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UNIVERSITI TEKNIKAL MALAYSIA MELAKA
OPENCOURSEWARE

INTRODUCTION TO MECHANICAL ENGINEERING
BMCG 2423
MECHANICS : CONCEPT OF STRESS

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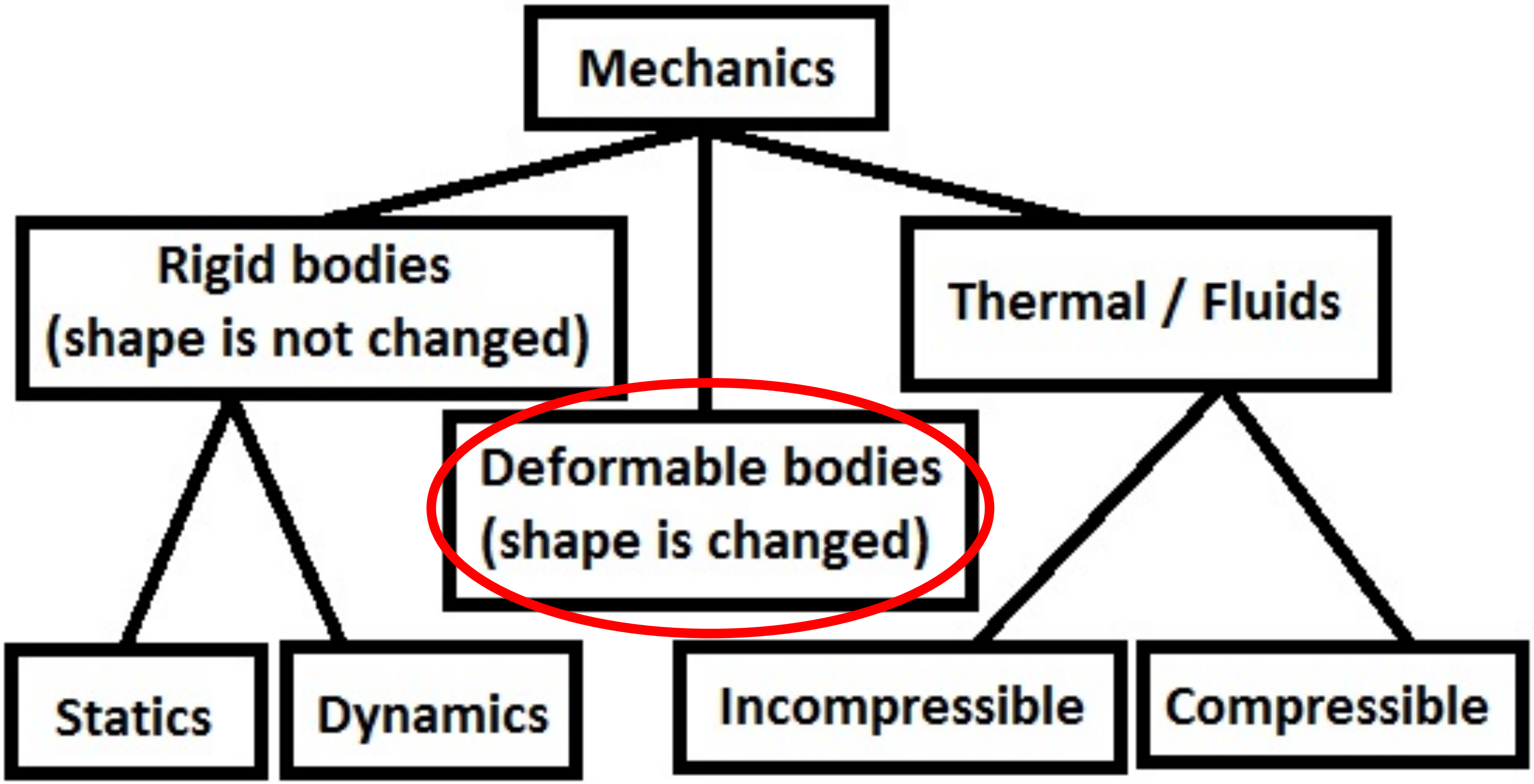
Lesson Outcome

At the end of lesson, students will be able to:

- define types of stress and factor of safety.
- apply basic concept of stress and factor of safety.

