Classification of Engineering Material

Depending upon the nature of substance materials are classified as

I. *Metals and alloys*
II. *Non-Metals*
III. *Ceramics*
IV. *Polymers*
V. *Composites*
VI. *Semi-conductors*
VII. *Bio Materials*

I. METALS AND ALLOYS:

Metals:

Metals show high thermal and electrical conductivity. General resistance of pure metals increases with temperature. Many metals display superconductivity at temperature near absolute zero.

The most prominent property of metals is electrons are non-localized i.e. in atomic arrangement outer valency electrons do not belong to individual atom rather it belongs to whole bulk of material. Localized electrons are free to carry charge to conduct electricity. Hence, they are good conductors for electrical and thermal charge.

Metals have lustrous appearance. At normal temperature majority of the materials are in solid state, but some metals like mercury lies in liquid state.

Based upon the presence or absence of iron content metals are named as:

1. *Ferrous metals*
2. *Non-ferrous metals*

1. Ferrous Metals:

The primary content of ferrous metals is iron and carbon. Ferrous metals are magnetic and are vulnerable to rust when exposed to moisture. Wrought iron won't rust due to purity and stainless steel due to presence of chromium.

Eg: iron, steel, etc.

2. Non-Ferrous Metals:

Iron is absent. Due to the absence of iron these metals have high resistance to rust and corrosion and they are non-magnetic.

Eg: copper, brass, aluminium, tungsten, lead, zinc, gold, etc.

Alloy:

Alloy is a combination of two or more metals. It is named based on metallic bonding character. It is of two types' ferrous metal alloy and non-ferrous metal alloy.

II. NON-METALS:

Non-metals are natural materials that do not show conductivity of heat or electricity and that are structurally brittle. These materials are insulators.

Eg: Carbon, Phosphorus, Arsenic, and Selenium etc.

III. CERAMICS:

Ceramics are non-metallic solids made up of inorganic compound such as ***oxides, silicides, nitrides and carbides*** *etc*. Due to its insulating property, they are used as insulators. They are very hard and brittle in nature.

Newly invent ceramics possess exceptional electrical, magnetic, chemical, structural and thermal properties due to which these are used in ***electronic control devices, computers, nuclear engineering*** *and* ***aerospace fields***

Eg: Alumina, Silica, Silicon Carbide, Bricks, Concrete, Cement, Silicate Glasses etc.

Applications:

- Manufacturing of pottery and porcelain (composed of clay materials).
- Because of their good thermal insulation ceramic tiles are used in ovens.
- Alumina, silica, silicon and carbide are used in making tools.

IV. POLYMERS:

Polymers have chain molecule structure of carbon as back bone atoms. They are mainly made up of tough organic compounds that are chemically based on ***Carbon, Nitrogen, Hydrogen, Silicon, Oxygen*** etc. non-metallic elements.

Polymers are not only used as structural materials; they can also be used as fibres and resins in the matrix of composite materials.

Eg : polyester as fibres, phenolics and epoxides as resins etc.

Natural Polymers:

Eg : wool, silk, DNA, cellulose, proteins, etc.

Synthetic Polymers:

- ***Thermo Plastics***
- ***Thermosetting Plastics***

Eg: nylon, polyethylene, polyester, Teflon, epoxy, Bakelite, etc.

Polymers can also be classified as ***Organic Polymers, Inorganic Polymers*** *and* ***Hybrid Polymers*** *(combination of organic and inorganic compound both).*

Applications:

- Polyethylene as carry bags, and packaging material.
- Polypropylene is used for making high temperature resistance products.
- Polyether ether ketone and polyethylene ketone are used in mineral water bottle concept.
- Poly carbonate is used to make high performance polymers like transparent polymers
- Polyaniline is a conducting polymer.
- Bakelite used for making insulating materials.

V. COMPOSITE:

Composite material is the composition of two or more constituent materials with different physical and chemical properties to produce a material of different characteristics.

Composite material may be both metals or metal and ceramic or metal and polymer, depending upon the applications

Eg : wood, concrete, fibre glass, CFRP (carbon fibre reinforced plastic), GFRP (glass fibre reinforced plastic), etc.

Applications:

- CFRP (Carbon Fibre Reinforced Polymer) and GFRP (Glass Fibre Reinforced Polymer) are used for automotive body parts.
- CRPF and honeycomb composites are used for automobile chassis.
- Reinforced thermosets are used in springs and bumper system.
- Fibreglass reinforced plastic used for fishing rods, tennis rackets, helmets, bows and arrows.

VI. SEMICONDUCTORS:

Semiconductor occupy an intermediate position between conductor and insulators. Their conductivity is not high as like metals and not low as like insulating ceramic materials.

In these materials' ***resistance decreases*** as their ***temperature increases***.

These materials behave partially as conductor and partially as insulator.

Eg : Silicon, Germanium, Gallium, Arsenic, Selenium, Carbon, Phosphorous, Sulphur, Iodine, Oxides, Halides, Alloys etc.

Note: Conductivity of a good conductor ***increases*** with purification, whereas conductivity of semiconductor ***decreases*** with purification.

Applications:

- In the field of Electrical Engineering such as Telecommunication and Radio Communication
- Electronics and Power Engineering
- as Amplifiers, Rectifiers, Photocells,

VII. Bio Materials:

Biomaterials are employed in components implanted into the human body to replace diseased or damaged body parts. These materials must not produce toxic substances and must be compatible with body tissues (i.e., must not cause adverse biological reactions). All of the preceding materials such as metals, ceramics, polymers, composites, and semiconductors may be used as biomaterials.

Eg: Man Made Proteins, Bio Sensors, Dental Implants, Cataract Lenses, Joint Replacement, Hip Replacement etc.

Extra

Smart Materials:

Smart (or intelligent) materials are a group of new and state-of-the-art materials now being developed that will have a significant influence on many of our technologies.

The adjective smart implies that these materials are able to sense changes in their environment and then respond to these changes in predetermined manners.

Advanced Materials:

Materials that are used in high-tech applications. These include semiconductors, biomaterials, nanomaterials etc.

