Tensile Test

Objective

The tensile test is used to

- Observe the behavior of materials under tensile load.
- Determine the strength and other several elastic and plastic
- Properties of various materials
- Study the fracture of metallic material.

Introduction

The Tensile test is used to obtain basic design information on the strength of materials. When the standard methods of test are employed the results are acceptable criteria of quality of materials and a given level of quality means satisfactory behavior in service.

Apparatus

<u>Universal Testing Machine (UTM):</u> The machine is digital type Tensile Strength Test Machine. Capable doing the following tests:

1. Tensile test.
2. Compression test.
3. 3 points bending test.
4. Direct shear test.

It uses sensor which has high accuracy of the load value. Experimenters can get well-done results. Experimenter can save the result by mean of connecting the U.T.M. and Computer. The machine is composed of:

- <u>Loading part:</u>
  Main body, crosshead, crosshead moving part, jig part, load cell sensor, and displacement sensor.
- <u>Measuring part:</u>
  Load display, strain display, and speed control device.

Theory

They typical stress-strain diagram with some of common nomenclature for a typical low-carbon steel specimen is shown in fig (1). And fig (2) shows a typical stress - strain diagram for brittle materials.

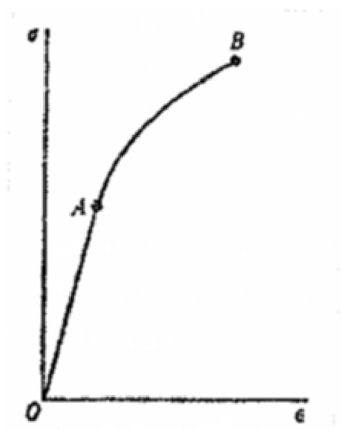

Figure 2: typical stress-strain diagram for a brittle material.

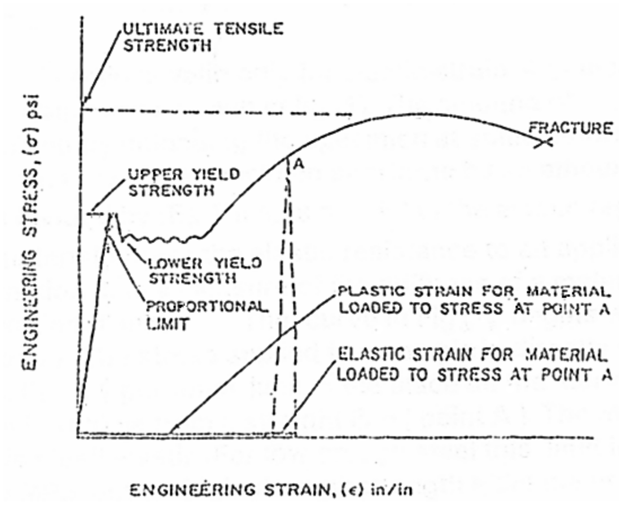

Figure 1: Engineering stress-strain Diagram for carbon steel showing important properties.

Figure (1) & (2) are plotted in terms of engineering stress,σ, and engineering strain ,ε, These are quantities based on the original dimensions of the specimens defined as:-

$$\sigma = \frac{Load}{Original^{\circ}Area} = \frac{P}{A_o}$$

$$\varepsilon = \frac{Deformed \circ Length - Oridinal \circ length}{Original \circ Length} = \frac{L - L_o}{L_o}$$

There are a number of definitions are shown in fig. (1):-

The Modulus of elasticity (E): It is the ratio of stress to strain,

$$E = \frac{\sigma}{\varepsilon}$$

This ratio is valid only for elastic strain, and measured from the stress stain curve shown in fig (1), The amount of elastic strain can be determined by unloading the specimen at some deformation, when the load is removed, the specimen shortens by an amount equal to the stress divided by (E), Thus, ($\varepsilon = \sigma/E$) in the elastic region. The value of E for a material shows the elastic resistance to an applied load that causes deformation. It is a measure of the stiffness of materials.

- ***Proportional limit:*** The curve in Fig (1) begins with a straight line from 0 to A. The stress applied to a sample is directly proportional to the strain; the proportional limit is the place on the curve where it deviates for the first time from a straight line (point A). The material in this point is steel elastic. For low carbon steel this limit is in the range 200 to 280 MPa, but for high strength steel the proportional limit is 550 MPa and more.
- ***Elastic limit:*** The elastic limit is the maximum load that can be applied to the specimen without permanently deforming it.
- ***Yield stress:*** If a slight increase in loading is applied to the elastic, the elongation occurs for the first time without any increase in loading. The Method for finding the yield stress of the sample is to draw a line parallel to the original straight portion of the stress-strain curve, but offset from the origin of this curve by some value of ε (usually between 0.001 and 0.003, indicated as 0.1% to 0,3%), the value of σ is taken from a point of Intersection of this line and the curve.
- ***Ultimate stress:*** It is the point on the curve that represents the maximum stress that can be applied to a ductile material before fracture (point D). For brittle materials the fracture point is essentially the same as the ultimate stress.
- ***Rupture stress:*** The stress at which the fracture occurs, the fracture is located at the last point in the curve (point E).
- ***The Modulus of Resilience (U_R):*** is the amount of energy stored in stressing the material to the elastic limit as given by the area under the elastic portion of σ - ε curve. This quantity is important in selecting materials for energy storage such as springs; the Modulus of Resilience is given by,

$$U_R = \int_0^{\varepsilon_{Elastic}} \sigma d\varepsilon = \int_0^{\varepsilon_e} E\varepsilon d\varepsilon = \frac{1}{2}E\varepsilon^2 = \frac{1}{2}\sigma_e\varepsilon_e = \frac{\sigma^2}{2E}$$

