

UNIT 1: MOMENT OF INERTIA

Q.1. Define Moment of Inertia and state its SI unit.

ANS : Moment of inertia is defined as,
 "Second moment of an area about an axis is called Moment of inertia."

or

"A quantity expressing the body's tendency to resist angular acceleration, it is equal to sum of product of mass of particles to the square of distances from the axis of rotation."

Moment of inertia =

$$\text{area} \times (\text{distance from axis})^2$$

SI unit of moment of inertia is m^4 (or mm^4)

Q.2. Define radius of Gyration.

ANS : Moment of inertia is defined as,
 "Radius of gyration of a body about an axis is a distance such that when square of that distance is multiplied by the area of that body gives Moment of inertia of that body."

$$k = \sqrt{\frac{I}{A}}$$

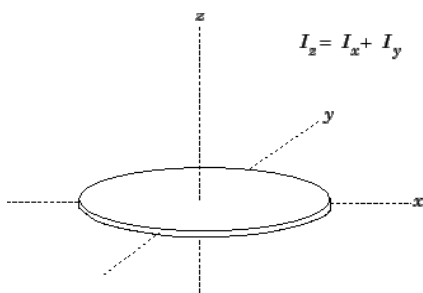
Q.3. State Parallel axis theorem.

It states that,
 "The moment of inertia of a lamina about any axis parallel to the centroidal axis is equal to the Moment of inertia of the body about its centroidal axis plus the product of the area and square of distance between these two axes." $I_{zz} = I_{xx} + A \cdot h^2$



Q.4. State Perpendicular axis theorem.

It states that,
 "The moment of inertia of a lamina about an axis perpendicular to plane of lamina about an axis perpendicular to the lamina and passing through its centroidal is equal to sum of its moment of inertia about two mutually perpendicular axes lying in the plane."



Q.5. Define Polar moment of Inertia.

"It is defined as the moment of inertia of body about its centroidal axis which is perpendicular to the plane of the body."

UNIT 2: SIMPLE STRESSES AND STRAINS

Q.1. State Hooke's law and define Moduli of elasticity

"Hooke's law states that within an elastic limit stress is proportional to strain."

Within elastic limits,

$$\text{Stress} \propto \text{Strain}$$

$$\frac{\text{Stress}}{\text{Strain}} = \text{Constant} = \text{Modulus of Elasticity}$$

This constant is known as Modulus of elasticity.. Based on types of stresses and strains there are three moduli of elasticity

1. Young's modulus: It is ratio of tensile/comp. stress to tensile/comp. strain.

$$\text{Young's Modulus (E)} = \frac{\text{Tensile/Compressive Stress}}{\text{Tensile/Compressive Strain}}$$

2. Shear modulus (Modulus of elasticity): It is ratio of Shear stress to Shear strain.

$$\text{Modulus of rigidity (G)} = \frac{\text{Shear Stress}}{\text{Shear Strain}}$$

3. Bulk modulus: It is ratio of Volumetric stress and volumetric strain.

$$\text{Bulk Modulus (K)} = \frac{\text{Volumetric Stress}}{\text{Volumetric Strain}}$$

Q.2. State the relation between three moduli of elasticity.

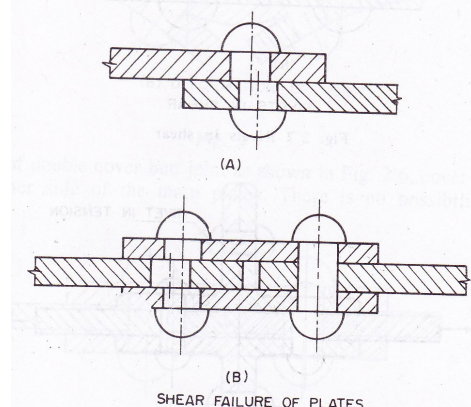
Relation between E and K and G

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

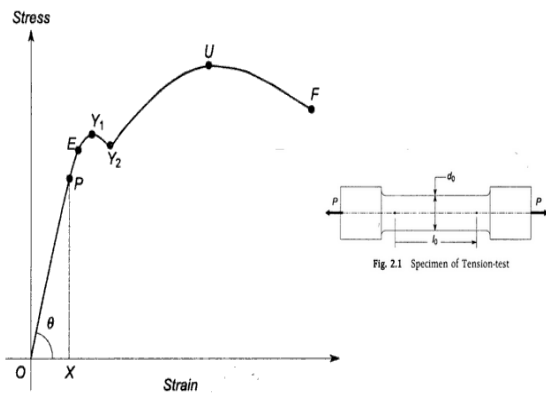
$$E = 2G(1 + \mu)$$

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

Q.3. Draw diagram for the single and double shear.



