MODULE 2 - ELASTICITY

Stress-Strain Curve, Stress hardening and softening. Elastic Moduli, Poisson's ratio, Relation between Y, n and σ (with derivation), mention relation between K, Y and σ, limiting values of Poisson's ratio. Beams, Bending moment and derivation of expression, Cantilever and I section girder and their Engineering Applications, Elastic materials (qualitative). Failures of engineering materials - Ductile fracture, Brittle fracture, Stress concentration, Fatigue and factors affecting fatigue (only qualitative explanation), Numerical problems.

The study of strength of materials is to provide the means of analysing and designing various machines and load bearing structures.

Elasticity: The property of material body to regain its original shape and size on removal of the deforming forces is called elasticity. Within certain elastic limit steel and quarts show elastic properties. The elastic property is desirable for materials used in tools and machines.

Plasticity: Bodies which does not show any tendency to recover their original condition are said to be Plastic and the property is called plasticity. Eg – polyethylene, Polystyrene etc
This property of the material is necessary for forging, stamping images on coins and ornamental works.

Load: The term load implies the combination of external forces acting on a body and its effect is to change the form or the dimensions of the body. It is essentially a deforming force.

Stress: The restoring force per unit area developed inside the body is called stress.
The magnitude of the restoring force is exactly equal to that of the applied force, **stress is given by the ratio of the applied force to the area of its application**
Stress = $\frac{Restoring\ Force}{cross\ sectiponal\ area} = \frac{F}{A}$, S I unit of stress is N/m^2.
<u>Concept of strain</u>: When a body is subjected to external force, there will be change in dimensions of the body. The change in dimension is called deformation. **The ratio of change in dimension of body or deformation to the original dimension of the body is called known as strain.** Strain $= \frac{change\ in\ dimension\ of\ the\ body}{original\ dimension} = \frac{\delta L}{L}$

Hooke's law Hooke's law states that when a material is loaded within its elastic limit, stress is directly proportional strain. It means that the ratio of stress to strain is constant within the elastic limit. This constant is known as Modulus of elasticity .

$\frac{stress}{strain}$ = constant or modulus of elasticity

STRESS-STRAIN CURVE

Typical stress strain curve for a metal is shown in Fig. 1.3. This graph is plotted between the stress (which is equal in magnitude to the applied force per unit area) and the strain produced.

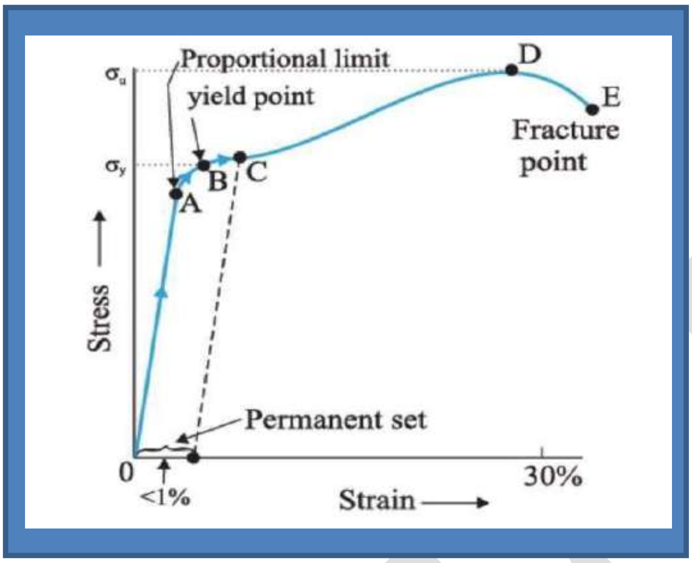


Fig. 1.3 A typical stress-strain curve for a metal

- The curve is linear in the region between O to A (Hooke's law is obeyed in this region and body behaves as elastic). The relationship between stress and strain in this initial region is not only linear but also proportional. Beyond point A, the proportionality between stress and strain no longer exists; hence the stress at A is called the proportional limit.

- With an increase in stress beyond the proportional limit, the strain begins to increase more rapidly for each increment in stress. Consequently, the stress-strain curve has a smaller and smaller slope, until, at point B, the curve becomes horizontal.

- Point B is the yield point (also known as elastic limit) and the corresponding stress is yield strength (σ_y) of the material.

- Above point B the strain increases rapidly even for a small change in the stress (The portion between B and D). In this region the body does not regain its original dimension and when the stress is made zero, the strain is not zero. Thus the material is said to have a permanent set and the deformation is said to be plastic deformation (See Fig. 1.3).

- After the point D, additional strain is produced even by a small applied force and fracture occurs at point E (See Fig. 1.3).

- The ratio of stress and strain, in the proportional region within the elastic limit of the stress strain curve (region OA in Fig. 1.3) is called modulus of elasticity and is characteristic of the material.

- It is of great importance to know the elastic limit for applications so that we can avoid the region of plastic deformation which may create problems in designing devices.

Strain hardening and strain softening

Strain hardening (also called work-hardening or cold-working) is the process of making a metal harder and stronger through plastic deformation. When a metal is plastically deformed, dislocations move and additional dislocations are generated. The more dislocations within a material, the more they will interact and become pinned or tangled. This will result in a decrease in the mobility of the dislocations and a strengthening of the material.

