5 * 10^3}{1000}$$

$\sigma_{al} = 5\ MPa$ → Ans.

Section ③—③



$\Sigma F x = 0$

$-F_{st} - 10 = 0 \Rightarrow F_{st} = -10$

$F_{st} = 10\,KN$ ←

$$\sigma_{st} = \frac{F_{st}}{A_s} = \frac{10 * 10^3}{700} = 14.28$$

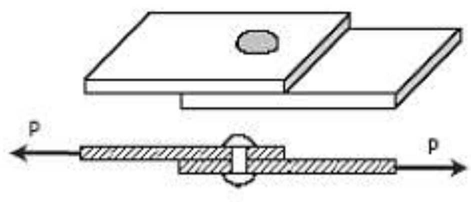
→ Ans

Shearing Stress

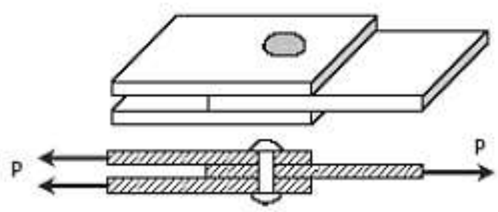
Forces parallel to the area resisting the force cause shearing stress. It differs to tensile and compressive stresses, which are caused by forces perpendicular to the area on which they act. Shearing stress is also known as tangential stress.

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

where (V) is the resultant shearing force which passes which passes through the centroid of the area A being sheared.



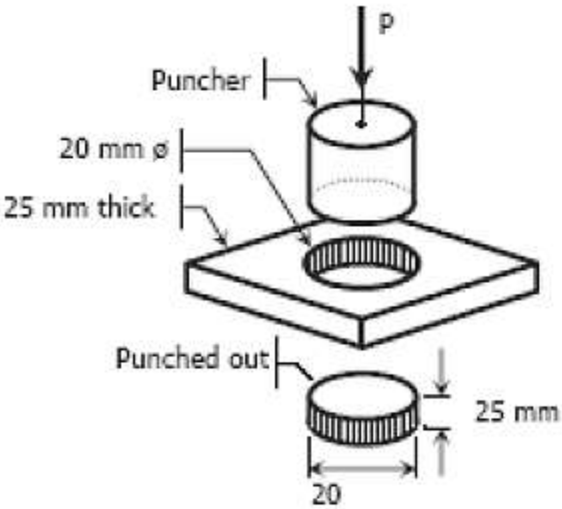
Single Shear



Double Shear

Problem 1: 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/m^2.

Solution:



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

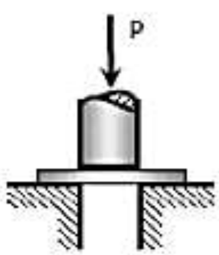
$$V = \tau A$$
$$P = 350[\pi(20)(25)]$$
$$= 549\,778.7 \text{ N}$$
$$= \mathbf{549.8 \text{ kN}}$$

Problem 2: 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.

Solution:



(a) Maximum thickness of plate:

Based on puncher strength:

$P = \sigma A$

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

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

Based on shear strength of plate:

$V = \tau A$ → V = P

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

$t = 0.781$ inch

(b) Diameter of smallest hole:

Based on compression of puncher:

$P = \sigma A$

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

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

Based on shearing of plate:

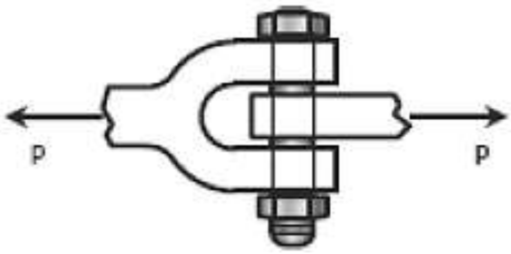
$V = \tau A$ → V = P

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

$d = 0.8$ in

Problem 3: Find the smallest diameter bolt that can be used in the clevis shown in Fig if P = 400 kN. The shearing strength of the bolt is 300 MPa.

Solution:



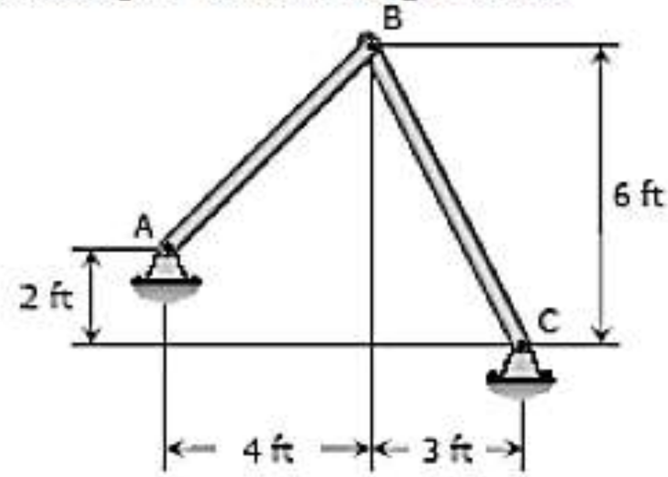
The bolt is subject to double shear.

$V = \tau A$

$400(1000) = 300[2(\frac{1}{4}\pi d^2)]$

$d = 29.13$ mm

Problem 4: The members of the structure in Fig weigh 200 lb/ft. Determine the smallest diameter pin that can be used at A if the shearing stress is limited to 5000 psi. Assume single shear.