Q.4. Draw stress strain curve for the ductile material (mild steel).



Stress-strain Diagram of Ductile Materials

Limit of proportionality- In the range of OP the strain is proportional to the stress and the graph is straight line. Point P is called as the limit of proportionality. It is the value of the stress up to which stress and strain has the constant ratio and the Hook's law is obeyed.

Elastic limit- at the point E, the curve deviates from the straight line and the stress –strain graph from P to E in nonlinear. If the load is increased beyond the P up to the point E, the material behaves in the elastic manner that is on the removal of the load, the whole deformation will vanish. The value of stress corresponding to point E up to which the material behaves in an elastic manner is called the elastic limit.

Upper Yield point: Point Y1 is called upper yield point. At this point there is an increase in the strain even though there is no increase in stress (load) A formation of creep makes specimen plastic and the material begins to flow. the value of stress corresponding to point Y1 is called yield stress or yield strength. The yield stress is defined as that unit stress which will cause an increase in length without an increase in load.

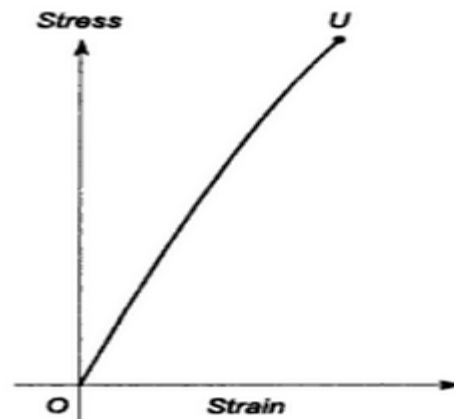
Lower yield point: A load may rise and fall while yielding occurs. This is indicated by wavy appearance of the stress-strain graph between Y1 and Y2 .Point Y2 corresponding to lower yield point. after yielding has ceased at Y2, further stresses and strain can be obtained by increasing the load.

Ultimate Load Point-: after increasing the load beyond the yield point, the stress-strain curve rises till the point U is reached which is called ultimate load; the stress corresponding to this point is called ultimate stress or ultimate tensile strength.

Breaking load point: up to F, the cross-sectional area of the specimen goes on uniformly decreasing forming a neck or waist and the load required to cause further extension is also reduced. As the elongation continues, cross-sectional area becomes smaller and smaller and ultimately the specimen is broken at F into two pieces giving cup cone type of ductile fracture. Point F is called as breaking load point and the stress corresponding to this point is called breaking stress & rupture stress.

Q.5. Draw Stress strain diagram for brittle material ?

For brittle material there are no elastic limit or yield points it fails all of sudden at a stage. so there is only ultimate stress.



Stress-strain Diagram of Brittle Materials

Q.6. What do you mean by thermal Stresses?

Ans : Thermal stresses are the stresses induced in the body due to change in temperature. But mere change in temperature does not produce the thermal stresses, but when the expansion/compression due to temperature changes is prevented, then only thermal stresses are developed. They may be tensile or compressive in nature.

The formula for the free expansion of the bar due to change in temperature is given by,

$$\delta L = \alpha T L$$

Thermal Stress is Given by

$$\sigma = \alpha T E$$

Where

L= original length of the body,

T= Rise in Temperature

E=Young's Modulus

α = Coefficient of Linear expansion for the material

δL = Change of Length

UNIT 3: MECHANICAL PROPERTIES AND ELASTIC CONSTANTS OF METALS

Q.1. Define the following terms 1)Elasticity 2) Plasticity 3)Ductility 4) Malleability 5) Stiffness 6) Brittleness 7) Hardness 8) Toughness 9)Flexibility

Ans :

Elasticity : It is defined as the ability of the material to regain its original shape and size after deformation, when the external forces are removed. Steel is an elastic material within elastic limit.

Plasticity : It is defined as the ability of the material to retain the deformation produced under the load on permanent basis.

