{ MATERIAL TESTING }

Importance of metals :->

Metals and their alloys are the back bone of all engineering projects and products.

Ranging from all primitive type agricultural implements to advanced aircrafts, automobiles, buildings, bridges, shipping, railways and in all such fields, metals occupy a place of prime importance.

Classification of Engineering Materials :->

- Metallic materials
  - Ferrous
    - → Steel
    - → Cast Iron
  - Non-Ferrous
    - Al, Cu, Zn, Pb, Ni } & its alloys
- Non-metallic materials
  - Organic
    - wood
    - paper
    - Leather
    - Rubber
  - Inorganic
    - glass
    - Ceramic
    - graphite
    - Cement

Testing of Materials :->

Material testing is done to determine various mechanical and metallurgical properties of metals. It is done to test metal's suitability and usability for service.

Classification of material Testing method :->

Generally material Testing can be ~~~~ classified into two types. Namely :

① DT (Destructive Test)
↳ The test specimen breaks after this test.

② NDT (Non-Destructive Test)
↳ Non-Destructive test specimen doesn't break in.

Examples :
- ↳ Hardness Test
- ↳ Tensile Test
- ↳ Impact Test
- ↳ Fatigue Test
- ↳ Creep Test

Examples :
- ↳ Visual test
- ↳ Leakage test
- ↳ Magnetic particle Test
- ↳ Dye penetration Test
- ↳ Ultrasonic Test
- ↳ Eddy Current test
- ↳ X-Ray Diffraction

OF NDT

Non- Destructive Testing :→ (NDT)

↳ Non- Destructive Testing methods are used to test the internal soundness of a material.
↳ In Non- Destructive Testing ; The materials to be tested are neither broken nor destroyed . The tested materials can be put to direct use after NDT with an enhanced ~~Sec~~. surity that, they will not fail when put in operation.

↳ Thus NDT imparts more safety and reliability of the manufactured components.

METHOD OF NDT :→

The commonly used NDT methods are :-

1- Visual Testing
2- Leakage Test or pressure Test
3- Magnetic particle Testing
4- Dye penetrant test or Liquid penetrant test.
5- Ultrasonic testing
6- Eddy Current testing
7- Radiography Test (X-Ray Diffraction)
8- Acoustic method

	Destructive Test (DT)	Non-Destructive Test (NDT)
Full form	DT stands for destructive Testing.	NDT stands for Non-destructive testing.
Purpose	It is carried out to find properties and behaviour of Specimen under different load	It is carried out to find out difects in a specimen.
Specimen	Specimen is damaged during test.	Specimen is not damaged during test.
Defects	Defects can not be found using DT.	Defects are found using NDT.
Cost	It is more costly.	It is less costly.
Example	~~Bending Test~~ Hardness Test Tensile Test Impact Test Fatigue Test Creep Test	Visual test Leakage test Die penetration test. Eddy Current test Ultrasonic test.

NDT

Date 23/04/21
Page 05

{Non-Destructive Test}

1/ (VISUAL TESTING)

Introduction:

↳ visual testing method is simple and widely applied.
↳ This testing is used as the first step in the inspection of a component.

Description:

↳ For visual testing of a component its surface is illuminated and observed with naked eye to detected the flaws.
↳ This is a cheap and easy technique and can be used for inspection of any material, any size, any shape where the surface can be observed.
↳ In visual testing; optical aids like microscope and magnifying glass can also be used for better observation of the surface.

Limitation

↳ It can be used for detection of surface defects only.
↳ The quality of result will soley depends upon the knowledge and skill of the observer.

2. (LEAKAGE TEST / PRESSURE TEST)

Introduction:

This is an important non-destructive testing method used in many engineering applications.

Description:

method: ↳ This testing method consist in filling the part with water under a specified pressure and examining the parts for leaks.

↳ Steam and air may also be used in pressure testing.

Application:

pressure test are used to locate leaks in castings, fabricated units, joined assemblies, vessels, valves and pipes.

3. (DYE PENETRANT TEST)

Introduction :

↳ It is a very simple and cheap method for detecting surface defects of a material.

Application :

↳ This method is widely used for all metals and non-metals of any size and shape.

↳ This method is used to detect several types of defects i.e. Cracks, porosity, leaks present in various components developed during forging, casting, welding, machining, grinding, bending and heat treatment method.

