Catalog

UNIT - V

MECHANICAL PROPERTIES AND DEFORMATION MECHANISM

5.1 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

E.g. Steel and rubber.

2. PLASTICITY :

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

E.g. Clay and lead.

3. DUCTILITY :

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

E.g. Gold, silver, iron, copper, aluminium and platinum

4. MALLIABILITY :

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

E.g. Gold, lead

5. BRITTLENESS :

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

E.g.: Cast iron, glass

6. HARDNESS :

It is the proper of a material by virtue of which it is able to resist abrasion, intentation, machining and scratching.

E.g. Diamond, quartz, glass

7. TOUGHNESS :

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

E.g. Mild steel, brass, iron

8. STIFFNESS :

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

9. RESILIENCE :

It is the property of a material by virtue of which it stores energy and resists shocks or impacts.

CREEP :

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

11. ENDURANCE :

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

12. STRENGTH :

It is the property of a material by virtue of which it can with stand or support an external force or load without 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.

5.2 TECHNICAL PROPERTIES :

1. MACHINABILITY :

It is the property of a material, which indicates the ease with which it can be cut or removed in various machining operations such as turning, drilling, boring, shaping.

2. CASTABILITY :

It is the property of a material, which indicates the ease with which it can be cast into different shapes and sizes.

3. WELDABILITY :

It is the property of a material, which indicates the ease with which two similar or dissimilar metals are welded.

4. FORMABILITY (OR) WORK ABILITY :

It is the property of a material, which indicates the with which it can be formed into different shapes and sizes.

FACTORS AFFECTED MECHANICAL PROPERTIES :

Grain size
Heat treatment
Atmospheric exposure
Low and high temperatures

5.3 MECHANISMS OF PLASTIC DEFORMATION :

The change that is produced in the shape of a metal piece due to the impact of forces acting on it is known as Deformation.

Deformation is of two basic types:

Elastic Deformation :
Stress is below the elastic limit.
Plastic Deformation :
Stress is above the elastic limit.

When a material is stressed below its plastic limit, the resulting deformation or strain is temporary. Removal of stress or strain is temporary. Removal of stress results in a gradual return of the object to its original position.

When a material is stressed above its elastic limit, plastic pr permanent deformation takes place and it will not return to its original shape. All metal working such as forging, rolling, spinning, drawing and extruding involve plastic deformation of metals. Various machining operations such as turning, milling, shaping and punching also involve plastic deformation.

Plastic deformation is a function of

1. Applied stress
   Temperature
   Strain rate

Plastic deformation is also carried out in order to improve some mechanical properties of metal and alloys.

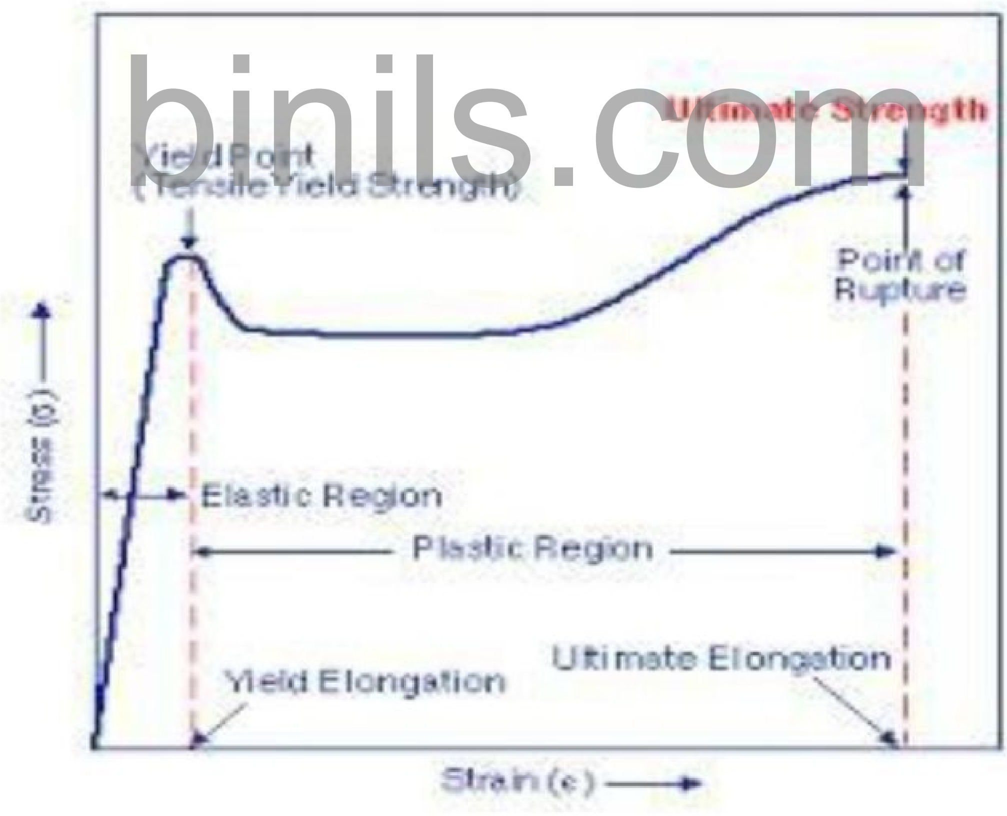
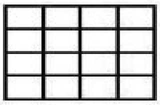
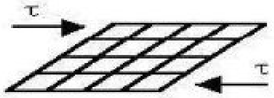


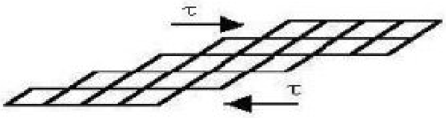
Fig 5.1 Permanent plastic strain



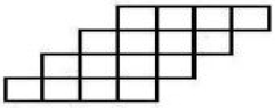
(a) Simple lattice



(b) Elastic deformation (reversible)



(c) Elastic plastic deformation



(d) Plastic deformation

5.4 METHODS / MODES OF PLASTIC DEFORMATION :

Slip

Twinning

Deformation by slip :

It is defined as the shear deformation, which moves the atoms through many inter atomic distances relative to their initial positions. The mechanism of slip is actually due to the movement or dislocation in the crystal lattice. The slip mode 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 mechanism of slip requires the growth and movement of dislocation line.

$$E \alpha l.ab^2$$

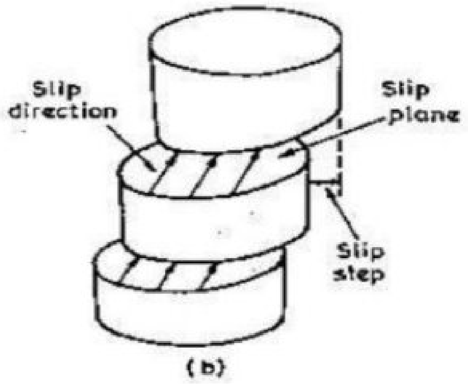
→ Young's modulus

l → length of dislocation

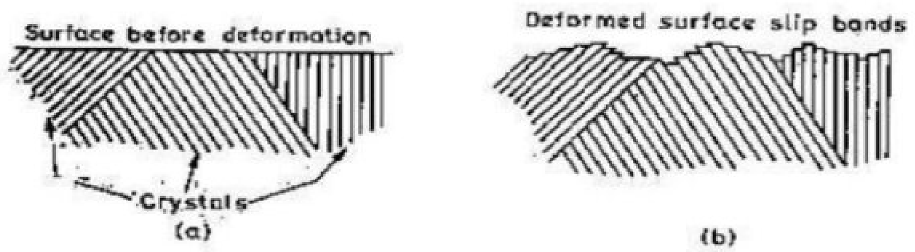
→ Shear modulus

b → Unit slip vector

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



Deformation by slip.



(a)

(b)

Fig 5.2 slip in a single crystal

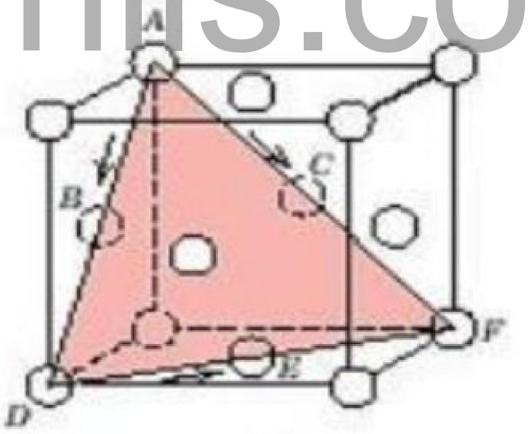


Fig 5.3 A slip plane for crystal

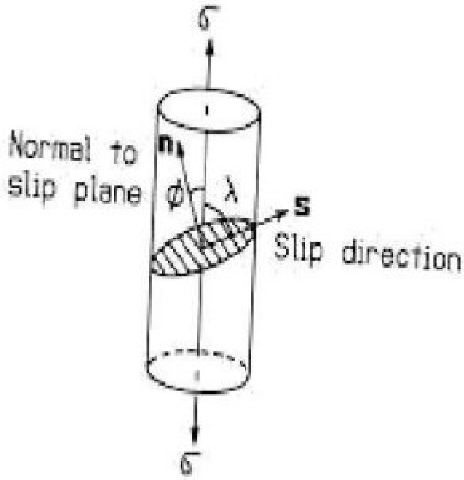


Fig 5.4 Critical resolved shear stress for slip

2.DEFORMATION BY TWINNING :

In addition to slip, plastic deformation is some materials occur by the formation of mechanical twins known as twinning. A shear force can produce atomic displacements such that on an one side of a plane, atoms are located in mirror image positions of atoms on the other side. The amount of movement of each plane of atoms in the twinned region is proportional to the distance from the twinned plane, so that a mirror image is formed.

Types of Twinning :

Mechanical Twinning

Annealing Twinning

Mechanical twinning occurs in metals that have BBC and HCP crystal structures at low temperatures and at high rates of loading. Annealing Twinning are more common in FCC metals.

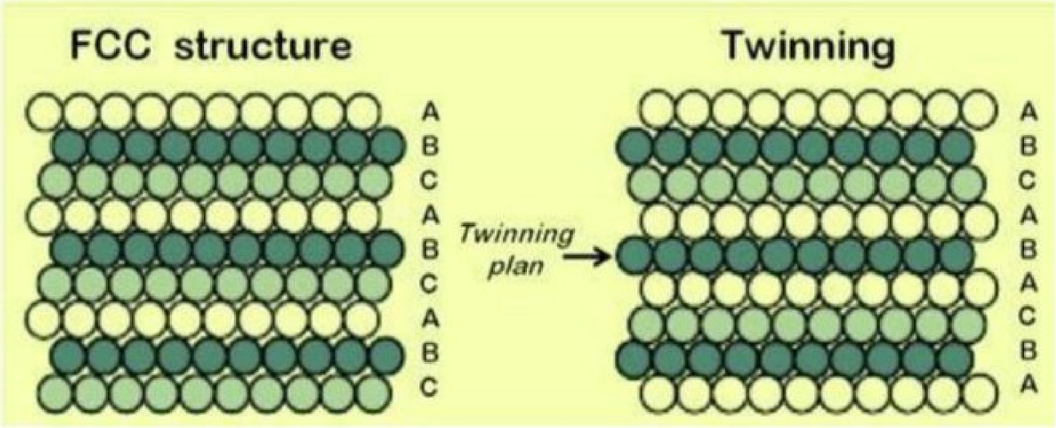


Fig 5.5 Twinning process

5.5 DIFFERENCES BETWEEN SLIP AND TWINNING :

Slip	Twinning
1. It appears as thin lines	It appears as broad lines
2. It occurs at low rates of loading	It occurs at high rates of loading
3. All atoms in one block move the same distance	Atoms in each successive plane within a block move different distance
4. There is a little change in lattice orientation	There is a great change in lattice orientation
5. It occurs along a single plane called the "slip plane"	It occurs between two planes called the "twin plane"

5.6 TYPES OF FRACTURE :

Fracture is the separation of a body into two or more parts under stress. The applied stress may be tensile, compressive, shear or torsional.

