ENGINEERING MECHANICS

UNIT-II Chapter – 6
SIMPLE STRESS AMD STRAIN

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Properties of Materials

- some properties of materials which judge the strength of materials are given below:
- Elasticity: It is the property by virtue of which a material deforms under the applied load and it is enabled to return to its original position when the load is removed.
- Plasticity: It is the property of the material by which it undergoes inelastic strain beyond those at the elastic limit is known as the plasticity. It is also defined as unrecoverable strain.
- Ductility: It is the property of the material by which it undergoes considerable amount of deformation without rupture. A ductile material must possess a high degree of plasticity and strength.
- Brittleness: It is lack of ductility, a brittle material rupture with little or no plastic deformation.

Properties of Materials

- Strength: This is the maximum stress that a material can take. This is equal to maximum load divided by area.
- Hardness: It is the ability of material to resist against surface abrasion or indentation.
- Toughness: It is the property of material which enables it to absorb energy without fracture. It is represented by area under stress-strain curve upto fracture.
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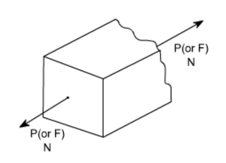
- Fatigue: Fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading or repeated loading and unloading.

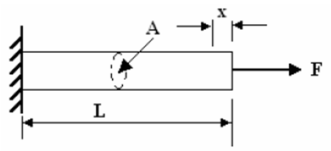
- Stress:
- when some external system of load acts on a body, the internal forces (equal & opposite) are set up at various section of the body, which resist the external force. This force per unit area at any section is known as stress.



Types of Stresses & Strains

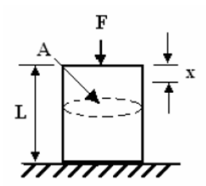
Direct Stress (σ)

When a force is applied to an elastic body, the body deforms. The way in which the body deforms depends upon the type of force applied to it.



Tensile Stress due to *tensile force*

A tensile force makes the body longer



Compressive Stress due to *compressive force*

A Compression force makes the body shorter.

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- **Resistance offered by the material per unit cross- sectional area is called STRESS**
- Tensile and compressive forces are called DIRECT FORCES
- Stress is the force per unit area upon which it acts.

$$Stress = \sigma = \frac{Force}{Area} = \frac{F}{A} \quad N/m^2$$ or Pascal (Pa)

(σ is called as **Sigma)**

Note: Most of engineering fields used kPa, MPa, GPa.

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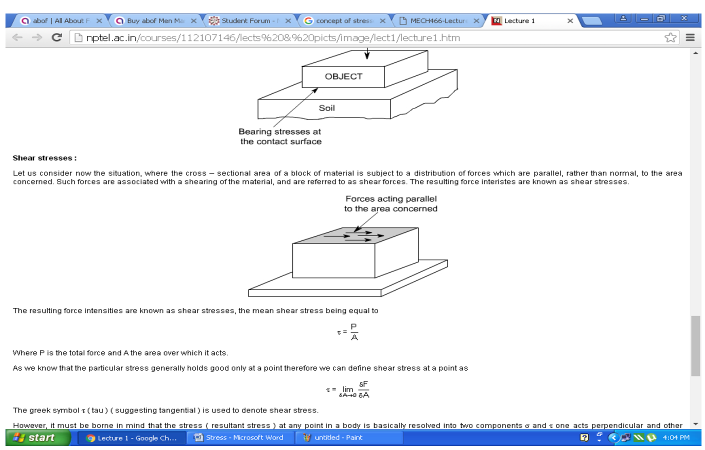
TYPES OF STRESSES:

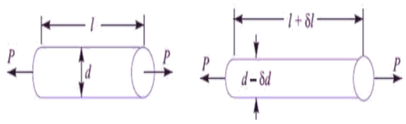
- Only two basic stresses exist: (1) normal stress and (2) shear shear stress. Other stresses either are similar to these basic stresses or are a combination of this e.g. bending stress is a combination tensile, compressive and shear stresses. Torsional stress, as encountered in twisting of a shaft is a shearing stress.

