Basic Mechanical Engineering

Engineering Materials

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What is manufacturing?

- ✓ Manufacturing is the process of conversion of raw material into the product.

Types of loads

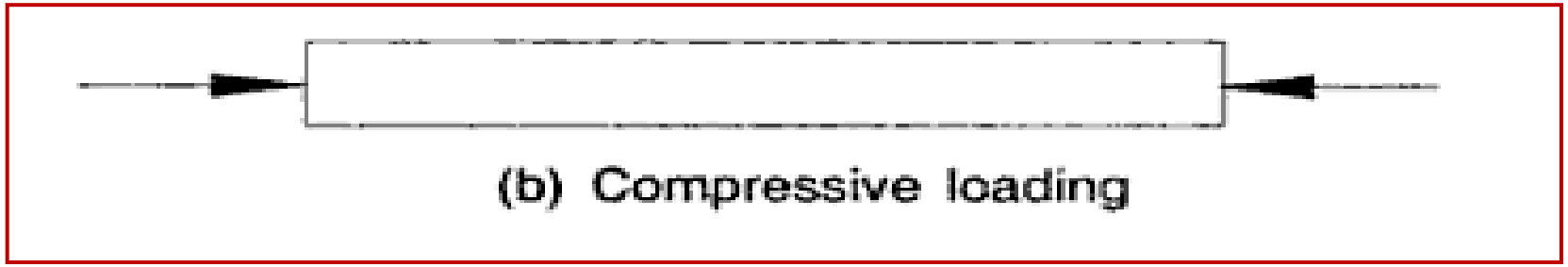
Types of loads:

- ✓ When a body is subjected to two equal and opposite forces acting to pull the body, the body tends to elongate and is said to be in tension and the type of load applied is called **tensile load.**

(a) Tensile loading

Types of loads (contd.)

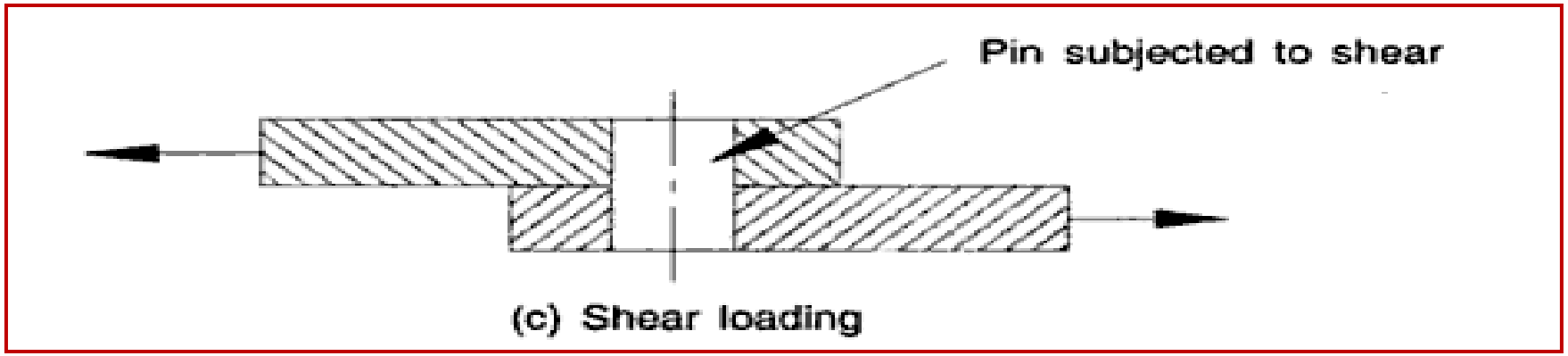
- ✓ When a body is subjected to two equal and opposite forces acting to push in to the body, the body tends to get shortened and is said to be under compression and the type of load is called **compressive load.**



(b) Compressive loading

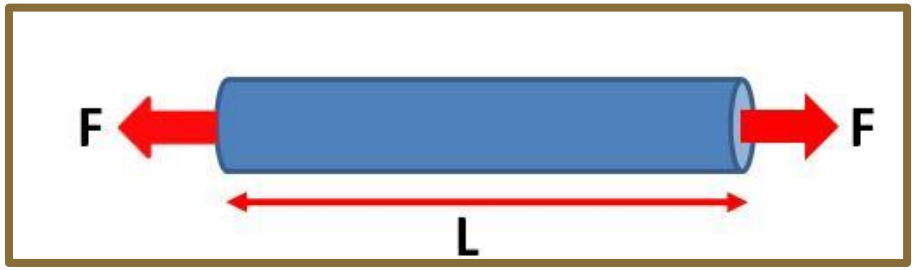
Types of loads (contd.)

- ✓ When a body is subjected to two opposite forces acting radially across the cross-section of the body. The body is said to be under shear and the type of load applied is known as shear load.



(c) Shear loading

Direct or Normal Stress



✓ **Direct or Normal Stress**: When a force is transmitted through a body, the body tends to change its shape or deform. The body is said to be strained.

$$Direct\ Stress(\sigma) = \frac{Resisting\ Force\ \ (F)}{Cross\ Sectional\ Area\ (A)}$$

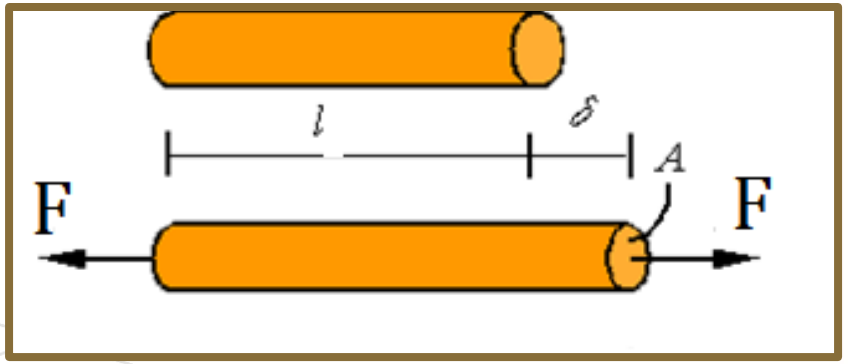
✓ Units: Usually N/m^2 (Pa), N/mm^2, GN/m^2 Note: 1 N/mm^2= 1 MN/m^2 = 1 Mpa.

