DEPARTMENT OF MECHANICAL ENGINEERING

ME6403- ENGINEERING MATERIALS AND METALLURGY

UNIT - V [MECHANICAL PROPERTIES AND DEFORMATION MECHANISMS]

SYLLABUS:

Mechanism of plastic deformation, slip and twinning - Types of fracture - Testing of materials under tension, compression and shear loads - Hardness tests [Brinell, Vickers and Rockwell]. Impact tests [Izod and charpy], Fatigue and creep failure mechanisms.

Properties of Engineering materials:

⇒ They are thousands of different engineering materials available today. But they can be placed into one (or) other of the following categories.

1. metals
2. polymers
3. ceramics and inorganic glasses
4. composites.

Mechanical properties: -

⇒ mechanical properties are those characteristics of material that describe its behaviour under the action of external forces.

⇒ A sound knowledge of mechanical properties is very essential for an engineer to select a suitable material for his various design purposes.

Mechanical Properties

1. Elasticity:

It is the property of a material by virtue of which it is able to retain its original shape and size after the removal of the load.

Examples: steel and rubber

This property is desirable in materials used in tools and machines.

2. Plasticity:

It is the property of a material by virtue of which a permanant deformation (without fracture) take place, whenever it is subjected to the action of external forces.

Examples: clay and lead.

This property is of importance in forming, shaping and extruding operations.

3. Ductility:-

It is the property of a material by virtue of which it can be drawn into wires before rupture take place.

=) Ductility of material can be measured by the percentage of elongation and the percentage of reduction of area before rupture.

Examples: Gold, platinum, silver, iron, copper and aluminium.

A knowledge of this property is important during fabrication operations.

4. Malleability:

It is the property of a material by virtue of which it can withstand deformation under compression without rupture.

Examples:- Gold and lead.

This property is of importance in forging and rolling operations.

5. Brittleness:-

It is the property of a material by virtue of which it will fracture without any appreciable defomation.

Examples: cast iron and glass

This property is desirable in machine parts which may be subjected to sudden loads.

6. Hardness:

It is the property of a material by virtue of which it is able to resist abrasion, indentation (or penetration) machining and scratching.

⇒ It is measured by the resistance of the material it offers to scratching.

Examples: Diamond, quartz and glass.

7. Toughness:

It is the property of a material by virtue of which it can absorb maximum energy before fracture takes place.

⇒ It is measured by the tenacity and hardness of the material

Examples: mild steel, brass, and wrought iron.

8. Stiffness:

It is the property of a material by virtue of which it resists deformation.

=> modulus of elasticity (i.e ratio of stress to the strain below elastic limit) is a measure of stiffness of a material.

9. Resilience:

It is the property of a material by virtue of which it stores energy and resist shocks (or) impact.

=> It is measured by the amount of energy that can be stored per unit volume after being stressed to elastic limit.

=> This property is desirable in materials used for springs.

=> The maximum energy which can be stored in a body upto the elastic limit is called the proof resilience and the proof resilience per unit volume is called the modulus of resilience.

10. Creep:-

It is the property of a material by virtue of which it deforms continuously under a steady load.

=> This property is considered in designing I.C engines, boilers, turbines, etc.

11. Endurance:

It is the property of a material by virtue of which it can withstand varying stresses.

=> The maximum value of stress that can be applied for an indefinite times without causing its failure is known as endurance limit.

=> This property is desirable in the design and production of parts subjected to vibrations.

12. Strength:

It is the property of a material by virtue of which it can withstand (or) support an external force (or) Load without rupture.

⇒ This property is very important while designing various structures and components.

a) Elastic strength:

It is the value of load corresponding to transition from elastic to plastic range.

b) Plastic strength:

It is the value of load corresponding to plastic range and rupture.

13. Impact Strength:

It is the property of a material by virtue of which it can resist (or) absorb shock energy before it fractures.

14. Fatigue:

It is the property of a material by virtue of which it deforms under the fluctuating (or) repeated loads.

Deformation of metals

⇒ When force is applied on a metal piece, then the size and/or shape will be altered. Any changes in the size and/or shape of the metal is called as deformation of the metal.

⇒ The deformation can be either permanent (or) temporary.

⇒ permanent deformation remains after the removal of the deforming force (or) applied load. ~~while~~ while temporary deformation disappears on removal of the load.

classification:-

1. Elastic deformation:-

Elastic deformation is the deformation of a body which completely disappears as soon as the external load is removed from the body.

2. plastic deformation:

plastic deformation is the deformation of a body which remains even after removing the external load from the body.

MECHANISM OF PLASTIC DEFORMATION

MODES OF PLASTIC DEFORMATION

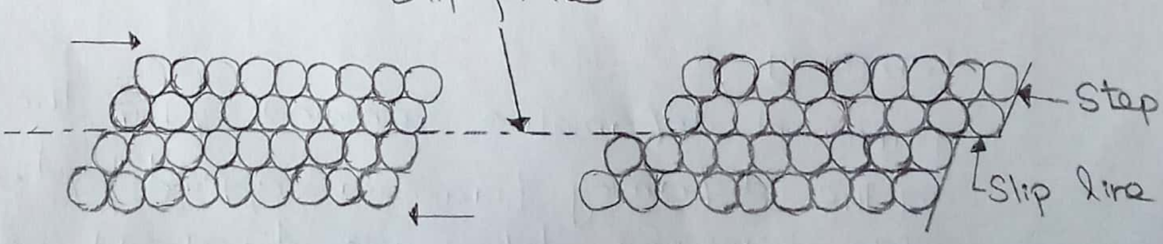
The two modes of plastic deformation are:

1. Slip
2. Twinning

Deformation by Slip

⇒ Slip may be defined as the sliding of blocks of the crystal over one another along definite crystallographic planes called slip planes and the preferable direction is called the slip direction.

⇒ In other words, the slip is defined as the shear deformation, which moves the atoms through many interatomic distances relative to their initial positions.



(a) Before slip (b) After slip

Mechanism of slip:

⇒ The mechanism of slip is actually due to the movement (or) dislocation in the crystal lattice.

⇒ The slip mode of deformation is the common mode in many crystals at elevated temperatures.

⇒ By examination of the surface of a deformed crystal under microscope shows groups of parallel lines which correspond to steps on the surface. They are called as slip lines.

⇒ The shear stress required for producing a slip due to the movement of dislocations is a small fraction of the theoretical value (i.e) (G/b) and it matches the observed shear strengths of metals.

⇒ The mechanism of slip requires the growth and movement of dislocation line.

⇒ Therefore the energy required for this movement of dislocation line is given by the relation,