Fracture are classified into two types :

Brittle Fracture
Ductile Fracture

Brittle Fracture :

It process involves two steeps crack formation and propagation. The mode of fracture is highly dependent on mechanism of crack propagation.

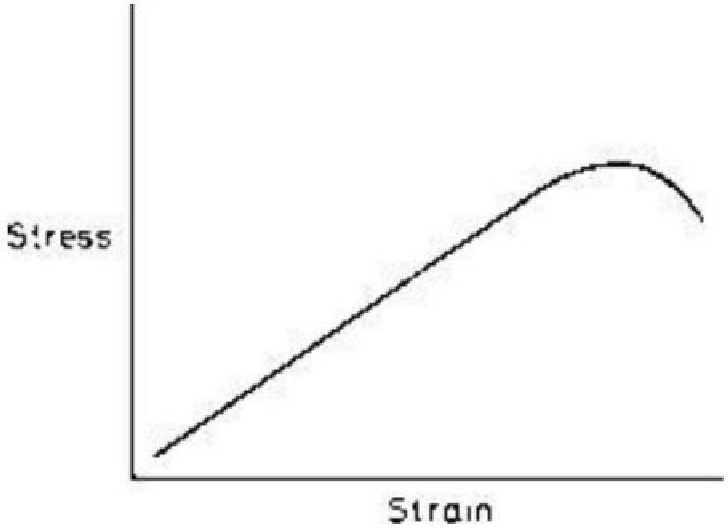


Fig 5.6 Brittle Fracture

Brittle fracture takes place without any deformation and by rapid crack propagation. In single crystals, brittle fracture occurs by fracture along a particular crystallographic planes. The failure in brittle materials was caused by many micro or fine elliptical cracks in the metal. Brittle Fracture it may occur in boilers, ships, airplanes and pipe lines.

2. Ductile Fracture :

It is a plastic deformation in the crack propagations. Strain energy is required high.

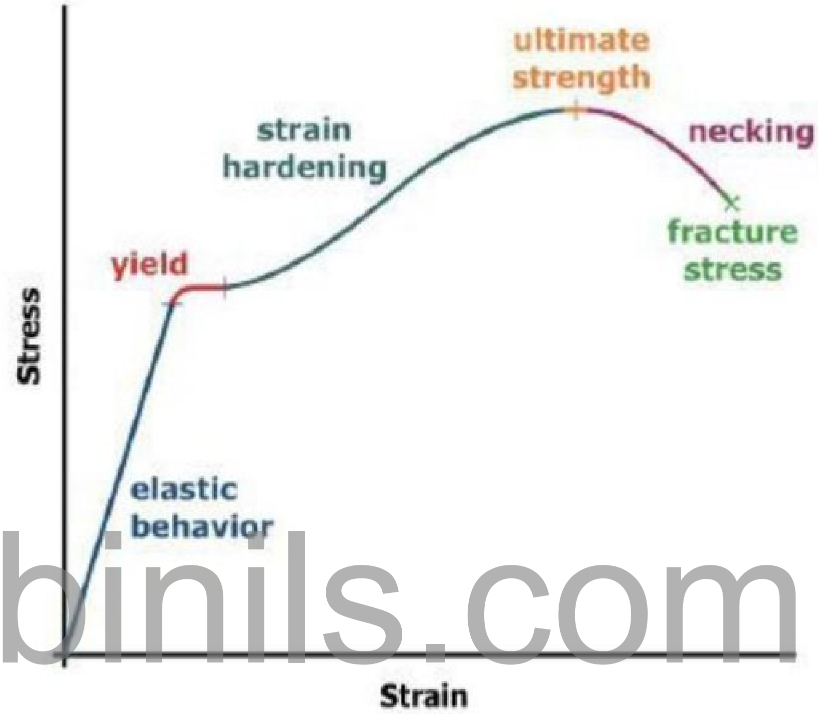


Fig 5.7 Stress strain curve for Ductile Fracture

Ductile Fracture (Cup and Cone) :

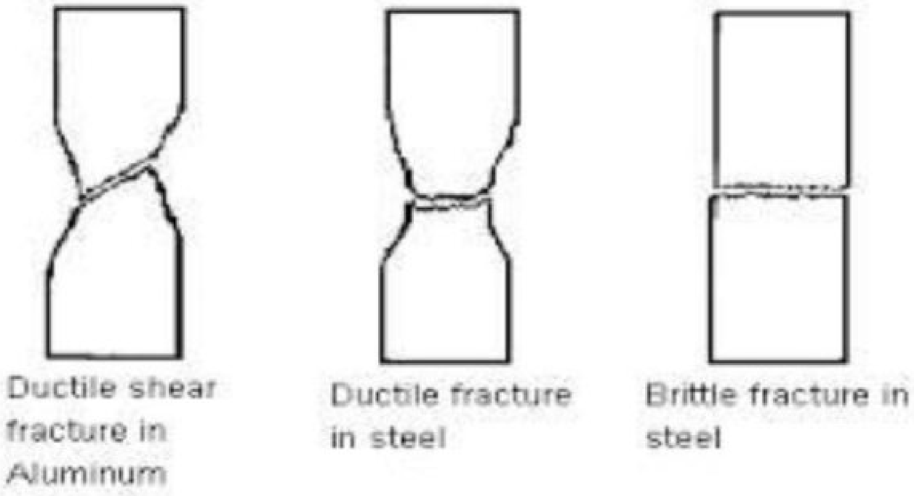


Fig 5.8 Ductile Fracture for Cup and cone

→ Neck Formation

→ Formation of crack

→ Propagation of crack

→ Final shear fracture at an angle 450 to the tensile direction.

Under tensile load, the neck formation first takes place. After necking, small cavities are formed. Next, as deformation continuous, the crack continuous to grow in a direction parallel to its major axis. Finally fracture occurs by the neck by shear fracture at an angle 45° to the tensile direction. A factor having this type of surface countour is termed as cup and cone fracture because one of the mating surfaces is in the form of a cup, the other is like a cone.

5.6.1 COMPARISON BETWEEN BRITTLE AND DUCTILE FRACTURE:

Brittle Fracture	Ductile Fracture
1. It occurs with negligible plastic Deformation	It occurs with large plastic deformation
2. Crack propagation rate is rapid	Crack propagation rate is slow
3. It follows the grain boundaries	It occurs through the grains
4. There is failure due to direct axial stress	There is failure due to shear stress.
5. It is characterized by the separations of normal to tensile stress.	It is characterized by the formation of cup and cone
6. The tendency of brittle fracture is increased with decreasing temperature and increasing strain rate.	The tendency of ductile fracture is increased with dislocations and other metal defects
7. Materials that undergo brittle fracture are glass, ceramics etc.	Materials that undergo ductile fracture are mild steel, brass etc.

Fracture of a material by cracking may occur in many ways :

They are :

Slow application of external loads (tension).

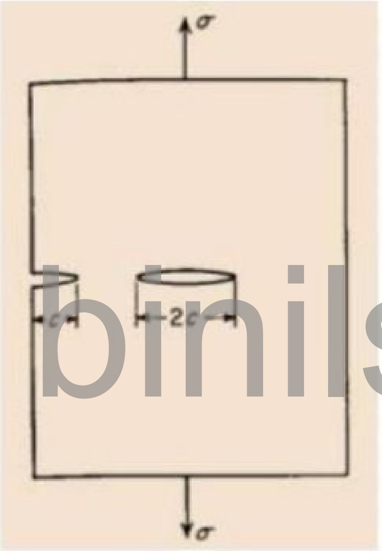
Rapid application of external loads (Impact).

Repeated cyclic loading (Fatigue).

Time and temperature dependent failure under a constant load(creep).

5.7 Griffith Theory :

Griffith theorized that the failure in brittle materials was caused by the many micro or fine elliptical cracks in the metal.



5.8 TESTING OF MATERIALS :

Tension Test

Compression Test

Shear Load Test

1.Tension Test :

One of the most useful tests applied to metallic materials is the tensile test.

The test is conducted at room temperature by applying a gradual increasing tensile load to a standard test specimen.

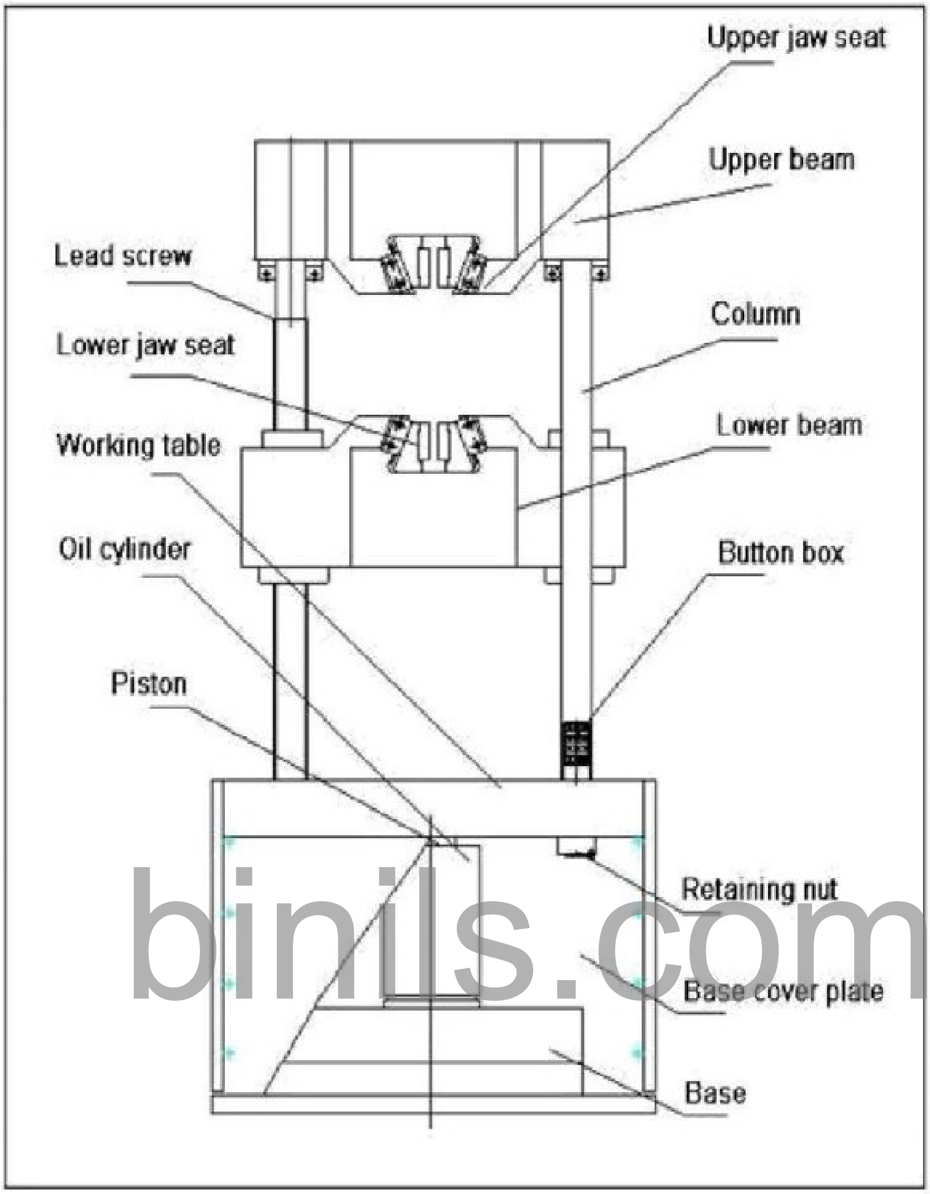


Fig 5.9 Universal Testing Machine

To conduct the test, the specimen is gripped between fixed and movable headers of universal testing machine.

In the test , load is increased gradually and corresponding stress –strain diagram is obtained with the aid of instrument , attached to the machine.

