

Mechanical properties

- The mechanical behavior of a material reflects the relationship between its response or deformation to an applied load or force. Key mechanical design properties are stiffness, strength, hardness, ductility, and toughness.
- The mechanical properties of materials are ascertained by performing carefully designed laboratory experiments that replicate as nearly as possible the service conditions.

Stress

- Stress is internal resistive force per unit area developed inside a material under loading condition.
- Unit of stress is N/m^2 , which is similar as unit of pressure.
- Pressure always acts normal to the surface and applied externally on the body, but stress is developed inside the material or body and it acts normal or along the internal surface of body.
- Pressure is a scalar quantity and stress is second order tensor quantity.
- A tensor is a quantity which has magnitude, direction, and a plane in which it acts.
- engineering stress or stress = $\frac{\text{force}}{\text{original cross sectional area}}$
- true stress = $\frac{\text{force}}{\text{actual cross sectional area}}$

Strain

- **Strain** is simply the measure of how much an object is stretched or deformed. Strain occurs when force is applied to an object. Strain deals mostly with the change in length of the object.
- For **engineering strain or strain** If the original length of the body L_0 changes by ΔL , then stress can be expressed as

$$\text{strain} = \frac{\text{change in length}}{\text{original length}} = \frac{\Delta L}{L_0}$$

- It is also a second order tensor quantity.
- **true strain** is defined as the natural log of the ratio of current length and the original length.

$$\text{true strain} = \ln \frac{L}{L_0}$$

Stress Strain Diagrams

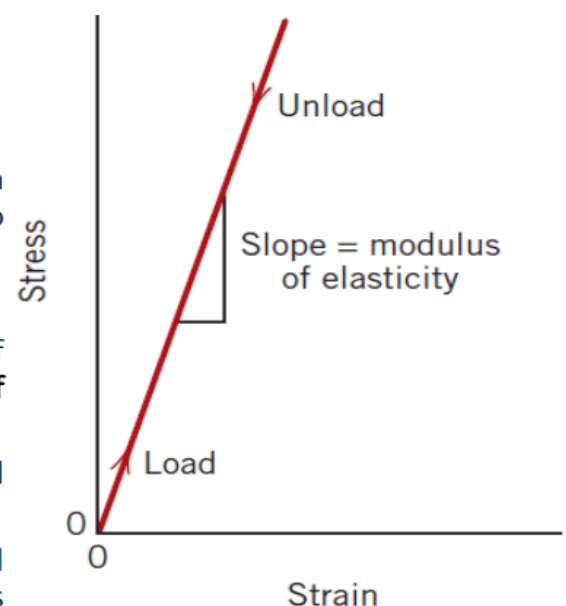
- It is a tool for understanding material behavior under load.
- It is a graph that represents how a part behaves under an **increasing load** and used by engineers when selecting materials for specific designs.
- Stress-strain diagrams are generated experimentally through the performance of controlled **tensile test** using fabricated test specimens.
- The **applied load and displacement** are monitored during the test, and are used to calculate stress and strain, respectively.

Stress-strain diagram region

- A stress-strain diagram generally contains **three regions**:
 1. **Elastic region**: This portion is generally represented as a **linear relationship** between stress and strain. If the load is released the specimen **will return** to its original dimensions.
 2. **Plastic region**: In this portion, the specimen begins to **yield**. The **maximum strength** of the specimen occurs in this zone. The specimen endures some **permanent deformation** that remains after the load is released.
 3. **Rupture**: The point at which a specimen **breaks into two parts**.

Stress strain diagram important points

- **Proportionality limit**-it is the point in the stress strain graph up to which stress is directly **proportional** to strain. Up to this point hook's law is applicable.
- $\sigma = E\epsilon$
- This is known as Hooke's law, and the constant of proportionality E (GPa or psi) is the **modulus of elasticity**, or *Young's modulus*.
- **Elastic Limit**: The limit in which the material will return its original shape when the load is removed.
- Most of the time these two points(elastic and proportionality point) are very close and treated as same point.

