

EE392 - ELECTRICAL ENGINEERING PRACTICE

MECHANICAL COMPONENT

Static Mechanics

Direct Stress

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1.1 Load:

Any engineering design built of a number of members is in equilibrium under the action of external forces and reactions at the points of support.

These forces constitute **load** on the member. Since the member is in equilibrium all forces must sum up to zero.

Simplest type of load is direct pull or push technically as tension or compression illustrated in fig. 1.1

If a member is in motion, the load maybe caused partly by dynamic or inertia forces.

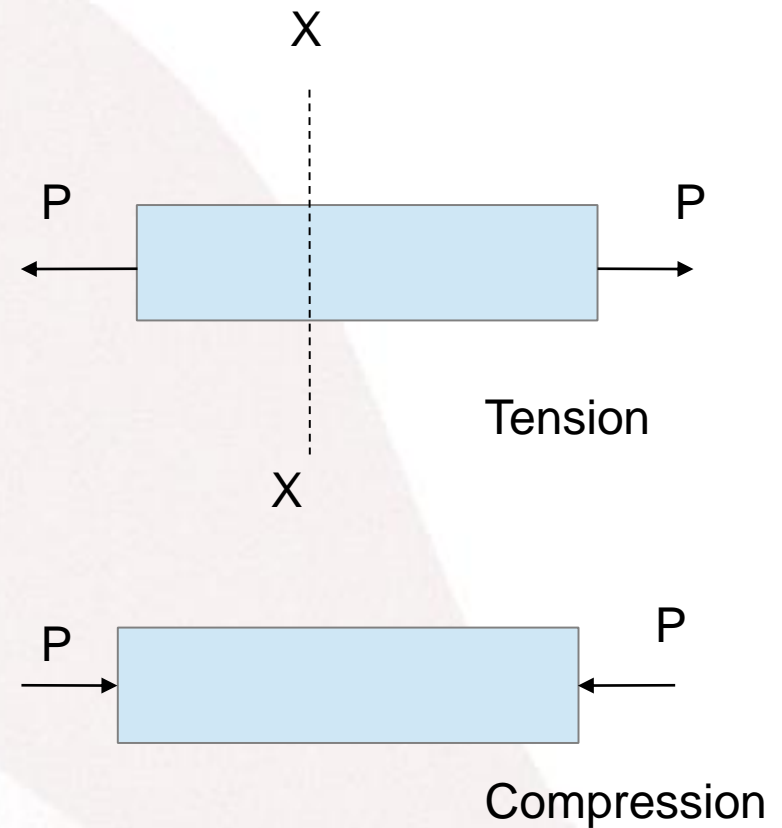


Fig1.1

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- 1.2 Stress

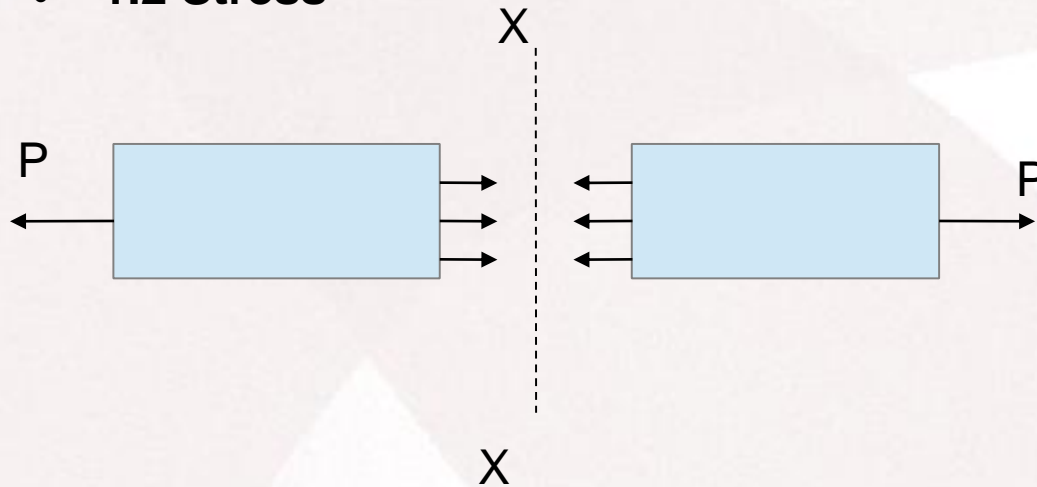


Fig 1.2

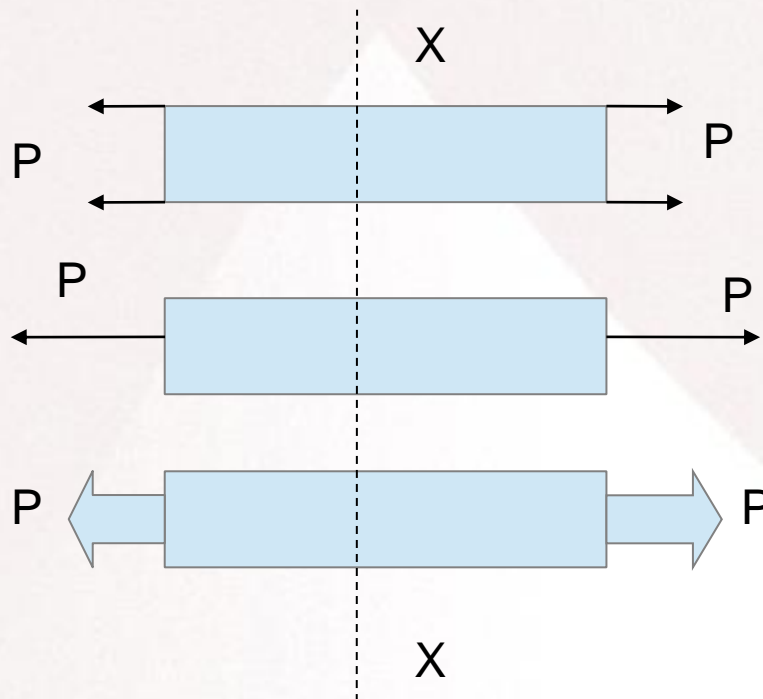
Consider any section X-X of the member, the total force carried by such a section must equal the load P

Stress $\sigma = P/A$, where A is the area.

Stress is force per unit area, in SI units **N/m²**

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1.3 Principle of St. Venant. States that the actual distribution of the load over the surface of its application will not affect the distribution of stress or strain on sections of the body which are at an appreciable distance (relative to the dimensions) away from the load.



Statically equivalent,
where section X-X is at an
appreciable distance away
from the load

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1.4 Strain. Strain is a measure of the deformation produced in the member by the load. Direct stress produce a change in length in the direction of stress. If a rod of length l is in tension and the stretch or elongation produced is x , then the direct strain ϵ is defined as the ratio

$$\text{Elongation / original length or } \epsilon = x/l$$

Normally tensile strains will be considered positive and compressive strains (I.e decrease in length) negative.

Note that strain is a ratio hence dimensionless

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1.5 Hooke's law. Principle of Superposition This states that strain is proportional to the stress producing it. It is obeyed within certain limits of stress by most ferrous alloys and can usually be assumed to apply with sufficient accuracy to other engineering materials such as timber, concrete and non-ferrous alloys. In general a material is said to be elastic if all the deformations are proportional to the load.

Where a number of loads are acting together on an elastic material, the principle of superposition states that the resultant strain will be the sum of individual strains caused by each load acting separately

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1.6 Modulus of Elasticity (Young's Modulus)

- Within the limits for which Hooke's law is obeyed, the ratio of the direct stress to the strain produced is called Young's Modulus or Modulus of Elasticity (***E***), i.e. ***E = σ / ε [N/m²]***
- For a bar of uniform cross section ***A*** and length ***l*** this can be written as
E = Pl / Ax, ***E*** is therefore a constant for a given material, and is usually assumed to be the same in tension or compression.
- Young's Modulus represents the stress required to cause unit strain, i.e. provided Hooke's Laws continued to be obeyed.

