Lecture No. Six, Seven & Eight: The tensile test **Time: 6 Hours**

The tensile test is the most important of the mechanical tests used to obtain data on the properties of materials. The test is usually performed by slowly and steadily applying a tensile load to standardize test specimen shown in Fig. below. After the sample has been loaded in tension and broken, the two halves are held firmly together and the distance between the marks is again measured.

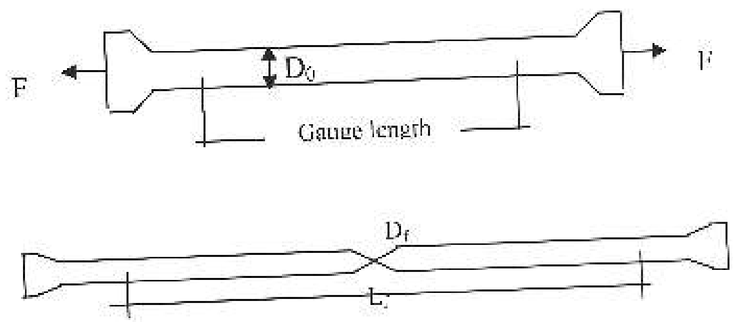
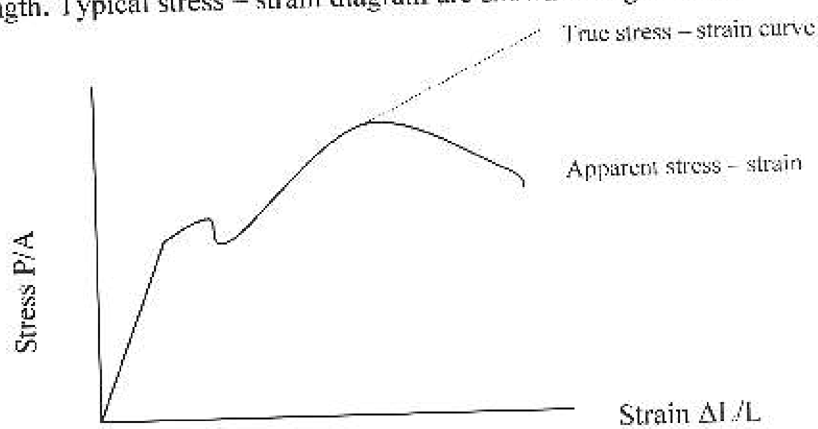


Fig.1

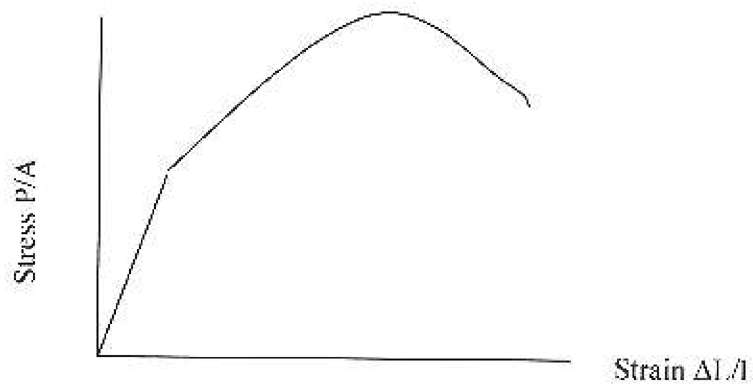
The stress – Strain curve in tension

After testing the specimen, it is necessary to represent the data in the form of stress – strain diagram. The stress is defined as the load divided by the cross sectional area of the specimen at the start of the test. As the test proceeds, the actual cross sectional area decreases. The stress based upon the initial area is not the true stress, but it is generally used. The strain used is the elongation of a unit length of the test specimen taken over the gauge length. Typical stress – strain diagram are shown in Fig. below:



Stress – Strain curve for low carbon steel

Stress – Strain curve for non ductile material – Cast iron (no plastic deformation)