Method :

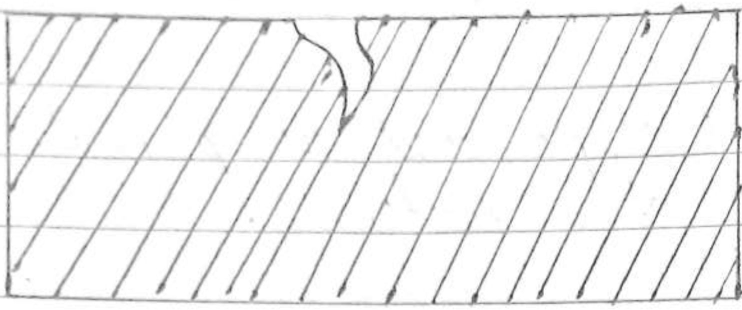
↳ At first the object to be tested is cleaned and dried. Then a thin coloured penetrating dye called 'penetrant' is applied to the surface of the cleaned object.

↳ The dye penetrant passes into the surface defects by capillary action and defects are detected.

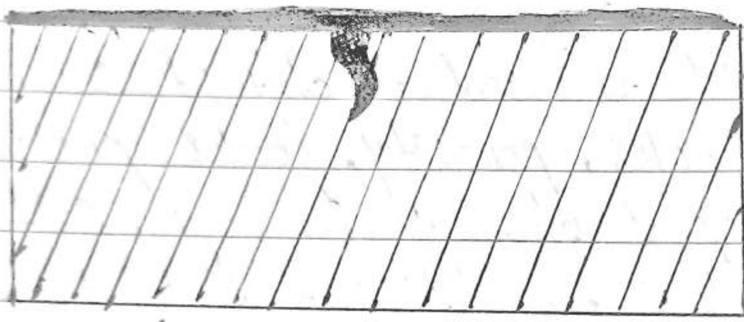
↳ Fine surface defects in a object which is not visible by naked eye is detected in this method.

★ Preparation of the surface and application of penetrate

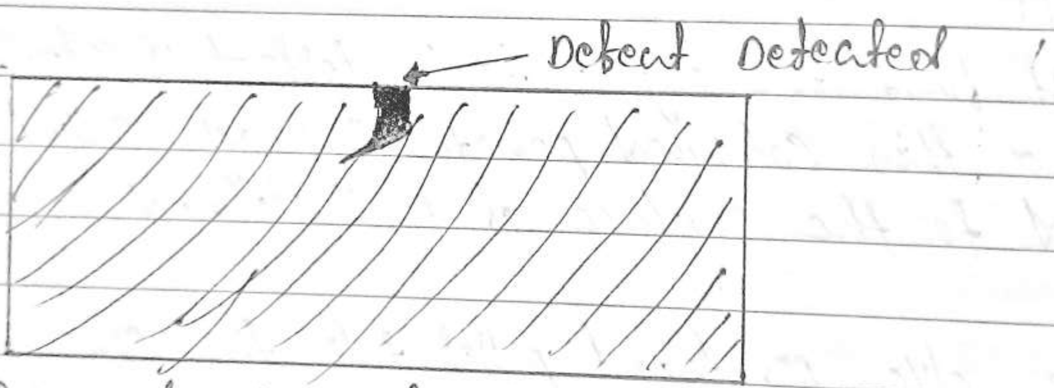
The surface of the component to be inspected is make clean by cleaner. Then the surface is treated with the dye penetrant by dipping, spraying or by dusting. The penetrant is oil like liquid which is penetrant through hole or defect by ~~which~~ capillary action.



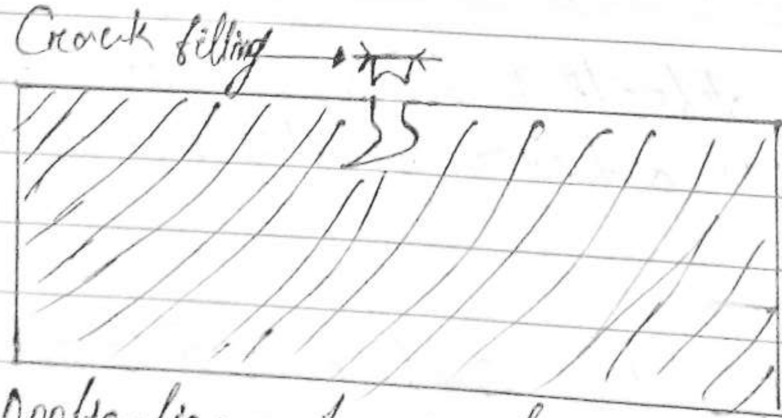
(a) Clean and drying of test specimen



(b) Application of penetrant to the specimen



(c) Removal of penetrant from the test specimen



(d) Application of Developer

4. # ((MAGNETIC PARTICLE TESTING))

Introduction:

Magnetic particle testing is use for the testing of material which can be easily magnetized.