Nanomaterials:

With the development of scanning probe microscopes, which permit observation of individual atoms and molecules, it has become possible to design and build new structures from their atomic level constituents, one atom or molecule at a time (i.e., "materials by design"). This ability to carefully arrange atoms provides opportunities to develop mechanical, electrical, magnetic, and other properties that are not otherwise possible. We call this the "bottom-up" approach, and the study of the properties of these materials is termed nanotechnology.

Some of the physical and chemical characteristics exhibited by matter may experience dramatic changes as particle size approaches atomic dimensions. For example, materials that are opaque in the macroscopic domain may become transparent on the nanoscale; some solids become liquids, chemically stable materials become combustible, and electrical insulators become conductors.

Because of these unique and unusual properties, nanomaterials are finding niches in electronic, biomedical, sporting, energy production, and other industrial applications.

Steel

Steel is an alloy of iron and carbon, and sometimes other elements. Because of its high tensile strength and low cost, it is a major component used in buildings, infrastructure, tools, ships, trains, automobiles, machines, appliances, and weapons. Iron is the base metal of steel.

Composition of Cast Iron:

Carbon, C	: 3 – 4%
Silicon, Si	: 1.8 – 2.8%
Manganese, Mn	: 0.15 – 0.9%
Sulphur, S	: 0.03% (Maximum)
Phosphorous, P	: 0.1% (Maximum)
Iron	: Rest of the composition

Composition of Carbon Steel:

Carbon, C	: 0.008 – 2%
Silicon, Si	: 0.1 – 0.38%
Manganese, Mn	: 0.2 – 0.8%
Sulphur, S	: 0.005 – 0.012%
Phosphorous, P	: 0.055%
Iron	: Rest of the composition

Alloy Steel:

When certain special properties are desired, some elements are added to Carbon Steels. Thus, the obtained steels are called Alloy Steel.

Carbon, C	: 0.2 – 0.4%

Silicon, Si	: 0.3 – 0.6%
Manganese, Mn	: 0.3 – 1%
Chromium, Cr	: 0.4 – 0.6%
Nickel, Ni	: 0.4 – 0.7%
Molybdenum, Mo	: 0.15 – 0.3%
Iron	: Rest of the composition

Types of Alloy Steels:

I. *High Strength Alloy Steel [HSLA Steel]:*

HSLA Steels are aimed to provide better mechanical properties and greater resistance to corrosion than conventional Carbon Steel.

These are designed to meet specific mechanical properties, rather than to obtain a specific chemical composition.

Low Alloy steel contains ***1.5% to 5%*** of total alloy mixture.

II. *High Alloy Steel:*

High Alloy Steels or ***Stainless Steel*** have more than ***10%*** of alloy mixture.

A stainless steel is one which contains ***11% or more of Chromium***. The chromium forms an oxide film giving a passive surface, rendering it generally ***more resistant to corrosion*** than that on the lower alloy or carbon steels.

Advantages:

- High Tensile Strength
- High Fatigue Strength
- Good Wear Resistance & Corrosion Resistance
- High Toughness

Applications:

- Coil Springs, Leaf Springs
- High Strength Gears
- Turbine Blades
- Transmission Shafts, Crankshafts etc
- Welded Structures

Effects of Alloying Elements in Steel:

- ***Manganese (Mn)***: improves hardenability, ductility and wear resistance and strength at high temperatures.
- ***Nickel (Ni):*** increases impact strength, toughness and corrosion resistance.

- ***Chromium (Cr):*** improves hardenability, strength and wear resistance and ***corrosion resistance at high concentrations.***
- ***Tungsten (W):*** increases hardness particularly at elevated temperatures due to stable carbides.
- ***Vanadium (V):*** increases strength, hardness, creep resistance and impact resistance.
- ***Molybdenum (Mo):*** increases hardenability and strength particularly at high temperatures.
- ***Silicon (Si):*** improves strength, elasticity, acid resistance.
- ***Titanium (Ti):*** improves strength and corrosion resistance.
- ***Cobalt (Co):*** improves strength at high temperatures.
- ***Zirconium (Zr):*** increases strength.
- ***Boron (B):*** highly effective hardenability agent, improves deformability and machinability.
- ***Copper (Cu):*** improves corrosion resistance.
- ***Carbon (C):*** affects melting point and improves hardness, tensile strength, machinability and compressive strength too.

Mechanical Properties of The Materials

- ***Strength:***

It is the amount of maximum stress induced in a material to resist the externally applied forces without breaking or yielding.

- ***Stiffness:***

Stiffness is the ability of a material to resist deformation under stress. The ***modulus of elasticity*** is the measure of stiffness.

- ***Elasticity:***

It is the property of a material to regain its original shape after deformation when the external forces are removed.

- ***Plasticity:***

Plasticity is a property of a material which shows permanent deformation in any material.

- ***Ductility:***

Ductility is the property of a material enabling it to be ***drawn into a wire*** with the application of a tensile force. A ductile material must be both strong and plastic. The ductility is usually measured by the terms, ***percentage elongation*** and percentage reduction in area.

The ductile material commonly used in engineering practice are mild steel, copper, aluminium, nickel, zinc, tin and lead.

- ***Brittleness:***

It is the property of breaking of a material with little permanent distortion. Brittleness of a material is opposite to ductility property.

Brittle materials are good in compression. Cast iron is a brittle material.

- ***Malleability:***

It is a special case of ductility which permits materials to be ***rolled or hammered into thin sheets,*** making wire. A malleable material should be plastic but it is not essential to be so strong.

The malleable materials commonly used in engineering practice are lead, soft steel, wrought iron, copper, and aluminium.

- ***Toughness:***

Strain energy absorption capacity of a material up to its fracture point.

This property is desirable in parts subjected to shock and impact loads.

- ***Machinability:***

It is the property of a material which refers to a relative ease with which a material can be cut.

The machinability of a material can be measured in a number of ways such as comparing the tool life for cutting different materials.

For example, that brass can be easily machined than steel. That means the machinability property of brass is high when compare to steel.