Ductility : It is defined as the ability of the material to deform to a greater extent before the sign of crack, when subjected to tensile forces. Mild steel, copper and aluminum are ductile materials. Ductile metals can be formed drawn or bent in required shape.

Malleability : It is defined as the ability of the material to deform to a greater extent before the sign of crack, when it is subjected to compressive force. Malleable metals can be rolled, forged or extruded. Low carbon steel, copper and aluminum are examples of malleable material.

Stiffness(or Rigidity) : It is defined as the ability of the material to resist the deformation under the action of external load. The material which shows less deformation is more stiff under given load..

Brittleness : it is defined as the property of material which shows negligible plastic deformation before fracture takes place. Brittleness is opposite property to the ductility.

Hardness: It is defined as the resistance of the material to penetration or permanent deformation. It usually indicates the resistance to abrasion, scratching, cutting or shaping.

Toughness : Toughness is the ability of a material to absorb energy and plastically deform without fracturing. One definition of material toughness is the “Amount of energy per unit volume that a material can absorb before rupturing.”

Flexibility : Flexibility is defined as the ease with which material can be deformed or bent. This property is opposite of the stiffness .

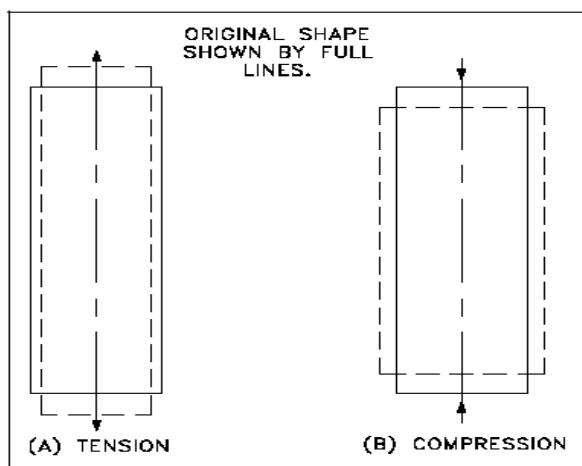
Q.2. Define Creep ?

Ans: When a component is under constant load, it may undergo slow and progressive plastic deformation over a period of time. This time dependent strain is called CREEP. Creep is defined as slow and progressive deformation of the material with time under constant stress. Creep deformation is a function of stress level and temperature. Therefore, Creep deformation is higher at higher temperature and creep becomes important for components operating at elevated temperature.

Q.3. Define Fatigue.

Fatigue Failure “The phenomenon of decreased resistance of material to repeated stresses is called fatigue failure.” It has been observed that materials fail under fluctuating stresses, at a stress lower than ultimate tensile strength of material. Sometimes the magnitude is even smaller than yield stress, further the magnitude of stress causing fatigue failure decreases as number of stress cycle increases

Q.4. Define and explain Poisson's ratio



Poisson's ratio : The ratio of lateral strain to the longitudinal strain is constant for a given material, when the material is stressed within the elastic limit. This ratio is called Poisson's ratio and it is generally denoted by μ .

$$\text{Poisson's ratio} = \frac{\text{Lateral strain}}{\text{linear strain}} = \frac{\frac{\delta d}{d}}{\frac{\delta l}{l}} = \frac{\delta d \times l}{\delta l \times d}$$

Q.5. Define Strain energy, Resilience and Proof resilience.

Strain Energy

When a piece of bar is subjected to a tensile or a compressive load, P, then there is a change in length which is proportional to the load P within elastic limit. It is said that work is done and is stored in the form of strain energy within a bar or material. On removal of the loading, the material returns to its original position due to release of stored energy.

It may be defined as

The work done by the load in straining material or bar.

It is denoted by U.

Resilience

Strain energy per unit volume stored in a material is called resilience.

Proof Resilience

Strain energy at elastic limit in a material or bar is known as Proof Resilience.

Strain energy is measured in N-m, N-mm or Joule.

UNIT 4: SFD-BMD AND SHEAR STRESS AND BENDING STRESSES

Q.1. Define Shear force and Bending moment. (imp)

Ans :

Shear force: The algebraic sum of vertical forces at any section of a beam either to the left or to the right of the section is called the shear force at that section.

Bending Moment: The algebraic sum of moments of all forces at any section of a beam either to the left or to the right of the section is called the bending moment at that section.