Branches of Mechanics



Applications

- What are the deformations in cables of crane during holding up the locomotive?

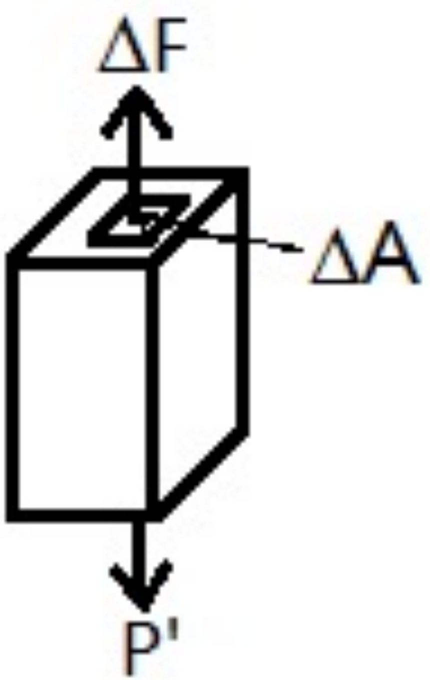
Axial Loading: Normal Stress

- For a member which is axially loaded (P'), the internal force (ΔF) is normal (perpendicular) to a cut section.
- Normal stress = force intensity

$$\sigma = \lim_{\Delta A \to 0} \frac{\Delta F}{\Delta A} \qquad \sigma_{ave} = \frac{P}{A}$$

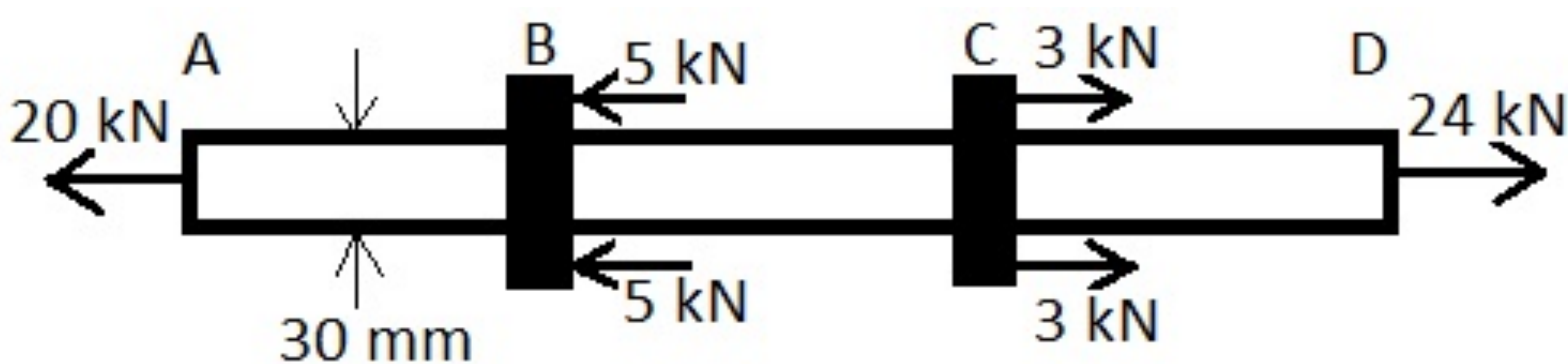
- Stress distribution resultant:

$$P = \sigma_{ave} A = \int dF = \int_A \sigma dA$$

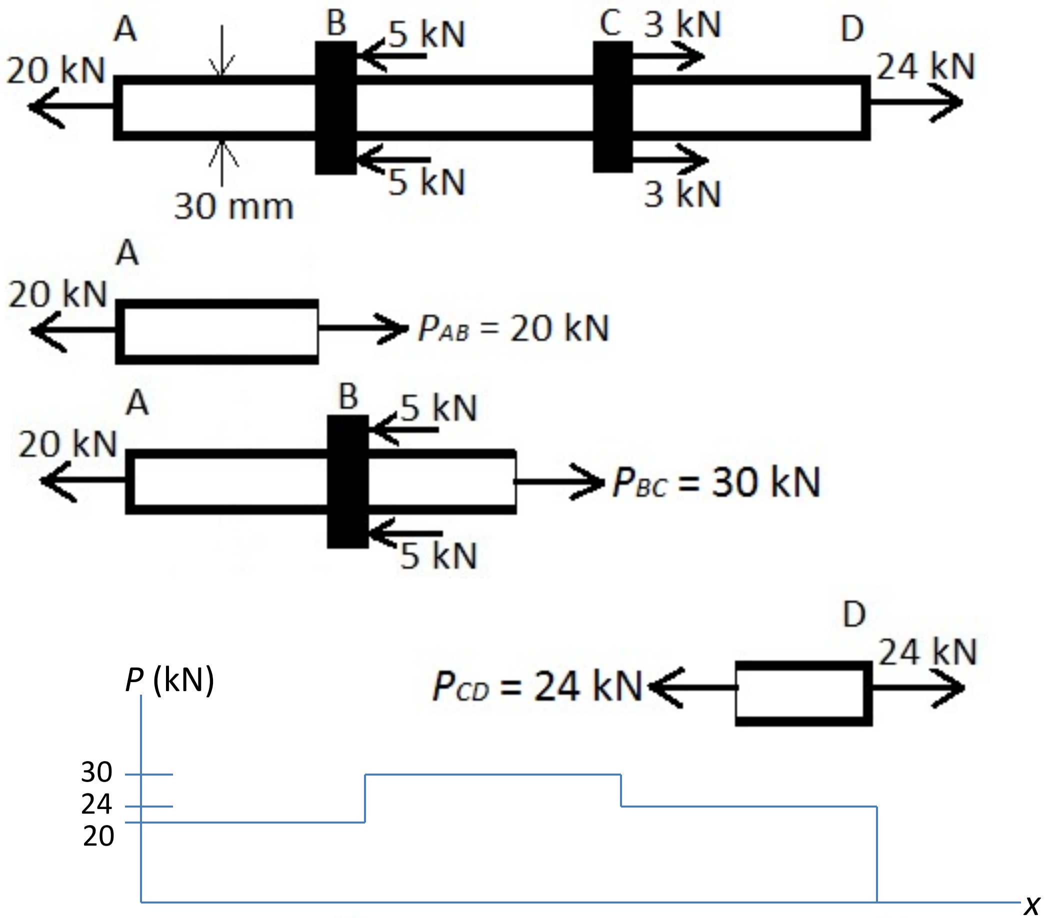


Normal Stress - Example

A rectangular-shaped bar has a uniform width of 30 mm and thickness of 10 mm. Calculate the maximum average of normal stress in the bar when it is subjected to the given loading as shown in Figure.



Solution: Cut into sections to find the internal forces, and the normal force can be graphically illustrated in diagram as shown at the bottom.