- ***Resilience:***

It is the property of a material to absorb energy and to resist shock and impact loads. It is measured by the ***amount of energy absorbed within elastic limit***.

- ***Creep:***

When a material is subjected to a constant stress at high temperature for a long period of time, it will undergo a slow and permanent deformation called creep.

This property is considered in designing internal combustion engines, boilers, and turbines.

- ***Fatigue:***

Fatigue is the repeated loading and unloading of metal due to direct load variation, eccentricity in a rotating shaft and differential thermal expansion of a structure. Even substantially below the yield point (elastic limit) of a metal or alloy this repeated loading can lead to failure, usually measured in terms of the number of cycles (repeated load applications) to failure.

Stress (σ)

When a material is subjected to an external force, an internal force is setup within the body. ***The internal resisting force per unit area*** offered by the body is called ***stress***.

$$\text{Stress,} \qquad \sigma = \frac{F}{A} \quad N/m^2 \text{ or } Pa$$

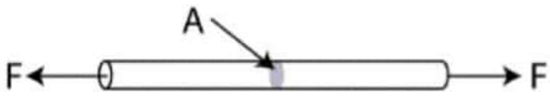
Where,

F = Force applied on the body, which is equal to ***internal resisting force*** offered by body (Every action has equal and opposite reaction).

A = Area Cross-Sectional Area

N/m^2 – Newton per metre square, Pa – Pascal

$1\ N/m^2 = 1\ Pa$



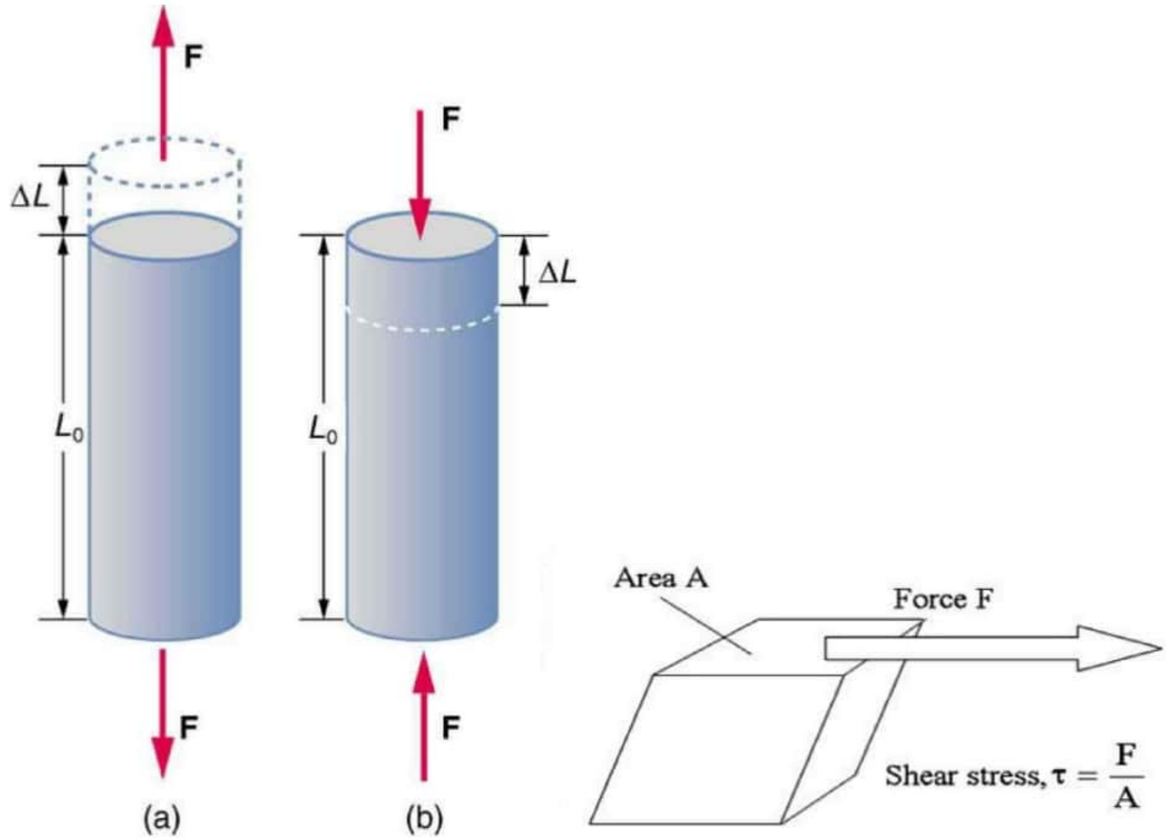


Fig: Tensile Stress, Compressive Stress and Shear Stress respectively

Strain (ϵ)

It is the ratio of deformation or change in length to the original length. It is dimensionless.

Strain, $$\epsilon = \frac{dL}{L}$$

Where,

dL = Change in Length, $dL = L_{Final} - L_{Original}$

L = Original Length

Hooke's Law

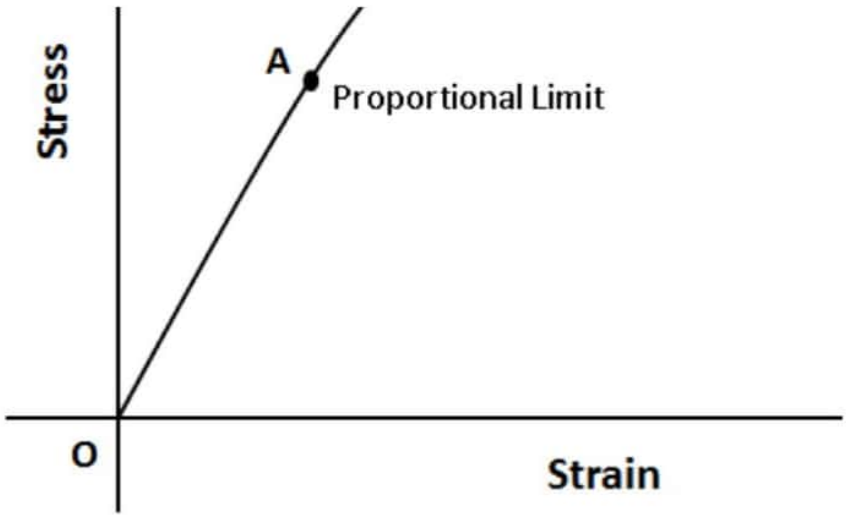
It states that ***stress is directly proportional to the strain*** up to the ***elastic limit.***

$$\sigma \, \alpha \, \epsilon$$

$$\sigma = E \, \epsilon$$

Where, E = Proportionality Constant

$$E = \frac{\sigma}{\epsilon} \quad N/m^2 \text{ or } Pa$$



E: Modulus of Elasticity or Young's Modulus

- It is the ***ratio of Stress & Strain***.
- It is the ***slope of stress strain curve*** up to ***proportional limit***.
- It is ***stress per unit strain***.