↳ This method is capable of detecting surface and surface having defects such as crake and invisible crack.

Surface preparation:

In order to identify the defects, It is necessary to remove rust, flakes and grease from the surface of inspection.

↳ If the surface is not cleaned thoroughly, It will restrict the free movement of the magnetic particle and being captured at the leakage area.

↳ Mechanical cleaning is carried out by using wire brushes or sand blasting and degreasing is possible by using solvent.

Basic principle:

The basic principle involved in this testing is, If a magnetic field is passes through a perfectly sound or defectfree component then lines of magnetic flux will be uniform and straight. But if the field is pass through a defective component then the lines of flux will get distored in the area of defect.

Method:

The equipment used in this test is known as "Magnaflux" for conducting the test the component is first magnetised. Then iron oxide powders is sprinkled over the surface of the magnetised component. The powder particles align themselves in the direction of the force.

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↳ polar ~~effect~~ effect exists at defects and powder particle jumble ~~down~~ round the defect. In case of sound or defectless components, the powder particle are uniformly distributed all over the surface.
Defect → Curve shape Defectless → linear shape

Limitation
↳ This test can't be used for non-magnetic material
✓ ↳ All Component under this test will carry some residual magnetisation. That's why the Component should be demagnetised before put in use.
↳ This is used only to detect the surface or interior defects of magnetic materials.

5) ((ULTRASONIC TESTING))

Application :

Ultrasonic testing method is very useful for detecting internal defects, cracks and voids in all-most all materials i.e metals, ceramic, graphite, glass, plastic etc.

-> This test is performed very speedily and can detect the defects to any depth below the surface because of its high penetration.

Method :

Ultrasonic testing method detects the interior defects of any object. The ultrasonic sound is passed through the object. If the object possesses any defect, the sound wave is reflected through that defective part and return in a shorter period of time.

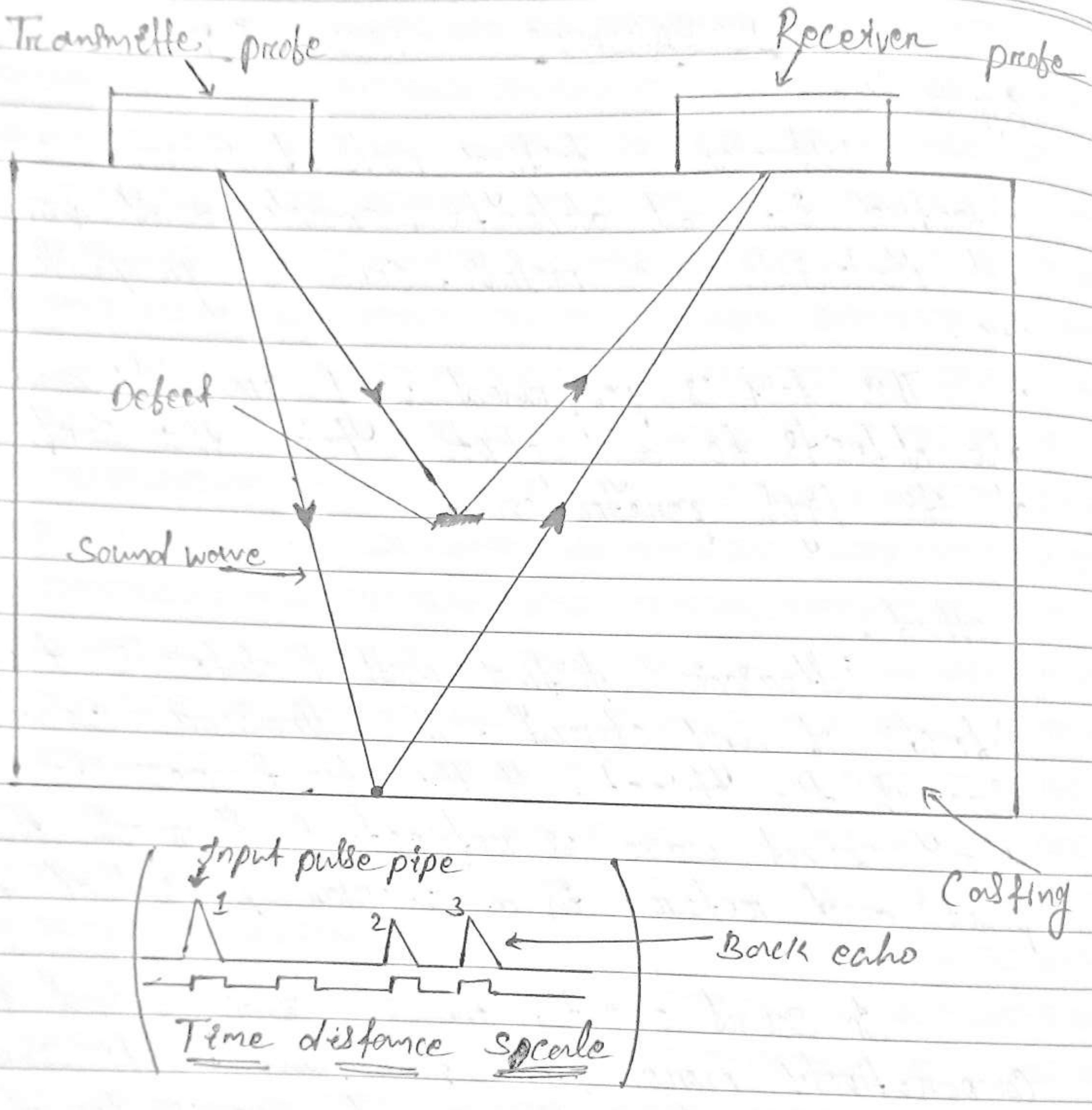
In sound object, the ultrasonic sound takes comparatively more time to return to its surface. The time of traveling the sound wave is found by an oscillograph.