Shear Force diagram (SFD): A diagram which shows the variation of the shear force along the length of the beam is called the SFD.

Bending moment diagram : A diagram which shows the variation of the bending moment along the length of the beam is called BMD.

Q.2 .State the relation between B.M., S.F. and rate of loading.

Ans:

1. Relation between rate of loading and Shear force
 $dQ/dx = -F$

The slope of shear force diagram is equal to magnitude of distributed load.

2. Relation between shear force and bending moment
 $dM/dx = Q$

The slope of bending moment diagram is equal to shear force.

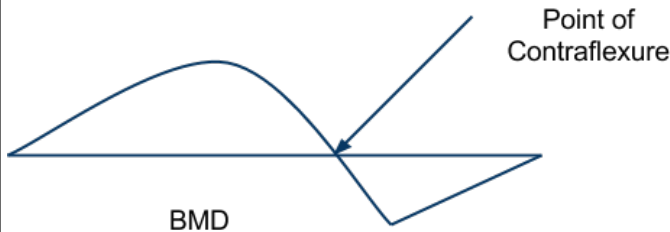
It means “ rate of change of bending moment is equal to shear force”

here F= load, Q= shear force and M= bending moment.

Q.3. Define the Point of Contra-flexure ?

Ans: "Point of contra-flexure (POC) is defined as a point in the bending moment diagram where bending moment changes its sign."

In other words, bending moment diagram the point where the bending moment curve cuts the "zero" line is called the point of contra-flexure.



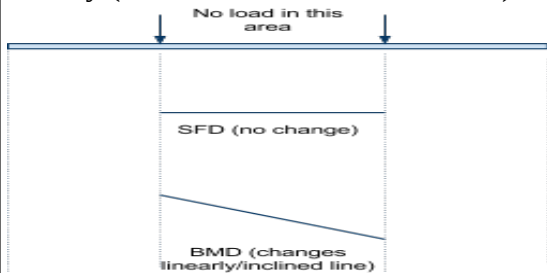
A bending moment diagram may have one or more points or contra-flexure.

The bending moment changes its sign at point of contra-flexure. at point of contra-flexure the bending moment is zero as well as fiber stress is also zero.

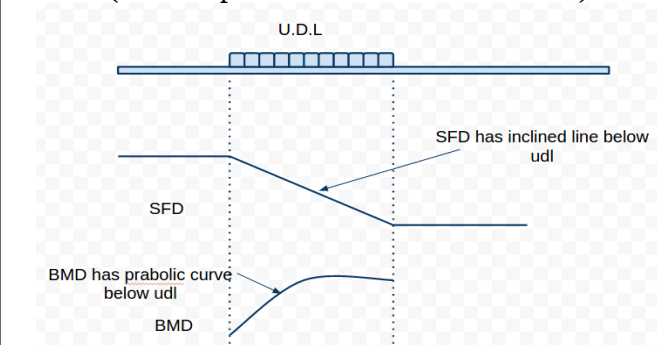
Q.4. Show how the following parts of BMD are related to the shear force and loading

- a) Nature of Bmd between two point loads
- b) Nature of BM and SF between udl..
- c) BM maximum at a point in a beam and value SF at that point

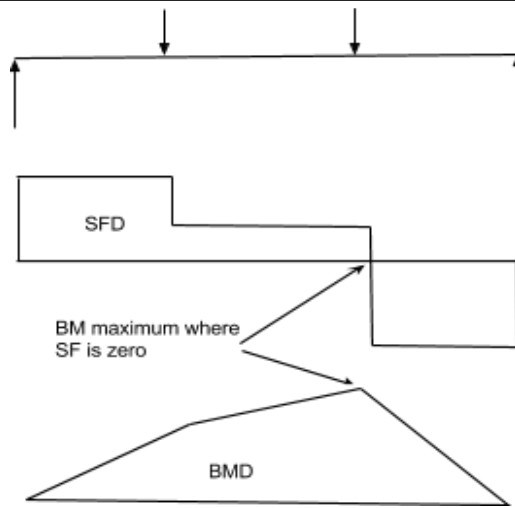
ANS :a) If there is no load between two points, then the shear force does not change (shear force line in SFD is straight) but bending moment changes linearly (in BMD there is inclined line).