- It is proportionality constant of Hooke's Law.
- It is an ***elastic property*** of the material.
- It tells us the ***amount of stress required to produce a unit strain*** in any material.
- It tells us about the resistance offered by material for elastic deformation, ie ***resistance to elastic deformation***.

Its unit is generally in GPa (Gega Pascal)

Note: Elastic Deformation = Temporary Deformation or Recoverable Deformation

Plastic Deformation = Permanent Deformation

1 Pa = 1 N/m^2

1 KPa = 1000 N/m^2 = 10^3 Pa

1 MPa = 1000 Kpa = 1000 * 1000 N/m^2 = 10^6 Pa

1 MPa = 1 N/mm^2

1 GPa = 1000 MPa = 1000 * 1000 KPa = 1000 * 1000 * 1000 Pa = 10^9 Pa = 10^9 N/m^2

K = Kilo = 1000 = 10^3

M = Mega = 1000 * 1000 = 10^6

G = Gega = 1000 * 1000 * 1000 = 10^9

Tensile Testing

Various properties determined by this test are:-

(I) Elastic Limit of material
(II) Ultimate Tensile Strength
(III) Breaking Tensile Strength
(IV) Maximum Elongation
(V) Reduction in area

These evaluated properties allow design engineer to predict behaviour of material in actual applications.

Test involves applying an increasing load or force on a standard test specimen till it fractures.

U.T.M. (Universal Testing Machine) :- or tensile testing machine is used to perform this test. The various test steps to perform a standard test on a given material are:-

Step I - preparation of specimen
Step II - holding specimen in UTM between jaws.
Step III - Gradual load/force is applied by pulling one end to stretch the specimen, while the other end is fixed. keep increasing the load and simultaneously measure the change in length of the specimen until fractures.

Step IV - make observations

Step V - make calculations

Step VI - Draw Stress Strain Curve

The applied load (stress) and displacement (strain) are plotted on a stress-strain curve. The entire process has been recorded or picturized by stress-strain curve. This graph picturize the condition of material under varying load. Data recorded by this curve is used to determine the mechanical properties of material. The following datas measured.

→ Ultimate Tensile Strength (UTS or Sut):- it is the maximum tensile stress induced in the material before fracture.

→ Yield Strength (Syt):- it is the stress at which plastic deformation or yielding is observed to begin.

→ Elongation:- it is required for ductility measurement and strain measurement.

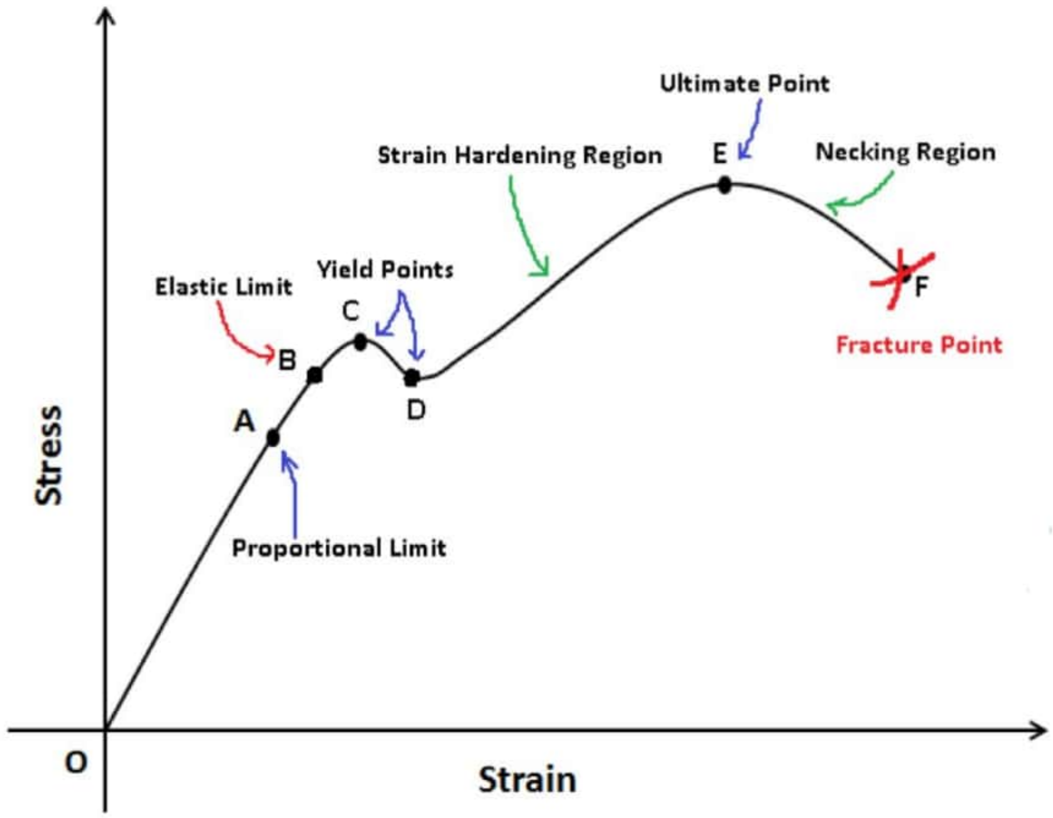
Step VII - Final Calculations:- various measurements (Sut, Syt, and elongation) are calculated after the test specimen has broken.