$$E \propto l \cdot Gb^2$$

where E = Young's modulus

l = length of dislocation line

G = shear modulus

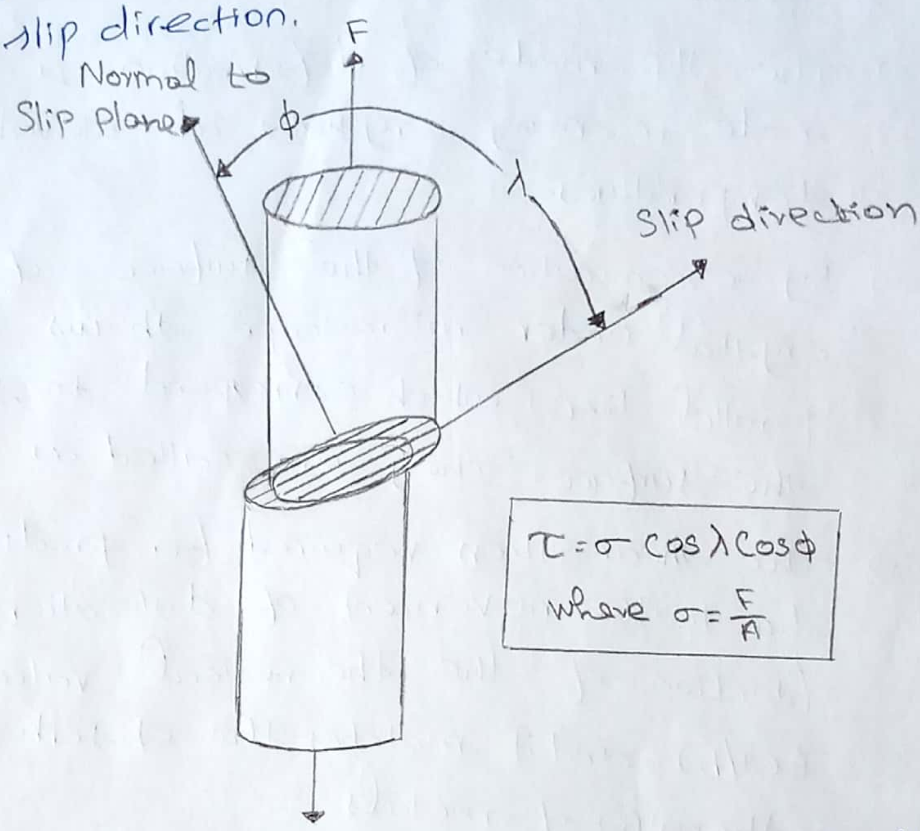
b = unit slip vector (or) Burgers vector.

⇒ The energy required will be minimum when b (vector) and G are having the lowest value.

⇒ It means that the dislocation having the shortest slip vector is the easiest dislocation to generate and expand for plastic deformation by slip.

Critical resolved shear stress for slip:-

The stress at which slip starts in a crystal depends on the relative orientations of the stress axis with respect to the slip plane and the slip direction.



$$\tau = \sigma \cos\lambda \cos\phi$$

where $\sigma = \frac{F}{A}$

The resolved shear stress, τ which is in the actual stress operating on the slip system resulting from the application of simple tensile stress.

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

F = externally applied force perpendicular to the cross-sectional Area(A).

A = Area of single crystal sample.

This resolved shear stress should reach a critical value called as critical resolved shear stress for a plastic deformation to start.

The important concept here is that the fundamental deformation mechanism is a shearing action based on the projection of applied force onto the slip system.

F = applied force along the crystal axis.

A = Area of the crystal (cross-sectional)

ϕ = Angle between normal to slip plane and F.

λ = Angle between normal to the slip-direction and F.

{Force operating in the slip direction} = $F \cos\lambda$

{slip plane on to the given area} = $\frac{A}{\cos\phi}$

As a result, the resolved shear stress τ is given by

$$\tau = \frac{F\cos\lambda}{A/\cos\phi}$$

$$= \frac{F}{A} \cos\lambda \cdot \cos\phi$$

$$\boxed{\tau = \sigma \cos\lambda \cdot \cos\phi} = P/A$$

where σ = applied tensile stress.

A - value of τ to produce slip by dislocation motion is called as critical resolved shear stress [CRSS] and is given by

$$\boxed{\tau_c = \sigma_c \cos\lambda \cos\phi}$$

=> The stress required at a given temperature to initiate slip in a pure and perfect single crystal, for a material is constant. This is known as Schmid's law.

=> In equation, the term $\cos\phi \cos\lambda$ is known as the Schmid's factor.

Deformation by Twinning

The next important mechanism by which metals deformation occur. is known as Twinning.

⇒ Twinning is the process in which the atoms in a part of a crystal subjected to stress, rearrange themselves so that one part of the crystal becomes a mirror image of the other part.

⇒ Twinning is the plastic deformation which takes place along two planes due to a set of forces acting on a given metal. The two planes are usually parallel to each other and are called the twin planes. Here each atom moves only a fraction of an interatomic distance relative to its neighbours.

⇒ Like slip, twinning almost take place in special planes called twinning planes.

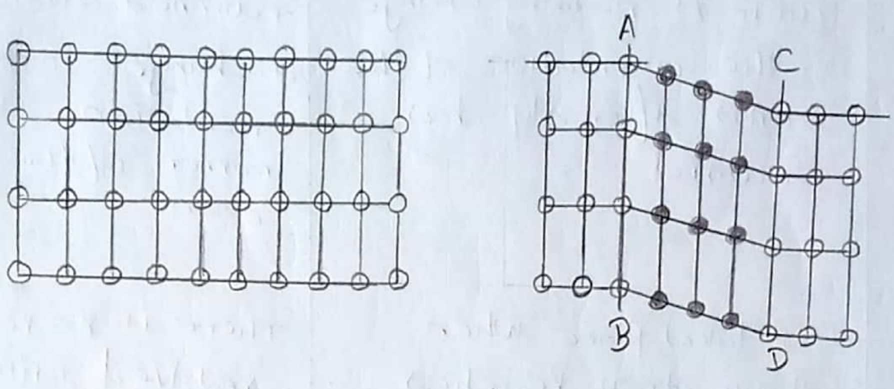
⇒ In most plastic deformation, twinning is relatively insignificant, but it may have considerable influence on the total amount of deformation.

⇒ It should be noted that twinning differs from slip in that every plane of atoms suffers some movement, and the crystallographic orientations of many unit cells are altered.

mechanism of Twinning

⇒ In twinning process, the movement of atoms is only a fraction of interatomic distance. Figure shows the circles indicating the arrangement of atoms.

⇒ The line AB and CD represents the planes of symmetry, from where the twinning starts and ends respectively. These planes are known as twinning planes.



(a) Before Twinning (b) After Twinning

Mechanism of Twinning

=) It has been observed that the crystals twin about the twinning planes and the atoms in the regions to the left of the twinning plane AB and the right of the twinning plane CD remain undisturbed.

=) whereas in the twinned region each atom moves by a distance proportional to its distance from the twinning plane AB. The dark circles indicate the new position of the atoms.

=) The twinning occurs due to the growth and movement of dislocation in the crystal lattice.

COMPARISON BETWEEN SLIP AND TWINNING

S.No	SLIP	TWINNING
1.	In slipping the deformation takes place due to the sliding of atomic planes over the others	In twinning, the deformation is due to orientation of one part of the crystal with respect to the other.
2.	It occurs along individual slip planes	It occurs over general crystallographic planes.

3	The atomic movements are over large distances	The atomic movements are over a fraction of atomic spacing.
4.	There is no ~~bang~~ change in the orientation of the atoms after slip has occurred	Twinned atoms undergo a change in their orientation and become mirror of the untwinned atom.
5.	Slip takes place when shear stress reaches resolved critical shear stress	There is no role for resolved critical shear stress.

FRACTURE:-

Fracture is the mechanical failure of the material which will produce the separation (or) fragmentation of a solid into two (or) more parts under the action of stresses.

Types of fractures:-

The four important types of fractures are

1) Brittle fracture
2) Ductile fracture
3) Fatigue fracture
4) Creep fracture.

BRITTLE FRACTURE:-

A brittle fracture may be defined as a fracture which takes place by the rapid ~~prog~~ propagation of crack with a negligible deformation.

=> It may be noted that in amorphous materials such as glass, the fracture is completely brittle whereas in crystalline materials, the fracture occurs after a small deformation.

Mechanism of brittle fracture: Griffith's Theory

[Griffith crack theory]

Introduction:-

It is proved that the stress at which a material fractures is far below the lower value of the ideal breaking strength calculated from the atomic strength.

In other words, the fracture strength of real materials is far lower than (about 10^4 MPa) the theoretical minimum value for an ideal solid.

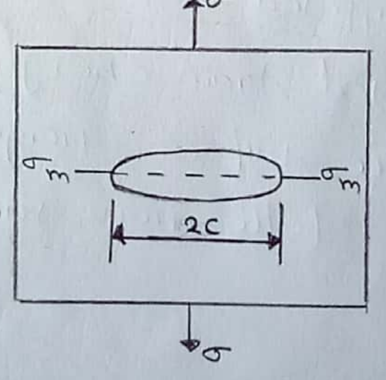
⇒ According to Griffith, the discrepancy between the strength of real and ideal materials is due to many fine cracks which acts to concentrate the stress at their tips (or) ends.