Stress –Strain diagram :

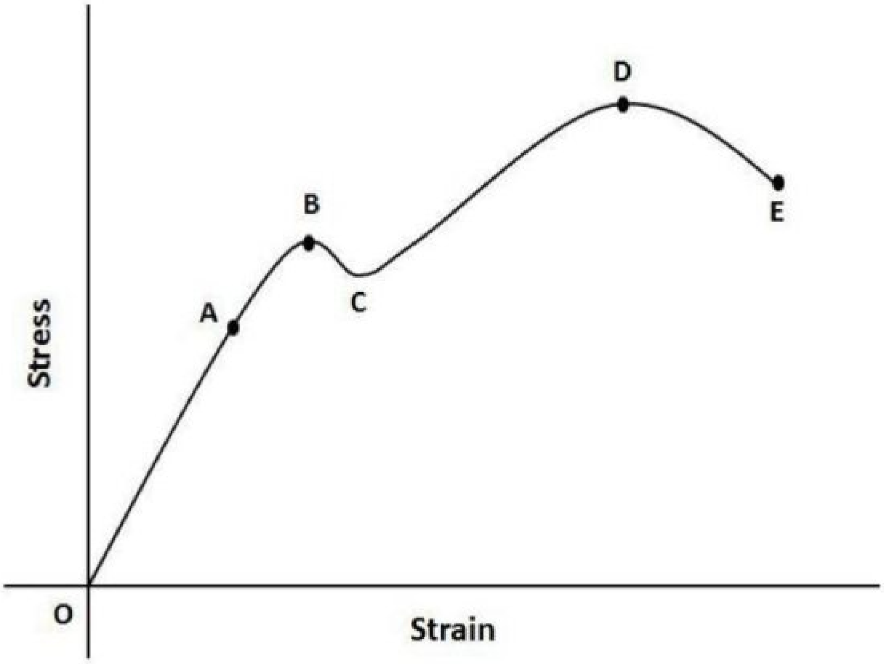


Fig 5.10 Stress-strain diagram for Tension test

A- Proportional

B- Elastic limit

C- yield point

D- tensile strength

E- Fracture

Proportional limit :

It is the maximum stress at which strain is directly proportional to the stress.

Elastic limit :

It is the maximum stress at which the specimen is deformed without fracture, under tensile load .

Yield point :

It is the minimum stress at which the specimen is deformed without an increase in load.

Tensile strength :

It is the maximum stress that a material can with stand, without fracture, under tensile load

3. Comprehension Test :

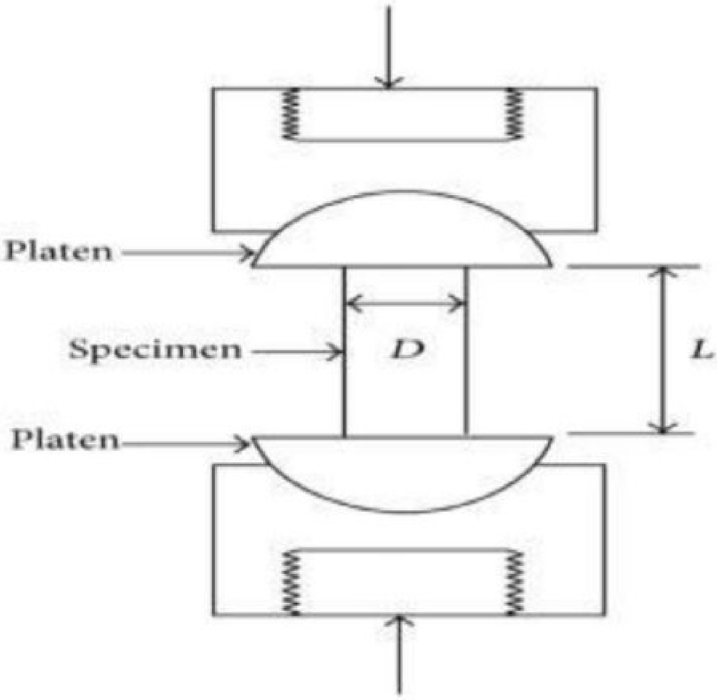


Fig 5.11 Compression test diagram

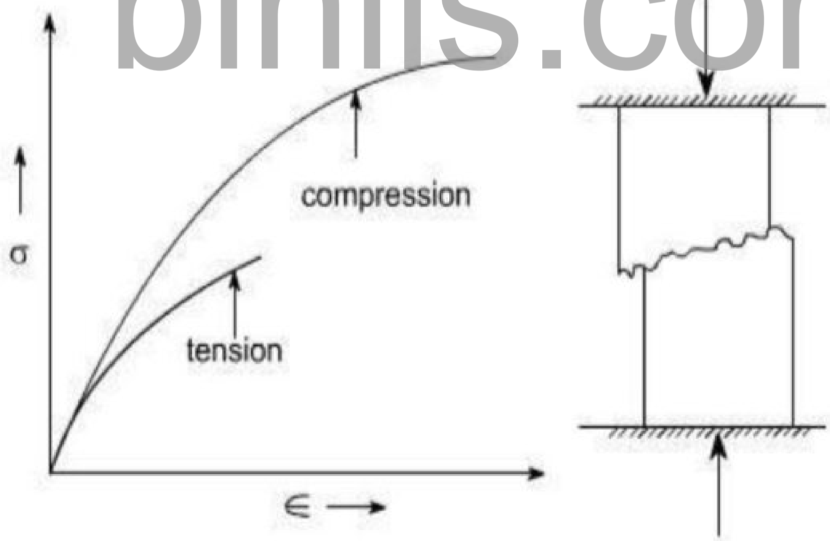
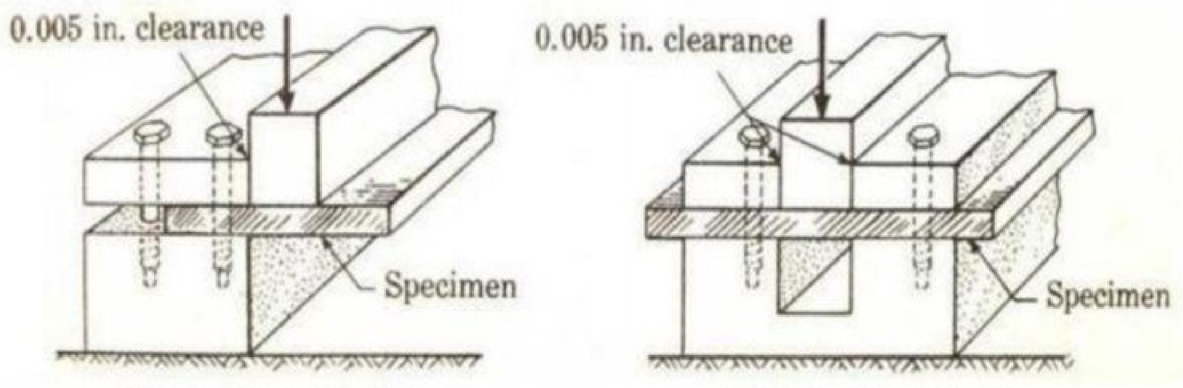


Fig 5.12 Stress strain curve for compression test

The comprehension test reverse the direction of the forces used in the tension test. In this test the stress increases rapidly hear the end of the test, due to an increase in area of the specimen. The specimen selected depends upon the metal being tested. To determine compressive properties a specimen is usually chosen in which the length is three times the diameter.

4. Shear test:



Single Shear Testing

Double Shear Testing

Fig 5.13 Shear test

Shear strength is the force required per unit area to produce fracture when impressed vertically upon the cross-section of a material. The methods of testing both single and double shear strength.

The percentage elongation (8) :

It is defined as the radio of the increase in the length of the specimen after fracture to its initial gauge length, expressed in percent.

$$\delta = \left(\frac{l - 10}{10} \right) \times 100$$

l- length of the specimen after fracture× 10-gavge length

The percentage reduction in area (Φ) :

It is defined as the ratio of reduction in area of the necked portion of the fractured expressed in percent.

$$\Phi = \left(\frac{A_0 - A_7}{A0} \right) \times 100$$

A_7 – cross –section area at fracture

A_0 – Initial cross –section area.

The percentage reduction in area and the percentage elongation are the two parameters to measure the ductility of the metal.

Stress – Strain diagram for various materials :

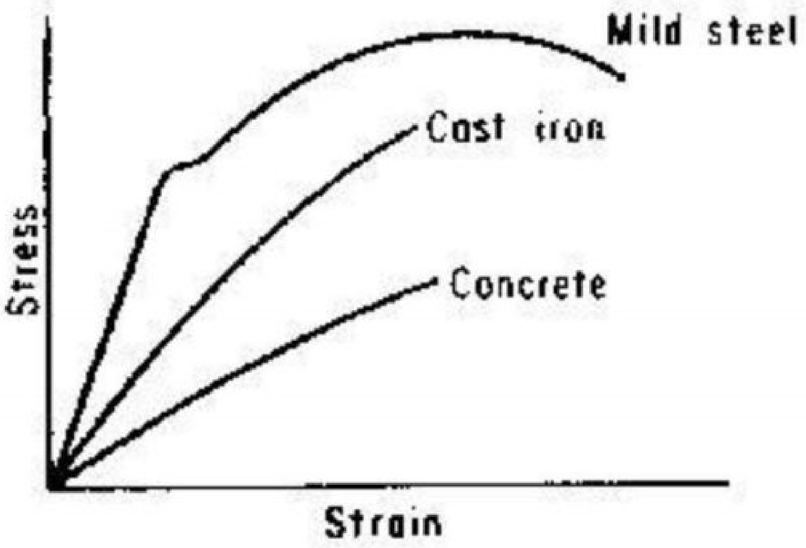


Fig 5.14 Stress-strain diagram for various materials

Shear strength may be calculated as the amount of force needed to make the shear over a given cross – sectional area.

Shear strength =

In double shear, the force and the area are doubled, resulting in the same shear strength.The shear stress is defined as the valve of load applied tangentially to same shear it off across the resisting section.

$$\text{Shear stress} = \tau = \frac{F}{A_0} \qquad \text{Shear strain, } \gamma = \tan\theta$$

F → Shear force applied along the upper and lower forces.

A_0 → Area of shear.

5.9 HARDNESS TESTS :

It is defined as the resistance to indentation. In this method of measuring the hardness. In this method of measuring the hardness of metals is by determining the resistance offered to the indentation.

They are three types of hardness test :

Brinell Hardness test
Rockwell Hardness test
Vicker's hardness test

Types of hardness are :

Indentation hardness
Rebound hardness
Screen hardness
Cutting hardness
Abrasive hardness

