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Program : **B.Tech**

Subject Name: **Basic Mechanical Engineering**

Subject Code: **BT-203**

Semester: **2nd**

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UNIT I

Materials- Engineering material classification, Cast iron and Carbon steel composition, Fe-C diagram. Steel alloys and applications. Mechanical properties of materials, Tensile testing, Stress-strain curve for ductile and brittle materials, hooks law, modulus of elasticity, Hardness and Impact testing.

Classification of Materials

Most engineering materials are classified into following categories.

(a) Metals

(i) Ferrous (ii) Non-ferrous

(b) Ceramics

(c) Organics

(d) Composites

(e) Semiconductors

Metals

Metals are composed of elements who shares electrons to form metallic bonds. In ferrous metals iron is present and Non-ferrous are free from iron.

Ceramics

Ceramics are any non metallic, inorganic solids used for high temp resistance.

Organics

These are polymeric materials composed of carbon compounds.

Composites

These materials consist of more than one material in structure to show the best characteristics of each compound in combination.

Semiconductors

These have electrical properties that are in-between the conductors and insulators.

Cast-Iron and Carbon-Steel Composition

Steels are alloys of iron, carbon and other alloying elements. Alloying is necessary for many reasons like improving properties, corrosion resistance, etc.

Mechanical properties of steels are dependent on carbon content. Hence steel classification is based on their carbon content. Thus steels are basically of three types,

Low-carbon steel (% wt of C < 0.3)

Medium carbon steel (0.3 <% wt of C < 0.6)

High-carbon steel (% wt of C > 0.6)

1. **Low carbon steel:** Carbon in these alloys is limited, and is not enough to give strength to these materials during heat treatment; hence by cold working strength is improved. Their microstructure consists of ferrite and pearlite; these alloys are relatively soft and ductile. Hence these materials are easily machinable and weld-able.
2. **Medium carbon steels:** These are stronger than low carbon steel. These are less ductile than low carbon steel. These can be heat treated to improve their strength. Typical applications include: railway tracks and wheels, gears etc.
3. **High carbon steels:** These are strongest and hardest of carbon steel, so ductility is very limited. These possess very high wear resistance, and capable of holding sharp edges. So these are used for tool making application like knives, razors, hacksaw blades, etc.
4. **Stainless steel:** These are high resistance to corrosion i.e. they are rust-less (stain-less). For making highly

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corrosion resistant addition of special alloying elements is required, especially a minimum of 12% Cr along with Ni and Mo.

Cast iron

Alloys with more than 2.14 wt. % C are designated as cast irons, commercially cast irons contain about 3.0-4.5% C along with some alloying additions. Alloys with this carbon content melt at lower temperatures than steels. Cast irons are categorized as gray, white, nodular and malleable cast irons.

1. **Gray cast iron:** These alloys consists carbon in graphite flakes form, which are surrounded by either ferrite or pearlite. Due to graphite flakes, gray cast irons are weak and brittle. However they possess good damping properties and thus typical applications are base structures, bed for heavy machines, etc.
2. **White cast iron:** In this Si content is low (< 1%) in combination with faster cooling rates, there is no time left for cementite to get decomposed. Because of presence of cementite, fractured surface appear white, which is the main reason of its name. These are very brittle and extremely difficult to machine. So their use is limited to wear resistant applications such as rollers in rolling mills.
3. **Nodular cast iron:** Small additions of Mg / Ce to the gray cast iron before casting can result in graphite to form nodules or sphere-like particles. These are stronger and ductile than gray cast iron. Typical applications are like pump bodies, crank shafts, automotive components, etc.
4. **Malleable cast iron:** It is formed by heat treating white cast iron. High temperature incubation causes cementite to decompose and form ferrite and graphite. Thus these materials are stronger with appreciable amount of ductility. Having applications like railroad, connecting rods, marine and other heavy-duty services