Griffith theory:-

1. In a brittle material, there are many fine cracks. These cracks concentrate the applied stress at their tips or ends.
2. When the stress at the tips of a crack exceeds the theoretical stress values, the crack expands and fracture occurs.

Explanation of mechanism of brittle fracture:

Let us consider a crack of elliptical cross-section in a rectangular specimen as shown in figure.



σ = Tensile stress applied to the specimen.

σ_m: maximum stress at the tip of the crack.

c = Half length of the crack.

ρ = Radius of curvature at the ends of the ellipse.

⇒ It is observed that when a tensile stress is applied to the specimen, then the applied stress is distributed about the crack in such a way that the maximum stress occurs at its tips. The maximum stress (σ_m) at the tip of the crack is given by

$$\sigma_m = 2\sigma\sqrt{\frac{c}{\rho}}$$

⇒ It is understood that when an elastic material is stressed, potential energy is stored in the material before crack occurs. This stored energy is known as elastic strain energy. when a crack begins propagating elastic energy is released.

⇒ It is also understood that as the crack propages, new surfaces are created and a certain amount of energy, called surface energy, must be provided to create them.

Derivation for fracture strength:

Griffith supposed that the crack propagates when the released strain energy is just sufficient to provide the surface energy necessary for the creation of the new surface.

According to elastic theory,

The strain energy per unit volume $= \frac{\sigma^2}{2E}$

where E = Young's modulus of the material.

The elastic strain energy released by the spreading of a crack of unit width is given by

$$U_E = \frac{\sigma^2}{2E} \times \text{Area} \times \text{width}$$

$$= \frac{\sigma^2}{2E} \times \pi c^2 \times 1$$

$$\boxed{U_E = \frac{\sigma^2 \pi c^2}{2E}} \quad \text{— (1)}$$

A more detailed calculation shows that the strain-free volume is larger and the elastic energy released will be twice the value given in eqn (1). Then eqn (1) becomes,

$$\boxed{U_E = -\frac{\sigma^2 \pi c^2}{E}} \quad \text{— (2)}$$

$-$ve indicates that the elastic energy stored in the material is released as the crack forms.

=) If γ = surface energy per unit area in joules/m², then the surface energy (U_S) for a crack of length $2c$ with unit width is given by

$$\boxed{U_S = 4\gamma c} \quad \text{— (3)}$$

Since there are two surfaces, the eqn (3) is multiplied by 2.

The total change in potential energy, resulting from the creation of the crack, is given by

$$U = U_E + U_S = \frac{-\sigma^2 \pi c^2}{E} + 4\gamma c$$

According to Griffith, the crack will propagate and produce brittle fracture when an incremental increase in its length does not change the total energy of the system.

mathematically,

$$\frac{dU}{dc} = 0$$

$$\therefore \frac{dU}{dc} = \frac{d}{dc}\left[\frac{-\sigma^2 \pi c^2}{E} + 4\gamma c\right] = 0$$

(or) $$\frac{-2\sigma^2 \pi c^2}{E} + 4c\gamma = 0$$

$$\boxed{\sigma = \sqrt{\frac{2E\gamma}{\pi c}}} \quad -(4)$$

The above equation is called Griffith's fracture equation.

From eqn (4), the following observations can be made.

i) The stress necessary to cause brittle fracture varies inversely as the square root of the crack length.

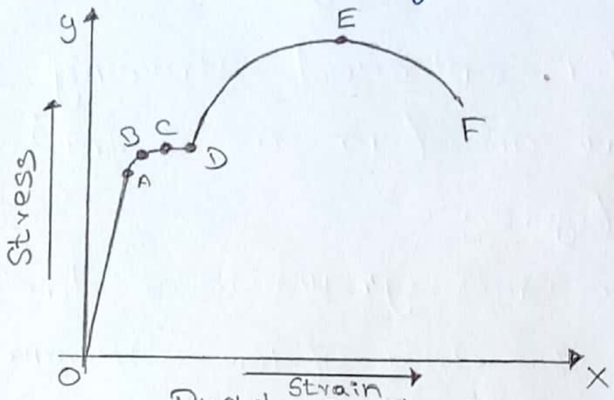
ii) The critical tensile stress required to propagate the crack spontaneously is smaller than the Young's modulus of the material.

iii) The Griffith theory is valid only for a perfect brittle material like glass.

DUCTILE FRACTURE:-

Ductile fracture may be defined as the fracture which takes place by a slow propagation of crack with appreciable plastic deformation.

⇒ when a ductile specimen is subjected to tensile stress, the stress-strain curve can be obtained as shown in figure.

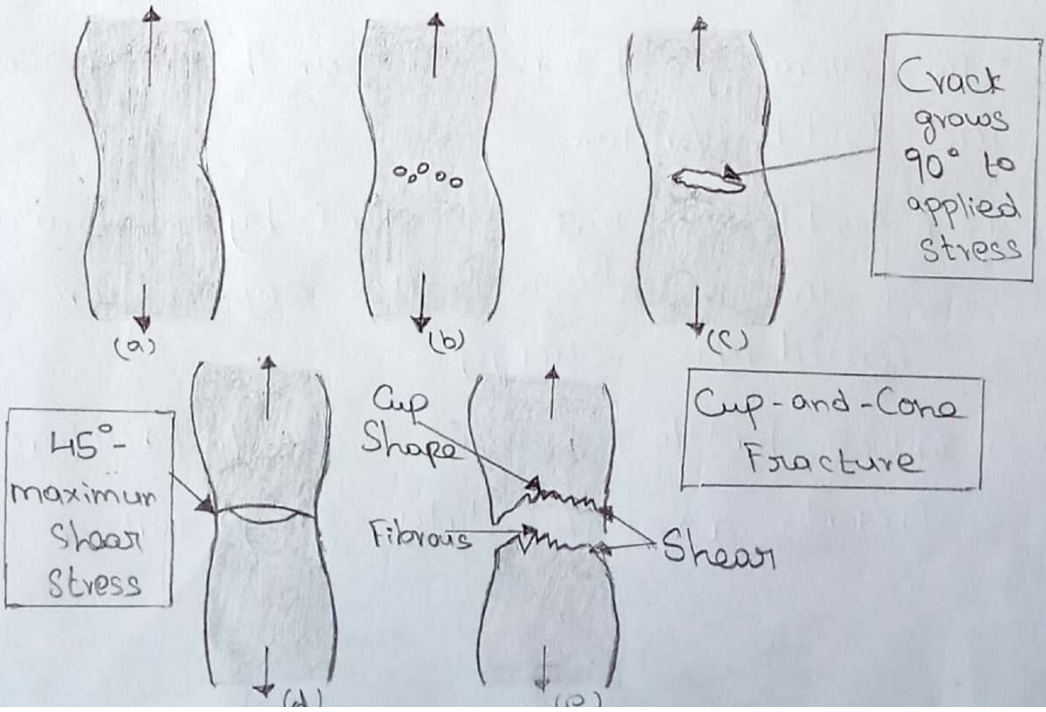


Ductile Fracture

⇒ in the figure, at point F the fracture takes place.

Mechanism of ductile fracture:

⇒ The various stages in the development of a ductile fracture, also called cup-and cone fracture is shown in figure.



⇒ Figure indicates the formation of a neck, when a ductile specimen is subjected to tensile stress. when the tensile stress is increased beyound the ultimate tensile stress [i.e. at point E in figure], a neck is formed in the specimen.

⇒ The continuation of the plastic deformation produces many fine cavities in the specimen, as shown in figure.

⇒ under continued straining, these cavities grow and form a central crack, as shown in figure.

⇒ The crack grows in a direction perpendicular to the axis of the specimen until it approaches the surface of the specimen. It then propagates to the surface of the specimen to form the cone part of the fracture, as shown in figure.

