German University in Cairo

Lecture 1

Strength of Materials I (ENME 401)

Spring 2021

Contents

Learning objectives:

- know the concept of stress in design
- the difference between all types of stresses

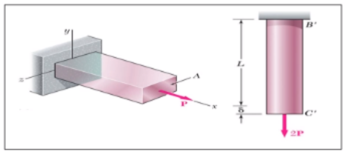
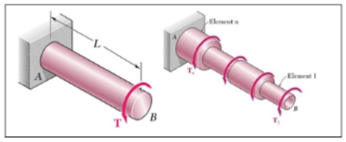
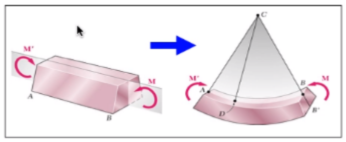
1 Concept of Stress

Exercise 1. Analyze Vs **Design** in problems

The main goal of our study in this course is to avoid deformation, we can do this in two ways either analyzing or desiging :)

Definition 1. Strength of materials

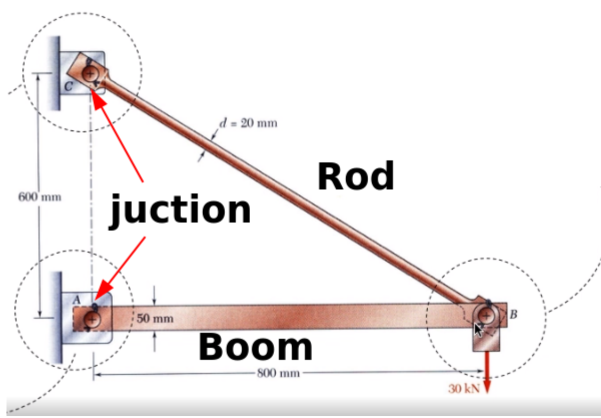
it's the branch of applied mechanics that deals with the behavior of elastic bodies subjected to various tyoes of loading.
Bodies under investigation represent the components of a machine or a structure.
Coponents

- **Bars** Axial Loading 
- **Shafts** Torsion 
- **Beams** Bending 
- **Columns** Compression-buckling (Strength II)

once you have a force, you have **stress**, and once you have a stress you have deformation. That **deformation** causes a **strain** .

1.1 Statics

in statics all our attention was directed upon finding forces only, we didn't care about the **thickness** of the cord, the **material** it was maded from, the **dimesnions** of it.
in order for the boom,rod and juncions to handle the forces and loads given and not deform, we have to study the stress on them.



Design and Analyze

To **design** is to take the load and make a structure that handels such a load, so the structure doesn't exist yet !
and to **analyze** is to check if the dimesnions and the material that already exist is able to handle that load ? if not we get the maximum load we can bear.

Rule 1. To solve any **strength** problem you have to solve the **statics** first!

$$Stress = \sigma = \frac{P}{A} = N/m^2 (or Pa) \tag{1}$$

Solving the previous problem using statics we will find that $F_{AB} = 40kN$ (Compression) and $F_{BC} = 50kN$ (Tension). Now let's assume it's made of steel and let's calculate the stress

$$\sigma_{BC} = \frac{P}{A} = \frac{50 * 10^2}{314 * 10^{-6}} = 159MPa. \tag{2}$$

we know from the material properties for steel theat the allowable strees is $\sigma_{all} = 165MPa$ and since $\sigma_{BC} <= \sigma_{all}$ thus the strength of memeber BC is adequate (safe).

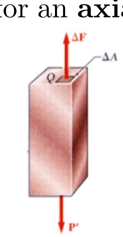
Note 1. if $\sigma_{member} = \sigma_{all}$ that's a risky region

1.2 Stress types

- Normal stress (force prependicular to the cross sectional area)
- Shear Stress (force parallel to the cross-sectional area)
  - single shear
  - double shear
- Bearing Stress ()

1.3 Normal Stress

when the resultant of the internal forces for an **axially loaded** member is **normal** to a section cut prependicular to the member axis.



the force intensity (force per unit area) on that section is defined as the normal stress.