Iron - Carbon Diagram:-

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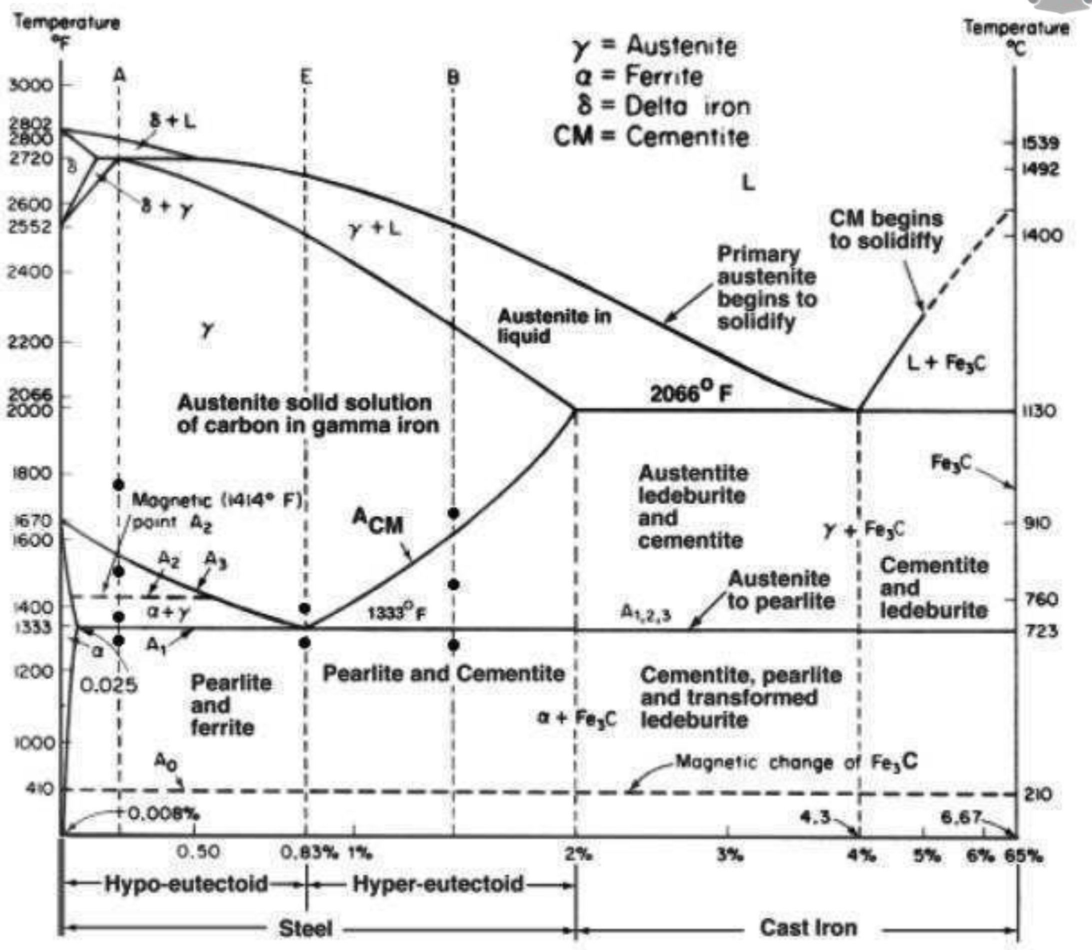

Fig. 1.1 Iron-Carbon Diagram

1. Ferrite – It is BCC in structure with magnetic properties.
2. Austenite – A non magnetic solid solution of ferri-carbide used in making corrosion resistant steel.
3. Cementite (Fe_3C) – Also known as Iron carbide and is hard and brittle material.
4. Bainite – These are needle like crystals.

Phase transformation in Fe-C system

Peritectic reaction at 1495 °C

L (0.53% C) + (0.09% C) → (0.17% C)

Eutectic reaction at 1146 °C

L (4.3% C) → (2.1 % C) + Fe3C (6.67% C)

The eutectic mixture of austenite (γ) and cementite (Fe3C) is called Ledeburite. Compositions right and left of 4.3% are called hyper and hypoeutectic steels (Cast iron) respectively.

Eutectoid reaction at 727 °C

(0.8 % C) → (0.025% C) + Fe3C (6.67% C)

The eutectoid mixture of ferrite (α) and cementite (Fe3C) is called Pearlite. Compositions right and left of 0.8% are called hyper and hypoeutectoid steels respectively. Compositions up to 2.1% C are steels and beyond this it is considered as cast iron.

Steel alloying Elements

1. Manganese (Mn) – It improves hardenability, ductility and wear resistance. It eliminates formation of harmful iron sulphides, increasing strength at high temperatures.