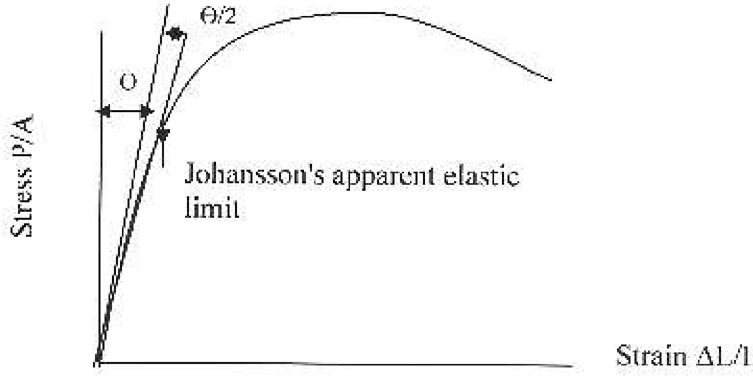


Stress – Strain curve for Aluminum – Ductile material

Proportional limit

It is the greatest stress that the material is capable of developing without deviation from Hook's law of stress – strain proportionality.

In order to determine the proportional limit, it is necessary to use very sensitive extensometer to detect the slightest deviation from a straight line in the tensile test diagram. Certain materials such as concretes and copper do not have the straight line portion of the stress – strain curve that steel does. For these materials a value known as Johansson's apparent elastic limit. Johansson's apparent elastic limit is defined as that stress at which rate of deformation is 50% greater than the initial rate of deformation as shown for concrete.



Modulus of elasticity

It is a measure of the stiffness of the ductile material. The slope of the initial straight portion of stress – strain diagram represents the modulus of elasticity or Young's modulus.

$$E = \tan \Theta = \text{Stress/ strain}$$

When no straight portion is present in the stress – strain curve, as in the case of concrete material, the modulus of elasticity can be obtained by one of the following methods:

1. Initial tangent modulus:

It is the tangent to the curve at the original, but it is little practical importance.

2. Tangent modulus

It is the tangent at any point on the stress – strain curve, but this modulus applies only to very small changes in load above or below the load at which the tangent modulus is considered.

3. Secant modulus

It is the slop of the line drawn from the origin to any point on the stress – strain curve. There is no standard method of determining the secant modulus, in some laboratories; it is measured at stress ranging from 3 to 14 N/mm^2, in others at stresses representing 15, 25, 33 or 50% of the ultimate strength.

Yield strength

Yield point is defined as the stress at which a marked increase in strain occurs without a concurrent increase in applied stress.

Many materials do not exhibit well defined yield points and the yield points and the yield strength is defined as the stress at which the material exhibits a specified limiting permanent set of 0.2 % (0.002 strain). The yield strength is therefore the stress corresponding to the intersection of a line parallel to the straight line portion of the stress – strain curve.

Ultimate strength

It is obtained by dividing the maximum load reach before the specimen breaks by the initial cross sectional area of the specimen. It is commonly used as basic for established working stresses for a material.

Ult. Str. For apparent stress – strain curve = max. Load/ A_0

Ult. Str. For true stress – strain curve = max. Load/ A_f

Elongation

Percentage of elongation is the measure of the ability of a material to undergo deformation without rupture. It is a measure of the ductility of material.

$$\% \text{ Elongation} = (L_f - L_0) / L_0 * 100$$

Where:

L_f – Final length

L_0 – Initial length

Breaking Strength (Rupture strength, fracture strength)

Breaking strength = Load at time of failure / A_0

The breaking strength on this basis is less than the ultimate stress of the data based on true area. While the true stress of failure is the maximum stress on the material. For the test interval between the ultimate stress and the breaking stress, the specimen continues to elongate even though the resisting stress based on the original area decrease.