Step VIII - Final Elongation:- the specimen is put back together to measure the final length, then this measured length is compared to the original length to find elongation.

Step IX - The original cross section is also compared with the final cross section to obtain reduction in area.

Stress-Strain Curve

[1] For Mild Steel (Ductile Material) under Tensile Test



Salient points of the graph:

A = ***Proportional Limit***

Hooke's Law holds good up to this point only, ie linear relationship of stress and strain follow up to this point then it vanishes.

B = ***Elastic Limit***

It is the limiting value of stress up to which the material is perfectly elastic. From the curve, point E is the elastic limit point. Material will return back to its original position, if it is unloaded before the crossing of point E. This is so, because material is perfectly elastic up to point E.

Region, ***O to B = Elastic Region***

C = ***Yield Stress Point***

Yield stress is defined as the stress after which material extension takes place more quickly with no or little increase in load. Point C is the yield point on the graph and stress associated with this point is known as yield stress.

Point C & Point D are upper and lower yield stress point respectively

Region, ***B to C = Elasto-Plastic Region***

ie material behaves partially elastic and partially plastic.

After point C, finally material becomes completely plastic, ie material undergoes permanent deformation.

Region, ***D to E = Strain-Hardening Region***

Material going harder and harder and resist further deformation due to strain energy stored in it. Crystal structure and atomic changes takes place due to that strain energy and material starts resisting further deformation.

E = ***Ultimate Stress Point***

Ultimate stress point is the maximum tensile strength of material that it can bear before breaking.

Region, ***E to F = Necking Region***

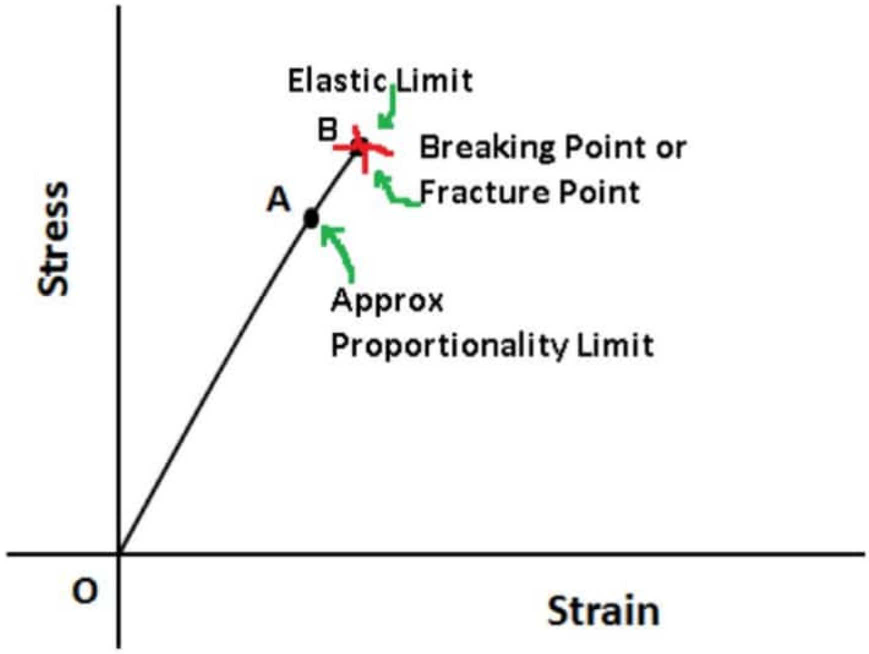
Diameter of specimen or body reduces rapidly over a small length and body is said to form a neck. This necking takes place while the load reduces and fracture of body finally occurs at point F.

F = ***Fracture Point or Breaking Point***

Breaking point or breaking stress is point where strength of material breaks. The stress associates with this point known as breaking strength or rupture strength.

Region, ***C to F = Plastic Region***

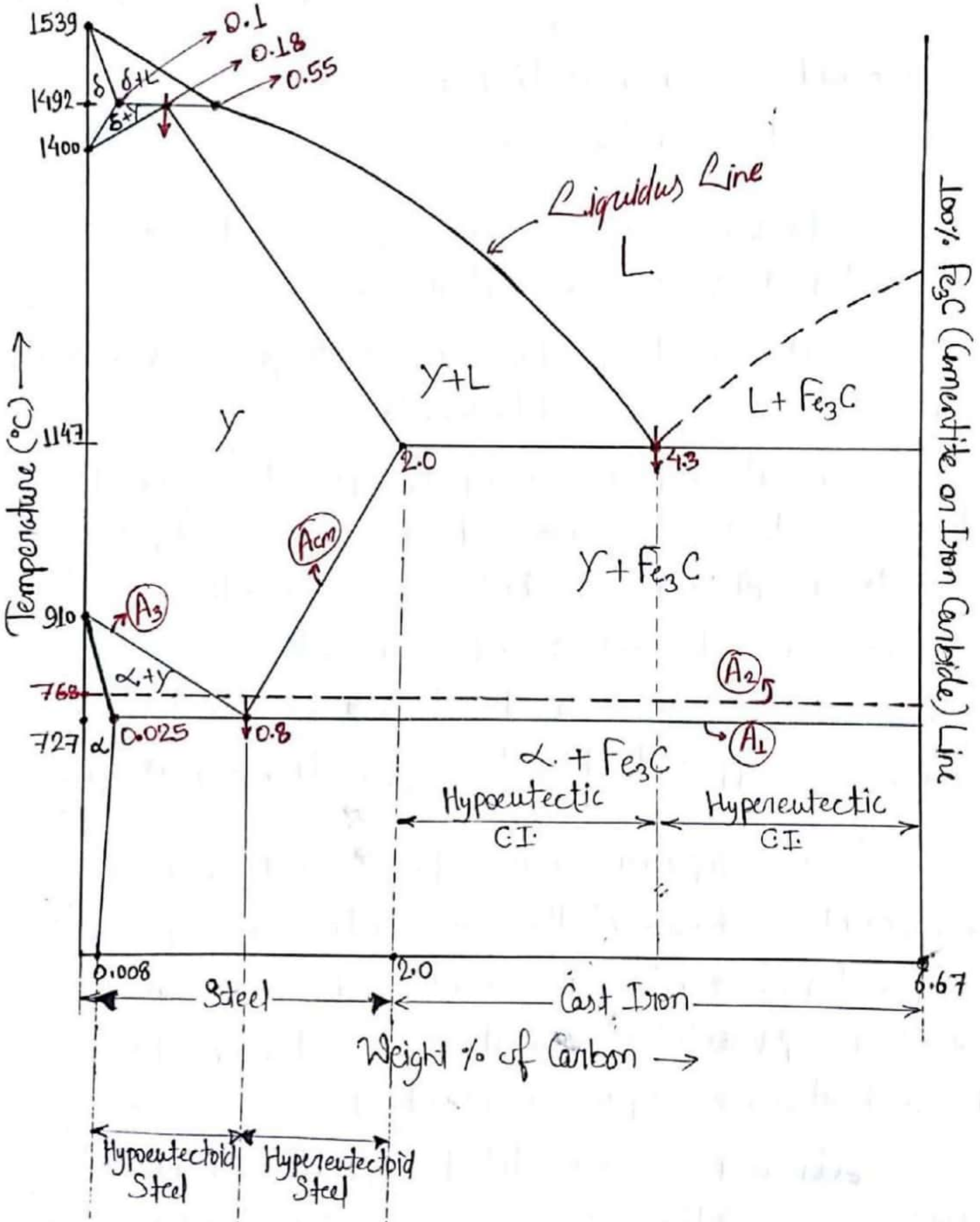
[2] For Cast Iron (Brittle Material) under Tensile Test



