Lab Manual
on
Mechanics of Solids

PREPARED BY :

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LECTURER

DEPARTMENT OF ME (UGV)

COURSE INFORMATION

COURSE INFORMATION			
Course Title	Mechanics of Solids Sessional	Lecture Contact Hours	34
Course Code	ME 0715-2244		
PRE-REQUISITE	Solid Mechanics Theory, Metallic Materials theory	Credit Total Marks	01 50
		CIE SEE	20 30
		SEE exam time: 2 Hours	

By understanding the properties and behavior of metals through testing, industries can make informed decisions about their usage, leading to safer, more reliable products and structures.

Course Learning Outcomes (CLOs)

The learning outcomes that are expected to be attained by the student at the end of the course are

Sl. No.	CLOs	Domain of learning
1	**Understand** the concepts to develop a clear understanding of the theoretical concepts related to hardness, toughness, and tensile strength, including their definitions, significance, and interrelationships.	Cognitive
2	**Analyze** the experimental data to learn how to collect, analyze, and interpret experimental data to determine the mechanical properties of materials.	Psychomotor
3	**Apply skills to** Cultivate critical thinking and problem-solving abilities by troubleshooting experimental issues and analyzing results.	Psychomotor
4	**Evaluate** the limitations of the testing methods and suggest improvements	Psychomotor, Affective
5	**Manifest** the professional responsibilities and norms of engineering practice.	Affective

Course Learning Outcomes (CLOs)

The learning outcomes that are expected to be attained by the student at the end of the course are

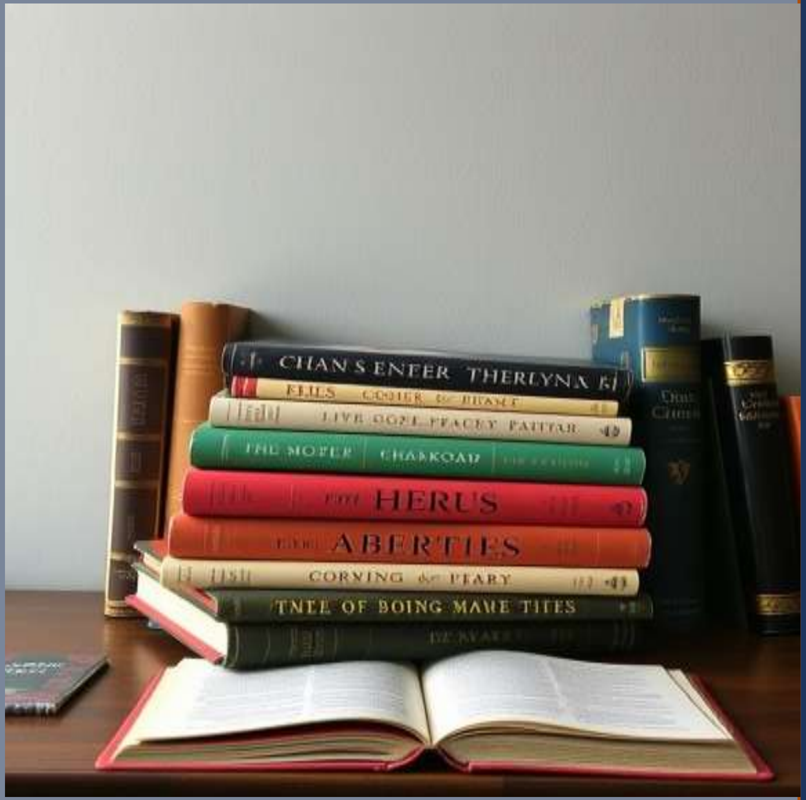
Sl. No.	Content	Hours	CLOs
1	Basic Introduction on Hardness, Toughness, Tension, Compression, Shear force, torsion and Mechanical Properties	04	CLO 1
2	Hardness Testing	08	CLO2, CLO3, CLO 4
3	Toughness Testing	08	CLO2, CLO3
4	Tension and Compression Testing	06	CLO2, CLO3, CLO 4
5	Torsion Testing	04	CLO2, CLO3, CLO 4
6	Practice, Review/Reserved Day, Lab Report Assessment, Self-study	04	CLO 2 CLO 4
7	Lab Test, Viva, Quiz, Overall Assessment, Skill Development Test (Competency)	During Sessional	CLO 1 CLO 3

REFERENCE BOOKS

"An Introduction to Solid Mechanics" by S. H. Crandall

"Introduction to Solid Mechanics" by James M. Pitarresi

"Mechanical Metallurgy" by George E. Dieter "Engineering Metallurgy by Dhanalakshmi Srinivasan



ASSESSMENT PATTERN

CIE- Continuous Internal Evaluation (20 Marks)
SEE- Semester End Examination (30 Marks)

SEE- Semester End Examination (50 Marks) (should be converted in actual marks (30)

Bloom's Category Cognitive	**Tests (20)**
Remember	**05**
Understand	**07**
Apply	**08**
Analyze	**07**
Evaluate	**08**
Create	**05**

Bloom's Category Psychomotor	**Practical Test (30)**
Imitation	10
Manipulation	5
Precision	5
Articulation	5
Naturalization	5

CIE- Continuous Internal Evaluation (40 Marks) (should be converted in actual marks (20)

Bloom's Category Marks (out of 60)	Lab Report (10)	Continuous lab performance (10)	Presentation & Viva (10)	External Participation in Curricular/Co-Curricular Activities (10)
Remember			02	Attendance 10
Understand	05	04	03	
Apply		02		
Analyze		02		
Evaluate	05	02		
Create			05	

Course Plan Specifying Content, CLOs, Teaching Learning Strategy and Assessment Strategy

Week	Topics	Teaching Learning Strategy	Assessment Strategy	Corresponding CLOs
1	Basic Introduction on Hardness, Toughness, Tension, Compression, Shear force, torsion and Mechanical Properties	Lecture, Oral Presentation	Quiz	CLO1
2	Rockwell Hardness Testing	Lecture, discussion, Video Presentation, Experiment	Lab Report Assessment, viva, Lab Test, Quiz	CLO2, CLO3, CLO 4
3	Brinell Harness Testing	Lecture, discussion, Video Presentation, Experiment	Lab Report Assessment, viva, Lab Test, Quiz	CLO2, CLO3, CLO 4
4	Practice on Rockwell and Brinell Hardness Testing	Group Discussion, Experiment Practice	Skill Development Test	CLO2, CLO3, CLO 4
5-6	Izod Impact Testing	Lecture, discussion, Video Presentation, Experiment	Lab Report Assessment, viva, Lab Test, Quiz	CLO2, CLO3
7	Charpy Impact Testing	Lecture, discussion, Video Presentation, Experiment	Lab Report Assessment, viva, Lab Test, Quiz	CLO2, CLO3
8	Practice on Impact Testing	Group Discussion, Experiment Practice	Skill Development Test	CLO2, CLO3

Course Plan Specifying Content, CLOs, Teaching Learning Strategy and Assessment Strategy

Week	Topics	Teaching Learning Strategy	Assessment Strategy	Corresponding CLOs
9	Tensile Testing	Lecture, discussion, Video Presentation, Experiment	Lab Report Assessment, viva, Lab Test, Quiz	CLO2, CLO3, CLO 4
10	Compression Testing	Lecture, discussion, Video Presentation, Experiment	Lab Report Assessment, viva, Lab Test, Quiz	CLO2, CLO3, CLO 4
11	Practice on Tensile and Compression Testing	Group Discussion, Experiment Practice	Skill Development Test	CLO2, CLO3, CLO 4
12-13	Torsion Testing	Lecture, discussion, Video Presentation, Experiment	Lab Report Assessment, viva, Lab Test, Quiz	CLO2, CLO3, CLO 4
14-15	Practice, Review/Reserved Day, Lab Report Assessment, Self-study	Group Discussion, Experiment Practice	Skill Development Test	CLO 2 CLO 4
16-17	Lab Test, Viva, Quiz, Overall Assessment, Skill Development Test (Competency)	Group Discussion, Experiment Practice	Skill Development Test	CLO 1 CLO 3

Indexing

Week - 1

Mechanical Properties of Metal

MECHANICAL PROPERTIES:

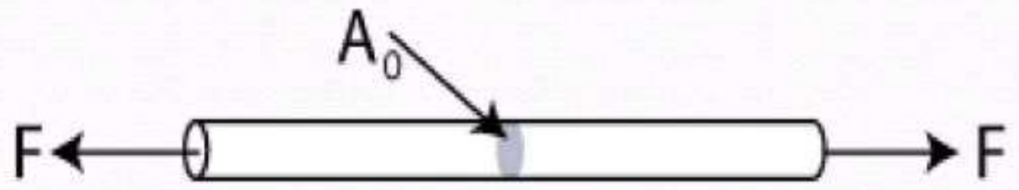
- The properties of material that determine its behaviour under applied forces are known as mechanical properties.
- They are usually related to the elastic and plastic behaviour of the material.
- These properties are expressed as functions of stress-strain,etc.
- A sound knowledge of mechanical properties of materials provides the basis for predicting behaviour of materials under different load conditions and designing the components out of them.

STRESS AND STRAIN

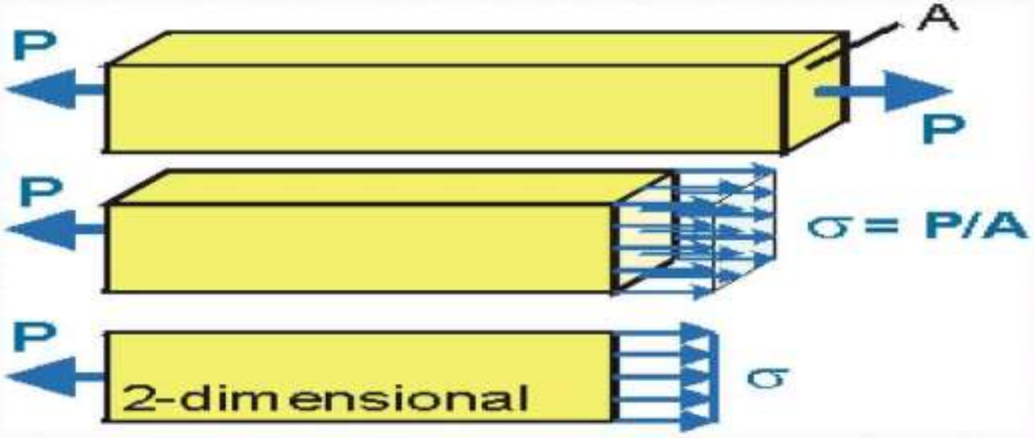
- Experience shows that any material subjected to a load may either deform, yield or break, depending upon the
  - The Magnitude of load
  - Nature of the material
  - Cross sectional dime.

CONTI..

- The sum total of all the elementary interatomic forces or internal resistances which the material is called upon to exert to counteract the applied load is called stress.
- Mathematically, the stress is expressed as force divided by cross-sectional area.

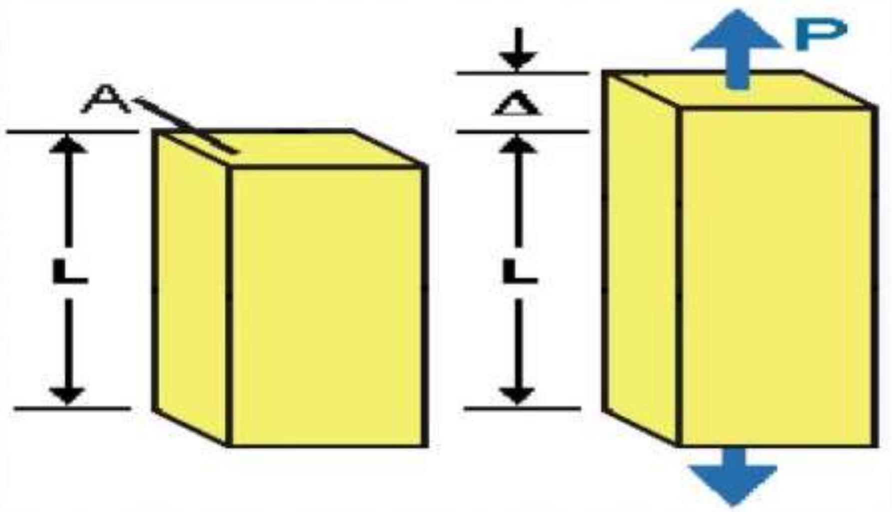


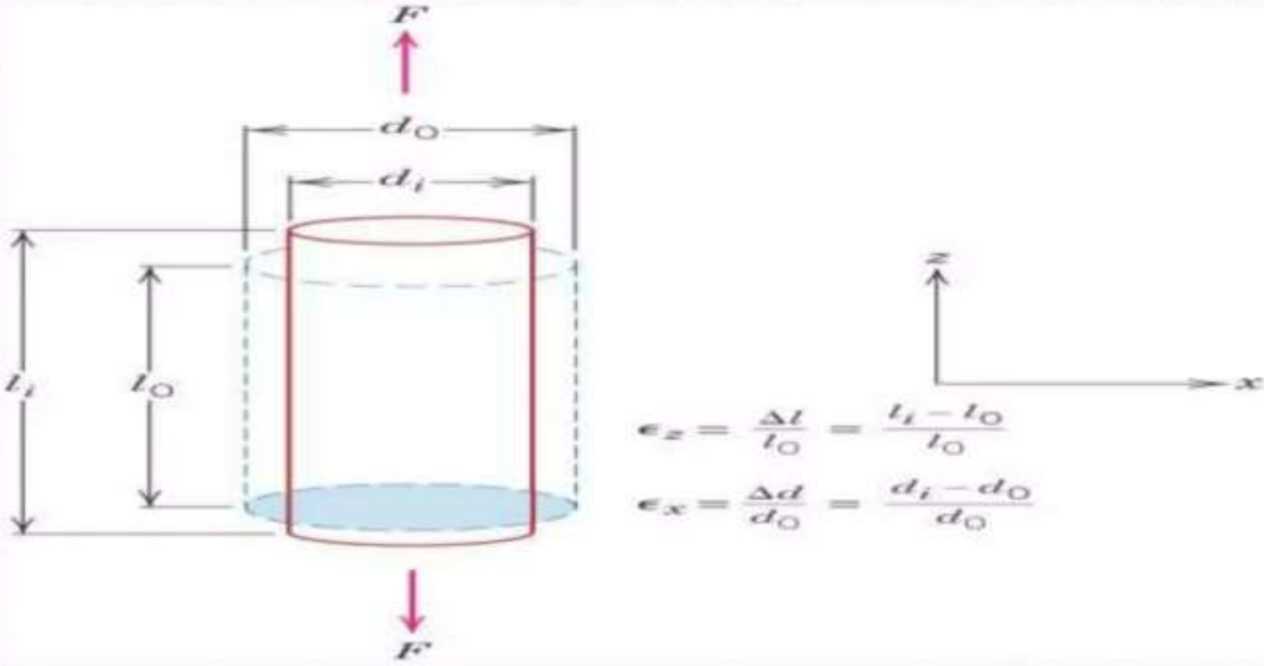
$$\text{Stress, } \sigma = \frac{\text{Force}}{\text{Cross-Sectional Area}} = \frac{F}{A_0}$$



CONTI…

- Strain is the dimensional response given by material against mechanical loading/Deformation produced per unit length.
- Mathematically Strain is change in length divided by original length.



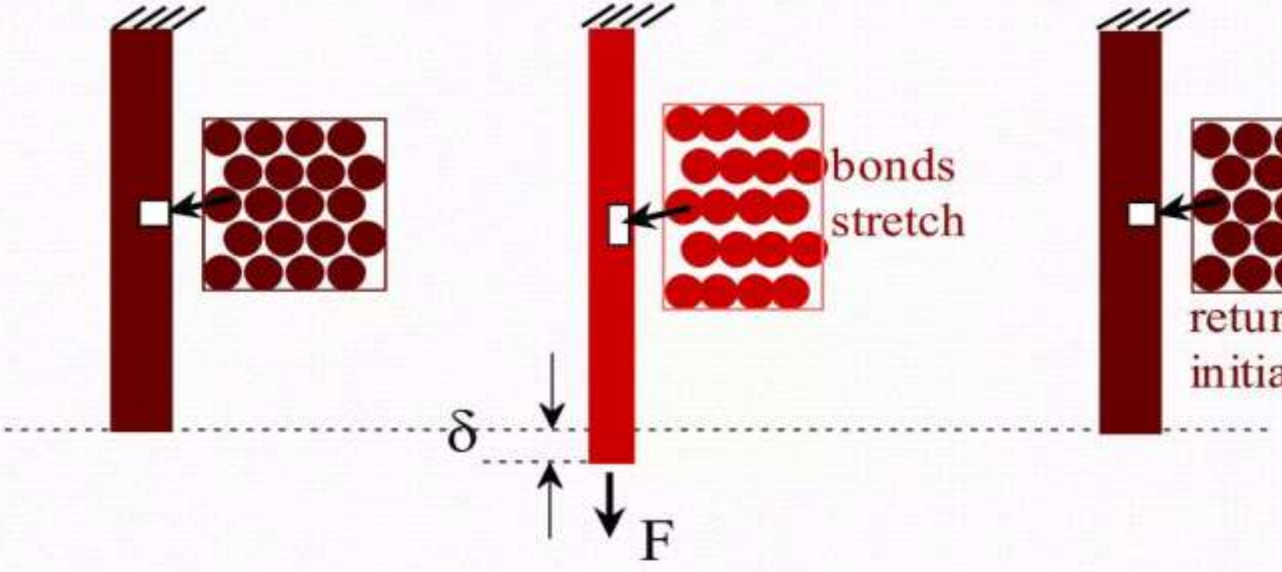


STRENGTH

- The strength of a material is its capacity to withstand destruction under the action of external loads.
- It determines the ability of a material to withstand stress without failure.
- The maximum stress that any material will withstand before destruction is called ultimate strength.

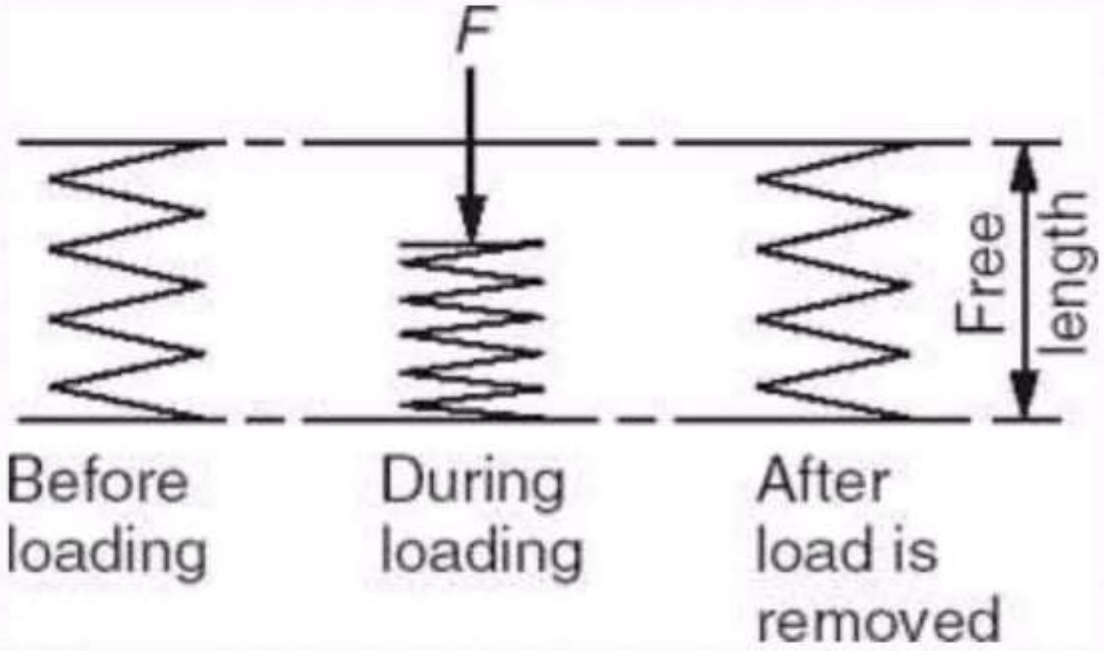
ELASTICITY:

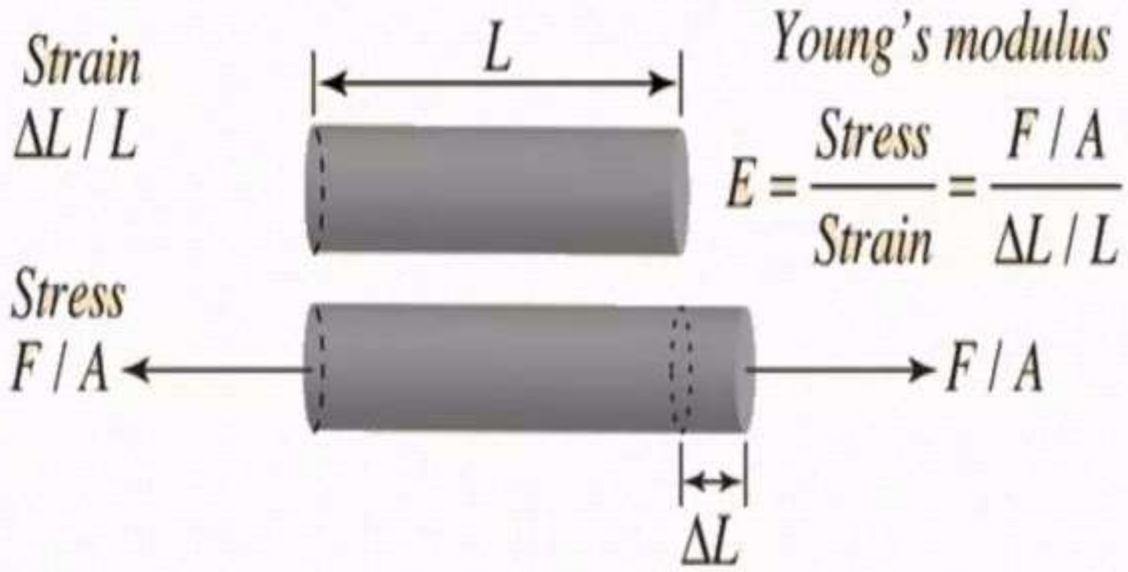
- The property of material by virtue of which deformation caused by applied load disappears upon removal of load.
- Elasticity of a material is the power of coming back to its original position after deformation when the stress or load is removed.