5.9.1 Brinell hardness Test :

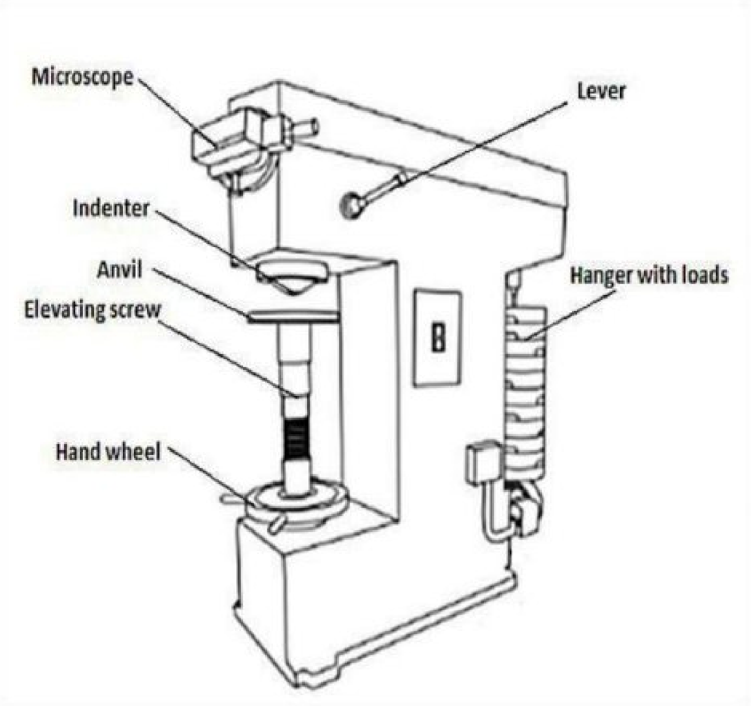


Fig 5.15 Brinell hardness testing machine

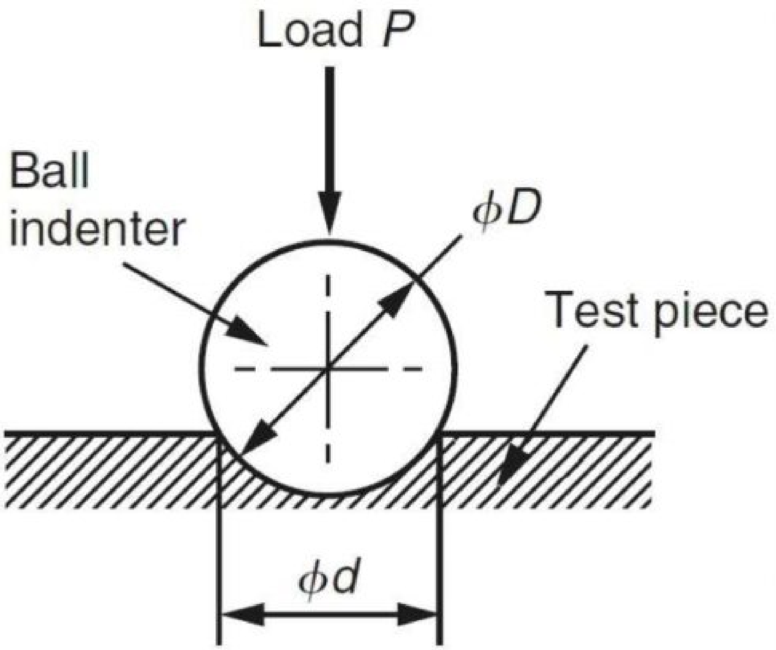


Fig 5.16 Brinell hardness test

Brinell hardness test was introduced by J.A Brinell in 1900. After polishing the surface the specimen is fixed on the plat form of hardness tester.

The test is carried out by pressing a hardened steel or tungsten carbide ball of 10mm diameter on the surface of the work piece.

A load of 3000 kg is applied for hard metals and a load of 500 kg for soft metals. Brinell Hardness number (BHN)

$$BHN = \frac{P}{A} = \frac{P}{\frac{\pi D}{2}\left(D - \sqrt{D^2 - d^2}\right)}$$

P →Load applied kgf,

D→Diameter of ball, mm

d→Diameter of the Impression, mm

A→Surface area of indentation

Limitations of Brinell test :

Size of impression is large

Not suitable for hard thin pieces

case – hardened parts

Testing metals of low and medium hardness

5.9.2 ROCKWELL HARDNESS TEST :

The principle of Rockwell test differ from that of the others. In that the depth of the impression is related to the hardness rather than the diameter of the diagonal of the impression

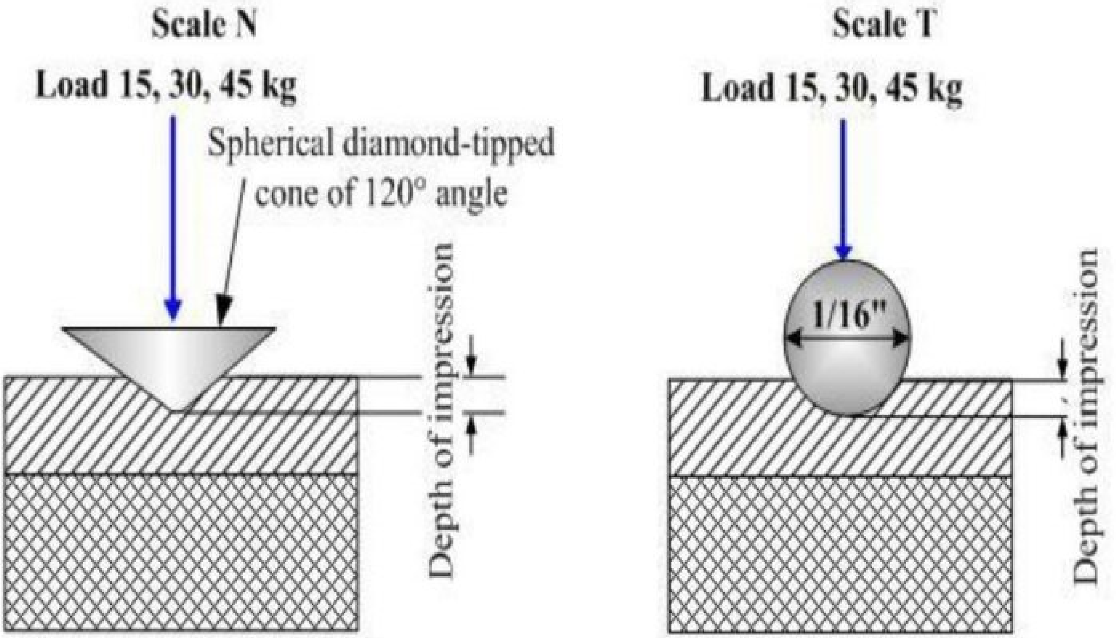


Fig 5.17 Rockwell Indenter

The Rockwell test uses a steel ball or a diamond cone with 120^0 apex angle.

It has a dial with different scales to read hardness numbers directly.

Rockwell B scales directly.

Rockwell C scales used for soft materials

Rockwell C scales used for hard material

It is more flexible

1/16 inch hardened steel ball load t 100 kg

Diamond cone ball load at 150 kg

5.9.3 VICKER HARDNESS TEST :

The vicker hardness is similar to the brinell test with a square based diamond pyramid being used as the indentor.

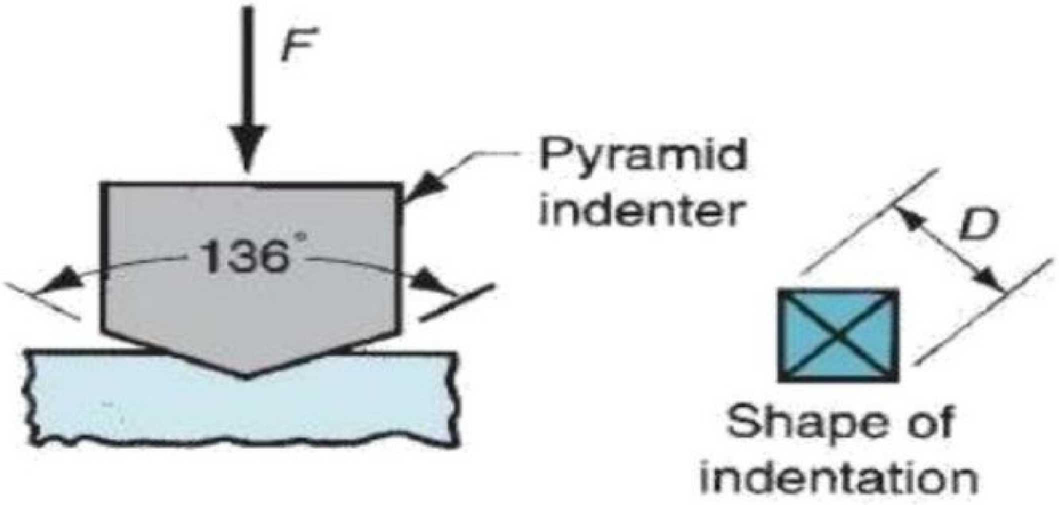


Fig 5.18 Vickers indenter and impression

$$\text{VHN} = \frac{\mathit{Appliedload}}{\mathit{surface\ area\ of\ impression}} \quad \frac{2P\ Sin}{\underline{\alpha}\ D_2}\ /2$$

$$\text{VHN} = \frac{1.854P}{D^{\ 2}} \qquad \theta = 136^0$$

It has an angle of 136^0 between opposite faces.

It is very suitable for testing polished and hardened materials with greater precision in measurement

It is more expensive than Rockwell and Brinell hardness machines.

Diamond square pyramid load at 30 kg

5.10 IMPACT TEST :

Impact test are classified into two types:

Izod Impact test

Charpy Impact test

Impact test is performed to study the behaviour of materials under dynamic load (i.e.) suddenly applied load. The capacity of the material to withstand blows without fracture is known as impact strength or impact resistance. The impact test indicates the toughness of the material, the ability of a material to absorb energy during plastic deformation. Toughness is a measure of both strength and ductility of the material.

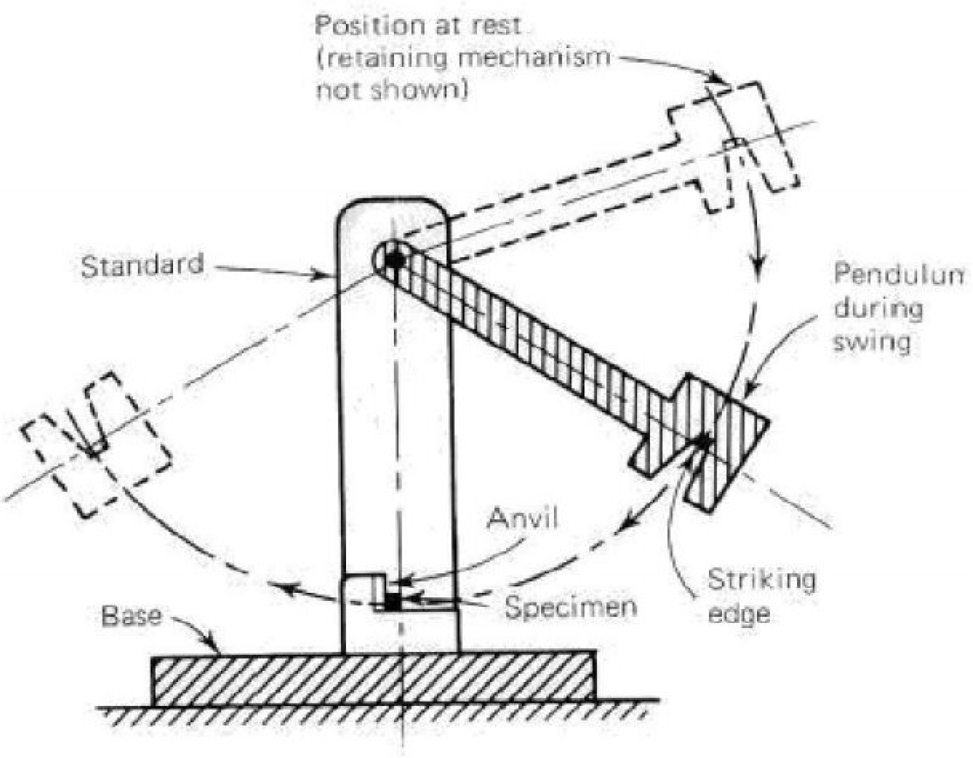


Fig 5.19 Impact Testing Machine

5.11 FATIGUE TEST :

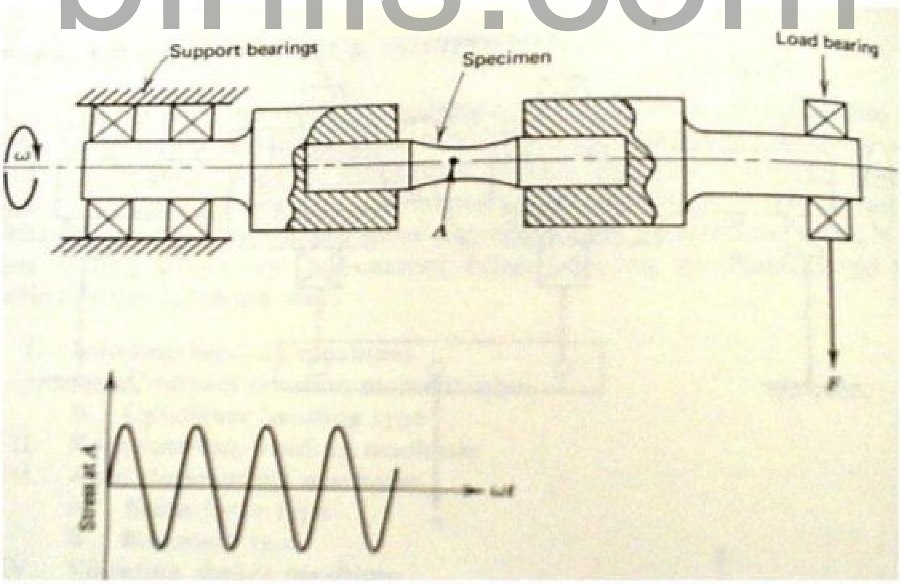


Fig 5.20 Rotating beam fatigue testing machine

When a material is subjected to repeated stress, it fails at stress below the yield point, stresses , such type of failure of a material is known as fatigue.