Strain softening: When the material is loaded either in tension or in compression, strain will build up with the applied stress. When it reaches the peak stress (for your case - yielding in tension) the material drops its shear resistance due to the continuous plastic deformation. This behaviour is called **strain softening.**

FACTOR OF SAFETY

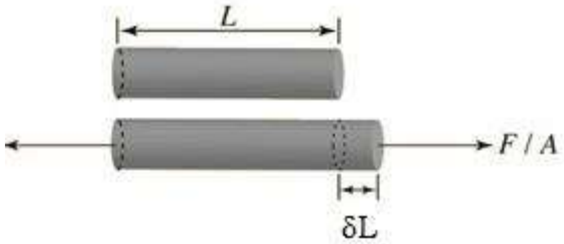
To avoid permanent deformation due to maximum stress, the engineering tools are to be used within the elastic limit with a working stress.

Factor of safety = Breaking stress / Working stress

Types of Elastic Moduli:

1. **Young's Modulus of Elasticity (Y)**

When a wire is acted upon by two equal and opposite forces in the direction of its length, the length of the body is changed. The change in length per unit length (δL/L) is called the longitudinal strain and the restoring force (which is equal to the applied force in equilibrium) per unit area of cross-section of wire is called the longitudinal stress.



For small change in the length of the wire, the ratio of the longitudinal stress to the corresponding strain is called the **Young's modulus of elasticity (Y)** of the wire. Thus,

Y = Longitudinal stress / Linear Strain = $\frac{(F|A)}{(\partial l|l)} = \frac{Fl}{A\partial l}$

Let there be a wire of length 'l' and radius 'r'. It's one end is clamped to a rigid support and a mass M is attached at the other end. Then

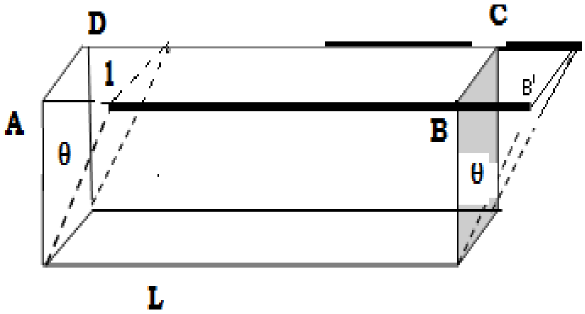
F = Mg and A = πr^2

Substituting in above equation, we have, $Y = \frac{Mgl}{(\pi r^2)\delta l}$.

2. Modulus of Rigidity (n) When a body is acted upon by an external force tangential to a surface of the body, the opposite surfaces being kept fixed, it suffers a change in shape of the body, its volume remains unchanged. Then the body is said to be sheared. The tangential force acting per unit area of the surface is called the **'shearing stress' (F/A).**

The ratio of displacement to perpendicular distance between the two surfaces is known as **shearing strain (θ)**.

Shearing strain $\theta = \frac{l}{L}$ when θ is small.



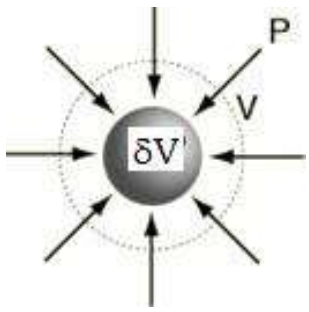
For small strain, the ratio of the shearing stress to the shearing strain is called the **'modulus of rigidity'** of the material of the body. It is denoted by 'n'.

Rigidity modulus (n) = Tangential stress / shear Strain

$$\mathbf{n} = \frac{F/A}{\theta} = \frac{F}{A\theta}$$

3. Bulk Modulus of Elasticity (K)

Describes volumetric elasticity or the tendency of an object to deform in all directions when uniformly loaded in all directions; it is defined as volumetric stress over volumetric strain, and is the inverse of compressibility. K = Volumetric stress / Volume strain $= \frac{FV}{A\delta V}$.



When a uniform pressure (normal force) is applied all over the surface of a body, the volume of the body changes. The change in volume per unit volume of the body is called the '**volume strain'** and the normal force acting per unit area of the surface (pressure) is called the normal stress or **volume stress**. For small strains, the ratio of the volume stress to the volume strain is called the '**Bulk modulus' of the material of the body**. It is denoted by K. Then $K = \frac{-P}{\delta V / V}$

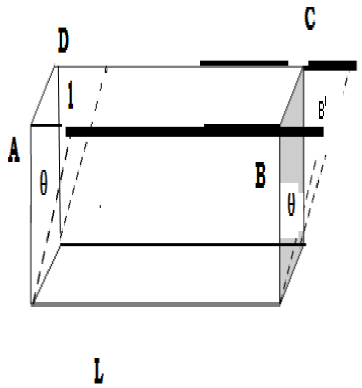
Negative sign in formula implies that when the pressure increases volume decreases and vice-versa. The reciprocal of the Bulk modulus of the material of a body is called the "**compressibility**' of that material. Thus, compressibility = 1/K

