CHAPTER TWO

Mechanical Properties of Materials

2-1 Stress

It is a measure of force acting on the unit area over which the force is applid.

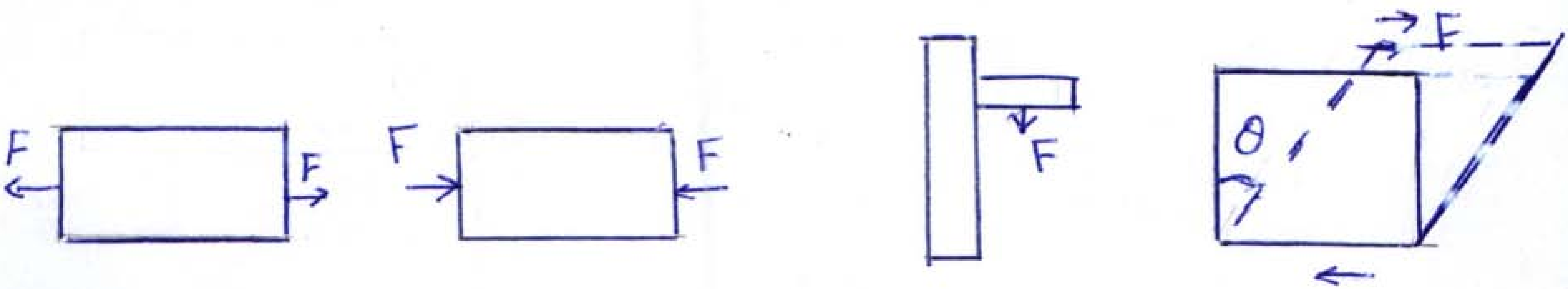
$$\sigma=F/A_0$$

Where F: force(N)

A_0: original area(m^2)

σ:stress (N/m^2)

There are tensile, compressive ,shear, and bending stresses illustrated in fig(2-1).



Tensile Stress · Compressive Stress Bending Stress Shear Stress

2-2 Strain

It is the deformation of material.

$$\epsilon = \Delta l / l_0$$

Where ϵ: strain , Δl :change in length, l_0:original length.

-Strain is expressed as a fraction (or percent).

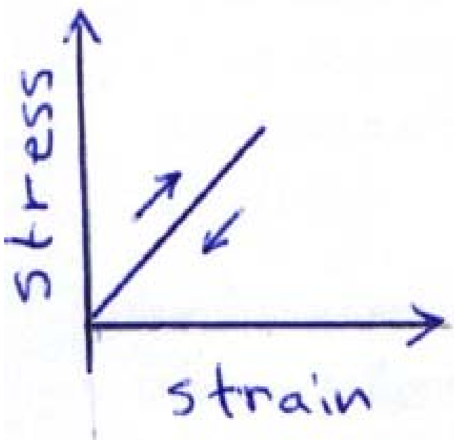
-Strain may elastic or plastic as shown in fig (2-2).

1- Elastic Strain .

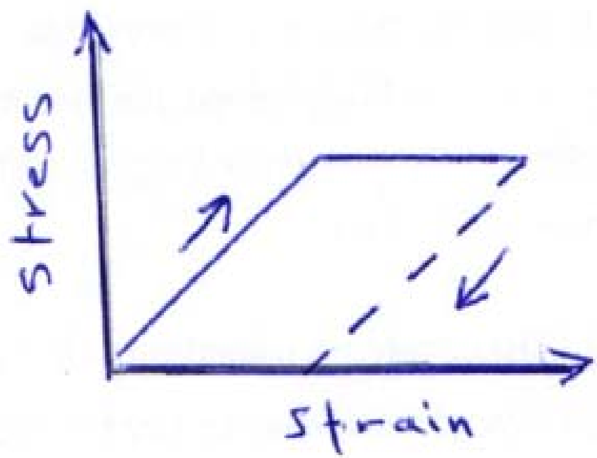
It is reversible ,that is, when the stress is removed,the strain disappears.Elastic strain is commonly alinear function of stress obeying Hooks' law of physics.

2-Plastic Strain

It is apermanent deformation in a material.In this case ,when the stress is removed,the material does not go back to its original shape.



Elastic Strain



Plastic Strain

Fig (2-2)

2-3 Stress-Strain Diagram

For most metals that are stressed in tension and at relatively low levels , a plot of stress versus strain results in a linear relationship , as shown in fig (2-3).Stress and strain are proportional to each other throughthe relationship: $\sigma=E\,\epsilon$

This is known as Hooks' law,and the constant of proportionality E is the **modulus of elasticity** , or **young s' modulus** .

The slope of the linear segment correspond to the modulus of elasticity.