✓ Direct stress may be tensile or compressive and result from forces acting perpendicular to the plane of the cross-section.

Direct or Normal Strain

- ✓ **Direct or Normal Strain:-** When loads are applied to a body, some deformation will occur resulting to a change in dimension.
- ✓ Consider a bar, subjected to axial tensile loading force, F. If the bar extension is d*l* and its original length (before loading) is *l*, then tensile strain is:

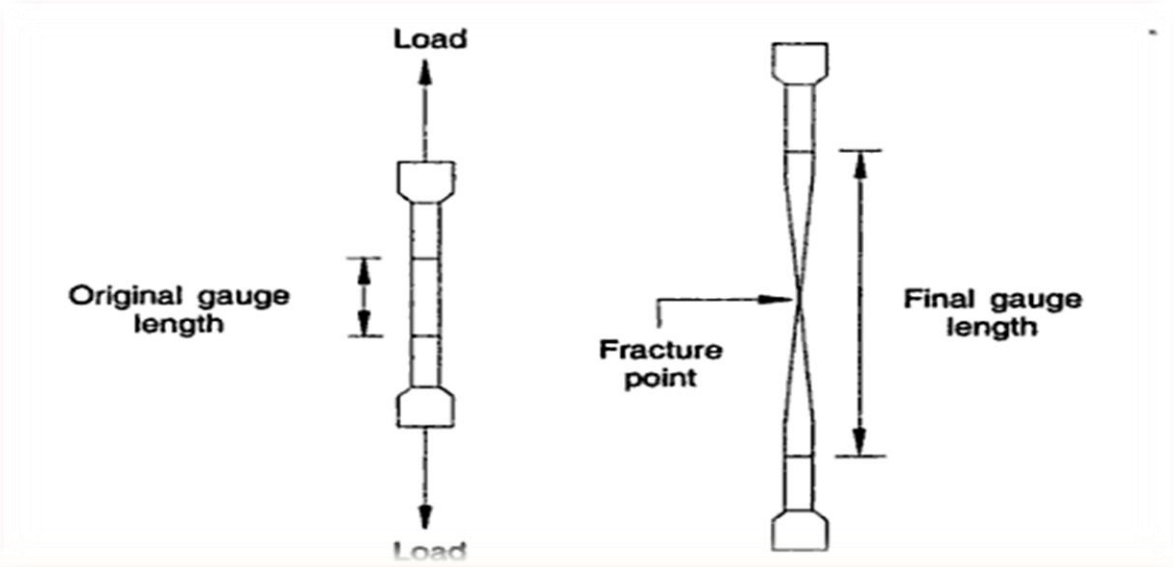
$$Direct\ Strain(\varepsilon) = \frac{Change\ in\ Length\ (dl)}{Original\ Length\ (l)}$$



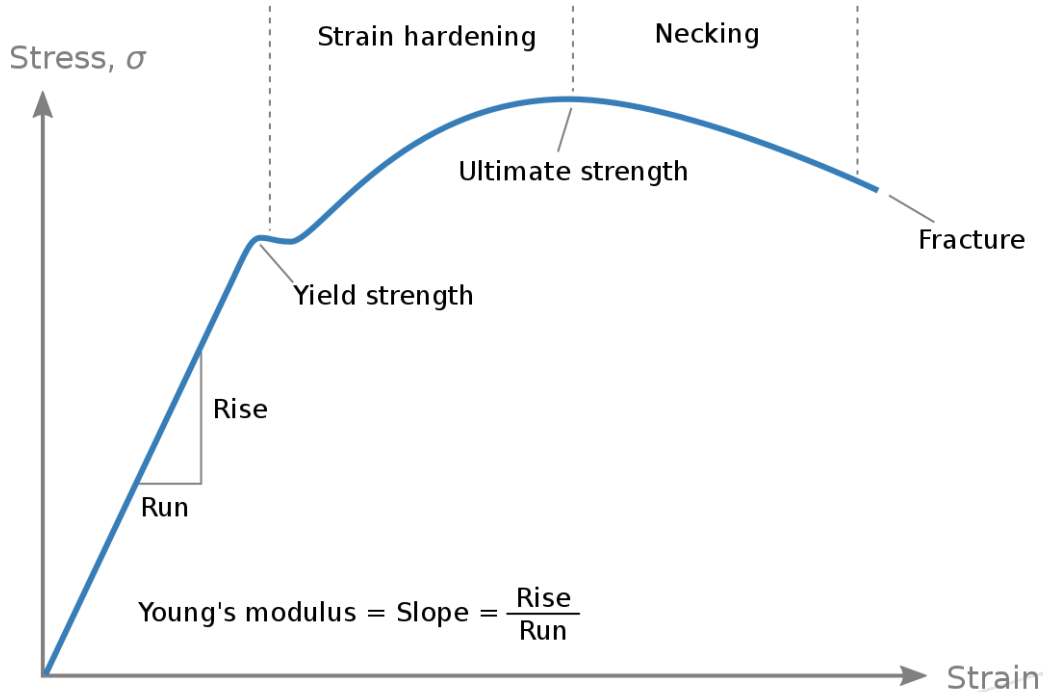
- ✓ As strain is a ratio of lengths, it is dimensionless.

Stress – Strain Relationship

- ✓ Consider a cylindrical rod made of some ductile material of some specific length , is subjected to the continuously increasing tensile load of sufficiently high magnitude. The rod will go on elongation until it breaks.



Stress-strain Relation



- ✓ **Limit of Proportionality:** It is the limiting value of the stress up to which stress is proportional to strain.
- ✓ **Elastic Limit:** This is the limiting value of stress up to which if the material is stressed and then released (unloaded) strain disappears completely and the original length is regained. This point is slightly beyond the limit of proportionality.