2.If there is a UDL between two points, then the shear force changes linearly (there is inclined line in SFD) but the bending moment changes in parabolic manner (there is parabolic curve in the BMD)



3. BM is Maximum at the point where the shear force is zero..



Q.5.State the assumptions in Pure(simple) bending. (VVimp)

Assumptions

1. The material of the beam is homogeneous and isotropic and follows the Hooke's Law
2. The transverse section of the beam which is plane before bending, will remain plane after bending.
3. Young's modulus for the material is same for tension and compression
4. Each layer is free to expand or contract independently.
5. the beam is initially straight and of constant cross-section

Q 6: State the Flexural formula (Bending Eqn), State meaning of each term in it?

The bending equation is given as,

$$\frac{M}{I} = \frac{f}{y} = \frac{E}{R}$$

Where M= Bending moment in N-mm

I= Moment of Inertia in mm⁴

f= bending stress in N/mm²

y= Distance of extreme fiber from neutral axis in mm

E= Young's modulus in N/mm²

R= Radius of curvature in mm

Q.7.What is Neutral axis in case of Bending?

In a beam subjected to bending, at a level between the top and bottom of beam, there is a layer which is neither shortened nor elongated. This layer has neither tension nor compression on it, this layer is called neutral axis.

For a circular cross-section neutral axis is at centre of circle , for rectangular section the neutral axis is at a distance of half the thickness from upper or lower end.

Q:8.What do you mean by Section modulus ? State the formula for section modulus of rectangular and circular section.

The ratio of moment of inertia at neutral axis to the maximum distance from neutral axis is called section Modulus. It is denoted by "Z" and its unit is mm³ . In bending equation,

$$\frac{M}{I} = \frac{f}{y}, \quad M = \frac{f}{y}I, \quad \text{simplifying } M = \frac{I}{y}f, \\ M = Z.f$$

Here $z=I/y$ is called section modulus.

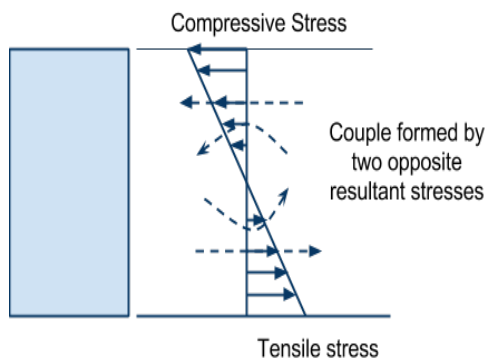
Section modulus for rectangular

$$z = \frac{I}{Y} = \frac{\frac{bd^3}{12}}{\frac{d}{2}} = \frac{bd^2}{6}$$

Section Modulus for circular section

$$z = \frac{I}{Y} = \frac{\frac{\pi d^4}{64}}{\frac{d}{2}} = \frac{\pi d^3}{32}$$

Q:9. Define the term Moment of resistance .



In a beam subjected to bending, at any section, compressive stresses are above/below neutral axis and tensile stresses are

below/above. The resultants of these opposite stresses forms a couple. The moment of these couple is called moment of resistance.

“The algebraic sum of the moment about neutral axis of the internal forces developed in a beam due to bending is called the moment of resistance.”

Q.10. What do you mean by Shear Stress in Beams?

“When due to loading on a beam, internal stresses are developed in a section, which resist shear force are called as shear stress.” it is denoted by ‘q’ or ‘ τ ’

Equation of shear stress:

$$q = \frac{F.A.y}{I.b} \text{ N/mm}^2$$

Where q = Shear stress at a section layer (N/mm²)

F = Shear Force at that section (N)

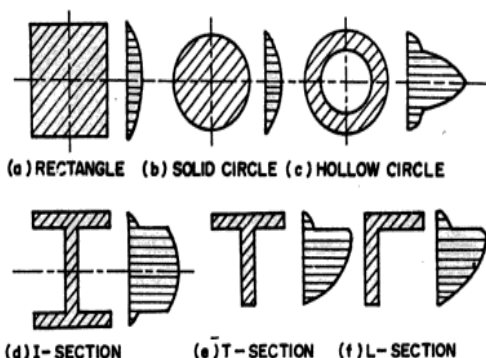
A = Area of section above that layer (mm²)

y = Distance of c.g of area under consideration from N-A (mm)

I = Moment of inertia (mm⁴)

b = width of section in mm

Q.7. Draw Shear stress distribution for different sections



Q.8. State the formula for Average shear stress and Maximum shear stress for rectangular and circular section.