- Bearing Stress: When one object presses against another, it is referred to a bearing stress (They are in fact the compressive stresses).
- Here resulting force intensities are known as shear stresses, the mean shear stress being equal to
- Where P is the total force and A the area over which it acts

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



- **Strain:** Strain is the deformation of a material from stress. It is simply a ratio of the change in length to the original length. Deformations that are applied perpendicular to the cross section are normal strains.
- **Linear Strain:** Linear strain of a deformed body is defined as the ratio of the change in length of the body due to the deformation to its original length in the direction of the force. If L is the original length and dL the change in length occurred due to the deformation, the linear strain e induced is given by ε=dL/L.
- Linear strain may be a tensile strain, εt or a compressive strain εc according as dl refers to an increase in length or a decrease in length of the body. If we consider one of these as +ve then the other should be considered as –ve, as these are opposite in nature.
- **Lateral Strain:** Lateral strain of a deformed body is defined as the ratio of the change in length (breadth of a rectangular bar or diameter of a circular bar) of the body due to the deformation to its original length (breadth of a rectangular bar or diameter of a circular bar) in the direction perpendicular to the force.



Volumetric Strain

- **Volumetric Strain** is defined as the ratio of change in volume to the initial volume.

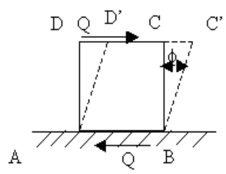
Volumetric strain, e_V $\dfrac{\text{Change in volume}}{\text{Initial volume}}$ $\dfrac{\Delta V}{V}$

Where, ΔV= change in volume

V= initial volume

Shear Strain:

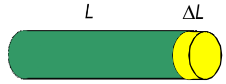
- Shear strain is defined as the strain accompanying a shearing action. It is the angle in radian measure through which the body gets distorted when subjected to an external shearing action. It is denoted by ε
- Consider a cube ABCD subjected to equal and opposite forces Q across the top and bottom forces AB and CD. If the bottom face is taken fixed, the cube gets distorted through angle Φ to the shape ABC'D'. Now strain or deformation per unit length is
- Shear strain of cube = CC' / CD = CC' / BC = Φ radian



Direct Strain **(ε)** Also called as **Longitudinal Strain**

In each case, a force '**F**' produces a deformation '**x**' . In engineering, we usually change this force into stress and the deformation into strain and we define these as follows:

- **Strain is the deformation per unit of the original length**.



Strain, $\boldsymbol{\varepsilon} = \Delta L/L$ = Change in length/ Original length
(ε is called as **Epsilon)**

- Strain has no unit's since it is a ratio of length to length

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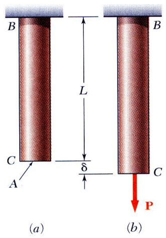

Fig. 2.1

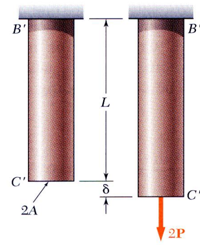

Fig. 2.3

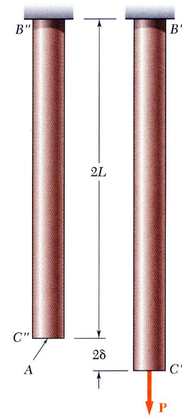

Fig. 2.4

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

$$\varepsilon = \frac{\delta}{L} = \text{normal strain}$$

$$\sigma = \frac{2P}{2A} = \frac{P}{A}$$

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

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

$$\varepsilon = \frac{2\delta}{2L} = \frac{\delta}{L}$$

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Hooks law

- Hooks law: Hooke’s law stated that within elastic limit, The linear relationship between stress and strain for a bar in simple tension or compression is expressed by the equation, Stress ⍰⍰Strain, = Eε
- In which is the axial stress, e is the axial strain, and E is a constant of proportionality known as the modulus of elasticity for the material. The modulus of elasticity is the slope of the stress-strain diagram in the linearly elastic region.
- The equation = Eε is commonly known as Hooke’s law

Hooke’s law

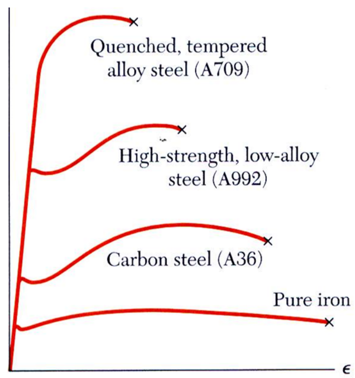

Fig. 2.16 Stress-strain diagrams for iron and different grades of steel.