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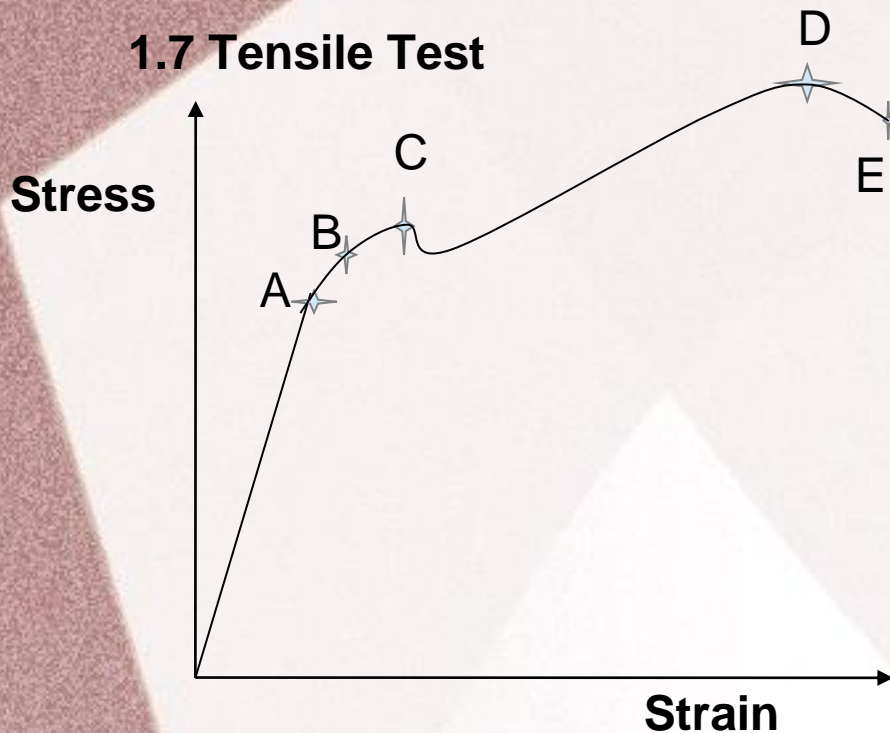


Fig 1.3

Mainly apply to the behavior of mild steel

A – Limit of proportionality (Hooke's Law obeyed)

B – Elastic Limit (Hooke's Law not obeyed but still in elastic region)

C – Yield point, metal shows appreciable strain even without further increase in load (some material will show upper and lower yield point)

D – maximum or Ultimate tensile stress calculated by dividing the load at D by original cross section area.

E- Rapture

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- **Tensile Test continued ...**
- The capacity for being drawn out plastically before breaking is called the **ductility** of the material measured by the following two quantities:
 - (1) percentage elongation = total increase in gauge length / original length expressed as a percentage
 - (2) percentage reduction in area or contraction – reduction in cross sectional area at the neck, expressed as a percentage of original area.

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1.8 Factor of Safety

Factor of Safety = Ultimate stress / Working Stress

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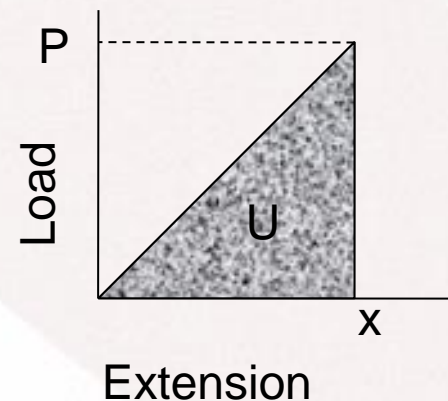
1.9 Strain Energy, Resilience

When a tensile or compressive load P is applied to a bar there is a change in length x which, for an elastic material is proportional to the load

The strain energy of a bar is defined as the work done by the load in straining it.

Under static or gradually applied load work done is represented by the shaded area, giving

$$U = 1/2Px \text{ ----- (1)}$$



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Strain Energy, Resilience continued ...

- In terms of stress and dimensions, for a bar of uniform section A and length l substitute $P = \sigma A$ and $x = \sigma l/E$, giving

$$U = \frac{1}{2} \cdot \sigma A \cdot \sigma l/E$$
$$= (\sigma^2/2E)Al \text{ ----- (2)}$$

- But Al is the volume of the bar, and hence equation (2) can be stated: “the strain energy per unit volume (usually called the resilience) in simple tension or compression is $\sigma^2/2E$ ”
- Strain energy is always positive quantity, being units, will be expressed in Nm (ie Joules).

References

- G.H Ryder, Strength of Materials,