The capacity of material to with stand repeatly applied stresses.

An electric motor capable of running at 10,000 rpm

A large bearing whose purpose is to relieve the motor from the large bending moment which is applied to the specimen

Collect chucks to hold the specimen

Revolution counter to count the number of revolution.

A rotating lever arms which is subjected to a downward force in order to give bending moment to the specimen.

The specimen is in the form of a cantilever and loaded at one end through a ball bearing.

The upper surface of the specimen is under tension and lower surface of the specimen is under compression.

5.12 S-N CURVE :

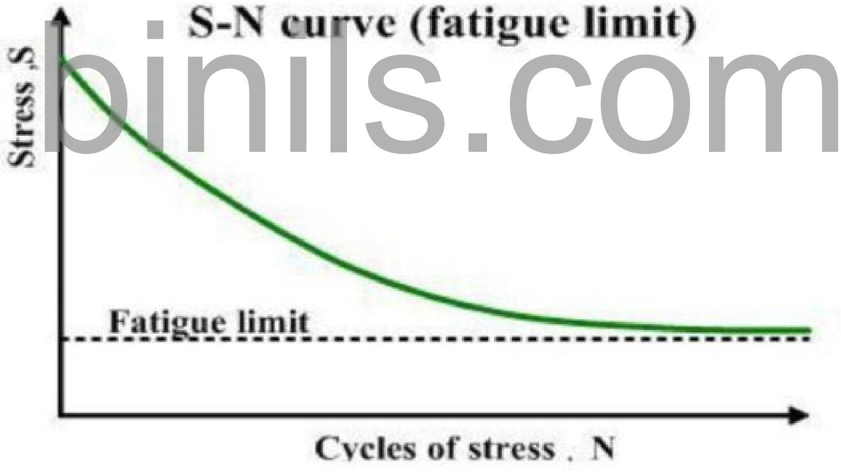


Fig 5.21 S-N Curve

where,

S → Stresses

N → Number of revolutions

Several specimens are tested one by one above, at gradually decreasing stress levels. The number of cycles to failure in each is noted. The results are presented as a graph, with the stress level (S) plotted versus the number of cycles to failure. Such as plot is known as S-N curve.

Two important information are obtained from S-N curve :

Endurance limit

Fatigue life

i) Endurance limit:

It is defined as the maximum stress that can be applied repeatedly for infinite number of times without failure of the material.

ii) Fatigue life:

It tells how long a component survives at a particular stress level.

5.13 CREEP TEST :

The continuous deformations of a metal under a steady load is known as creep. When a material is subjected to static loads at higher temperatures for a long period, the materials deforms under stresses well below the yield strength.

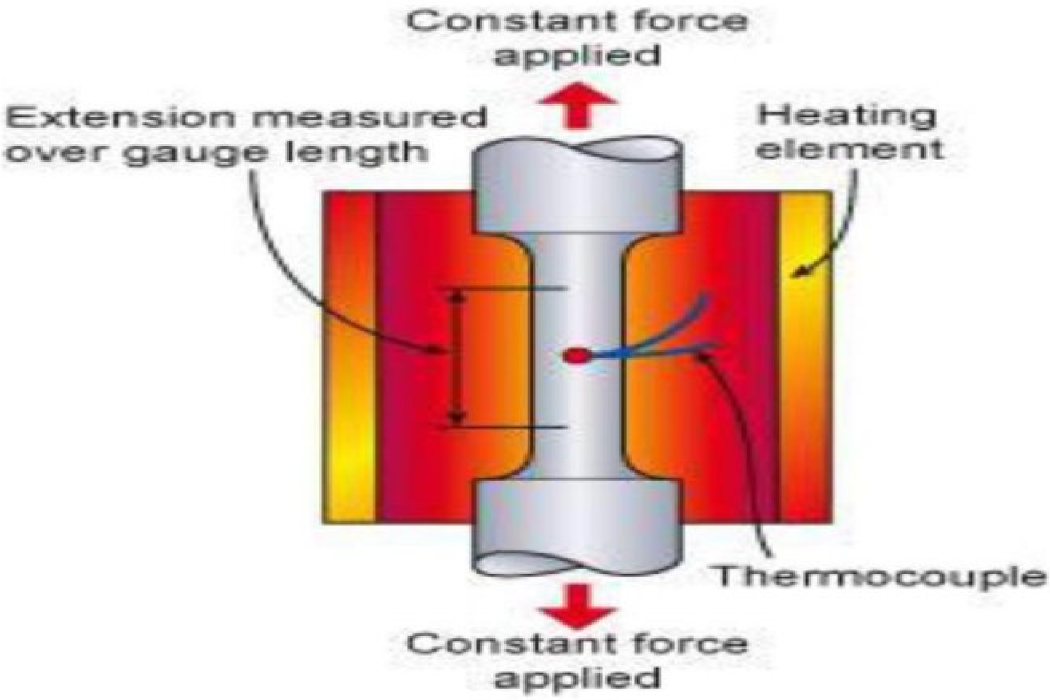


Fig 5.22 Creep test

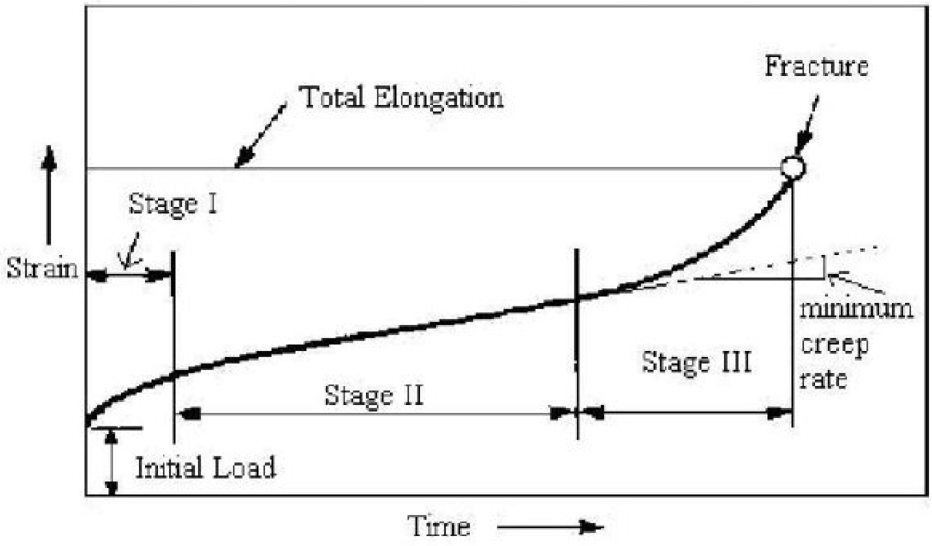


Fig 5.23 Creep curve

The specimen is subjected to a constant load by means of dead weights and levers. A tubular, electrically heated furnace surrounds the specimen. The ends of the specimen are sometimes fitted with thermo couple for the measurement of temperature or to maintain a constant temperature. The total creep or percentage elongation can be measured by an extensometer and the percentage elongation is plotted against time for the entire duration of the test.

Primary creep:

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

Secondary creep :

During this stage, the rate of work hardening and recovery are equal. So the material creep at steady rate.

Tertiary creep :

In this stage, creep rate increases with time until fracture occurs. Generally the tertiary creep occurs. Generally the tertiary creep occurs due to necking of the specimen or grain boundary sliding .Creep curve is plotted between strain and time in hours.

Factors affecting creep :

Grain size

Thermal stability of micro structure

Chemical reaction

Prior strain.

UNIT – 5:

MECHANICAL PROPERTIES AND DEFORMATION MECHANISMS

PART: A

1. Define the term elasticity and plasticity.

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.

Plasticity: It is the property of a material by virtue of which permanent deformation takes place, whenever it is subjected to the action of external force.

2. What are the factor affecting mechanical properties?

The numbers of factor affect mechanical properties, the following factors are:

Grain size
Heat treatment
Atmospheric exposure
Low and high temperature

Classify the different hardness testing methods. [N/D'16]

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

What are the different types of fracture?

5. Why impact specimen is notched?

The impact specimens are notched because the impact test also indicates the notch sensitivity of material.

6. Define creep.

Creep is defined as the slow and progressive deformation of materials with time under a constant stress at temperature approximately above 0.4 Tm.Where Tm is melting point of metal in ^{O}K.

7. Define endurance limit in fatigue test.

The value of limiting stress below which a load may be applied repeatedly for an indefinitely large of time is called as endurance limit for fatigue test.

Define toughness, modulus of toughness and ductility.

Toughness is the total amount of energy absorbed by a materials before its failure.

Modulus of toughness is the total energy absorbed by the materials before failure per unit volume. MOT = TOUGHNESS / VOLUME.

Ductility is the ability of a material to undergo plastic deformation under tensile loading before fracture.

9.Distinguish between slip and twinning

It is defined as the shear transformation, which moves the atoms over a number of interatomic distances relative to their initial position.

It is the plastic deformations which takes place along two planes due to set of forces acting on a given metal.

b

10. Distinguish between elasticity and plasticity. [M/J'16]

Elasticity	plasticity
Deformation disappears when external load is removed	Permenant deformation occurs.
Obeys hook's law	Does not obey hook's law

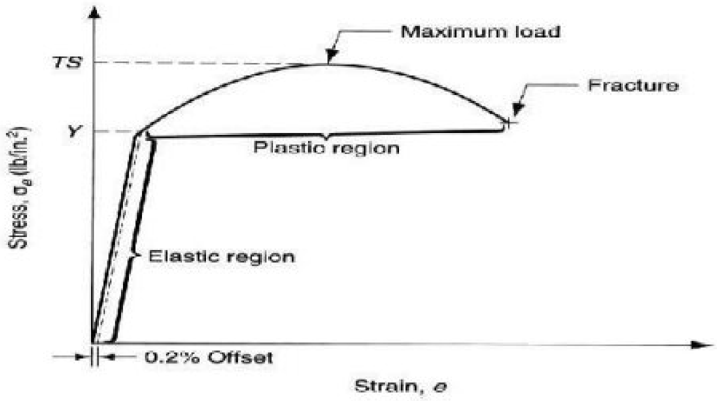
11. What are the factors affecting creep?