Limitation :

Ultrasonic testing method is not well suited for complicated shapes, rough surfaces, small and thin articles and objects in which the structure is not homogenious.

* Ultrasonic sound : It is a sound of small wavelength beyond the hearing range of human ear.

Date 27/04/21
Page 12



6. ((RADIOGRAPHY TEST))

Application :

Radiography method are commonly used for inspection and determination of internal defects in castings forging etc.

Radiography is a method of inspection that produces a shadow image of the exterior and interior of an object by absorption of radiations. Radiographs may be taken by X-rays or gamma-rays.

Method :

For conducting the test ; X-Ray or Gamma-Ray are directed on the material. After passing through the material the rays strike on the photographic film to show an image there.

The photographic film can be developed to reveal the formed image which consists of darker and lighter areas.

Since more radiation can pass through less denser areas i.e. cavities, voids, cracks, blowholes etc. these defects will be indicated by lighter portion on the film. The denser part of the material through which less radiation can pass will appear as darker portion on the film. Inclusions will appear more darker on the film.

→ In radiographic test ; the inclusion appear darker while blowhole, cavity, voids, cracks appears lighter than the surrounding metal.

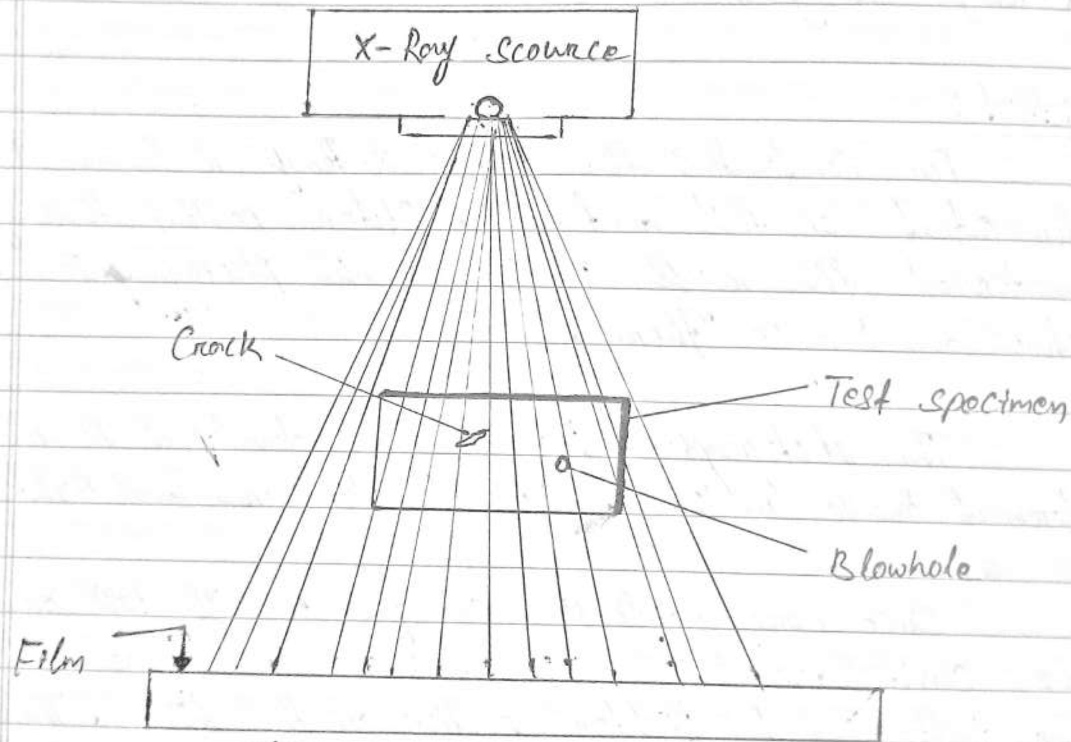
classmate
Date 28/04/21
Page 14

Limitation:

High level precautions is required for handling X-rays & gama-rays.

Advantages:

This method is quicker and is now gaining more popularity in the field of material testing.



《Radiography testing》

7. ## ((EDDY CURRENT TESTING))

Application:

This method can be used to detect surface and near surface defects in both ferrous as well as non-ferrous metals. It is a low cost method and prior surface cleaning of the ~~surface~~ component is not required.