From the normal force diagram, it is known that the largest force is at part BC,

$$P_{BC} = 30 \text{ kN}$$

It is mentioned that the rectangular cross-sectional area is constant throughout the bar, thus the maximum average normal stress is,

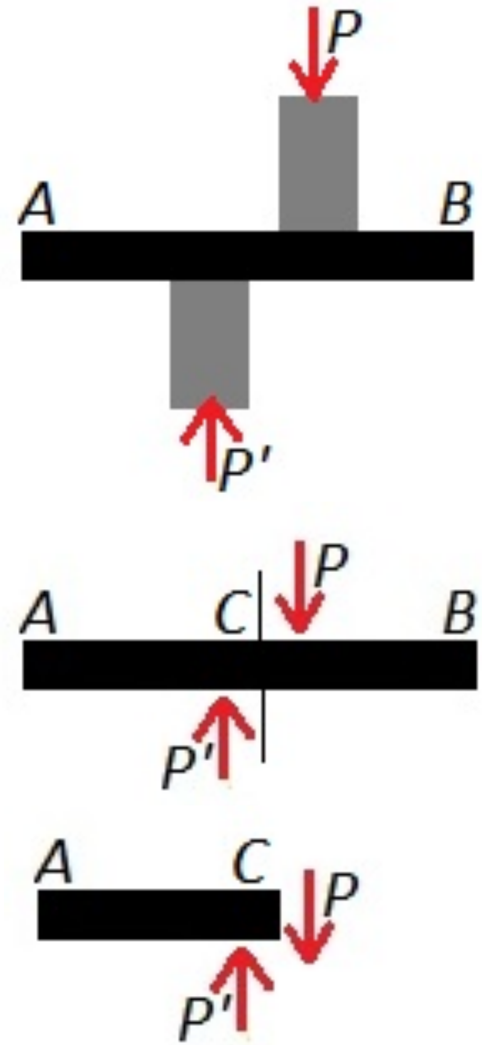
$$\sigma_{BC} = \frac{P_{BC}}{A} = \frac{30 \times 10^3}{(0.030)(0.01)} = 100 \text{ MPa}$$

Shear Stress

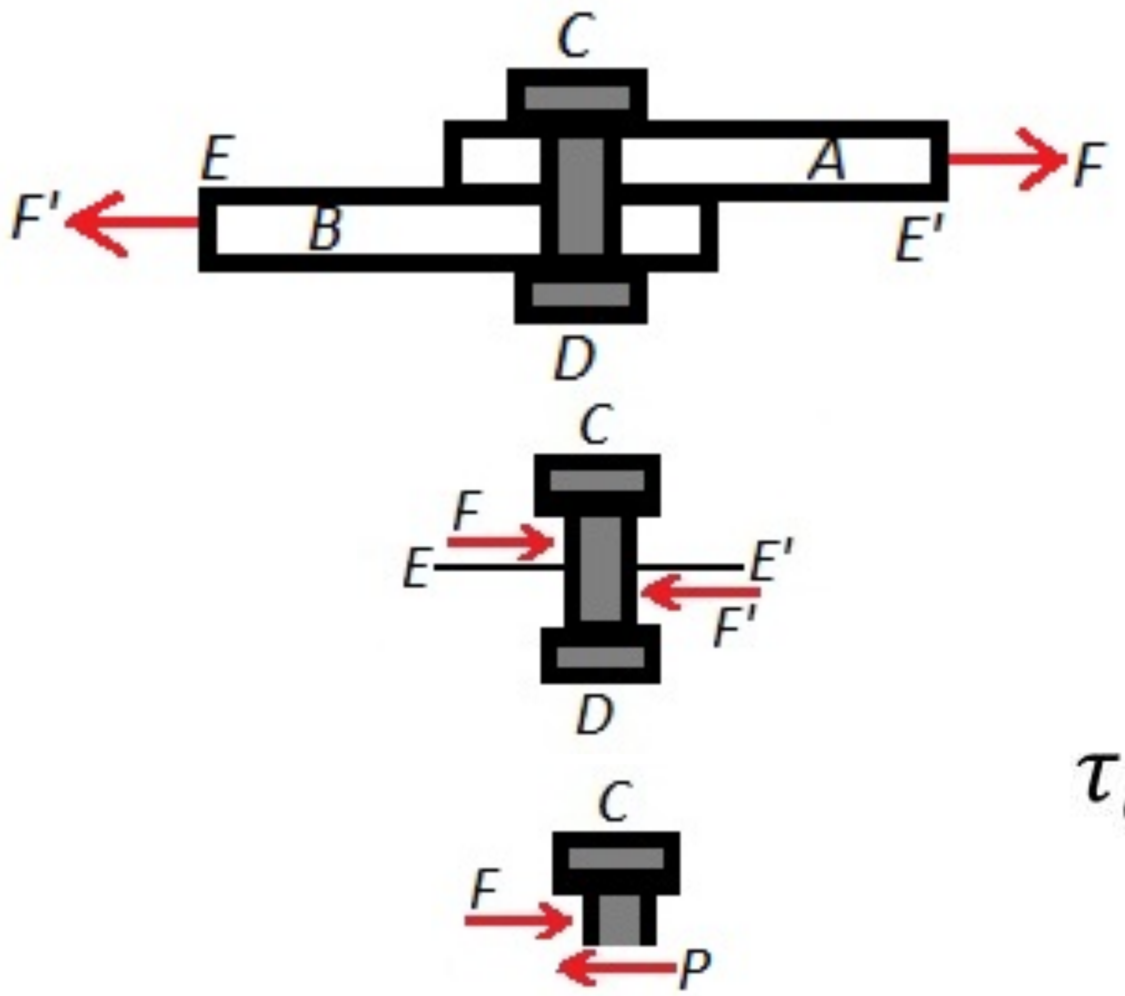
- The transverse forces *P* and *P'* are applied to member *AB*.
- The internal force that takes place at section-*C* is called shear force, and it is equal to the load *P*.
- The average shear stress is,