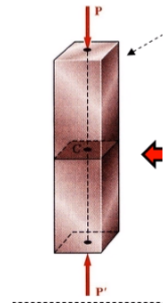
$$\sigma = lim_{\Delta A \to 0} \frac{\Delta F}{\Delta A} = \sigma_{ave} = \frac{P}{A} (average) \tag{3}$$

Note 2. Why average ? Because the stress is not unifromly distributed across the cross-sectional area.

1.4 Types of Normal Load

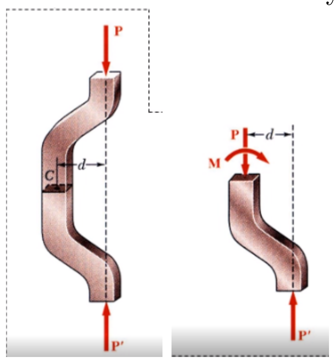
- **Centric** → when the line of action of the resultant of the internal forces passes through the centroid of the section.

Rule 2. Uniform distribution of stress is possible in this case; where the concentraded loads



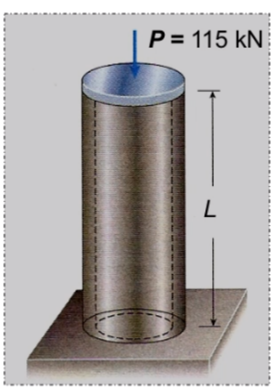
on the end sections of two-force members are applied at the section centroids.

- **Eccentric** → this is when the two-force member is **eccentrically loaded** then the resultant of the streess distibution in a section must yiels in an axial force and a moment. This moment causes **bending**



Rule 3. Eccentrically loaded members' stress cannot be uniform neither symmetric.

Exercise 2. A short post constructed from a hollow circular tube of aluminum supports a compressive load of 115 kN. The outer and inner diameters of the tube are do= 115 mm and di= 100 mm, respectively.
Determine the compressive stress in the post



Solution 1.

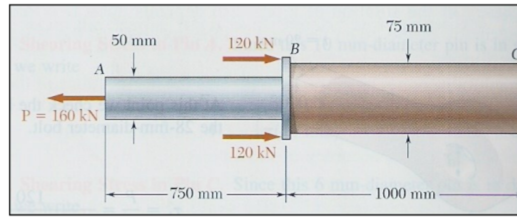
$$\sigma = \frac{P}{A}$$

$$P = 115 \times 10^3 \quad N$$

$$A = \frac{\pi}{4}\left(d_o^2 - d_i^2\right) = \frac{\pi}{4}\left(115^2 - 100^2\right) = 2532.91 \quad mm^2$$

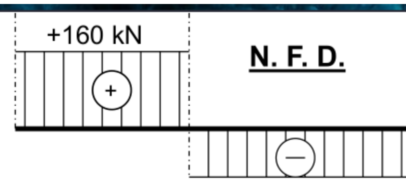
$$\sigma = \frac{115 \times 10^3}{2532.91} = 45.4 \quad MPa$$

Exercise 3. Two solid cylindrical rods AB and BC are welded together at B and loaded as shown.



Determine the average stress at the midsection of: (a) rod AB, (b) rod BC.

Solution 2.



At first determine the axial force in each rod.
So, draw the Normal Force Diagram.

a- <u>rod *AB*</u> (rod 1)

$$\sigma_1 = \frac{P_1}{A_1}$$

$$P_1 = +160\times10^3 \quad N$$

$$A_1 = \frac{\pi}{4}(50)^2 = 1963.5 \ mm^2$$

$$\sigma_1 = \frac{+160\times10^3}{1963.5} = +81.49 \ MPa$$

b- <u>rod *BC*</u> (rod 2)

$$\sigma_2 = \frac{P_2}{A_2}$$

$$P_2 = -80\times10^3 \quad N$$

$$A_2 = \frac{\pi}{4}(75)^2 = 4417.86 \ mm^2$$

$$\sigma_2 = \frac{-80\times10^3}{4417.86} = -18.1 \ MPa$$

+ tensile stress
− Compressive stress

NFD = Normal Force Diagram