⇒ The central 'cup' region of the fracture has a very fibrous appearance as shown in figure.

The following observations can be made during the ductile frature.

1) A ductile fracture occurs by a slow tearing of the metal with the expenditure of considerable energy.

2) unlike brittle fracture, a ductile fracture presents a rough dirty-grey surface.

COMPARISON BETWEEN BRITTLE AND DUCTILE FRACTURES

S.No	BRITTLE FRACTURE	DUCTILE FRACTURE
1.	It occurs with negligible plastic deformation	It occurs with large plastic deformation.
2.	It occurs at the point where micro crack is more	It occurs in some localised region where the deformation is very large.
3.	The rate of crack propagation is rapid	The rate of crack propagation is slow.
4.	Failure is due to the direct stress	Failure is due to the shear stress
5.	It is characterised by separation of normal to tensile stress	It is characterised by the formation of cup and cone.
6.	Fractured surface shows a sharp planar facet	Fractured surface is a rough dirty-grey contour.
7.	The brittle fracture can be increased by decreasing temperature increasing strain rate and work hardening	The ductile fracture can be increased by dislocations and other defects in metals.

FATIGUE FRACTURE:

The fatigue fracture is defined as the fracture which takes place under repeatedly applied fatigue stresses.

Stress cycles:

Figure illustrates the different arrangements of fatigue loadings.

=> Figure (a) shows the arrangement of the reversed stress

=> Figure (b) shows the arrangement of the fluctuating stress

=> Figure (c) shows the arrangement of the irregular stress.

mechanism of Fatigue Fracture:

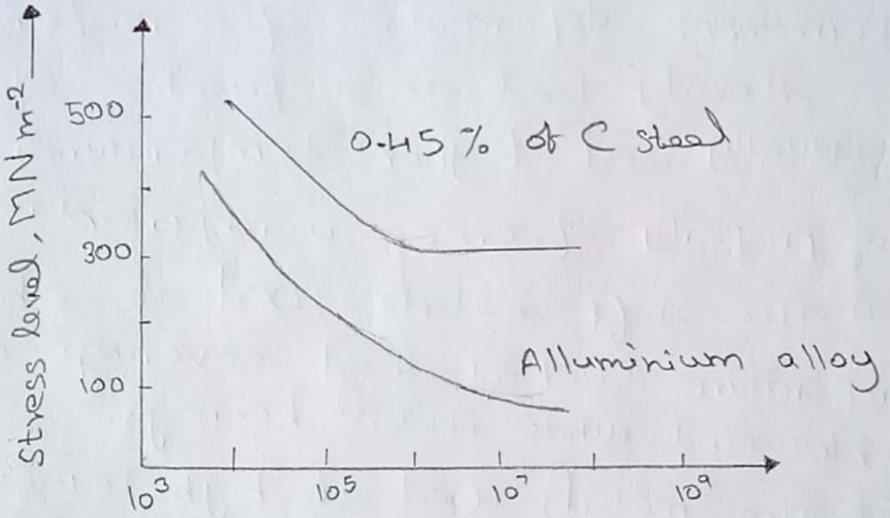
=> Fatigue fracture begins at irregularities on the surface imperfections such as machine making and slip steps. The nucleation of microcrack is due to the slip movements. The slip movements starts within few cycles of loading. The microcracks acts as the points of stress concentration.

=> As the cycles of loading continue, the microcrack propagates and grows in its size. In brittle materials, the crack grows to a critical size very fastly. But in ductile materials, the crack keeps growing untile the remaining area cannot support the load. So the fatigue fracture in ductile materials occur suddenly.

=> The high temperature increases the mobility of atoms facilitating slip and hence the fatigue fracture.

S-N Diagram:

The S-N diagram can be obtained by plotting the number of cycles of stress reversals (N) required to cause fracture against the applied stress level (S), as shown in figure.



⇒ It can be seen from the figure that the fatigue strength is more for steels than for non-ferrous metals (such as aluminium) and their alloys.

- **Fatigue stress [(or) fatigue strength]:**

The stress at which a metal fails by fatigue is termed as fatigue strength.

Fatigue limit [(or) endurance limit]:

It is defined as the value of stress below which the material will not fail even when it is loaded for infinite number of cycles.

Fatigue life:

It is the total number of cycles required to bring about final fracture under a given condition of use.

CREEP:

The creep is defined as the property of a material by virtue of which it deforms continuously under a steady load.

=> In other words, creep can be defined as the permanent deformation of a material under a steady load as a function of time, usually at higher temperatures.

The property of creep is important in

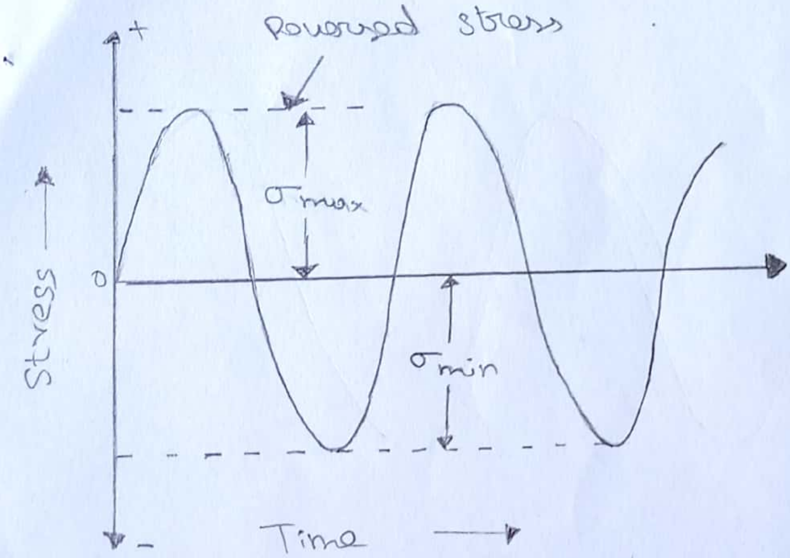
1) The soft metals used at about room temperature such as lead coverings on telephone cables and white metal bearings.

2) The metals used at high temperature such as furnace parts, turbine blades, pressure vessel parts, rocket and missiles, supersonic jet, etc.

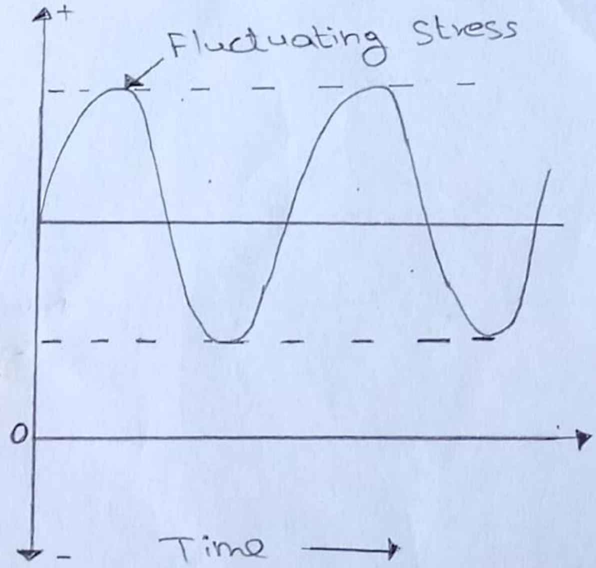
=> When a material is subjected to a constant loading, then the time-dependent strain occuring under the constant stress is known as creep.

=> Some materials such as zinc, lead and tin creep more at room temperature. Some other materials such as iron, nickel and copper creep more at elevated temperatures only.