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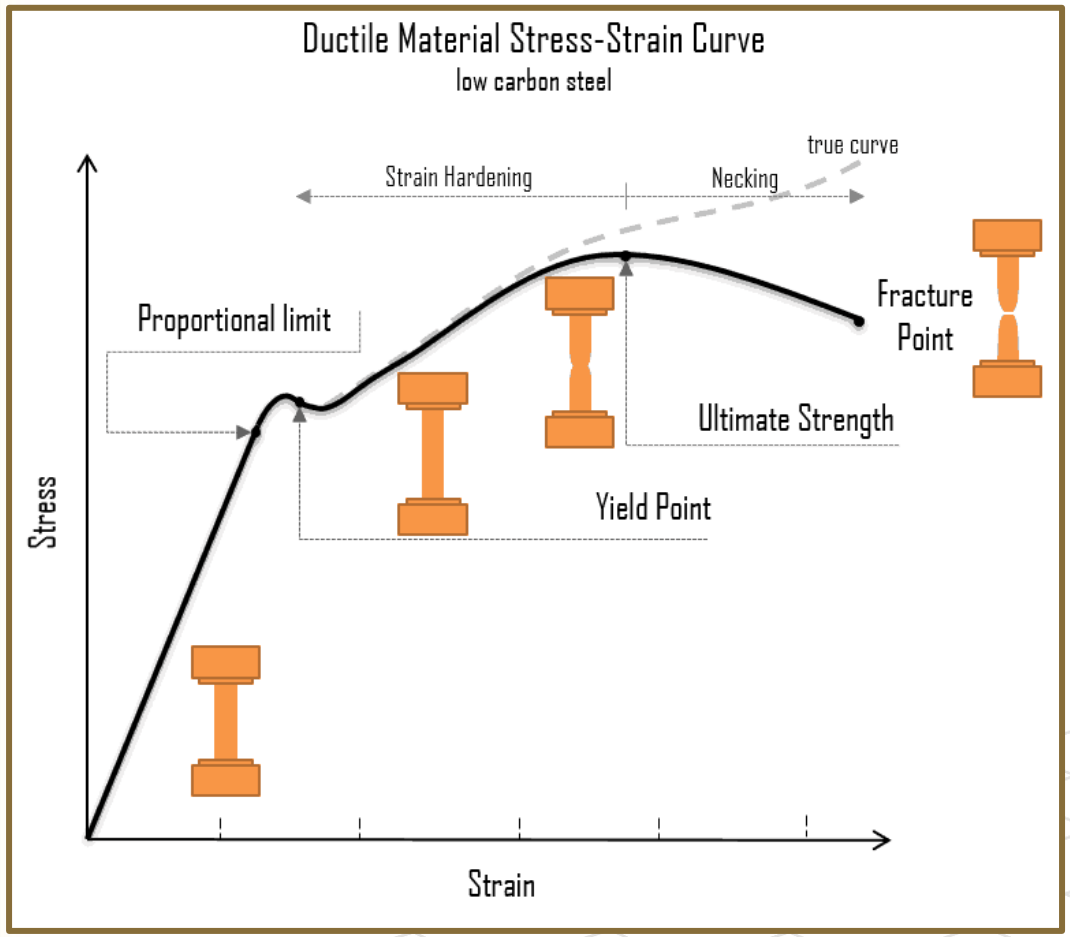
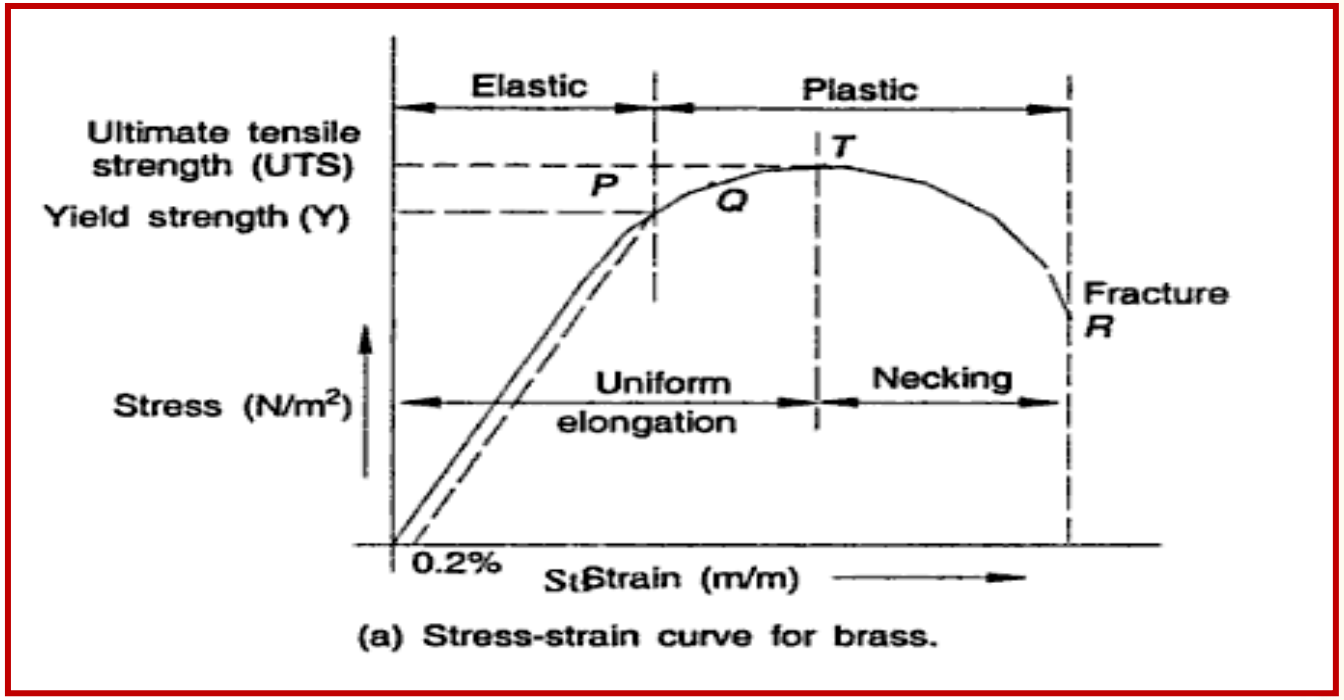
Stress-strain Relation



- ✓ **Upper Yield Point:** This is the stress at which, the load starts reducing and the extension increases. This phenomenon is called yielding of material.
- ✓ **Lower Yield Point:** At this stage the stress remains same but strain increases for some time.
- ✓ **Ultimate Stress:** This is the maximum stress the material can resist.
- ✓ **Breaking Point:** The stress at which finally the specimen fails is called breaking point.