Limitation:

It can be only for those materials which are electrical conductors.

Method:

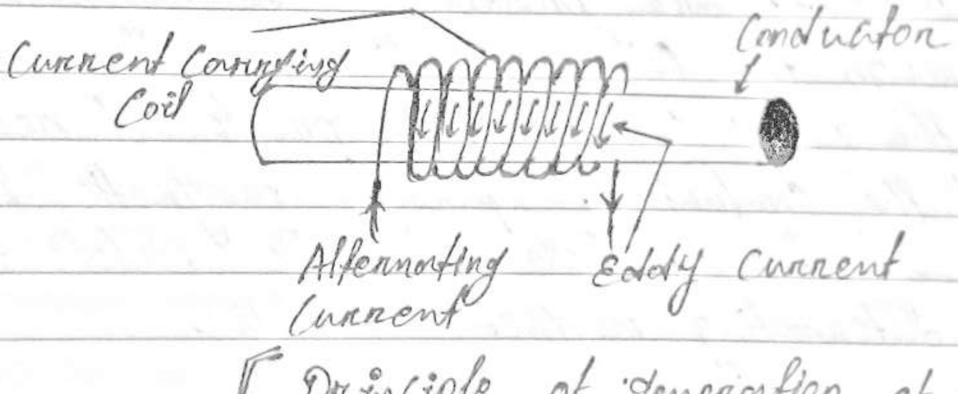
When an electrical conductor is brought near a coil carrying alternating current, eddy current or surface currents are produced because the current flowing through the coil products an alternating magnetic field. As the eddy current are produced near the surface of the conductor, separate magnetic fields are generated by them. These magnetic fields interact with the alternating magnetic fields.

Consequently, the impedance of the current carrying coil is changed. The changes effected in the impedance of the coil are measured. The defects are then detected by identifying and ~~interating~~ interpreting the differential characteristic changes in impedance.

Date 03/05/21
Page 16

Equipments required for Eddy current test :

↳ A source of generating eddy currents in the test specimen.
↳ A source to sence the changes due to interaction of two types of magnetic fields.
↳ A source to detect changes in the impedance.
↳ A source to measure and interpret the changes in the impedance.



[Principle of Generation of Eddy Current]

DT

{Destructive Test}

HARDNESS TEST :

Hardness may be defined as the resistance of a material to withstand abrasion, wear, scratching and indentation.

Hardness is closely related to the strength of a material.

Different method of Hardness tests :-

1. Brinell Hardness Test
2. Rockwell Hardness Test
3. Vickers Hardness Test

1 ★ Brinell Hardness Test :-

↳ This is the most commonly used Hardness Test method

↳ This test is done in Brinell Hardness testing machine.

↳ The testing method consists of pressing a hardned steel ball into a test specimen. Generally 10 mm diameter steel ball is used as indenter.

↳ The load is maintained for about 10-15 sec, and withdrawn so as to make an impression or indentation on the test specimen.

↳ The diameter of the impression is measured.