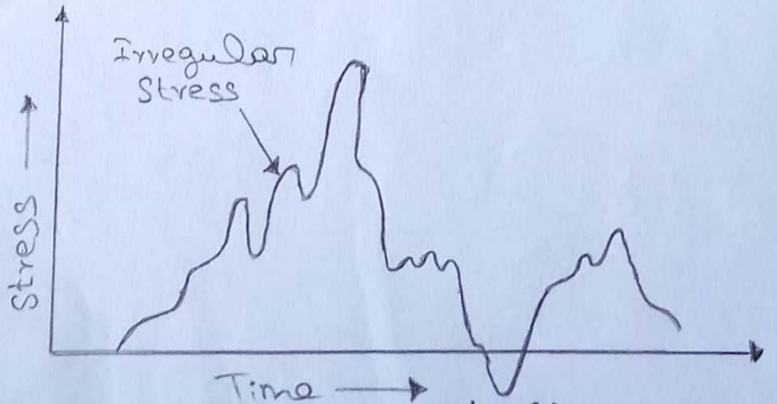
=> A creep curve shows the variation of the extension of a metal with time under different stresses. A typical creep curve under constant nominal stress and constant temperature is shown in figure.



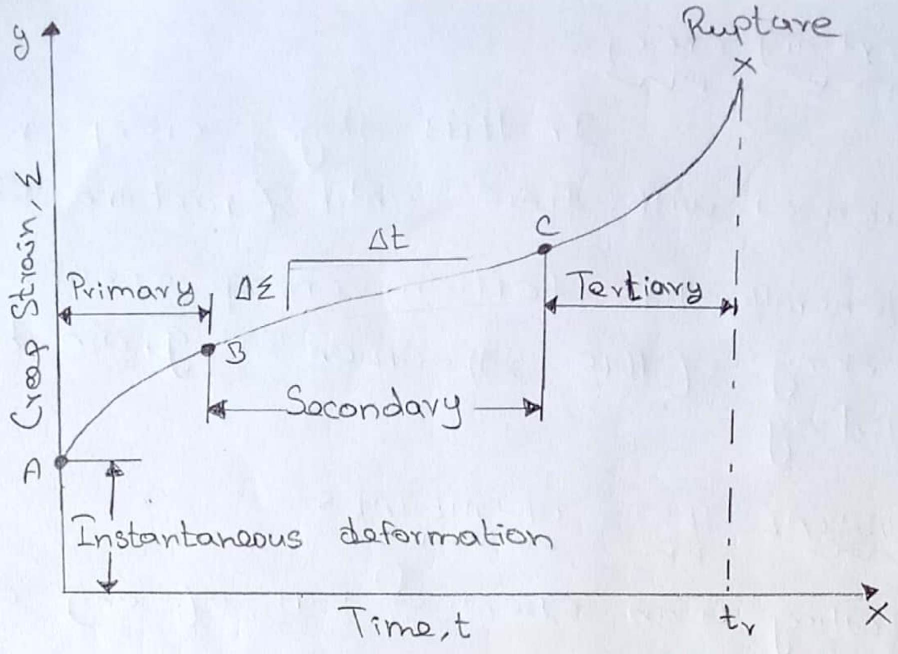
(a) Reversed stress



(b) Fluctuating stress



(c) Irregular stress



Different stages in creep curve:

1. primary creep:

In this stage, the creep is mainly due to dislocation movement. The creep rate decreases with time.

⇒ During this stage, the recovery effect is less than the work hardening effect. Hence the creep rate decreases logarithmically.

2. secondary creep:

⇒ During this stage, the rates of work hardening and recovery are equal. so the material creeps at steady rate.

⇒ For the above reason, secondary creep is usually termed as steady-state creep.

⇒ steady-state creep.

⇒ steady-state creep may be viscous (or) plastic in character, depending upon the state level and temperature.

⇒ It is the important part of the creep curve which is used to estimate the service life of the alloy.

3. Tertiary creep:

In this stage, creep rate increases with time until fracture occurs.

⇒ Generally the tertiary creep occurs due to necking of the specimen (or) grain boundary sliding.

MECHANICAL TESTS OF METALS

⇒ Testing is an essential part of any engineering activity. Testing is applied to materials, components, and assemblies.

⇒ It consists of measurement of fundamental properties (or) measurement of responses to particular influences as load, temperature, and corrodants.

Classification: -

1. Destructive tests
2. non-destructive tests.

1) Destructive tests: -

In this type of testing, the components (or) specimen to be tested is destroyed and cannot be reused.

Example:

tensile test, impact test, bend test, fatigue test, torsion test, creep tests, etc.

2) Non - destructive test:

In this type of testing, the component (or) specimen to be tested is not destroyed and can be reused after the test:

example: radiography, ultrasonic inspection, etc -

Tensile test:

The tensile test is one of the most widely used of mechanical tests.

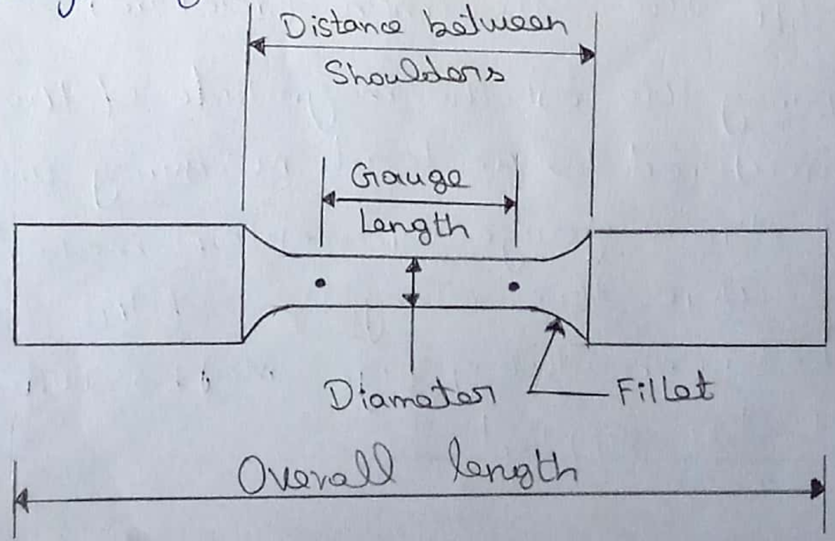
=) A tensile test of a material is performed on ductile materials to determine tensile properties such as:

1) Limit of proportionality
2) yield point (or) yield strength
3) maximum tensile strength
4) Breaking strength
5) percentage elongation
6) percentage reduction area
7) modulus of elasticity.

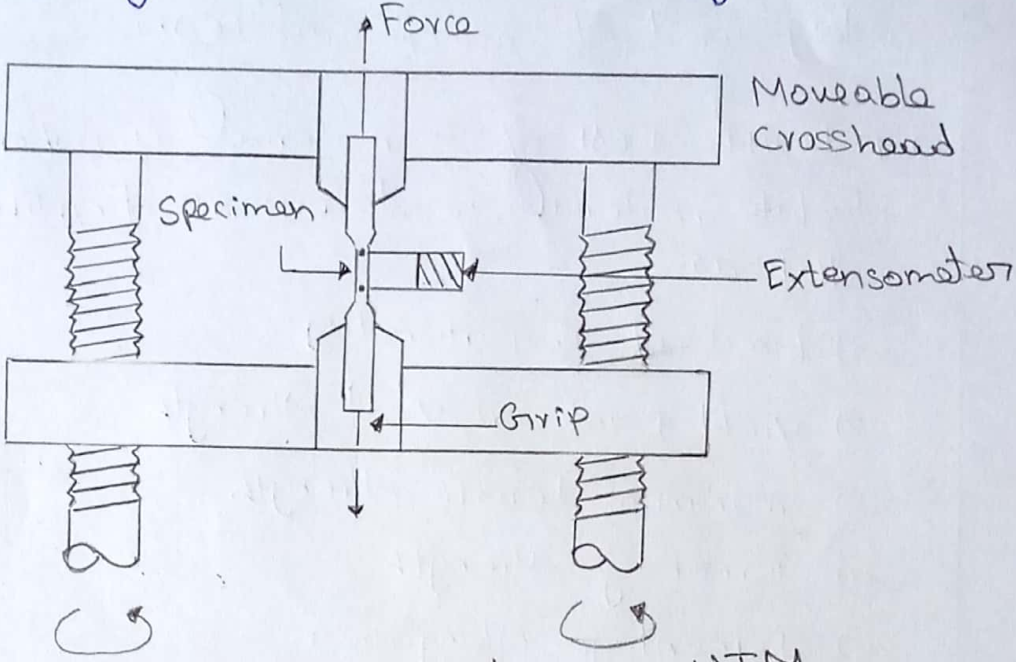
=) The tensile test is usually carried out with the help of a universal testing machine (UTM).