Stress – Strain Curve

- ✓ The maximum stress from which the bar can return to its original length is the materials elastic limit, also called as proportionality limit



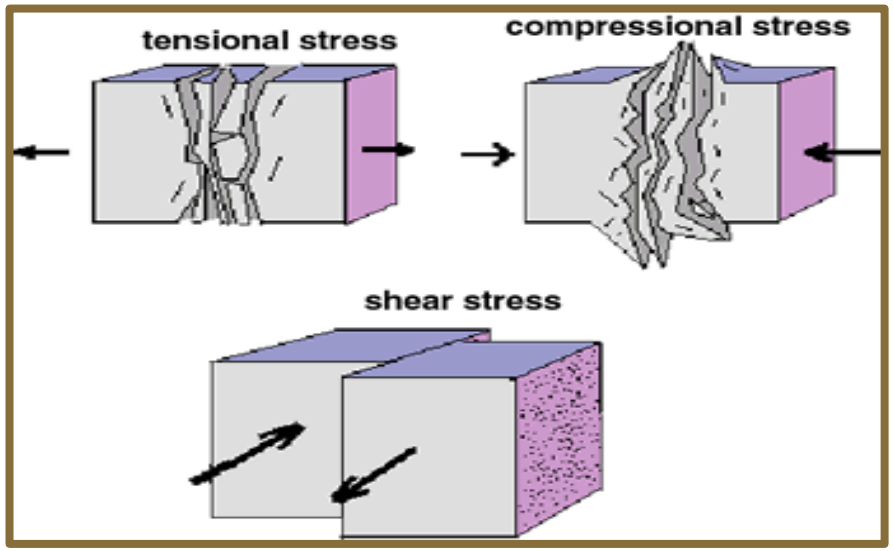
(a) Stress-strain curve for brass.

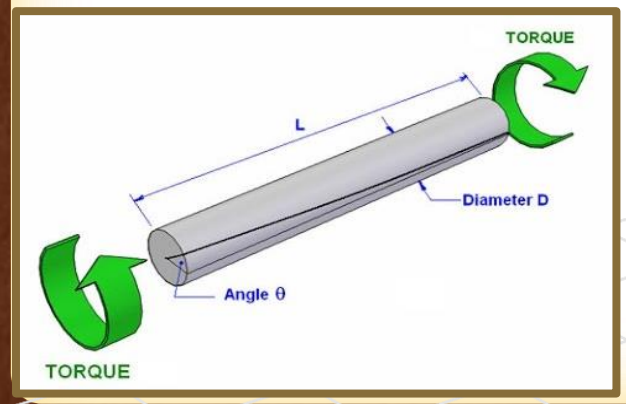
Mechanical Properties

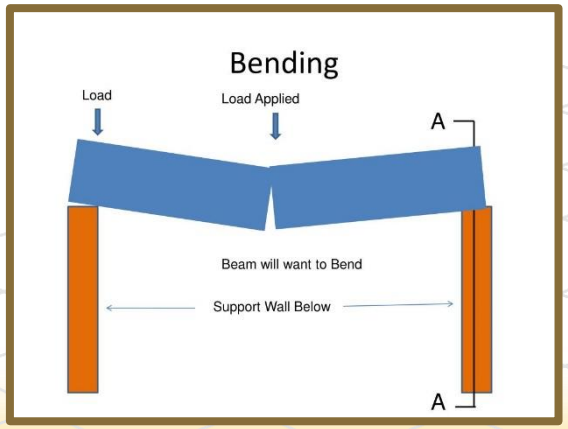
Resistance to various applied forces is referred as mechanical properties. Some of these properties are briefly presented below:

Strength:- It is the ability of the material to resist the application of force without any fracture.

- ✓ Properties related to axial loading
  - (a) Tensile strength
  - (b) Compressive stress
- ✓ Properties related to shear loading







- ✓ Properties related to torsional moment
- ✓ Properties related to bending

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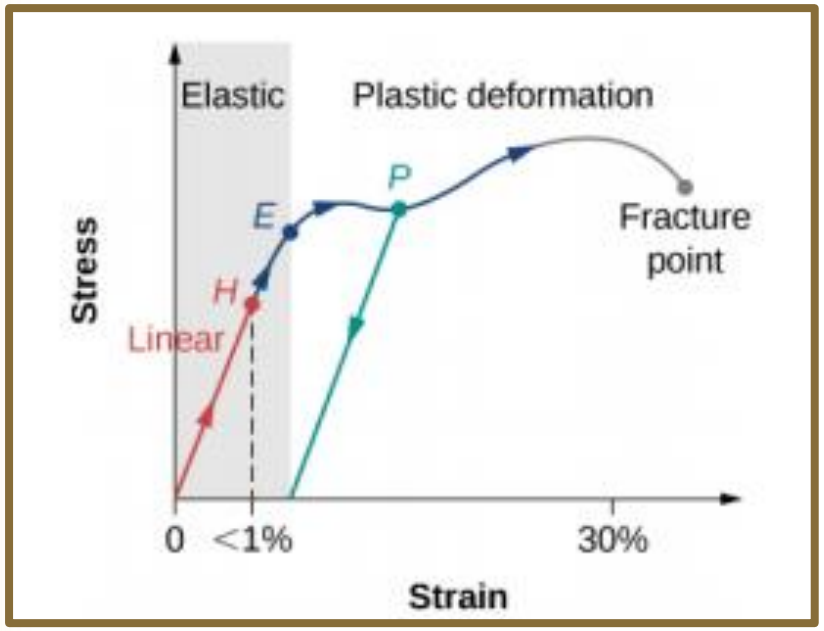
Mechanical Properties



- ✓ **Elasticity**: Property of material by which it return to its original shape and size after removing the applied load , is called elasticity. And material itself is said to elastic.
- ✓ **Plasticity:** Characteristics of material by which it undergoes inelastic strains (Permanent Deformation) beyond the elastic limit, known as **plasticity**. This property is useful for pressing and forging.