Elastic means reversible.

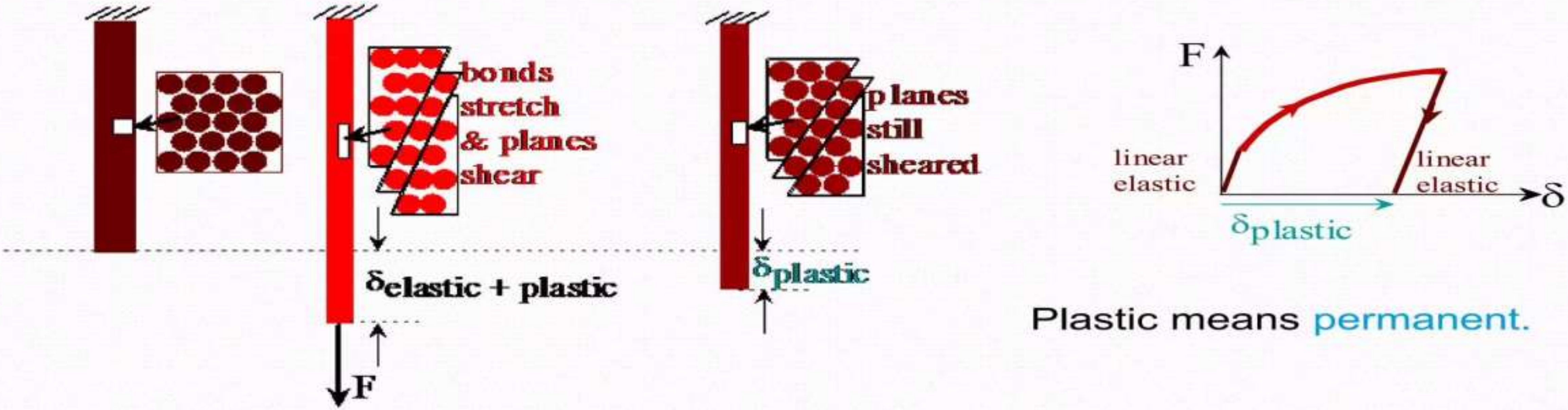
CONTI..


F
Free length
Before loading
During loading
After load is removed

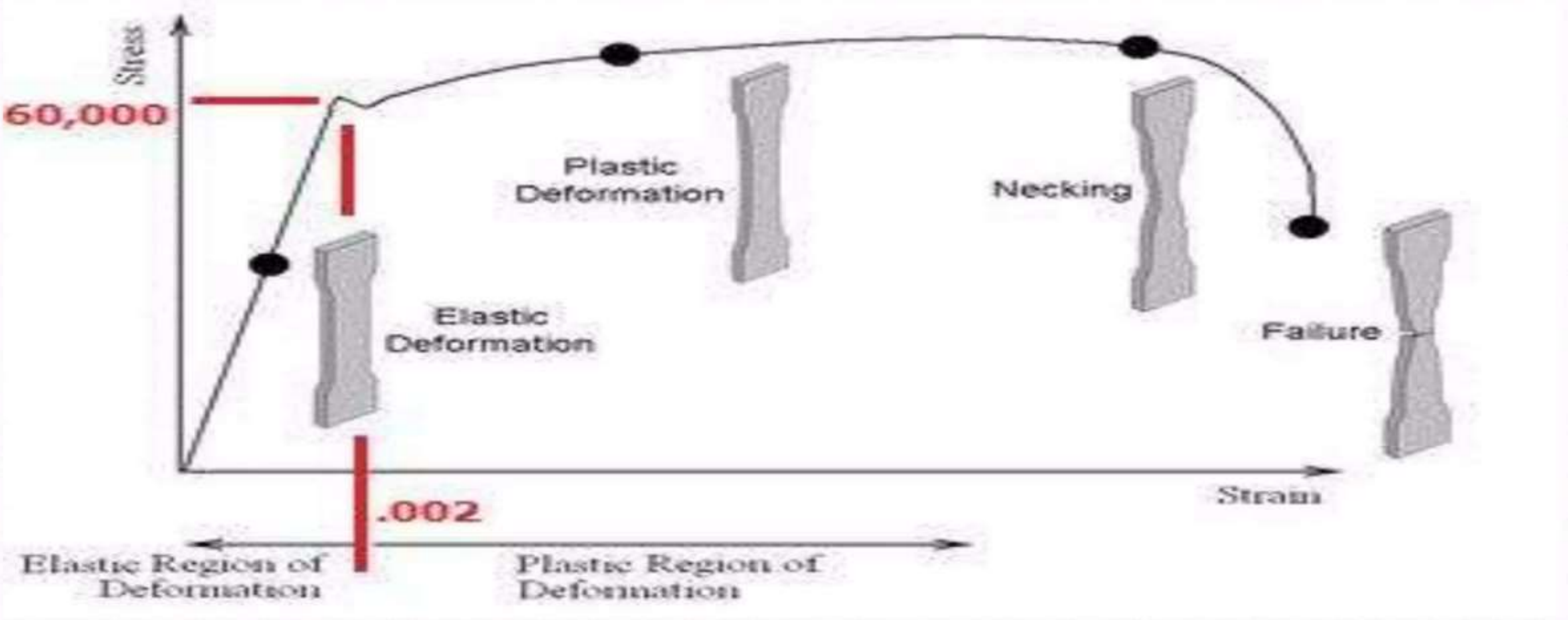

Strain
ΔL / L
L
Young's modulus
$E = \frac{Stress}{Strain} = \frac{F / A}{\Delta L / L}$
Stress
F / A
F / A
ΔL

PLASTICITY:

- The plasticity of a material is its ability to undergo some degree of permanent deformation without rupture or failure.
- Plastic deformation will take only after the elastic limit is exceeded.
- It increases with increase in temperature.



STRESS STRAIN CURVE SHOWS ELASTICITY AND PLASTICITY FOR MATERIALS:



STIFFNESS:

- The resistance of a material to elastic deformation or deflection is called stiffness or rigidity.
- A material which suffers slight deformation under load has a high degree of stiffness or rigidity.
- E.g. Steel beam is more stiffer or more rigid than aluminium beam.

DUCTILITY:

- It is the property of a material which enables it to draw out into thin wires.
- E.g., Mild steel is a ductile material.
- The percent elongation and the reduction in area in tension is often used as emperical measures of ductility.

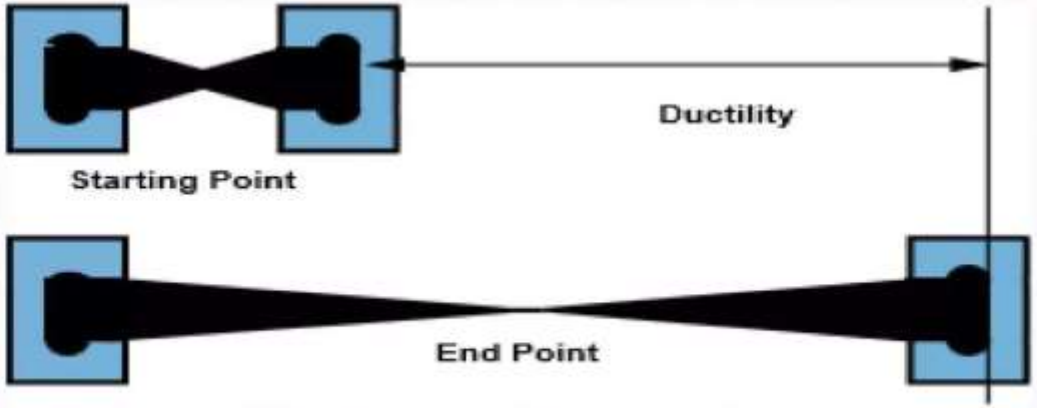
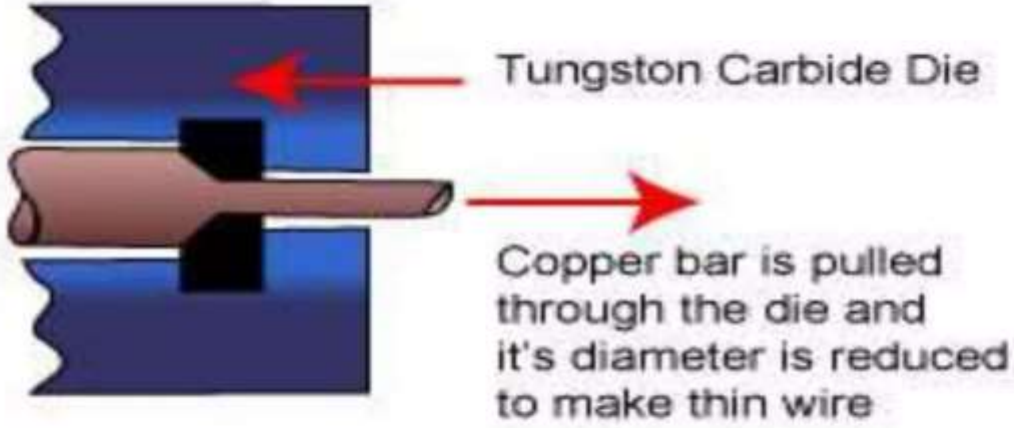
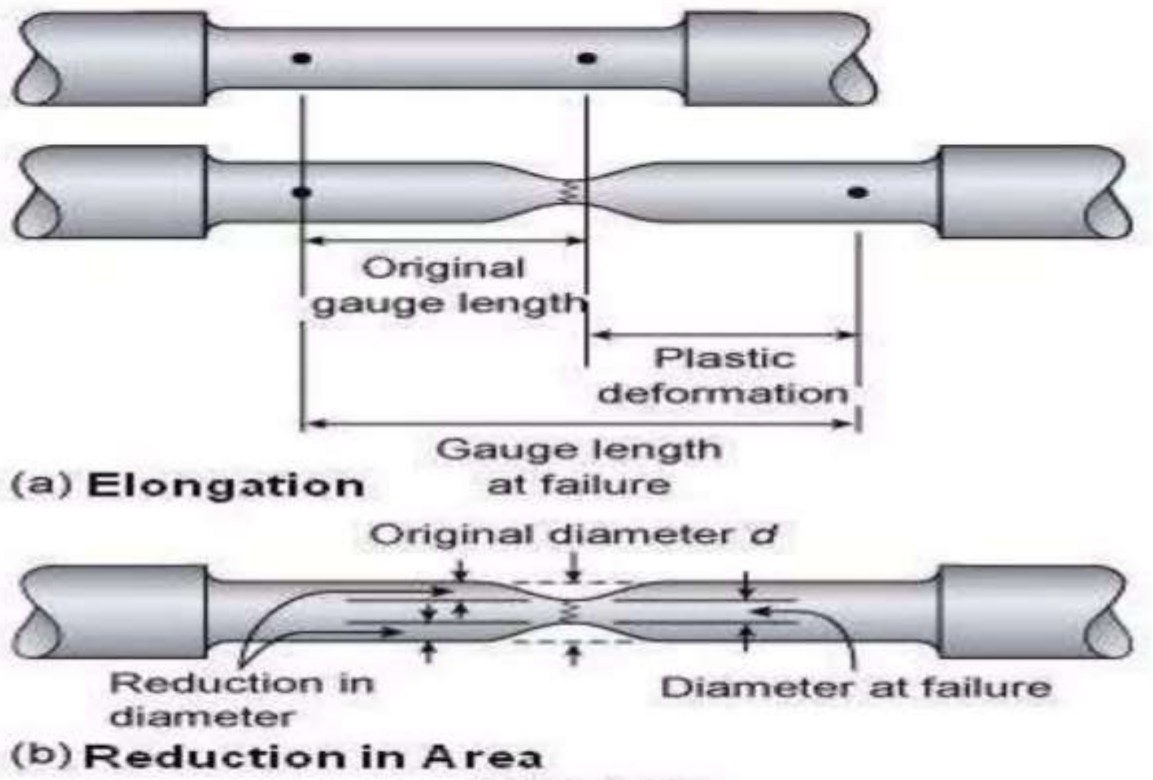
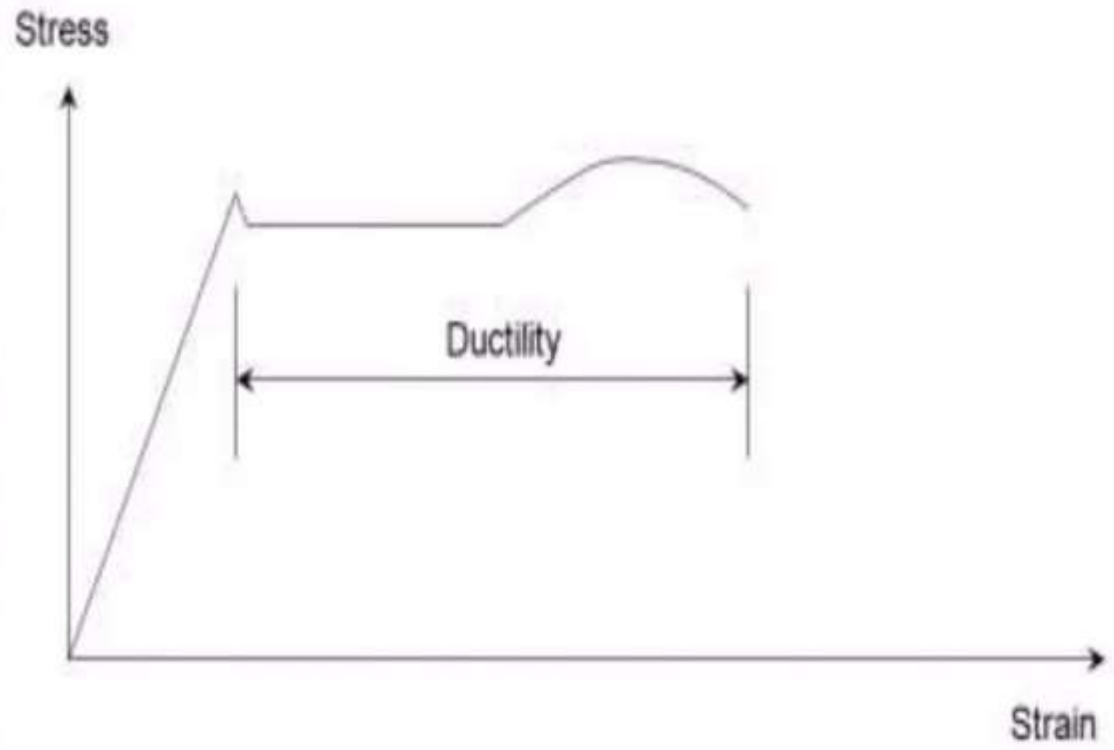


Figure 23:2: Ductility Test




Original
gauge length
Plastic
deformation
Gauge length
at failure
(a) Elongation
Original diameter d
Reduction in
diameter
Diameter at failure
(b) Reduction in Area

Ductility


Stress
Ductility
Strain

Malleability:

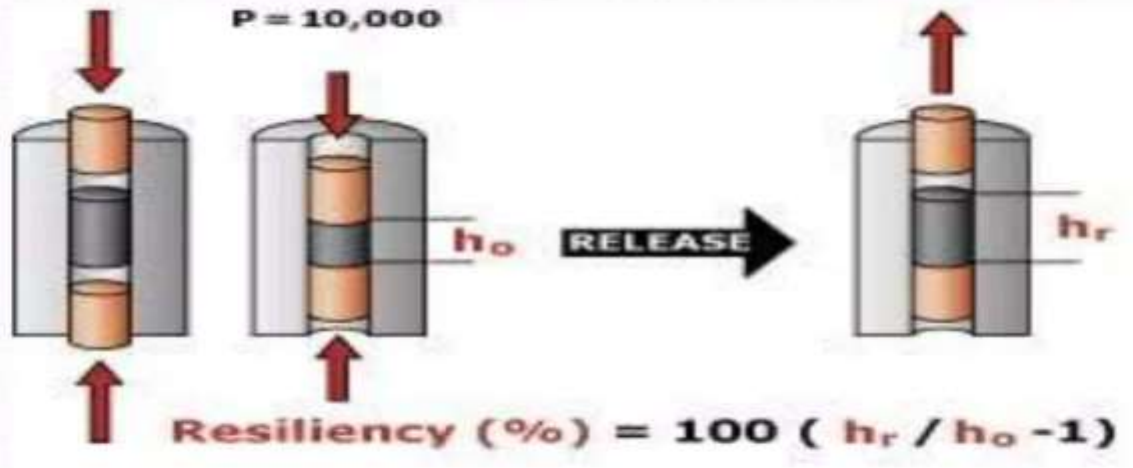
- Malleability of a material is its ability to be flattened into thin sheets without cracking by hot or cold working.
- E.g Lead can be readily rolled and hammered into thin sheets but can be drawn into wire.

Comparision of ductility and malleability

- Ductility and Malleability are frequently used interchangeably many times.
- Ductility is ***tensile quality,*** ***while*** malleability is ***compressive quality.***

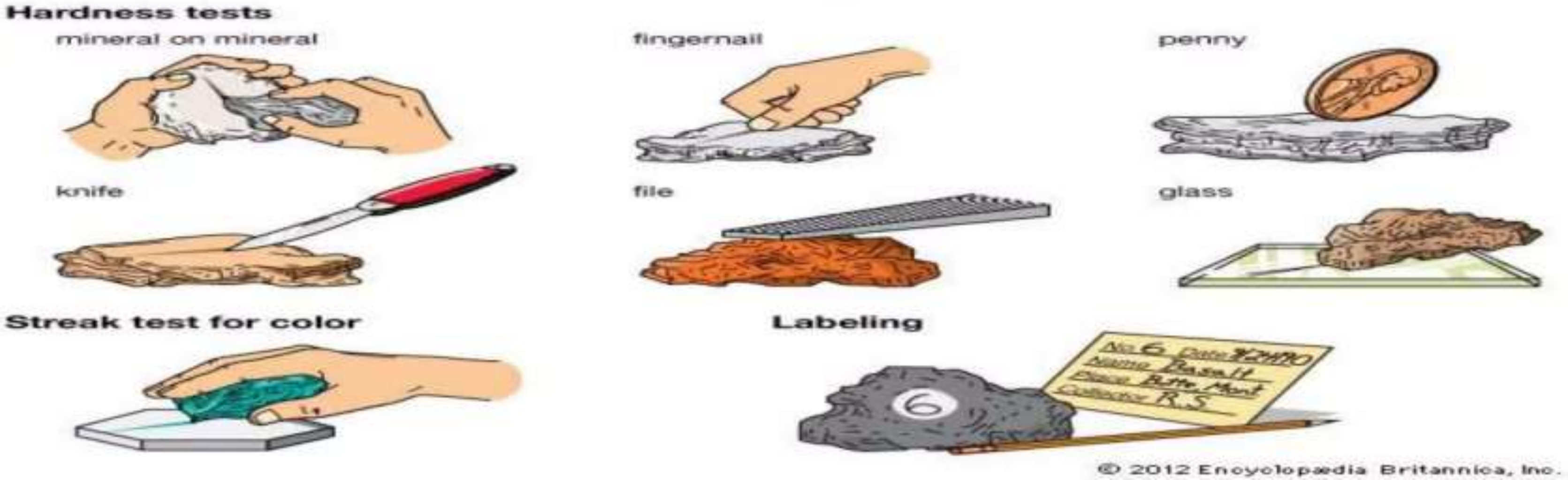
RESILIENCE:

- It is the capacity of a material to absorb energy elastically.
- The maximum energy which can be stored in a body upto elastic limit is called the ***proof resilience, and*** the proof resilience per unit volume is called ***modulus of resilience***.
- The quantity gives capacity of the material to bear shocks and vibrations.



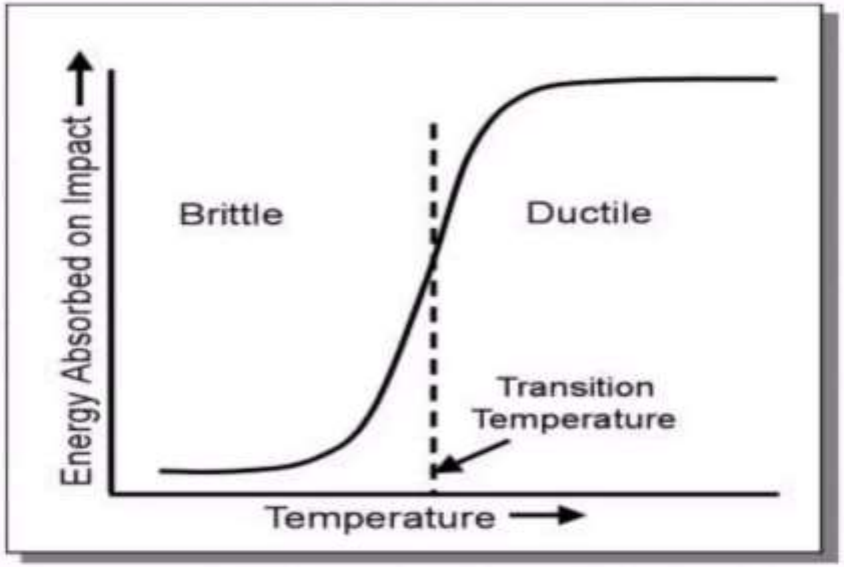
HARDNESS:

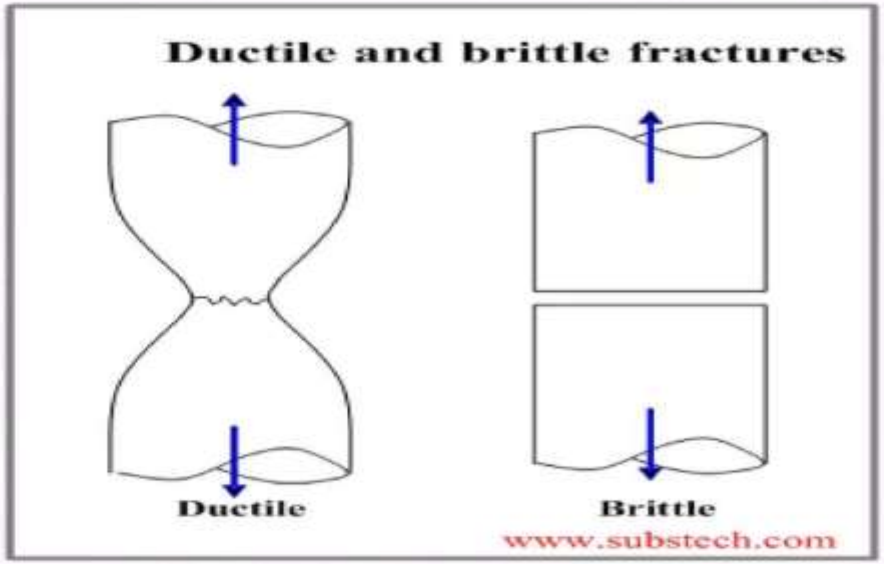
- Hardness is a fundamental property which is closely related to strength.
- Hardness is usually defined in terms of the ability of a material to resist to ***scratching, abrasion, cutting, identation,or penetration.***
- Methods used for determining hardness: Brinel, Rockwell ,Vickers.