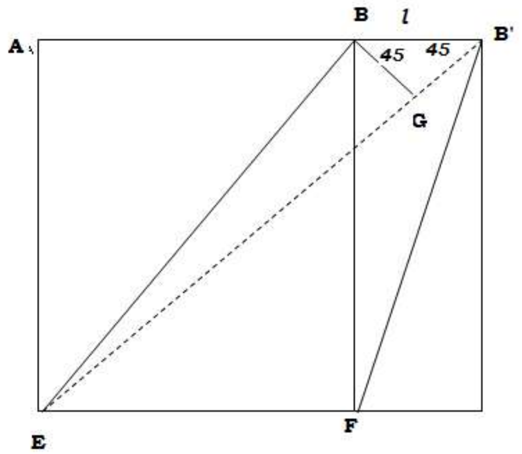
Poisson's ratio (σ)

When a material is stretched, the increase in its length (Linear strain α) is accompanied by decrease in cross section (lateral strain β). Within the elastic limit, the lateral strain is proportional to longitudinal strain and the ratio between them is a constant for a material known as **Poisson ratio (**σ). σ = lateral strain / longitudinal strain, i.e, $\sigma = \frac{\beta}{\alpha}$

The ratio of change in diameter/breadth to original diameter/breadth is called the **lateral strain (β)**. The ratio of change in length to original length is called the **linear strain (α)**.

Relation between Rigidity Modulus (n), linear strain (α) &Young's modulus (Y) :





Let the face ABCD of a cube of side L be sheared by a Force F through an angle θ.

Then the Shearing stress, $T = \frac{F}{L^2}$

Shearing Strain, $\theta = \frac{l}{L}$

Therefore Rigidity Modulus (n) = $\frac{T}{\theta}$

Shearing stress along AB is equivalent to expansive stress along EB and compressive stress along AF. Let α be the longitudinal expansive strain per unit Stress per unit length and β be the lateral compressive strain per unit stress per unit length respectively.

Elongation along EB= $EB.\alpha.T.$

Compression along AF = $EB..T.\beta$ (Since AF =EB)

Net extension of the body is GB^1= $EB..T(\alpha+\beta))$ $= L.\sqrt{2}.T(\alpha+\beta))$ ---- (1)

From the Triangle AEB, $(EB)^2 = (AB)^2 + (BE)^2$

$(EB)^2 = L^2 + L^2 \rightarrow$ **EB = L.√2**

Also , from right angled triangle BB^1G,

Elongation $GB^1 = BB^1 \cos 45$ (θ is approximately 45 in the Δle B B^1G) → $\mathbf{GB^1} = \dfrac{l}{\sqrt{2}}$

Eqn (1) becomes, $L.\sqrt{2}.T(\alpha + \beta) = \dfrac{l}{\sqrt{2}}$

$$\frac{T}{\left(\frac{l}{L}\right)} = \frac{1}{2(\alpha + \beta)}$$

$$\boxed{n = \frac{1}{2(\alpha + \beta)}}$$

If the unit stress (F/A equal to 1) acting on a body along longitudinal direction, the strain produced is linear strain (α). Then the Young's modulus, Y = stress/strain,

$\boxed{\mathbf{Y} = \frac{1}{\alpha}.}$ This is the relation between young's modulus (Y) and linear strain (α).

$$n = \frac{1}{2\alpha\left(1+\frac{\beta}{\alpha}\right)} = \frac{1}{2\alpha(1+\sigma)} = \frac{Y}{2(1+\sigma)} \Rightarrow \boxed{Y = 2n(1+\sigma)}$$

LIMITS OF σ : Generally the Poissions ratio of materials varies from -1 to 0.5

We have the Equation 3K(1-2σ) = 2n(1+σ)

1. If σ be a positive quantity, (1-2σ) should be positive
   2σ<1 = σ < 0.5,

A perfect incompressible material deformed elastically at small strains would have a poissions ratio exactly 0.5.

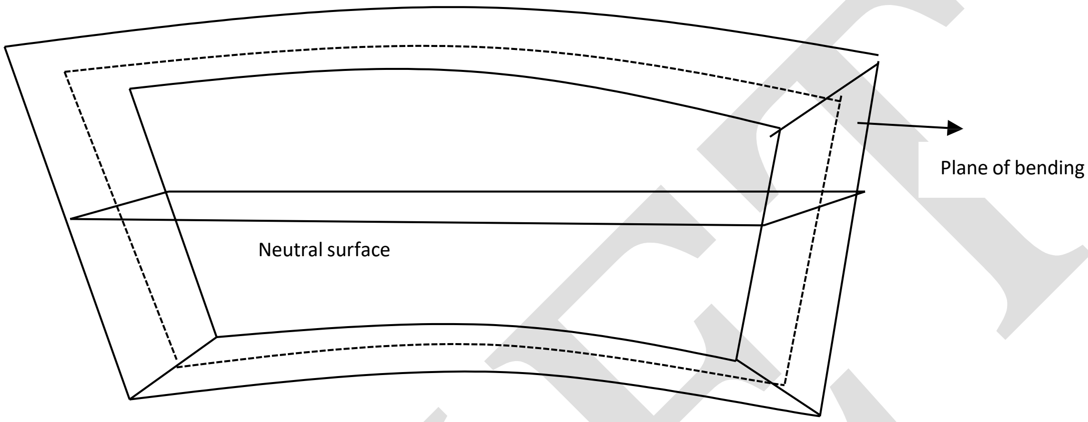
2. If σ be a negative quantity, (1 + σ) should be positive, σ < -1.