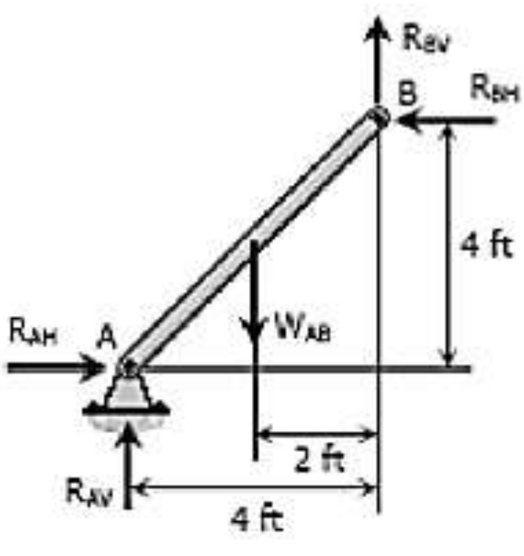


Solution:

For member *AB*:

Length, $L_{AB} = \sqrt{4^2 + 4^2}$
$= 5.66$ ft

Weight, $W_{AB} = 5.66(200)$
$= 1132$ lb



FBD of member

$\Sigma M_A = 0$

$4R_{BH} + 4R_{BV} = 2W_{AB}$

$4R_{BH} + 4R_{BV} = 2(1132)$

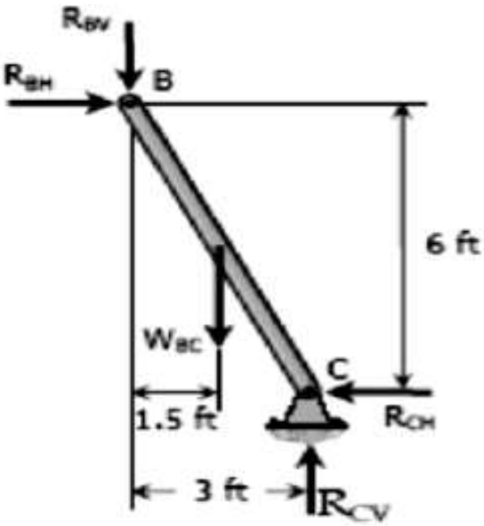
$R_{BH} + R_{BV} = 566 \quad \rightarrow (1)$

For member *BC*:

Length, $L_{BC} = \sqrt{3^2 + 6^2}$
$= 6.71$ ft

Weight, $W_{BC} = 6.71(200)$ =1342

$\Sigma M_C = 0$
$6R_{BH} = 1.5W_{BC} + 3R_{BV}$
$6R_{BH} - 3R_{BV} = 1.5(1342)$
$2R_{BH} - R_{BV} = 671 \quad \rightarrow (2)$



FBD of member BC

Add equations (1) and (2)

$R_{BH} + R_{BV} = 566 \quad \rightarrow (1)$
$2R_{BH} - R_{BV} = 671 \quad \rightarrow (2)$
$3R_{BH} = 1237$
$R_{BH} = 412.33 \text{ lb}$

From equation (1):
$412.33 + R_{BV} = 566$
$R_{BV} = 153.67 \text{ lb}$

From the FBD of member AB
$\Sigma F_H = 0$
$R_{AH} = R_{BH} = 412.33 \text{ lb}$

$\Sigma F_V = 0$
$R_{AV} + R_{BV} = W_{AB}$
$R_{AV} + 153.67 = 1132$
$R_{AV} = 978.33 \text{ lb}$

$R_A = \sqrt{R_{AH}^2 + R_{AV}^2}$
$= \sqrt{412.33^2 + 978.33^2}$
$= 1061.67 \text{ lb}$ → shear force of pin at A

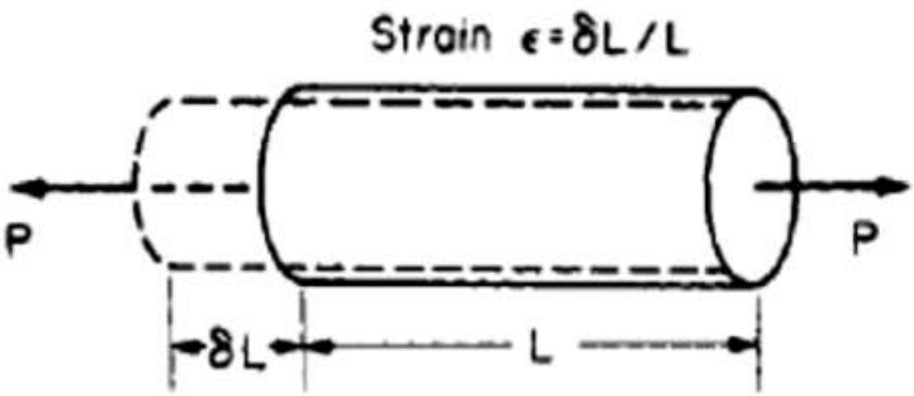
$V = \tau A$
$1061.67 = 5000(\frac{1}{4}\pi d^2)$
$d = 0.520 \text{ in}$

STRAINS

If a bar is subjected to a direct load, the bar will change in length. If the bar has a length L and changes in length by ΔL, the strain produced is defined as:

$$strain = \frac{\text{change in length}}{\text{orginal length}}$$

$$\varepsilon = \frac{\Delta L}{L}$$



Stress – Strain Diagram

The strength of material is not the only criterion that must be considered in designing structures the stiffness of material is frequently of equal importance.