BRITTLENESS:

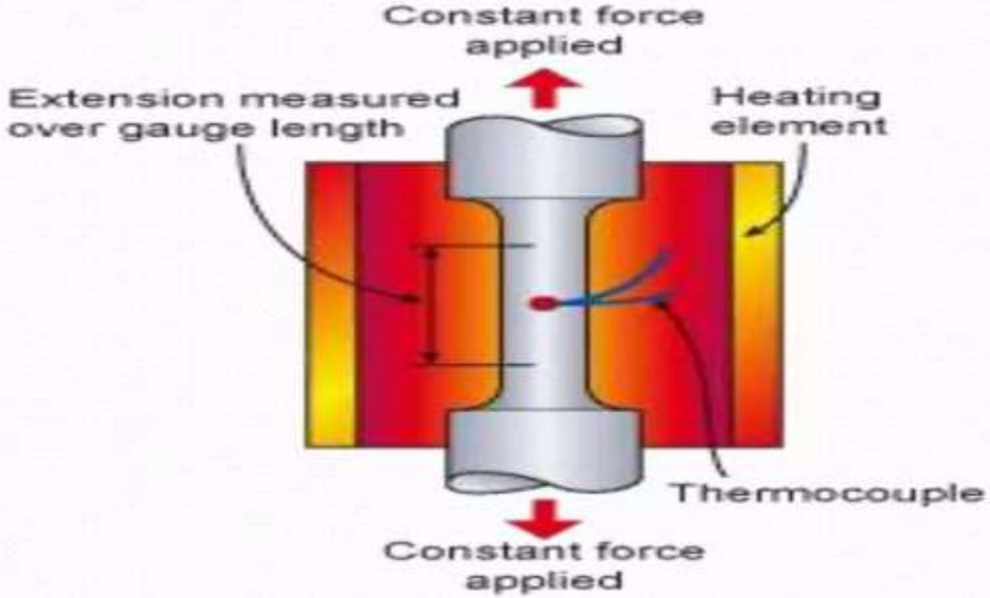
- It is the property of breaking without much permanent distortion.
- Non-Ductile material is considered to be brittle material.
- E.g, Glass, Cast iron,etc.





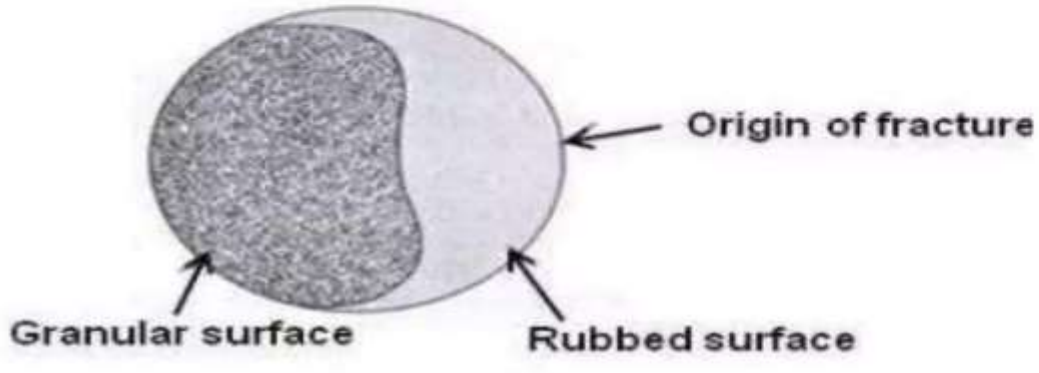
CREEP:

- The slow and progressive deformation of a material with time at constant stress is called creep.
- Depending on temperature, stresses even below the elastic limit can cause some permanent deformation.
- It is most generally defined as time-depndent strain occuring under stress.

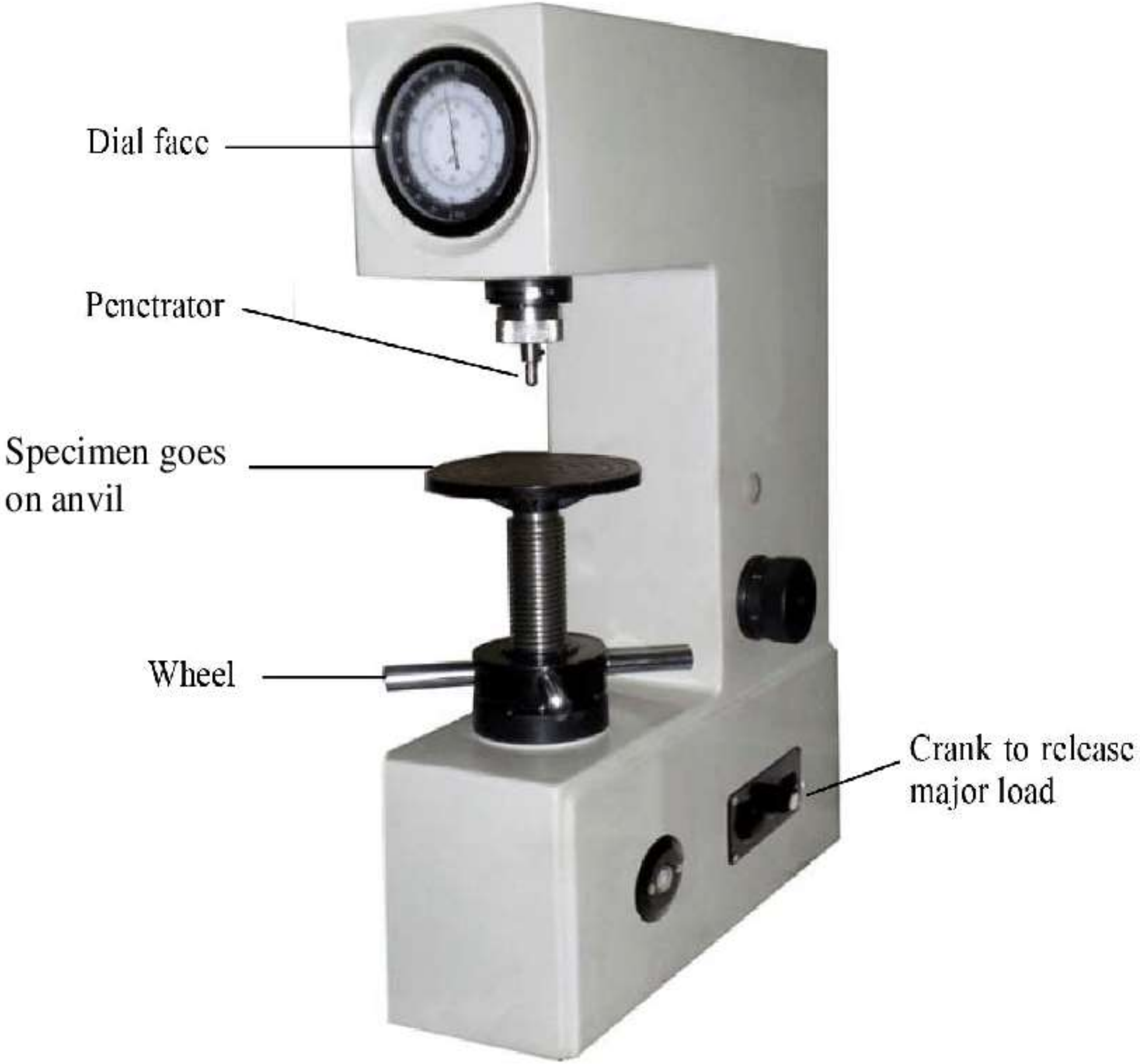


FATIGUE:

- This phenomenon leads to fracture under repeated or fluctuating stress.
- Fatigue fractures are progressive beginning as minute cracks and grow under the action of fluctuating stress.
- Many components of high speed aero and turbine engines are of this type.

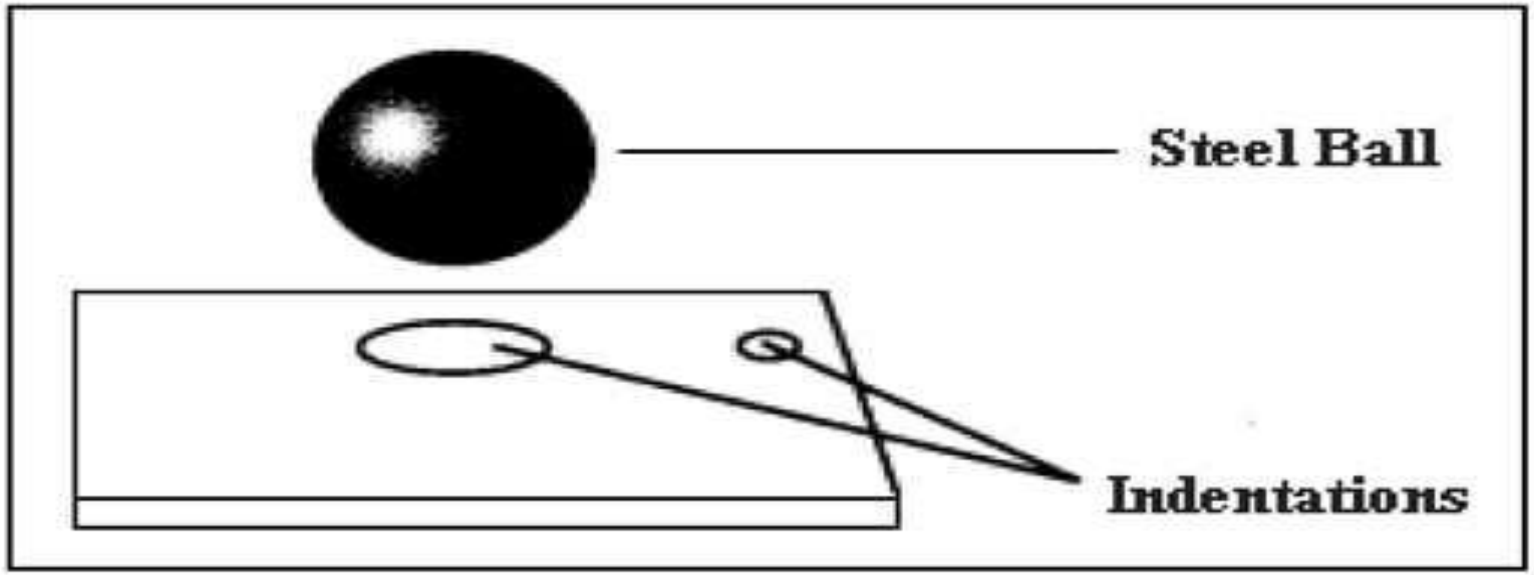


Surface of a Fatigue Fracture



Week
(2-3)
Rockwell Hardness Testing

Hardness is the resistance of a material to abrasion or localized plastic deformation



Hardness

- Hardness is not necessarily an indication of strength , although for some materials such as steel, a harder steel is a stronger steel.
- Measure of a material's ability to resist surface indentation or scratching.
- A difficult property to describe in terms of first principles Φ value depends greatly on method of testing.
- Different testing methods Φ different scales and values.

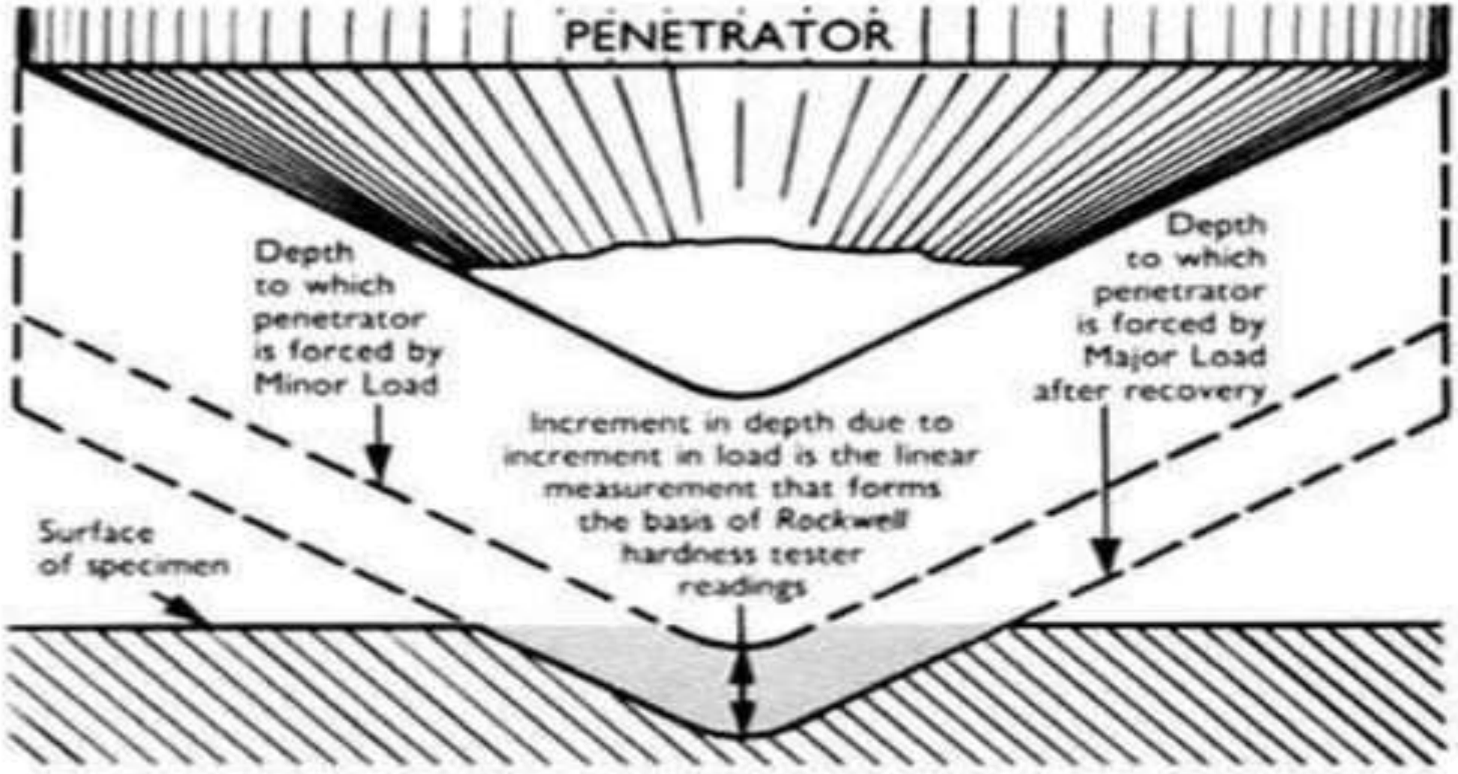
Hardness Testing

- Brinell Hardness Test: 10mm diameter ball with a load of 500, 1000 or 3000kg
- Rockwell Hardness Test: A cone shape indenter; the depth of penetration is measured.
- Vickers Hardness Test: Pyramid shape indenter

Rockwell Hardness

Rockwell Hardness Method

Machine measures depth of penetration and computes hardness



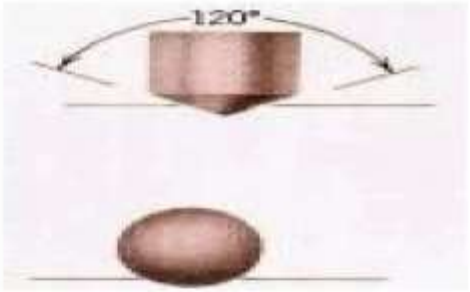
Rockwell Hardness Testing

- **Test Principle:**

  Rockwell hardness Number (RHN) based on an inverse relationship to the measurements of the additional depth

  Which an indenter is forced by a heavy (major) load beyond the depth resulting from a previously applied (minor) load.

- **Indenter:**
- 120 degree sphero-conicall diamond indenter is used for hard material.
- Hardened steel ball indenter with diameter of 1/16,1/8,1/4.1/2 inch.



Dial Gauge

- One revolution of the large pointer equals 1mm
- There are 100 divisions to a revolution
- Therefore ,1 division=0.01 mm
- Dial gauge is connected to a plunger system in the head of a tester
- By means of the index lever having 5:1
- Therefore depth for 1 division = 0.01x0.2=0.002

$$HRC = 100 - \frac{\text{Indentation depth caused by major load}}{0.002}$$

$$HRB = 130 - \frac{\text{indentation depth caused by major load}}{0.002}$$

Depth of indentation

- Indentation depth from minor to major load: in case of **Rockwell test**

  (60HRC).

  (100-60)x0.002mm= 0.08mm.

  (130-Ball indentation reading)x0.002mm.

  Superficial test

  (regardless of the indenter used)

  80HR30N

  (100-80)x0.001mm=0.02mm

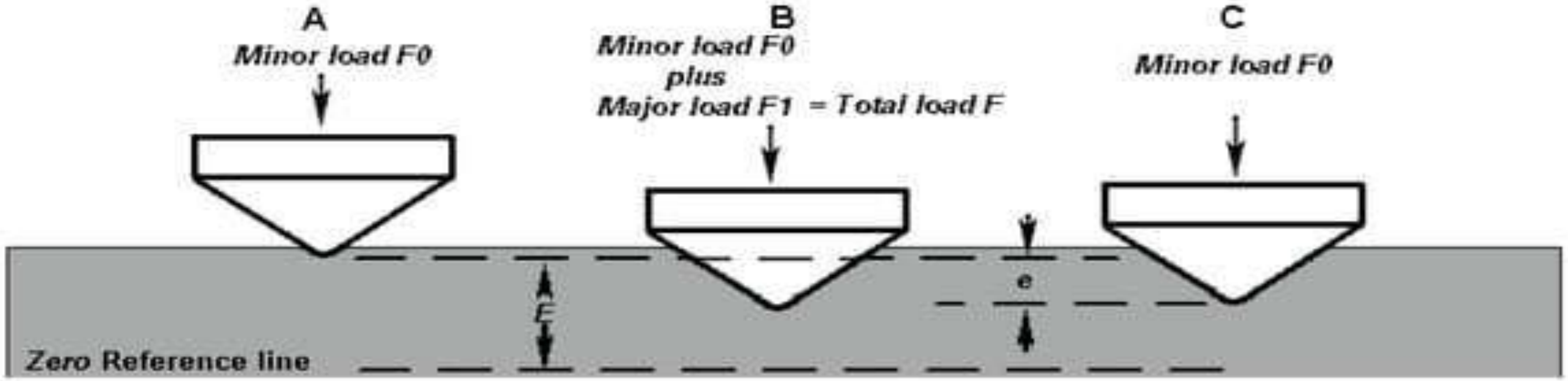
Factors that control Scale selection

- -Type of material,
- -Specimen thickness ,
- -Test location ,
- -Scale limitation.

Test location

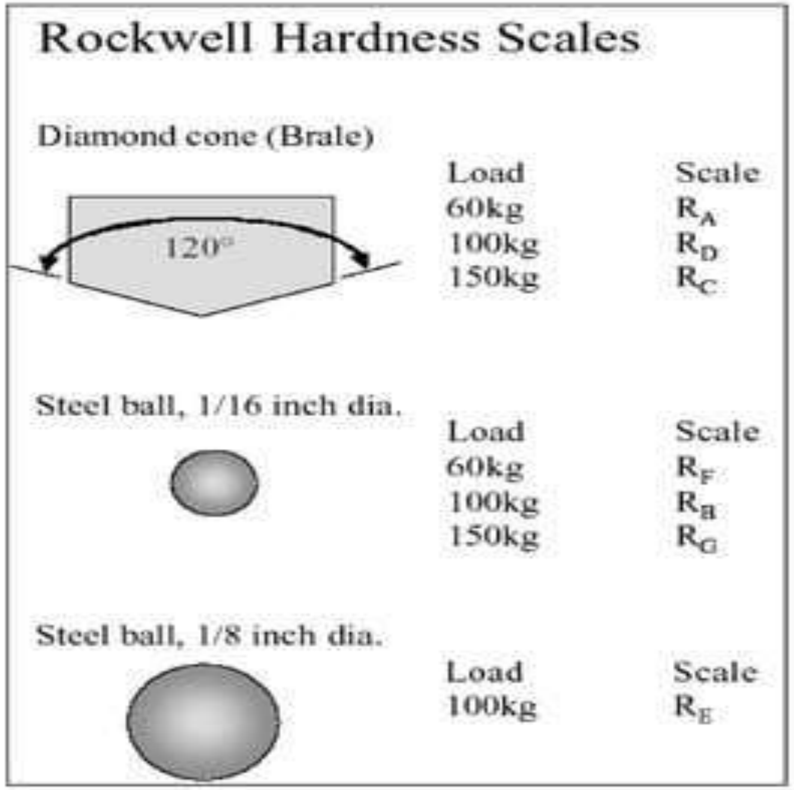
- If an indentation is placed with in the cold worked area (previous indentation).
- The reading usually will be higher than that obtained had it been placed out side this area.
- As a precaution three diameter from the centre of one indentation to another is sufficient for most material.
- The distance from edge should be minimum of 2.5 diameter of indentation.

