Strength of Materials or Mechanics of Materials

Mechanics is that branch of science which deals with the behavior of a body under the action of applied forces. Mechanics is further sub divided into two parts

i. Statics ii. Dynamics

Branch of mechanics which deals with the study of a body when the body is at rest is known as **Statics**.

Branch of mechanics which deals with the study of a body when the body is in motion is known as **Dynamics**

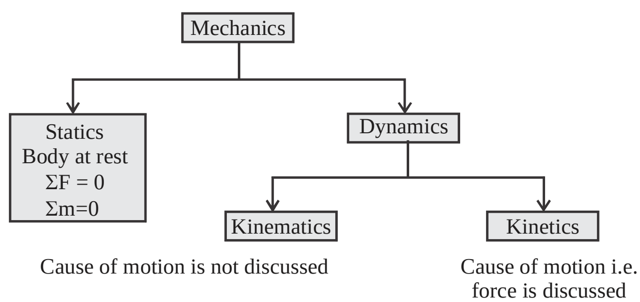
Dynamics is further sub-divided into two branches:-

a) Kinematics

b) Kinetics

Kinematics: - It is that branch of dynamics which deals with the bodies in motion without considering the forces which causes that motion.

Kinetics: - It is that branch of dynamics which deals with the bodies in motion considering the forces which causes that motion.



Mechanics is also classified as:-

i. Mechanics of rigid bodies (also known as Applied mechanics)

ii. Mechanics of deformable bodies (also known as Solid Mechanics)

Concept of rigid body

A rigid body is defined as a body which does not change in shape or size when acted upon by external forces. Bodies are considered as rigid when the distance between any two parts in the body remains constant even on the application of external forces.

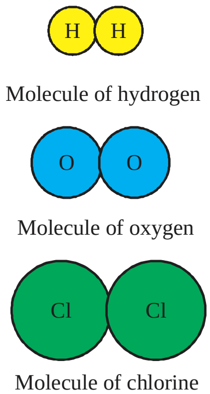
In actual practice, bodies are never perfectly rigid. Each and every body when acted upon by an external force undergoes certain deformations in the shape or size of the body. However if deformation is too small that it can be ignored, the bodies are considered to be rigid bodies.

But if these deformations play significant role in some application (as it is in our subject), then it is important to treat that body as a deformable body. For example: -

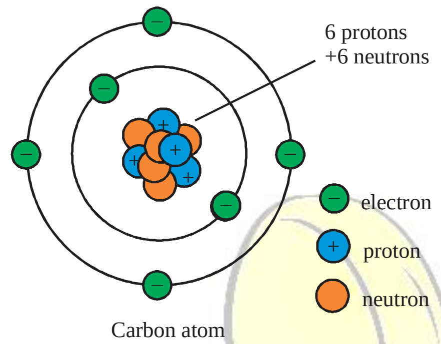
Bars, Beams, Columns, Shafts and Pressure vessels.

Thus Strength of Materials may be regarded as Statics of deformable bodies.

Concept of strength



Inter atomic distance between different atoms



Structure of an atom

$$\text{Stress} = \frac{\text{Internal Resisting Force}}{\text{Area}}$$

SOM is the study of internal resisting forces which are developed due to the deformation of body under the action of load.

Aim of SOM is to derive the expression for deformations, stress and strain which are developed under different loading conditions by using experimentally obtained elastic properties like Young's Modulus and Poisson ratio.

Deformation

When a sufficient load is applied to a material, it will change the shape or dimensions of that material. This change in dimensions is called deformation.

There are two types of deformation

i. Elastic deformation

ii. Plastic deformation

A temporary change in dimension that is self reversing after the force is removed, so that the object returns to its original dimensions is called elastic deformation When the stress is sufficient to permanently deform the material, it is called plastic deformation.

Note: - All equations derived in SOM are for elastic deformation only.

Stress

When a body deforms under the action of external force or load, a resisting force is setup in it and is then said to be in a state of stress, where stress is the resistance offered by the body to that deformation.

Strength of material is defined as the maximum or limiting value of stress that a material can withstand.

Note: - Stress is variable but strength is constant (It is the property of material).