ANS:

1) Rectangular section :

Average shear stress $q_{av} = \frac{F}{bd}$

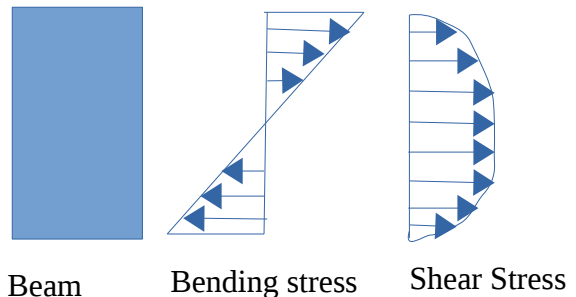
Maximum shear stress $q_{max} = \frac{3}{2} q_{av}$

2) Circular section :

Average shear stress $q_{av} = \frac{F}{\text{area of circle}}$

Maximum shear stress $q_{max} = \frac{4}{3} q_{av}$

Q.7. Draw Bending stress and shear stress distribution diagram for the rectangular section?



UNIT 5: TORSION

Q:1: Explain the theory of pure torsion?

When equal and opposite forces are applied tangentially to the ends of a shaft, it is subjected to a twisting moment which is equal to the product of the force applied and the radius of the shaft. This causes the shaft either to remain stationary or to rotate with constant angular velocity. In either case, the stress and strain set up in the shaft will be the same. When the shaft becomes subjected to equal and opposite torques at its two ends the shaft is said to be in torsion and as a result of which the shaft will have a tendency to shear off at every cross-section perpendicular to its longitudinal axis. So the effect of torsion is to produce shear stress in the material of the shaft.

Q:2: State the Assumptions in Pure Tension (VVIMP)

The following assumptions are made, while finding out shear stress in a circular shaft subjected to torsion:

- 1) The shaft circular in section remains circular after twisting.
- 2) The material of the shaft is uniform throughout.
- 3) A plane section of the shaft normal to its axis before twist remains plane after the application of torque.
- 4) The twist along the length of the shaft is uniform

throughout.

- 5) All diameters of the normal cross-section which are originally straight remain straight after twisting and their magnitudes do not change.
- 5) Maximum shear stress induced in the shaft due to the application of torque does not exceed its elastic limit value.

Q:3: Define TORQUE and state its S.I.unit?

Ans : Torque is defined as the “Force that causes rotation of the body”..In is numerically equal to the Force multiplied by the radius at which it acts.

$$\begin{aligned} \text{Torque} &= \text{Force} \times \text{radius} \\ &= \text{Newton} \times \text{Meter} \\ &= \text{N} - \text{m} \end{aligned}$$

Q: 4: State the Torsional equation stating the meaning of every term in it

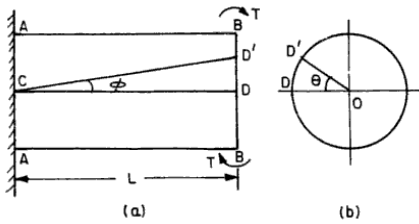


Fig. 21.2. Shaft fixed at AA and subjected to torque T at BB.

$$\frac{T}{J} = \frac{fs}{r} = \frac{c\theta}{l}$$

where T= Torque acting on shaft in N-mm
J= Polar moment of inertia in mm⁴

$$\begin{aligned} \text{for solid shaft } (J &= \frac{\pi}{32} d^4) \\ \text{for hollow shaft } (J &= \frac{\pi}{32} (D^4 - d^4)) \end{aligned}$$

- fs= Shear stress (N/mm²)
- r =radius of shaft (mm)
- C= modulus of rigidity (N/mm²)
- theta = Angle of twist (radians)
- l = length of shaft (mm)

Strength Equations of torsion for the solid and hollow shaft.

$$\begin{aligned} \text{For solid shaft } T &= \frac{\pi}{16} \cdot f_s \cdot d^3 \\ \text{For Hollow shaft } T &= \frac{\pi}{16} \cdot f_s \cdot d_o^3 (1 - k^4) \end{aligned}$$

k= ration of inside diameter to outside diameter

Q:5: How power transmitted by shaft is calculated?