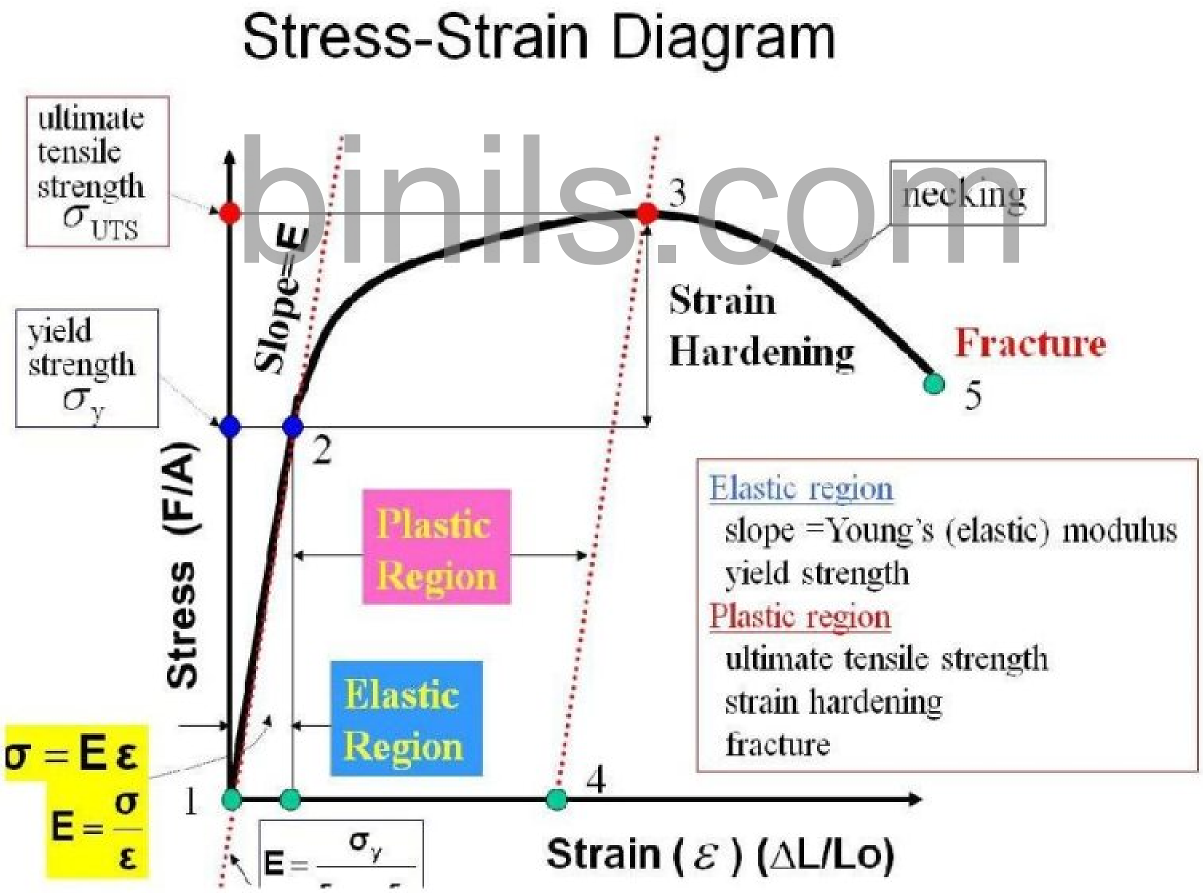
Grain size
Thermal stability
Chemical reaction
Prior strain

PART: B

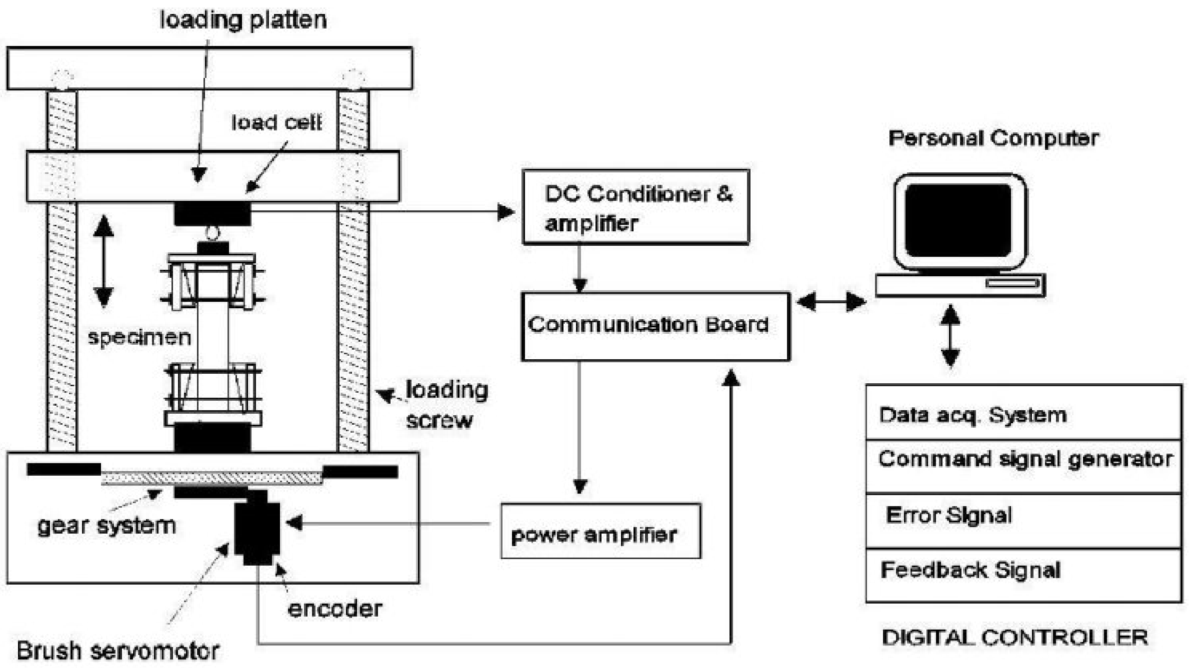
Explain the two modes of Plasticdeformation.Describe the working of universal testing machine with suitable diagram. [N/D'16]

- In a tensile test of mild steel specimen, usually a round or flat bar is gradually pulled in a testing machine until it breaks.
- Two points, called gauge points, are marked on the central portion. The distance between these points, before the application of the load, is called gauge length of the specimen.
- The Load is applied gradually and at regular interval of loads extension is measured.
- The strains corresponding to the recorded extensions are calculated by dividing the extensions by the gauge length, while the stresses are calculated by dividing the loads by the original area of cross-section of the specimen.
- Stresses so arrived at is called nominal stress to distinguish it from actual stress which is obtained by dividing the load at a particular instant by the area of the cross-section at that instant


Maximum load
TS
Fracture
Y
Plastic region
Stress, σ_e (lb/in.^{2})
Elastic region
0.2% Offset
Strain, e


Stress-Strain Diagram
ultimate tensile strength σ_{UTS}
yield strength σ_y
Slope=E
3
necking
Strain Hardening
Fracture
5
2
Stress (F/A)
Plastic Region
Elastic Region
Elastic region
slope =Young's (elastic) modulus
yield strength
Plastic region
ultimate tensile strength
strain hardening
fracture
$\sigma = E\varepsilon$
$E = \frac{\sigma}{\varepsilon}$
1
4
$E = \frac{\sigma_y}{}$
Strain (ε) (ΔL/Lo)

b



Write down the procedure for preparing Charpy and Izod specimens for impact testing and also explain how testing is performed? (N/D2009)

Impact Test

Impact Testing, ASTM E23 and IS/ BS Standard

The impact test is a method for evaluating the toughness and notch sensitivity of engineering materials. It is usually used to test the toughness of metals, but similar tests are used for polymers, ceramics and composites. Metal industry sectors include Oil and Gas, Aerospace, Power Generation, Automotive, and Nuclear.

The notched test specimen is broken by the impact of a heavy pendulum or hammer, falling at a predetermined velocity through a fixed distance. The test measures the energy absorbed by the fractured specimen.

Charpy Impact Test

A test specimen is machined to a 10mm x 10mm (full size) cross-section, with either a —V‖ or —U‖ notch. Sub-size specimens are used where the material thickness is restricted. Specimens can be tested down to cryogenic temperatures.

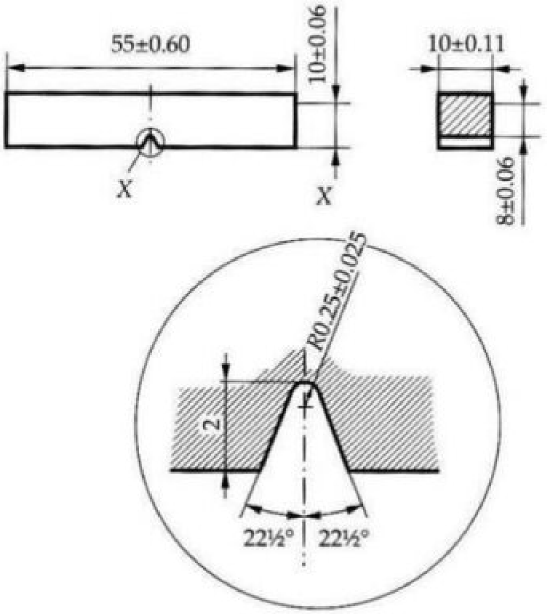
Izod Impact Test

The test specimen is machined to a square or round section, with either one , two or three notches. The specimen is clamped vertically on the anvil with the notch facing the Hammer.

Keyhole Impact Test

The steel casting industry uses this type of specimen more frequently. The notch is machined to look like a keyhole. It is tested in the same manner as the —V‖ and —U‖ notch.

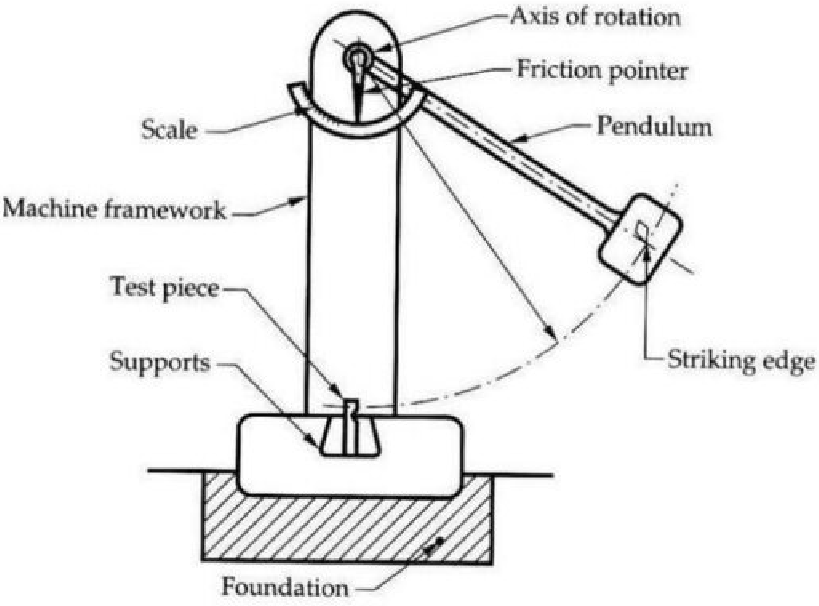
Charpy Impact TestPRINCIPLEThe Charpy impact test is a dynamic test in which a test piece U-notched or V-notched in the middle and supported at each end, is broken by a single blow of a freely swinging pendulum (Fig.1). The energy absorbed is measured. This absorbed energy is a measure of the impact strength of material.

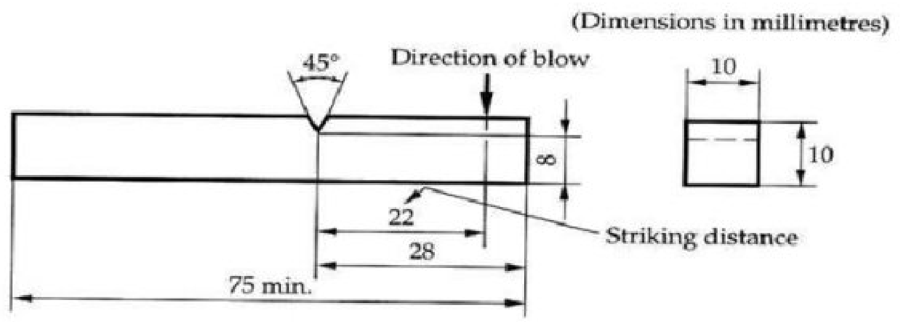


(b) Charpy V-notch impact test piece

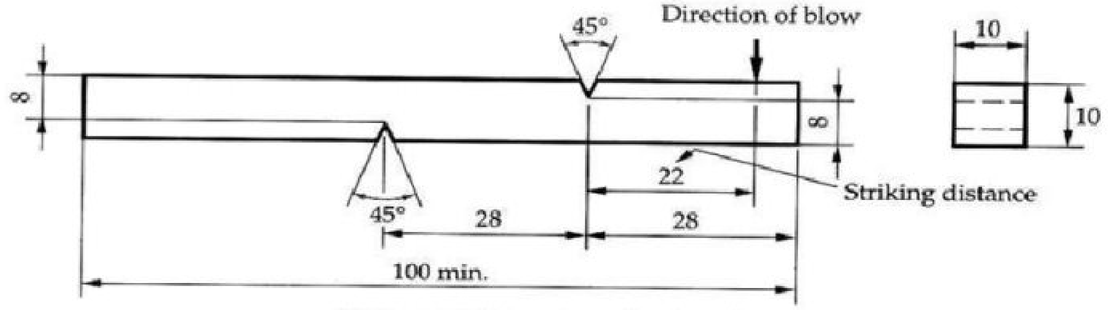
PRINCIPLE

The Izod impact test is a dynamic test in which a test piece V-notched test piece, gripped vertically, is broken by a single blow of a freely swinging pendulum (Fig.4). The blow is struck on the same face as the notch and at the fixed height above it. The energy absorbed is measured. This absorbed energy is a measure of the impact strength of material.