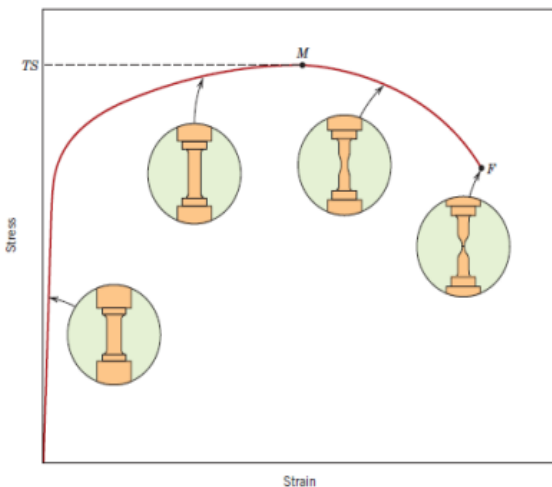
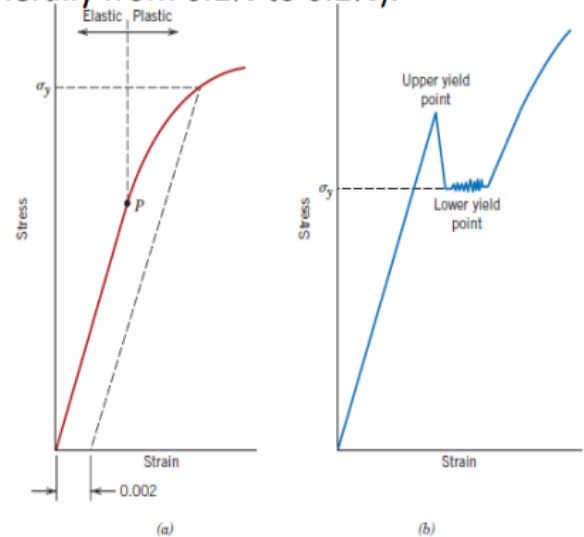


- **Yield Point:** Yield point is the point at which the material will have an appreciable elongation OR a slight increase in stress above the elastic limit will result in permanent deformation. This behavior is called yielding for ductile materials (In Engineering, the transition from elastic behavior to plastic behavior).
- Less ductile materials such as aluminum and medium to high carbon steels do not have a well defined yield point. For these materials the yield strength is typically determined by “**offset method**” by which a line is drawn parallel to linear portion of the curve and intersecting at some value most commonly 0.2%. (generally from 0.1% to 0.2%).

Figure 6.10

- **Upper yield point:** which corresponds to the load reached just before yield starts.
- **Lower yield point:** which corresponding to the load required maintain yield. Lower yield point should be used to determine the **yield strength of the material**.

(a) Typical stress-strain behavior for a metal showing elastic and plastic deformations, the proportional limit P , and the yield strength σ_y as determined using the 0.002 strain offset method. (b) Representative stress-strain behavior found for some steels demonstrating the yield point phenomenon.

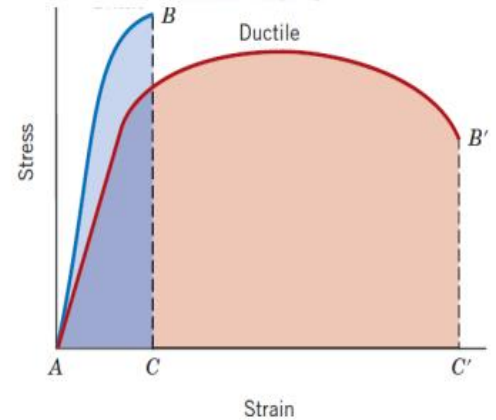
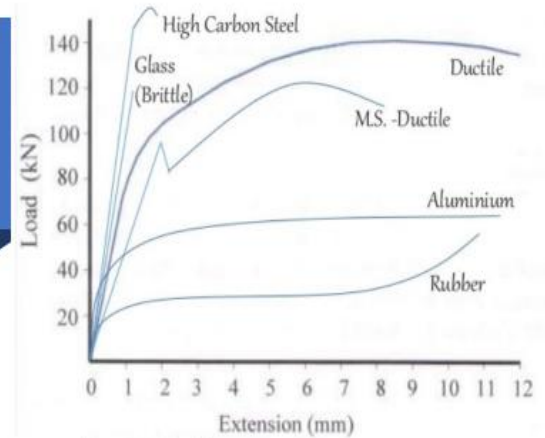


Typical Engineering stress-strain behavior to fracture, point F. The tensile strength TS is indicated at point M. The circular insets represent the geometry of the deformed specimen at various points along the curve.