↳ Hence the Brinell Hardness Number (BHN) Can be calculated as:

$$BHN = \frac{Load}{Area\ of\ impression}$$

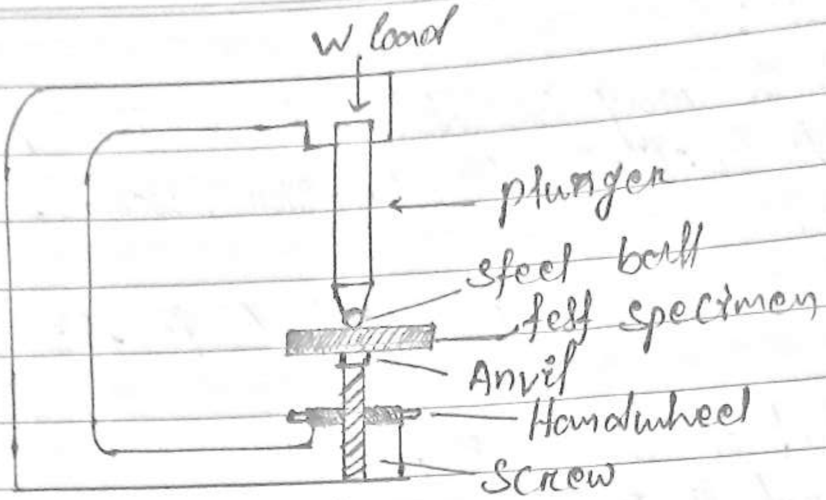
$$= \frac{W}{\left(\frac{\pi D}{2}\right)\left(D - \sqrt{D^2 - d^2}\right)}$$

where,

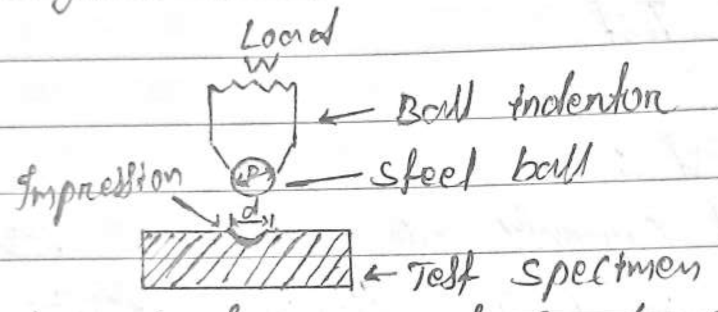
W = Load Applied in kg.

D = Diameter of steel ball (mm)

d = Diameter of the impression (mm)



[Diagram of Brinell Hardness Testing machine]



(Important parameters of Brinell Hardness Test)

↳ BHN is the indication of relative hardness of the material.

↳ The higher the number, harder the material

↳ The load applied varies from 500 kg to 3000 kg. according to the material to be tested.

↳ Brinell Hardness Test is used for measuring hardness of Grey iron castings.

2) * Vickers Hardness Test :

↳ The procedure adopted for conducting this test is similar to Brinell Hardness test.

↳ In Vickers Hardness test a square based diamond pyramid containing 136° angle between opposite faces is used as indenter.

↳ In this test the load generally varies from 5 kg to 120 kg.

↳ The main advantage of this test is the shape of indenter which ensures a higher accuracy.

↳ After the test the Vickers Hardness Number (VHN) or Diamond pyramid Number (DPN) can be ~~calculated~~ calculated as :

$$VHN = DPN = \frac{Load}{Area\ of\ impression}$$

$$= \frac{P}{\frac{d^2}{2} \sin\left(\frac{\theta}{2}\right)}$$

$$= \frac{2P \sin\left(\frac{\theta}{2}\right)}{d^2} = 1.8544 \frac{P}{d^2}$$

(unit is kg/mm²)

where, P = applied load in kg

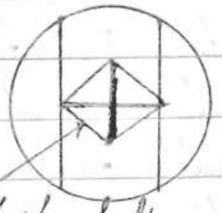
d = Average diagonal length (mm)

θ = Angle between opposite faces = 136°

Application :

Vickers Hardness Test is used for very thin and hard metals and alloys.

Diagonal



Indentation By Square pyramid.

3.★ Rockwell Hardness Test :

It is very widely used Hardness test because of its speed and free from personal errors.

- Rockwell test is faster on compared to Brinell test
- This test gives direct reading.
- Generally there are two scales in Rockwell Hardness testing machine.