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

- The shear stress distribution cannot be assumed as uniform. The real values vary from zero at surface to maximum at middle.



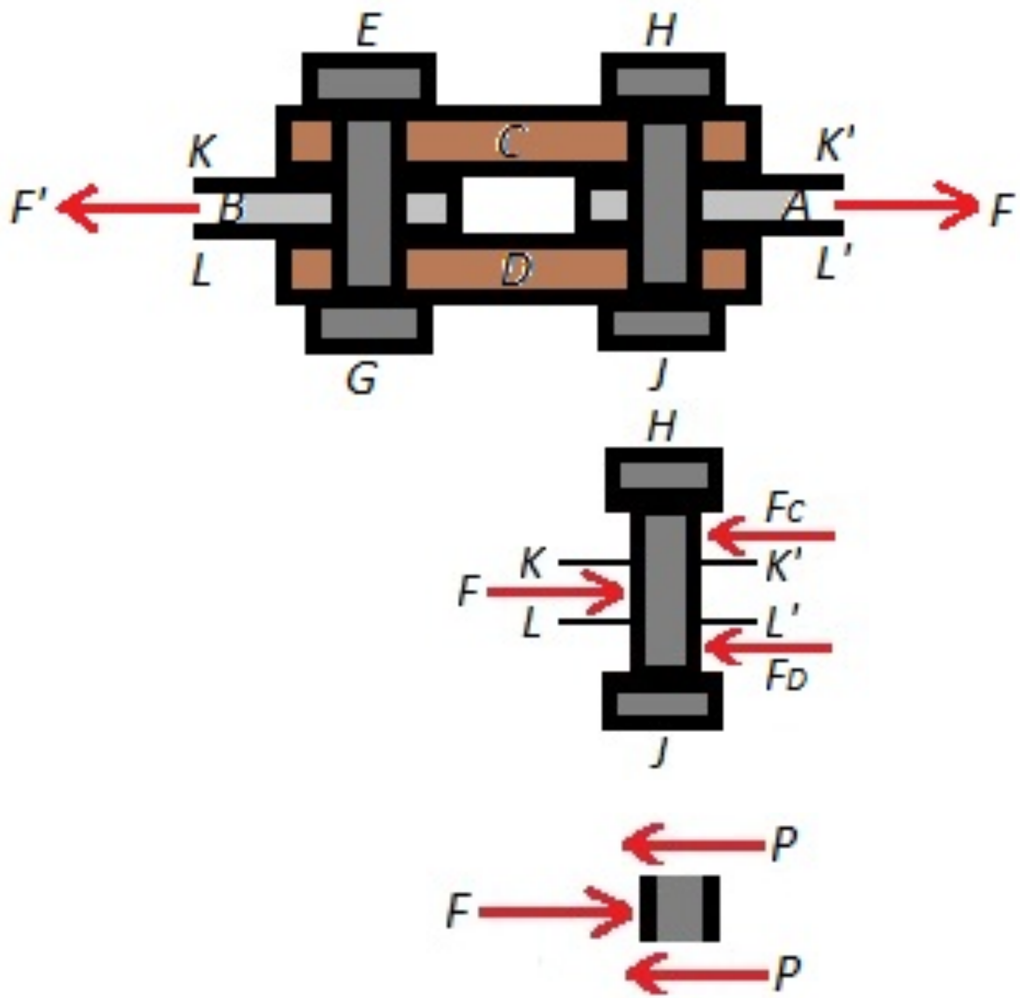
Type of Shear Stress



Single Shear

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

Type of Shear Stress

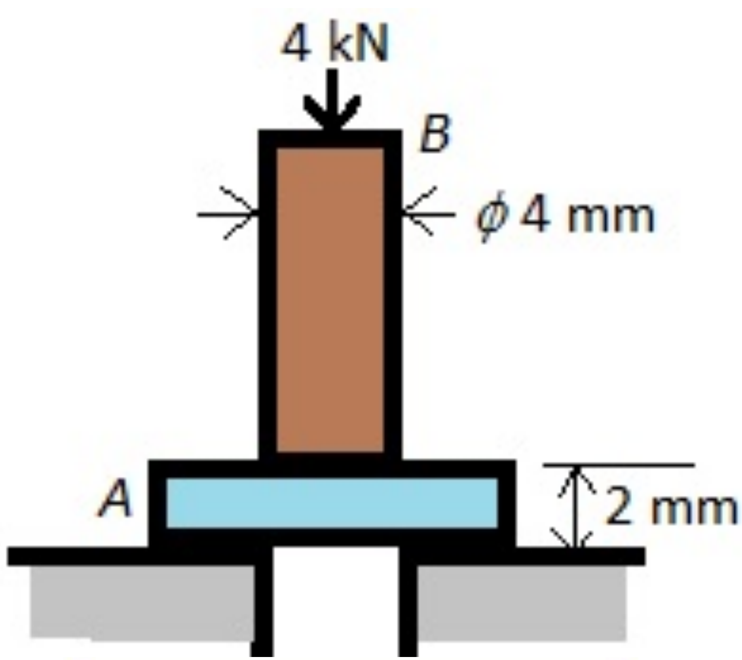


Double Shear

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

Shear Stress - Example

A force of 4 kN is applied by a circular punch B on top of circular plate A. Calculate the average shear stress in plate A as a result of this applied force.



Solution: This is a single shear problem.

The shear area

$$A = \pi(0.004)(0.002) = 8\times10^{-6}\pi \text{ m}^2$$

$$\tau_{ave} = \frac{V}{A} = \frac{4(10^3)}{8\times10^{-6}\pi} = 159.15 \text{ MPa}$$

Factor of Safety

Structural members or machines must be designed for condition where the allowable stress values are smaller than that of ultimate strength of the material.

$$F.S. = \text{Factor of Safety}$$

$$F.S. = \frac{\sigma_{ult}}{\sigma_{all}} = \frac{\text{ultimate stress}}{\text{allowable stress}}$$

$$F.S. = \frac{F_{ult}}{F_{all}} = \frac{\text{ultimate load}}{\text{allowable load}}$$