2. Nickel (Ni) – It increases strength, impact strength and toughness.

3. Chromium (Cr) – This improves harden ability, strength and wear resistance, sharply increases corrosion

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resistance at high concentrations (> 12%).
4. Tungsten (W) – This increases hardness particularly at elevated temperatures due to stable carbides and refines grain size.
5. Vanadium (V) – Vanadium increases strength, hardness, creep resistance and impact resistance due to formation of hard vanadium carbides.
6. Molybdenum (Mo) – Molybdenum increases harden ability and strength particularly at high temperatures and under dynamic conditions.
7. Silicon (Si) – Silicon improves strength, elasticity, acid resistance and promotes large grain sizes.
8. Titanium (Ti) –It improves strength and corrosion resistance, limits austenite grain size.
9. Cobalt (Co) – It improves strength at high temperatures.
10. Zirconium (Zr) – It increases strength and limits grain sizes.
11. Boron (B) – This is highly effective harden ability agent, improves deformability and machinability.
12. Copper (Cu) – It improves corrosion resistance.
13. Aluminium (Al) – It acts as deoxidizer, limits austenite grains growth.

Mechanical Properties of Engineering Materials: -
1. Elasticity: - The ability of a material by virtue of which it recover its original shape on the removal of distorting load.

Elasticity E = Stress / strain

2. Plasticity: - It is the ability of material by virtue of which the material undergoes permanent deformation after removal of distorting load.
3. Tensile Strength: - The ratio of the maximum load to the original cross-section area is known as tensile strength or the ability to sustain force needed to fracture the material is known as tensile strength.
4. Ductility: - Ability of a material to undergo deformation under tension without rupture.
5. Brittleness: - It's the tendency of material to fracture without appreciable deformation i.e. less than 5% for a 50 mm gauge.
6. Malleability: - The capacity to withstand deformation y the material under compression without rupture is known as malleability.
7. **Toughness:** - Ability of material to absorb energy during plastic deformation up-to fracture.
8. **Creep:** - It is the time dependent permanent deformation that occurs under constant stress.
9. Hardness: - It is the resistance of material to plastic deformation by indentation.
10. Fatigue: -The fatigue is the failure of material, when it is subjected to cyclic loads in which the value of developed stress is less than the tensile strength of material.
11. Resilience: - It is the capacity of a material to absorb energy when elastically deformed then on unloading to have this energy recovered.
12. Yield strength: - Ability of material to oppose the plastic deformation is known as yield strength.
13. Impact Strength: - Capacity of material to absorb shock energy before it fractures is called its impact strength.

Tensile Test
In this test ends of work piece are fixed into grips connected to a straining device with a load measuring system. For the small load, the deformation of work piece is entirely elastic, in which the material will return to its original form as soon as load is removed. If the load is too large, the material can be deformed permanently. The starting part of the tension curve which is recoverable immediately after unloading known as elastic and the rest of the curve represents the manner in which solid undergoes plastic deformation known as plastic. The stress below in which the deformations is entirely elastic known as the yield strength, Point known as ultimate strength point where the ratio of the load on the test piece to original cross-sectional area, reaches a maximum value. Further loading will eventually cause 'neck' formation and rupture.
Procedure for testing
1) Measure the original length and diameter of the specimen.
2) Insert the specimen into grips on the test machine and attach strain-measuring device to it.

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3) Start applying load and record load v/s elongation data.
4) Take readings frequently as yield point is appeared.
5) Measure elongation values with the help of a ruler.
6) Continue the test till Fracture occurs.
7) In the end joining the two broken pieces of the specimen together to measure the final length and dia. of specimen.