Generally brittle material (metal) doesn't show the yield point (elongation) in the stress-strain curve as found in ductile materials (Mild Steel). A perfect brittle material would fracture nearly as the elastic limit. However; a brittle material ie white Cast Iron shows some tendency of plasticity before fracture.

That's mean, brittle material doesn't undergo any plastic deformation.

Iron (Fe) – Iron Carbide (Fe_3C) Diagram or Iron - Carbon Diagram



Graph → Y-Axis → represents pure iron ie 100% Iron and 0% Carbon. and Temperature also.

x-Axis → represents weight percentage of Carbon in iron.

6.67 Weight % of Carbon Vertical line → 100% Cementite or Fe_3C or Iron Carbide.

Pure iron upon heating experiences two changes in crystal structure before it melts.

At room temperature, the stable form, called ferrite or α-iron, has BCC crystal structure.

Ferrite experiences a polymorphic transformation to FCC Austenite or γ-iron at 910°C. This austenite persists to 1400°C at which temperature the FCC austenite reverts back to a BCC phase known as δ-Ferrite, which finally melts at 1539°C. All these changes are apparent along the left vertical axis.

The composition axis extends only to 6.67 or 6.7 Weight % of Carbon, at this concentration the intermediate compound iron-carbide or cementite (Fe_3C), is formed, which is represented by a vertical line at 6.67 wt % C, ie 6.67 wt % C corresponds to 100 wt % Fe_3C.

Carbon is an interstitial impurity in iron and forms a solid solution with each of α-ferrite and δ-ferrite and also with austenite, as indicated by the α, δ and γ single phase fields.

In the BCC α-ferrite, only small concentrations of carbon are soluble, the maximum solubility is 0.025 wt % at 727°C. The limited solubility is explained by the shape and size of the BCC interstitial positions which make it difficult to accomodate the carbon atoms.

Austenite or γ-phase of iron, when alloyed with carbon alone, is not stable below 727°C. The maximum solubility of carbon in austenite, 2.0 wt %, occurs at 1147°C. This solubility is approximately 100 times greater than the maximum for BCC ferrite, because the FCC interstitial positions are larger.

The δ-ferrite is virtually the same as α-ferrite, except for the range of temperatures over which each exists. Because the δ-ferrite is stable only at relatively high temperatures.

Cementite (Fe_3C) forms when the solubility limit of carbon in α-ferrite is exceeded below 727°C. Cementite (Fe_3C) will also coexist with the γ phase between 727°C and 1147°C. Mechanically cementite is very hard and brittle, the strength of some steels is greatly enhanced by its prence.

Definitions of Important Phases

α-Ferrite:- It is an interstitial solid solution of carbon in α-iron (pure) which is of **BCC structure.**

Maximum Carbon solubility in α-ferrite phase is 0.025%

Max. Carbon solubility in α-ferrite at room temperature is 0.008%.

δ-Ferrite:- It is an interstitial solid solution of carbon in δ-iron which is of BCC structure.

Maximum Carbon solubility in δ-ferrite phase is 0.1%

γ-Austenite:- FCC Structure

It is an interstitial solid solution of carbon in γ-iron.

Maximum Carbon solubility in γ-Austenite phase is 2%

Cementite (Fe_3C or Iron Carbide):-

It is an intermetallic compound of Iron and Carbon

Maximum Carbon solubility in Cementite is 6.67%

Some important Invariant Reactions

(I) Peritectic Reaction :- (1492°C, 0.18 % C)

$$\delta + L \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftharpoons}} \gamma$$

i.e. $S_1 + L \rightleftharpoons S_2$

{where, $\delta \rightarrow \delta$-ferrite, $\gamma \rightarrow \gamma$-iron or Austenite

$L \rightarrow$ Liquid , $S_1, S_2 \rightarrow$ Solid 1 and 2 respectively }

(II) Eutectic Reaction :- (1147°C, 4.3% C)

$$L \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftharpoons}} \gamma + Fe_3C$$

$$L \rightleftharpoons S_2 + S_3$$ {$S_3 \rightarrow$ Solid 3}

$\gamma + Fe_3C \leftarrow$ Ledeburite

γ → Solid Solution, Fe_3C → Compound

ie Ledeburite = Austenite (γ) + Cementite (Fe_3C)

⇓

It is an eutectic mixture of Austenite and Cementite. It has no phase ie Polyphase Alloy.