Arrangement:

=) The material to be tested, also known as a specimen, is machined to standardised dimensions as shown in fig. A typical specimen has a diameter of 12.5mm and a gauge length of 50mm.



⇒ A schematic working arrangement of a universal testing machine is shown in fig.



Schematic arrangement of a UTM

⇒ The specimen is elongated by the moving cross head; load cell and extensometer measure the magnitude of the applied load and the elongation respectively.

Testing procedure:

⇒ The specimen to be tested is fastened to the two end-jaws of the UTM. Now the load is applied gradually on the specimen by means of the movable cross head, till the specimen fractures.

⇒ During the test, the magnitude of the load is measured by the load measuring unit (load cell). A strain gauge (or) extensometer is used to measure the elongation of the specimen between the gauge marks when the load is applied.

Compression test:

=) The compression test is conducted in a manner similar to the tensile test, except that the force is compressive.

=) since brittle materials are unsuitable for tension test, therefore they are tested for compression.

=) Brittle materials such as cast iron, concrete, mortar, brick and ceramics are commonly tested in compression.

=) The compression test is also conducted on a universal testing machine.

Testing procedure:

=) For compression tests, specimens are made of cubical (or) cylinderical shape to avoid eccentric loading.

=) The specimen to be tested is fitted in between compression plates of the universal testing machine.

=) Now the compression load is gradually applied on the specimen and the corresponding reduction in lengths of the specimen are recorded.

=) using the recorded values of loads and their corresponding values of change in length, one can find the various compressive properties in the same manner as that of the tensile test.

HARDNESS TESTS:

Hardness maybe defined as the ability of a material to resist scratching, abrasion, cutting (or) penetration.

⇒ The hardness test is performed on a material to know its resistance against indentation and abrasion.

Types of Hardness tests:

The three most commonly used hardness tests are:

1) Brinell hardness test
2) Vickers hardness test
3) Rockwell hardness test.

Common principle:

The hardness is measured from an indentation produced in the component by applying a constant load on a specific indenter in contact with the surface of the component for a fixed time.

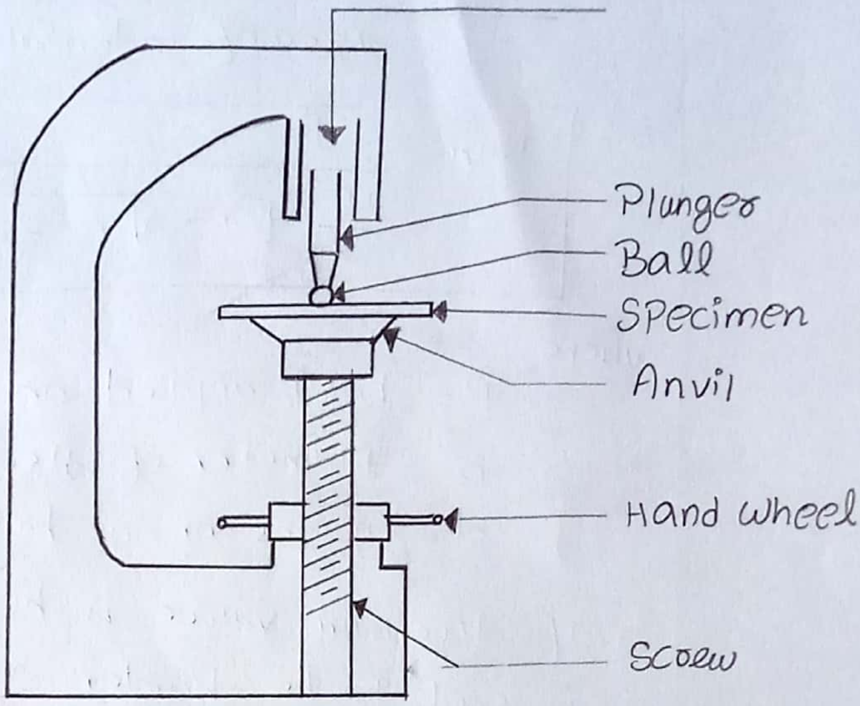
BRINELL HARDNESS TEST:

⇒ One of the earlier standardised methods of measuring hardness was brinell test.

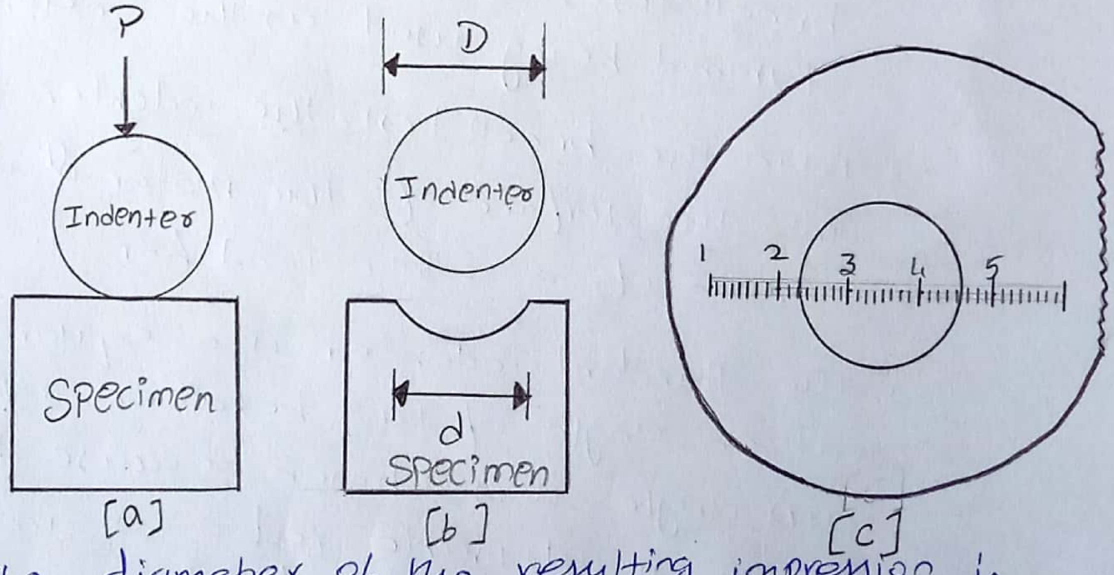
⇒ In the brinell test, a hardened steel hall indenter is forced into the surface of the metal to be tested. The diameter of the hardened steel (or ~~tung~~ tungsten carbide) indenter is 10mm. ~~standard~~

⇒ standard loads range between 500kg and 3000kg in 500kg increments. During a test the load is maintained constant for 10 to 15 seconds.

Testing arrangement and procedure:



⇒ The Brinell's hardness test is performed by pressing a steel ball, also known as indenter, into the specimen as shown in figure.



⇒ The diameter of the resulting impression is measured with the help of a calibrated microscope.

⇒ The measured diameter is converted into the the equivalent Brinell hardness number (BHN) using the following eqn:

$$BHN = \frac{\text{Load on the ball}}{\text{Area of indentation of steel ball}}$$

$$BHN = \frac{P}{\frac{\pi D}{2}\left[D - \sqrt{D^2 - d^2}\right]}$$

where,

P = Load applied on indenter in kg

D = Diameter of steel ball indenter in mm

d = Diameter of ball impression in mm.

⇒ If the BHN value is higher, then the material is said to be harder. If BHN is less, then the metal is soft.