Resilience: Capacity to resist a heavy stress without acquiring permanent elongation.

BENDING OF BEAM

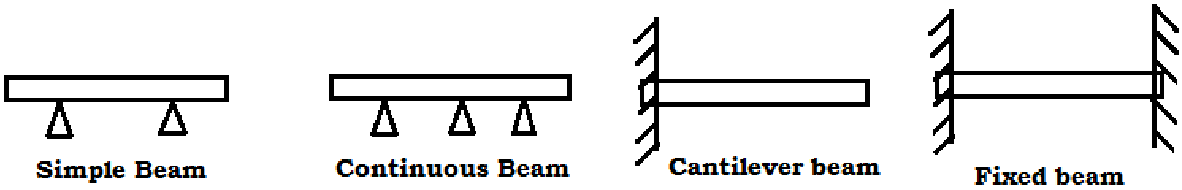
Beam is a bar or rod of uniform cross section whose length is very much larger than thickness. When such a beam is fixed at one end and loaded at the other, the beam is bent under the action of couple produced by the load. Upper surface of the beam gets stretched and lower surface gets compressed. The extension is maximum in the upper most filaments and compression, maximum in the lowermost ones. The surface which does not get affected is known as neutral surface.

If the bending is uniform, the longitudinal filaments get bent into circular arcs in planes parallel to the plane of symmetry (plane of bending).The line of intersection of plane of bending with neutral surface is called neutral axis.



Types of Beam:

Depending on the support, beams are classified as following four types



1. **Simple beam**: It is bar resting upon supports at its ends and is the kind most commonly in use.
2. **Continuous beam**: It is a bar resting upon more than two supports.
3. **Cantilever beam**: It is a beam whose one end is fixed and the other end is free.
4. **Fixed beam**: A beam fixed at its both ends is called a fixed beam.

Applications of beam: Beams are used

i) In the fabrication of trolley ways.

ii) In the Chassis/ frame as truck beds.

iii) In the elevators.

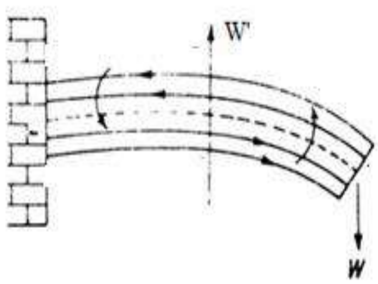
iv) In the construction of flatform and bridges.

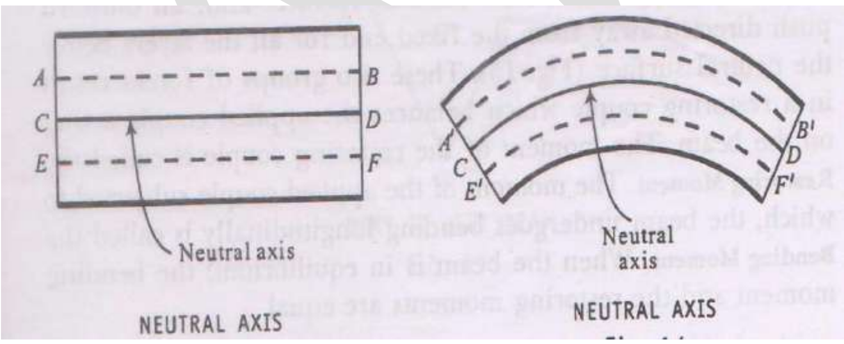
v) Beams are an integral part of Civil engineering structural elements (bridges, dams, multistoreid buildings).

vi) In the measuring devices (Tunneling microscopes)

BENDING MOMENT The load is attached to the beam at the other end the beam bends. The successive layers now strained.

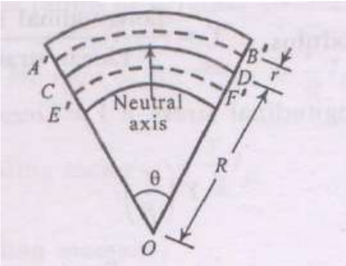
In the figure, ABCD is a beam fixed at AD and loaded at the end B. EF is neutral axis. The applied load (W) tends to bend the beam, an equal and opposite reactional force W^1 will be acting upwards along pp^1. These two forces constitute a couple and the moment of this couple is called **bending moment**. When the beam is in equilibrium position the bending moment and restoring moment should be equal. In order to find the expression for moment of restoring couple, consider a fiber A'B' at a distance r from neutral axis CD shown in Fig. Let the beam be bent in the form of circular arc subtending angle θ at the centre of curvature O.





Consider a long uniform beam whose one end is fixed. The beam can be thought of made up of a number of parallel layers like AB, CD, EF etc. If now a load is attached to the other end the beam bends. The successive layers now strained. The layer AB which is above the neutral axis will be elongated to A'B' and the one like EF below the neutral surface will be contracted to E'F'. CD is the neutral surface which does not change.