Rockwell Hardness



Rockwell Hardness Method

- Select Scale - load and indentor depending on the scale
- Press a point into material
  - - Diamond Point (Brale)
  - - 1/16" ball
  - - 1/8" ball
  - - ¼" ball



Rockwell Test Limitations

- Sample must be ten times thicker than the indentation depth (sample usually should be at least 1/8" thick).
- Need 3 tests (minimum) to avoid inaccuracies due to impurities, hard spots.
- Test is most accurate if the Rockwell Hardness is between 0 and 100. Adjust scale to achieve this.

For Steel:
If HRa > 60, use HRc scale
If HRa < 60, use HRb scale

Comparison of HT Methods

Test	Indenter	Shape of Indentation: Side View	Shape of Indentation: Top View	Load	Formula for Hardness Number[a]
Brinell	10-mm sphere of steel or tungsten carbide			P	$HB = \frac{2P}{\pi D[D - \sqrt{D^2 - d^2}]}$
Vickers microhardness	Diamond pyramid			P	$HV = 1.854P/d_1^2$
Knoop microhardness	Diamond pyramid	 $l/b = 7.11$ $b/t = 4.00$		P	$HK = 14.2P/l^2$
Rockwell and Superficial Rockwell	Diamond cone; $\frac{1}{16}$, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$ in. diameter steel spheres			60 kg, 100 kg, 150 kg: Rockwell; 15 kg, 30 kg, 45 kg: Superficial Rockwell	
					

EXPERIMENT -1

ROCKWELL HARDNESS TEST

AIM: To determine the Rockwell hardness of the given test specimen.

APPARATUS:
Rockwell hardness testing machine, test specimen.

THEORY:

Hardness-the resistance of a metal to plastic deformation against indentation scratching, abrasion or cutting.The depth of penetration of the indenter measures the hardness of a material by this Rockwell's hardness test method. The depth of penetration is inversely proportional to the hardness. Both ball or diamond cone types of indenters are used in this test. There are three scales on the machine for taking hardness readings.

Scale „A- with load 60kgf or 588.8N and diamond indenter is used for performing tests on steel and shallow case hardened steel.
Scale „B- with load 100kgf or 980.7 N and 1.588mm dia ball indenter is used for performing tests on soft steel, malleable iron, copper and aluminum alloys.
Scale „C- with load 150kgf or 1471 N and diamond indenter is used for performing tests on steel, hard cost steel, deep case hardened steel , other metals which harder.
First minor load is applied to overcome the film thickness on the metal surface. Minor load also eliminates errors in the depth of measurement due to spring of the machine frame or setting down of the specimen and table attachments.

The Rockwell hardness is derived from the measurement of the depth of the impression. This method of test is suitable for finished or machined parts of simple shapes.

PROCEDURE:

1.Select the load by rotating the nob and fix the suitable indenter.

2.Clean the test piece and place on the special anvil or worktable of the machine.

3.Turn the capstan wheel to evaluate the test specimen into contact with the indenter point.

4.Further turn the wheel for three rotations forcing the test specimen against the indenter. This will ensure the minor load has been applied.

5.As soon as the pointer comes to rest pull the handle in the reverse direction slowly. This releases the major but not the minor load. The pointer will now rotate in the reverse direction.

OBSERVATIONS:

Material of the specimen
Thickness of test specimen
Hardness scale used

Test no	Material	Rockwell Scale of weights			Rockwell number			Average Rockwell no.
		Scale	weight	indent	1	2	3	

PRECAUTIONS:

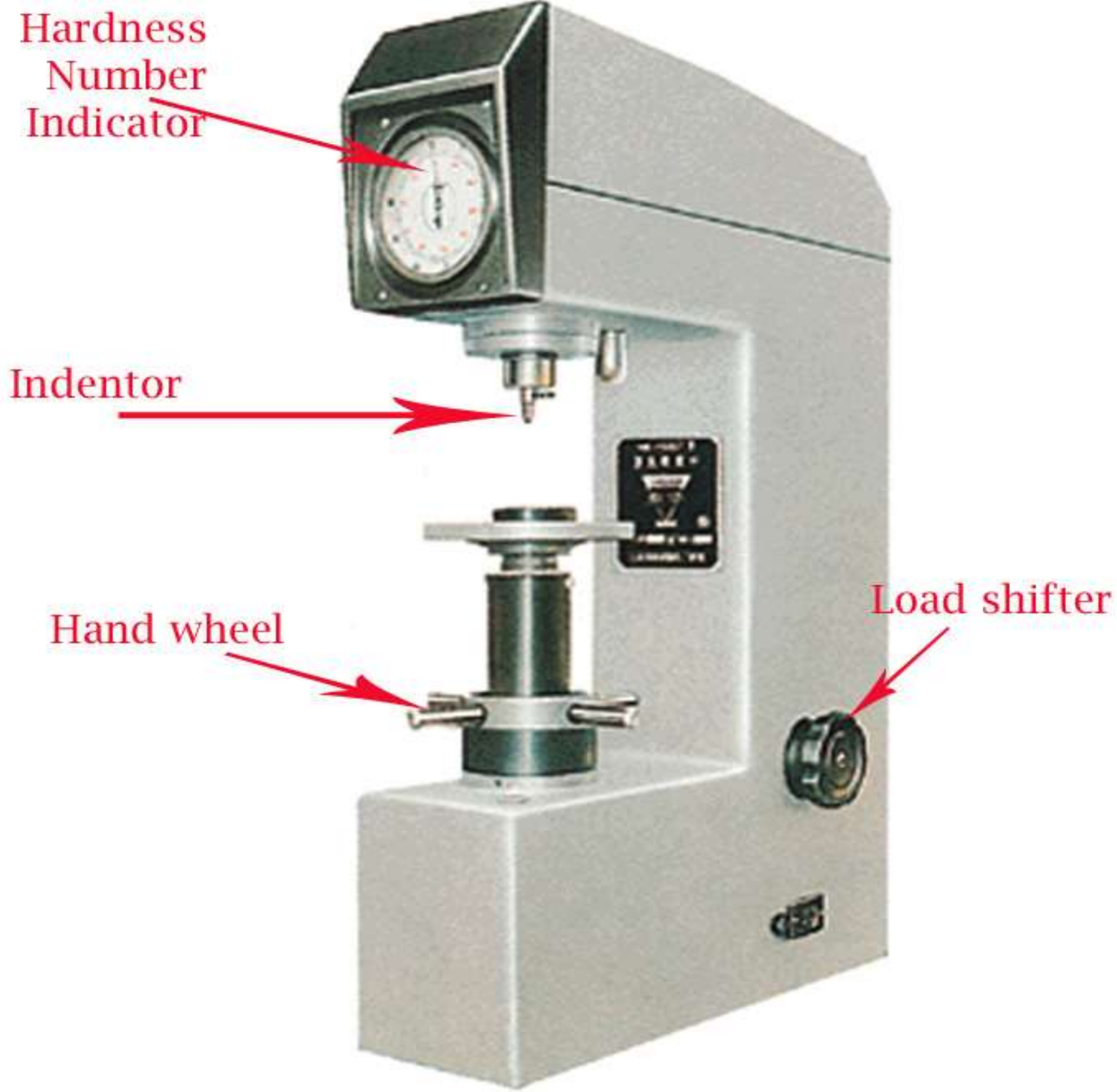
1. For testing cylindrical test specimens use V-type platform.
2. Calibrate the machine occasionally by using standard test blocks.
3. For thin metal prices place another sufficiently thick metal piece between the test specimen and the platform to avoid any damage, which may likely occur to the platform.
4. After applying major load wait for some time to allow the needle to come to rest. The waiting time may vary from 2 to 8 seconds.
5. The surface of the test piece should be smooth and even and free from oxide scale and foreign matter.
6. Test specimen should not be subjected to any heating of cold working.
7. The distance between the centers of two adjacent indentation should be at least 4 times the diameter of the indentation and the distance from the center of any indentation to the edge of the test piece should be at least 2.5 times the diameter of the indentation.

Calculation Part:

RESULT:

EXERCISE PROBLEMS

Perform the same experiment for two different materials i.e., Alluminum and Mild Steel

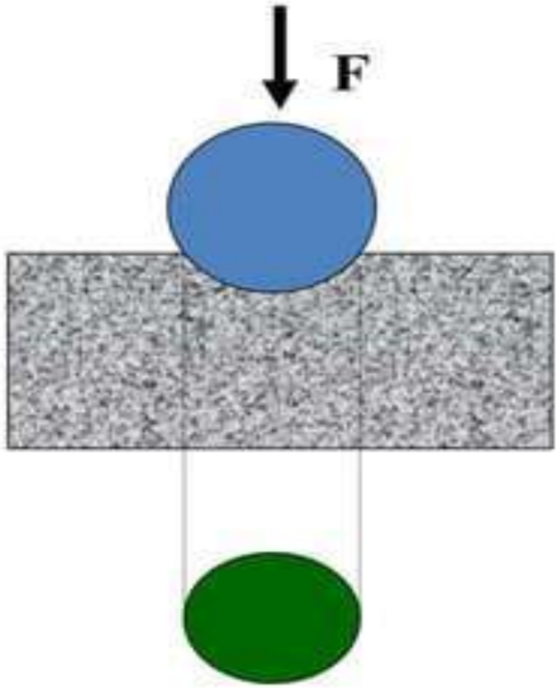


Week

(4-5)

Brinell Hardness Testing

Brinell Hardness Test (BHN)

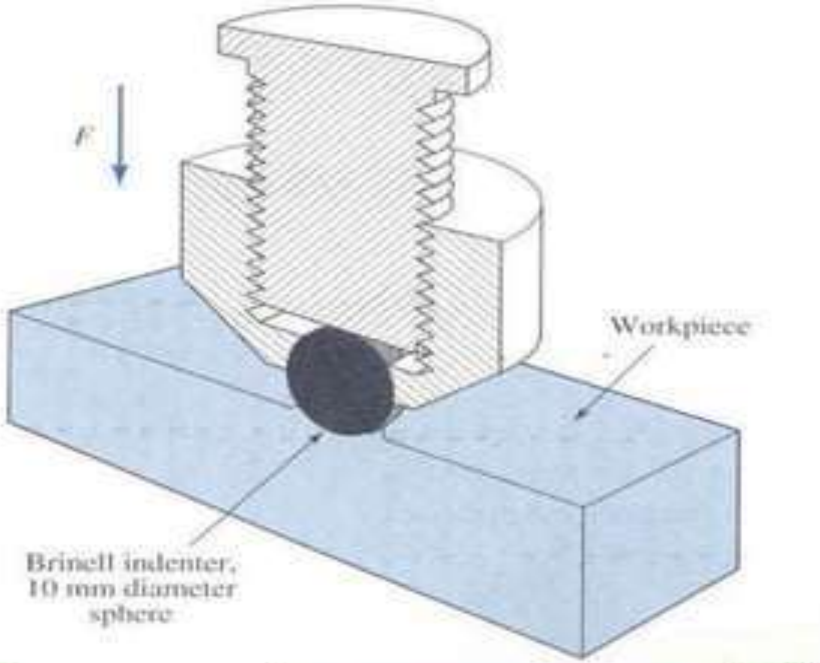


Brinell's Hardness

Brinell's Hardness Testing

P from 500 - 3000 kg

D= 10 mm



$$BHN = (2P) \Big/ \left\{ \pi D \left[D - \sqrt{\left(D^2 - d^2 \right)} \right] \right\}$$

Brinell Test Protocol

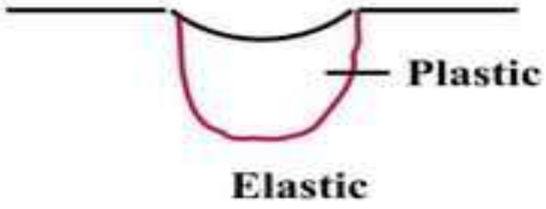
1. Press a 10mm (3/8") diameter ball into material with a known amount of load.
2. Measure diameter of the indentation.
3. $$BHN = \frac{Load}{Surface\ Area} = \frac{2L}{\pi D[D-(D^2-d^2)^{1/2}]}$$

   a) L = Load placed on ball, usually 3000 kg , but 1500 kg, and 500 kg can also be used.

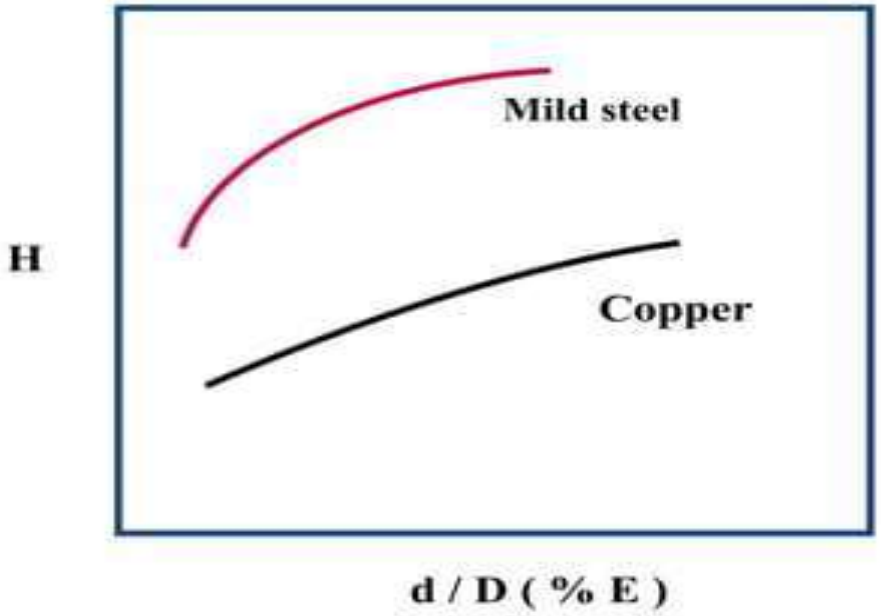
   b) D = Diameter of steel ball (= 10 mm)

   c) d = diameter of dent, measured by looking thru a Brinell microscope.

Analysis of Plastic Deformation during Brinell Hardness Test



$$H = Ae^{-BT}$$



Limitations of the Brinell Hardness Test

- Sample must be ten times thicker than the indentation depth (sample usually should be at least 3/8" thick).

- Test is most accurate if the indentation depth is 2.5 - 5.0 mm. Adjust load to achieve this.

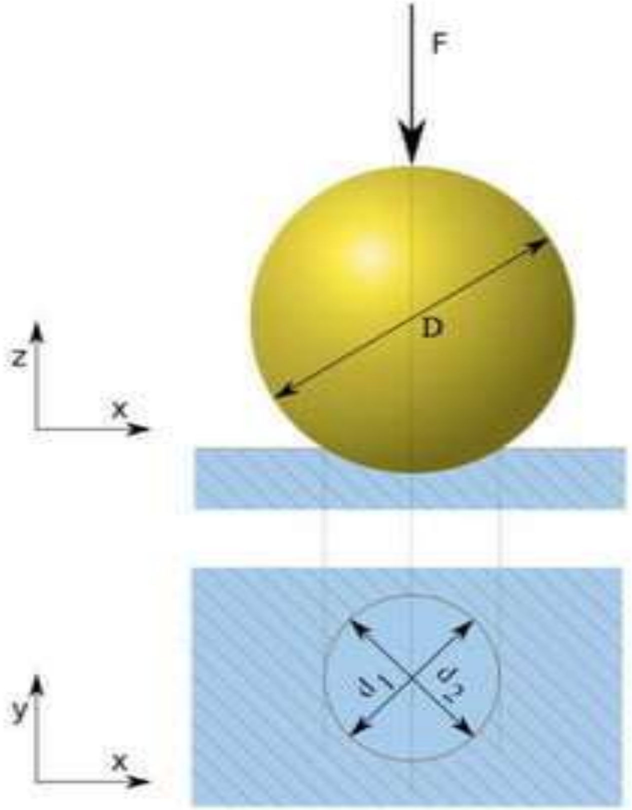
- Test is no good if BHN > 650

BHN PROS & CONS

- Widely used and well accepted
- Large ball gives good average reading with a single test.
- Accurate
- Easy to learn and use

- Destructive
- Non-portable
- High initial cost ($5,000)
- Error due to operator reading Brinell Microscope (10% max)

Brinell Hardness

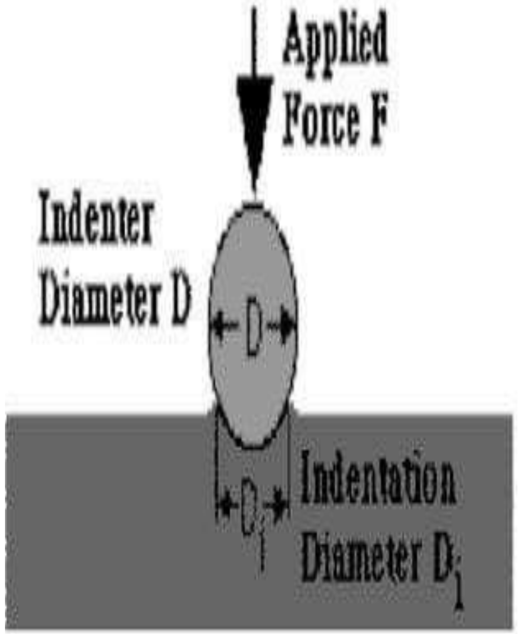


Brinell Hardness

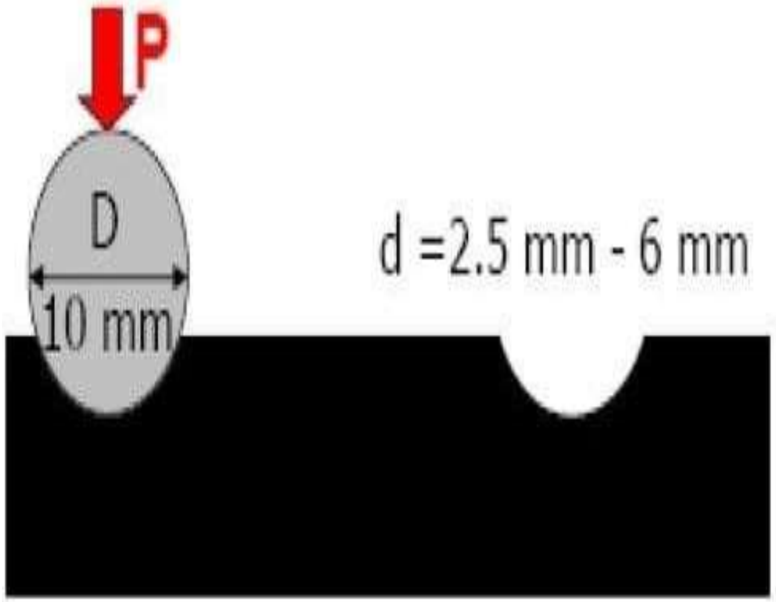
- A spherical indenter (1 cm diameter) is shot with 29 kN force at the target
- Frequently the indenter is steel, but for harder materials it is replaced with a tungsten carbide sphere
- The diameter of the indentation is recorded
- The indentation diameter can be correlated with the volume of the indentation.

Brinell Hardness

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



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



EXPERIMENT -2

BRINELLS HARDNESS TEST

AIM: To determine the Brinells hardness of the given test specimen. **APPARATUS:** Brinells hardness machine, test specimen, Brinells Microscope.

THEORY:

Indentation Hardness-

A number related to the area or to the depth of the impression made by an indenter or fixed geometry under a known fixed load.This method consists of indenting the surface of the metal by a hardened steel ball of specified diameter D mm under a given load F kgf and measuring the average diameter d mm of the impression with the help of Brinell microscope fitted with a scale. The Brinell hardness HB is defined, as the quotient of the applied force F divided by the spherical area of the impression.

HB= Test load in kgf/surface area of indentation

$=2F/ \{\pi D (D- D^2- d^2)\}$ kg/mm^2 Where F = Applied load in kg

D = Diameter of the specified ball in mm d = Diameter of impression in mm

PROCEDURE:

1.Select the proper size of the ball and load to suit the material under test.

2.Clean the test specimen to be free from any dirt and defects or blemishes.

3.Mount the test piece surface at right angles to the axis of the ball indenter plunger.

4.Turn the platform so that the ball is lifted up.

5.By shifting the lever applies the load and waits for some time.

6.Release the load by shifting the lever.

7.Take out the specimen and measure the diameter of indentation by means of the Brinell microscope.

8.Repeat the experiments at other positions of the test piece.

9.Calculate the value of HB.

OBSERVATIONS:

Test piece material

Diameter of the ball" D "

Load section F/D^2

Test load

Load application time

Least count of Brinell Microscope

S. No	Diameter			F in kg	D in mm	Average HB Kg/mm^2
	(d_1)	(d_2)	$(d_1+d_2)/2$			

PRECAUTIONS:

1. The surface of the test piece should be clean
2. The testing machine should be protected throughout the test from shock or vibration.
3. The test should be carried out at room temperature.
4. The distance of the center of indentation from the edge of test piece should be at least 2.5 times the diameter of the indentation and the distance between the center of the two adjacent indentations should be at least 4 times the diameter of the indentation.
5. The diameter of each indentation should be measured in two directions at right angles and the mean value readings used the purpose of determining the hardness number.

Week (06-10)

Impact Testing

1) **Izod Test**
2) **Charpy Test**

Impact Strength

- The impact test is performed to study the behavior of materials under dynamic load i.e., suddenly applied load.
- *Impact strength defined : 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.
- In an impact test, a notch is cut in a standard test piece which is stuck by a single blow in a impact testing machine. Then the energy absorbed in breaking the specimen can be measured from the scale provided on the impact testing machine.

What is Impact

- In mechanics, an impact is a high force or shock applied over a short time period when two or more bodies collide. Such a force or acceleration usually has a greater effect than a lower force applied over a proportionally longer period.
- At normal speeds, during a perfectly inelastic collision, an object struck by a projectile will deform, and this deformation will absorb most or all of the force of the collision
- The effect depends critically on the relative velocity of the bodies to one another.
- Example : **car crush, wind force, earthquake** etc.

Impact Strength (same as Toughness)

- Impact strength is the resistance of a material to fracture under sudden load.
- It is a complex characteristic which takes into account both the toughness and strength of a material.
- It is defined as the specific work required to fracture a test specimen with a stress concentrator in the mid when broken by a single blow of striker in pendulum type impact testing machine.