Factor of Safety

- Material Properties Uncertainties
- Loadings Uncertainties
- Analysis Uncertainties
- Loading Cycles Number
- Failure Types
- Maintenance Requirements and Deterioration Effects
- Importance of Member to Structural Integrity
- Risk to Life and Property
- Influence on Machine Function

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Safety

Example

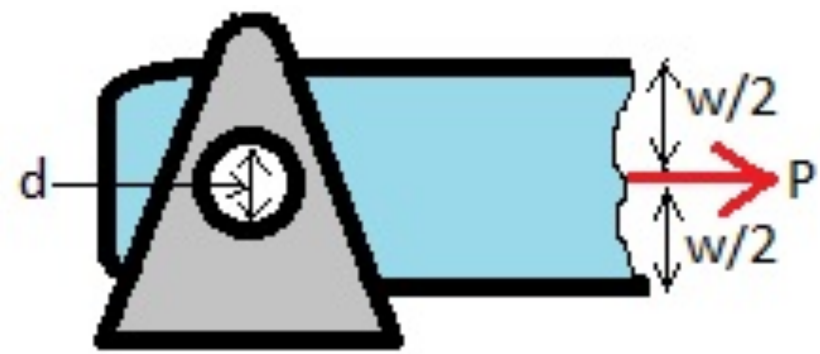
An end of joint is subjected to 40 kN force, P as shown in the Figure. It is made of steel, and supported by a pin and bracket at both of its' sides.

If the ultimate normal stress is 600 Mpa, determine the thickness of the joint. Given that the factor of safety is 2.5, and width w of the joint as 4 times of it's thickness t.

(Hint: this is a normal stress problem)

If the pin is made from steel with an ultimate shearing stress of 350 Mpa, determine the diameter d of the pin. Given that the factor of safety is 2.5.

(Hint: this is a double shear problem)



Example - **Solution**

An end of joint is subjected to 40 kN force, P as shown in the Figure. It is made of steel, and supported by a pin and bracket at both sides.

First, find the allowable stress from factor of safety and ultimate stress.

$$F.S. = \frac{\sigma_{ult}}{\sigma_{all}} = \frac{\text{ultimate stress}}{\text{allowable stress}}$$

$$\sigma_{all} = \frac{\sigma_{ult}}{F.S.} = \frac{600\ MPa}{2.5} = 240\ MPa$$

Then, find the area A from the allowable stress and force given to the joint.

$$\sigma_{all} = \frac{40\ kN}{A} = 240\ MPa$$

$$A = \frac{40\ kN}{240\ MPa} = 166.67\ mm^2$$

Then, calculate the thickness from the area.

$$A = t \times w = t \times 4t = 4t^2$$

$$t =$$

Example - **Solution**

A pin is made of steel with ultimate shear stress of 350 MPa.

First, find the allowable stress from factor of safety and ultimate stress.

$$F.S. = \frac{\tau_{ult}}{\tau_{all}} = \frac{\text{ultimate stress}}{\text{allowable stress}}$$

$$\tau_{all} = \frac{\tau_{ult}}{F.S.} = \frac{350\ MPa}{2.5} = 140\ MPa$$

Then, find the area A from the allowable stress and force given to the joint. Note that the pin and bracket system leads to double shear problem.

$$\tau_{all} = \frac{40\ kN}{2A} = 140\ MPa$$

$$A = \frac{20\ kN}{140\ MPa} = 142.86\ mm^2$$

Then, calculate the diameter of pin from the area.

$$A = \frac{\pi d^2}{4}$$

$$d =$$

End of Lesson

<u>Recall:</u>

- What is the definition of normal stress?
- What is the definition of shear stress?
- What are the types of shear stress? Can you differentiate between the types?
- What is factor of safety, and what are causes that contribute to the importance of using factor of safety?

References

- Beer, F.P., Johnston Jr., E.R., DeWolf, J.T, 2014, **Mechanics of Materials**, Fourth Edition in SI Units, McGrawHill, Singapore.