The modulus of elasticity is:-

a-A measure of stiffness, the greater the modulus, the stiffer the material.

b-A material s' resistance to elastic deformation ,the greater the modulus, the smaller the elastic strain.

c-A measure of the resistance to separation of adjacent atoms, that is, the interatomic bonding forces.So:

$$E_{ceramic} > E_{metal} \text{ and } E_{polymer}$$

The proportionality of stress to strain ends at the **proportional limit** , which is defined as the level of stress above which the relationship between stress and strain is not linear. Deformation in which stress and strain are proportional is called elastic deformation .

2-3-1 Some Concepts Developed From The Stress-Strain Diagram

1-The elastic limit:it is the critical stress value needed to initiate plastic deformation.

2-yield point:at which there is an appreciable elongation or yielding of the material without any corresponding increase of load; indeed, the load may actually decrease while the yielding occurs. However, the phenomenon of yielding is peculiar to some materials and other material do not posses this point as shown in fig (2-4).

3-yield strength: closely associated with yield point. For materials which do not have a well defined yield point, yield strength is determined by the offset method. This consists of drawing a line, parallel to the linear portion of the stress-strain curve ,this line being started at some specified strain offset, usually 0.002. As shown in fig .(2-5),the intersection of this line with the stress-strain curve is called **the yield – strength**. The magnitude of the yield strength for the a metal is a measure of its resistance to plastic deformation.

4-ultimate or tensile strength: it is the maximum tensile stress a material can withstand before failer.It is a feature of the engineering stress-strain curve and cannot be found in the true stress-strain curve. However, at this maximum stress, a small contraction or neck begins to form at some points, all subsequent deformation is confined at this neck.fig.(2-6).

5-rupture or fracture strength (engineering breaking strength): it is the stress at fracture,it is computed by dividing the fracture load by the original cross-sectional area, so its some what lower than tensile strength.

6-actual rupture strength or true fracture strength :it is the true stress at fracture which is defined as the load divided by the instantaneous cross-sectional area(A_i) over which deformation is occurring (i.e.,the neck,past the tensile point). The true stress-strain curve is compared with the stress-strain curve in fig.(2-3).it can be seen that the true stress continues to increase after necking because, although the load required decreases, the area decreases even more.

$\sigma_T = F / A_i$ where σ_T = True fracture strength.

$\epsilon_T = \int dl / l = \ln l_i / l_0 = \ln A_0 / A_i$ where ϵ_T =True fracture strain.

If no volume change occurs during deformation , that is, if $A_0 l_0 = A_i l_i$,then:-

$\sigma_T = F / A_i = l_i F / A_0 l_0 = \sigma \, l_i / l_0 = \sigma \, [(l_0 + \Delta l)/l_0] = \sigma \, (1+\epsilon)$

and

$\epsilon_T = \ln l_i / l_0 = \ln [(l_0 + \Delta) / l_0] = \ln (1+\epsilon)$

The above equations are valid only to the onset of necking.

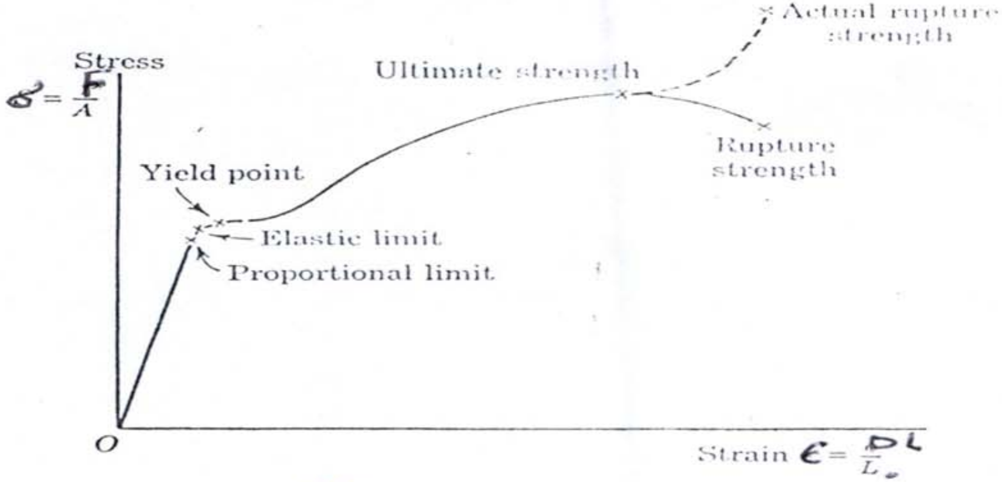


Fig. 2-3 — Stress-strain diagram.