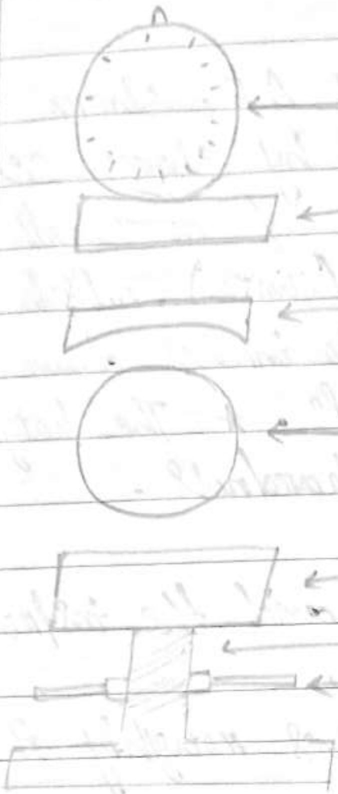
① B-scale	② C-scale
It is used for low and medium cast steel.	It is used for harder material i.e - alloy cast Iron.
In B-scale steel ball indenter is used.	In C-scale diamond cone penetrator i.e 'Brale' is used
Load (100 kg)	Load (150 kg)

Rockwell test is carried out in 2 stages 1st stage; Minor load

In this stage the indenter is set against the test specimen and a minor load of 10 kg is applied resulting a very small penetration into the surface.

2nd stage : Major load

In this stage a heavier load i.e (60-150kg) is applied to the indenter to produce a deeper indentation. This load is called as Major load. After the indentation is made the major load is removed and the test gauge indicates the Rockwell Hardness Number.



Moh's Scale of Hardness :
This scale deviced by German Scientist Friendrich Moh's.
↳ In Moh's scale of Hardness minerals have been arrang by the increasing order of hardness.

Moh's Scale

1- Talc (softest)
2- Gypsum
3- Calcite
4- Fluorite
5- Apatite
6- Orthoclase
7- Quartz
8- Topaz
9- Corundum
10- Diamond (Hardest)

Date ______
Page ______

Shore's scleroscope :→

This device was invented by A.F. Shore

↳ Rebound hardness is measured by shore's scleroscope.

2) The shore's scleroscope consists of a small diamond pointed hammer weighting 1/12 oz (ounce), which is allow to fall freely from a height of 10 inches down a glass tube graduated into 140 equal parts. ★ The height of rebound is taken as the index of hardness.

↳ This test is used for testing rolls and the instrument can be carried about in the workshop.

↳ Shore value multiplied by 6 gives roughly the Brinell hardness number.

★ The hammer is enclosed in a glass tube which carries graduations when the hammer falls on the surface of the materials from a height, it rebounds and the height of this rebound is noted with the help of graduatly in the glass tube.

classmate
Date
Page

Imperical relationship of hardness with stregth

Both hardness and stregth are the important properties of materials. The relationship between hardness and stregth are quite different for different type of materials

There is an empirical relationship between hardness and tensile stregth . .

$$H_V \approx 3\sigma \text{ UTS}$$

H_V = Hardness value.
σ = ultimate tensile stregth.

This means one third of hardness represents the ultimate tensile stregth of some materials.

The ratio between hardness to UTS is lower than 3 in materials having good ductility i.e. anealed Cu & Cu-Zn alloys.

The ratio is increased to a high level in materials which exhibit normal fracture behaviour in tensile test.

$H_V = 3\sigma$ UTS — The equation is valid for materials with relatively high hardness and better toughness.

↳ Hardness is approximately 3 times of UTS.

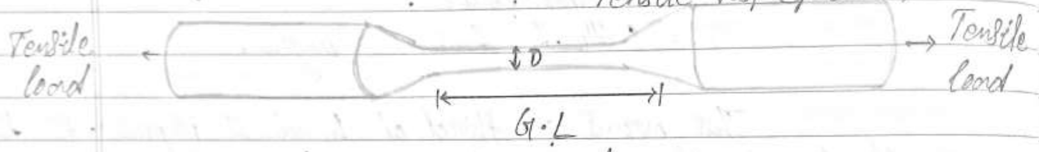
TENSILE TEST

↳ This is a destructive test method of engineering materials. This is the most widely used mechanical test.

↳ Tensile test is done in UTM (Universal Testing Machine).

↳ This test helps to determining proportional limit, elastic limit, yield point, ultimate tensile strength, % Elongation, % Reduction in area.