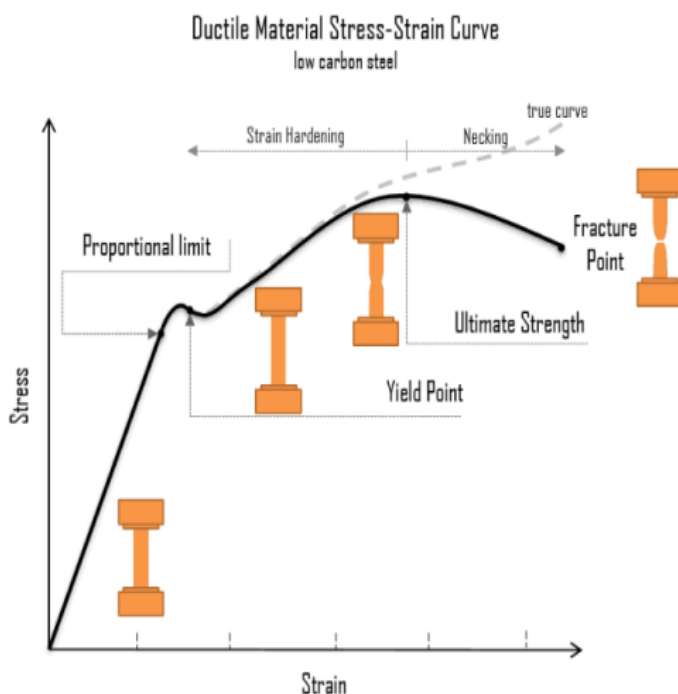
- **Ultimate stress(strength) point or tensile strength** this is the maximum stress or strength of the material. After this point cross section of specimen start decreasing, this phenomenon is known as necking.
- **Fracture point** is the point where material ruptured. fracture ultimately occurs at the neck. The fracture strength corresponds to the stress at fracture.
- For engineering stress strain curve it has magnitude below the ultimate strength point(UT). But for true engineering stress strain curve it is above the UT.
- **Strain Hardening:** The stress must be **increased** to keep elongating the specimen, until the **maximum** value has been reached. This is due to a property of the material known as **strain hardening**.

Stress strain diagram for different material

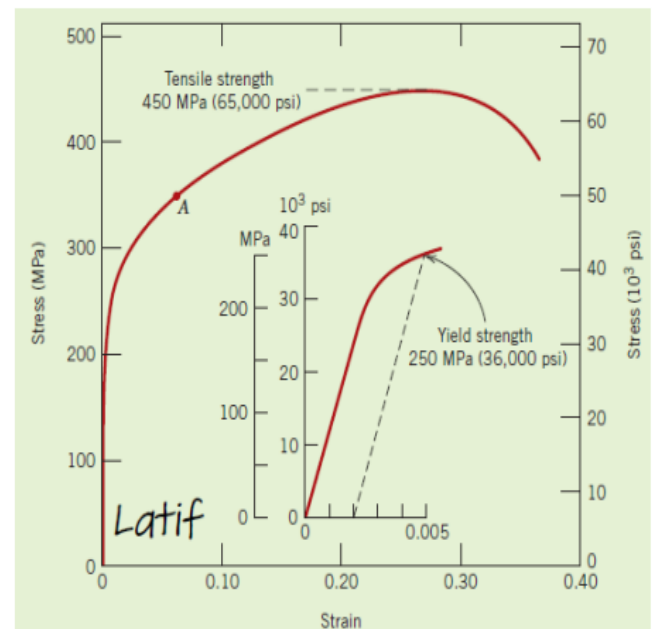
- Stress strain diagram is different for different material , but it is seen that some material elongate more before its rupture and some hardly elongates.
- A **ductile material** is one having relatively large tensile strain up to the point of rupture like structural **steel and aluminum**.
- whereas **brittle materials** has a relatively small strain up to the point of rupture like **cast iron and concrete**.



Ductile material



Stress and strain curve for low carbon steel



Stress and strain curve for brass

Brittle materials

- **Brittle materials:** such as **cast iron, glass, concrete and carbon fiber (composite materials)** are characterized by the fact that rupture occurs without any prior change in the rate of deformation.
- These do not have a yield point and do not strain harden, which means that ultimate strength and breaking strength are at same point.
- we note the absence of **any necking of the specimen** in the case of the **brittle materials** and observe that rupture occurs along the surface perpendicular to the load. And we conclude that **normal stresses** are responsible for the **failure of brittle materials**.

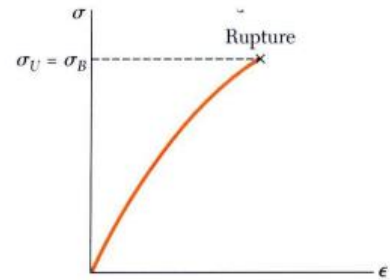


Fig. 2.11 Stress-strain diagram for a typical brittle material.