The shape of the different layers of the bent beam can be imagined to form part of concentric circles of varying radii as shown in figure



PART OF BENT BEAM

Let R be the radius of curvature of the circle to which the neutral surface forms a part.

$$CD = R\theta$$

where θ is the angle subtended by the layers at the centre of curvature O.
Then, the length of fibre in the unstrained position AB= CD = Rθ

The length of fibre in the strained position A'B' = (R + r)θ

Change in length = (R + r)θ -Rθ = rθ

Original length = Rθ

Liner strain $= \frac{r\theta}{R\theta} = \frac{r}{R}$

Youngs modulus Y=$\frac{Longitudinal\ stress}{Linear\ strain}$

Longitudinal stress=Y x Linear strain

$$=Y\frac{r}{R}$$

Stress $=\frac{F}{a}$ where F is is the force acting on the beam and a is the area of the layer AB

$$\frac{F}{a} = Y\frac{r}{R}$$

$$F = \frac{Yar}{R}$$

Moment of this force about the neutral axis

=F x its distance from the neutral axis.

$$M = F \times r = \frac{Yar^2}{R}$$

Total moment of forces acting on the entire beam $M = \sum \frac{Yar^2}{R} = \frac{Y}{R}\sum ar^2 = \frac{Y}{R} I$, here I = $\sum ar^2$ = aK^2 & I is Geometrical Moment of Inertia.

Bending moment of the beam, $\boxed{\mathbf{M} = \frac{Y}{R} I}$

For rectangular cross section, area = b X d, $k^2 = \frac{d^2}{12}$

$$I = ak^2 = \frac{bd^3}{12}$$

$$M = \frac{Ybd^3}{12R}$$

For Circular cross section, area = πr^2, $k^2 = \frac{r^2}{4}$

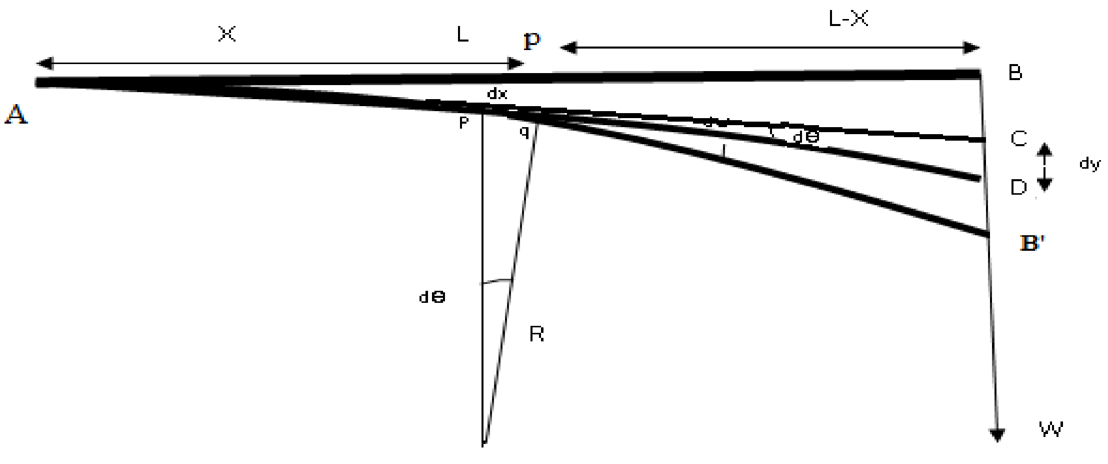
$$I = ak^2 = \frac{\pi r^4}{4}$$

$$M = \frac{Y\pi r^4}{4R}$$

Where I is the geometrical moment of inertia and k is **Radius of gyration**, It is the distance of a point from the axis of rotation where whole mass of the body is assumed to be concentrated.

CANTILEVER

A beam fixed horizontally at one end and loaded at the other is called **Cantilever**.



Let AB be the neutral axis of the cantilever of length L fixed at A and loaded at B. Consider a section P of the beam at a distance x from A.

Bending moment = W (L-X) $= Y\frac{I}{R}$

i.e, W (L-X) $= Y\frac{I}{R}$ ---------------------- (1)

Here R is the radius of curvature of neutral axis at P. The radius of curvature is different at different points . For a point Q at a small distance dx from P, it is same as at P.

Therefore PQ = dx = R.dΘ $\Rightarrow$ R = (dx /dθ) --------- (2)

Bending moment W (L-X) = $Y\frac{Id\theta}{dx}$ [substituting (2) in (1)]

$$d\theta = \frac{W(L - X)dx}{YI} \quad \text{-------------} \quad (3)$$

Draw tangents to the neutral axis at P and Q meeting the vertical line at C and D. The angle subtended by them is dΘ. The depression of Q below P is given by

$$dy = (L - X)d\theta \quad \text{----} \quad (4)$$

Substituing Eqn.(3) in Eqn.(4) Then, dy $= W\frac{(L-X)^2}{YI}.dx$

Total depression BB^1 of the loaded end $\int dy = \int_0^L W\frac{(L-X)^2}{YI}.dx$

$$\int dy = \int_0^L W\frac{(L^2 - 2LX + X^2)}{YI}.dx$$

$$= W\frac{[L^2X - LxX^2 + \frac{X^3}{3}]}{YI}$$

$$\boxed{\mathbf{y} = W\frac{L^3}{3YI}}$$

For rectangular cross section I $= \frac{bd^3}{12}$ Then the depression, y $= \frac{4mgl^3}{Ybd^3}$ [W = mg]

Therefore Young's Modulus Y $= \frac{4mgl^3}{ybd^3}$

Failures of engineering materials - ductile fracture, brittle fracture, stress concentration, fatigue and factors affecting fatigue (only qualitative explanation),

Failures (Fracture/Fatigue)

Mechanical failure is defined as any change in the size, shape or material properties of a structure, machine or machine parts that renders it incapable of satisfactory performance its intended function.