Power transmitted by a shaft is calculated in following steps

- 1) Calculate polar moment of inertia
for solid shaft $(J = \frac{\pi}{64} d^4)$ mm⁴
for hollow shaft $(J = \frac{\pi}{64} (D^4 - d^4))$ mm⁴

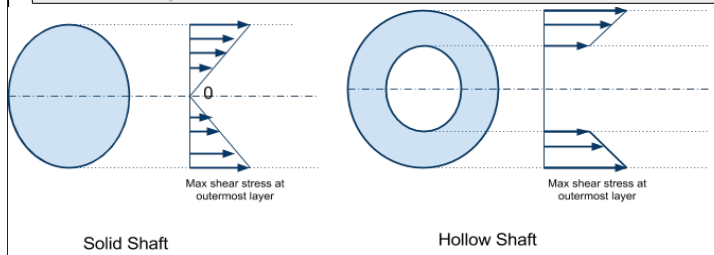
2) calculate torque transmission capacity

$$T = \frac{f_s}{r} \times J \quad \text{N} - \text{mm}$$

3) Power is calculated by formula,

$$P = \frac{2\pi NT}{60} \quad \text{Watts}$$

Q:6: Draw Shear stress distribution for the Solid and hollow shaft?



Q:7: Define Torsional stiffness?

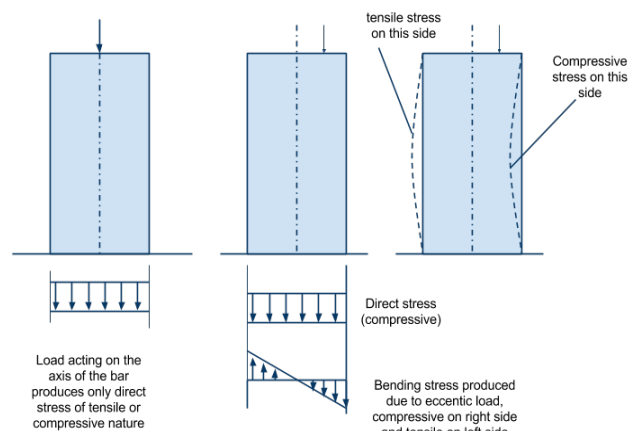
Torsional stiffness is defined as the ,”Torque required to produce unit angular deflection.”

$$\text{Torsional stiffness} = \frac{\text{Torque}}{\text{angular deflection}} \quad \text{N} - \text{m} / \text{rad}$$

SI unit of torsional Stiffness is N-m/rad.

UNIT 6: DIRECT AND BENDING STRESSES

Concept:



When a member is subjected to load on the centroidal axis only direct stress (either tensile or compressive as per load) is produced in the member. But when the member is subjected to the eccentric load (load on axis another than centroidal axis) it results in direct stress as well as stress due to bending.. As shown in figure above. The bending stress has both tensile and compressive stresses..

Now when both direct and bending stresses are combined together on one side there is addition because both are of same nature(compressive) and on the other end there is subtraction because they are of opposite nature (direct is compressive and bending is tensile).

Q.1. State the formula for the maximum and minimum stress intensities in case of Direct and bending stresses. Or.. Sketch the resultant stress distribution at the base section for condition that direct stress is equal/greater/less than bending stress Or State the condition for the NO TENSION at the base of column.

ANS :

$$\text{Direct stress} = \sigma_d = \frac{P}{A}$$

$$\text{Bending stress} = \sigma_b = \frac{P \cdot e \cdot y}{I}$$

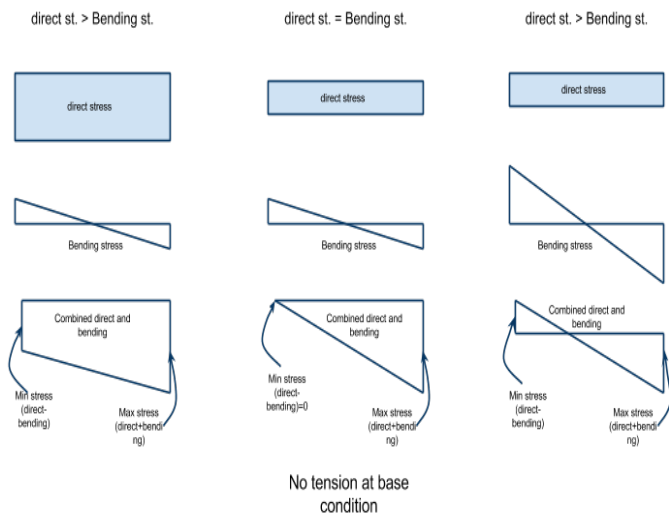
When these both stresses get combined on one side