Types of Impact Tests

- Based on the types of specimen used on impact testing machine the impact tests can be classified into:

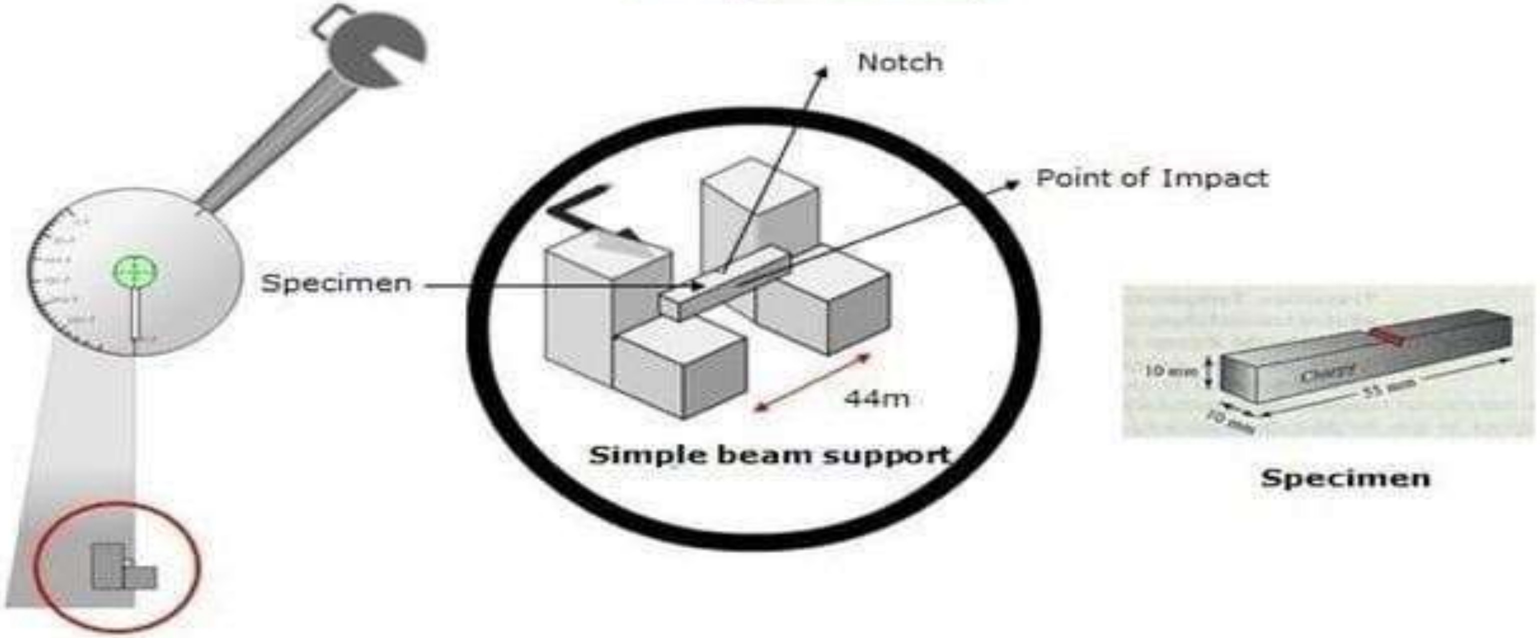
  1. Izod test, 2. Charpy test

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

Charpy test Method

- The Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture.
- The specimen is set like a simply supported beam.

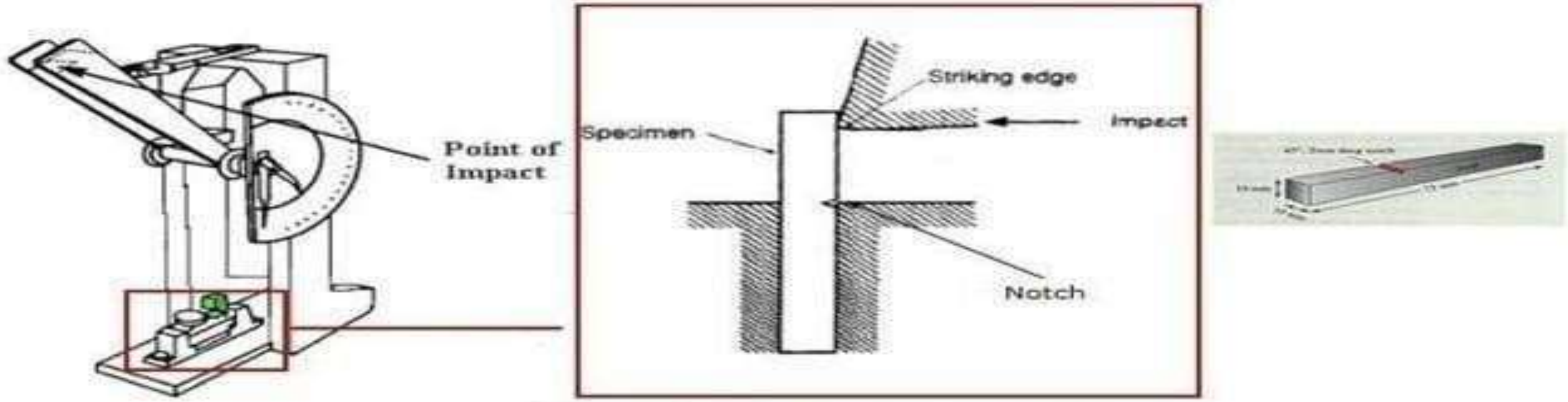
Charpy Test Setup



Izod test Method

- The test piece is a cantilever, clamped upright in an anvil, with a V notch at the level of the top of the clamp.
- The test piece is hit by a striker carried on a pendulum which is allowed to fall freely from a fixed height, to give a blow of 120 ft lb energy.

Izod Test Setup



Cantilever beam support

Procedure

1. Preparation of test piece
2. Place the sample in position
3. Record the initial reading
4. Move the pendulum
5. Pull on the red handle break
6. Record read out from display

Calculation

- Impact energy
  $= mgH - mgh$;

Where,
m=mass of pendulum.
g=acceleration due to gravity.=$9.81 ms^{-2}$
The absorb energy in Joule Unit.

- Toughness of the material
  $= \frac{\text{Impact energy}}{\text{Area of specimen}}$

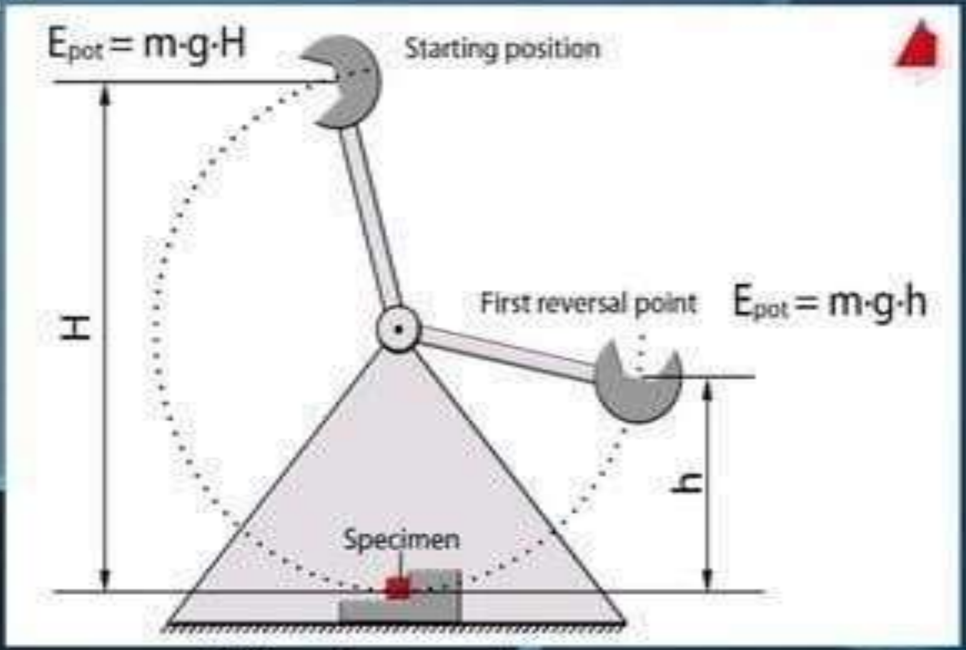


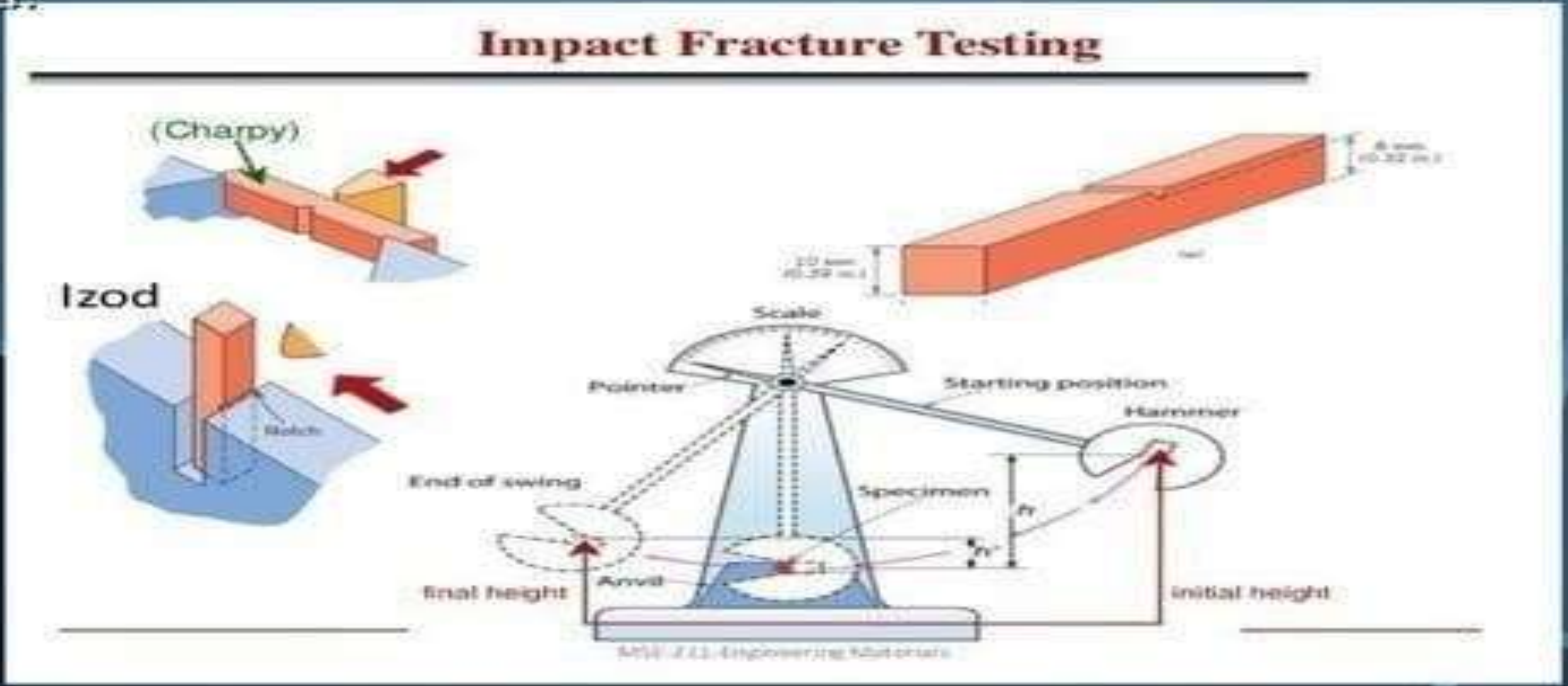
Fig : Impact energy

Difference between Charpy & Izod test

In Charpy method the Specimen set is like a simply Supported beam

On other hand in Izod method the Specimen set is like a Cantilever.

Thus Why in Charpy method gives a higher reading than the Izod method.



EXPERIMENT -3

IZOD IMPACT TEST

AIM: To perform the izod impact test on materials.

APPARATUS: Izod impact test machine, test specimen, vernier calipers, steel rule.
IMPACT STRENGTH: The resistance of a material to fracture under sudden load application

MATERIALS: Two types of test pieces are used for this test as given.
1)Square cross-section
2)Round cross-section.

THEORY: The type of test specimen used for this test is a Square Cross-section

The specimen may have single, two or three notches. The testing machine should have the following specifications.
The angle between top face of grips and face holding the specimen vertical=90^0 The angle of tip of hammer =$75^0 \pm 1^0$
The angle between normal to the specimen and underside face of the hammer atstriking point=$10^0 \pm 1^0$
Speed of hammer at impact=3.99m/sec Striking energy=168N-m or Joules Angle of drop of
pendulum =90^0 Effective weight of pendulum=21.79kg Minimum value of scale graduation=2 Joules.
Permissible total friction loss of corresponding energy=0.50%
Distance from the axis of rotation of distance between the base of specimen notch and the point of specimen hit by the hammer=22mm±0.5mm
The longitudinal axes of the test piece shall lie in the plane of swing of the center of gravity of the hammer. The notch shall be positioned so that it is in the plane of the hammer .the notch shall be positioned its plane of symmetry coincides with the top face of the grips .for setting the specimen the notch impact strength I is calculated according to the following relation.
where I= impact strength in joules/m^2

PROCEDURE:

1. For conducting Izod test, a proper striker is to be fitted firmly to the bottom of the hammer with the help of the clamming piece.
2. The latching take for izod test is to be firmly fitted to the bearing housing at the side of the columns.
3. The frictional loss of the machine can be determined by free fall test, raise the hammer by hands and latch in release the hammer by operating lever the pointer will then indicate the energy loss due to friction. From this reading confirm that the friction loss is not exceeding 0.5% of the initial potential energy. Otherwise frictional loss has to be added to the final reading.
4. The specimen for izod test is firmly fitted in the specimen support with the help of clamping screw and élan key. Care should be taken that the notch on the specimen should face to pendulum striker.
5. After ascertaining that there is no person in the range of swinging pendulum, release the pendulum to smash the specimen.
6. Carefully operate the pendulum brake when returning after one swing to stop the oscillations.
7. Read-off position of reading pointer on dial and note indicated value.
8. Remove the broken specimen by loosening the clamping screw.

The notch impact strength depends largely on the shape of the specimen and the notch. The values determined with other specimens therefore may not be compared with each other.

OBSERVATION TABLE:

S .No	**A(Area of cross section of specimen)**	**K Impact energy observed**	**I Impact Strength**

Calculation Part :

RESULT:

EXERCISE PROBLEMS

Perform the same experiment for two different materials i.e., Alluminum and Mild Steel

Experiment No: 04

AIM : To study the Impact testing machine and perform the Impact tests (Charpy)

THEORY :- In manufacturing locomotive wheels, coins, connecting rods etc. the components are subjected to impact (shock) loads. These loads are applied suddenly. The stress induced in these components are many times more than the stress produced by gradual loading. Therefore, impact tests are performed to asses shock absorbing capacity of materials subjected to suddenly applied loads. These capabilities are expressed as (i) Rupture energy (ii) Modulus of rupture and (iii) Notch impact strength.

Two types of notch impact tests are commonly-

In charpy test, the specimen is placed as 'cantilever beam'. The specimens have V-shaped notch of 45°. U- shaped notch is also common. The notch is located on tension side of specimen during impact loading. Depth of notch is generally taken as t.5 to t/3 where 't' is thickness of the specimen.

SPECIFICATION OF M/C AND SPECIMEN DETAILS :

Its specifications along-with their typical values are as follows:

- Impact capacity = 300joule
- Least count of capacity (dial) scale = 2joule
- Weight of striking hammer = 18.7 kg.
- Angle of hammer before striking = 160° Distance between supports = 40mm.
- Striking velocity of hammer = 5.6m/sec. Specimen size = 55x10x10 mm.
- Type of notch = V-notch Angle of notch = 45°

PROCEDURE :-

1. Lift the hammer to an appropriate knife edge position and notch the energy stored in the hammer. For the standard charpy test the energy stored should be 164j.
2. Locate the test specimen on the m/c supports.
3. Release the hammer. The hammer will break the piece and shoot up the other side of the specimen.
4. Note the residual energy indicated on the scale by the hammer.
5. Impact strength of the test specimen is the difference of the initial energy stored in hammer and the residual energy.

OBSERVATION :-

S.No.	Initial Energy (E1) in joule	Residual Energy (E2) in Joule	Absorb Energy (E1-E2)

CALCULATION :-

- Modulus of rupture = Rupture / Effective volume of specimen
- Notch impact strength = Absorb energy / Effective cross section area

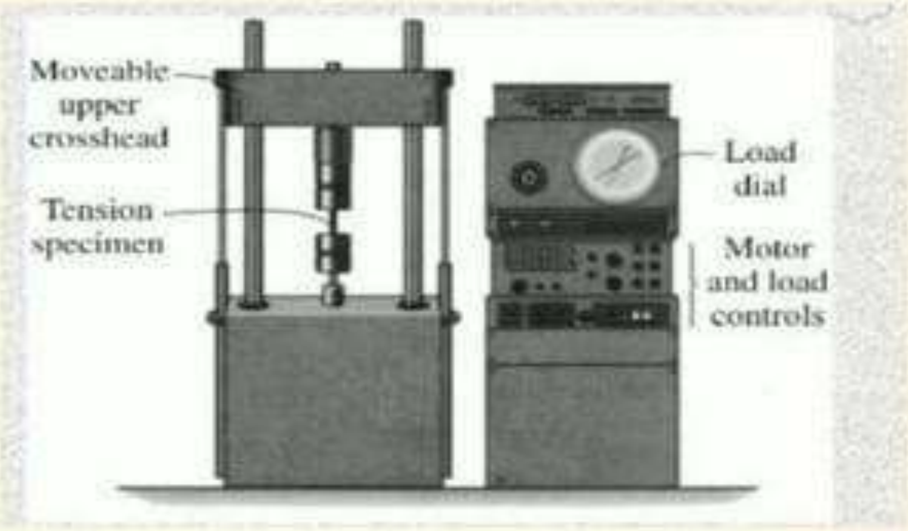
PRECAUTIONS :-

6. The specimen should be prepared in proper dimensions.
7. Take reading more frequently.
8. Make the loose pointer in contact with the fixed pointer after setting the pendulum.
9. Do not stand in front of swinging hammer or releasing hammer.
10. Place the specimen proper position.

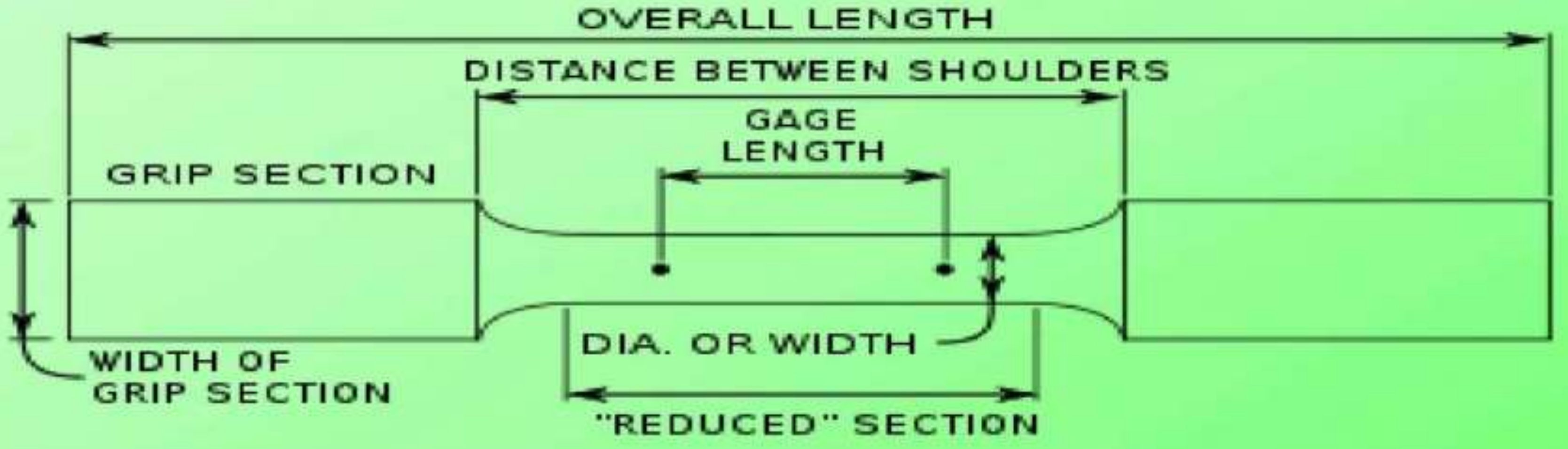
RESULT :- The impact strength of given specimen = ------- joule/mm^2

Week (11-12)

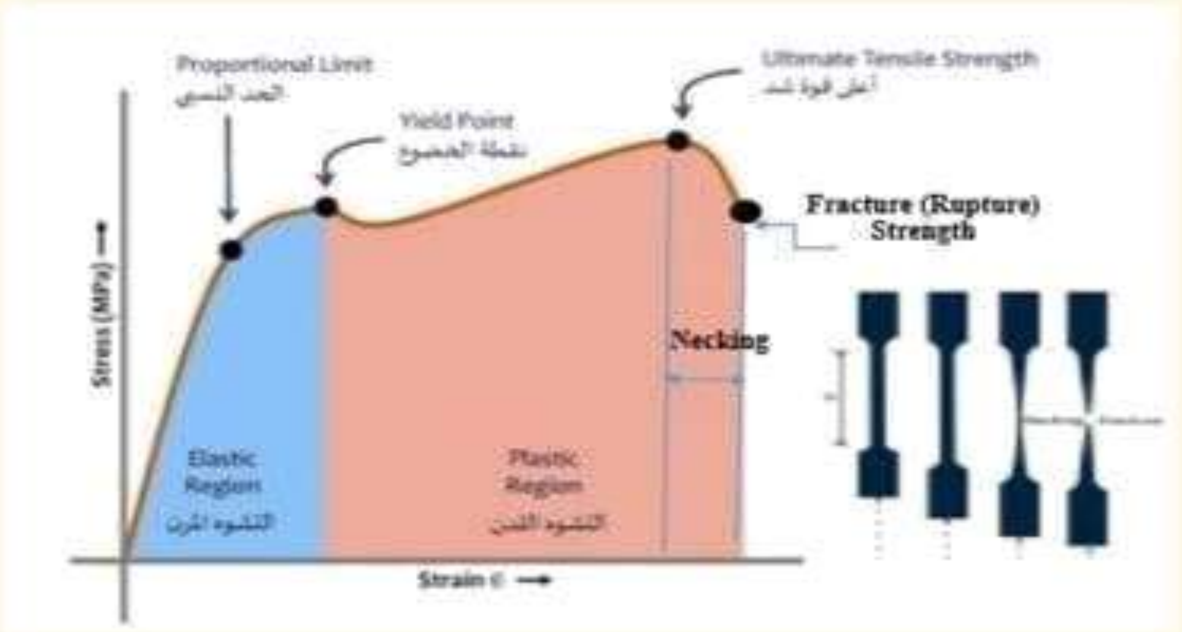
Tensile Testing


Moveable
upper
crosshead
Tension
specimen
Load
dial
Motor
and load
controls

Standard tension specimen



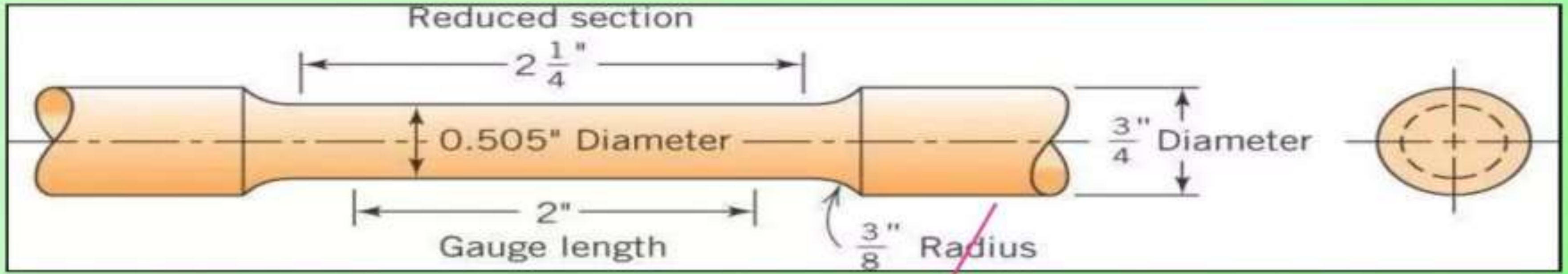
- The accurate measurement of dimensional change achieved by attaching the sensitive measurement device to test piece. The devices used to measure longitudinal strain are termed as extensometer.