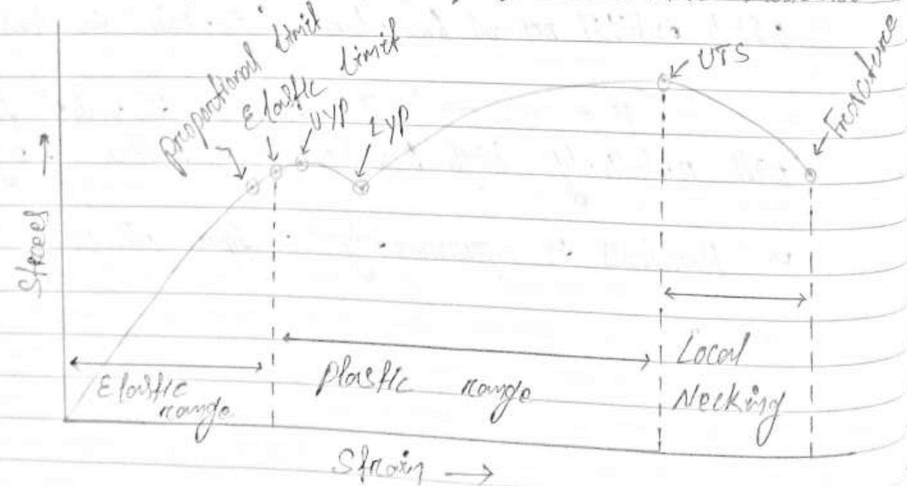
Tensile test specimen



Where, D = Diameter
G.L = Gauge length.

↳ The round cylindrical test specimen is placed in the tensile testing machine and tensile load is applied until the specimen fractures.

↳ The stress-strain curve for a ductile material



Various tensile properties can be calculated as :-

① $$\text{Elastic limit} = \frac{\text{Max}^{m} \text{ load within elastic limit}}{\text{Original area of the specimen}}$$

② $$\text{yield strength} = \frac{\text{Load at yield point}}{\text{Original area of the specimen.}}$$

③ $$\text{UTS} = \frac{\text{Max}^{m} \text{ load}}{\text{Original area of the specimen}}$$

④ $$\text{\% Elongation} = \frac{\text{Final length} - \text{Original length}}{\text{Original length}} \times 100$$

⑤ $$\text{\% Reduction in area} = \frac{\text{Original area} - \text{Final area at breaking point}}{\text{Original area}} \times 100$$

⑥ $$\text{Breaking strength} = \frac{\text{Braking load}}{\text{Original area of the specimen.}}$$

Defination of Ductility :->

Ductility may be defined as the property of a material by virtue of which it can be drawn into wires. Some common ductile metals are lead, tin, silver, aluminium, copper, iron, steel etc.

Defination of Toughness :->

Toughness may be defined as the property of a material by virtue of which it can absorb maximum energy before fracture takes place.

Defination of proof stress :->

proof stress may be defined as the amount of stress a material can withstand without taking more than a small amount of set, 0.1% - 0.2% of the original gauge length.

↳ Most ductile materials exhibit proof stress.

Defination of Stress :->

Stress may be defined as load per unit area.

Defination of Strain :->

Strain may be defined as the change in length per unit length of the specimen.

Definition of resilience

Resilience may be defined as the capacity of a material to absorb energy when it is elastically deformed.

Modulus of Elasticity :→

Hook's law states that; when a material is loaded within its elastic limit, the stress is proportional to strain.

Thus $\frac{Stress}{Strain} = E = Constant.$

This proportionality constant 'E' is called young's modulus of Elasticity.

yield point phenomenon :→

yield point is the point where the specimen begins to elongate. With the increasing load in any specimen a point comes when elongation increases very rapidly with very slight increase in load. This point is called ~~yield~~ 'yield point' of that material.

Upper yield point :→

The first behaviour at which materials begins to flow without any increase in load is called 'upper yield point'.

Lower yield point :→

The point at which the stress begins to rise is called 'Lower yield point'.

Engineering Stress vs True Stress

Engineering Stress	True Stress
↳ Also called conventional stress or normal stress.	↳ Also called natural stress
↳ $\frac{\text{Load}}{\text{Original Area}}$	↳ $\frac{\text{Instantaneous load}}{\text{Instantaneous Area}}$
↳ Unit kgf/mm^2 / N/mm^2	↳ Unit kgf/mm^2 / N/mm^2

Engineering Strain vs True Strain

Engineering Strain	True Strain
↳ Also called conventional strain or normal strain.	↳ Also called natural strain
↳ $\frac{\text{change in length}}{\text{original length}}$	↳ $\frac{\text{change in length}}{\text{Instantaneous length}}$
↳ $\frac{\delta L}{L}$	↳ $\int_{L_0}^{L_i} \frac{\delta L}{L}$

True strain may be defined as the integral of the ratio of an incremental change in length to the instantaneous length of the sample.

The true stress - true strain curves for a number of materials & Alloys.

Q. A mild steel of 13 mm diameter was tested for tensile test with a gauge length of 50 mm. The following observations are:

Final length = 65 mm
Final dia = 8 mm
yield load = 6800 kg
Maximum load = 8400 kg
Fracture load = 7300 kg

Calculate the yeild strength, UTS, breaking strength, % Elongation and % Reduction in area.