there is addition (due to same nature) and on another side there is subtraction. so the maximum and minimum stress formulas are

$$\sigma_{max} = \frac{P}{A} + \frac{P.e.y}{I}$$

$$\sigma_{min} = \frac{P}{A} - \frac{P.e.y}{I}$$

Three possible situations of the maximum and minimum stresses.



Q.2. What do u mean by limit of eccentricity? or State the condition for “No tension at Base”...

If the stresses in the member are to be completely compressive (both maximum and minimum stresses to compressive), then ,

$$\frac{P.e.y}{I} \leq \frac{P}{A}$$

$$e \leq \frac{P}{A} \times \frac{I}{P.y}$$

$$e \leq \frac{I}{A.y}$$

Thus for the no tension at base the eccentricity must be less than (or equal to) $\frac{I}{A.y}$.

Q:3: What do you mean by Core or kernel of a section? Draw core of a section for the rectangular and circular section.. or Calculate limit of eccentricity for circular section of diameter D for no tension at base or Calculate limit of eccentricity for a rectangular section width B and thickness D.

ANS : “The area within which the load may be applied so as to avoid tensile stresses is called the core or kernel of the section”. In other words if the load is applied within the core then the stresses produced in the section are both (maximum and minimum) are of compressive nature.”

Core for rectangular section :

Using the condition of no tension at base {considering eccentricity in plane bisecting

thickness}

$$e \leq \frac{I}{A.y}$$

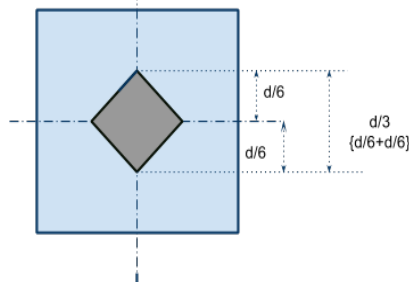
$$e \leq \frac{db^3}{12} \times \frac{1}{b \times d} \times \frac{1}{b/2}$$

$$e \leq b/6$$

Thus the eccentricity for a rectangular section must be less than b/6..

Similarly if the eccentricity is in plane bisecting width, then the eccentricity will be d/6.

It is diagrammatically shown below.



Core for circular section :

Consider a solid circular section of diameter d as shown in figure below..

using condition for no tension ,

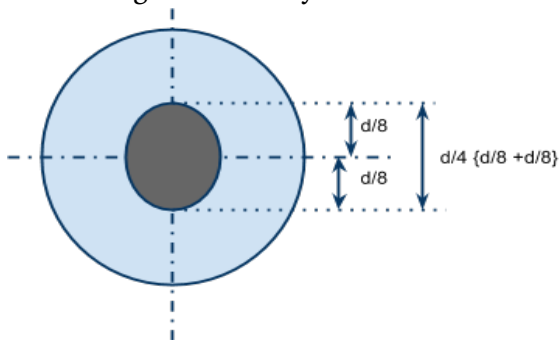
$$e \leq \frac{I}{A.y}$$

$$e \leq \frac{\pi}{64} d^4 \times \frac{1}{\frac{\pi}{4} d^2} \times \frac{1}{d/2}$$

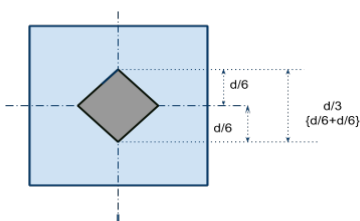
$$e \leq d/8$$

Thus the eccentricity for the circular section must be less than d/8 from centre so as to avoid tensile stress.

This is diagrammatically shown below.



Q.4. State the “Middle one third rule”.



The rule states that, “for a rectangular section if the load is applied within middle one third of the section then no tension is developed in the section.” the above

diagram is explanation of this rule.