A Machine is meant for repeated use. Machine has many structural components/parts [example parts of aircraft, automobile, pumps etc] that are subjected to repeated loading while in use it gets stressed. Due to their continuous use, they are stressed repeatedly and cracks begin to form. Formation of a crack which results in a complete destruction of continuity constitutes fracture.

Types of Failure :

1. Simple fracture

a) Ductile fracture

b) Brittle fracture

2. Fatigue Failure

3. Creep fracture

1. Simple Fracture : Simple fracture is the separation of a body into two or more pieces in response to an imposed stress that is static (i.e., constant or slowly changing with time) and at temperature that are low relative to melting temperartureof the material. The applied stress may be tensile, compressive, shear, or torsional. For engineering materials, two fracture modes are possible: ductile and brittle based on the ability of the material to deform plastically.

Any fracture process involves two steps :-

a. crack formation and

b. crack propagation

The mode of fracture is highly dependent on the mechanism of crack propagation.

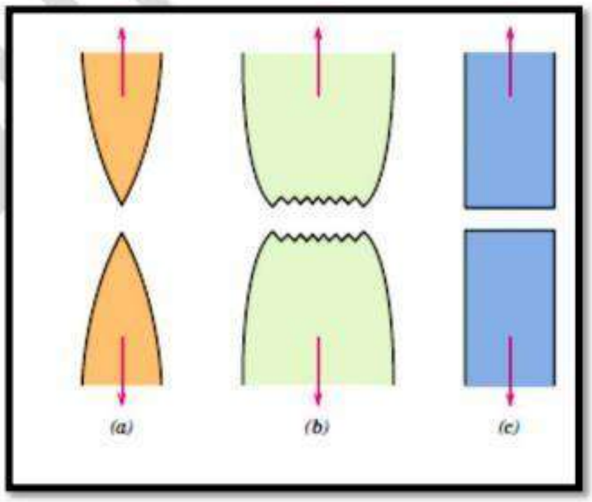
Brittle fracture :

- In brittle fracture, cracks may spread extremely rapidly, with very little accompanying plastic deformation.
- The cracks may be said to be unstable, and crack propagation , once started, will continue spontaneously without an increase in magnitude of the applied stress.
- In brittle materials little or no plastic deformation with low energy absorption before fracture.

Ductile Fracture :

- Ductile materials typically exhibit substantial plastic deformation with high energy absorption before fracture.
- The presence of plastic deformation gives warning that fracture is imminent, allowing preventive measures to be taken.
- More strain energy is required to induce ductile fracture in as much as ductile materials are generally tougher.
- Under the action of an applied tensile stress, most metal alloys are ductile, whereas ceramics are notably brittle, and polymers may exhibit both types of fracture.

Ductile fracture surfaces will have their own distinctive features on both macroscopic and microscopic levels.
Figure (3.1) shows schematic representations for two characteristic macroscopic fracture profiles.

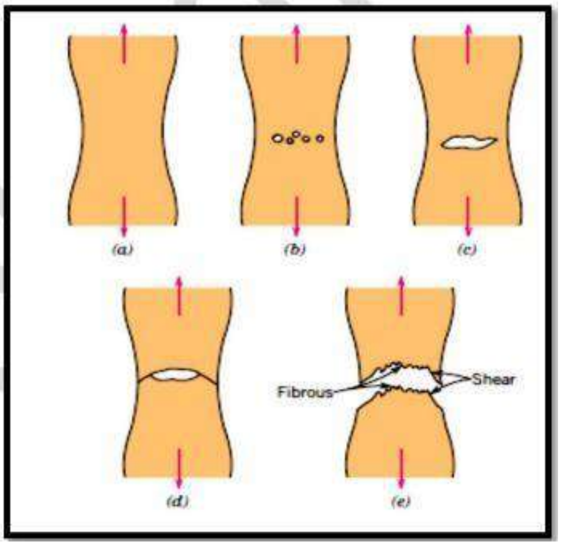


Figure(3.1)

(a) Highly ductile fracture in which the specimen necks down to a point.

(b) Moderately ductile fracture after some necking.

(c) Brittle fracture without any plastic deformation.



Figure(3.2): Stages in the cup-andcone fracture.

(a) Initial necking.

(b) Small cavity formation.

(c) Coalescence of cavities to form a crack.

(d) Crack propagation.

(e) Final shear fracture at a °45 angle relative to the tensile direction.