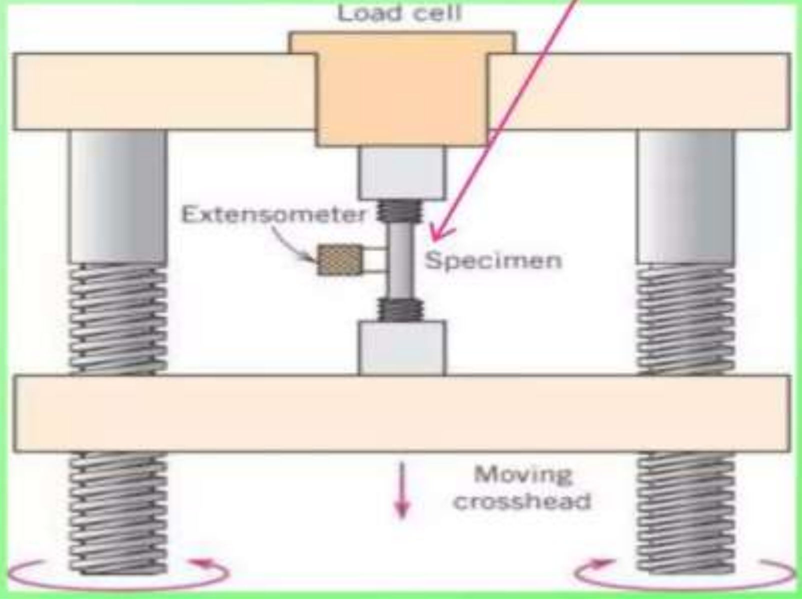
Proportional Limit
الحد النسبي
Yield Point
نقطة الخضوع
Ultimate Tensile Strength
أعلى قوة شد
Fracture (Rupture) Strength
Necking
Stress (MPa)
Elastic Region
التشوه المرن
Plastic Region
التشوه اللدن
Strain ε

Schematic arrangement of a UTM

Tensile Strength - Extensometer

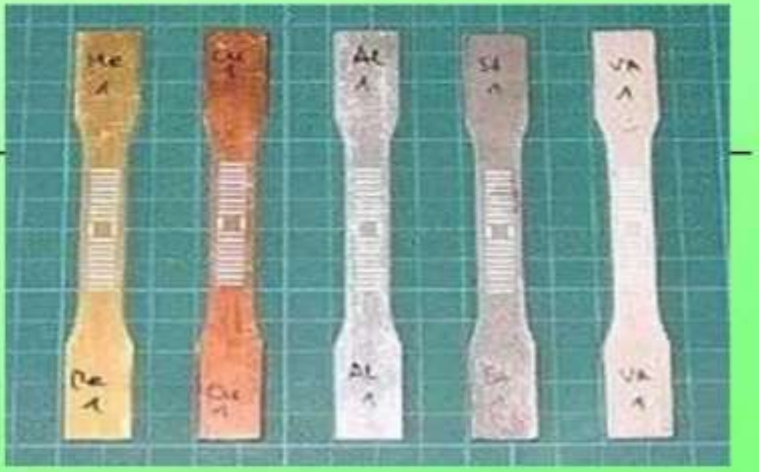


Specimen

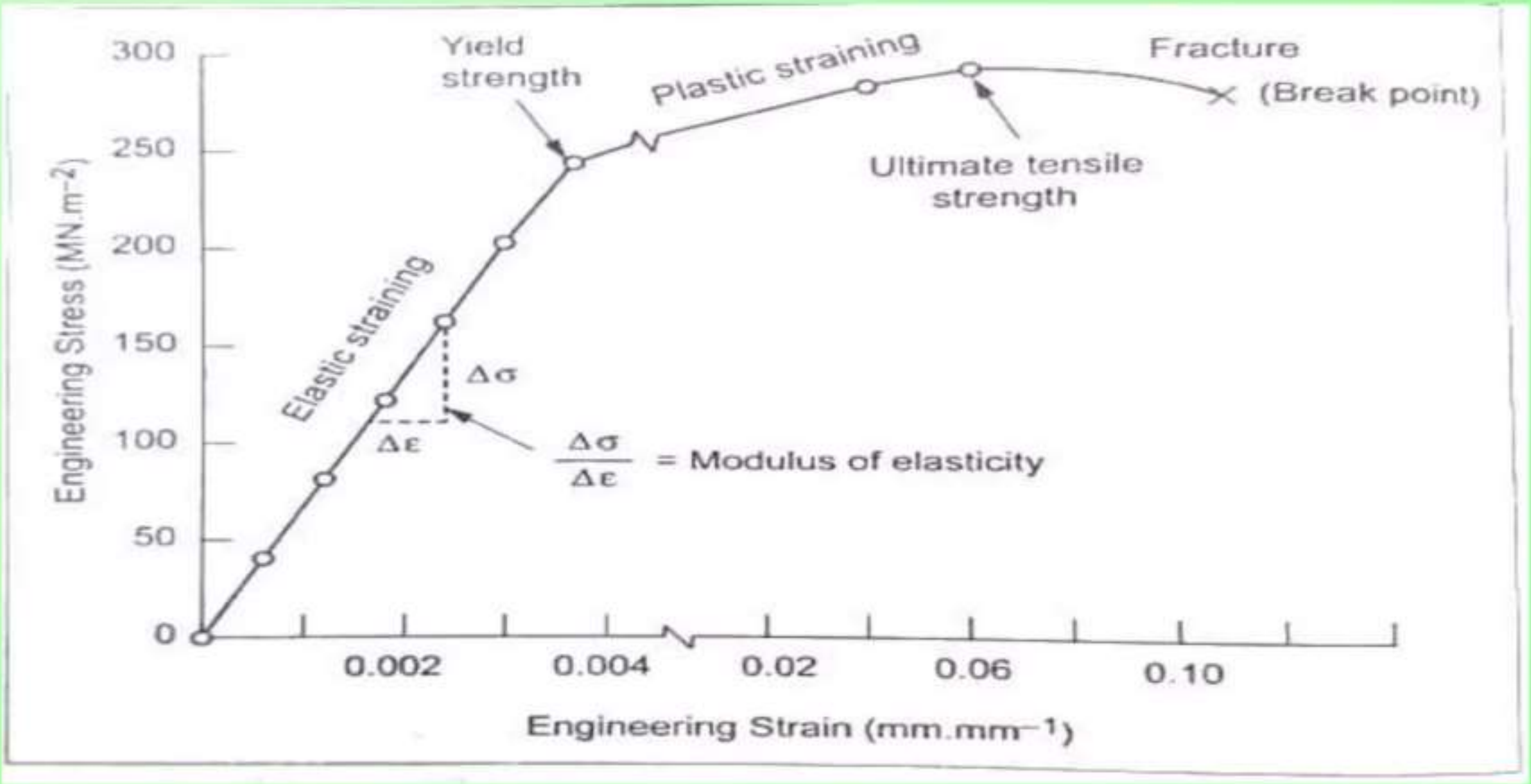


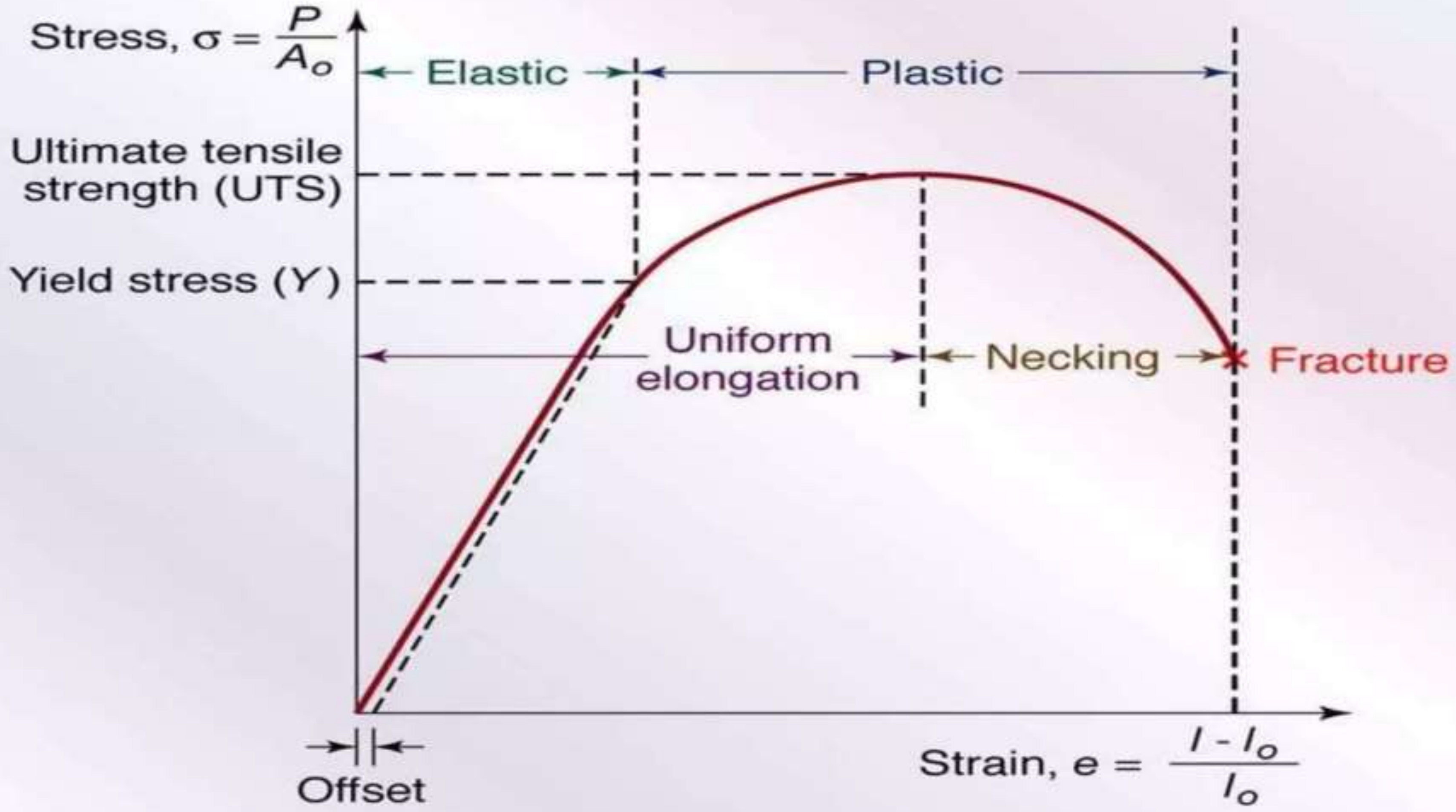
Extensometer

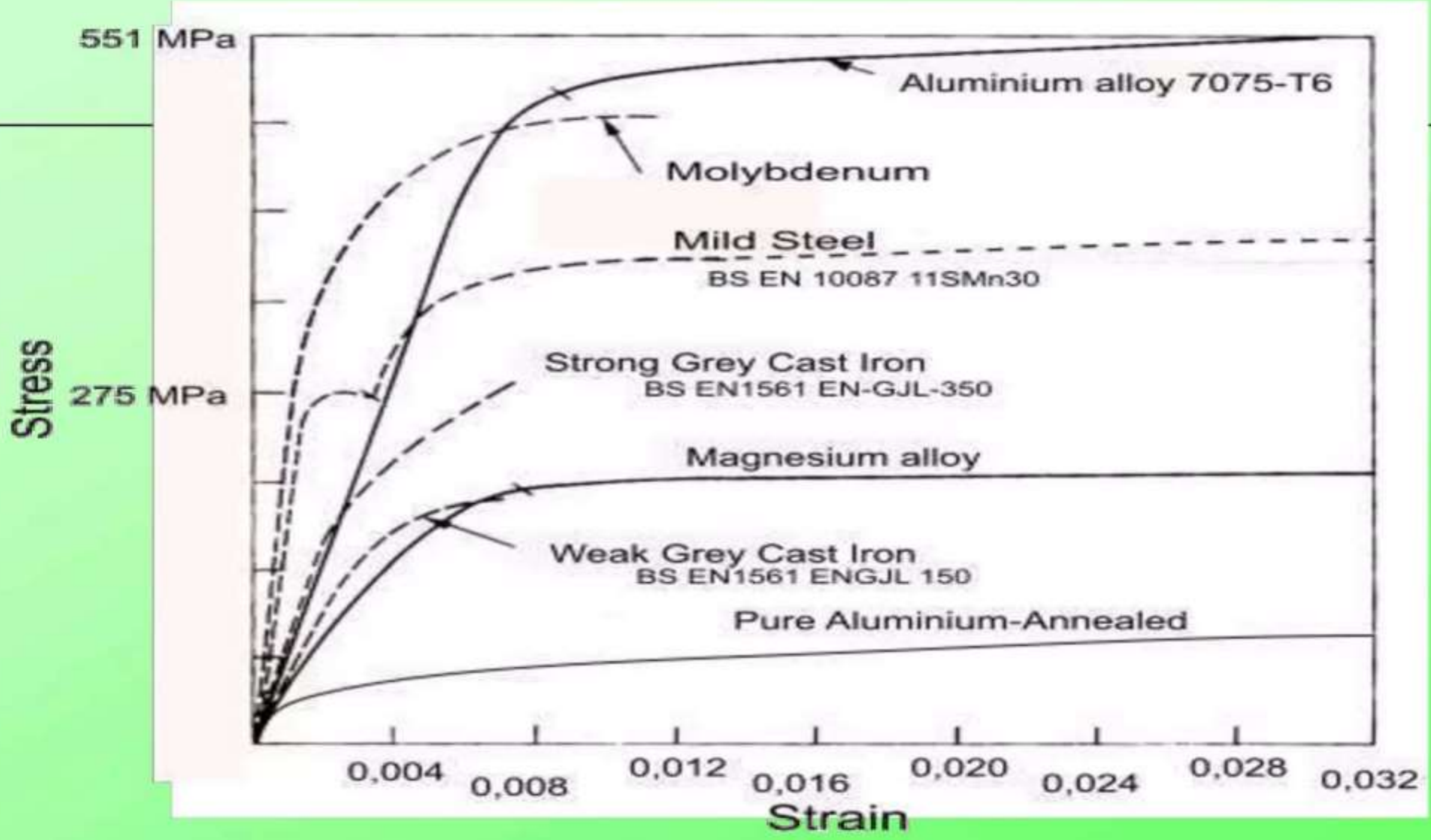
Tensile Strength



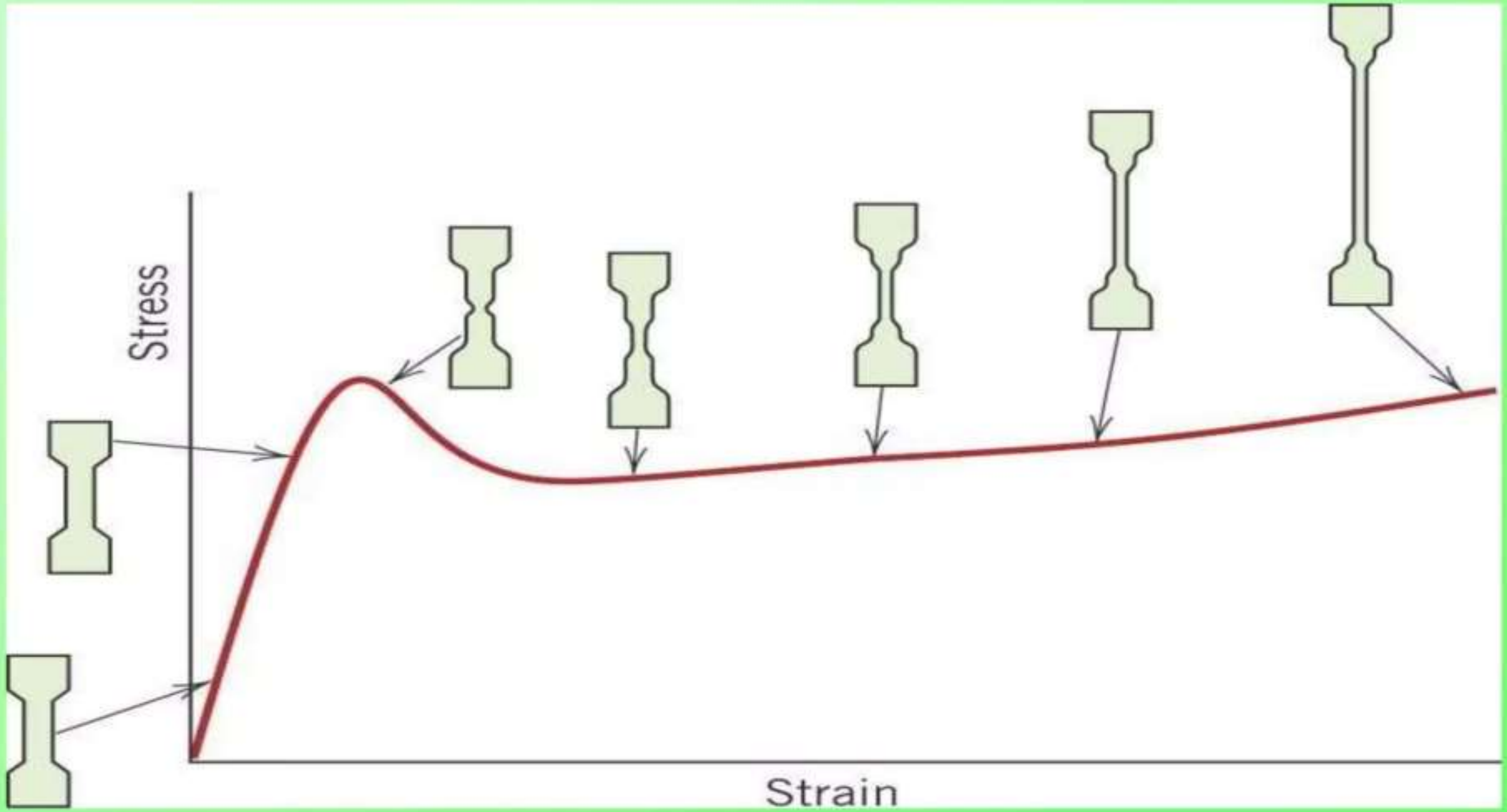
Ex: The stress-strain curve for an Al alloy plotted (Data from previous table)