(III) Eutectoid Reaction :- (727°C, 0.8% C)

$$\gamma \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftharpoons}} \alpha + Fe_3C$$

$$S_2 \rightleftharpoons S_4 + S_3$$

$\{S_4 \rightarrow \text{Solid } 4\}$

Pearlite $= \alpha + Fe_3C$

It is eutectoid mixture of ferrite (α) and Cementite (Fe_3C)

or It is an eutectoid decomposition product of Austenite (γ)

Some important Lines and their significance

A1 Line:- It is known as lower critical temperature line. This line signifies the transformation of pearlite ($\alpha + Fe_3C$) into austenite upon heating of eutectoid steels.

A2 Line:- It is known as Curie Point temperature line. It signifies the magnetic to non-magnetic transformation upon heating.

It is 768°C Constant temperature line upon heating above 768°C, iron looses its magnetic property and become non magnetic and upon cooling below 768°C iron becomes magnetic, but carbon has no effect of curie point temperature.

A_3 Line ÷ It is known as upper critical temperature line for Hypoeutectoid Steels. It signifies the transformation of pearlite ($\alpha + Fe_3C$) into γ- Austenite upon heating of Hypoeutectoid Steels.

Acm Line ÷ It is known as upper critical temperature line for Hypereutectoid Steels. It signifies the transformation of Cementite (Fe_3C) into γ- Austenite upon heating of Hypereutectoid Steels.

Hardness Testing

Hardness is defined as resistance offered by a material to scratch, wear, indentation or localized permanent deformation. on surface.

Brinell Hardness Testing (Ball)

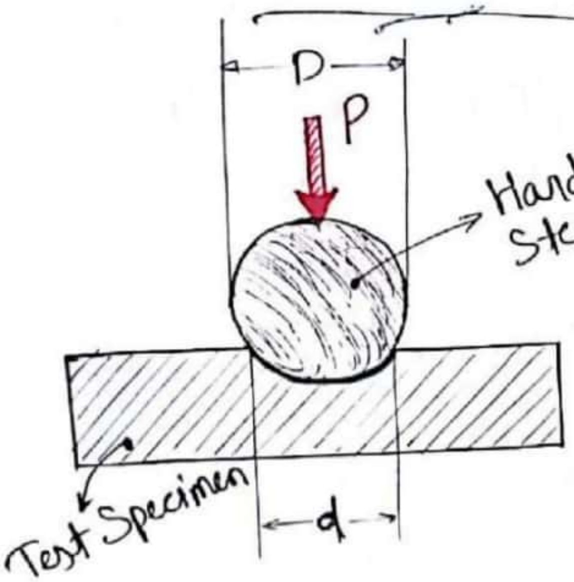


Fig:- Front View

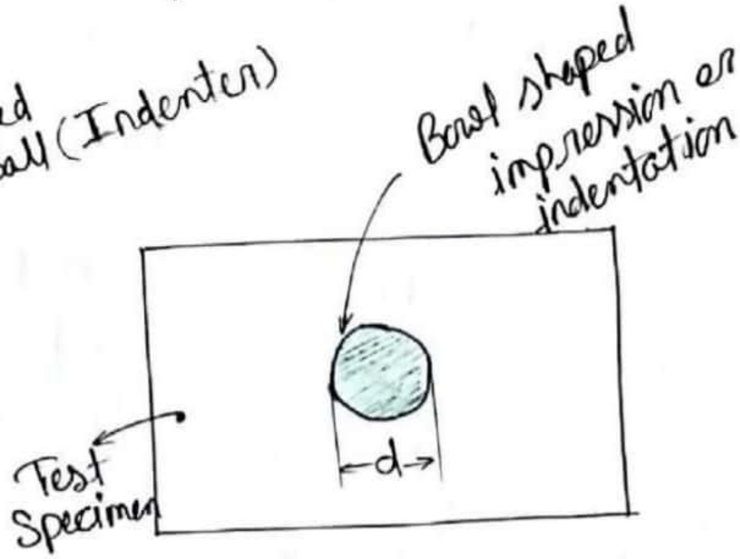
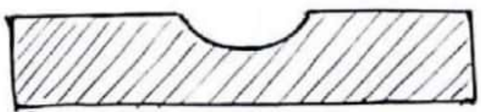


Fig:- Top view



P → applied load or force

D → Indenter diameter ie Ball diameter

d → Impression or Indentation diameter on test specimen

This test consists of indenting the test specimen material by a hardened steel or carbide ball subjected to a load of 3000 kg.

This load can be reduced to 1500 kg or 500 kg for testing soft materials to avoid excessive indentation

The load is applied for 10–15 seconds in case of iron and

The diameter of the indentation left in the test specimen is measured with the help of a microscope.

The Brinell Hardness Number (BHN) is obtained by dividing the applied load by the surface area of the indentation.

$$B.H.N. = \frac{\text{Load Applied (in kg)}}{\text{Surface Area of the Indentation (in mm}^2\text{)}}$$

$$\boxed{B \cdot H \cdot N. = \frac{P}{\frac{\pi D}{2}\left(D - \sqrt{D^2 - d^2}\right)}}$$

Imact Testing or Toughness Testing

Objectives:-

(I) To determine dynamic toughness/notch toughness/impact toughness. of the material.

(II) To determine ductile to brittle transition behaviour in materials.

→ Impact testing is used to determine the material toughness or impact strength in the presence of flaw or notch by impact loading conditions.

→ It is a dynamic test. It has a V-notched test specimen gripped vertically.