(a) First, after necking begins, small cavities, or micro voids, form in the interior of the cross section

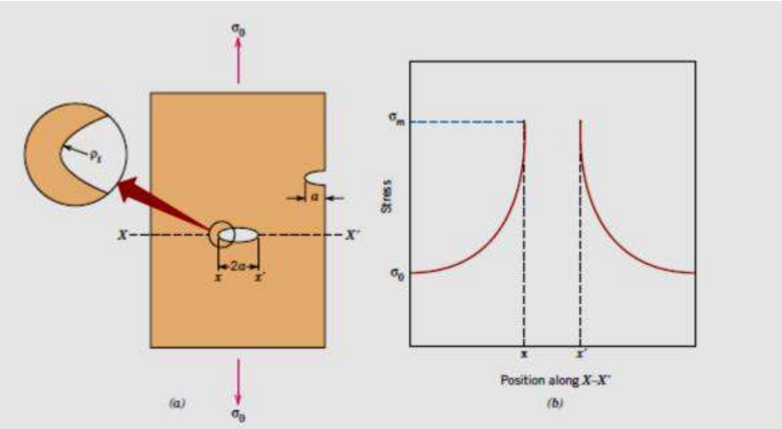
(b) Next, as deformation continues, these micro voids enlarge, come together, and coalesce to form an elliptical crack, which has its long axis perpendicular to the stress direction.

(c) The crack continues to grow in a direction parallel to its major axis by this micro void coalescence process.

(d) Finally, fracture ensues by the rapid propagation of a crack around the outer perimeter of the neck by shear deformation at an angle of about °45 with the tensile axis

Sometimes a fracture having this characteristic surface contour is termed a cup-and-cone fracture because one of the mating surfaces is in the form of a cup, the other like a cone.

Stress Concentration The measured fracture strengths for most brittle materials are significantly lower than those predicted by theoretical calculations based on atomic bonding energies. This discrepancy is explained by the presence of very small, microscopic flaws or cracks that always exist under normal conditions at the surface and within the interior of a body of material. These flaws are a detriment to the fracture strength because an applied stress may be amplified or concentrated at the tip, the magnitude of this amplification depending on crack orientation and geometry. This phenomenon is demonstrated in Figure 3.6, a stress profile across a cross section containing an internal crack. As indicated by this profile, the magnitude of this localized stress diminishes with distance away from the crack tip. At positions far removed, the stress is just the nominal stress or the applied load divided by the specimen cross-sectional area (perpendicular to this load). Due to their ability to amplify an applied stress in their locale, these flaws are sometimes called stress raisers.



Figure(3.6) : (a) The geometry of surface and internal cracks. (b) Schematic stress profile along the line X–X in (a), demonstrating stress amplification at crack tip positions.

If it is assumed that a crack is similar to an elliptical hole through a plate, and is oriented perpendicular to the applied stress, the maximum stress, occurs at the crack tip and may be approximated by

$$\sigma_m = 2\sigma_0\left(\frac{a}{\rho_t}\right)^{1/2}$$

where : σ_0 is the magnitude of the nominal applied tensile stress, ρ_t : is the radius of curvature of the crack tip (Figure 3.6a), and a : represents the length of a surface crack, or half of the length of an internal crack. Sometimes the ratio is denoted as the stress concentration factor (K_t) which is simply a measure of the degree to which an external stress is amplified at the tip of a crack.

Sometimes the ratio is denoted as the stress concentration factor (Kt) which is simply a measure of the degree to which an external stress is amplified at the tip of a crack.

$$K_t = \frac{\sigma_m}{\sigma_0} = 2\left(\frac{a}{\rho_t}\right)^{1/2}$$

Fatigue Failure : Fatigue is a form of failure that occurs in structures subjected to dynamic and fluctuating stresses (e.g., bridges, aircraft, and machine components). Under these circumstances it is possible for failure to occur at a stress level considerably lower than the tensile or yield strength for a static load. The term ―fatigue‖ is used because this type of failure normally occurs after a lengthy period of repeated stress or strain cycling. Fatigue is important inasmuch as it is the single largest cause of failure in metals, estimated to comprise approximately 90% of all metallic failures; polymers and ceramics (except for glasses) are also susceptible to this type of failure. Furthermore, fatigue is catastrophic and insidious, occurring very suddenly and without warning. Fatigue failure is brittle like in nature even in normally ductile metals, in that there is very little, if any, gross plastic deformation associated with failure. The process occurs by the initiation and propagation of cracks, and ordinarily the fracture surface is perpendicular to the direction of an applied tensile stress.

FACTORS THAT AFFECT FATIGUE LIFE

The fatigue behavior of engineering materials is highly sensitive to a number of variables. Some of these factors include mean stress level, geometrical design, surface effects, and metallurgical variables, as well as the environment.

Mean Stress

The dependence of fatigue life on stress amplitude is represented on the S– N plot. Such data are taken for a constant mean stress σ_m, often for the reversed cycle situation ($\sigma_m = 0$). Mean stress, however, will also affect fatigue life; this influence may be represented by a series of S–N curves, each measured at a different as depicted schematically in Figure 3.16 As may be noted, increasing the mean stress level leads to a decrease in fatigue life.