(a) Single-notch square section test piece



(b) Two-notch square section test piece

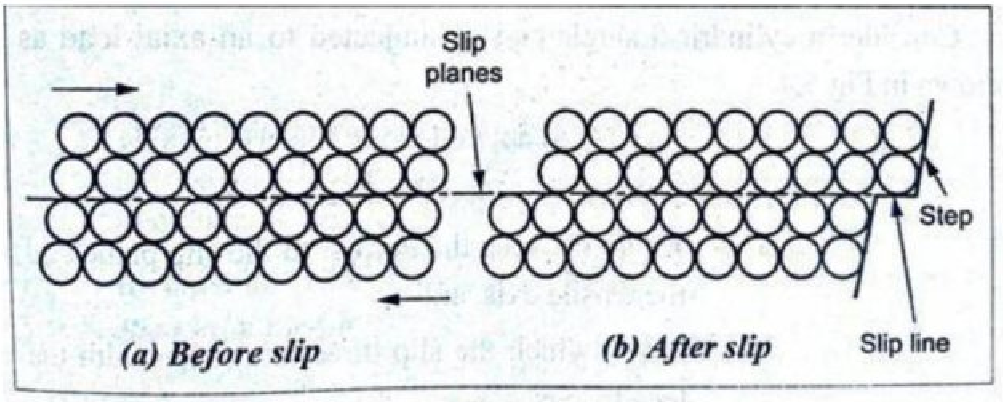
Explain the mechanism of plastic deformation by slip and twinning with neat sketch. [N/D’15]

Two modes of plastic deformation may occur. They are slip and twinning.

Slip:

Slip is defined as a shear deformation that moves atoms b y mass inter atomic distance in one crystal plane over the atoms of another crystal plane.The combination of a slip plane and slip direction is known as slip system.

This slip system for FCC lattice.



Mechanism of slip

b

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 surfaces of a deformed crystal under microscope shows of parallel lines which corresponded to steps on the surfaces. They are called as slip lines.

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.

Where , E – Young's modulus

L – length of dislocation line

G- Shear modulus

B- Unit slip vector

The energy required will be minimum when b vector and g are having the lowest valve.

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:

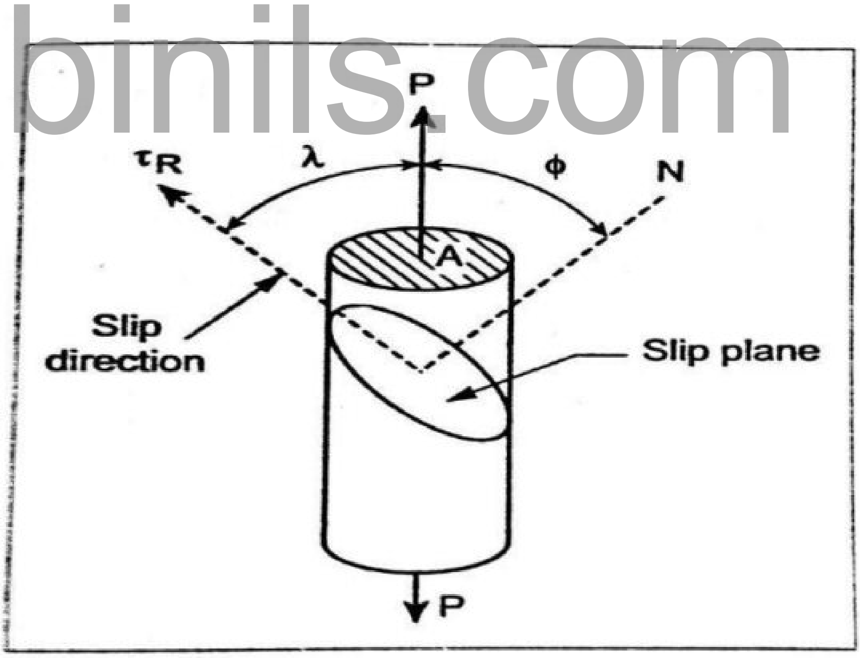


Fig 5.1

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

F – externally applied forces perpendicular to the cross sectional area.

A – Area of single crystal sample.

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

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

F – applied force along the crystal area

A – area of the crystal 197 Ø – angle between normal to slip plane and F

Angel between normal to the slip direction and F

A value of z to produce slip by dislocation motion is called as CRSS and is given by

Mechanical twins:

As a result of mechanical deformation of crystals, twins may occur and these twins that occur during mechanical deformation are called mechanical twin.

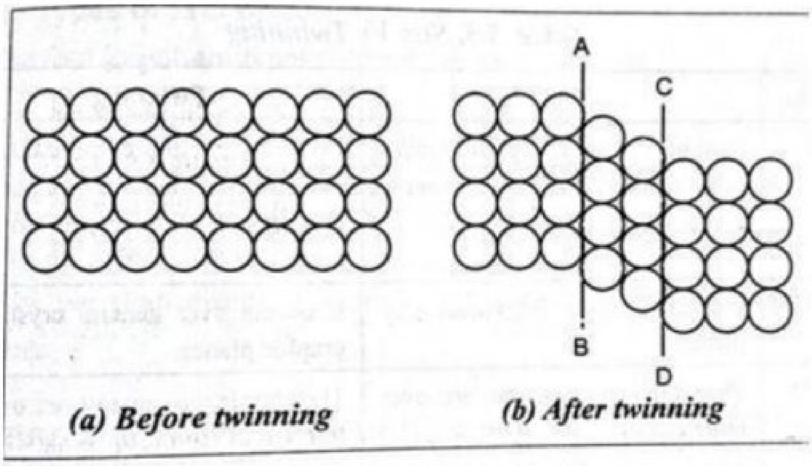
Annealing Twins:

The twins that are produced by annealing are called as annealing twins. Most of FCC metals form annealing twins.

Mechanism of Twinning :

In twinnig process, the movement of atoms is only a fraction of inter atomic distance. The circles indicating the arrangement of atoms. The line AB and CD represents the places of symmetry , from where the twinng starts and ends respectively. These planes are known as twinning planes.

Where



(a) Before twinning (b) After twinning

Mechanism of twinning

AB and the right of the twinning plane CD remain undisturbed. Where as in the twinned region each atom moves by a distance proportional to its distance from the twinning plane AB.The dark circular indicated the new position of the atoms.

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

Definition of twinning:

Twinning is that process by which a portion of the crystal takes up an orientation which makes that portion a mirror image of the parent crystal.

Twinning is the plastic deformation which takes place alone 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 inter atomic relative to its neighbor. The deformation of the crystal lattice caused by twinning.

Twinning planes:

The planes where the twinning almost takes place is known as twinning plane. These plane are also called as special planes.

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

Types of twinning:

There are two types of twins

a) Mechanical twins b) Annealing Twins

Difference between slip and twinning:

Slip :

Slip is associated with line defect.
Stress required to slip is less than in twinning.
Slip is move common in BCC and FCC metals.
The slipped portion has the same orientation.
Slip lines disappear after polishing the surfaces.
Slip takes several seconds to form.
During formation of slip level sound not heard.
The atomic movements are over large atomic distance.

Twinning :

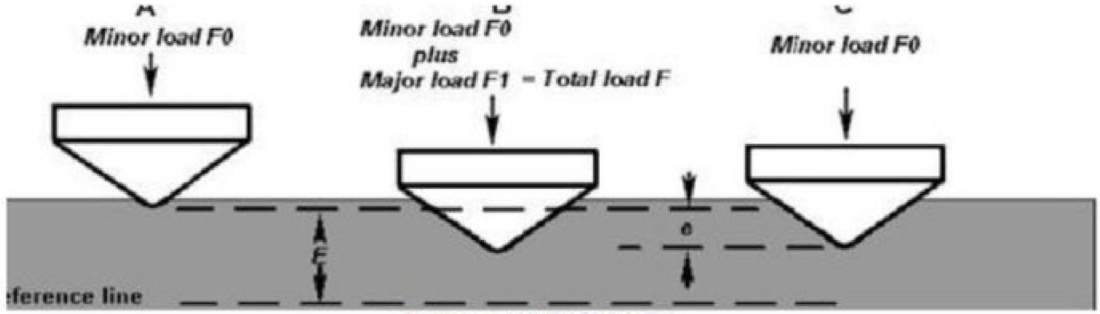
Twinning is higher than slip when stress produced.
Twinning is more common is HCP.
The twinning portion is s mirror image of original lattice.
Twin remain even after polishing the surface.
Twin can form in a few micro seconds.
During twin formation, a loud sound called twin cry can by heared.

Explain the testing procedure for determining the following properties.
Rockwell hardness test (8) [M/J'16]
Brinell hardness number (4)
(iii) Vickers hardness test (4)

Rockwell Hardness Test

The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel ball indenter. The indenter is forced into the test material under a preliminary minor load $F0$ (Fig. 1A) usually 10 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration (Fig. 1B). When equilibrium has again been reach, the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration (Fig. 1C). The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.

$HR = E - e$
$F0$ = preliminary minor load in kgf
$F1$ = additional major load in kgf
F = total load in kgf
e = permanent increase in depth of penetration due to major load F1 measured in units of 0.002 mm
E = a constant depending on form of indenter: 100 units for diamond indenter, 130 units for steel ball indenter HR = Rockwell hardness number D = diameter of steel ball



Rockwell Principle

Rockwell Hardness Scales

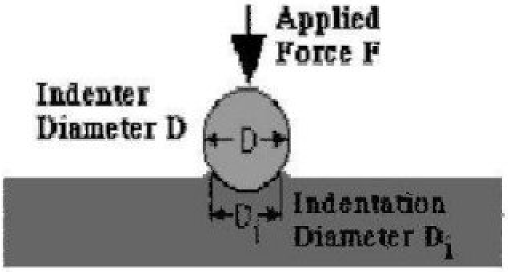
Scale	Indenter	Minor Load *F0* kgf	Major Load *F1* kgf	Total Load *F* kgf	Value of *E*
A	Diamond cone	10	50	60	100
B	1/16" steel ball	10	90	100	130
C	Diamond cone	10	140	150	100
D	Diamond cone	10	90	100	100
E	1/8" steel ball	10	90	100	130
F	1/16" steel ball	10	50	60	130
G	1/16" steel ball	10	140	150	130
H	1/8" steel ball	10	50	60	130
K	1/8" steel ball	10	140	150	130

Typical Application of Rockwell Hardness Scales

HRA . . . . Cemented carbides, thin steel and shallow case hardened steel
HRB . . . . Copper alloys, soft steels, aluminium alloys, malleable irons, etc
HRC . . . . Steel, hard cast irons, case hardened steel and other materials harder than 100 HRB
HRD . . . . Thin steel and medium case hardened steel and pearlitic malleable iron
HRE . . . . Cast iron, aluminium and magnesium alloys, bearing metals
HRF . . . . Annealed copper alloys, thin soft sheet metals
HRG . . . . Phosphor bronze, beryllium copper, malleable irons HRH . . . . Aluminium, zinc, lead
HRK . . . . }
HRL . . . . }
HRM . . . .} . . . . Soft bearing metals, plastics and other very soft materials
HRP . . . . }
HRR . . . . }
HRS . . . . }
HRV . . . . }

The Brinell Hardness Test

The Brinell hardness test method consists of indenting the test material with a 10 mm diameter hardened steel or carbide ball subjected to a load of 3000 kg. For softer materials the load can be reduced to 1500 kg or 500 kg to avoid excessive indentation. The full load is normally applied for 10 to 15 seconds in the case of iron and steel and for at least 30 seconds in the case of other metals. The diameter of the indentation left in the test material is measured with a low powered microscope. The Brinell harness number is calculated by dividing the load applied by the surface area of the indentation.