VICKERS HARDNESS TEST :-

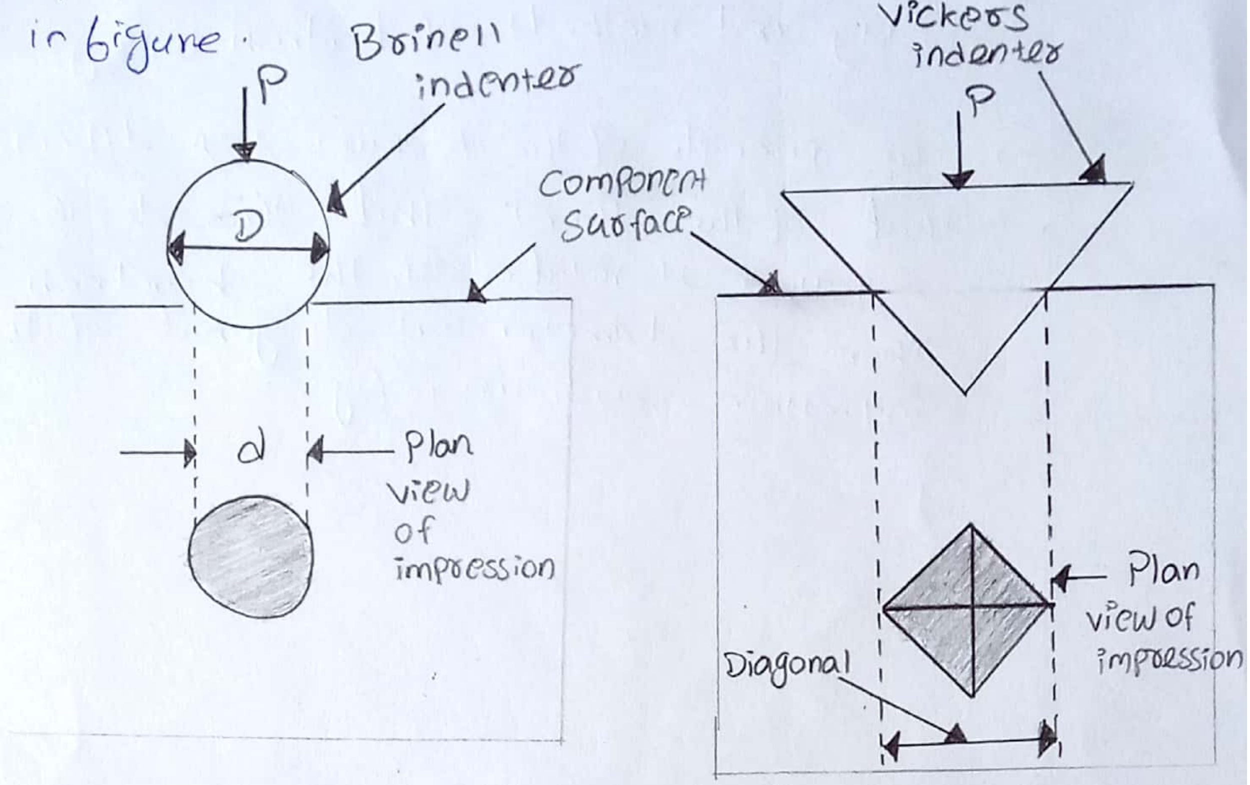
⇒ The vickers hardness test is similar to the brinell test, with a square-based diamond pyramid being used as the indenter.

⇒ As in the brinell test, the indenter is forced into the surface of the material under the action of a static load for 10 to 15 seconds

⇒ The standard indenter is a square pyramid with an angle of 136° between opposite faces. This angle was chosen because it approximates the most desirable ratio of indentation diameter to ball diameter in the brinell hardness test.

⇒ Because of shape of the indenter, this test is frequently called the diamond-pyramid hardness test.

⇒ An advantage of the vickers test over the brinell test is that the accuracy is increased in determining the diagonal of a square as opposed to the diameter of a circle, as shown in figure.



⇒ The diamond-pyramid hardness number (DPH) (or) Vickers hardness number (VHN (or) VPH) is defined as the applied load divided by the surface area of indentation.

$$VHN = \frac{\text{Applied load}}{\text{surface area of impression}}$$

$$= \frac{2P \sin\frac{\theta}{2}}{D^2}$$

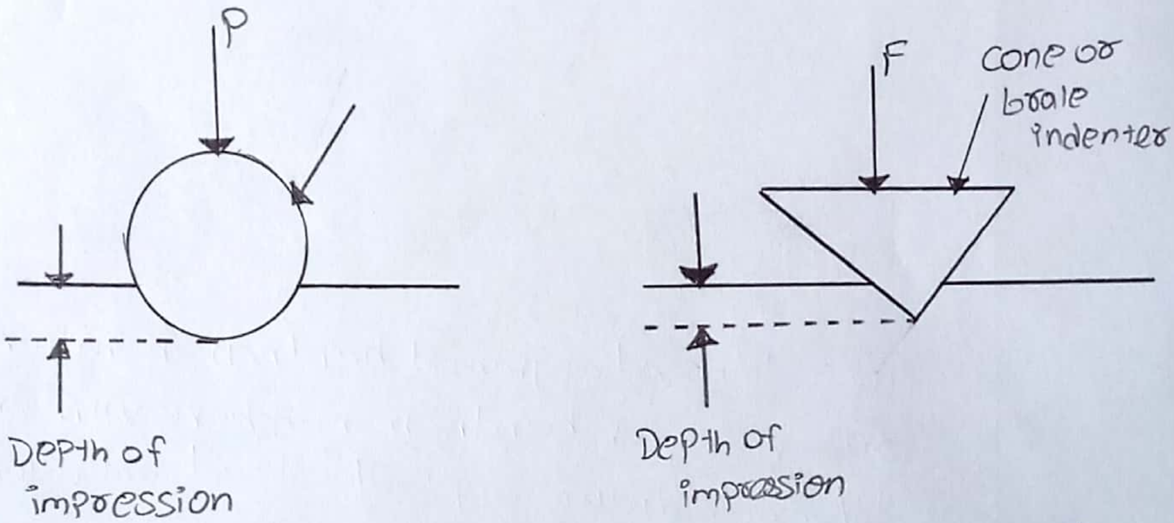
$$= \frac{1.8544P}{D^2} \quad [\because \theta = 136°]$$

where
P = Applied load in kg
θ = Angle between the opposite faces of diamond = 136°
D = mean diagonal length in mm

ROCKWELL HARDNESS TEST:

⇒ The rockwell hardness test is probably the most widely used methods of hardness testing.

=) The principle of the rockwell test differs from that of the others in that the depth of the impression is related to the hardness rather than the diameter (or) diagonal of the impression, as shown in fig.



⇒ Rockwell test are widely used in industries due to its accuracy, simplicity and rapidity. In this test, the dial gives a direct reading of hardness, no need for measuring indentation diameter (or) diagonal length using the microscope.

Rockwell scales:-

There are many rockwell scales available. But the most commonly used are:

1. B-scale: (1/16 inch diameter steel ball indenter; 100kg load), used to measure the hardness (HRB) of non-ferrous metals.
2. C-Scale: (120° diamond cone indenter, called a BRALE; 150kg load), used to measure the hardness (HRC) of steel.

IMPACT TESTS:

⇒ The impact test is performed to study the behaviour of materials under dynamic load i.e suddenly applied load.