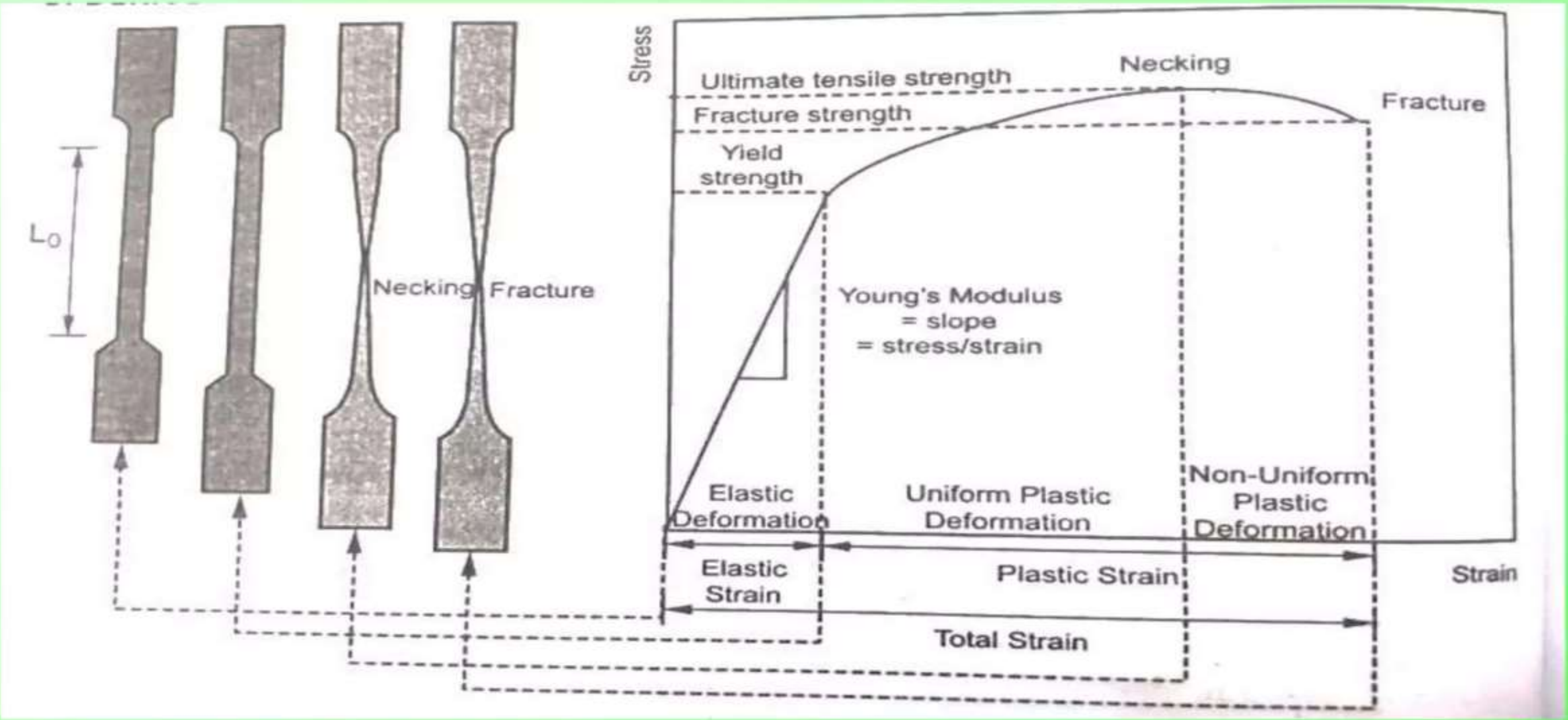

Stress, σ = P/A_o
Elastic
Plastic
Ultimate tensile strength (UTS)
Yield stress (Y)
Uniform elongation
Necking
Fracture
Offset
Strain, e = (l - l_o)/l_o


551 MPa
Aluminium alloy 7075-T6
Molybdenum
Mild Steel
BS EN 10087 11SMn30
Strong Grey Cast Iron
BS EN1561 EN-GJL-350
Stress
275 MPa
Magnesium alloy
Weak Grey Cast Iron
BS EN1561 ENGJL 150
Pure Aluminium-Annealed
0,004
0,008
0,012
0,016
0,020
0,024
0,028
0,032
Strain

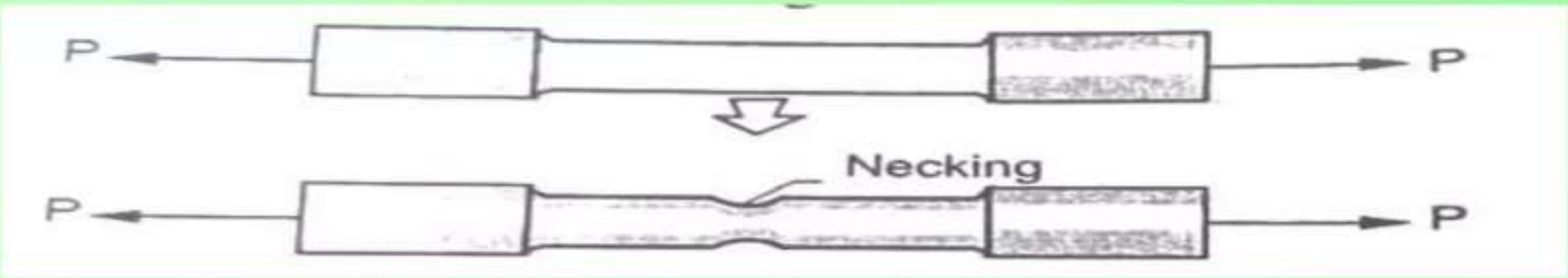
Tensile Strength



Stress Strain curve of Mild-steel



Tensile Strength



- Localized deformation of a ductile material during a tensile test produces a necked region.
- The image shows necked

EXPERIMENT -5

TENSILE TEST

AIM:

To conduct tensile test on a mild steel specimen and determine the following

1. Limit of proportionality
3. Upper yield point
5. Ultimate strength
7. Young`s Modulus

2. Elastic Limit
4. Lower yield point
6. Fracture strength
8. Percentage elongation
10. Ductility
12. True stress & true strain

9. Percentage reduction in area
11. Toughness
13. Malleability

APPARATUS: Universal testing machine, specimen, steel rule, vernier caliper, micrometer

THEORY:

The tensile test is most applied one of all mechanical tests. In this test, a test specimen is fixed into grips connected to a straining device and to a load-measuring device. (One end in stationary grips and the others are in movable grips). If the applied load is small enough, the deformation of any solid body is entirely elastic. An elastically deformed solid will return to its original form as soon as load is removed. However if the load is too large, the material can be deformed permanently. The initial part of the tension curve, which represents the manner in which solid undergoes plastic deformation is termed as plastic. The stress below which the deformation is essentially entirely elastic is known as the elastic limit of the material. In some materials like mild steel a sudden drop in load indicating both an upper and lower yield point denotes the onset of plastic deformation. However some materials do not exhibit a sharp yield point. During plastic deformation at lager extensions, strain hardening cannot compensate for the decrease in section and thus the load passes through a maximum and then begins to decrease. At this stage the ultimate strength, which is defined as the ration of the load on the specimen to the original cross-section area, reaches a maximum value. Until this point the deformation is uniform at all the sections of the specimen. Further loading will eventually cause „neck" formation and rupture follows. Usually a tension test is conducted at room temperature; the tensile load is applied slowly. During this test either round or flat specimens may be used. The load on the specimen is applied mechanically or hydraulically depending on the type of testing machine.

1.Nominal/Engg stress and Nominal/Engg strain:

Original C/S area = A_0 (mm^2) Original gauge length = L_0 (mm) Increase in gauge length = δL_0 Nominal stress = P/A_0 (N/mm^2) Nominal strain = $\delta L_0/L_0$

2.Limit of Proportionality:

Stress is proportional to strain up to this point. Normal Stress = P_A/P_O

Normal Strain = $(\delta L_O)A/L_O$

3.Elastic limit:

When the load is removed at "B" , the specimen will go back to original Dimensions i.e L_O and δ A_O Nominal stress = P_B/A_O

Normal Strain = $(\delta L_O)_B/L_O$

If the specimen is loaded beyond elastic limit it will undergo permanent strain ie. Plastic deformation.

4.Upper yield point:

Nominal stress = P_C/A_O Nominal strain = $(\delta L_O)_D/L_O$

5.Lower yield point:

Nominal stress = P_D/A_O Nominal strain = $(\delta L_O)_D/L_O$

6.Ultimate load or maximum load point:

Nominal ultimate stress = P_E/A_O Nominal strain = $(\delta L_O)_E/L_O$

7.Fracture Load point F:

Nominal fracture stress = P_F/A_O Nominal strain at fracture = $(\delta L_O)_F/L_O$

PROCEDURE:

1. Measure the original gauge length and diameter of the specimen.
2. Insert the specimen into grips of the test machine.
3. Begin the load application and record load vs elongation data.
4. Take the readings more frequently as yield point is approached.
5. Measure elongation values.
6. Continue the test till fracture occurs.

RESULTS AND DISCUSSIONS:

1. Plot the Engg. Stress strain curve and determine the following

Limit of proportionality	=	(N/mm²)
Yield strength	=	(N/mm²)
Ultimate strength	=	(N/mm²)
Young`s modulus	=	(N/mm²)
Percentage elongation	=	%
Percentage reduction in area	=	%
Fracture strength	=	(Nominal /Engg)
Toughness	=	Area under stress – strain curve up to fracture
Malleability		

2. Plot True Stress, True strain curve after calculating true – stress and true strain values at various points.

Estimate

1) Strength coefficient

2) Strain hardening coefficient

3) Determine whether the material is ductile or brittle

4) Comment on the results.

S.No	Load	Deformation	Stress	Strain	E

Week (13-14)

Compression Testing

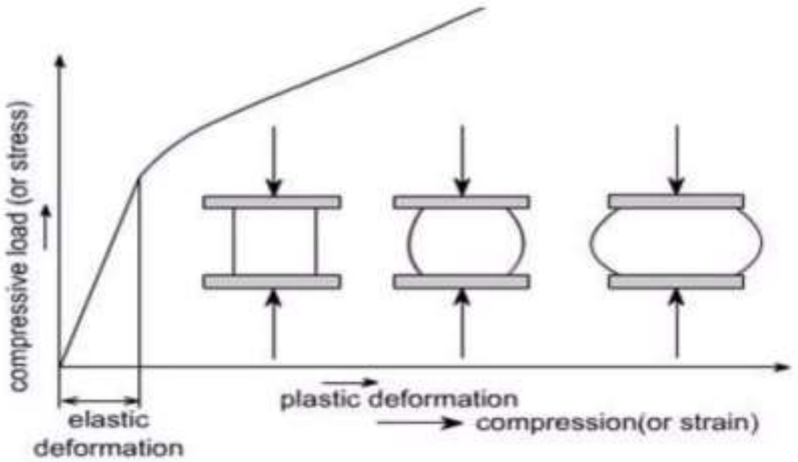
INTRODUCTION

- A compression test is a mechanical test in which a material or product responds to **forces that push, compress, squash, crush and flatten the test specimen.**
- Compression testing is a fundamental mechanical test, similar in nature to tensile and bend tests. Compression tests **characterize material and product strength and stiffness under applied crushing loads.** These tests are typically conducted by applying **compressive pressure** to a test specimen using platens or specialized fixtures with a testing machine that produces **compressive loads.**
- Compression test could be used to **obtain the mechanical properties of metals** however it is not preferred due to the following;

– It is difficult to apply a truly axial load in compression which leading to non uniform stresses

COMPRESSION TEST

The test sample is generally placed in between two hard metal bearing blocks that distribute the applied load across the entire surface area of two opposite faces of the test sample and then the plates are pushed together by a universal testing machine causing the sample to flatten. A sample will get shortened in the direction of the applied forces and expands in the direction perpendicular to the force.



Certain materials subjected to a compressive force show initially a linear relationship between stress and strain.

The Hooke's Law states that,

E = Stress(s)/Strain(e)

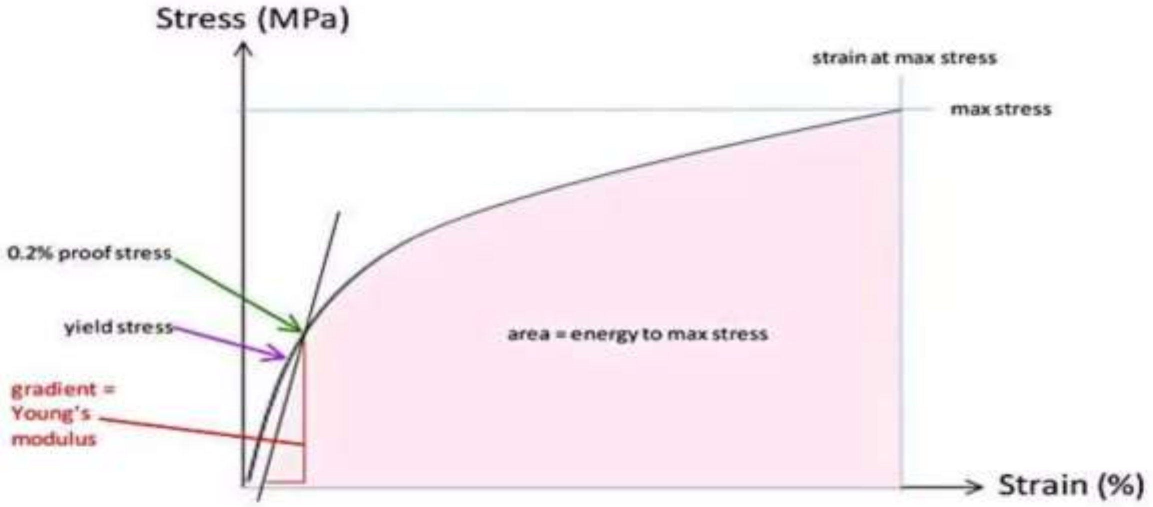
Where E is Young's modulus. This value represents how much the material will deform under applied compressive loading before plastic deformation occurs.

COMPRESSION TEST

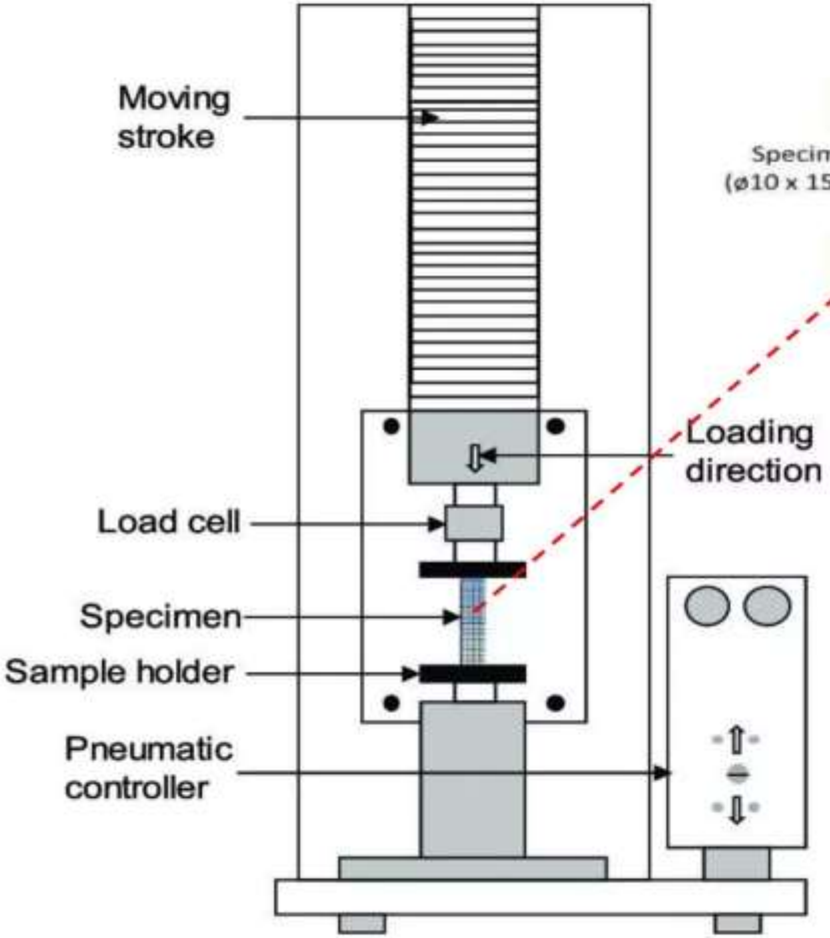
- A material's ability to return to its original shape after deformation has occurred is referred to as **its elasticity.**
- At certain force the permanent or plastic deformation will occur, this is known as **proportional limit.**
- At this point the linear behaviour of graph stops. The force at which the material begins exhibiting this behaviour is called the **yield point or yield strength.**

A specimen will then exhibit one of two types of behaviour, either it will continue to **deform** until it eventually **breaks** or **it will distort until flat.**

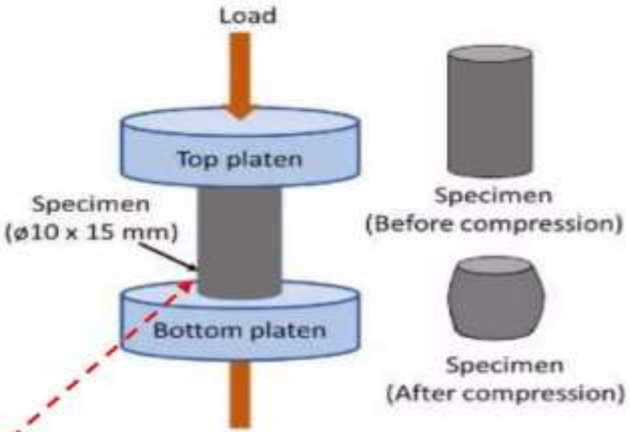
In either case a maximum stress or force will be evident providing its ultimate compressive strength value.



PRINCIPLE



Moving stroke
Loading direction
Load cell
Specimen
Sample holder
Pneumatic controller



Load
Top platen
Specimen (ø10 x 15 mm)
Bottom platen
Specimen (Before compression)
Specimen (After compression)

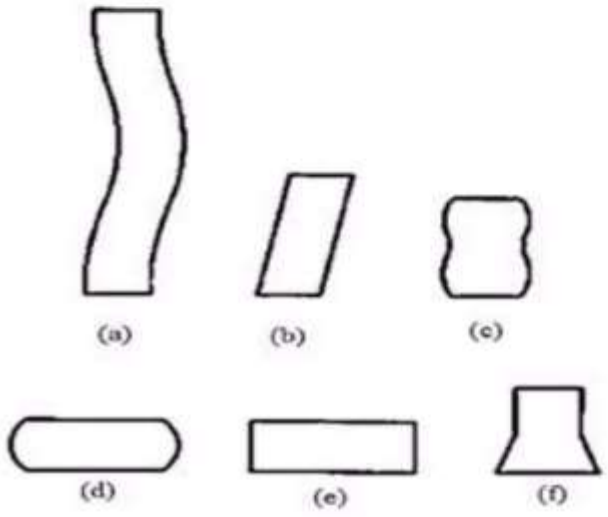
COATED CERAMIC
4X SPEED
clideo.com

COMPRESSION TEST

Modes of deformation in compression testing

The figure below illustrates the different modes of failure in compression testing.

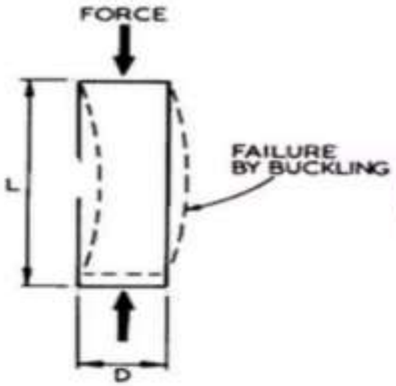
a) when L/D > 5,Buckling
b) when L/D > 2.5, Shearing
c) when L/D > 2.0 and friction is present at the contact surfaces, Double barrelling
d) when L/D < 2.0 and friction is present at the contact surfaces, Barrelling
e) when L/D < 2.0 and no friction is present at the contact surfaces, Homogenous compression.
f) Compressive instability due to work-softening material.

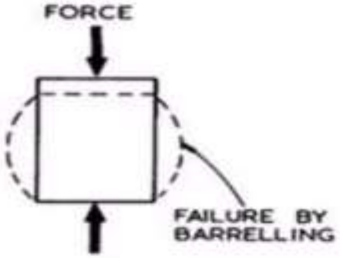


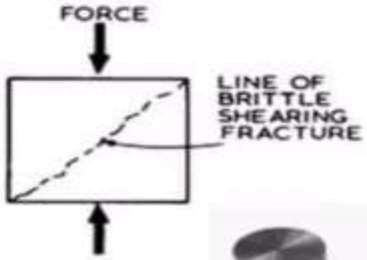
COMPRESSION TEST

Failure patterns:

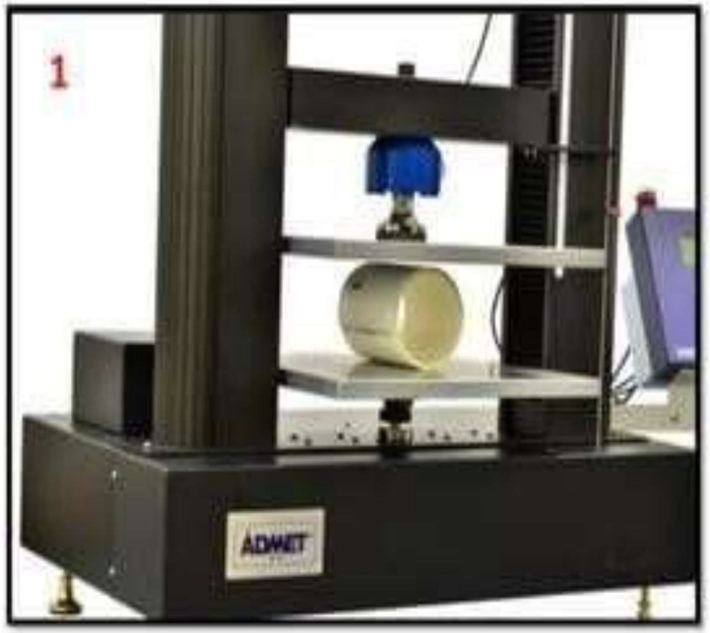
Ductile material will have proportional limit in compression very close to those in tension. The initial regions of their compression stress strain diagram are very similar to tension diagrams. When a mild steel specimen is compressed, it begins to bulge outward on the sides and become barrel shaped. With increasing load the specimen is flattened out, thus offering increased resistance to further shortening.