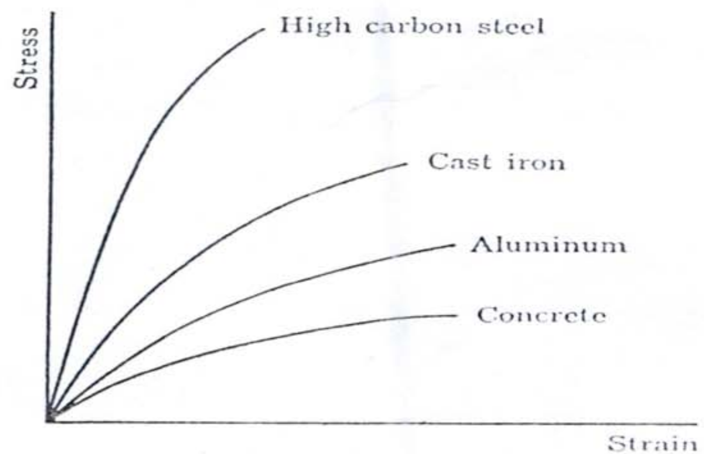


Fig. 2-4 — Comparative stress-strain diagrams for different materials.

Assist.Prof.Dr.Anaam A.S.

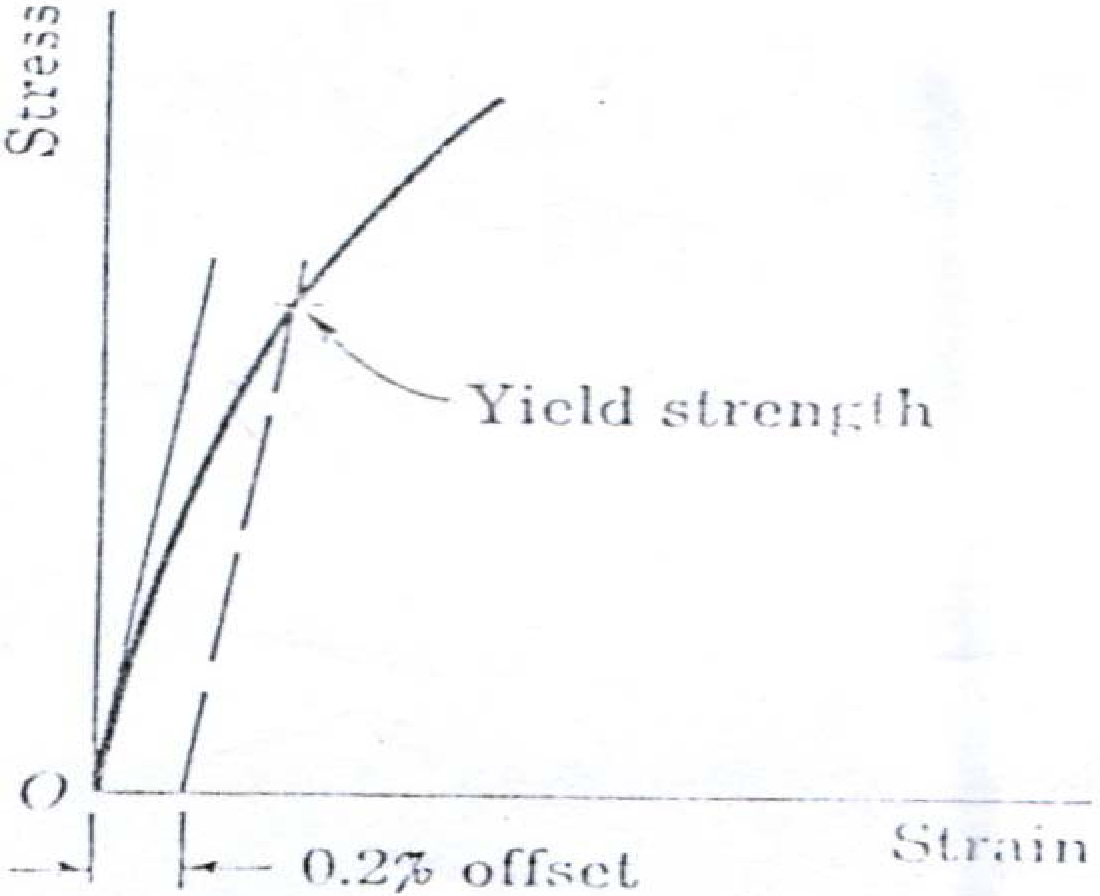


Fig. 2-5 — Yield strength determined by offset method.