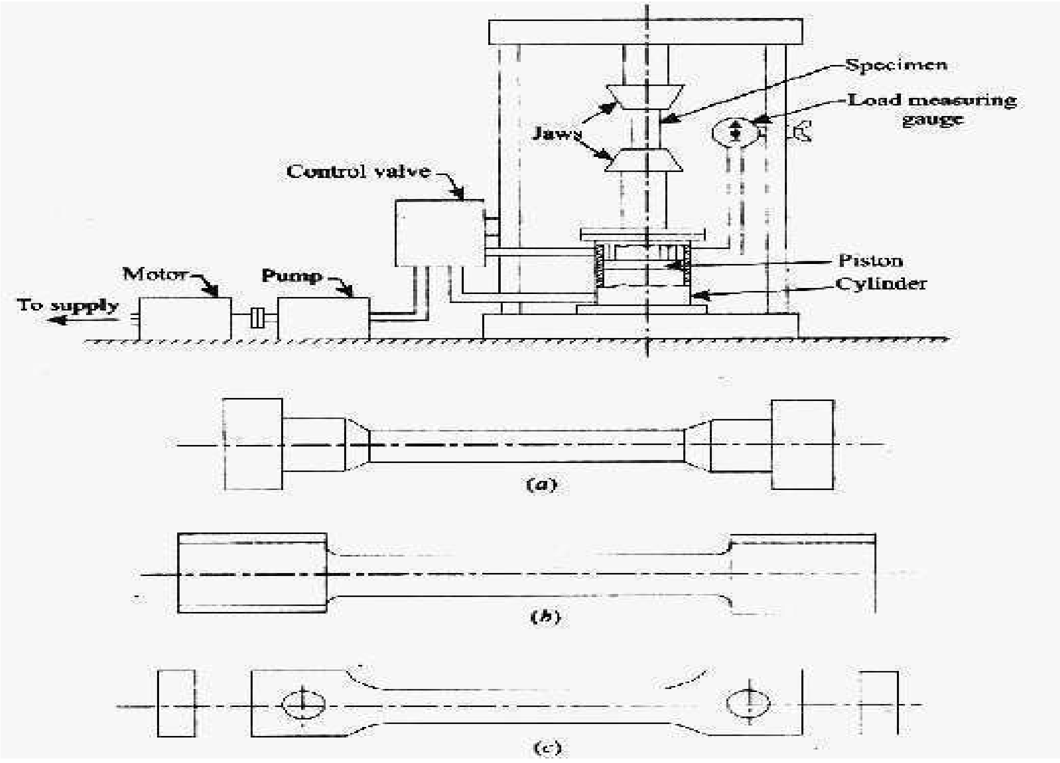

Fig. 1.2 Tensile Test

Stress - Strain Curve

The stress and strain curve for ductile material is as below which shows the behaviour of material under loading and its different strengths before fracture. Here part I show two points A and B up-to which applied load is known as proportional limit where load does not changes the shape of work piece beyond A and on point B applied load is in elastic limit and material will regain its original shape. Beyond point B and up to point C in II phase of the curve load will be resist by the material for its plastic deformation and known as yield strength but after point C and till point D applied load causes permanent deformation in the test piece. Load sustained by the work piece up to point D shows the tensile strength of the material. Beyond point D applied load changes the shape of the test piece and area of cross section decreases in this, at point E material fails and point knows as rupture point.

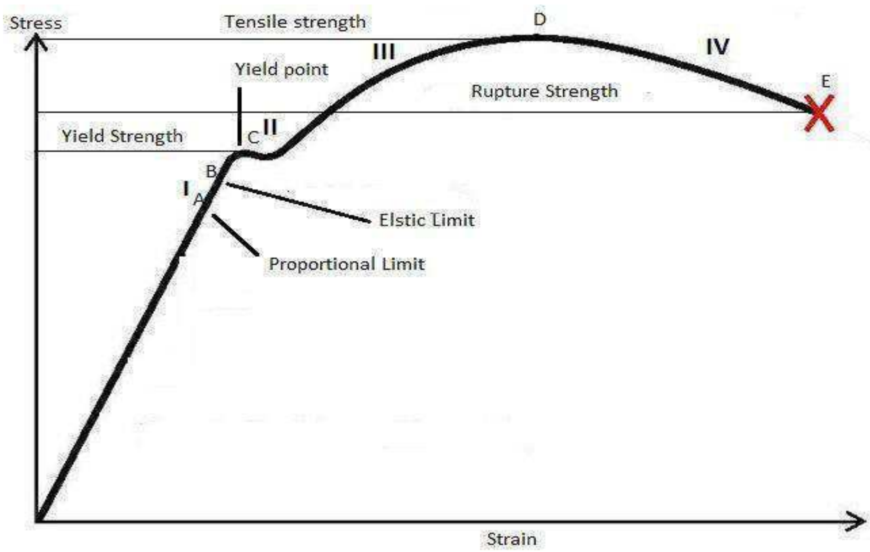

Fig. 1.3 stress - Strain Curve for Ductile Material

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Stress strain curve for brittle material is shown below in which it is clearly shown that like ductile materials brittle materials does not shows yield point load applied up-to that limit results fracture of test piece.