Below the *yield stress*

Stress α Strain (ie) **σ α ε**

$$\sigma = E\,\varepsilon$$

Where **E** is a constant called as

Youngs Modulus or ***Modulus of Elasticity***

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Elastic Constants

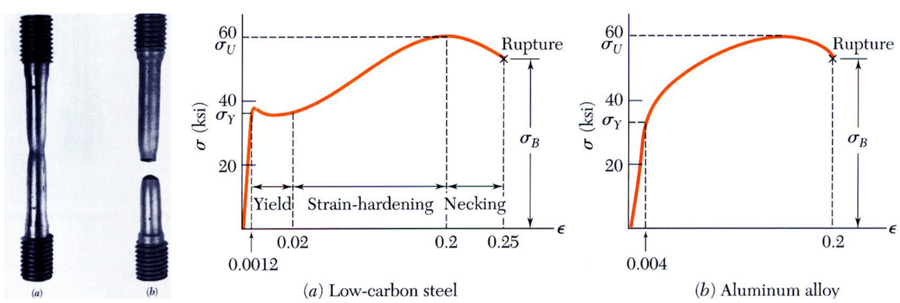
Elastic Constants:

- The elastic constants mostly used in engineering mechanics E, G and K can be defined as follows

- **Modulus of elasticity** (Young's modulus) (E) describes tensile elasticity, or the tendency of an object to deform along an axis when opposing forces are applied along that axis; it is defined as the ratio of tensile stress to tensile strain. It is often referred to simply as the elastic modulus.

- **Modulus of Rigidity** or Shear Modulus (G): is the coefficient of elasticity for a shearing or torsion force. Modulus of Rigidity is the coefficient of elasticity for a shearing force. It is defined as "the ratio of shear stress to the displacement per unit sample length"
- Bulk modulus (K): When a body is subjected to like and equal direct stress along three mutually perpendicular directions, the ratio of this direct stress to corresponding volumetric strain is called Bulk modulus.
- The **Bulk Modulus Elasticity** or Volume Modulus is a material property characterizing the compressibility of a fluid, how easy a unit volume of a fluid can be changed when changing the pressure working upon it. It describes the elastic properties of a solid or fluid when it is under pressure on all surfaces.

Stress-Strain diagram



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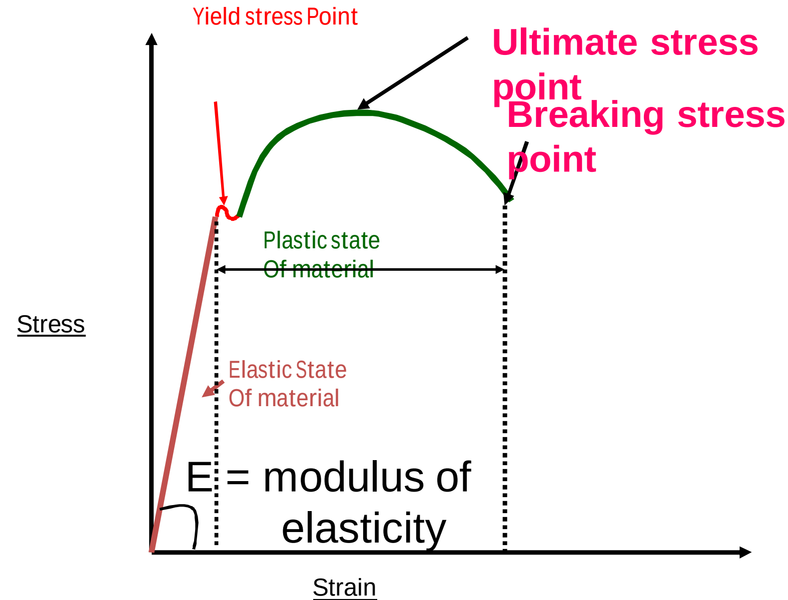
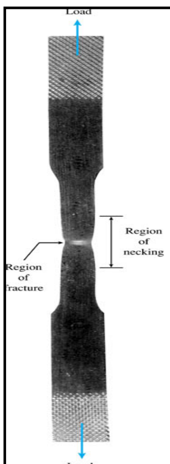
Stress- Strain Curve for Mild Steel (Ductile Material)



Stress (σ) – strain (ε) diagrams



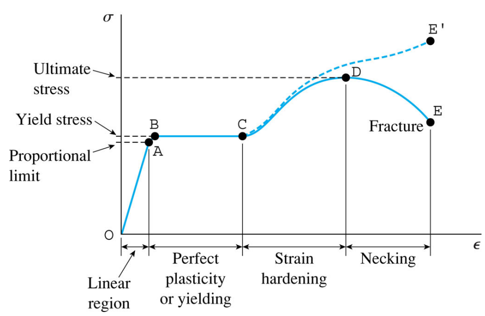


FIG. 1-10 Stress-strain diagram for a typical structural steel in tension (not to scale)

OA: Initial region which is linear and proportional

Slope of OA is called modulus of elasticity

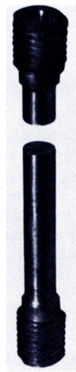
BC: Considerable elongation occurs with no noticeable increase in stress (yielding)

CD: Strain hardening – changes in crystalline structure (increased resistance to further deformation)

DE: Further stretching leads to reduction in the applied load and fracture

OABCE': True stress-strain curve

West Virginia University.