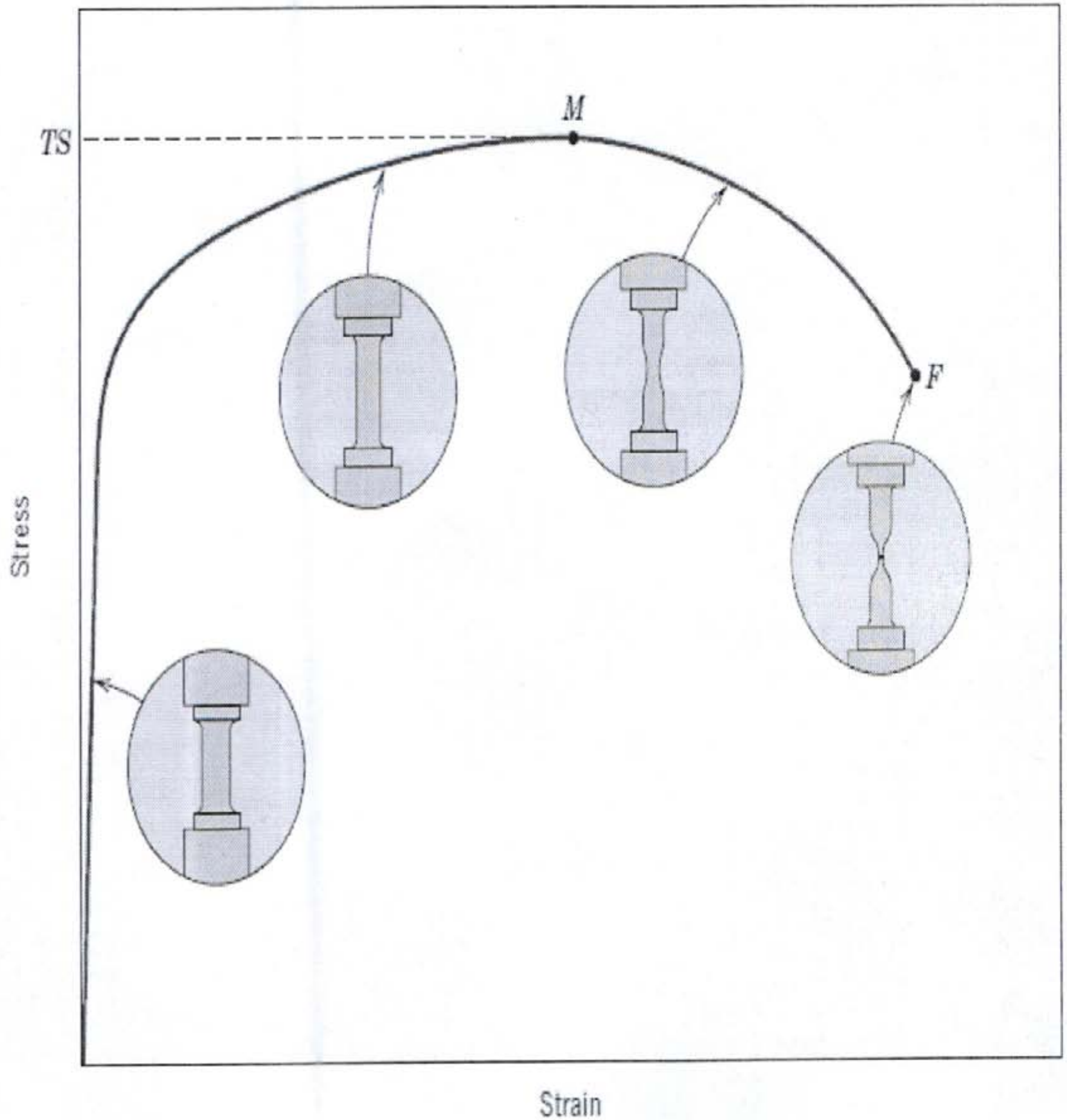


Figure 2.6 Typical engineering stress–strain behavior to fracture, point F. The tensile strength TS is indicated at point M. The circular insets represent the geometry of the deformed specimen at various points along the curve.

Assist.Prof.Dr.Anaam A.S.

Elongation (Elastic) Computation

A piece of copper originally 305 mm (12 in.) long is pulled in tension with a stress of 276 MPa (40,000 psi). If the deformation is entirely elastic, what will be the resultant elongation?

Solution

Since the deformation is elastic, strain is dependent on stress according to Equation 6.5. Furthermore, the elongation Δl is related to the original length l_0 through Equation 6.2. Combining these two expressions and solving for Δl yields

$$\sigma = \epsilon E = \left(\frac{\Delta l}{l_0}\right)E$$

$$\Delta l = \frac{\sigma l_0}{E}$$

The values of σ and l_0 are given as 276 MPa and 305 mm, respectively, and the magnitude of E for copper from Table 6.1 is 110 GPa (16×10^6 psi). Elongation is obtained by substitution into the expression above as

$$\Delta l = \frac{(276 \text{ MPa})(305 \text{ mm})}{110 \times 10^3 \text{ MPa}} = 0.77 \text{ mm } (0.03 \text{ in.})$$