- ***The modulus of Toughness (U_T):*** is the total energy absorption capabilities of the materials to failure and it is given by,

$$U_T = \int_0^{\varepsilon_{fracture}} \sigma d\varepsilon \cong \frac{\sigma_{yi} - \sigma_{ult}}{2} * \sigma_{Ult}$$

and is given by the total area under the σ - ε curve, it is often approximated by ($2/3*\sigma_{max}*\varepsilon_{max}$), this quantity is important in selecting materials for applications where high overloads are likely to occur and large amounts of energy must be absorbed.

- ***The ductility of material:*** is ability of material to deform under load, ductility is indicated by the tensile property of percentage of elongation. The percentage of elongation, which is the percent strain to fracture, is given by,

$$\%\,Elongation = \frac{L_f - L_o}{L_o} * 100\%$$

Where:

L_o: the original length between gage marks.

L_f: the length between gage marks at fracture.

Percentage of reduction in cross-sectional area of a specimen is another way to indicate the tensile property of ductility, thus

$$\%\,\text{Re}duction\;Of\;\;Area = \frac{A_f - A_0}{A_0} * 100\%$$

Where :-

A_o: is the original cross-sectional area

A_f: is the cross-sectional area at fracture

If the percentage of elongation and reduction of cross-sectional are large, the material is said to be ductile; when they are low, the material is said to be brittle.

The stress-strain diagram previously discussed, using engineering quantities σ & ε, are based on area and lengths that no longer exist at the time of measurement. To correct this, situation true stress (σ_T) and true strain (ε_T) quantities are use. The true stress and true strain quantities are defined as:

$$\sigma_T = \frac{P}{A_i}$$

Where:

A_i: the instantaneous area at the time is measured and,

$$\varepsilon_T = \int_{L_o}^{L} \frac{dL_i}{L_i} = Ln\frac{L}{L_o} = -\int_{A_o}^{A} \frac{dA_i}{A_i} = Ln\frac{A_o}{A}$$

Where

L: the instantaneous length between gage marks at the time P is measured.

A: the instantaneous cross-sectional area at the time P is measured.

These two definitions of true strain are equivalent in the plastic region where the material volume can be considered constant during deformation. Since

$$A_o.L_o = A.L$$

This is only true in the plastic region of deformation, in the elastic region the change in volume (ΔV) per unit volume is given by the bulk Modulus (K), and,

$$K = \frac{E}{3(1-2v)}$$

Where the Shear modulus of elasticity is given by the equation:

$$G = \frac{E}{2(1-v)}$$

The relation ship between the engineering values and true values are given below:

Since

$$\varepsilon_T = Ln\frac{L}{L_o} = Ln\frac{L+\Delta L}{L_o}$$

Then

$$\varepsilon_T = Ln(1+\varepsilon)$$

And

$$\frac{A_o}{A} = \frac{L}{L_o} = \frac{L_o+\Delta L}{L_o} = 1+\varepsilon$$

Then

$$A = \frac{A_o}{1+\varepsilon}$$

$$\sigma_T = \frac{P}{A}$$

So

$$\sigma_T = \frac{P}{A_o}(1+\varepsilon) = \sigma(1+\varepsilon)$$

Procedure

1. Check the specimen dimensions, measure the diameter or width, thickness of the specimen and compute the cross-sectional area and measure the gauge length.
2. Tight the specimen at the grippes located at the machine.
3. Calibrate the machine in such a manner that the extension and load are set to zero.
4. Choose a suitable loading rate.
5. Apply the tension load on the specimen.
6. Obtain the load-extension (stroke) curve from the machine.

Results & Analysis:

1. Determine the following properties:
    a. Proportional limit.
    b. Yield point.
    c. Yield stress for an offset of .2%.
    d. Ultimate and fracture stress.
1. Percentage elongation and reduction in area at fracture.
2. Modulus of Elasticity.
3. Modulus of Resilience.
4. Modulus of Toughness.
5. Shear Modulus of elasticity (G)
6. Bulk Modulus of elasticity (K).
7. Compare your values of Modulus of elasticity, yield stress, Ultimate stress, with the typical values for the tested specimen(s).
8. State difficulties when testing brittle materials.
9. Comment on the type & shape of fracture for tested specimen(s).
10. What are the advantages of a stress- strain curve over a load-elongation curve?
11. Based on the observations of your test, forecast the stress-strain curve for glass and draw its stress-strain curve. Comment in your graph stating why it should be drawn that way.