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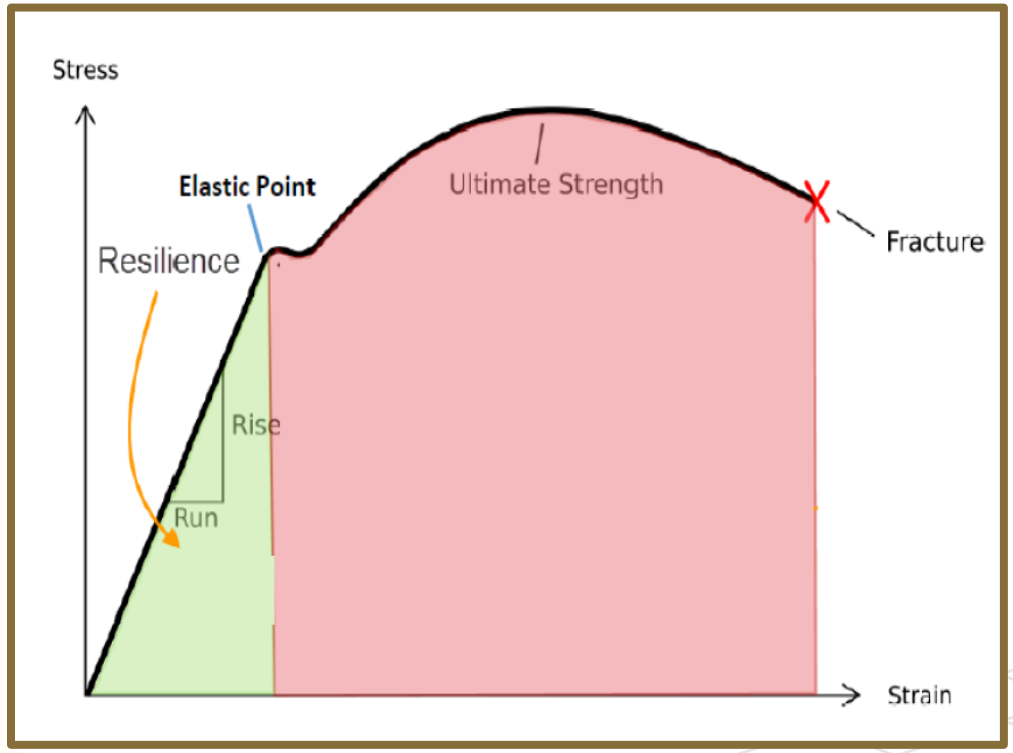
Mechanical Properties



- ✓ **Toughness:-** It is the ability of the material to absorb energy before it fractures. It is the total area under the stress strain curve till fracture point.
- ✓ **Resilience:-** It is the ability of the material to absorb energy when deformed elastically and return it when unloaded is called resilience. It is the area under the stress strain curve till elastic point.

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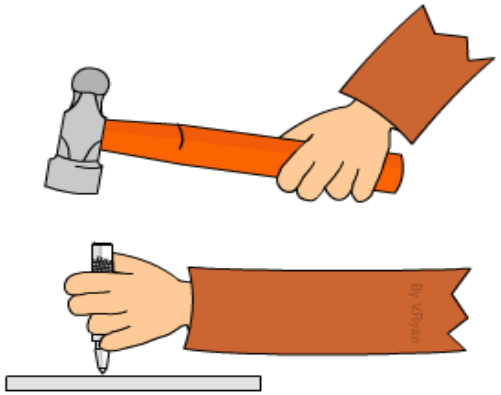
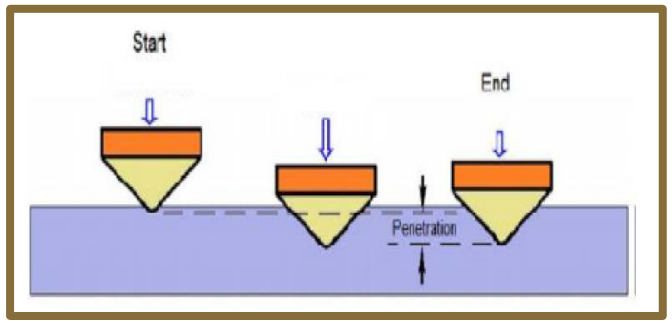
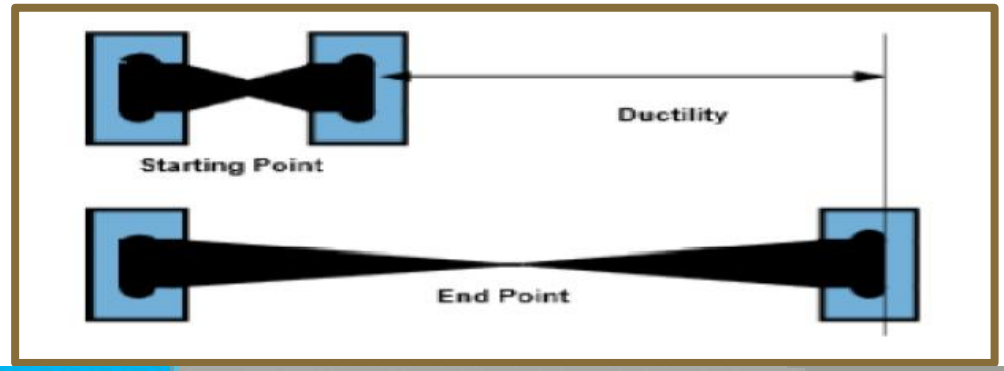
Mechanical Properties