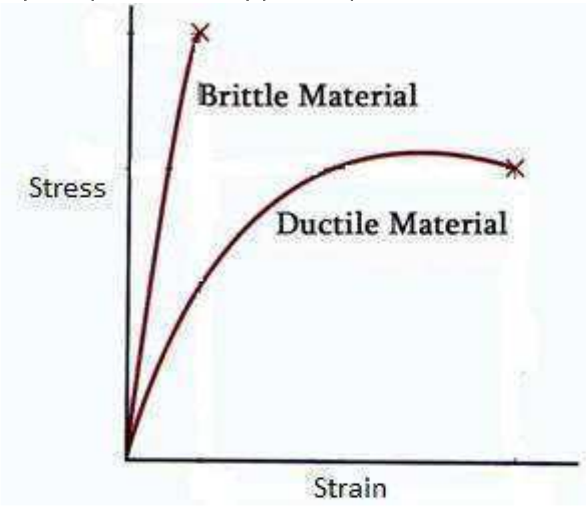

Fig. 1.4 stress - Strain Curve for Brittle Material

Hooke's Law
The Law stated that stress is proportional to strain within elastic limits.

Stress α strain

Modulus of Elasticity: The ratio of stress to the strain is known as modulus of elasticity.

$$Y \text{ or } E = \text{Stress} / \text{Strain}$$
$$= \sigma / \varepsilon$$

Hardness Test

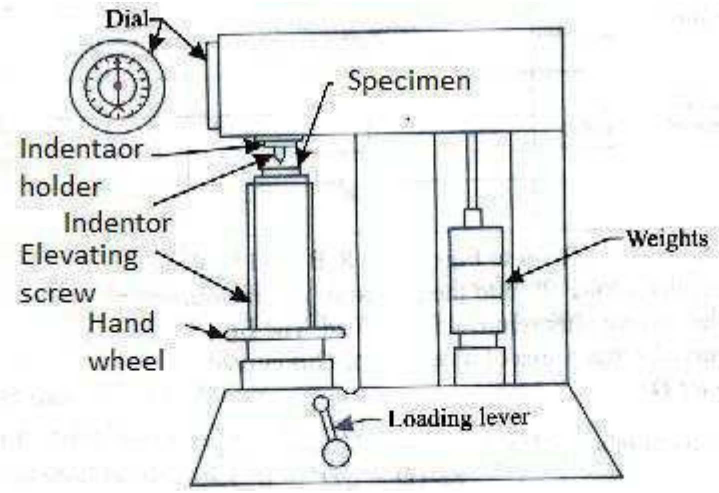

Fig. 1.5 Hardness Test

Hardness is the resistance of a material to plastic deformation or abrasion. This test gives an accurate, fast and economical way of find the resistance of materials to deformation. There are three types of hardness measurement procedures:

i. Scratch hardness measurement,
ii. Rebound hardness measurement
iii. Indention hardness measurement

In scratch hardness test the materials are rated on their ability to scratch the other and it is usually used by mineralogists only.

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In rebound hardness test, a standard body is usually dropped on to the material surface and the hardness is measured in terms of the height of its rebound.
In indentation test, the indenter is usually a ball cone or pyramid of a material much harder than the test specimen. A load is applied by pressing the indenter at right angles to the surface being tested and hardness of the material depends on the resistance which it exerts during a small amount of yielding.

Impact Test

The purpose of impact testing is to measure the ability of material to resist sudden applied loads, or to test the behaviour of two objects striking each other at high relative speeds or one is in steady state and another is moving. To resist impact often is one of the determining factors in the service life of a part, or in the suitability of a designated for a particular application.
The Charpy, Charpy V notch, Izod Tests and other Impact testing determines the material toughness or impact strength in the presence of a flaw or notch and fast loading conditions.

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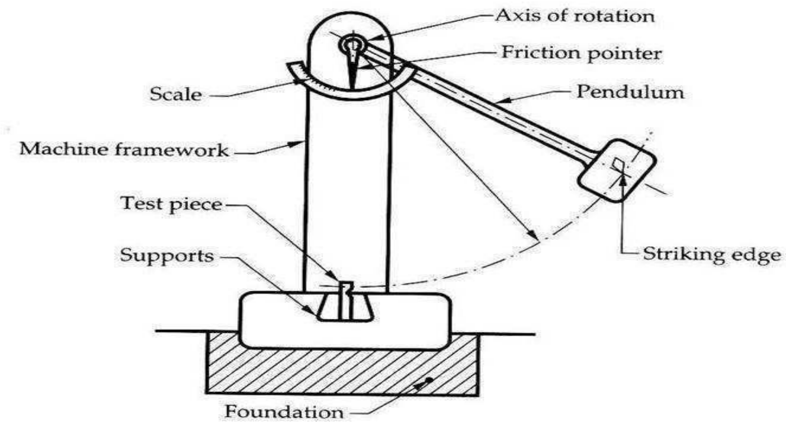

Fig. 1.6 Impact Test

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