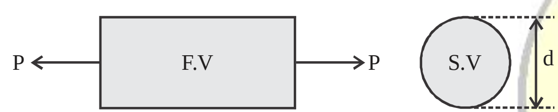
Types of stress

1. Normal Stress (σ)

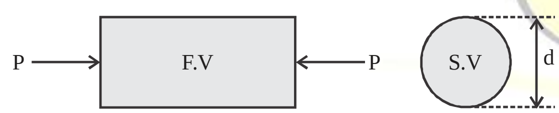
(A) Tensile stress (B) Compressive stress

2. Shear stress (τ)
3. Bending stress (σ_b)
4. Torsional Stress (τ_s)
5. Thermal stress (σ_{th})

(1) Normal Stress (σ)



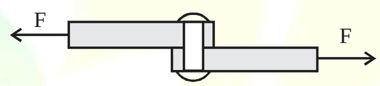
Tensile Stress (+ve)



Compressive Stress (–ve)

$$\sigma = \frac{p}{A} \quad ; \quad A = \frac{\pi d^2}{4} \text{ or } \pi r^2$$

(2) Shear Stress:



Riveted Lap Joint

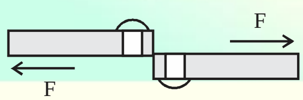
Types of failure

(1) Shear failure of Rivet

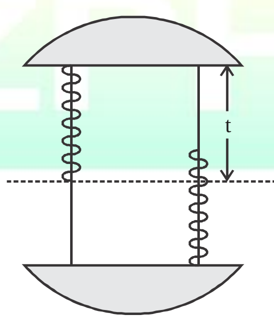
(2) Crushing failure of Rivet

(3) Tearing failure of plate

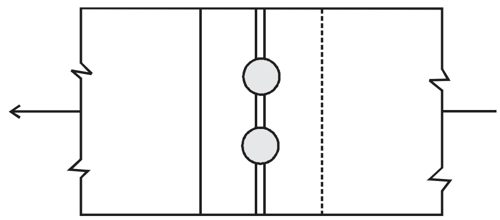
(a) Shear Failure of plate:



(b) Crushing failure of rivet



(c) Tearing Failure of Plate

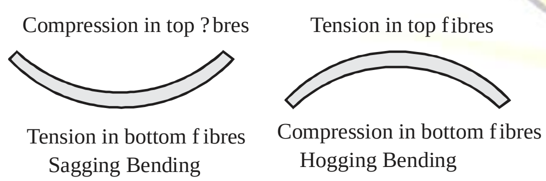


TEARING FAILURE OF PLATES

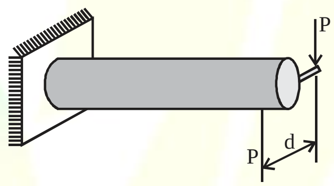
Bending couple & twisting couple

A couple is said to be a bending couple when plane of a couple is perpendicular to the plane of cross section of member whereas a couple is said to be a twisting couple when it is acting in a plane which is parallel to the plane of cross section of member.

3. Bending Stress: (σb)

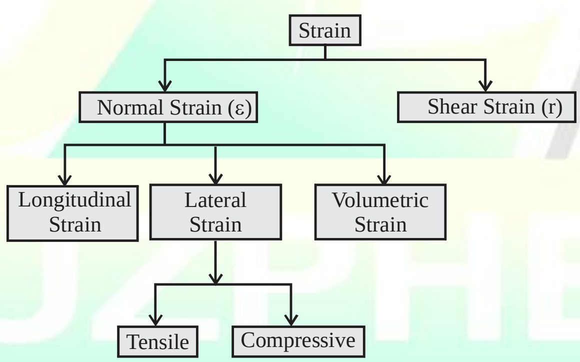


4. Torsional Stress



In this example, the magnitude of the moment, or torque, T, due to the couple is T = Pd

Strain:



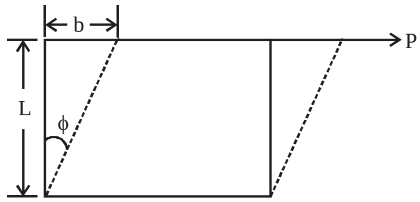
$$\text{Normal Strain} = \frac{\text{Change in Dimension}}{\text{original Dimension}}$$