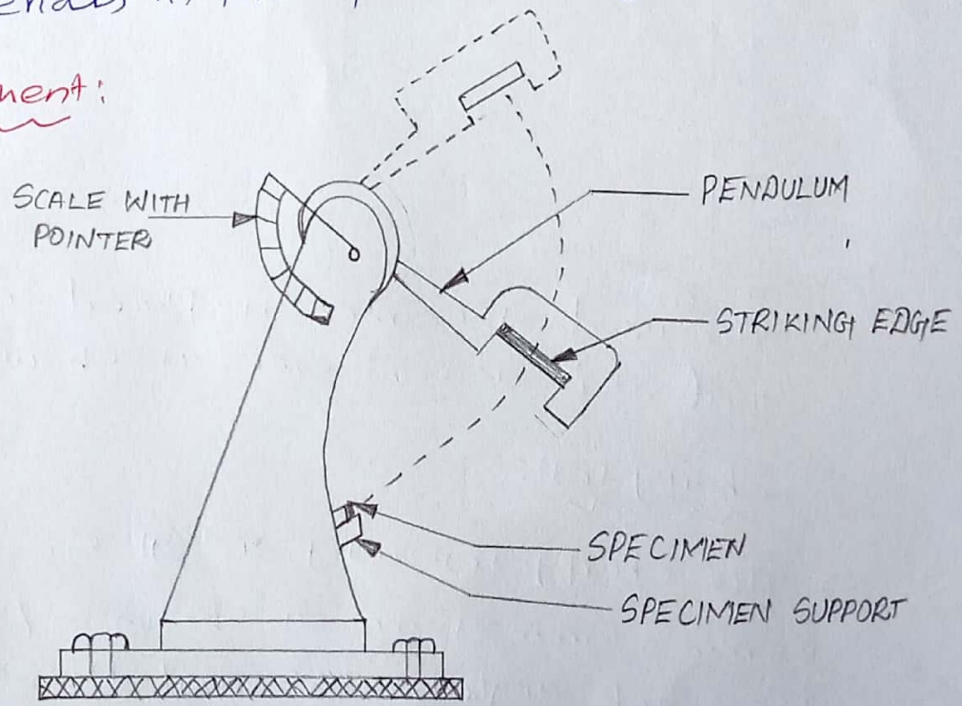
Impact strength:-

The capacity of a metal to withstand blows without fracture, is known as impact strength (or) impact resistance..

⇒ The impact test indicates the toughness of the material i.e, the amount of energy absorbed by the material during plastic deformation.

⇒ The impact test also indicates the notch sensitivity of a material. The notch sensitivity refers to the tendency of some normal ductile materials to behave like a brittle materials in the presence of notches.

Arrangement:



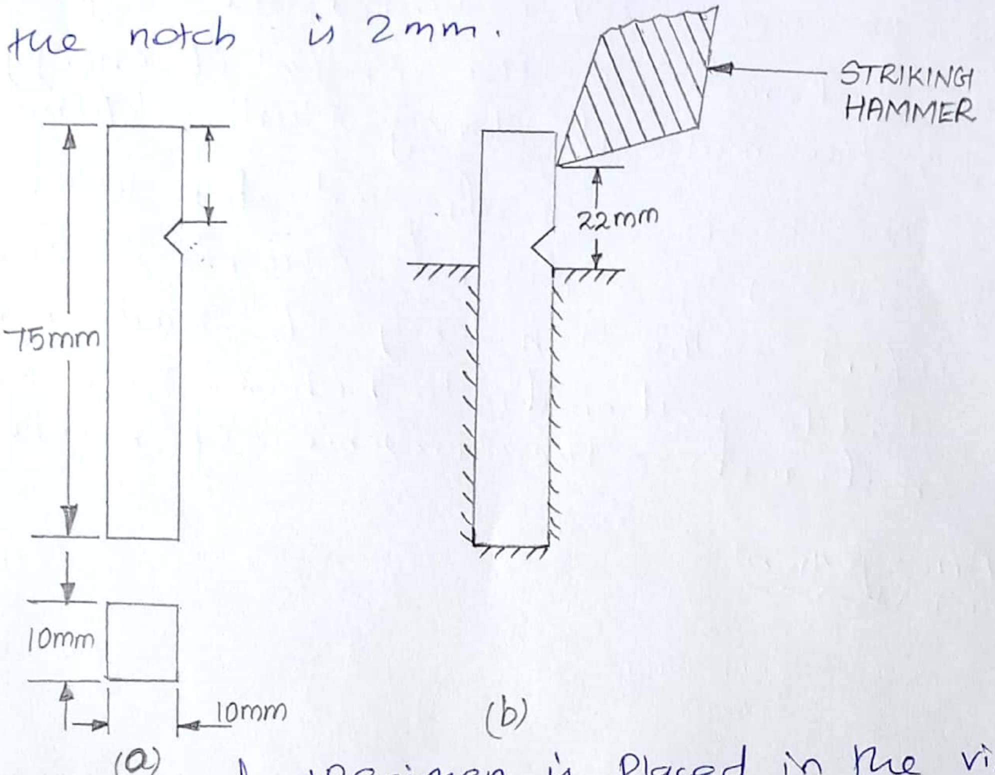
Types of impact Tests:

1. Izod test
2. Charpy test.

⇒ It can be noted that the impact testing machines are designed so that both types of test can be performed on the same machine with only minor adjustments.

1. Izod test:

⇒ Izod test uses a cantilever specimen of size 75mm × 10mm × 10mm as shown in figure. The V-notch angles is 45° and the depth of the notch is 2mm.

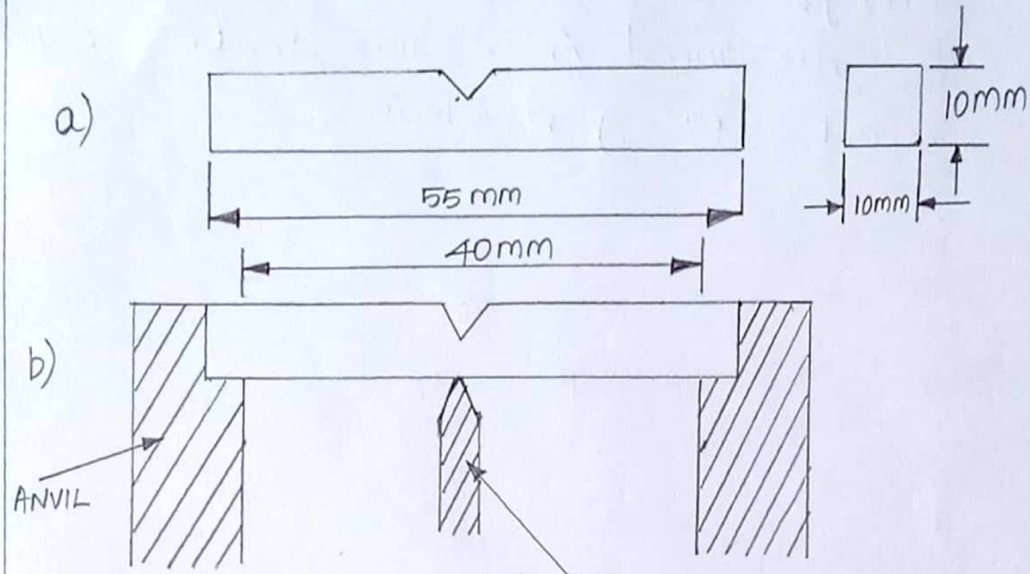


⇒ The Izod specimen is placed in the vise such that it is a cantilever, as shown in figure.

2. charpy test:

⇒ The charpy test uses a test specimen of size 55mm × 10mm × 10mm, as shown in figure. The V-notch angles is 45° and the depth of the notch is 2mm.

⇒ The charpy specimen is placed in the vise as a simply supported beam.



Testing procedure:

1) The specimen is placed in the vice of the anvil.

2) The pendulum hammer is raised to known standard height depending on the type of specimen to be tested.

3) When the pendulum is released, its potential energy is converted into kinetic energy just before it strikes the specimen.

4) Now the pendulum strikes the specimen. It may be noted that the izod specimen is hit above the V-notch and the charpy specimen will be hit behind the V-notch.

5) The pendulum, after rupturing the specimen rises on the other side of the machine.

6. The energy absorbed by the specimen during breaking is the weight of the pendulum times the difference in two heights of pendulum on either side of the machine.

7. Now the energy i.e the notched impact strength, in foot-pounds (or) metre-kg, is measured from the scale of the impact testing machine.