Reduction of area

As the load on the test material is increased, the original cross sectional area decrease until it is a minimum at the instant of fracture. It is usual to express this reduction in area as the ratio of the change in area to the original specimen cross sectional area expressed as a percentage.

$$\% \text{ reduction in area} = \{(A_0 - A_f)/A_0\} * 100$$

Where - A_f – Final cross sectional at the point of failure
A_0 – Original cross sectional

Ductility

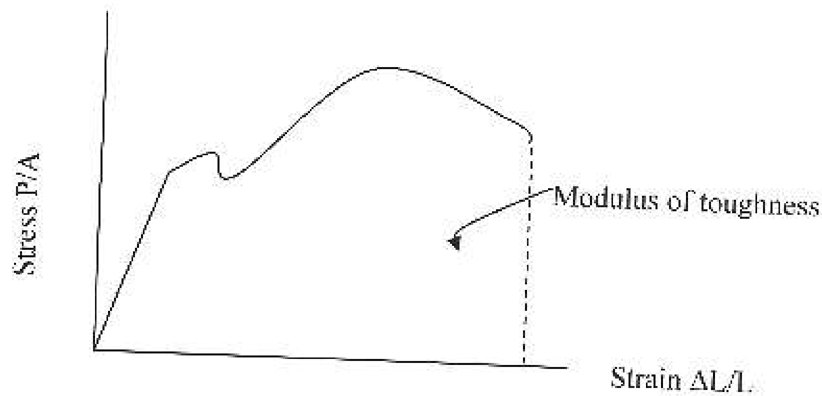
Is the property of a material of being deformed by stretching without recovery of shape upon removed of stretching force. Ductility of metals is ordinarily determined by measuring the elongation and reduction of cross sectional area of a tensile strength test specimen.

Toughness

The resistance to impact. Toughness is also considered to mean resistance to fracture when the material is deformed above the elastic limit.

It is a measure of the work required to cause fracture to occur. The area under stress – strain curve represent modulus of toughness.

$$\text{Modulus of toughness} \angle 2/3 (\epsilon_f * \sigma_f)$$



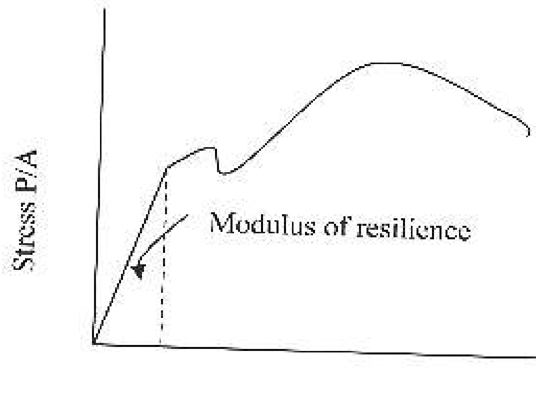
Brittleness

Is the opposite of toughness and ductility and refers to small resistance to sudden blow. A brittle meta breaks suddenly without appreciable permanent deformation or warning of approaching failure.

Resilience

Is that property of an elastic body by which energy can be stored up in the body by loads applied to it and given up in recovering it\s original shape when the loads are removed. The area under the straight portion of stress - strain curve represent the modulus of resilience.

$$\text{Modulus of resilience} = 1/2 (\epsilon_{P.L.} * \sigma_{P.L.})$$



Plasticity

Is the property by which a body, when deformed by the application of forces, remains in the deformed shape without recovering the original shape, when the force is removed.

H.W.:

The following data where obtained during the tensile test of mild steel circular bar 12.75 mm diameter and 203.2 mm gauge length. Determine the following:

1) The apparent stress at each point
2) Strain at each point
3) True stress at each point (Assume D at failure is 8,51 mm and D at max. load is 11.15 mm)
4) Draw stress – strain curved based on:
    a) Original cross sectional area
    b) True cross sectional area
5) Proportional limit
6) Modulus of elasticity
7) Upper and lower yield point
8) Ultimate strength
9) Breaking strength based on the original cross sectional area and on true cross sectional area
10) Percentage of elongation
11) Percentage of reduction in cross sectional area.
12) Ductility
13) Resilience and toughness

Load (N)	4393	16902	29357	33360	33627	35584	41366	48839	52709	55378	56356	43768
Deformation (mm)	0.0254	0.127	0.228	0.305	0.356	3.81	6.35	11.68	16.76	26.92	43768	42.42