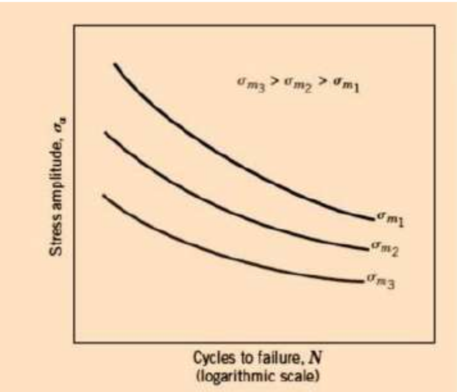
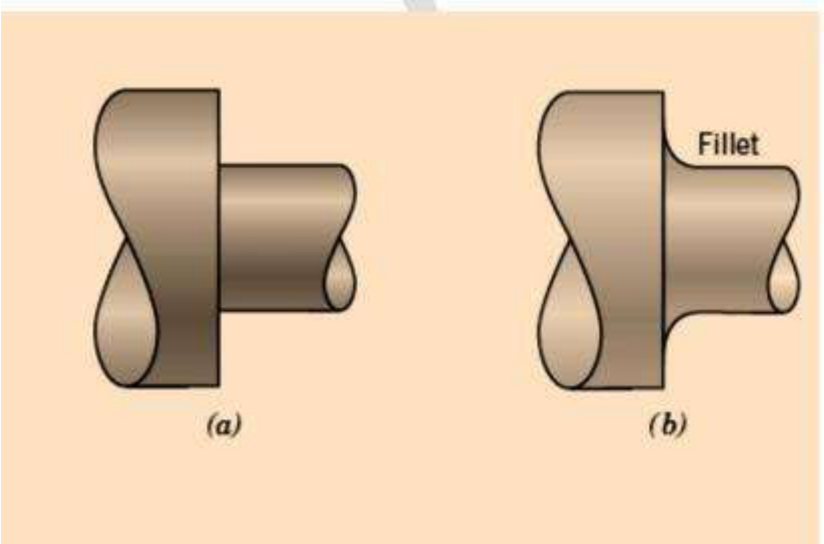


Figure 3.16: Demonstration of the influence of mean stress on S–N fatigue behavior.

Surface Effects: For many common loading situations, the maximum stress within a component or structure occurs at its surface. Consequently, most cracks leading to fatigue failure originate at surface positions, specifically at stress amplification sites. Therefore, it has been observed that fatigue life is especially sensitive to the condition and configuration of the component surface. Numerous factors influence fatigue resistance, the proper management of which will lead to an improvement in fatigue life. These include design criteria as well as various surface treatments

Design Factors The design of a component can have a significant influence on its fatigue characteristics. Any notch or geometrical discontinuity can act as a stress raiser and fatigue crack initiation site; these design features include grooves, holes, keyways, threads, and so on. The sharper the discontinuity (i.e., the smaller the radius of curvature), the more severe the stress concentration. The probability of fatigue failure may be reduced by avoiding (when possible) these structural irregularities, or by making design modifications whereby sudden contour changes leading to sharp corners are eliminated—for example, calling for rounded fillets with large radii of curvature at the point where there is a change in diameter for a rotating shaft (Figure 3.17).



Figure(3.17): Demonstration of how design can reduce stress amplification. (a) Poor design: sharp corner. (b) Good design: fatigue lifetime improved by incorporating rounded fillet into a rotating shaft at the point where there is a change in diameter

Surface Treatments During machining operations, small scratches and grooves are invariably introduced into the work piece surface by cutting tool action. These surface markings can limit the fatigue life. It has been observed that improving the surface finish by polishing will enhance fatigue life significantly.

Case hardening: is a technique by which both surface hardness and fatigue life are enhanced for steel alloys. This is accomplished by a carburizing or nitriding process whereby a component is exposed to a carbonaceous or nitrogenous atmosphere at an elevated temperature. A carbon- or nitrogen-rich outer surface layer (or ―case‖) is introduced by atomic diffusion from the gaseous phase. The case is normally on the order of 1 mm deep and is harder than the inner core of material.

ENVIRONMENTAL EFFECTS Environmental factors may also affect the fatigue behaviour of materials. A few brief comments will be given relative to two types of environment assisted fatigue failure: thermal fatigue and corrosion fatigue

Thermal fatigue : is normally induced at elevated temperatures by fluctuating thermal stresses; mechanical stresses from an external source need not be present

Corrosion Fatigue : Failure that occurs by the simultaneous action of a cyclic stress and chemical attack is termed corrosion fatigue. Corrosive environments have a deleterious influence and produce shorter fatigue lives. Even the normal ambient atmosphere will affect the fatigue behavior of some materials.

Questions

1.Define elasticity.

2. Write a note on strain hardening and strain softening.

3. Explain stress – strain curve with Hooke's law.

4.. Derive an expression for bending moment in terms of moment of inertia.

5. Derive the expression for bending moment and depression at a loaded end of single cantilever.

6. Derive the expression of rigidity modulus (n) in terms of linear strain (α) and Youngs modulus(Y).

7. Explain different types of beams and its engineering applications.

8. A force of 10 N is applied along the length of a wire of length 4m and radius 0.03×10^{-2} m. Calculate the extension produced in the wire. Given the Young's modulus of the material of the wire Y is 2.1×10^{11} N/m^2.

9. Calculate the force required to produce an extension of 1mm in a steel wire of length 2meter and diameter 1 mm. Given, Young's modulus of the material of the wire Y is 2.1×10^{11} N/m^2.

10. A metal cube of side 0.20 m is subjected to a shearing force of 4000 N. The top surface is displaced through 0.50 cm with respect to the bottom. Calculate the shear modulus of elasticity of the metal.

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