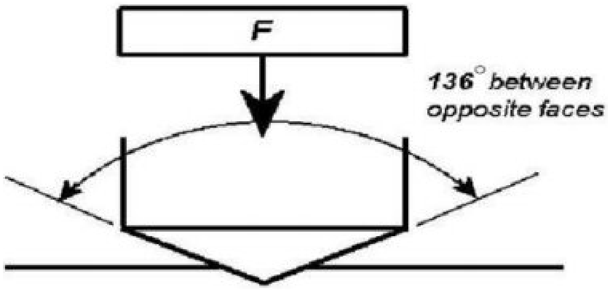


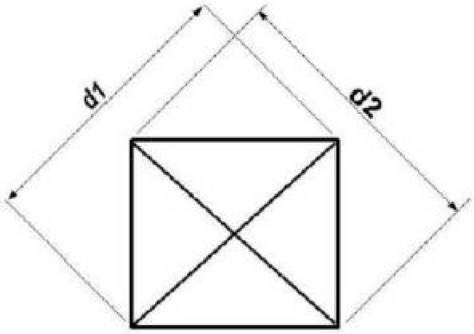
$$BHN = \frac{F}{\frac{\pi}{2} D \cdot \left(D - \sqrt{D^2 - D_i^2}\right)}$$

The diameter of the impression is the average of two readings at right angles and the use of a Brinell hardness number table can simplify the determination of the Brinell hardness. A well structured Brinell hardness number reveals the test conditions, and looks like this, —75 HB 10/500/30ll which means that a Brinell Hardness of 75 was obtained using a 10mm diameter hardened steel with a 500 kilogram load applied for a period of 30 seconds. On tests of extremely hard metals a tungsten carbide ball is substituted for the steel ball. Compared to the other hardness test methods, the Brinell ball makes the deepest and widest indentation, so the test averages the hardness over a wider amount of material, which will more accurately account for multiple grain structures and any irregularities in the uniformity of the material. This method is the best for achieving the bulk or macro-hardness of a material, particularly those materials with heterogeneous structures.

Vickers Hardness Test

The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 100 kgf. The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation.





F= Load in kgf
d = Arithmetic mean of the two diagonals, *d1* and *d2* in mm

b

HV = Vickers hardness

$$HV = \frac{2F\sin\frac{136^{o}}{2}}{d^{2}} \qquad HV = 1.854\frac{F}{d^{2}} \text{ approximately}$$

When the mean diagonal of the indentation has been determined the Vickers hardness may be calculated from the formula, but is more convenient to use conversion tables. The Vickers hardness should be reported like 800 HV/10, which means a Vickers hardness of 800, was obtained using a 10 kgf force. Several different loading settings give practically identical hardness numbers on uniform material, which is much better than the arbitrary changing of scale with the other hardness testing methods. The advantages of the Vickers hardness test are that extremely accurate readings can be taken, and just one type of indenter is used for all types of metals and surface treatments. Although thoroughly adaptable and very precise for testing the softest and hardest of materials, under varying loads, the Vickers machine is a floor standing unit that is more expensive than the Brinell or Rockwell machines.

There is now a trend towards reporting Vickers hardness in SI units (Mpa or Gpa) particularly in academic papers. Unfortunately, this can cause confusion. Vickers hardness (e.g. HV/30) value should normally be expressed as a number only (without the units kgf/mm2). Rigorous application of SI is a problem. Most Vickers hardness testing machines use forces of 1, 2, 5, 10, 30, 50 and 100 kgf and tables for calculating HV. SI would involve reporting force in newtons (compare 700 HV/30 to HV/294 N = 6.87 Gpa) which is practically meaningless and messy to engineers and technicians. To convert a Vickers hardness number the force applied needs converting from kgf to newtons and the area needs converting form $mm^2$to m^2 to give results in pascals using the formula above.

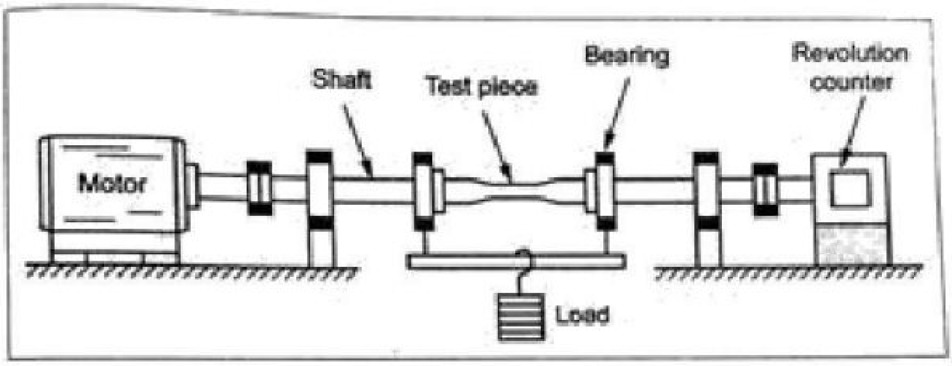
To convert HV to Mpa multiply by 9.807
To convert HV to Gpa multiply by 0.009807

PART-C

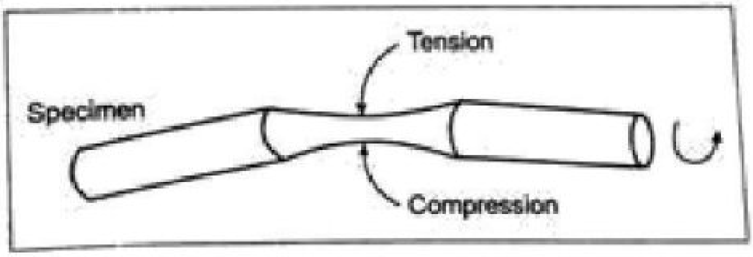
1.i) Sketch and describe the fatigue test.

Fatigue test:

The failure test of a material under repeatedly applied stress is called fatigue. Machine parts such as shaft, axles, pinion teeth etc are subjected to varying stresses, the loading may be either the same type of stress or change from tensile to compressive varying stresses can be classified into the following four types.



Rotating beam fatigue testing machine



Stress varying between two limits of equal valve, but opposite sign.
Stress between two unequal valves but opposite sign.
Stress between zero and a definite valve.
Stress between two limits of un equal valves but of same sign.

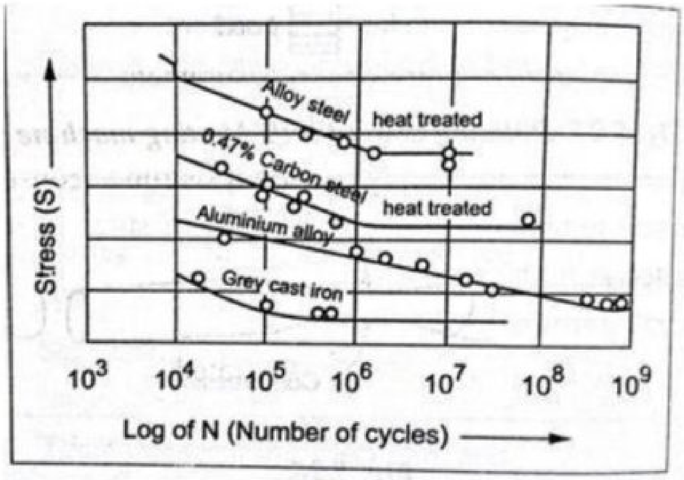
The specimen is loaded in pure bending are rotated with the help of a motor. In this case, with each rotation all the points on the circuimference of the specimen will alternate between tension and compression. Each resolution will have several of stresses and the speed to revolution of the motor will indicate the frequency of this reversal.

White doing the test, a number of test pieces are made from the same material. The first test pieces are made from is loaded on the machine and motor is started. Generally this load should not be less than that which can create a stress equal to ¾ of the tensile stress of the specimen. The speed of the shaft should be constant. After a number of cycles, it will be found that a crack will appear on the surface of the specimen in the form of a ring.

This will keep increasing until the specimen breaks. The second test piece is loaded and is tested with a decreased load. In the same way the test pieces are tested with the load being decrease each time. After some tests, a limit is reached where the stress is not enough to break the specimen even after 10x106 . This safe stress ie the stress which does not cause the piece to break is called the endurance limit or fatique limit.

b

Fatigue limit:



Fatigue test (S-N) curves

The fatigue limit test result are than plotted on a graph called s-n graph. This has the stress on the y axis and the number of cycles on the x axis.

There are two types of fatigue that is normally found by means of using this apparatus.

1. Low cycle fatigue 2. High cycle fatigue

Low cycle fatigue:

The specimen is subjected to very high loads which results in plastic and elastic deformation that finally results in failure of the specimen on repeated loading. High cycle fatigue:

The specimen is subjected to low loads which results in elastic deformation. The failure of specimen happens when number of cycles is greater than 10 5 cycles in logarithmic scale.

Differentiate between ductile fracture and brittle fracture.

A fracture is considered as a brittle one when it takes place with the minimum of plastic deformation and Very rapid crack propagation.It consists of destroying the inter atomic bonds with normal stresses.

In crystalline materialism the fracture takes place normal to specific crystallographic planes called cleavage planes.

Brittle fracture also occurs along the grain boundaries in poly crystalline materials.

Ductile fracture:

A ductile fracture can be defined as a fracture which is the result of intense localized plastic deformation of metal at the tip of the crack.

At elevated temperatures all fractures tend to become ductile because slip can occur more easily.

Ductile fracture is a less serious problem and compared to brittle fracture it is slow and occurs with the temperature of large amount of energy.

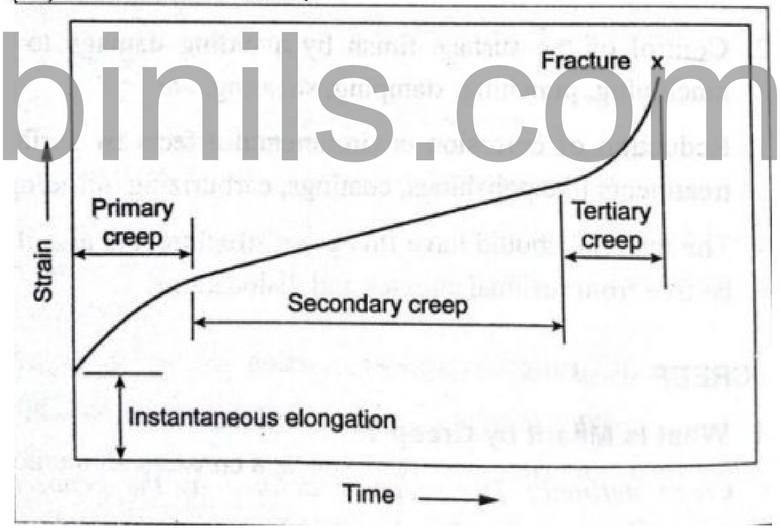
ii).Draw creep curve and explain the different stages of creep damage. [N/D'16]`

Creep is the slow and progressive deformation of a materials with time under a constant stress at a temperature approximately above 0.4 Tm.

Creep curve:

The creep is tested for a material by subjected the specimen at constant tensite stress at constant temperature and measuring the extent of strain or deformation with respect to time.

The three stages of elongation are
Primary (or) Transient creep
Secondary (or) Steady state creep
Tertiary (or) accelerated creep



Primary creep:

In this stage, strain hardening effect occurs and the deformation is slow at a decreasing rate for low melting temperature metal, primary creep is the predominant creep process.

Secondary creep:

In this stage, the creep is constant and the creep rate is constant. This is due to an equilibrium between the strain hardening effect and the annealing effect. Hence there is a balance between the strain hardening effect and the annealing effect which results steady state creep.

Tertiary creep:

b

In this the final stage of creep before fracture creep occurs rapidly due to decrease in cross sectional area and necking of the specimen occurs, the true stress increase rapidly.

During this stage, there is a progressive damage to the inter crystalline region by the formation of voids and severe oxidation of the metal. The material is unable to harden and finally fractures.