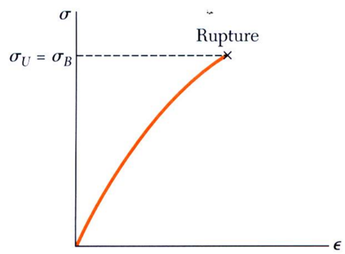


Fig. 2.11 Stress-strain diagram for a typical brittle material.

Working stress

- The stress to which the material may be safely subjected in the course of ordinary use. Also called as **Allowable Load or Allowable stress**
- Max load that a structural member/machine component will be allowed to carry under normal conditions of utilisation is considerably smaller than the ultimate load
- This smaller load = Allowable load / Working load / Design load
- Only a fraction of ultimate load capacity of the member is utilised when allowable load is applied
- The remaining portion of the load-carrying capacity of the member is kept in reserve to assure its safe performance

Factor of safety

- Factor of Safety (FoS) or safety factor (SF): is a term describing the load carrying capacity of a system beyond the expected or actual loads. Essentially, the factor of safety is how much stronger the system is than it usually needs to be for an intended load.
- It is a multiplier applied to the calculated maximum stress to which a component will be subjected. Typically, for components whose failure could result in substantial financial loss, or serious injury or death, a safety factor of at least four (4) is used. Non-critical components generally have a safety factor of two (2). Safety factors are needed to account for imperfections in materials, flaws in assembly, material degradation, and unexpected stresses.

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Elastic moduli

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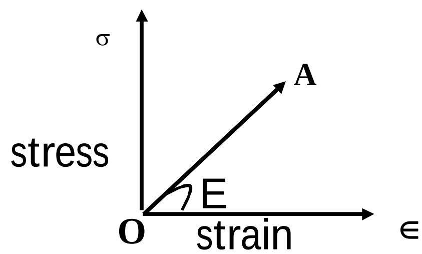
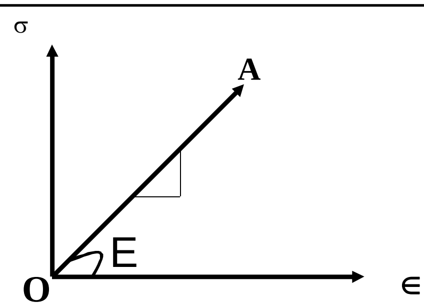
Modulus of Elasticity:

- $\sigma = E \in$
- Stress required to produce a strain of unity.
- Represents slope of stress-strain line OA.



Value of E is same in Tension & Compression.



- Hooke's Law:-

  Up to elastic limit, Stress is proportional to strain

  $\sigma \propto \in$

  $\sigma = E \in$; where E=Young's modulus

  $\sigma = P/A$ and $\in = \delta / L$

  $P/A = E (\delta / L)$

  $\boxed{\delta = PL / AE}$

Volumetric Strain . . . .

Also we know that

$$\epsilon_1 = \frac{\sigma_1}{E} - \mu\frac{\sigma_2}{E} - \mu\frac{\sigma_3}{E}$$

$$\epsilon_2 = \frac{\sigma_2}{E} - \mu\frac{\sigma_1}{E} - \mu\frac{\sigma_3}{E}$$

$$\epsilon_3 = \frac{\sigma_3}{E} - \mu\frac{\sigma_1}{E} - \mu\frac{\sigma_2}{E}$$

Futher Volumetric strain $= \epsilon_1 + \epsilon_2 + \epsilon_3$

$$= \frac{(\sigma_1 + \sigma_2 + \sigma_3)}{E} - \frac{2\mu(\sigma_1 + \sigma_2 + \sigma_3)}{E}$$

$$= \frac{(\sigma_1 + \sigma_2 + \sigma_3)(1 - 2\mu)}{E}$$

hence the

$$\boxed{\text{Volumetric strain} = \frac{(\sigma_1 + \sigma_2 + \sigma_3)(1 - 2\mu)}{E}}$$

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Problems

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