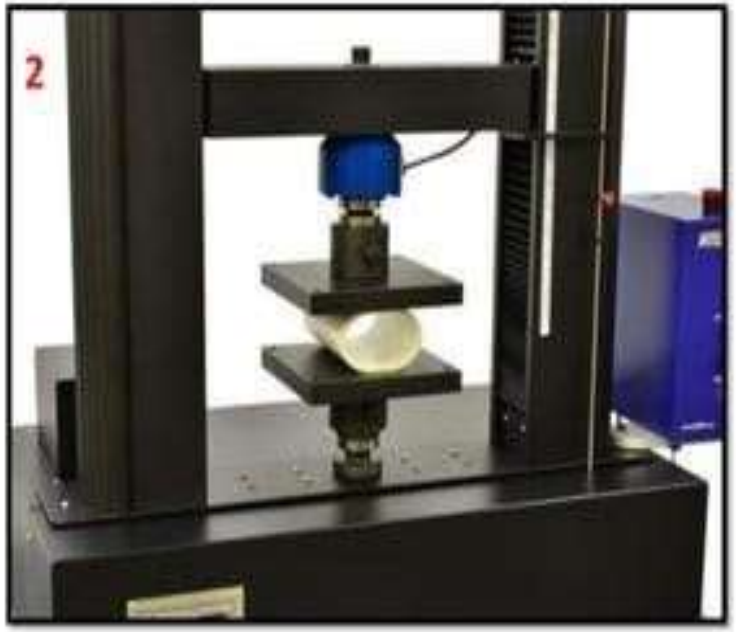






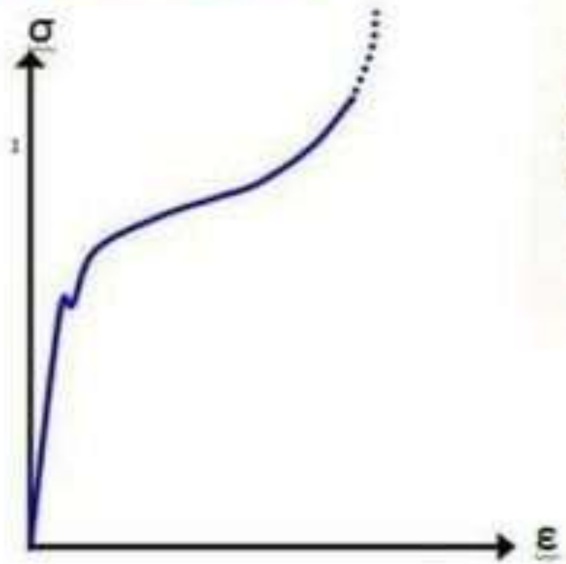
Compression test

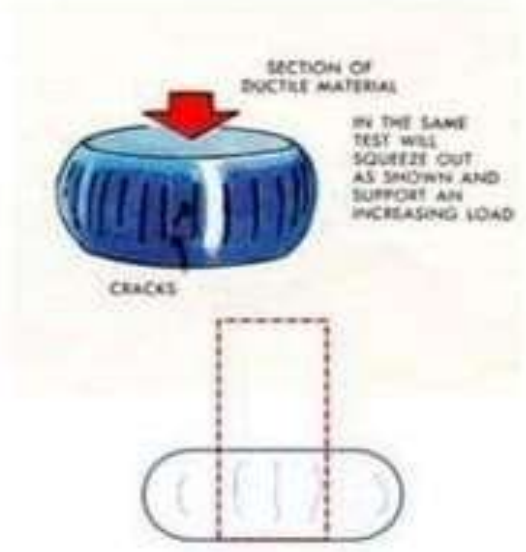


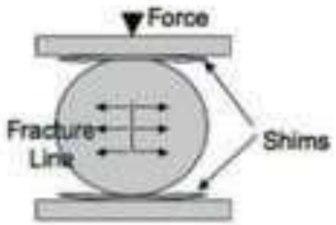


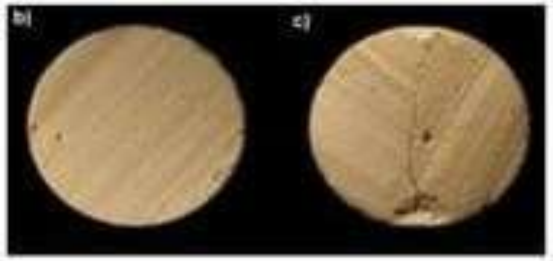
Break and Fracture

Ductile metals

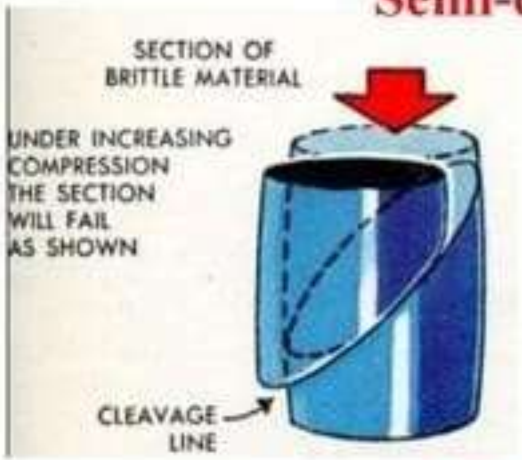


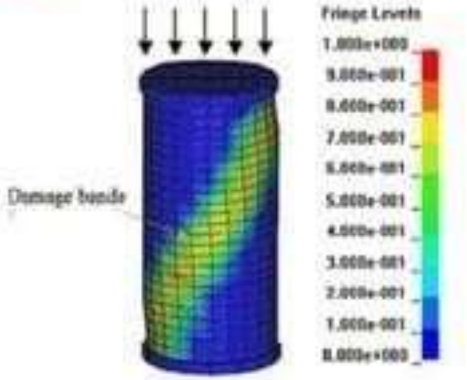




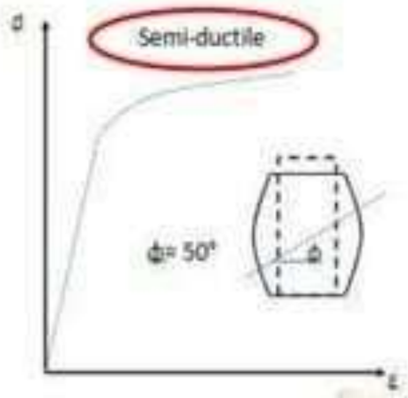


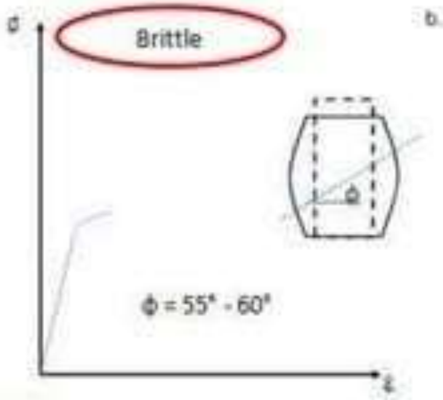
Break and fracture
Semi-ductile and Brittle material



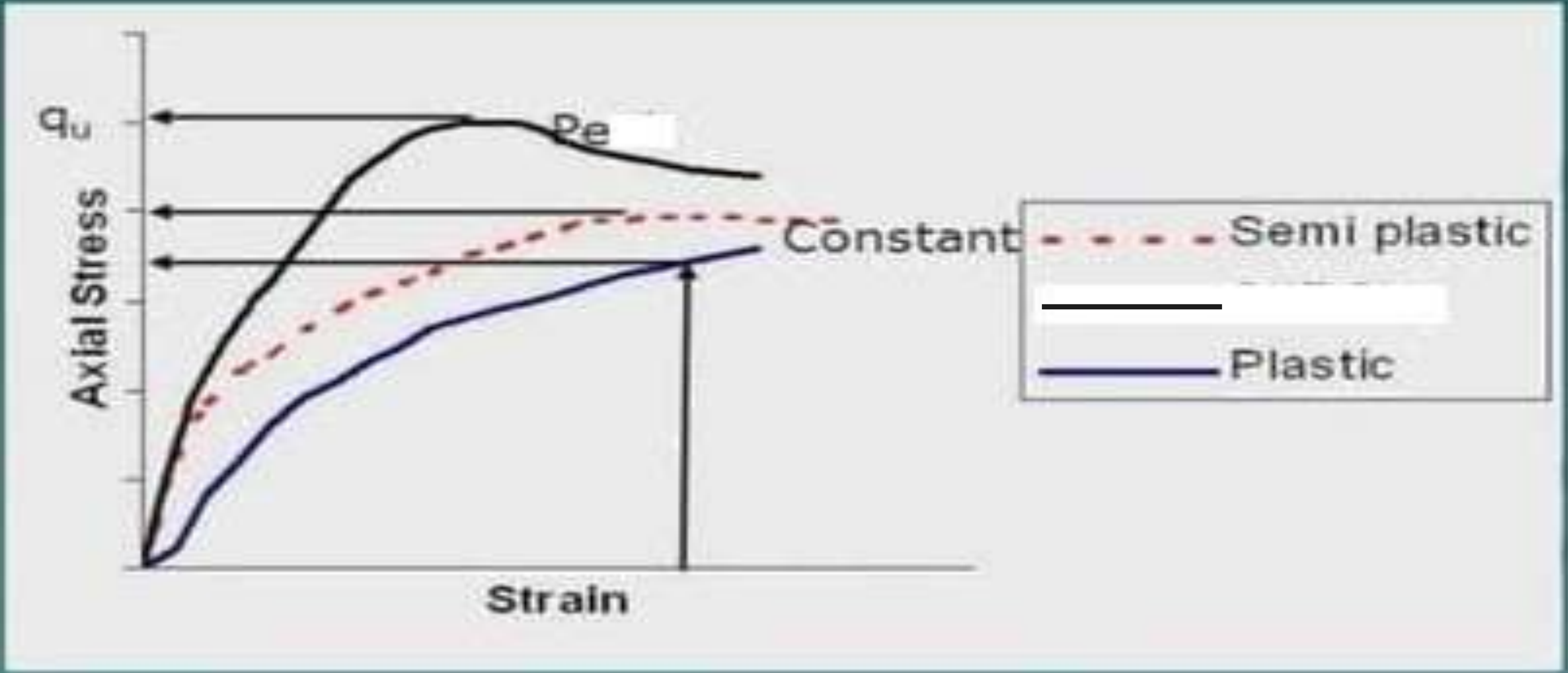


b. Compression. c. Fringe scale.





PRESENTATION OF RESULTS



Compression Test

Objective:

The compression test is used to:

- Observe the stress - strain behavior of some metals under compression load.
- Determine the strength and other properties of various materials.

Introduction:

In theory the compression test is just the opposite the tensile test. However, there are special limitations on the compression test:

1. Appling a truly axial load is difficult.
2. There is always a tendency for bending stresses to be set up.
3. Friction between the heads of the testing machine or bearing plates and the end surfaces of the sample.

Theory:

For a compression test, the stress – strain diagrams have different shapes from those of for tension. Ductile metals such as steel, aluminum, and copper have proportional limits in compression very close to those in tension; and therefore the initial regions of their compression stress – stain diagrams are very similar to the tension diagrams. However, when yielding begins, the behavior is quite different. In a tension test, the specimen is stretched, necking may occur, and fracture ultimately takes place. When a small specimen of ductile material is compressed, it begins to bulge outward on the sides and become barrel shaped. With increasing load, the specimen is flattened out, thus offering increased resistance to further shortening (which means the stress-strain curve goes upward). These characteristics are illustrated in Fig. 1, which shows a compression stress-strain diagram for copper.

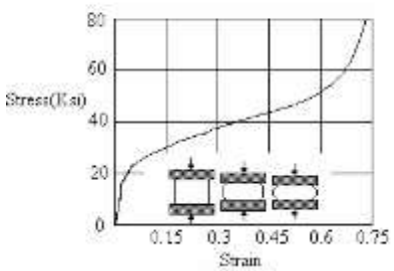


Figure 1

Brittle materials in compression typically have an initial linear region followed by a region in which the shortening increases at a higher rate than does the load. Thus, the compression stress-strain diagram has a shape that is similar to the shape of the tensile diagram. However, brittle materials usually reach much higher ultimate stresses in compression than in tension. Also, unlike ductile materials in compression, brittle materials actually fracture or break at the maximum load.

Apparatus:

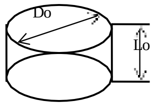
Same apparatus of tension test, but the clamps of the tension test were replaced by the compression jig parts.

Precautions:

1 Machined surfaces should be finished to 1.6μm or better.
2 Test specimens ends should be flat and parallel within .0005 in/in.
3 Test specimens should be loaded concentrically.

Procedure:

1 Measure Do and Lo at three locations along the circumference, or any other dimensions of the used specimen.



2 Lubricate bearing surfaces using suitable lubricant.
3 Start the machine, and apply a compressive force to the ends of the specimen until failure occurs.
4 The results are taken as a load deflection curve.

Results & Analysis:

1. From the load – deflection curve construct the stress – strain curve.
2. From the stress – strain curve determine the following properties for tested material:
    a. Proportional limit.
    b. Yield point.
    c. Yield stress for an offset of .2%.
    d. Ultimate and fracture stress.
3. Percentage elongation and reduction in area at fracture.
4. Modulus of Elasticity.
5. Modulus of Resilience.
6. Modulus of Toughness.
7. Shear Modulus of elasticity (G)
8. Bulk Modulus of elasticity (K).
9. Compare between engineering and true stress measures and comment on the difficulty in obtaining a uniform measure in tension and compression with the engineering stress - strain.
10. Comment in the calculated values of E, G, and ν as compared to known values in tension.
11. In compression test a greater load is necessary to cause yielding than that required in tension test for the same sample. State the reason.

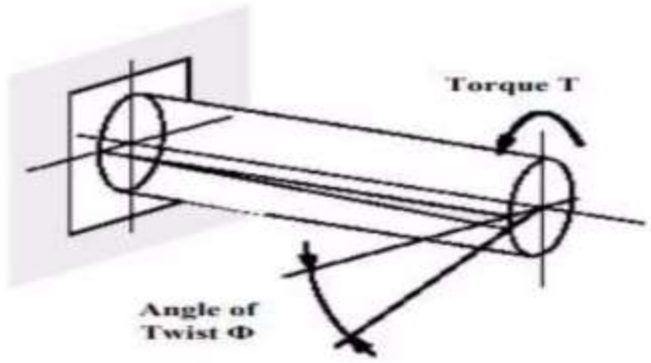
Week (15-16)

Torsion Testing

INTRODUCTION

- Generally, torsion occurs when the twisting moment or torque is applied to a member.
- The torque is the product of tangential force multiplied by the radial distance from the twisting axis and the tangent, measured in a unit of N.m.
- The purpose of a torsion test is to determine the behavior a material or test sample exhibits when twisted or under torsional forces as a result of applied moments that cause shear stress about the axis. Measurable values include: the modulus of elasticity in shear, yield shear strength, torsional fatigue life, ductility, ultimate shear strength, and modulus of rupture in shear.

In a torsion test, a solid or hollow cylindrical specimen is twisted and the resultant deformation, measured as the angle through which the bar is twisted. The test then consists of measuring the angle of twist, Φ (rad) at selected increments of torque, T (N.m).



TORSION TEST

- For transmitting power through a rotating shaft it is necessary to apply a turning force. The force is applied tangentially and in the plane of transverse cross section. The torque or twisting moment may be calculated by multiplying two opposite turning moments. It is said to be in pure torsion and it will exhibit the tendency of shearing off at every cross section which is perpendicular to the longitudinal axis.
- The three common forms that torsion testing take include failure, proof and operational.
- A torsion test for failure requires that the test sample be twisted until it breaks and is designed to measure the strength of the sample.
- A proof test is designed to observe the material under a specified torque load over a set period of time.
- Finally, operational testing is measures the material's performance under the expected service conditions of its application. All of these forms of tests may be performed with either torsion only loading or a combination of torsion and axial (tension or compression) loading depending upon the characteristics to be measured.

TORSION TEST

Torsion equation:-

$$T/J = \tau/R = G\theta/L$$

$$G = T\,L/J\,\theta \ N/mm^2$$

T= maximum twisting torque (N mm),

J = polar moment of inertia (mm^4) = $\pi\, d^4 /32$,

τ = shear stress (N/mm^2)

G = modulus of rigidity (N/mm^2),

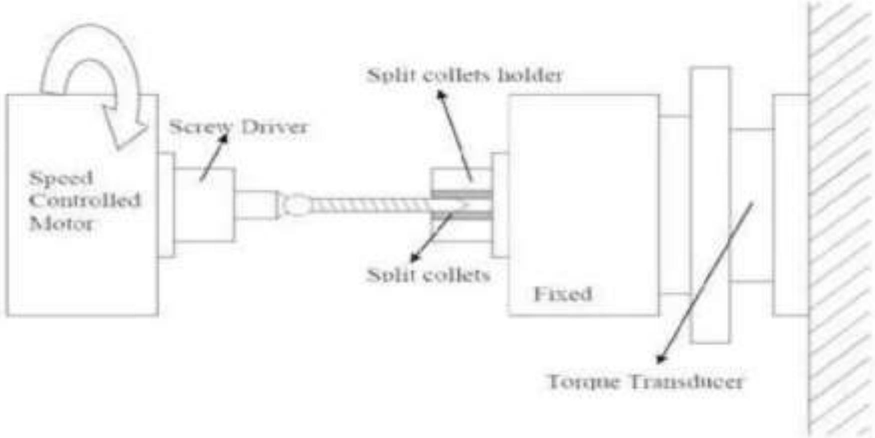
θ = angle of twist in radians

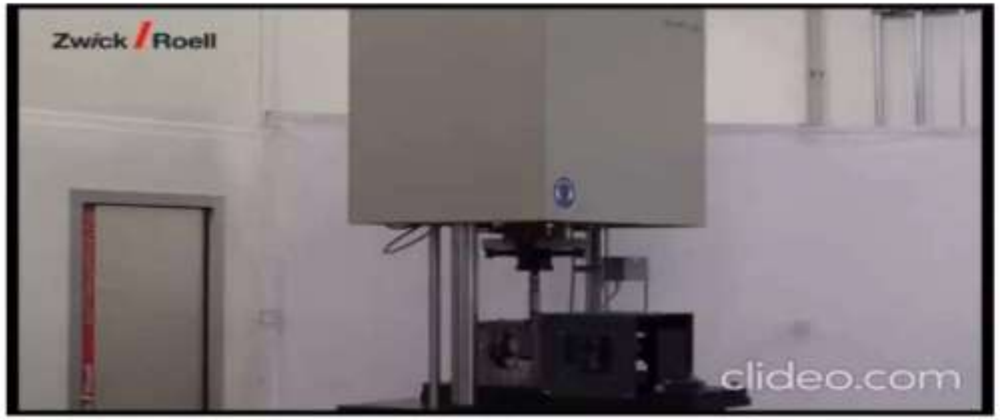
L= length of shaft under torsion (mm)

Precautions:-

1. Measure the dimensions of the specimen carefully
2. Measure the Angle of twist accurately for the corresponding value of Torque.
3. The specimen should be properly to get between the jaws.
4. After breaking specimen stop to m/c.

TORSION TEST





ADVANTAGES AND DISADVANTAGES

- The torsional test is useful for to study the torsional stress-strain relationship and determine shear modulus (G) and Poisson's ratio (v) and relationship between torsional load and angle of twist for a full range of strains till failure.
- It is useful to determine the mode of failure (ductile or brittle).
- Many materials experience torques or torsional forces in their applications and so will benefit from or require torsion testing. Materials used in structural, biomedical and automotive applications are among the more common materials to experience torsion in their applications. These materials may be composed of metals, plastics, woods, polymers, composites, or ceramics among others and commonly take the forms of fasteners, rods, beams, tubes and wires.
- One of the disadvantages of the hot torsion test is its non-homogeneity of deformation. It mostly occurs outside the gauge section of the specimen due to a longitudinal gradient in torsional stiffness along the specimen.

APPLICATIONS

- In many areas of engineering applications, materials are sometimes subjected to torsion in services, for example, drive shafts, axles and twisted drills.
- Moreover, structural applications such as bridges, springs, car bodies, airplane fuselages and boat hulls are randomly subjected to torsion.
- The materials used in this case should require not only adequate strength but also be able to withstand torque in operation.
- Torsion test is applicable for testing brittle materials such as tool steels and cast iron.

EXPERIMENT -7

TORSION TEST

AIM: To conduct torsion test on mild steel or cast iron specimen to find modulus of rigidity or to find angle of twist of the materials which are subjected to torsion.

APPARATUS:

1. A torsion test machine along with angle of twist measuring attachment.
2. Standard specimen of mild steel or cast iron.
3. Steel rule.
4. Vernnier caliper or a micrometer.

THEORY:

For transmitting power through a rotating shaft it is necessary to apply a turning force. The force is applied tangentially and in the plane of transverse cross section. The torque or twisting moment may be calculated by multiplying two opposite turning moments. It is said to be in pure torsion and it will exhibit the tendency of shearing off at every cross section which is perpendicular to the longitudinal axis.

Torsion equation:

Torsion equation is given by below

$$T / I_P = C\theta/L = \tau/R$$

T= maximum twisting torque (Nmm) I_P = polar moment of inertia (mm^4)

τ =shear stress (N/mm^2)

C=modulus of rigidity (N/mm^2)

θ=angle of twist in radians

L=length of shaft under torsion (mm)

Assumptions made for getting torsion equation

1. The material of the shaft is uniform throughout.
2. The shaft, circular in section remain circular after loading.

3. Plane sections of shaft normal to its axis before loading remain plane after the torque have been applied.
4. The twist along the length of the shaft is uniform throughout.
5. The distance between any two normal-sections remains the same after the application of torque.
6. Maximum shear stress induced in the shaft due to application of torque does not exceed its elastic limit.

PROCEDURE:

1. Select the suitable grips to suit the size of the specimen and clamp it in the machine by adjusting sliding jaw.
2. Measure the diameter at about the three places and takeaverage value.
3. Choose the appropriate loading range depending upon specimen.
4. Set the maximum load pointer to zero
5. Carry out straining by rotating the hand wheel or by switching on the motor.
6. Load the members in suitable increments, observe and record strain reading.
7. Continue till failure of the specimen.
8. Calculate the modulus of rigidity C by using the torsion equation.
9. Plot the torque –twist graph (T Vs θ)

OBSERVATIONS:

Gauge length **L** =

Polar moment of inertia **IP** =

Modulus of rigidity **$C = TL/ I_P \theta$** =

S.No	Twisting Moment		Angle of Twist		Modulus of rigidity C	Average C N/mm
	Kgf	Nm	Degrees	Radians		

Calculation Part:

RESULT:

Exercise

Perform the same experiment for two different cross sections on a given specimens

For Mild Steel and Alluminum


Thank you