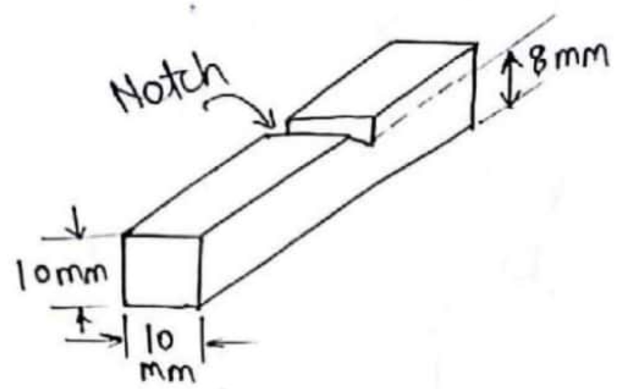


Fig:- specimen used for Izod and Charpy impact test.

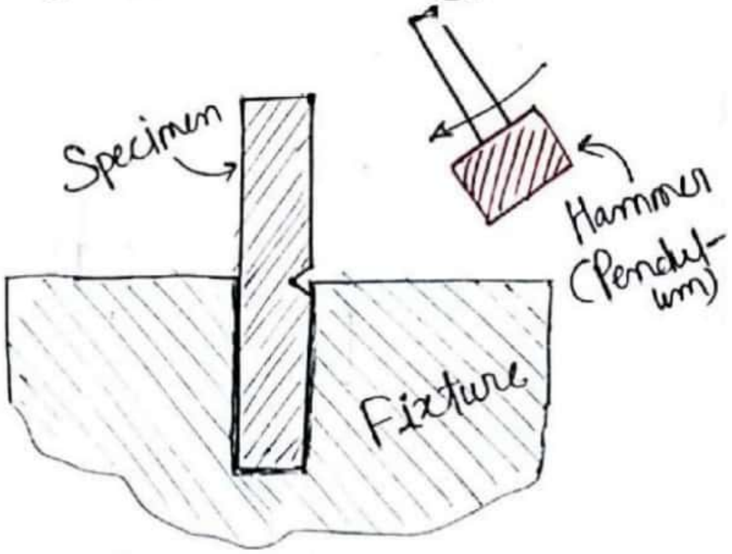
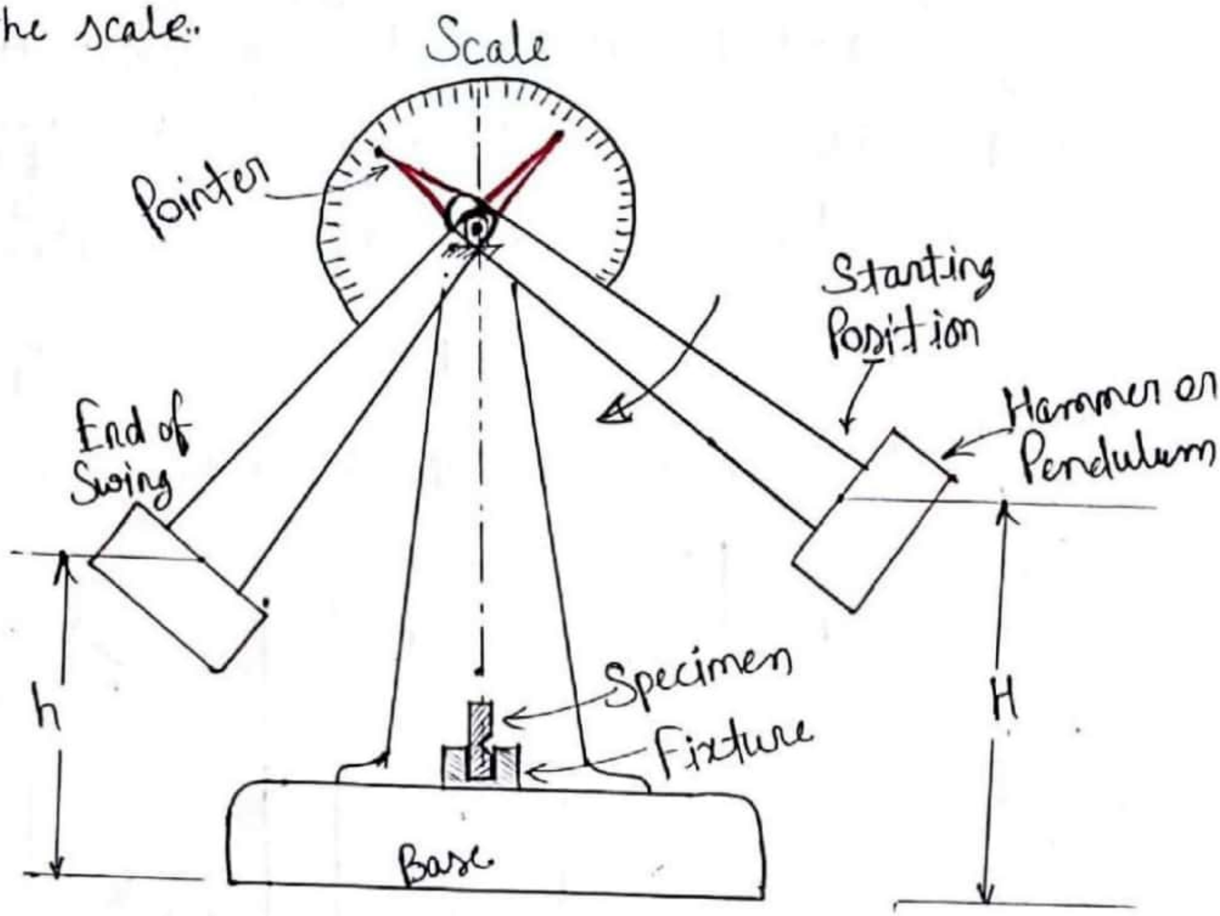


Fig:- Specimen gripped vertically for Izod impact test

→ { Only difference between charpy and izod impact test is that in charpy test, the specimen is gripped horizontally } ← Extra Information.

→ It is broken by a single blow of a freely swinging pendulum.

The hammer or pendulum is released from a fixed height 'H' and strikes the specimen. The energy expended in fracture is reflected in the difference between 'H' and swing height 'h'. and represented on the scale.



$$\text{Impact Value} = \frac{\text{Energy absorbed before fracture}}{\text{Cross Section area under the notch}}$$

$$= \text{Joule}/mm^2$$

Impact value is an index of dynamic toughness.