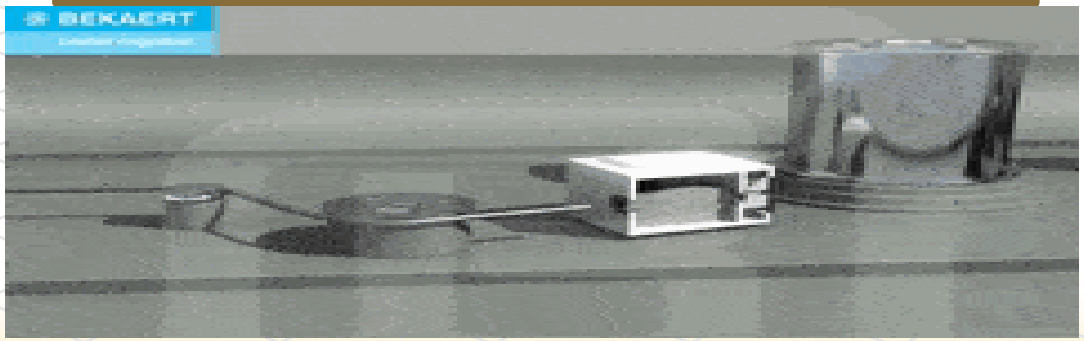




✓ **Hardness:-** It is the resistance offered by material to penetration when a compressive force is applied.

✓ **Ductility:** It is the measure of the amount of permanent deformation a material can undergo under tensile force without fracture. It is also termed as ability of material to be drawn into thin wires.





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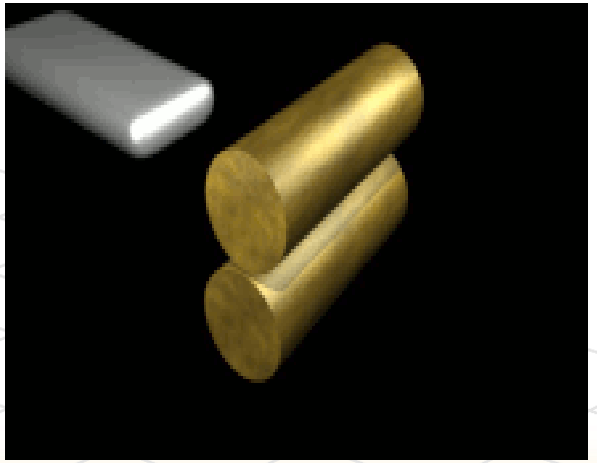
Mechanical Properties

- ✓ **Brittleness:-** It is the breaking or failure of the material without much permanent deformation. It is the property opposite to ductility.
- ✓ Example: Cast Iron is brittle material, Glass

- ✓ **Malleability:-** It is the property of material to extend in all directions without fracture by pressing, hammering etc. It is also termed as ability of material to be drawn into thin sheets.



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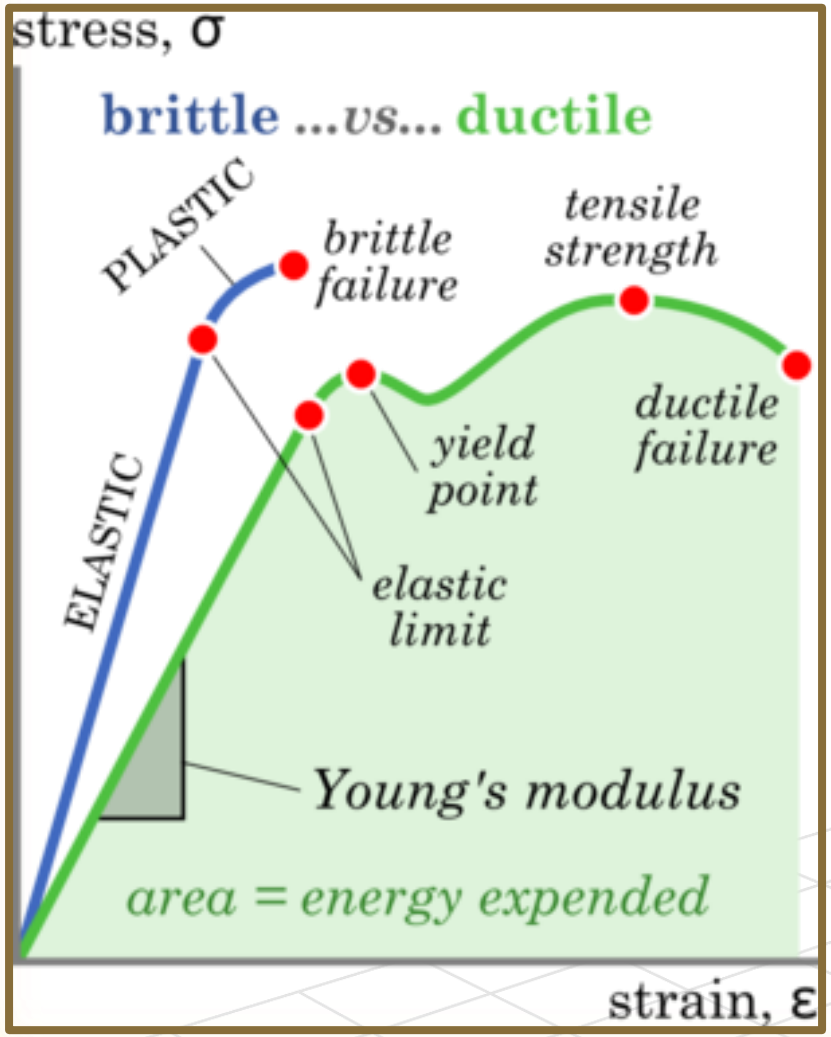
Mechanical Properties