(a) $\text{Longitudinal strain} = \frac{\text{change in length}}{\text{Original length}}$

(b) $\text{Lateral Strain} = \frac{\text{Change in Lateral dimension}}{\text{Original lateral dimension}}$

(c) Volumetric strain= $\frac{\text{Change in volume}}{\text{Original volume}}$

Shear strain (γ) = Tangent of angle formed due to deformation



$$\text{Tan}\,\phi = \frac{b}{\ell} = \gamma$$

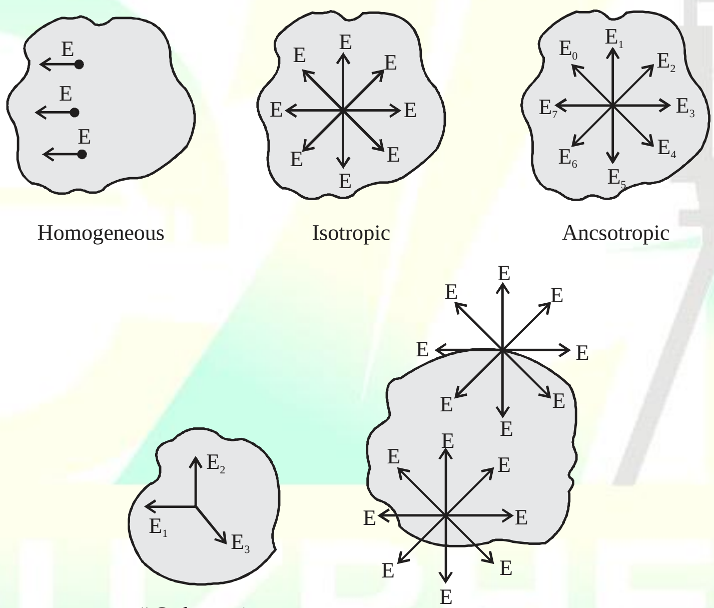
As ϕ is very small, thus Tanϕ can be written ϕ.

Thus:-

$$\phi = \frac{b}{\ell} = \gamma$$

Elastic constants:

Types of Material



Homogeneous   Isotropic   Ancsotropic

Orthotropic   # Homogeneous & isotropic

A material is homogeneous if it has same composition throughout the body. For such a material, the elastic properties are the same at each & every point in the body but need not same in all the directions. If a material is equally elastic in all the directions, it is said to be isotropic.

If, however it is not equally elastic in all direction i.e, it possesses different elastic properties in diff. directions, it is called anisotropic.

Many structural material met to requirement of homogeneity and isotropic, we shall be dealing with only homogeneous & isotropic materials in this subject.

Note: Different properties in orthogonal diesel (i.e, 3 mutually ⊥r directions) is orthogonal e.g. wood.

Number of independent elastic constants: -

1. Isotropic – 2
2. Orthotropic – 9
3. Anisotropic – 21

Homogenous & isotropic Material:

Total no. of elastic constant – 4

No. of independent elastic constant – 2

Relationship between elastic constants

$E = 2G(1 + \mu)$

$E = 3k(1 - 2\mu)$

$$E = \frac{9KG}{3K + G}$$

Where:-

E - Young's Modulus

G - Shear Modulus

K - Bulk Modulus

μ or $\frac{1}{m}$ - Poison's Ratio

1. Young's Modulus (E) of elasticity = $\frac{\text{Normal stress}}{\text{Longitudinal strain}}$
2. Shear modulus (G) or Modulus of Rigidity = $\frac{\text{Shear stress}}{\text{Shear strain}}$
3. Bulk Modulus of (k) Elasticity = $\frac{\text{Normal stress}}{\text{Volumetric strain}}$
4. Poisson Ratio (μ or $\frac{1}{m}$) = $\frac{\text{Lateral strain}}{\text{Longitrudinal stress}}$

Value of Poisson Ratio:

E, G, K > 0

$1 + \mu > 0$

$\mu > -1$

$1 - 2\mu > 0$

$1 > 2\mu$

$\mu < \frac{1}{2}$

$\mu \simeq 0.5$ – (Rubber)

$\mu = 0$ (cork)