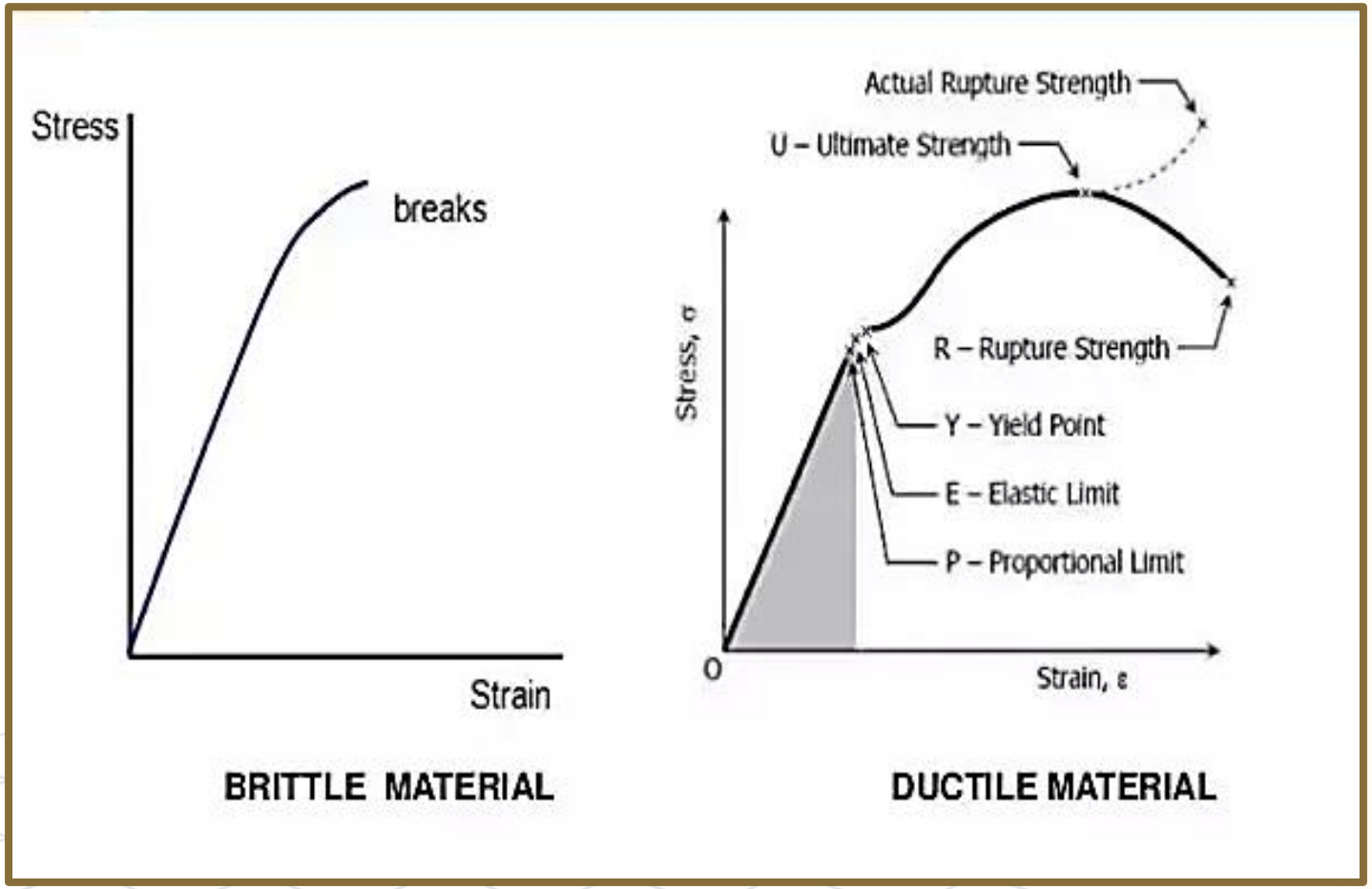
- **Fatigue:** When a body is subjected to repeated and fluctuating load it tends to develop a characteristic behaviour under which failure occurs which is referred to as fatigue It is weakening of a material due to repeatedly applied loads, in such condition the failure occurs below their normal strength.

Example: Railway tracks

- **Creep**: It is the property of material to progressively deform under constant force, at high pressure and temperature.

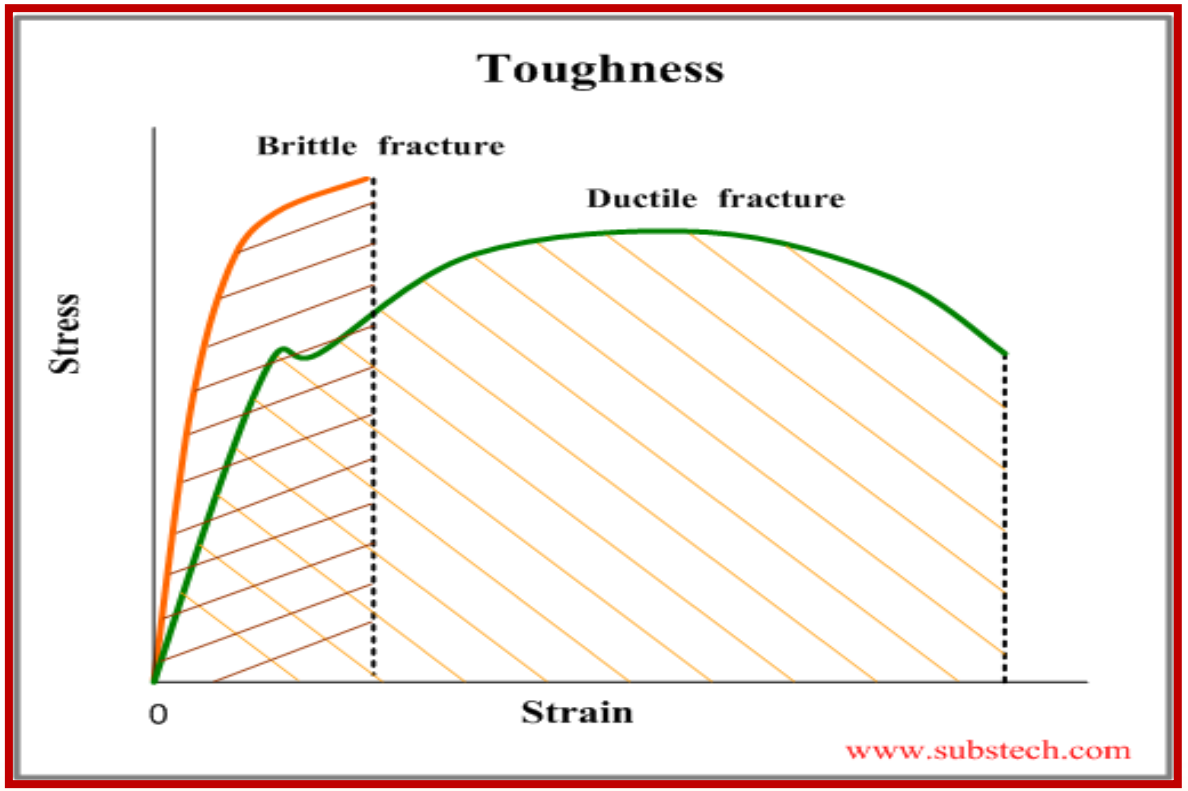
Brittle Vs. Ductile





Ductile Facture

- ✓ If a material is subjected to load above yield point, process of deformation continues, fracture eventually occurs.



Steel

When the carbon content is reduced to a limit of 0.15% to 1.5%, the product obtained is known as steel. This steel is called "plain carbon steel" in general.

Plane Carbon Steel

Plain Carbon Steel: Plain carbon steels are those which primarily contain Iron and carbon. Besides carbon it also contains other impurities like manganese, sulphur, phosphorous and silicon. The properties of plain carbon steel are greatly influenced by increase in carbon content.

As the carbon content increases

1. Tensile strength increases
2. Hardness increases
3. Ductility decreases
4. Toughness decreases
5. Weldability decreases

Effect of Impurities

1. Sulphur: It is harmful impurity in steel. It combines with iron to form iron sulphide which causes brittleness (or decreases ductility).

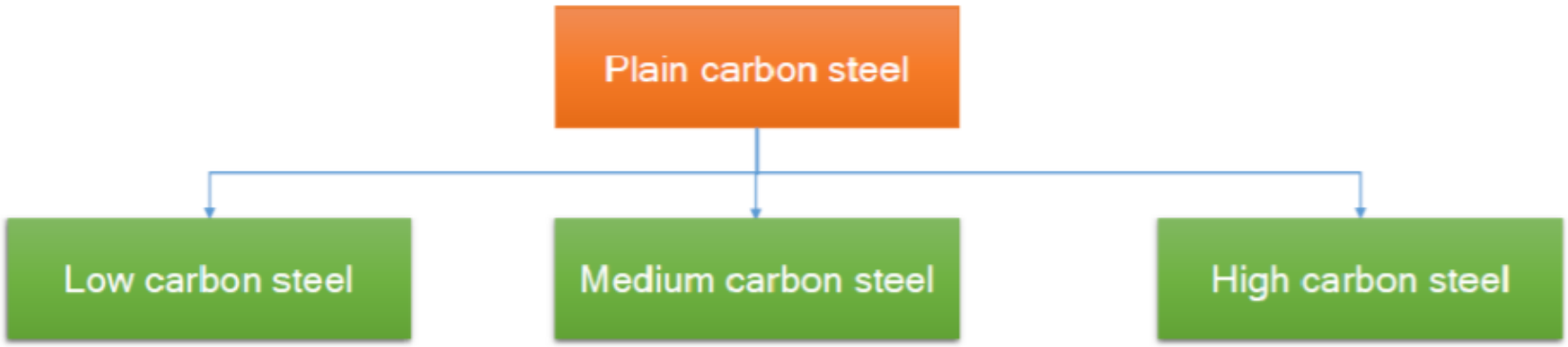
2. Manganese: It combines with sulphur to produce manganese sulphide and thus reduces the harmful effect of sulphur present in steel. It also contributes to strength and hardness but its effect is less than carbon.

3. Phosphorous: It is also harmful impurity in steel and causes brittleness. It increases resistance to corrosion. It also increases strength and hardness.

4. Silicon: It makes the steel tougher and harder. It decreases weldability

Types of steel

- ✓ Broadly classified, there are three types of plain carbon steel:
  - Low Carbon Steel
  - Medium Carbon Steel
  - High Carbon Steel



Types of steel

- ✓ The carbon content of these three types of steels are:

  (i) 0.05-0.30% in Low Carbon Steel

  (a) 0.05-0.15% in Dead Mild Steel (b) 0.15%-0.30% in Mild Steel

  (ii) 0.30-0.60% in Medium Carbon Steel

  (iii) 0.60-1.5% in High Carbon Steel

In addition to carbon, these steels also contain upto 1% manganese, phosphorus upto 0.5%, Sulphur upto 3% and silicon upto 0.03%.

Properties and Uses

Low Carbon Steel:

- ✓ It possesses good formability and weldability but lacks in hardness.
- ✓ It is used in making nuts, bolts, sheets, tubes and machine components not requiring much high strength.
- ✓ It is also used in making beams and channels.

Properties and Uses

Medium Carbon steel:

- ✓ It has higher strength than low carbon steel and is harder due to increased content of carbon.
- ✓ Its properties can be improved by heat treatment processes and hence is very popular.
- ✓ It is used for making machine parts such as gears, axles, crank-shafts and parts for metal working machinery.

Properties and Uses

High Carbon Steel:

- ✓ It has low toughness and formability but hardness and wear resistance are high.
- ✓ It is used generally for making parts such as cutting tools, cables, springs, etc.